Auto-Capto Six

Proceedings of the Sixth International Symposium
on Automated Cartography

Les actes du sixième Symposium international
sur la cartographie automatisée

Volume I

AUTOMATED CARTOGRAPHY : INTERNATIONAL PERSPECTIVES ON ACHIEVEMENTS AND CHALLENGES

LA CARTOGRAPHIE AUTOMATISÉE : PERSPECTIVES INTERNATIONALES SUR LES RÉALISATIONS ET LES DÉFIS

Volume I

Edited by
BARRY S. WELLAR

Sous la direction de
BARRY S. WELLAR

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CHAIRMAN'S FOREWORD

The Proceedings of the Sixth International Symposium on Automated Cartography are landmark in the documentation of the field of computer assisted cartography. None of the previous five sets of proceedings is comparable, as Auto-Carto Six has a number of unique characteristics which are reflected in this record of the symposium.

A special effort was made to emphasize international perspectives and the authors whose papers are presented here represent more nations than at any other Auto-Carto meeting. The proceedings also have a uniquely Canadian flavour, with a number of outstanding papers in both English and French. Canada has been in the forefront of the field of computer assisted cartography for the last two decades, and Auto-Carto Six provides Canadians with a unique opportunity to take stock of their achievements and to identify new challenges.

Although the editor of the Proceedings, Dr. Barry Wellar, has played a special role in their production, they would not have been possible without the assistance of all those who participated in Auto-Carto Six. The Proceedings of Auto-Carto Six are the written record of a remarkable collective endeavour.

D.R.F.T Taylor, Chairman
National Steering Committee
for Auto-Carto Six

September 27, 1983

PROGRAM DIRECTOR/EDITOR'S FOREWORD

The Proceedings are a single, but nevertheless very important indicator of what was said and done at any Conference. And, their value increases if a representative selection of papers can be assembled for the benefit of participants, as well as for interested parties not able to attend the meeting.

In the instance of Auto-Carto Six, it appears fair to say that the international Auto-Carto community outdid itself: one hundred and ten complete papers and fifty abstracts from speakers representing nineteen countries, including submissions in English and in French. I am grateful to the Technical Program Committee for assistance in securing papers, and to authors and their typists for submitting materials in the appropriate format. Their cooperation made distribution of the Proceedings in a timely manner possible.

It is appropriate in closing to acknowledge the efforts of several persons who not only made my job easier but improved the quality of Auto-Carto Six products and processes: David Douglas, Department of Geography, University of Ottawa, who was of invaluable assistance through his work as Special Sessions Coordinator, and as a resource person for the General Tracks as well; Johanne C. Forgues and Manon Forget, Department of Geography, University of Ottawa, and Doreen Ramplee-Smith, Carole Baker, Lloyd Mackey and Anne Buie of Carleton University, who prepared much of the material leading up to production of the Proceedings; and Bob Aangeenbrug, University of Kansas, Director of Auto-Carto 2, 3 and 4, Jack Foreman, (U.S.) National Oceanic and Atmospheric Administration, Director of Auto-Carto 5, and William French, American Society of Photogrammetry, who by their efforts set the production precedents for this publication.

September 27, 1983
Ottawa, Ontario, Canada

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PREFACE

Papers in the Proceedings are grouped to reflect the Symposium themes and sub-themes as follows:

A. Keynote and Plenary Addresses (Volume I)

B. General Track Sessions (Volume I)
   a) Integrated Systems
   b) Practical Applications
   c) Problem Analysis/Decision Support Systems
   d) Research and Development
   e) Education and Training

C. Special Track Sessions (Volume II)
   1. Limited Investment Mapping Systems
   2. Institutional Mapping Efforts: Status and Prospective
   3. Data Structures
   4. Mathematical Cartography
   5. Problem Analysis: Projects to Processes
   6. Thematic Mapping
   7. Remote Sensing: Systems and Activities
   8. Electronic Distribution/Exchange of Cartographic Data

The majority of articles presented in the Proceedings were assembled from camera-ready copy provided by authors. Abstracts are included in cases where complete papers were not submitted. In all events, editorial changes were kept to a minimum.

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GENERAL TRACK SESSIONS: EDUCATION AND TRAINING

KEYNOTE SESSIONS

ACHIEVEMENTS AND CHALLENGES IN THE FIELD OF AUTOMATED CARTOGRAPHY: THEIR SOCIETAL SIGNIFICANCE

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ABSTRACT

Serious reflection upon the significance of achievements and challenges in any field of disciplinary inquiry must take cognizance of two fundamental, interdependent dimensions: the scientific and the societal.

The purpose of this paper is to consider the significance to society of effort - research, teaching, and application - in the field of automated cartography (AC). A companion presentation focuses on the scientific significance of effort in the field, and as a result that dimension is taken into account only when it is directly pertinent in a producer-product sense to the central thrust of this discussion.

The paper is comprised of five primary components:

1. Introduction of the doing-thinking paradigm of an Information Society.

2. Elaboration of the automated cartography-mass media-societal significance connection.

3. Definition of terms of reference for assessing the societal significance of effort in the field of automated cartography.

4. Overview and interpretation of mass media reportage - "popular" print (newspapers, magazines), and electronic (television) - as a measure of the status and progress of the AC field with respect to societal enhancement.

5. Overview and interpretation of selected professional/technical literature in terms of the extent to which the societal significance dimension is factored into research, teaching and application in the field of automated cartography.

INTRODUCTION

The Information Society was hinted at in the early 1960's, became perceived in broad terms in the mid 1970's, and, while still very rough around the edges, now appears to be in place, or imminent, from a technological standpoint at least, in much of the industrialized world. (Masula, 1980; Wellar, 1983.)

Among the many promises that such a Society is perceived to hold, there are several which go well beyond the current widespread fixation (hopes and fears) on job creation and job loss, and which are most pertinent to the topic under study.

First, such a Society promises dramatically altered distances* - political, social/psychological, intelligence (in the sense of privileged position through proprietary information) - between and among institutions and individuals comprising the Society at the local, national and international levels.

Second, there are portents of fundamental change, many of them associated with the "distances" noted above, to the underlying activities and processes that have defined and will continue to define the essence of Society. In particular, the situation, event or process descriptors or referents commonly known as the 5Ws and H (Who, What, Where, When, Why and How) will be entered into a new paradigm for describing, analysing and assessing situations, events and processes. This development will be of significance to the field of automated cartography in all its dimensions of teaching, research and application.

DOING/THINKING: THE INFORMATION SOCIETY PARADIGM

The proposed new paradigm, which calls for correspondence between doing and thinking, may be illustrated by the following variations on the 5Ws and H theme:

Who does/Who thinks
What done/What thought
Where done/Where thought
When done/When thought
Why done/Why thought
How done/How thought

Obviously, for both doing and thinking, the elements (Ws and H) vary by situation, event or process in terms of importance, elements involved, and relations between or among them, and that holds whether one is working on either the left or right side of the do/think paradigm.

It is equally obvious, however, that if we are indeed entering the Information Era and becoming the Information Society with an information resource basis, then doing and thinking take on a degree of active, explicit correspondence (for all the Ws and H) that simply did not exist during the Pre-Information Era: in other words, the Information Society will be marked by structural and functional state-of-the-art changes to doing/thinking in the Society. If that does not become the case (and this point needs to be emphasized), and new generations of information technology do not lead to new generations of doing/thinking in the affairs of individuals and institutions, then the Information Society will not be attained; rather, the more appropriate label of the Technological Society with its connotation of doing and things, as opposed to thinking and people, will be warranted.

In expectation, therefore, that reference to the Information Society will not ring hollow for many years, attention is directed to the matter at hand: assessing the societal significance of achievements and challenges in the field of automated cartography by pursuing two lines of inquiry:

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*For elaboration of "distances" see Wellar (1983a, 1983b).

Automated cartography (teaching, research, application) as a factor in the doing/thinking paradigm in the larger or universal sense, that is, the contributions made by the field to the evolutionary or revolutionary* shift from the Industrial to the Information Society; And,

The purposes, ways and extent to which the field, through its contributions to description, analysis, prediction and assessment of situations, events and processes on the one hand, or data/information generation and manipulation (including map inputs/outputs) on the other, is a doing/thinking factor in the tasks undertaken, approaches adopted, and results or consequences achieved by individuals and institutions.

THE AUTOMATED CARTOGRAPHY-MASS MEDIA-SOCIETAL SIGNIFICANCE CONNECTION

The thrust of these remarks does not permit the assumption that automated cartography effort, or the reportage of that effort in the mass media is, per se, of societal significance. It is appropriate, therefore, to address at this point the "So what?" or "Who cares?" assessment criterion elaborated in the next section. That is, to illustrate by means of a question, "Who cares whether the societal significance of automated cartography effort is expressed (positively or negatively) in the mass (print-electronic) media?"

Briefly, in response, both the AC community and (the larger) society have a stake in 1) confirming or refuting the societal significance of AC effort,and 2) ensuring that such determinations are respected or dealt with accordingly. It is noted that the stake may be factual, analytical, managerial and so on in its dimensions, with the resultant confirmation or refutation likely to determine the amount of popular or professional and, hence, political and financial support accorded the effort. To the extent, then, that society influences such considerations, the AC community is obliged to pay attention to the societal perspective, and to contribute to the formation of that perspective.

There is, however, little more than academic value in an elaboration of significance (benefits arrayed against costs, or advantages against disadvantages) which does not ensure that both sides (AC community and society) are apprised of their respective positions vis-a-vis awareness, appreciation and preference associated with AC effort.** As a result of that need to be apprised it follows, therefore, that the mass media (print and electronic) form a vital connection with the field and society*** That is, since the mass

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*For discussion of "evolutionary" vis-a-vis "revolutionary" change see Kraemer and King (1983), Parker-Martin (1982), and Wellar (1983b).
**By way of illustration, the societal significance of the AC community apprising the media of developments in the 5Ws and H of AC doing/thinking is considerably enhanced if the AC community is, in turn, apprised of what those developments mean to the 5 Ws and H of reportage doing/thinking.
***The word "vital" was chosen advisedly: Mass media comprise the forum whereby society is informed and apprised of situations, events and processes and whereby society can make known (via letters to editors, interviews, demonstrations, etc.) its awareness, appreciation or preferences in association with those situations, events and processes.

media comprise the only medium capable of communicating accounts to the public or by the public, of observed or documented phenomena and processes(by means) involving AC products and services, they must be considered in this or any attempt to assess the societal worth of AC effort. (Further, and although beyond the purview of these remarks, consideration should be given to both the content and the process of the reportage.)

TERMS OF REFERENCE FOR ASSESSING THE SOCIETAL SIGNIFICANCE OF EFFORT IN THE FIELD OF AUTOMATED CARTOGRAPHY

In spite of the enlightenment connoted by the term Information Society, there are grounds for not assuming that the AC effort has intrinsic utility or worth which will provide for sustained, substantial progress in the field. Indeed, what with the cutting (reduction to elimination) of teaching, research, and development programs in a variety of existing lines of inquiry and endeavour, and new areas seeking support, there is nothing whatsoever that is sacred about effort in the field. And, one only needs to pay cursory attention to electronic and print media reports to appreciate that society (individuals and institutions) is by no means limited to AC products and services when it comes to depicting, analysing or learning about the doing/thinking phenomena and processes which comprise our economic, cultural, behavioral, political, technological and environmental milieu, respectively, at the individual and collective levels.

There is competition, then, between and among means and messages (and their sponsors or proponents) that shape the nature and degree of awareness, appreciation and preference associated with doing/thinking (for the 5Ws and H); further, as one of many means or messages competing to create or attract awareness, appreciation and preference, those of the AC persuasion must achieve a level of performance commensurate with society's expectations if it is to maintain or improve its position as an Information Society element.

The terms of reference proposed to assess level of performance, that is, the real and perceived significance to society of AC effort, are based on the preceding remarks, and on a selected number of evaluation fundamentals. (Hammond, 1982; OECD, 1974; Reinermann, 1983; Wellar, 1981, 1982) Reflecting society's sometimes hard-edged approach to critical evaluation, the terms are challenging and blunt in their expression:

1 What has the field caused to be done/thought in the first instance? That is, what has the field created or precipitated in deed/thought that is of significance to society?

2 What has the field caused to be done/thought differently that is of significance to society? and

3 Is there an (identifiable) element of society which has responded or could respond, with justification, to questions of "So what?" or "Who cares?" posed with regard to 1 or 2?

To summarize, the proposed terms of reference for considering the societal significance of effort in the field of automated cartography place the matter of achievement and challenge in a three-question context:

1 What's new from a creative doing/thinking perspective?

2 What's different from a modified doing/thinking perspective?

3 So what?, or Who cares?, about any aspect of this (new) creative or modified doing/thinking?

In the following sections replies are attempted for the terms of reference questions, but it is acknowledged and emphasized that all replies are partial. As examination of the literature reveals, terms of reference have just begun to be considered by the field*, and the act of explicitly assessing societal significance of AC effort is particularly short on achievement and long on challenge.

ASSESSING THE SOCIETAL SIGNIFICANCE OF AUTOMATED CARTOGRAPHY ON THE BASIS OF MASS MEDIA REPORTAGE

The assessment which follows is based on print and electronic media reportage for the period May 1983 - August 1983, and is notably indicative and ad hoc rather than comprehensive and systematic in terms of both coverage and approach. That is, while on the order of 750 reports from the combined media in a number of countries were assembled or noted, both for explicit AC reference and non-reference, no claim is being made in terms of the quality of coverage. It is suggested, however, that since there is considerable report transfer among electronic networks and stations, and since wire service reports (CP, AP, UPI, Reuters, LA Times, etc) are utilized by many members of the print media, the assessment drawn, preliminary as it is, is both a reasonable measure of the state-of-affairs, and is applicable in many of the twenty-five or so countries represented at Auto-Carto Six.

Structure of the Assessment

While there are dependencies of various sorts between news sources and news reporters, they have been set aside in this paper to permit focussing on a particular concern: that is, to assess and comment on the extent of AC use in mass media reportage. Toward that end the presentation is structured to first consider the media in terms of the relationships established with AC products and services as reflected in reportage, and to then consider groups of key players in terms of their use of AC in reportage circumstances.

Print Media-Newspapers

Articles reveal: 1 a widespread lack of basic awareness, appreciation or preference for maps in general; and, 2 that AC products and services are held in very low regard as means to construct or conduct reportage on situations, events or processes.

The following titles are indicative of articles appearing daily which are prime candidates for map support to elaborate stories, but which appear without that support: "Europe faces a new air war - Acid rain and dying forests;" "Acid rain threatens Northeast lakes;" "Fires out

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*In spite of the fact that the mass media are both of and in the computer/communications field of development and change, there has been limited learned analysis in that regard. For discussion of aspects of the situation see Black and Caldwell (1983) and Nisenholtz (1982).

of control and spreading in Victoria;" "The escalation of world poverty;" "Desertization threatens agriculture;" "Economic assistance plans for one-industry communities announced;" "Nation's forests in grave danger;" "East-coast fisheries to be rationalized;" "Manufacturing firms moving to action;" "Large cities losing, small cities gaining population;" "Low income housing concentrated in downtown wards;" "Nation's capital losing green spaces." Newspapers assume, it appears, either that their readers are very geographically aware, or that they have atlases (world, regional, local) beside them while reading the paper!

Print Media - Magazines

Considerable and comfortable use is made of maps and AC products and services, as either the main or the supporting means to depict or discuss situations, events and processes, although the medium is obviously self-limiting in terms of the amount of dynamism possible.

Electronic Media - Television

Given the hardware-software, and image (as in living visuals) orientation of television networks and stations, the industry makes remarkably little use of AC. Indeed, when AC products and services are used in news shows, for example, the commentator, reporter or reader frequently affects a "Buck Rogers" wonderment about the demonstration. There are exceptions, of course, such as when scientific or high tech shows or spots on space, military, bio-technology, etc. topics are involved, or when a leading edge station uses AC for its weather component. By and large, however, television reportage is primitive in terms of the purposes, ways and extent that AC products and services are put to use.

In brief, then, and based upon a non-rigorous but extensive first-cut sample of media reportage, the products and services of automated cartography are of little societal significance as means to create, stimulate or modify awareness, appreciation or preference of situations, events and processes among readers or viewers.

Before accepting or reading too much into such a conclusion, however, it is necessary to acknowledge the non-media "others" involved, as sources or receivers of reportage, and their roles in shaping the 5Ws and, in particular, the How of reportage. Some four groups of "others" were identified as sources/receivers for reasons of prominence and/or frequency of presence in association with reportage that did, or should have, involved AC products and services as inputs or outputs.

Government Officials - Elected

Of the 175 or so instances of reportage involving elected federal government officials, in either media, there is a singular absence of AC products and services (as inputs, outputs, support mechanisms). That state of affairs is especially discomfitting because many of these same officials (in Canada and other countries) are: 1) spokespersons or promoters in the high-tech/info-tech domain; and 2) responsible for agencies which have in their policy/program domains situations, events and processes which are thoroughly spatial and dynamic in nature. Of the 150 instances involving elected provincial or state and municipal (elected) officials, maps in general as well as AC products and services are more prevalent, reflecting, perhaps, closer ties with the real world than those of their federal counterparts.

Government Officials - Appointed

To a large degree professional/technical officials make as full use of AC products and services in reportage circumstances as those circumstances and their AC capabilities allow. Managers and administrators, on the other hand, tend to mirror the performances of electeds in that AC products and services are not part and parcel of presentations, and could not confidently be called upon and used with familiarity during the presentations.

It is evident that the status of AC products and services in the thinking and doing of officials is fully consistent with the quantitative methods gap that has existed for more than a decade between professionals/technicals and electeds and managers/administrators. That is, the latter generally lack basic methods/techniques training, and AC is widening the gap rather than narrowing it. Further, it is most noteworthy that the interactive capability, one of the most powerful features of the modern AC effort, is seldom called upon by any official (according to reportage) no matter how germane that capability would be to the task under consideration, which may be a very good measure of just how far away we actually are from an operational Information Society.

Public-At-Large

Based on what appears in print and shown on television, the lay public is only vaguely aware of AC, and is ill-equipped to appreciate AC-based reportage. The seriousness of this state of affairs is best demonstrated by reference to an irony: we are (apparently) moving into a high-tech Information Society but at the same time the population (in Canada, and countries in general) is overwhelmingly lacking in its capacity to think/do in a spatial mode by means of AC products and services. (I hasten to add that this assessment will likely undergo significant change with the current generation of elementary and high school students [being accorded considerable computer exposure in education and entertainment], but from the present through the 1990's they will be responsible for little reportage as "others" noted above.)

As for the institutionalized component of the public-at-large, including universities, research institutes, and the business sector, AC products and services are routinely brought to bear to describe, analyse, predict, and assess the spatial/temporal distributions of phenomena (situations, events, processes). However, the order of use reflected in the reportage is frequently primitive relative to the AC state-of-the-art for two reasons. First, the parallel between officials in government and the public-at-large is striking: that is, regardless of the particular institutional milieu, the management function is far from competent or comfortable with AC in reportage circumstances. Second, neither medium is anywhere close to attaining an operational level that begins to reflect what AC products and services could contribute to description, explanation, prediction or assessment of mappable phenomena, including situations, events and processes.

In summary, then, and using reportage in newspapers, magazines and television as the measure of the societal significance of AC effort, the following conclusion is offered: automated cartography is not yet very significant as a means of creating, stimulating or shaping awareness, appreciation or preference about situations, events or processes. Implications of that state of affairs are numerous, with but two of the most important mentioned here:

1 The incipient Information Society is likely going to continue its inception for some time because without a dramatic increase in mass media use and comfort with AC products and services, the Society will remain an Ill-Informed Society.

2 The media and the AC community have a social obligation (from search-for-truth to economic grounds) to jointly take on the burden of bringing AC products and services directly to bear on doing/thinking reportage.

ASSESSING THE SOCIETAL SIGNIFICANCE OF AUTOMATED CARTOGRAPHY ON THE BASIS OF SYMPOSIUM PRESENTATIONS

In terms of what the AC community itself thinks and does in the area of creating, stimulating or shaping societal awareness, appreciation, or preference of or for AC products and services, this Symposium is an excellent basis upon which to construct such an assessment. That is, with a theme of "Computer-Assisted Cartography: International Perspectives on Achievements and Challenges", international participation by more than 20 countries, and diversity of subject and coverage, Auto-Carto Six can be justified as an appropriate basis for examining what kind of case the AC community makes for itself when it comes down to the matter of documenting the societal significance of AC effort.

What follows is not to be construed as a "review" of the Program or the Proceedings; it is, rather, an assessment that is narrowly-defined, but important to the field. That is, assuming that it matters to the AC community whether its effort has societal significance, to what extent is that concern or interest reflected in what the community has prepared for Auto-Carto Six?

Structure of the Assessment

For reasons of time and space the basis of assessment is structured around two dimensions of extent:

1 The extent to which submissions are seen (with reasonable, non-specialized effort) to be of social significance or relevance; and

2 The extent to which contributors explicitly referenced or associated society as an AC force or client (awareness, appreciation, preference) with their submissions. That is, what proportion of papers had direct or non-direct real-world implications, and how many of them were explicit about it?

Societal Significance of Submissions

As shown in Table 1, a total of 135 papers and abstracts were considered. Of those, twenty-seven (20 per cent) were seen to be so removed from the real world as to require a heroic effort to render them of social relevance or significance*. On the order, then, of 80 per cent of the submissions were of a nature that some degree of relevance or significance to society could be claimed for them.

Table 1: Assessment of Auto-Carto Six Submissions in Terms of a) Society as "Client" for AC Effort, and b) Explicitness of Reference to Society as "Client".

Submissions with Demonstrated or Readily Demonstrable Societal Significance			Submissions Requiring Considerable Interpretive Effort to Draw Out Their Societal Significance	Total
Explicit Reference to Society as Client for AC Effort	Society as Client Taken as Obvious or For Granted	Little or No Sensitivity to Society As Client		
19 (14)	41 (30)	48 (36)	27 (20)	135 (100)%

Explicit Societal Reference in Submission

Of the 108 documents that qualified as being of relevance or significance to society, only nineteen (19) were explicit, in their claims, promises, hopes, etc. in that regard, and only half a dozen of those submissions allocated more than a paragraph or two in stating or developing the societal significance aspect.

The remaining papers fell fairly evenly (41, 48) into the two remaining columns of non-explicitness:

1 Submissions which for reason of omission or commission did not address the societal significance aspect, but which apparently took that aspect as given, for granted, as self-evident, etc. And,

2 Submissions which for reason of omission or commission did not address the societal significance aspect, and which show little if any sensitivity whatsoever in that respect.

It is highly likely that examination of the documentation in terms of purposes and ways that the societal dimension is considered would lead to additional, relevant insights. For the purposes of this paper, however, what has been considered from the dimension of "extent" alone is sufficient to make the following points:

*A number of articles in this group were of a research-for-the-sake-of-research nature, or of such scientific purity as to make it most difficult to relate them to real world situations, events or processes. They might, on the other hand, be highly germane to the companion Keynote Remarks of Jack Dangermond (Dangermond, 1983).

1 The AC community effort - research, teaching, application - for the most part <u>is</u> of societal significance or relevance.

2 The AC community takes <u>few</u> pains in explicitly factoring the societal dimension - awareness, appreciation, preference for AC products and services - into that effort.

In summary, and from the AC community's own files (Auto-Carto Six presentations), the societal significance of effort in the AC field is not an abiding concern of the community, despite an achievements and challenges theme, and sub-themes, that pointed contributors in that direction. Further, and still in this vein, it appears from the preceding section that the community is at present reaping as it has sown: that is, since the AC community does not regard it as necessary to consider achievements and challenges in a societal context, then it is only fitting that society tends not to consider achievements and challenges - related to awareness, appreciation, preference of situations, events, processes - in an automated cartography context.

CONCLUSION

The purpose of this presentation was to consider the societal significance of effort - teaching, research, application - in the field of automated cartography. The approach taken was to first establish the value and necessity of taking the subject seriously - which the AC community has not yet done - and to propose terms of reference to be used by the field as it attempts to establish and justify its place in the doing/thinking paradigm of the Information Society.

With regard to assessing the societal significance of AC effort, the basis of the assessment was mass media reportage. That is, the extent to which automated cartography was used in mass media reportage involving elected and appointed officials, and the lay public, in situations, events and processes was used as a measure of the societal significance of automated cartography. As demonstrated, the field and society have a long way to go before they even <u>begin</u> to take advantage of what AC has to offer to mass media reportage.

Finally, the assessment used Auto-Carto Six submissions to measure the AC community's thinking/doing vis-a-vis the matter of societal significance of AC effort: to what extent were submissions advanced as being relevant to society's identified or expressed needs, and to what extent were submissions explicit in establishing need-response or need-anticipation.

As demonstrated, the AC community is less than fully attentive in both respects, but especially the latter, which may account for much of the price that it is paying for that lack of attention to detail. That is, neither the mass media (in terms of reportage), nor the public at large (in terms of creating or fostering awareness, appreciation or preference of situations, events or processes via AC products and services), has been sufficiently apprised of what the field has to offer (if Auto-Carto Six is a good case-in-point), with the result that AC effort is still much more marked by challenge than by achievement at least as far as societal significance is concerned.

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SCIENCE AND GEOGRAPHIC INFORMATION SYSTEM (GIS) TECHNOLOGY

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ABSTRACT

For years geographers, cartographers and other professionals who work in computer cartography have discussed the details of how automation can provide benefits of increased efficiency, lower cost, and better analysis within the application areas of thematic mapping for planning, resource management, reporting and decision making.

Less acknowledged is the potential of this technology as a support tool for scientific discovery and investigation. This paper outlines a basis for examining the relationship between the GIS technology and Science. It also attempts to distinguish this context as an area worthy of professional endeavors.

PLENARY SESSION: DIGITAL INTEGRATED MAPPING SYSTEMS

THE DUTCH STUDY CENTRE FOR LAND INFORMATION

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1. Introduction

In October 1980 the then under-secretary of the Home Office installed the first Board of the Dutch Study Centre for Land Information. In this Board are participating:

- the Ministry of Housing and Physical Planning (the Dutch Cadastre and the Government Planning Service);
- the Ministry of Home Affairs (the Directorate for Government and Automation);
- the Ministry of Agriculture and Fisheries (the Land Division, Soil and Forest Management Service);
- the Delft University of Technology (Department of Geodesy);
- the Dutch Central Organisation for Applied Scientific Research (the Study Centre for Planning);
- the Royal Netherlands Brotherhood of Notaries;
- the International Institute for Aerial Survey and Earth Sciences (ITC);
- municipalities;
- private firms: KLM-Aerocarto; Grontmij; KAFI; Fugro; Dwars, Heederick en Verhey; Oranjewoud; Van Steenis.

The objectives of the Study Centre are:

a. the promotion of study en scientific research in respect of land information in its broadest sense and assistance in the coordination of such study and research;
b. promoting the transfer of knowledge and experience in the field of landinformation.

The Study Centre's highest decision-making body is the General Committee, made up of representatives of all participants. The General Committee (the Board) has delegated a number of tasks and competences to the Executive Committee consisting of the president, secretary and treasurer of the General Committee, and the scientific consultant.
Operational activities are performed by the Bureau of the Study Centre, under management of the Director.
For a proper level of scientific research and the field of investigation to be covered by the Study Centre, the Board will be advised by a Council. The members of the Council have been invited on personal title.
Finally it has to be emphasized that The Dutch Study Centre for Land Information is an open Centre, both relating to the accessibility of research results and the possibility of participation and/or donation.

2. Why this Study Centre ?

At a rough estimation an amount of 30 milliard guilders is spent yearly by the Dutch government on activities related to land. This is a quarter of the total Dutch government budget and not less than 10% of the Gross National Product.
These are huge amounts which, however, may sound less astounding if one realizes the many things that are understood by land. It includes not only real estate (such as ground, houses, water-ways, industrial buildings, etc.), but also drainage systems, telephone systems, electricity systems, sewerage systems, etc.

Every day decisions have to be made on the purchase, use, installation, maintenance and many other questions which have to do with land. Such decisions can be correct only if adequate land information is available on all elements in the world surrounding us and which have a fixed location on, in or under the earth surface. Some 200,000 Dutch employees (most of them public servants) cannot do their duties without land information. Collecting and controlling the information on real estate only (which is just a part of what is called "land") already costs more than one milliard guilders a year. Some 6,000 people in the Netherlands have a full-time job in this field.

This field of activity in society is, at the same time, a problem field.
Four developments can be distinguished here:

a. We have to do with rapidly increasing activities with land, whereby use is made of available land information systems. There are hundreds of such systems in the Netherlands, and at various levels.
With all respect to their own aims and purposes, it must be said that, taking all of them together, these information systems are able to supply only a part of the information required. They do not describe the real situation fully enough: there are overlaps and large gaps. Moreover, the relations between the systems are bad or do not exist at all.
b. The transfer from analogous to digital data systems. Maps are an important element in land information. These maps are analogous pictures of terrain situations. As a result of the increasing automation more and more digital pictures are made instead of analogous pictures.
c. The tendency towards collecting and recording detail information at the lowest level in the organisation, without the use of large external computer systems. This tendency is often referred to as the changeover from centralized to decentralized information systems. In the short history of automated information systems this development is very remarkable.
d. The increasing demand from society for integrated information. This integration refers to place, time and certain functions.

The Dutch Study Centre now tries, in this field - as it were between the university and the user at the basis - to carry out investigations with regard to relevant social problems, by applying scientific methods. The more so, because with various land information system investigations are carried out, in most cases however only with their own aims and purposes (budget!). And even then the investigations often cover only the so-called automation. There is generally no active investigation that goes beyond the direct interests of industries, services, institutions or parts thereof.

The foundation of the Study Centre which intends to achieve a better and well-structured approach is the answer to the challenge hidden in these problems.

3. Land; land information

To avoid misunderstanding with regard to the meaning of the terms "land" and "land information", more detailed descriptions are necessary. Within the field of research activities of the Study Centre, the approach given by M.J.M. Bogaerts is in use. See for instance paper 304.1 of the XVII Congrès de la Federation Internationale des Géomètres 1983 (Sofia). There it is stated as follows.
An important part of the surrounding reality consists of "land" which includes all geographic units having a fixed location on, in and under the surface of the earth. They vary from large administrative areas to small objects. A concession area of an oil company, for instance, is a geographic unit, as wel as a house, a plot of ground, a radio link, a cable or a pipeline. Since the activities of the government, industry and private persons, with regard to land are increasing, we see in our society a growing demand for information in connection with land. Collecting, processing and supplying land information is effected in so-called "land information systems". These systems do not cover the complete land information; there are gaps and overlaps.

Land information
Land information may be classified in two groups. The information referring to the geographic units themselves is called topographical information. The other group is the thematic information. We hereby mean the information that can be added to the geographic units (see figure 1).
Another classification of land information is in registrative and statistical information groups. Registrative information refers to geographic units such as the cadastre, cadastral parcels and houses. Statistical information refers to larger units. Such as street segments, quarters and squares of 500 x 500 m.
Statistical information is usually expressed in percents and is sometimes gathered by means of samples.
In literature there sometimes is confusion about the terms "data" and "information". "Data" can be seen as the material for information systems. During the procedure of processing, the data are subjected to a number of operations, such as arranging, coupling, multiplying by certain factors, etc. They result in the information that is supplied to users for special purposes.

Topographic information
This kind of information refers to the geographic units themselves. Among other things: the name of the unit, the dimensions, the boundaries, and the material it consists of. Certain provisions also belong to the topographic information, such as the drainage of a plot of grounds. Problems occuring with topographic information are caused by the use of the same name for different kinds of units, or different names for the same unit. Sometimes it is difficult to determine the limits of a geographic unit (what is the boundary of a bridge, of a road, etc.). Geographic units may occur in one data file and not occur, or appear in a different arrangement, in another. The choice of the geographic unit is often connected with the scale at which the units are depicted.

Thematic information
In principle any information can be coupled to a geographic unit. For instance: the legal situation, the value or the use that is made of a unit.

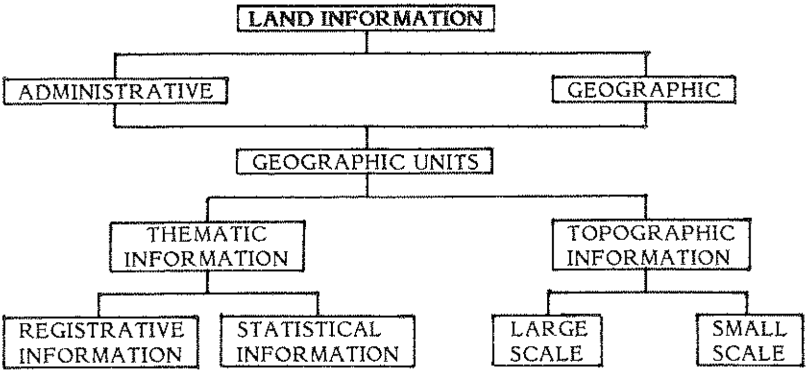

Figure 1

The following can be concluded from it: land information is information about the geographic units themselves (topographic information) and thematic information which is very closely connected with them.
Very important is the location of the geographic units with respect to the surface of the earth. This, in fact, is the only common information of all geographic units. Therefore, the location is pre-eminently the information that serves for the exchange of data between land information systems.

4. Field of attention and programme

Land information refers to enormous flows of data stored in many different ways and used for a variety of purposes. Information systems existing in this field partly overlap, have been arranged according to different methods and also present gaps. There is a tendency towards an increasing demand for land information and, when now techniques are applied (computerized cartography and image screen technology), there are possibilities to solve existing problems, to render the information supply more efficient and to realize new methods of application.

The problems, for which the investigators have to find solutions are, in the first place, of structural nature. The existing maps are being modernized. This modernization refers especially the arrangement and standardization of the available material, in such a manner that basic systems are made, which can be used for different applications. It must be possible for these basic systems to be coupled without any problems and they must contain up-to-date information. It is of primary importance that the existing information be available in a usable form. Many a planner knows from experience the lot of information that may be missing, so that he has to spend the greater part of his time on the gathering of the required information. In the case of well-organized land information systems it must be possible to carry out such work considerably more efficiently. The same holds good for many other examples. Standardizing research (category 1) is a prerequisite in this case.
This kind of problems is connected with the second field of attention covered by the research; the fact of its being aimed at the intended application of the land information (category 2). For a number of years there has been a tendency in the Netherlands towards more and more decentralization. This makes special

demands on the land information, for instance in matters like housing and municipal tax levying. The problems which arise during the levy of real estate tax are common knowledge. The different ways in which hither and thither the value of real estate was ascertained led to controversial results causing a feeling of inequality of rights among the taxpayers.

It can be said in general that good administration depends on the quality of the available information. Besides information about the composition of the population, land information is one of the most important data sources required. In the same way adequate environment control - which is considered of increasing importance - is to a large extent dependent on land information.

Last but not least, there are numerous innovative possibilities in the field of land information.
Therefore, the key-item of the research programme of the Study Centre is the innovative research (category 3). Special consideration is given here to existing social demands; it is a matter of the development of knowledge with commercial value. For example, a research is being carried out at this very moment covering the development of digital topographic basic systems for municipalities. This research tries to find out in what way it can be made possible for municipalities to use one basic system for different applications.
Another important research project is FRANK, by which is understood: Photographic registration for analogous image presentation and map collection.
This research covers the gathering of data with the aid of the most modern recording cameras and scanners. Because of the application of computers special demands are made on the gathering of data. The technique of processing and reproducing data is still in the course of development as well.

Based on the abovementioned grouping the following programme can be given, whereby it is indicated for each category what has been done (F), what is being done (R) and what should be done (P).

Category 1 : Projects with a standardizing effect

In this category the following projects have or will be given high priority:

a. Classification (F; P)
During the research in the field of classification an investigation has already been made in the matter of large-scale topography. Further research has to be carried out, however, in the matter of classification of topographic information (geographic units). The items to be covered are classification of the small-scale topography, standardization in the depiction of topographic units, and investigation of the pictures with the geographic units in administrative systems. In due course the classification of thematic aspects of land information has to be started, notably with respect to the use and the users of the geographic units.

b. Norm-setting and norm-description in land-survey (R)
Geographic units are often expressed by means of coordinates. In the last few years many new measuring and computing techniques have been developed for the determination of these coordinates.
Services in the field of land-survey have been extended considerably as well. The services are often meant for a variety of purposes. All these factors have led to a great number of computed results which are often too heterogeneous of character (in each project or from one project to the other) to enable an adequate coupling of results, which coupling is often

considered necessary from a social point of view.
Therefore, a new framework has to be designed for the description of the measured and the computed results. It is not only a matter of qualitative description but also of weighing costs and, in this way, achieving optimum measuring and computing procedures.

c. Data structures (P)
The investigation is suggested in the field of line segments and squares. Both systems offer the possibility to couple administrative data to geographic units and to make thematic maps. In addition, these systems are of fundamental importance for the application of computer cartography. Moreover, they can be used to find out the best possible location for all kinds of provisions. The investigation shall cover the question of the general application possibilities of the abovementioned methods and the method that can best be used in the various applications.

d. Conversion (R)
The conversion of analogous to digital data is an important activity in the case of land information systems. Continuous research is a must in this field. Priority is given to an investigation of the conversion of detailed topographic data systems.

The parts concerned are:
1. continuing activities with regard to the methods or techniques for the conversion to a digital form of data of elements belonging to the so-called hard topography. The ultimate end here is a comparison of aspects with reference to costs, precision, reliability and identification; all this with the aid of existing data;
2. activities regarding data conversion of the information about the location of cables and pipelines, whereby attention will be paid to:
   - the applicability of the various conversion techniques;
   - the usability of the various basic data;
   - the identification problems.

Category 2 : Projects aimed at the intended application

In this category we find the following projects:

a. Land information in the case of municipalities (R)
With regard to municipalities there is a great demand for adequate land information for many applications. It is necessary to investigate the optimalization (or automation) of:
- municipal cadastral information;
- information on buildings;
- topographic information and information on cables and the like.

This investigation intends principally to assess the contents of the systems, standardize the data of the existing systems, improve the information flows and the supply of land data of national, municipal and other systems.

b. Possibilities of thematic information
It is hardly possible to foresee what initiatives will be brought forward to the Study Centre with regard to investigation in the field of thematic information. Generally it is a question here of meeting a social requirement. Three examples of thematic information are given.

b1 Energy-card (R; P)
An example of such a project is the research regarding the graphic representation of the demand for and the supply of energy and their relevance in the physical planning. One of the reasons of this research is the increasing interest in the re-use of residual heat.

b2 Uniform valuation and value registration of real estate (R; P)
For many applications in the Netherlands the thematic terms "value of real estate" is used. This is done, for instance, for a number of fiscal purposes and for some aspects in land- and town-planning.
For this purpose an investigation is required to arrive at a uniform valuation and registration of real estate. The investigation is important, in particular, for the drainage districts, municipalities, national taxation department and land registry.
The investigation helps towards a more efficient and better understandable levying of taxes.

b3 Index figures physical planning (R; P)
A third example of thematic information refers to index figures on behalf of physical planning.
One of the problems in the case of town renovation and public housing is that no adequate instruments are available to come to a systematic plan evaluation in these fields.
The information required for this purpose consists of so-called index figures, by means of which the distribution of land use can be evaluated.
Further research in this field is required.

c. Land planning (R)
Within the framework of the new Land Planning Act measures have to be taken not only in the interest of agriculture, horticulture and sylviculture, but also to protect nature, landscape, land- and water-ways, and open-air recreation. As a result of this integration of functions of rural areas, a further integration of the required information is necessary as well. In the course of time the research in this field will have to be continued.
At short term priority will be given to the research regarding the application of Linear Programming as an aid in the design of the allocation plan in land planning.
The use of interactive graphic systems should be preferred here. At a somewhat later stage this research has to be connected to the information researches for the land planning itself.

d. Information supply and plan formation for town-renewal (R)
One of the problems when setting up town-plans for town-renewal is the lack of adequate systematics for an efficient information supply.

The research for this purpose aims in the first place at:
- planning and lay-out of the registers of property and use;
- development of the plan forming and evaluation systematics of the allocation plan.

Category 3 : Projects with an innovative effect

This subject covers the investigation regarding new methods and techniques to gather, process and supply land information.

a. FRANK 2^{nd} phase (R)
With the FRANK system topographic data can be obtained in a photographic and electronic way, by means of a terrestrial recording system.
In the second phase of FRANK function models are being developed for a recording camera and a processing instrument; for an electronic scanner; for the development of a computing programme for the computation of the coordinates of the recorded points.

b. Digital topography 2^{nd} phase (R)
In a preliminary study entitled "the application of digital topographic data systems for municipalities" an investigation has been carried out of the desirability and the possibilities to set up, for municipalities and users of municipal information systems, a digital topographic basic system containing such data and being so accurate that this topographic basic system can be used for carrying out the various municipal tasks.

The second phase covers the investigation regarding the setting up of a digital topographic basic system and the planning of a data structure for various municipal applications. The investigation will enter into the question of how thematic information stored in administrative systems can be graphically presented.

c. Data communication in land information systems (P)
This research will cover the developments in the field of communication techniques to see how they can be made applicable to statistical information, as well as in the field of the registrative land information. In addition, the possibilities will be investigated of computer networks for deconcentrated land information system at national and municipal level.

d. Development of new automated land-survey systems (P)
This project deals with the application of new locating systems in land-surveying, and in particular the application of inertia navigation and satellite geodesy. These navigation devices together with recently developed photogrammetric apparatus could be applied in model-aircraft or model helicopters.

e. Investigation of interactive systems (P)
The rapid development in the field of the administrative and graphic processing possibilities render a comparative research necessary of new systems, extensions of the hardware and software, application of colour image screens, possibilities of micro-computers, etc.

f. Spatial dynamic data supply (P)
An investigation is necessary to make the new possibilities in the field of the interaction between man and computer applicable to land information systems.

g. Development of automated information systems for small administrative units (P)
The project "Digital Topography for Municipalities" encloses an investigation of the structure of certain data systems. An additional investigation has to be carried out to find the best manner for the automation of such data. Possibilities for this purpose are, for instance, central computers, interactive systems, network of micro-computers, etc.

Since 1980 approximately 25 projects have been dealt with, a number of them being finished, some of them are being carried out and some others are in the course of preparation.
Reports are available of the projects put into practice, seminars have been organized as well.

5. Financing

Figure 2 indicates how the medium-long term financing of the programme will be:

Cost estimate (in Dfl 1000,--)

	Projects	1983	1984	1985
A.	Standardizing	255	480	350
B.	Projected towards application	596	550	350
C.	Innovative (projected towards system)	1000	1250	1950

Figure 2

Ways are being considered to realize the financing in a more structural manner, whereby the Board divides the means according to the programme and priorities to be set.
The following, most important financiers can be mentioned:
- Ministry of Home Affairs;
- Ministry of Housing and Physical Planning;
- Ministry of Education (Science);
- Ministry of Economic Affairs;
- Municipalities and industries.

Additional, new sources of financing may be found in future, especially if the research carried out is specifically projected towards intended applications.

6. Conclusions

a. In the Netherlands, but no doubt also outside the Netherlands, there is a distinct demand for scientific research in the field of land information, projected towards the solution of various problems of social relevance.

b. There appears to be a clear task for the Study Centre for Land Information: approximately 25 projects in about three years, aimed at standardization, application and innovation.

c. The prospects for further financing on the medium-long term are not unfavourable; efforts are being made to arrange the financing so as to come off in a more structural way, based on a programme of several years.

ALBERTA LAND INFORMATION SYSTEMS: CONCEPT TO REALITY

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ABSTRACT

In 1981, the province of Alberta concluded a two year study which described the requirements of a provincial Land-Related Information Systems Network. This paper identifies key developments during the past decade and describes in general detail the primary components of the Provincial Network. In this context the Alberta Bureau of Surveying and Mapping and its' specific responsibility for the development of the geographical positioning and base mapping system is discussed. Some elaboration is given on the digital mapping data bases being developed, including preliminary results obtained using laser scanning technology.

INTRODUCTION

The province of Alberta has capitalized on its land based economy and related developments which occurred over the past 100 years such that the province is now at the leading edge of Automated Land-Information Systems development. This paper provides in two sections an over-view of major milestones and provides insight into the logic behind the provinces current strategy.

THE ALBERTA CONCEPT OF LAND INFORMATION SYSTEMS

Concept Development

To begin at the beginning, it is necessary to start with the original land survey of Western Canada, then known as the Northwest Territories. The original survey of the Western Canadian Provinces which dates back to the 1880's is considered an outstanding achievement and possibly the largest single survey project ever undertaken anywhere in the world. The Dominion Land Survey (DLS), as it is known, resulted in 6 mile square townships with road allowances of 1 chain with east/west roads on every second section line, covering the whole of the Province. This system created approximately 40 000 township units.

This early development coupled with effective Federal/ Provincial government survey control coordination through the past 100 years is the reason why Alberta has been able to achieve significant advances in the area of computerized land information systems, during the 1970's and into the 80's.

To provide insight as to how Alberta evolved to it's current highly developed state, a review of the key happenings during the past decade is appropriate.

- 1973: Report of the Committee for the Coordination of Statistics and Research on Land Data: Identified the need for a high level of coordination within the provincial government to reduce costly duplication and mistakes.

- 1974: The Task Force on Urbanization and the Future: A task force formed at the request of a number of cities, regional agencies and provincial departments. This effort was directed at the coordination of land related information systems.

The task force recommendations gave direction to all subsequent provincial activities.

- 1975: User's Conference on Provincial Coordinates. A conference stimulated by private sector concern over the rapid growth of information systems and the need for commitment from government for more and better survey control and over-all coordination of Information Systems Development.

- 1976-77: As a result of the growing perception within government that there was a requirement for a coordinating body of sorts, the Alberta Bureau of Statistics of Alberta Treasury was charged with the responsibilities of providing a Land Related Information Systems "clearing house service". The Bureau was effective in providing a medium for the exchange of information as well as compiling a catalogue titled "Inventory and Index of Land Related Information System" a first in the province.

- 1977: Government approved a 10 year program "to establish a comprehensive survey control base and coordinate system for the entire province over the ten year period 1977 - 1987.

- 1978: Cabinet agreed to establish a central agency within the Government of Alberta having the responsibility to coordinate the introduction of and modification to Land-Related Information Systems which would be available to the private sector, Municipal and Provincial governments. The responsibility was assigned to the Alberta Bureau of Statistics with final delegation of programme responsibility to be reviewed on the basis of the initial recommendations.

Initially, this "Agency" was to exist as a two year project and was identified as the Land Related Information Systems (LRIS) Coordination Project.

- 1981: A cabinet decision was taken to establish one agency with the responsibility for the overall coordination of surveying and mapping activities within the Government of Alberta. This agency is the Alberta Bureau of Surveying and Mapping.

The LRIS Coordination Project tabled its final report to government.

- 1982-83: A cabinet decision was taken to implement the LRIS Coordination Project report recommendations. Accordingly, the Land Related Information Group was created through a transfer of resources from Treasury (LRIS) to the Alberta Bureau of Surveying and Mapping.

LAND RELATED INFORMATION SYSTEMS COORDINATION PROJECT

The requirement for a central government body dedicated to the on-going coordination of development and use of Land Information Systems, has been handled throughout the 1970's by both public and private interests within the province. The decision by Government to create an interim body, the project, and place it with Treasury met with general support throughout.

The advantages to this approval are important and deserve to be mentioned.

- Treasury was accepted by all other Departments as having no vested interest in the outcome (i.e. Systems Related).
- The Alberta Bureau of Statistics offered sufficient functional continuity to offer a reasonable interim home.
- Through Treasury, project staff were able to access program planning information as it related to other line Departments.
- Where Departments were sceptical as to how they would benefit, the fact that it was a Treasury project assured their participation.

Great care was taken throughout the two years of the project to work cooperatively with all Departments. To assure this, the project reported to an inter-departmental committee comprised of senior representatives from key Departments.

The Project itself was made up of three project employees whose efforts were augmented by contract funds.

Project Purpose. The overall objective of the Land-Related Information Systems Coordination Project was to facilitate the development of a network of Land-Related Information Systems within the Province. The network was to exist in terms of improved access to and user value of land related data as maintained by both the public and private sectors and, as such, minimize systems development and operational costs. For the purpose of the project, a Land-Related Information System was defined as a collection of related or geographically-referenced data and the methods and procedures developed to organize, manage, retrieve and analyse or interpret them. These systems could be either manual or automated.

The Network Concept. The project developed a concept to provide for the existence of any number of systems, which, through their dependence on certain common sources of data and the adoption of a variety of standards would provide for interactivity. The concept was dependent upon the existence of three primary systems which would be well defined, very structured and have formal linkages between them. All other land-related information systems would be considered secondary systems and either be derived in part from the primary systems, be dependent on them as a source or last of all, related back to the primary system as well as other systems through the use of universal data elements.

The Network Plan. The highlights of the Network Plan were as follows:

- The creation of three primary systems characterized by partially centralized control. These were the:

(a) Provincial Geographical Positioning System comprised of three component systems (Survey Control, Land Survey and Aerial Survey).

(b) Provincial Mapping System as described by the Interdepartmental Committee on Surveying and Mapping.

(c) Provincial Land Registry or an Alberta Land Registry incompassing both crown and patented lands within the province.

- The creation of a centralized referral function supporting decentralized information access with access and dissemination of land-related information to be facilitated through system automation and policy guidelines.

The successful creation of a networking effect for secondary systems requires the institutionalizing of mechanisms which support and enhance the sharing/exchange of information, technology and expertise, cooperative efforts amongst producers and users of information and the continued monitoring of network effectiveness.

- Provision for the ongoing transfer of technology directed at continued and compatible development of information systems as well as the means to access and utilize other systems by areas outside the provincial service.

- Coordination identified as essential to the on-going maintenance of the network and to occur as part of a process rather than as a separate control. Recommended therefore that the LRIS Coordination Project be transferred to the Alberta Bureau of Surveying and Mapping.

Implementation. The 1970's saw considerable investment in Land Information Systems in both the public and private sectors. These initiatives resulted through necessity as Alberta experienced both continual growth in development of the natural resources as well as a dramatic increase in urban populations with the associated requirement for services. Change was taking place, there was no need to stimulate it. The LRIS Coordination Projects' challenge was one of describing relationships, setting out additional requirements and creating a suitable framework within which existing systems fit and future systems would be developed with the assurance that a desired level of interactiveness and user value was attained.

Implementation of the LRIS Network Plan began to occur during the preparation of the Projects final report and has continued over the past two years. The emphasis, appropriately enough, has been on the primary systems.

- Provincial Geographical Positioning System: This is viewed as the generic base for all Land Related Information Systems within the Province. The creation of the Alberta Bureau of Surveying and Mapping as the one agency responsible for the overall coordination of surveying and mapping within the province was key to development and maintenance of this system. The details of the system are provided further on in this paper.

- Provincial Mapping System: The requirements of this system were set out by the Interdepartmental Committee on Surveying and Mapping but required the creation of the Bureau of Surveying and Mapping to effect the required level of service to provincial users. Details of the system are provided further on in this paper.

- Provincial Land Registry: Land ownership information is viewed as a primary form of information, essential to the largest majority of information systems and users. The LRIS Coordination Project recommended the consolidation, through procedures and technology, of all existing registry functions supporting the provincial government administration of crown lands as well as the standardization of common aspects of the two existing major systems, that of Energy and Natural Resources and of the Attorney General. The system proposed was called the Alberta Land Registry (ALR).

Progress towards the creation of the Alberta Land Registry System saw the province commence a plan to automate the Energy and Natural Resources System (Land Status Automated System - LSAS) for crown lands and the Attorney General's Land Titles (Alberta Land Titles Automation - ALTA) for patented lands. Complimentary to this was the Alberta Bureau of Surveys and Mapping survey control programme from which is generated the Alberta Township System (ATS) which provides the geographical positions of townships, sections and quarter section corners.

To-date the Land Status Automated System which was initially to encompass all public lands (surface and sub-surface) is under scheduled development and is designed to have the capacity to retain information for every parcel of land in the province down to a 1/4 of a quadrant or 1 hectare. This system is being constructed for an estimated cost of $6.5 million (1982 dollars) over a period of five years. The first of five operational releases will be up late in 1983. The final release is scheduled for July, 1985.

Work commenced on the Land Titles ALTA system during 1981 with considerable work being undertaken to assure the ultimate compatibility of these two very large systems. Unfortunately, the economic down turn caused Land Titles to put the project on hold. As there has been no change in policy, it is assumed that this will be a set-back in time only.

- Secondary System: Cabinet's acceptance of the LRIS Coordination Project recommendations carried with it an approval for making the project unit a permanent central function. This group would provide a clearing house for land related information systems, develop and implement the means to support the sharing and exchange of data, and plan the provincial thematic information standards with particular reference to quality, quantity and access.

To-date, the group has been officially transferred from Treasury to the Bureau of Surveying and Mapping and is being staffed.

ROLE OF ALBERTA BUREAU OF SURVEYING AND MAPPING

The Alberta Bureau of Surveying and Mapping was formed in 1981, when the terms of reference of the former Surveys and Mapping Branch of Alberta Transportation were expanded, and that branch was transferred to Alberta Energy and Natural Resources. This move followed a provincial cabinet decision to establish one agency with responsibility for the overall coordination of surveying and mapping activities within the Government of Alberta. A document prepared by a committee of senior executives entitled, "Report of the Interdepartmental Review Committee on Government Surveying and Mapping Services", defined the following general terms of reference for the Bureau:

1. To provide a geographical positioning framework for the Province, suitable for use by Government departments and the private sector in the integration of position dependent land-related information.

2. To provide for a standardized mapping system for the Province, suitable as the basis for display of position dependent land-related information.

As discussed in the previous section, an additional term of reference was added in April, 1983, as follows:

3. To coordinate the development and implementation of Provincial land-related information systems.

The Bureau's primary production activities are currently directed towards goals embodied in the first two terms of reference. These goals are to develop two major primary land information systems - the Alberta Geographical Positioning System (AGPS) and the Alberta Mapping System (AMS). These systems provide the essential framework required for the subsequent development of computerized data bases of information which are geographically referenced or "position dependent". The following sections describe the scope, current status and future planning related to the development of those systems.

ALBERTA GEOGRAPHICAL POSITIONING SYSTEM

This system is comprised of three data bases which, when completed, will provide the capability to determine the geographical position of virtually any object or entity in the province. Such a determination will be possible through field survey measurements from a survey control marker or land survey monument, or by photogrammetric measurements from controlled aerial photography.

Survey Control Data Base

The Survey Control Data Base provides the basic coordinate referencing system for the Province. This system is being developed through the establishment of provincial and municipal networks of survey control markers, and the determination of their geographical positions (latitude, longitude and height above Mean Sea Level) in an homogeneous system based on the National Geodetic Survey System. A record of marker positions is maintained in a data base management system on the government mainframe computer, together with field observational data, marker location descriptions and statistical qualification data. The development of this data base began in the early 1960's, when the provincial government first began to supplement the federal Geodetic Survey's production efforts in Alberta by establishing rural networks of second order control, and by densifying to third order control in major urban centres.

In 1978, a ten year program was funded to establish a complete provincial framework of second order survey control markers at an approximate spacing of 10 km by 20 km, and to accelerate the program of control densification in urban municipalities.

The determination of the level of funding required for the development of this data base was predicated upon intergovernmental cooperation on its establishment, in the form of cost- and work-sharing agreements which had been initiated in the mid 1970's. The provincial framework is being established jointly by the province and the federal government, with the province undertaking site selection and preparation, marker installation, targetting and photo identification photography, and the federal government providing positioning (primarily with the helicopter-mounted Inertial Survy System technology), data processing and coordinate computations. Municipal networks are established through the mechanism of an urban surveying and mapping program (Kennedy, 1981 and 1982). Municipal-provincial agreements are signed, which establish each party's responsibilities, with municipalities providing and installing markers, and maintaining and perpetuating networks, and the province surveying the networks and computing coordinate values. At the end of the last fiscal period, March 31, 1983, approximately 4 500 markers (65% completion) had been placed under the provincial survey control program, and approximately 19 500 markers (75% completion) were established under the municipal program. The long range goal is to have complete provincial coverage, as well as coverage of urban centres with a population greater than 3 000, by 1988.

Photogrammetric Control Data Base

This data base, which is presently in the early stages of development, will consist of blocks of aerial photography (at a scale of 1:60 000 for complete provincial coverage and 1:8 000 for coverage of major urban areas), controlled by photogrammetric control points whose geographical positions have been determined relative to the positions of targetted survey control markers. The primary use of this data base will be for the compilation of 1:20 000 and 1:1 000 Digital Mapping Data Bases.

Although significant photogrammetric control work has been undertaken by the Bureau and other government agencies, dating back to the mid-1970's, the results of these products have heretofore not been consolidated and structured in an integrated Photogrammetric Control Data Base. In 1982, a program was established to develop such a data base, and assessment of existing materials is currently underway. Standards and specifications have been prepared and adopted, and production processess have been modified to meet the new standards. At the end of the past fiscal year, approximately 15% of provincial coverage was completed, and approximately 60% (i.e. 44 urban centres) of municipal coverage was completed. As with the Survey Control Data Base, the long range goal for development of this data base is to have complete provincial coverage and coverage of major urban centres by 1988, with new photography to be flown on a 5 year cycle.

Land Survey Data Base

The Land Survey Data Base consists of the geographical positions of the governing monuments and points of the land survey system. Consistent with the previous two data bases, the accuracy requirements for the positions are commensurate with mapping scales of 1:20 000 and 1:1 000 in rural and urban areas, respectively. The objective is to determine the positions of points in primary surveys (i.e. DLS township system) to an accuracy of ±5 m in rural areas, and the positions of points in secondary surveys (i.e. subdivisions, rights-of-way, etc.) to an accuracy ±0.25 m in urban areas.

The development of this data began in the mid-1970's with the initiation of the urban surveying and mapping program. Positions of urban land survey points are determined through rigorous computation, based on survey ties from the survey control network to key points, and using bearings and distances obtained from registered survey plans. In 1977, the first iteration of a coordinate record of the rural land survey system, called the Alberta Township System (ATS) File, was published. This record was a strictly theoretical determination of the geographical positions of township, section and quarter section corners, with an estimated accuracy of from ±10 m to ±100 m, depending on the deviation of the actual township survey from the theoretical DLS model. A process is now under development which will upgrade the ATS File to the required accuracy level through recomputation, based on survey ties from the survey control network to each township corner, and using bearings and distances shown on the official township plans. As of March 31, 1983, the data base covered 42 municipalities, and although upgraded ATS coordinates were not yet available, approximately 20% of the survey control ties had been completed. The long range goal is to have coverage of all major urban centres and rural areas of the province by 1988, and to revise the data base on an on-going basis as new surveys are completed.

ALBERTA MAPPING SYSTEM

The Alberta Mapping System is being created to satisfy a broad spectrum of requirements for the visual display of position dependent land information. Comprised of four discrete digital mapping data bases, the System's design reflects the belief that no single representation of the terrain and manmade improvements can satisfy diverse requirements which range from urban utility systems design to general administration of the province's natural resources. The data bases described below are being developed to satisfy this range of user needs, within the constraints inherent in presently available digital mapping hardware and software. Data base development is being undertaken on the Bureau's Geo-digital Mapping System (GMS), which consists of Intergraph interactive graphics and Gerber photo-plotting sub-systems. The present GMS configuration is illustrated schematically in Figure 1.

1:1 000 Digital Mapping Data Base

As the name implies, this data base provides a very high level of accuracy and detail. Coverage is limited to major urban centres and costs of development are shared by the municipalities. Development has evolved from the previously mentioned urban surveying and mapping program, which has traditionally provided cadastral mapping at a scale of 1:1 000 and orthophoto-line mapping at the 1:5 000 scale (Kennedy, 1982). Production of this data was initiated in 1981, following the installation of the GMS in mid-1980, and at the end of the last fiscal year, the data base covered 8 municipalities and was under production in 7 others. Manual mapping is available for 28 additional urban centres, and conversion of this coverage to digital form is being undertaken during revision.

The long range goal is to complete data base coverage of all urban municipalities having a population greater than 3 000 by 1988, with content including hydrography, 1 m contours, land survey (cadastral) system, and transportation system, as a minimum. However, due to factors including original analog mapping system design and resource limitations, coverage presently includes only cadastral and contour data, with other features provided by orthophoto imagery. The complete 1:1 000 Digital Mapping Base is gradually evolving, as several municipalities in the current year's program are opting for full digital line mapping rather than orthophoto-line mapping. The speed with which this evolution occurs is largely dependent on the needs of the municipalities, since a significant proportion of the increased costs of digital mapping must be borne by them. Major land information systems are being developed by the Cities of Edmonton and Calgary (Ritchie, 1982, Somers, 1982), and the benefits being demonstrated are encouraging smaller municipalities to plan for future development of similar systems, either in-house or through computer graphics service bureaus. This developing trend is expected to significantly promote the rapid growth of the 1:1 000 Digital Mapping Data Base.

1:20 000 Digital Mapping Data Base

This data base, which is in the advanced planning stage, will provide the primary digital graphics framework for the development of provincial land information systems in Alberta. Its creation has been widely endorsed and long awaited by public and private sector users alike. Production will be carried out primarily by the Resource Evaluation and Planning Division of Energy and Natural Resources, supplemented by the Bureau's resources, through contracts with the aerial surveying industry. Data base content will include major features such as hydrography, 10 m contours, land survey system, transportation system, municipalities, and major man-made facilities. The design is based primarily on the results of a recent Map User Survey, conducted by the Land-Related Information Services Group (Beattie, 1983).

Full scale production of the 1:20 000 Digital Mapping Data Base is scheduled to commence in April, 1984. A pilot project is currently underway to develop production methodologies, cost and production time estimates, and industry capabilities. A prototype production phase is planned for this winter, to test any modifications in design or production processes which may result from the pilot project. It is anticipated that the completion of this data base will take 15-20 years at the present level of funding, and because of resource constraints, it is likely that the initial data base will contain planimetry only. An agreement has been reached with the federal Surveys and Mapping Branch to mutually explore the feasibility of converting contours from the 1:50 000 NTS mapping to digital form (10 or 20 m), and adding them to the data base as an interim hypsographic component. The results of this study, and of the 1:20 000 pilot project and prototype production phases, will provide the necessary ingredients for the formulation of a long range production plan for this data base, in the Spring of 1984.

1:250 000 Digital Mapping Data Base

Coverage has recently been completed with a provincial 1:250 000 series of base maps produced by the Bureau. Similar in content to the new 1:20 000 data base, this mapping currently uses hydrography and contour components from the NTS 1:250 000 base. This map series is being converted to digital form to create the 1:250 000 Digital Mapping Data Base. This data base is required by a number of public sector agencies who do not require the level of accuracy and detail which will be provided by the 1:20 000 Digital Mapping Data Base, and by several others who have an urgent need for an "interim" base until the 1:20 000 base becomes available.

It is proposed to develop this data base through the use of automated digitizing technology. This conversion methodology is appropriate because the existing 1:250 000 map series has significant feature separation on film overlays. The Bureau's investigation of automated digitization was initiated in early 1982, and tests have been conducted on five systems since that time. The most promising results were experienced with the Kongsberg Syscan System, which uses a Laser Scanner for conversion of graphics. Development efforts are now focussed on refining procedures for the use of that System for the 1:250 000 data conversion process. Experiments and negotiations have been conducted to resolve the most cost-efficient combination of pre-processing (overlay separation) and post-processing (interactive editing) required to meet the data base design specifications. Preliminary results are very promising, and a pilot project now underway is scheduled for completion in November, 1983. If this pilot project is successful, the Bureau plans to contract with a Kongsberg service bureau for the conversion of the 50 map sheets which cover the province, and to complete the 1:250 000 Digital Mapping Data Base by 1985. Once the 1:20 000 base is established, it will be used to revise this data base.

1:1 000 000 Digital Mapping Data Base

This data base is proposed for the representation of generalized administrative or planning data which is province-wide in scope. It will contain very generalized base mapping data, and like the 1:250 000 base, will be created from an existing base map. It is proposed to use laser scanning for conversion of a significant portion of the graphics. The system design and conversion plan will be finalized this year, and the data base is planned for completion by 1985.

CONCLUSION

In summary, Alberta recognized the potential benefits which would occur from central coordination and a long-range development plan which could include all land information systems within the province, public or private. This is most clearly represented in the key decision to support the creation of a central provincial Geographical Positioning

System. Although considerable work remains and the need for additional funding exists, progress continues to be consistent with the long-range strategy adopted by the province continues.

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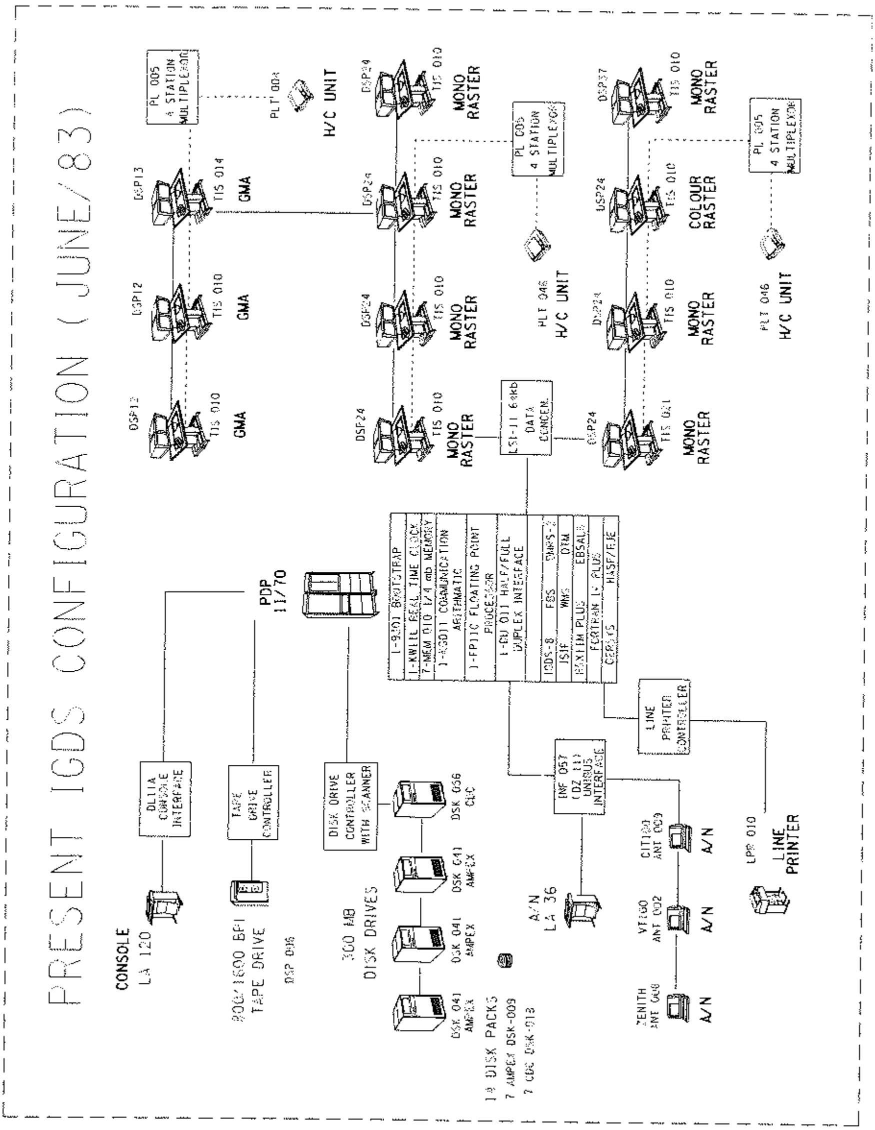
FIGURE 1


PRESENT IGDS CONFIGURATION (JUNE/83)
GMA
GMA
GMA
H/C UNIT
MONO RASTER
MONO RASTER
MONO RASTER
MONO RASTER
H/C UNIT
MONO RASTER
MONO RASTER
COLOUR RASTER
MONO RASTER
H/C UNIT
PL 005 4 STATION MULTIPLEXOR
LSI-11 64KB DATA CONCEN.
PDP 11/70
CONSOLE LA 120
DL11A CONSOLE INTERFACE
TAPE DRIVE CONTROLLER
800/1600 BPI TAPE DRIVE
DISK DRIVE CONTROLLER WITH SCANNER
300 MB DISK DRIVES
19 DISK PACKS
A/N LA 36
A/N
A/N
A/N
LINE PRINTER CONTROLLER
LINE PRINTER

PLENARY SESSION: PRACTICAL APPLICATIONS OF COMPUTER-ASSISTED MAPPING SYSTEMS

ORGANIZATIONAL NEEDS OR TECHNOLOGICAL ADVANCEMENT - THE PARENTHOOD OF 'THE AUTOCARTOGRAPHER' REVISITED

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ABSTRACT

Computer-Aided Cartography has largely been driven by technological advances originating outside cartography and in the computing industry. The result has been the creation of an increasing number of specialized jobs in mapping organizations, changing 'The Cartographer' from an A to Z map maker into a team of digitizer operator, graphics terminal operator, plotter operator, data base manager, etc.

This is potentially detrimental to cartographic innovation. The paper describes the Mikado System, a Norwegian research prototype, attempting to use very advanced hardware to recreate the old cartographic workshop. Functions for automated digitizing from existing maps and stereo air photos, digital terrain modelling and dynamic perspective synthetic photographs are integrated in a unified low-cost work station. Using an object oriented programming language (Simula), unified operator-machine interface, purpose-built processor and laser input/output devices, it is possible to offer the cartographer a complete set of tools for map creation from the beginning to the printing plate. This will lessen the need for major organizational changes when introducing new technology.

"GEOGRAPHIC INFORMATION SYSTEMS: NEW TECHNOLOGIES AND USES"

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ABSTRACT

This paper examines the impact of computer graphic technological trends on the use of geographic information systems. A classification of the types of geographic information systems is proposed, and recommendations for research and development are suggested. Examples of recent developments will be used to illustrate each recommendation.

FROM LAND INVENTORY TO LAND MANAGEMENT THE EVOLUTION OF AN OPERATIONAL GIS

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ABSTRACT

Virtually all long-lived information systems, whether spatial or not, proceed (by intent or by unconscious incremental change) through a characteristic evolution from a simple data bank - an _inventory_ tool, to incorporate complex retrieval and statistical processing - an _analysis_ tool, and finally to a system involving modelling and complex decision support capabilities - a _management_ tool. This evolution is evident and still going on in the world's oldest operational geographic information system - the Canada Land Data System (CLDS). The system began with the specific intent of serving the needs of the Canada Land Inventory - to store very extensive and fairly detailed data on the land use potential of Canada. This initial goal having been achieved, increasing demands were placed on the system to explore data and spatial relationships within this huge data bank, and to provide insight for land resource scientists into more localized and specialized concerns - in short, an _analysis_ capability. The CLDS is now entering the third phase of evolution to meet the inevitable demands as a land planning and management tool. The implications of this are mainly: increased user access and interactivity with existing data, forecasting, planning and modelling capabilities, enhanced variety of display outputs, ability to service non-expert users locally and interactively for small-area data sets in a land use planning setting.

INTRODUCTION

Information systems, regardless of their field of application, have certain elements in common - a large central bank of data, facilities for manipulating, retrieving, updating, and reporting of data. The common principles and capabilities have been extensively studied and reported in the literature and will not be re-iterated here. Another commonality amongst information systems, again independent of application - whether it is a personnel system, financial system, management system, is a tendency to progress through a characteristic evolution which can be convieniently divided into three stages. These stages are typical of and perhaps necessary to a _successful_ information system. Systems die, or are murdered, mainly for their inability to evolve in this

TABLE 1

PHASE	SYSTEM CAPABILITIES	PRIMARY ACTIVITY	USER/SUPPLIER RELATIONSHIP
INVENTORY	-data input -editing -simple retrieval -routine reporting	-data input	-clear division between client and supplier -little interaction
ANALYSIS	all above plus: -complex retrievals -ad hoc queries -statistical processing -derived reporting (eg. graphics) -derived data sets	-data retrieval and manipulation	-supplier involved in determining output needs -interactive retrievals and direct data access by user
MANAGEMENT	all above plus: -modelling, simulation -decision support tools (eg. forecasting) -integration of local data sets	-data exploration and modelling	-user and supplier indistinguishable -fully interactive -distributed responsibility

pattern. In this generalized sense, geographic information systems are no different, and to succeed must be capable of following the same evolutionary pattern.

This paper describes the principal stages of the evolutionary process and elaborates them in terms of a particular system (or group of systems) known as the Canada Land Data System (CLDS), which contains the Canada Geographic Information System (CGIS). This system has recently celebrated its 15th anniversary as a production GIS and has in that period undergone considerable evolution and adaptation, so that it continues to be a highly successful broad-scope GIS.

CHARACTERISTIC STAGES OF INFORMATION SYSTEM EVOLUTION

The stages as outlined are essentially arbitrary and dividing lines between them are necessarily fuzzy. It is recognized as well that successful systems probably exist which have not followed this pattern for one reason or another. Such counter-examples should not detract from the general principle described. The three characteristic stages are named (again arbitrarily) by their principal functional purpose as Inventory, Analysis and Management. The main characteristics of the phases are outlined in (Table 1).

As the system functionally evolves, the organizational relationship between the user and supplier of system services must change as well. The changes in this environment parallel to some extent the general evolutionary pattern of all EDP organizations as defined by (Nolan 1979).

Phase I: Inventory

In this initial phase of an information system, the reason for its existance or development is to assemble, organize and determine the extent of existence of data on a particular subject. In a personnel system for example, the initial thrust is normally to develop a file of basic common information about each employee. At this phase the system serves to answer data queries of how much?, how many?, where?, with an emphasis on reports which derive directly from the data in the file based on summations, counts and other minor manipulations of the raw data. In short, an inventory function.

The principal activities are data collection, input, and editing - in general those activities which ensure the development of an accurate, high integrity base of primary data.

For a GIS this represents a system whose primary task is the development of a broad integrated collection of mapped or geocoded data which may encompass a broad area, but of very well defined scope, e.g. all the forestry maps for a province, with capabilities to answer direct queries on area by selected criteria, or to redisplay the data in various ways.

During this phase, the relationship between the user and the supplier of system services tends to be simple and consist of a well defined separation of function - a classic customer/client relationship. System functions are well known and relatively simple, the user "menu" is well defined. The supplier's role is one of ensuring the integrity of the data, ensuring on-going operational continuity of software and hardware and providing standard (albeit complex) reports and outputs routinely or on demand.

Phase II - Analysis

The second phase of the evolution is spawned by the user's desire to make more use of the data than direct tabulations and summaries - the desire to explore data relationships in order to shed light on subject matter problems, to help confirm hypotheses or to provide data for research and modelling. In the personnel system example, the demand might be to examine relationships between occupational level and place of residence, or to search for evidence of relationships between salary and ethnic origin, etc.

The emphasis in this phase is much more on complex retrievals, and queries which may generate additional queries in an unexpected or unstructured way, hence the implications of a need for extensive user interaction. Advanced statistical analysis tools are required and the queries tend to relate much more indirectly to the raw data.

The queries, in fact, become more like those typical of a "scientific" system (Crain 1978) in that they do not relate directly to the record ("tell me all about employee number 1234"), but rather span across records seeking relationships ("tell me the age distribution and correlation with salary of female employees living in the city centre").

The principal activity moves from data gathering to data retrieval and manipulation. New data inputs are less likely to be broad and comprehensive, but will be more specialized to focus on particular subject matter concerns.

In the case of a GIS, the primary requirement is for user interaction, usually graphically, with the data - the ability to sort, select, derive new data from old, extract and re-display data on the basis of complex geographic, topological and statistical criteria. New data collections may still represent very high data volumes, but cover smaller areas in more detail.

Apart from the obvious need for the system supplier to provide interactive services, the supplier of an analysis system must evolve organizationally to become more involved in subject matter and data context issues. In order to develop the necessary system tools to meet user requirements, considerable emphasis must be placed on determining and anticipating user information needs in the short and long term, and an understanding of the existing and evolving data analysis techniques of subject areas. While most data will still be held centrally, there is a growing decentralization of user access and associated handware.

Phase III - Management

A true management information system must provide the tools to assist directly in the decision making process - not merely an inventory of what exists, not only analyses of data relationships which might hint at problems or solution. The essential new ingredient for a system to evolve to this phase is the addition of forecasting and planning facilities - the ability for the user to ask "What if...". This implies the need for more advanced statistical packages and more importantly, modelling and mathematical forecasting capabilities. To extend the personnel system example, a personnel management system might, for instance, be able to model the process of advancement of minority groups, allowing the manager to forecast potential impact of various strategies for improving their advancement opportunity. A land management GIS might provide answers to "what if?" questions related to alternate land use policies or various strategies for optimization of land use under conflicting demand. It is with these modelling and planning tools, superimposed on a broad base of hard raw data that a GIS reaches maturity as a resource management system.

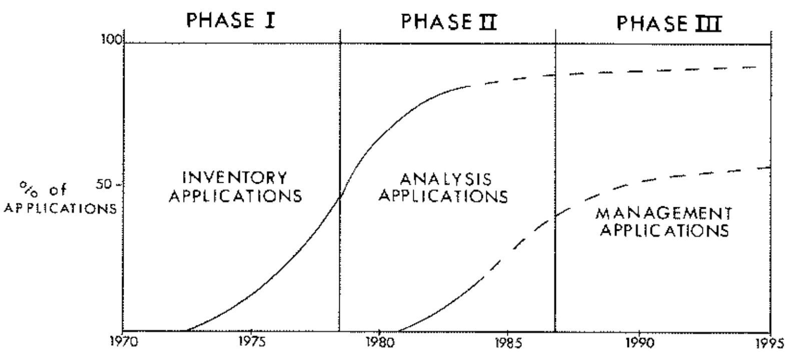
When a system reaches this point in evolution, the distinction between user and supplier virtually disappears. With the exception of some purely technical EDP staff (such as machine operators and software people) all system "users" must be integrated into an overall system management process. Decentralization of data holdings as well as data access will occur and necessary integrated controls must be developped. Knowledge and skill requirements of those involved cannot be divided on the basis of "computer" or "subject matter" and must be divided instead on functional and managerial lines. This change in relationship is by far the most difficult step in the evolution and the greatest barrier to integrating an MIS or GIS truly into the decision process.

EVOLUTION OF THE CANADA LAND DATA SYSTEM

The assembly of systems now known as the Canada Land Data System has origins that go back more than twenty years to the "ARDA project" of 1962. During that long period, the system has evolved in the characteristic pattern, previously described and I would like to use the CLDS to exemplify the process.

The original purpose for the system (which has had several names, the most well known of which is the Canada Geographic Information System - CGIS) was to store the

FIGURE 1


PHASE I
PHASE II
PHASE III
100
50
% of APPLICATIONS
INVENTORY APPLICATIONS
ANALYSIS APPLICATIONS
MANAGEMENT APPLICATIONS
1970
1975
1980
1985
1990
1995

Canada Land Inventory (CLI). The actual system was delivered in 1968 (now celebrated as the birthdate for CLDS) and full production operation began in 1971. As implied, it commenced life as an inventory system. The initial data collection was of five coverages of land capability for all the arable land of Canada - an enormous area of some 2.7 million Km^2.

This required the input of approximately 1500 detailed polygon maps, a process which was essentially complete by 1979. These "early days" were concerned by data entry and routine tabular reporting. Raw data tabulations and summary reports were produced on a national and regional basis in standard formats. While considerable topological processing was built into the system - e.g. ability to do multicoverage overlays, reporting and derived graphics facilities were quite limited.

Somewhere in the interval between the commencement of production operations in 1971 and the completion of the Canada Land Inventory in 1979 the system ceased to be solely an inventory system and evolved into an analysis facility. One clear symptom of this was the introduction in 1974 of an interactive graphics subsystem. Users demanded increased ability to relate variables, to select and study particular areas, and to extract derived data for planning, prioritizing and problem analysis.

The subject matter focus changed from a national resource inventory perspective to more specific issues such as arctic land use, coastal zones, national parks, etc. By 1978 more maps of this regional nature were being input than CLI maps. (Figure 1) schematically outlines this evolution. The changes required to bring the system to Phase II include advanced statistical program packages, interactive graphics enquiry facilities through a network of terminals across Canada to provide user access, and improved hard-copy graphics output capability.

Today the system stands fully in Phase II even though data holdings (inventories) still grow at a rate of 1000 maps per year, and is on threshold of Phase III.

Over 350 interactive data bases of complexly overlayed map data are available for user analysis using various systems and subsystems which collectively make up CLDS.

In spite of this, strong demand exists for CLDS to become an integrated land management system and the first steps in this evolutionary phase have begun. Several small applications have used the existing facilities for land planning and management purposes - for camp site location in National Parks and transportation corridor planning in the Beaufort Sea area. Within five years, with suitable system changes, the CLDS will be fully into Phase III.

To accomplish this many new system functions are needed and organizational relationships must change. Land planning models and accompanying facilities to define model parameters from the data bases, and forecast quantitative and qualitative impact must be developped.

At this time, testing is underway of simple linear models which allow for the subjective weighting of land use suitability in order to evaluate the impact of variable land policy options. Data input facilities are being upgraded to reduce the time required to make data available to planners - a necessary step if rapidly changing conditions are to be monitored by resource planners.

The demand is growing for increased local processing capability for local land use management, with continued access to the central regional and national data banks. Preliminary trials are underway to equip mini and micro computers for this purpose.

CHALLENGES TO ACHIEVING PHASE III

The transition to Phase III is not as easy as the movement from inventory to analysis. Many geographic information systems are now facing this transition and face similar challenges. While placed in the specific context of CLDS, these barriers are of general applicability.

1) Resource constraints: The resources (both dollars and human) required to enhance and distribute the processing power as needed in Phase III are substantial. In today's cautious economic climate, especially in government, major one time injections of resources for system enhancement are unlikely. Thus the change will have to be made gradually as funds become available. Software development is always very expensive and time consuming, and user demands will always exceed the capacity of software development resources.

2) Ensuring continual quality control: Quality control of outputs and maintenance of the integrity of the data bases are increasingly difficult to achieve as the system becomes more decentralized. Where the distinction between user and supplier becomes blurred, as it will in Phase III, responsibility for ensuring the correctness of data input, its consistency with global quality and subject matter standards, and its protection from corruption become an administrative issue rather than a technical issue. The degree of collective rather than individual responsibility for this incredibly valuable asset increases greatly and is difficult to achieve.

3) Choosing appropriate new technology: This is the constant technical challenge of any evolving system - how to take advantage of the latest technological advances without extreme risk or without jeopordizing future alternatives. It requires constant research and a balance between conservatism - selecting only the proven, and opportunism - selecting the correct new (unproven) machine or software where the risks seem worth it.

4) Ensuring continuity of production operation during change: This is both a technical and administrative challenge which is difficult to achieve and highly important to on-going success and credibility. It is essential to recognize that a Phase III system is not only a management tool, but will have continued application as an inventory and analysis system as well. The "inventory" of data collected continues to have vital importance and the production processes to maintain it must continue.

SOLUTIONS

The first steps are now underway at CLDS to face the challenges that the transition to Phase III requires. Technical solutions to the need for distributed processing and local data bases are being found through the use of mini computers. The exact configuration is undecided at this time, but the eventual distributed land resource analysis system will likely involve a network of mini computers (or powerful micros) across Canada, linked to the central facilities. As well, it is anticipated that small portable microcomputers will be used in remote locations to analyse small area data sets extracted from the main files. At least one land planning software package is being tested for mini/micro implementation and existing graphics and statistical processing capabilities being upgraded.

The most significant barrier is the organizational/ educational one. The disappearance of the distinction between user and supplier can only come through a long process of education and gradual change. The current "user" will need to be greatly more aware of system operations and EDP principles and, moreover, be willing to assume much more responsibility for data control, standards, coordination, quality assurance, etc, than now is the case. The current "suppliers" (EDP professionals) must learn considerably more about the techniques and practices of land use planning, modelling and subject matter data interpretation. It is implied that, in general, knowledge and skill levels of all concerned must be much greater and such multi-qualified people are in extremely short supply. It is expected that this problem will slow the development of a generalized modelling/ planning system, although more application specific land management capabilities can be implemented where skill levels are high and appropriate management practices are in place.

As well, the techniques for forecasting land change or quantifying policy impact analysis are not well advanced. Mathematical models which are in use are simple, and clearly preliminary. Much research is required in this field before significant systems advances can be made.

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PLENARY SESSION: COMPUTER-ASSISTED SUPPORT FOR DECISION-MAKING

GEOGRAPHIC FRAMES OF REFERENCE FOR DECISION SUPPORT SYSTEMS AND SERVICES IN AN INFORMATION SOCIETY

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ABSTRACT

The broad concepts and technologies, and implications, of "decision support systems and services" and the "Information Society" have taken on increased shape and substance in recent years and months. Indeed they can now be assessed and related, in preliminary terms at least, to the information systems field in general and the geographic information systems field in particular. My reading of the convergences of these powerful forces for change is that we are now entering a period of thinking and doing in the information systems field, and sub-fields, which involves major states-of-the-art differences in terms of both challenges to be confronted and opportunities to be realized.

In this presentation an attempt is made to indicate the purpose, ways and extent of the GIS presence in a decision support system and services /Information Society context. Emphasis is placed upon three key factors or frames of reference:

1. The essential natures of the geo-factor in the policy, plan and program domain of both the public and private sectors;

2. The continuing modification and incrementalism of the technological infrastructure (systems and services) of the GIS of an Information Society; and

3. The changing decision processes and outcomes as a consequence of the "new geography" perceptions of decision participants in an Information Society.

RETHINKING DIDS; THE NEXT GENERATION OF INTERACTIVE COLOR MAPPING SYSTEMS

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ABSTRACT

The Decision Information Display System (DIDS) was a highly touted statistical mapping system designed for use by the highest level of decision makers within the federal government. On the basis of an evaluation of a major pilot study conducted in South Carolina between 1980 and 1982, DIDS was found to have several shortcomings that prevented it from reaching its full potential as a decision support system. This paper examines the general lessons that have been learned from the DIDS experience in terms of user behavior, data base organization and both hardware and software. In addition, it describes the functional categories of raster based color mapping systems and illustrates how these have been economically implemented on a hardware system that has been integrated into a general purpose data processing network. The next generation of mapping system was developed to incorporate the full capability of color frame buffer hardware to perform the following operations:

1. statistical mapping of polygons
2. manipulating and displaying grid or raster data
3. drawing plot files generated on other systems
4. altering and embellishing existing displays with basic computer aided design features.

DIDS UPDATE

When the Domestic Information Display System (DIDS) burst onto the scene in 1978 it was viewed by many as the ultimate solution for providing statistical data to decision makers in a form they could easily understand. This magical device was envisioned as revolutionizing the entire process of map production to the extent that no report would be complete without at least one DIDS color glossy. It received the highest level of support and publicity as an operational part of the White House Information System.

Five years later DIDS has been essentially mothballed. In September of 1982 Richard Beale, the White House assistant responsible for its operation, stated that, "members did not maintain adequate levels of usage to justify the continuation of the interagency DIDS program into FY1983." (Beale, 1982) Although some members of the mapping community may take sadistic pleasure in witnessing the demise of DIDS, the decline was due more to the fact that decision makers were not sufficiently impressed to continue to fund the system rather than its inability to generate color maps of statistical data. More importantly, it is essential that the DIDS experience be examined from the perspective of providing valuable lessons for the designers of future systems. The two fold purpose of this paper is to describe the major shortcomings of DIDS that were identified during the two year pilot study of a DIDS remote terminal in South Carolina, as well as to describe specific attempts at implementing a more adequate mapping system reflecting these experiences. (See Cowen, et al., 1982)

MAJOR SHORTCOMINGS OF DIDS

From the state or local government perspective it was possible to identify the following major drawbacks of the original DIDS system.

1. The centralized database made it difficult for users to incorporate data or geographical bases of local interest. The high overhead cost of the database made it desirable that all variables on the host be of national importance.

2. The hardware was too expensive for a single purpose or single user system. It was unreasonable for a local government to attempt to justify the estimated cost of about $100,000 for a remote terminal with camera system merely to generate choropleth maps.

3. The system was not part of an integrated data processing environment, therefore, it was difficult to exchange data or to separate analytical and display functions. Many data extraction or simple statistical procedures would be more appropriately carried out on a batch mode from a remote terminal.

4. The software was too restrictive in its mapping options. Choropleth and bivariate maps were not always appropriate, while zooming by square areas often resulted in the display of strange regions.

5. The color raster display technology did not support inexpensive or easily reproduced hardcopy products.

6. The menu driven operating system was cumbersome and tedious for the experienced user. While enhancing demonstrations, the user friendly design severely retarded the systems performance for the actual users who were operators and not decision makers. (Cowen, 1982)

In other words, DIDS was isolated, expensive, restrictive, inflexible, somewhat tedious and produced maps that were appropriate for only certain functions.

DIDS represented an attempt to take advantage of advancements in color raster display and microcomputer technology. In fact, the resultant system must be considered a technical success. It was truly a marvelous experience to have a local computer request a variable from a host computer four hundred miles away, and observe as it was transmitted and displayed in full color within approximately fifteen seconds. Technically there still is nothing inherently wrong with the original host and remote terminal design. Similar configurations are easily justified for presenting satellite weather images on the nightly news, however, as a system displaying chronically outdated statistical data DIDS represented an overkill.

EVOLUTION OF A MAPPING SYSTEM FOR STATISTICAL NEEDS

Any mapping system must recognize that clients have a variety of needs in terms of data, geographical bases, style and mode of output. The DIDS experiment dramatically demonstrated the results of attempting to utilize a single approach. Over the past decade the University of South Carolina has developed an integrated approach to statistical mapping that has evolved to meet a diverse set of needs. The latest step in this process has incorporated a dedicated color raster display system that builds upon the experience with the DIDS system.

The core of the system is a current and easily updated data base that resides on the University's main computer network as SAS datasets. The University's role as the official data processing arm of the State Census Data Center ensures a timely flow of the most relevant data sets into the system. SAS provides a simple to use set of procedures for accessing, selecting, manipulating and even displaying elements of this database. Contrary to the DIDS database this one is accessible from hundreds of readily available terminals. From their own offices users throughout the state can easily conduct preliminary data analysis tasks and even submit jobs to generate maps. Geographical bases can be derived from existing digital files, such as the Bureau of Census County Boundary file, or digitized from existing maps.

Although SAS/GRAPH (SAS Institute, 1981) does provide several mapping options GIMMS (Waugh, 1978), a more flexible system,has proven valuable in meeting a more diverse set of map production needs. For example, GIMMS graduated symbol and dot maps are used for the display of absolute values. This is a substantial improvement over the misuse of DIDS choropleth maps for this purpose.

Maps serve a variety of purposes and audiences, therefore, it is essential for a mapping system to offer several output modes. In fact, it may very well have been DIDS dependence upon flashy color raster display output that most hindered its acceptance. With today's technology RGB monitors can be used to generate excellent 35 mm slides and expensive glossy color prints. Unfortunately, neither of these modes is particularly useful for producing maps for inclusion in a report that must be distributed to several readers. Thus, it is essential that a full service system include a quick but inexpensive electrostatic plotter and a high quality pen plotter.

Multipurpose Color Display System

Notwithstanding their severe limitations in terms of reproduction, maps generated on color CRTS are undoubtedly here to stay. They create interest and sell systems. DIDS greatly underutilized the capabilities of its color processing hardware. In addition to statistical mapping, modern color frame buffer hardware should be able to manipulate raster or grid cell data, draw plot files generated on other systems, and create drawings with computer aided design procedures. It should be noted that the Australians (CSIRO, 1982) have incorporated several of these features in their colormap system on the DIDS hardware.

The color mapping system that has been developed in South Carolina represents a cost effective, integrated, mobile and highly flexible approach to mapping. The hardware system was assembled at about a quarter of the cost of a DIDS remote terminal without sacrificing anything in terms of resolution and very little in terms of storage and color capabilities. The statistical mapping software SCIDS (South Carolina Information Display System) incorporates a user friendly menu driven approach to variable selection, color change and determination of class intervals. Variables are easily transferred from the main University system to floppy disk. This method enables the user to actually analyze, recode and run proof plots on the main system while only employing the color system to generate the final color maps on slides, glossy prints or transparencies. Although the process may require a longer total throughput, it usually involves a minimal amount of the users' time.

Raster or grid cell datasets are easily passed to the system and then displayed with PIXDRW, a generalized pixel handling program. PIXDRW provides simple to use commands for color change, annotation, pan and zoom. It is a versatile system that can handle any matrix comprised of less than 481 x 621 cells and a maximum of 64 categories. This is an excellent system for display and feature extraction from land use or other grid cell data bases. It also provides an excellent base for development of grid modelling routines.

Often a user simply needs an attractive color slide of a map or other graphic that has been produced on the mainframe with standard vector based software. The resultant plot files created by these programs can easily be transferred to and plotted on a color display system using graphics commands.

The latest frontier in computer mapping may well be the utilization of computer aided design (CAD). Even inexpensive ($20,000) color frame buffer systems enable a user to create, edit, store, and retrieve map images through commands initiated from a menu on a digitizing table. As a cartographic tool the CAD features can be efficiently employed to create a polygon base map which can be embellished with elements, such as titles and legends. Polygon flooding and zooming functions provide excellent methods of digitizing boundary segments and checking for closure. These functions greatly improve the man-machine interactions that have often hindered the cartographer.

FUTURE DIRECTIONS

In the five years since the development of DIDS there has been an unprecedented combination of technological breakthroughs and market expansion of the computer graphics industry. Furthermore, the current price tag of $20-25,000 for a system very comparable to the DIDS remote terminal may well be cut in half within the next twelve months. Such improvements in price and performance strongly indicate that affordable systems can be developed. In addition, these new systems can be part of a local area network which can reside inboardrooms and private offices. Clearly the barriers of cost, inflexibility, and lack of integration that hindered DIDS can now be eliminated.

Challenge

Although it is possible to place a powerful mapping system on the desk of a decision maker there is no assurance that it will be used in the fashion cartographers would like. It is apparent that most users perceive statistical maps to be simply another form of business graphics. As such, class intervals and color schemes are most often going to be determined by system defaults and not user interaction. The challenge for software developers of the next generation will be the incorporation of an intelligent set of commands that will enable the user to quickly produce maps pleasing to the decision maker without offending the cartographers' sensibilities.

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PLENARY SESSION: RESEARCH AND DEVELOPMENT IN AUTOMATED CARTOGRAPHY

GIS - BEYOND GRAPHICS

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ABSTRACT

For many years there has been a discussion regarding what constitutes a full Geographic Information System.

The widely held view at present is that there are four capabilities that are basic to the functionality of such a system. They are: electronic preparation; entry; analysis; display and management of geographic data held in an electronic form. Each of these categories contains a series of specific generic components that operate on geographic data.

For the buyer of a GIS system there is a need to examine which of these components is really needed, and which systems best perform each of the functions. At present there remains a clear distinction between "graphic systems" which are built around the interactive display and graphics management technology, and those systems which emphasize the full spectrum of GIS components. The state of GIS technology is gradually changing in 3 ways:

1. The suppliers of interactive graphics systems are claiming they have full GIS functionality and are attempting to adapt their data base structures to accommodate the types of entry, analytic and management functions required of such systems.

2. The GIS system manufacturers are moving in the direction of designing and developing better interactive display capabilities to supplement their strong emphasis to performing analytical work.

3. Hybrid and, in most cases, duplicate systems are developing where a common processor is host to both analytic and graphics software.

A list and definition of GIS generic functions is presented, as well as the current industry trends and their implications.

THE IMPACT OF COMPUTER TECHNOLOGY IN THE MAPPING ENVIRONMENT

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ABSTRACT

The introduction of computer technology has had a tremendous impact on the traditional mapping environment. In addition to the vast changes in instrumentation and methodologies, a very different design and utilization philosophy has surfaced with respect to project mapping.

The technology has enhanced the capacity for storage, transfer, integration, manipulation and analysis of geographic data. This has affected the way the map producing community functions as a profession, operates as a business, evolves as a science and ultimately the way in which it presents geographic information to the end user.

INTRODUCTION

The impact of the use of computerized techniques in the mapping community will be examined with respect to the production environment, the cartographic product, spatial and conceptual constraints, information availability, the data sharing phenomenon, and the dynamics of computer mapping.

THE PRODUCTION SHOP

With the advent of computerized methods, many physical, operational and psychological changes have occurred in the typical map production shop.

The personal work spaces formerly organized according to the constraints of access and drawing size are now clustered in relation to a computer room which is usually enveloped in glass, sound proofing and strictly controlled temperature and humidity. Individual work places are allocated according to cable lengths, electrical outlets, varying lighting requirements and access to the other essential hardware peripherals necessary to generate a final product. Due to the need to protect expensive equipment and storage sensitive data and to maintain information control, many parts of this environment may be subject to locked or coded entry.

The office that has traditionally worked double shifts only where equipment intensive jobs require, may now have an entire facility that needs to be utilized, supervised and maintained around the clock. Uptime demands become critica and production people often find themselves working against an electronic clock. Processing capabilities currently available allow many tasks to be initiated, monitored and controlled during the absence of personnel. The clamour to utilize computing resources in the mapping environment differs very little from that of the traditional 'technomaniacs' of the pure data processing professions.

A circumstance that is relatively new for the mapping community is that of utilizing a central computer resource drawing data capture, processing and display capabilities across communication lines from a service bureau, an associated organization or a head office. The inconvenience of structured working hours, remote system management and limited physical control is offset by the opportunity for the uninitiated to evaluate capabilities and establish working methods that are best suited to their particular application. The company or organization that controls a central computer resource is able to distribute its computing and support personnel resources, maintain procedural and specification compatibility and transfer information and data quickly and easily between the many production facets of the organization. The impact of this capability to the production shop is that a requirement emerges for cooperation, coordination and exchange between groups of people that are physically and perhaps personally removed from each other. The realm of day to day interdependency and exchange is ever expanding.

The storing and handling requirement of information regarding automated map production is becoming increasingly challenging. Job specification changes tend to be inherent in the software that processes the data, while daily procedural information is often disseminated 'online' through the communication facilities of the computer operating system. Vast quantities of documentation are available for most computer systems and must be distributed or filtered in an efficient manner. Keeping abreast of periodic upgrades to software capabilities and the associated documentation can seem time consuming to the photogrammetrist or cartographer accustomed to applying a skill based on experience and existing training. Online 'help' text greatly enhances the users capability to upgrade without drastically interrupting the production flow.

As in most industries, a full complement of qualifications in the mapping industry now includes data processing, application programming and system management skills. Acquiring new computing support individuals and retraining professional staff is an inevitable necessity. The decisions as to who will be trained, when, where and how, and the organized commitment to that training are critical to the success of the implementation. Equally critical are the management decisions as to how computer support expertise will be integrated. Although most educational institutions that teach mapping techniques also include training in computerized techniques, there is still the basic question of whether mapping professionals should be fully trained in the art of systems management and programming or computer specialists should go through the necessary orientation to the project mapping world. To many members of the existing mapping community the introduction of computerized methods brings them to an abrupt halt in the productivity cycle until, through adequate orientation, the techniques become transparent and exist only as a tool to assist their professional pursuits and production achievements. The management and supervision of this increasingly diverse and ever changing group becomes a challenge to even the most effective organization.

The production flow chart of the computerized mapping shop is infinately more intricate than the conventional one. Data from many sources, that will undergo many processes during compilation, editing, checking, manipulating and preparing for final plotting must be carefully scheduled through the flow path that will include numerous pieces of automated equipment, various individuals, and be processed by a variety of programs. The potential for bottlenecks throughout this flow must be anticipated and provision made for alternate methods as well as the recycling of data at all points for revision or correction. The evaluation of progress is not as evident because of the nature of the data storage and must be closely monitored by all participants. Constant improvement of methods or productivity demand a flexible approach to the flow of work.

THE CHANGING FACE OF CARTOGRAPHY

The introduction of computer technology has had the most dramatic affect on the cartographic product since the invention of the printing press and photographic reproduction.

The ability to display an electronically generated representation of the earth is in itself a cartographic revolution. Continuous technical advancements in the area of data collection, interactive display, graphic data processing and high quality output support the growth of computer assisted cartography. Interactive sterodigitizing equipment now includes voice recognition, voice synthesis and superimposition of compiled data. Recent interactive display capabilities include full three dimensional model space, dynamic zoom and pan, color fill and shading capabilities and an ever increasing capacity for manipulation and response. Sophisticated output devices such as color electrostatic and high precision light beam plotters assist in the generation of quality printed products. Digital terrain models, polygon overlays, utility networks and color fill statistical representations are all readily generated due to advanced computer graphic capabilities.

A frequent hesitation experienced during the computerization of a mapping organization is the feeling that the cartographic profession will lose a quality that is often refered to as artistic license or design quality. It is certainly true that given interactive compilation, much of the cartographic technique can be applied at the compilation stage and the preparation of that data for final production often includes only minor touchups or automatic processing to detect and correct commonly recognized error situations. However, given a system with adequate graphic flexibility, cartographic design expertise is applied at the project design and setup stage. The intricacies and flexibilities of machine generated graphic elements provide an additional challenge to that project design phase. Of course, one of the greatest satisfactions comes from the standard quality achieved throughout an entire project by the application of repeatability once the project design is complete.

One of the most significant impacts of the use of this technology has been a long overdue internal analysis of the standards and specifications that have become firmly established over years of refining the conventional cartographic product. It has become necessary for all aspects of the mapping community to evaluate the intention, the effectiveness and the quality of cartographic procedures, specifications and standards. Graphic specifications that have become accepted because of the ease in which they can be applied manually with available drafting tools, may not necessarily be the most appropriate specifications for the automated mapping system. Consideration must now be given to the way in which features are presented by machine driven methods, by logical algorithms for the generation of geometric representation, and the storage requirement necessary to maintain accepted specifications. For example, in a machine driven environment an arc applied to a tree line is a true arc with geometric definition, and cannot be 'manipulated' as it might be in a conventional application to bend back from the corner of a house.

With the elimination of the drafted 'redraw' the term 'what you see is what you get' can be applied to computer mapping. To a greater degree than in conventional operations, cartographic standard must be considered at the compilation stage to avoid extensive editing of a file prior to job completion.

Given the additional capabilities of electronically stored data, there are many more aspects to consider. Is it really desirable to break a contour in order to annotate the elevation, when that contour is no longer only a pictoral description of elevation but also a numerically recorded entity of geographic information. The desire to maintain continuity of an intelligent and manipulative feature is surely more important than maintaining a standard that was established as the best method of presentation of manually drafted elevation indicators.

Standards must be examined in light of new methods and procedures. Since data is used universally across scales and applications all the flexibility of a system must be carefully applied to best meet an ever expanding diversity of demand. Because digital mapping standards and specifications are often imbedded in programs and system libraries they have to be clearly documented to allow for future modification and subsequent use in the next generation of the project. The requirement for an organized documented approach is heightened by the fact that so much more information can very easily be stored and retrieved about map features by using computer storage and manipulative capabilities.

The ability to associate non-graphic information with graphic elements is probably the most dramatic change brought about by computer technology. The computer system becomes an analytical tool to query the natural, social and economic attributes of our earth's description. Data redundancy is reduced by structuring the data base organization in such a way that entities share common informational records. If this data base system is also a stand alone database, multiple usage can be made of it without depending on graphic display. Because there is an option of temporarily retrieving textural information, the graphic cartographic product is relieved of the need to be cluttered with every conceivable piece of annotation. The ability to manipulate and change the graphic characteristics of map features according to common or related data base entries, such as highlighting a utility service route, further enhances the analytical advantage.

The singular nature of a mapping project is a thing of the past. Single data sets can be used to generate a variety of products for many applications. The integrated approach to computerized mapping is extremely popular. Two dimensional data mixes with three dimensional data, cross sections are recovered, terrain models generated, logical traces accomplished, site plans are integrated with construction plans, mines shaft designs are integrated with terrain description and so on.

Many presentation alternatives emerge with the use of computerized methods. Color display, raster display, three dimensional display, mesh presentations of terrain are all new options. Data can be stored and displayed as linear entities, as spatial entities or as volume entities. The digital storage and interactive display of map data is truly the map product of today, which is only rendered into print to achieve the portability desired by our present society.

KNOWING NO BOUNDS

Many of the physical and conceptual constraints of conventional mapping projects are eliminated by the use of interactive computer graphics systems.

The typical map sheet is becoming less and less the definitive map unit. Varying configurations of rectangular map sheets based on an established gridding system are certainly a popular method of data conversion, data storage and product generation. Software that organizes these map units into a conceptual distributed mapping system provides greater flexibility to the many potential users of digital data. The ability to address the data in a mapping project with reference to an index map and extract regions irrespective of the mapping units that were originally digitized, allows the same data to meet the presentation and scale requirement of all users. There is no longer the requirement to amass many rectangular mapping sheets in order to present an irregularly shaped transportation or drainage route.

The value of digitally stored map data is unmeasurable when the ageless nature of the data is examined. Theoretically portions of this data bank might never have to be recorded again since an organized data base can simply be revised through time as the face of the earth changes. Hence, data integrity and security become paramount to data base management. Distributed graphics software that allows for controlled access to all features and the ability to update a master data base provide the necessary tools for handling a large area of quality sensitive data that must serve the user through an infinite time span.

Being confined to one selection of symbology must be considered a conventional constraint. The use of computer graphics systems allows for varied and optional use of symbology. Each map user may have his own recognizable symbol or require a different degree of detail. Symbology standards will change through time and the versatility must be there to keep up with these changes. The storage of extraneous pattern data is not desirable in a master data storage system and therefore should be applied at the product extraction stage.

The logical distribution of data across many selectively displayable 'levels' provides immediate flexibility in map composition. Only that data which is pertinent to the user need be displayed or plotted.

The storage of data in ground units renders digital data virtually 'scaleless' in the sense that scale is only a characteristic that is applied at the time of final output. Consideration must always be given to the scale of the source of map data. Scale changes within the acceptable ranges provide the mapmaker with needed flexibility and eliminates lengthy photographic reproduction costs.

Cartographic source data need no longer be confined to the projection or coordinate system in which it was originally compiled. Numerical manipulations of point data according to established projection conversion algorithms allow map data to be presented in the projection best suited to the users application. Data to be used from a variety of sources and projections can be easily integrated by neutralizing all data and applying a conversion to a common projection presentation.

As automated methods become more and more popular the sources of data also increase. The computerized record management data that has existed for many years in most business and government agencies are now available to be integrated with map data and associated information data bases. Governing bodies and private industry alike are pushing toward a universal graphic data exchange system that will eliminate yet another obstacle to the smooth flow and exchange of computerized data.

INFORMATION EXPLOSION

The mapping organization that becomes involved in computerized methods often finds itself in a position of at least temporary responsibility for the storage of vast amounts of digital information.

Rather than simply creating and presenting a graphic product, the computer oriented mapping organization is compelled to store, maintain and manipulate ever increasing volumes of not only digital format graphics but also non-graphic information that is associated with that graphic description. As system capabilities are continually enhanced economic and organizational pressure is brought to bear on the management of the computer facility to expand the traditional production mandate and become involved in as many system utilizations as possible.

For example, if a municipal mapping agency is going to store digital base map data, why would they not also use the same resource to store geographically coincident utility information, and access routes, and service records and billing information, and legal title and demographic statistical data, and taxation records and so on. No mapping organization is equipped to deal with the compilation, storage or manipulation of so much diversly related information. Much of this information is certainly not the responsiblity of the map producers. However, since it is the responsibility of the mapping community to produce and maintain that geographic base, there will always be an inevitable link between the cartographic base mappers and the users that must integrate information with it. Automated data storage capabilities exceed the present ability of the mapping community and all of its information prolific colleagues to determine an organized structure for information control.

This issue is perhaps the most important and pressing of the issues that surround the concepts of the computer controlled mapping business. There is a necessity to track graphic and non-graphic data according to origin, date of compilation, control standard, revision responsibility, revision content, access and availability control. As never before, there is a requirement to scrutinize the vast amounts of data available that can be stored as graphic display or in association with graphic display and determine just what is essential and eligible for expensive and timeless storage and retrieval. Who is to be responsible for this 'information filtering'? Regardless of the degree of involvement of the mapping community in this social and economic issue the 'rules' of map information production add a brand new realm of responsibility to the mapping task. Validation of the printed product is no longer an effective production quality check. Merely the fact that a description of the ground is numerically stored for display and drawing purposes compels us to determine that the numbers are indeed correct.

A practical example of the expansive capability of map feature information capacity is that of a single plotted tree. This feature that is traditionally phogrammetrically interpreted and plotted as a dot or circular pencil mark and subsequently cartographically reproduced as a scalloped symbol, takes on explosive information capacity once entered into a computer storage bank. Information that conventionally could only be added as text can be electronically determined or stored against that tree. First, because the computer file into which this tree is placed has design units that represent the ground, the diameter, perimeter, absolute and relative location are automatically stored in the description and location of the graphic element and are subject to automatic text generation reflecting these values. Secondly, various patterns can be applied to this tree to satisfy the recognition requirements of various users. Thirdly, a single record in the description of the graphic element may point to a location in an associated data base that can store virtually limitless researched attribute values such as the ownership, age, height, type, canopy size, disease record etc. Through interactive capabilities this information can be extracted as text or graphics in a design file to enhance the original element as well as being made available for stand alone information manipulation. Finally, this feature may be stored and displayed in three dimensional space allowing for the presentation and analysis of subsurface data as well as illustrating a features internal and external relationships within model space. Although this example may be excessive for a mere tree, it does make a statement about an explosive new capacity for information storage and the potential and ramifications that it represents for the map making industry.

INTERDISCIPLINARY MAP DATA

Due to the storage intensive and dynamic nature of digitally stored data there is a strong desire on the part of map users everywhere to share data of common interest and the resources to manipulate that data.

Base map data of course, has always been shared, but was subject to repeated drafting and copying to meet unique presentation needs. With the use of computer technology data transfer can easily take place and save the second-time user a tremendous amount of effort. This situation leaves the administrator of the base map information with the tremendous task of presenting the required information of an extremely diverse set of disciplines. Can one data set meet all the needs of three or four levels of government, the utility professions, civil engineering, resources analysts, property assessment, taxation evaluators, etc. Perhaps not, but properly applied rules of data distribution resymbolization and controlled data extraction can greatly improve the common environment into which many disciplines can tap, as well as reflecting a significant cost saving for all.

The interdisciplinary involvement of mapping projects also brings the bureacratic cobwebs between related disciplines abruptly to the attention of the master data base administrator or supplier.

One valuable advantage of shared data is that as a society we have the potential to all broaden our horizons and close the understanding gap between the data requirements of related professions.

DYNAMIC MAPPING

As a result of the application of computer technology the map is increasingly becoming a dynamic entity.

Mapping revision cycles are narrowing rapidly. The five year replacement of most mapping projects narrows to yearly updates to a master data base. The Landsat program updates its supply of data every 16 days, certain airline navigational charts are published every 28 days, utility service records are updated on an ongoing basis as they occur, and the weather map on the evening news is a real time dynamic presentation. Computer graphics displays are now being used as static or dynamic navigational aids in water vessels or sophisticated defence aircraft. Dynamic updates of social locational data is critical to modern crises control systems such as crime detection and prevention.

The typical decision making cycle has speeded up considerably as well. If a site engineer can instruct a computer on the details of a desired excavation plan and can within a matter of minutes view that modified terrain ready for analysis, obviously valuable time can be saved or redirected to more pressing matters of business.

The dynamic and ever changing needs of a new generation of mapping users will affect the standards that are applied to map presentation of the future and the design approach of equipment manufacturers and mapping project designers alike.

SUMMARY

The map making business has always been an intriguing and challenging one. The existing and ongoing developments in the area of automated geographic information management and presentation are as encouraging as they are exciting. The impact of these technological developments is changing and enhancing the way the cartographer views his product, the way the mapping organization views its function, and the way the world views its home.

PLENARY SESSION: APPROPRIATE TECHNOLOGY FOR THE THIRD WORLD

THE PROBLEMS - AND SOME SOLUTIONS - OF PROVIDING TECHNICAL ASSISTANCE TO DEVELOPING SURVEY DEPARTMENTS*

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ABSTRACT

This paper describes in general terms the problems encountered in giving technical assistance to developing survey departments and explains why they would be especially severe in automatic cartography, which is very sophisticated but politically unattractive. The historical background and effects of sudden political - but neither financial nor technical - independence from a colonial or trustee administration are outlined, and also the state of cartography in developing countries, which depends in many cases on how much help they have been given.
The problems described include illiteracy, nepotism, shortage of hard currency, weakness of basic services, corruption, lack of dedication, loss of trained staff, and the number (up to eight) of departments in the donor and recipient countries involved in negotiating a technical assistance project.
The final section describes some solutions under four heads: self-contained and joint projects, and training in the donor and recipient countries. The point is emphasized that sophisticated manipulation of cartographic data is unlikely to be of much use to departments still unable to collect the basic data itself; and that this often cannot be completed without a great deal of labour-intensive ground work.

* The views expressed are those of the author and do not necessarily reflect those of any institution or agency with which the author has been affiliated.

INTRODUCTION

1.1 This paper aims to describe in general terms the main problems of providing technical assistance to developing countries. These problems will turn up in any attempt to sell or introduce automatic cartography in such countries. They may well in fact be even more severe in this than in other projects for two reasons. First, it is a very sophisticated technology; and secondly it is very specialised and of little political interest. The high sophistication creates severe difficulties in countries where only a few per cent of the people are literate; and the lack of political appeal puts cartography far down in any competition for funds and effort. Maps and survey are not subjects in which politicians and administrators are interested or knowledgeable; there are seldom any votes in good maps. As usual there can be exceptions, for printing presses suitable for maps can also print posters; and in the Sudan soon after independence they were much in demand for printing election posters and ballotting forms. It was probably the only occasion on which anyone would have noticed if the Survey Department had gone on strike; perhaps it was a pity they did not! Before discussing the problems, and some solutions, in more detail it will be worth while giving an outline of the general background to technical assistance.

THE BACKGROUND OF TECHNICAL ASSISTANCE

2.1 In Britain we still recall as part of our national memory being colonised by the Romans, and then, after several hundred years of abandonment, by the Normans. In North America only the Eskimoes and the Red Indians experienced colonisation and I suspect that there are not many of them at this conference. While the Norman influence, transmitted both by example and by inter-marriage, continued until we stood on our own feet as a nation; it was the period after the Romans had departed which tells us most about the state of developing countries today, following tens or hundreds of years of colonisation, or decades of United Nations trusteeship. This applies particularly to many African countries where, after sometimes less than a century of European administration, they suddenly gained independence of a sort - political, yes, but often neither financial nor technical.

2.2 In trying to understand the situation in the most backward countries it pays above all to remember that for most of their population life still remains very much as it was hundreds or even thousands of years ago; and that it often resembles to a striking degree the sort of life that our forebears lived hundreds of years ago. For example, the Normans organised with great thoroughness soon after their arrival that wonderful first national register of landed property - the Domesday Book; but of course it was done without maps since they knew neither how to make nor to use these. In Ethiopia a few years ago I was shown an exactly similar register of land holdings, entirely without maps. One can also see today in action many agricultural practices we have abandoned.

2.3 The gap between the sophistication and technology of the European colonists and the native populations of hunters or nomads was far greater in many cases than that between the Romans and the British; and yet after their departure we took hundreds of years of the Dark Ages to get back to the sort of organised and disciplined community which we had under their administration. With modern communications and good will we should be able to shorten this period but it cannot be achieved overnight, or even in a few decades. Many of the politically independent Third World countries are still going downwards in terms of financial solvency, technical advance, and honest and stable government; they have not yet reached bottom and we must look very carefully at any technical assistance we are trying to give or sell to them, however much it may increase our own profits or provide jobs for our own people. Another consequence of these difficulties is of course that public security is often very bad; and many Third World countries are still battlegrounds between rival tribes or ideologies.

2.4 There is however one great source of hope, and this is the astonishing adaptability of the human species and particularly of its intelligence and capacity to learn new skills. Only thus can we account for the few brilliant individuals in science and technology who have come from the Third World; the numbers of successful and safe first generation local aircraft pilots in their air lines, and at a less important level the winning of the Wimbledon ladies tennis championship on two occasions by the granddaughter of an Australian Aborigine, whose culture is generally reckoned to have been one of the most primitive in the World. But of course you have got to find these exceptional people, and that is one of the major problems as I shall describe.

2.5 I have had to say some hard things, and readers may think I am too pessimistic and prejudiced; but I believe most people with experience of work in the Third World will agree with what I have said - though they cannot say it themselves. For obvious reasons I have not given too many details of individual cases, following the old army saying: "No names, no pack drill."

THE STATE OF CARTOGRAPHY IN THE THIRD WORLD

3.1 Clearly it would be impossible to describe this in detail; but it is possible to outline a few features in comparison with conditions in North America. There is a tremendous variety depending, as it does with you, not only on the size and density of population of each country, province or area, but on the energy of the local survey department, and possibly more important, the amount of mapping aid provided from outside. On the whole Britain has a good record, and while the less populated desert countries we administered may still have (as in the Sudan) large areas covered only by 1/250,000 sketch maps, even they now have 1/50,000 maps or better of their populated areas; and most towns in the ex-British colonies have 1/2,500 topographic cover in addition to the earlier cadastral surveys. The Nile valley is covered by cadastral plans, and by contoured surveys for irrigation, while in India and Malaysia there is good medium scale mapping and large scale cadastral cover of settled areas. Much of the mapping in Africa and the Caribbean was done by the Directorate of Overseas Surveys (DOS) which I think some of this Conference know; in 35 years they have mapped over two million square miles, mainly in Africa but also in the Caribbean. Moreover, except in very empty areas, this mapping was controlled by an accurate and well marked framework of triangulation, traverse, or trilateration.

3.2 By contrast the French tended to rely on astro fixes for plan control even in quite densely populated wetter areas further south. The Italians had produced very accurate contoured maps of parts of Eritrea; but in their short occupations of Libya and Ethiopia they only produced 1/400,000 sketch maps. German mapping and survey was very good but preceded aerial survey and only covered small areas. Others here will know better than I do the details of American and Canadian assistance mapping of the Third World; but the little I have seen leads me to think that the former concentrated on geodetic surveys of more use to the USA than the recipient country.

3.3 The special case of Caribbean and oceanic islands (like Mauritius or the Falklands) under British administration is worth mentioning, for in most cases the map cover is very good; for example most Caribbean islands were mapped at 1/25,000 scale with good control by DOS; half of Mauritius and much of the Falklands are covered by 1/2,500 scale maps; and in a few small islands where land values have escalated with growing tourism and tax-free facilities (like the Cayman Islands) DOS and our land tenure people have completed a comprehensive cadastral survey and land register which recorded the shape and size and ownership of every parcel of land from shore to shore.

3.4 Obviously the only way to find out the state of mapping in a country or for a given area is to visit the local department concerned; writing is of little use. But it will also be well worth while to consult any European or American commercial company or aid agency which has worked there, because the chances are that their records will be in better order and more accessible. There is no substitute for a personal visit; and such a visit will achieve far more if the visitor has done all he can beforehand to find out from agencies like DOS and the USGS and Canadian

Surveys and Mapping Branch not only what they themselves have produced but what they know already existed in the country concerned. This will help to overcome local resistance in producing maps, survey data, and air photographs, which may be based officially on security grounds but is often due simply to laziness. All this applies also to non-topographic data like geological, forest, and vegetation surveys, many of which were carried out very thoroughly by the colonial officials when they were there but are now buried in some forgotten office or store. There is a temptation, which may be augmented by local enthusiasm, and hopes of pickings, for using glamorous and expensive modern technology like satellite or radar imagery, or fresh aerial photography, without first checking locally whether the information required already exists.

3.5 To sum up: virtually none of these countries has succeeded in mapping itself without expatriate help and direction; and very few are now able even to maintain the maps with which they have been provided, either by the original colonists, or under some form of technical assistance.

THE PROBLEMS

4.1 Illiteracy. In Asia and the Middle East the use of writing in many cases preceded its use in Europe; but in most of Africa and elsewhere something like 80% of the population are still illiterate, in spite of strenuous efforts made both by the countries themselves and by aid agencies. Even primary education does not reach a great number of children; and the number of secondary schools and technical colleges or universities is so small that their graduates are eagerly sought by government departments and commercial firms. Thus the relatively low status of cartography attracts very few able and well educated young people; but as mentioned below, the office side of it is more attractive than the field work. Possibly more important is the fact that the map-using general public found in developed countries scarcely exists at all. Virtually the only users of maps are those members of government departments, tourists or expatriates working in aid projects. There is sometimes a tendency to hoard maps as precious documents, or as vital to security; and in one far eastern country government officials restrict free issue so as to sell them privately. In the more advanced countries of the Far and Middle East, where settled land tenure has been known for a long time; and also in the Caribbean with inflated land values, maps have been used for several decades for recording land ownership; and property owners understand their use.

4.2 One of the problems created by a shortage of graduates, and the consequent competition for them, is the high salary and status they can get. Thus a young graduate, who in Europe or North America would have to serve several years in the field or on the shop floor before being made a manager or administrator, may get behind a desk almost at once and before getting any worth while operating and managerial experience. A further complication is the conflict between these graduates and the older and much more experienced, but less well educated, senior technicians.

4.3 Nepotism. The education problem is aggravated by the fact that selection for higher education and training - and of course for subsequent promotion - is often based not on ability but on good connections and having the right background, of race, family, religion, or politics. Of course this is not new; we in Britain still have it, though entrance to University is no longer based on birth and money but to a very large extent on ability to pass our public GCE examinations at A level. If you read the history of the disastrous 1850s Crimean war, and of the charge of the Light Brigade, you will find that the reason why they happened was very largely that the commanding officers were lords who had bought their way up the promotion ladder and had never seen active service; while lieutenants and captains with twenty years active service could get no further without financial or influential connections. Again, one sees happening now in the Third World the events that we read about for our own countries in the history books.

4.4 Very much the same situation occurred in Ethiopia before the fall of the Emperor. In one joint project the man nearest to the Emperor was a clerk in the department; but it was he who had to be consulted by the American trained Ethiopian project manager when any decision was required. In several Caribbean countries colonised by Europeans, African slaves were brought over initially to work the plantations; but after Abolition they were replaced by indentured labour from India, China and southern Europe. As a result they have a dual population, with those of African and Indian descent in almost equal numbers, and small minorities of mixed origins. One or other of the main groups has come out on top and it is then very difficult for anyone else, however able, to get a top job. At worst this may break down into civil war, and we do not have to look very far to see repetitions today of the sort of internal strife from which developed countries suffered only a century or so ago.

4.5 Shortage of Foreign Currency. Only a few of the developing countries have been lucky enough to find - or more often have found for them - deposits of valuable minerals like oil, gold, diamonds, etc; and even some of these have built up large arrears of interest and capital repayments. Where the economy was and still is mainly agricultural, production has declined - and world market prices have often also declined - since independence, with the departure of the expatriates who managed the large plantations and farms. Many of these have now been fragmented into individual native farms which only produce enough for their own subsistence. Few Third World countries have succeeded in getting enough industry going to earn substantial amounts of foreign currency beyond that required to repay the interest on the capital investment. Thus there is a chronic shortage of hard currency for the purchase, not only of the sort of expensive technology with which this Conference is concerned, but even of spares and replacements for items we take for granted: motor vehicles, air conditioning, power generators, irrigation pumps, telephones, books for schools, and any foreign goods normally available in our own shops.

4.6 Weakness of Basic Services. The combination of the preceding problems is responsible for the weakness of basic services which is often aggravated in the towns by their too rapid growth. This has often outstripped the expansion of such basic requirements as water supplies, power and drainage. All of these are liable to fail without notice; and any technical project must be organised so that lowering of voltages, complete power failures, or contamination of the water supply, do not have expensive consequences. One experienced African traveller I know always fills up his bath or basin as soon as he moves into a hotel so that he can be sure of a supply of water. In many areas it is advisable to sterilize the water before drinking or washing with it. Projects using local transport are likely to have severe problems, since the vehicles are often very old. In the Sudan for instance in 1977 the Survey Department were still using trucks bought before independence in the 1950s; and they were only kept going by the ingenuity and skill of the local mechanics and blacksmiths, who made by hand the spares required. Many fine roads have been built by aid programmes, and most of the main routes in Africa have now been paved; but maintenance has often fallen into arrears, and away from them there will often be only dirt tracks, corrugated and full of pot holes at best in the dry weather and often impassable in the wet, and with often unreliable ferries across main rivers. Four wheel drive, winches and special jacks, have to be used by all survey parties operating in such areas. Of course this kind of work is not the direct concern of this symposium, but it has to be remembered that somebody at some time has to go into these areas and get the ground data if the maps are to be complete and not just line drawings or mosaics made from air photographs without field completion and ground control. Telephones often do not work, even in the big cities. During this year's Wimbledon tennis tournament a successful Nigerian player admitted on television that he would find it very difficult to ring up his parents and tell them of his success.

4.7 Lack of Manipulative Skills. There is no evidence that individuals of the developing countries lack the innate ability to acquire manipulative skill, as is shown by their craftsmanship and in some of their hunting and agricultural skills using very backward equipment. But these have required long years of training and practice as children and young adults; and what is lacking is a similar period of experience with the sophisticated machinery and instruments of modern civilisation. Our own children start playing with clockwork toys, wear wrist watches, and even own radio sets at quite an early age and operate television sets; many of them can use a telephone much earlier than their parents would like; and the boys certainly start taking these things to pieces and finding out how they work very early on. In the poor conditions of many Third World families a boy or girl may not have any possessions of this kind until they go on to further education in a developed country; and their use and handling of them suffers accordingly. Certainly it seemed to me when watching overseas mathematics and geography graduates (except those from Hong Kong with departmental experience) doing the long survey course at Newbury, that although they were nearly as good at the theoretical studies as their British or North American colleagues, they were a long way behind in the handling of theodolites and levels and photogrammetric plotters.

4.8 Corruption. Having worked for government agencies most of my life and only for a short time for a commercial company, which had high professional standards, I have no personal experience of this; but there is no doubt that it is common in the Third World, as of course it was in Britain only a hundred years or so ago, when parliamentary seats and commissions in the armed services were up for sale. In West Africa the 'dash' is still part of life, and in many countries expatriate firms trying to get contracts employ a 'fixer' who spends large sums - without detailed accounts - on making contact with, and influencing the decisions of, politicians and civil servants. In technical and financial terms the main harm done by this may be the diversion of funds from worth while cheaper schemes to those which are more expensive and provide more pickings. Another cause of the acceptance of up to date but unsuitable technology is national pride; only the larger developing countries with a longer period of independence (like India) will accept that while a small cadre of people can use the latest equipment, for the great majority of technicians the old fashioned vernier theodolite or level, and simple instruments like the plane table, or graphical air survey techniques, are more suitable. We all know of cases where, especially soon after independence, huge sums were wasted on prestigious but almost useless projects like national airlines, international conference centres, and dual carriageway roads which the local traffic never justified. The equivalent in our field may be elaborate computer and automatic plotter systems which cost a great deal of hard currency, require expatriates to operate them, and do not employ the large number of school leavers now being produced in the Third World. Anyone who connives at the corrupt setting up of such projects bears a heavy responsibility.

4.9 Lack of Dedication. One aspect of the different attitude to employment in the Third World is the lack of dedication to a job, especially when it is a government one. All of us are activated by self-interest; but in the developed world this can take more subtle forms - pride in our work, our professional reputation, a desire to be well thought of by our fellows and so on. The Third World is still too near the subsistence level, in memory if not in fact, to get very far away from basic needs; and personal gain is still the prime mover in getting things done. Thus anyone with a safe job, and without adequate supervision from superiors equally lacking in dedication, will often be working most of the time at something else - a factory, shop, or farm; and will be absent much of the time from his government job. In one country I heard from the last expatriate left in the survey department in charge of the instrument store, that he now had nothing on the shelves because all the surveyors were out working, and employing assistants, on private surveys, while arrears of government work piled up untouched. Education does not yet lead to dedication.

4.10 Loss of Trained Staff. One major problem is that when staff have been trained in some advanced technology in developing countries with rich neighbours, they will emigrate, or even fail to return after their course overseas, and get a much better paid job in one of these. This is liable to happen particularly in the Caribbean, with North America so handy, and in northern Africa, where British trained technicians and professionals find jobs in the Arabian Peninsula at perhaps five times the rate of pay. I was told of a case where elaborate negotiations about a boundary between two Arab oil states were conducted on both sides by Sudanese. The temptation to leave the country areas and seek work in the towns is part of the same problem. Yet another problem is the 'professional student', who through undue influence is able to continue in Europe or N. America on a series of courses of further education leading to post graduate qualifications, but never seems to return to his own country actually to do some real work.

4.11 The preference for work in towns and offices rather than in the field is a constant problem for survey departments; but one which should help in establishing cartographic or data bank systems since these should be more popular than field survey posts. However, they could then find there are no data to manipulate. Britain claims to be one of the best mapped countries in the world, mainly because we have a comprehensive large scale topographic map which can be used as a cadastral index, rather than the systems of individual title plans found elsewhere. Although our Ordnance Survey was one of the pioneers in digital mapping, most of the work of maintaining our large scale series is still done in the field by small parties of locally based surveyors using simple equipment. They learn about changes from the local government planning authorities; and their revision work is incorporated in the master traces of the plans concerned - or increasingly in the digital tapes now replacing these plans for most professional users like local authorities, public utilities and consulting engineers or surveyors. In spite of our advanced technology in handling it, we are not ashamed to use these simple old fashioned methods to get the data required.

4.12 In developing countries it is difficult to attract young men to do this kind of field work, or undertake the more arduous and challenging work of establishing or breaking down the national control framework. In one large Caribbean island some years ago complete photogrammetric coverage at 1/12,500 scale was achieved from air photographs by a United Nations project led by a senior cartographic superintendent on secondment from DOS; but even some years later, out of the several hundred map sheets involved, only a handful had got beyond the provisional edition, since it had proved impossible to organise the field parties required to complete them on the ground.

4.13 Intermediate Agencies. Setting up a successful technical assistance project is a complicated business; and it is not made easier by the number of agencies through which the initial proposals and subsequent negotiations have to pass. In a highly specialised technical field of relatively low political status like ours this problem is aggravated by the generally low grade of administrator handling the negotiations in all but the technical departments at the two ends of the chain. Anything up to eight departments may be involved in all: the recipient technical department, its own ministry, the recipient ministry (of planning or finance) coordinating all aid requests, the recipient foreign ministry, the donor embassy or high commission, the donor ministry coordinating aid, the ministry of the technical department, and finally the donor technical department itself. Only at the two ends do the people concerned really know what they are talking about; and if the administrators in between feel they ought to earn their pay by suggesting alterations in the scheme, then the initial request or offer (even if it was then technically sound) may be hopelessly distorted by those in between. In any case it may well take six months for the proposals to pass through the chain; and if it was wrongly conceived in the first place at either end, by a lack of understanding of local conditions in the donor, or at the recipient end by an inexperienced Third World technologist, it will take another six months or a year for the necessary amendments to filter through.

4.14 The problem is aggravated by the often low grade of official in the intermediate agency dealing with the proposals, for, as I have emphasized, surveys and mapping form a very small part of a national budget and do not have the political attraction of new schools or hospitals. I have often found myself, a professionally qualified Cambridge graduate with 30 years experience, dealing with the last twig on the tree of the aid department or embassy, who may well be a newly joined clerk or junior administrator whose qualifications and experience scarcely add up to those of our most junior surveyor or cartographic manager. Only in the smaller countries, or with the most enlightened ambassadors or high commissioners, would one get access to them; and in my own case this was often only because of the British old boy network of private school and university to which I belonged. From their point of view even aid, compared with local politics—or in the worst cases the protocol, drink supplies, and seating arrangements of some diplomatic party—had very low priority.

4.15 However there is one aspect of this which is worth mentioning; and I draw your attention to it as a possible means of getting the attention that in some circumstances mapping really does deserve. Although survey may form only one per cent of the total cost of some large project like an irrigation or hydro-electric scheme, or a new capital city, it must come first in time. And, odd as it may seem, I have more than once found myself, as a surveyor offering aid, required to decide which of two major projects should have priority since none of the more general agencies in between seemed to be able to decide about this; and by giving one project survey priority we gave it a head lead of several years. Thus in visits to discuss survey aid to developing countries one has often to consider very much wider aspects than just the survey proposals alone. It is a good idea to consult not only the local survey department but also its customers on visits of this kind. Personally, also, I always made a point of getting out in the country to see any proposed projects requiring survey before getting involved in any discussions back in the capital with aid agencies and embassies, so that I had some idea of what we were discussing. I shall be interested to learn if the North American survey administrators concerned with aid have had the same kind of experience.

SOME POSSIBLE SOLUTIONS

5.1 Introduction. Having outlined the main problems of providing technical assistance to developing countries it is time to look at a few possible solutions which I have seen in action, some of which appeared to be successful. These will be tied in to the problems mentioned, but by no means in the same order, and they will also be geared to the four main aspects of technical assistance:

- (i) Self-contained projects
- (ii) Joint projects
- (iii) Training (a) in the donor and (b) in the recipient country
- (iv) Secondments from the donor to the recipient country.

But before doing this we should look at how technical assistance schemes start. They may in fact start at either end, as a problem diagnosed by the donor or one known to the recipient; but in theory they have to be requested by the recipient when it comes to an official submission - even if someone from the donor country guides the pen that writes it. The only practical way through the problem of the intermediate agencies (paras 4.13-15) is to have direct contact, personal if possible, between the two technical departments, so that the submission meets the needs of the recipient and is in a form which the donor can handle. If this is not done endless time can be wasted by suggestions and counter-proposals passing to and fro. However, this must be done tactfully or the intermediate agencies can be offended and gum up the works. I remember at one of our Commonwealth Survey Conferences, which helped to cement close personal relationships already established by personal visits, the Minister for Aid referring to our network as a 'Mafia'; and I am not sure that he was being complimentary. But these relationships - often real friendships - and mutual trust were an essential ingredient in DOSs' success.

5.2 Self-Contained Projects. There are usually two ways of gathering information in a developing country - the highly sophisticated, and the simple and labour-intensive. The first, in terms of long term aid, should only be used if speed is essential, literate labour is short, and plenty of hard currency is available, for example in the rapidly expanding capital of an oil-rich state with a small population. The disadvantage is that while they may solve a particular problem, or provide some urgently needed data, and perhaps set up a new technique, they do nothing to help or train local people to carry them on, since a few skilled expatriates flying around in helicopters with black boxes never have any time for the slow and often frustrating business of finding suitable local staff and getting them to work hard and productively. Good examples of this sort of operation are the recording of stream flow for proposed hydro-electric or irrigation schemes;or in our own field the cadastral and topographic mapping of an agricultural area for individual land settlement. In all such cases external finance and expertise are required to set the scheme up; but unless local people are brought in from the start they will not be able to maintain it, and after a few years it will join the long list of projects in developing countries which have ground to a halt. Highly sophisticated automatic stream gauges, or photogrammetric plotters and computers for cadastral survey, will be less easy to maintain than simple instruments, with plenty of school leavers trained to use them. This can apply equally well to the use of air or ortho photos as to ground survey techniques.

5.3 The attraction of self-contained projects is that one has complete control over them - subject of course to the kind of problems mentioned above about basic services (para 4.6) - and usually one has far fewer problems with low grade local staff - labourers, servants, office sweepers and messengers - than with those who have been better educated. The cost and duration of the project can then be estimated with some accuracy, and this also makes it easier to let a contract. But, as so often is the case, the harder the task the more worth while in the long run. As in bringing up children, rigid discipline may mean peace in the home; but it does not produce responsible or mature adults. One lesson of the last thirty years of technical assistance has been that few projects, even when well designed with a maximum of local participation, continue at the same rate of production once the expatriate staff have left. After a few years they generally need a further injection of technical assistance and energy; and clearly this process will have to be repeated many times in the more backward countries for some decades if not centuries ahead.

5.4 <u>Joint Projects</u>. This leads on naturally to joint projects in which, in theory, the donor country's staff provide the sophisticated expertise, and the recipient staff do most of the work and are trained to take over. However, there is usually a good deal more to it than this; and donor staff acting simply as advisors and technical instructors are unlikely to achieve very much. The problems of nepotism in distorting the selection and promotion of local staff, mentioned in paras 4.3-4, of currency difficulties in 4.5, and of lack of dedication in 4.9 will also have to be solved. One of the lessons of later colonial and trustee administrations (as with the Normans) is how few are the energetic and dedicated expatriates (less than one per cent) required to activate a colonised people into doing so much; and yet how the removal of these few leads so quickly to the virtual collapse of technical departments in terms of output or getting anything done.

5.5 The way to tackle nepotism is to accept that it exists, but try to use it. In crude terms, instead of trying to select for training and promotion the most able students or technicians, regardless of their background, and keeping out 'the Minister's nephew', one should accept that those from minority backgrounds will not be able to achieve very much; and so if necessary one must look for, and hope to get, the right minister's nephews. Lack of dedication can only be overcome if the professional donor staff have some executive authority, such as joint managership of the project, rather than being just advisors. Lower down, even more important expatriate staff are the technicians (NCOs in service terms) who actually demonstrate the techniques to local staff, but at the same time run the office or laboratory. They must instil simple rules like 'nine to five is nine to five' and not eleven till one, with the staff spending the rest of the day at their farms or shops. This usually results in a confrontation at some stage and it is important that the expatriate staff keep their noses clean, work hard themselves, keep regular hours, and avoid the temptations of male staff separated from their wives; so that when this comes there is no lever by which they can be driven out. Clearly also the donor project manager, and the HQ at home, must back them all the way. Where tribal, racial or religious differences are so extreme that riots and even civil wars break out there is little that Technical Assistance personnel can do except get their people out safely and wait till the dust has settled and a more stable government has emerged.

5.6 The currency problem can be overcome by making sure that the donor part of the joint project includes a small team, with their own instruments and equipment, to produce results regardless of what the local part of the project is doing. This team will not be hampered by lack of spares or other requirements needing hard currency; and if one is not too scrupulous about accounting and stores records some of this can leak across to the recipient part. The training aspect should be stressed all the time, for this is more politically acceptable than production - at any rate of maps.

5.7 The weaknesses of local services (para 4.6) can only be overcome by foresight and experience, and patience. It may be necessary to include voltage control units, or even one's own generators, to provide a constant power supply; and the necessary filters and storage tanks will certainly be needed in any photographic or chemical work to ensure a supply of clean water, together of course with reliable air conditioning plant for temperature control. In field work and communication one has to adopt the alternative plan system used by any experienced overseas operator. This assumes the likelihood of breakdowns somewhere along the line, and goes something like this: "I will meet you on the 25th at A, but if the ferry at B has broken down I shall be a day late. I will try to let you know by telephone but if not you must wait at C; if I don't turn up after two days proceed to D and wait there" - and so on. It is simply no good making the sort of single detailed plan with split-second assignments one can organise at home.

5.8 Lack of manipulative skill with modern instruments can only be overcome by time; and by training the senior staff in conditions where they get the maximum usage of instruments; in too many technical colleges there is only one level or theodolite or plotting machine or computer for five or six students; only the most energetic and aggressive really use them unless the teaching staff are very watchful about this; and even then the usage by individuals is too diluted. A particularly important aspect of this is the use of sophisticated and electronic equipment which few surveyors or cartographers can repair, because it gives a golden opportunity for stopping work for breakdowns. The Tellurometer has not been the success it should have been in developing countries for this reason; and unless local supervisory staff know how to effect repairs themselves and to detect deliberate sabotage of sophisticated equipment, they will have difficulty in imposing discipline - which they find hard enough anyway.

5.9 Training in the Donor Country. The most important feature of this is the correct selection of the trainees, and the realisation that the combination of lower standards of education in the Third World, and the culture shock of going to another country, and having to learn techniques in a second (or perhaps third or fourth) language, means that overseas qualifications cannot be accepted at their face value. In Britain we find that an overseas university graduate is roughly the equivalent of a good British secondary school leaver; it is no good sending him or her directly onto a post graduate course. There are two attitudes to overseas students taking courses. One was propounded by that great man Professor Schermerhorn, who started ITC in Holland, and this was to give them a piece of paper at the end of the course, regardless of how well or badly they had done. In Britain we do not accept this: overseas students get the same treatment, except probably for extra coaching, as our own; if they pass it is a real pass, and if they fail they fail. The same applies to our professional qualifications — in mapping — of the Royal Institution of Chartered Surveyors. Obviously it is very important that they should not fail, or be sent home halfway through a course; and this can only be achieved by careful selection in the first place, and possibly a special course in English before they start on the main course. It is often worth while to organise special courses in the donor country for the sort of senior technicians mentioned in para 4.2. They are often of more use than the young and inexperienced graduates under whom they have to work, and this enables them to talk on equal terms with these and refute some of the impracticable ideas they may have picked up abroad.

5.10 Training in the Recipient Country. Some aspects of this have already been mentioned under Joint Projects, (para 5.5) but the essence of it is as far as possible to include local trainees in a good working group where they see something actually being produced and where their own lack of skill does not hold things up too much. They must be under the authority of the group leader and not free to come and go as they wish; and they should be given opportunities as they gain experience to exercise responsibility, particularly if they are well educated and likely (see para 4.2) to be promoted to senior positions much earlier than they should because of this. Local training colleges or departmental schools can usefully be run by expatriates who can impose a reasonable discipline; but they must of course have the backing of the local departmental and ministerial officials. They have to be both firm and tactful - not an easy combination - and must be mature and well balanced individuals with plenty of patience.

5.11 Secondments. As in joint projects and training, secondments are of little use if purely advisory. The seconded person must be in a position - which will usually not be at the top for political reasons - where he or she can exercise authority; if the position offered is too far down the scale then it is better not to accept it. This applies mainly to professionals who should be directors or assistant directors; but there are, as in joint projects, important key posts further down the production line of the sergeant major type, where the seconded person controls the work force directly.

CONCLUSION

6.1 To sum up, the provision of technical assistance to the Third World in a form as sophisticated and specialised as automatic cartography is bound to have serious problems. Those providing it must appreciate the immense gap which may exist between their own culture and that of the recipients, and consider whether alternative technologies of a simpler and more old fashioned form are not more appropriate and helpful. It must also be realised that in addition to the well known problems of weakness in the support services, many of the problems are ones of personal management rather than technology; and that although these can be solved it cannot be done quickly. There is a great deal to be learnt from history; and although that of early European colonisation had features of which we are now ashamed, its last decades contain many lessons for modern aid donors.

STATUS AND CONSTRAINTS OF AUTOMATED CARTOGRAPHY TRAINING IN AFRICA - THE NIGERIAN EXAMPLE

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ABSTRACT

Shortage of technical cartographic manpower in Survey Departments, at the same time as there are phenomenal increases in demand for maps, creates an enigmatic situation in most developing countries of Africa. In Nigeria, the Federal government's Green Revolution, Urban and Rural Planning and other programmes, heighten the demand for various types of maps. Soil survey and conservation, land capability inventory, forestry, new highway planning, land acquisition and real estate development for rapidly expanding cities, mineral prospecting and population studies, all demand maps at unprecedented new rates.

Cartographic manpower shortages at professional levels mean that government lacks personnel to even advise it effectively on its needs in such areas as remote sensing and computerized mapping. Occasional hard copy remote sensing pictorial outputs, covering parts of African countries such as Kenya, Morocco and Algeria, and information on computer assisted cartography in Britain and other Western countries, trigger sporadic re-evaluation of the colonial heritage in the area of cartographic technology. This in turn lends support to the proliferation of colleges and universities of technology.

The extent to which these institutions provide adequate training and appropriate cartographic technology is examined in this paper. The hypothesis of the paper is that the poor embryonic status of automated cartography education in Africa results from two main factors: first, the submergence of cartography within the purview of surveying or geography in academic institutions and government service; second, the protracted dependence on short term map production contractors.

Using Nigeria as a case study, the paper analyses training objectives and current developments in cartographic education. It assesses the effectiveness of computerized cartography education in producing the technological manpower for various aspects of national development requiring maps. It tackles the question of adequacy or superfluity of training objectives at various levels. Training programmes examined include formal, informal and in-service (on-the-job) education at the technician, technological and professional levels. The paper spotlights the common constraints of automated cartography education in the country.

It considers how these relate to developmental areas which have need for automated cartography. Some recommendations it makes relate to re-organisation of Federal and State mapping agencies; restructuring of cartographic education and stage by stage consolidation of automated cartographic technology.

NOUVELLES TECHNOLOGIES ET TIERS-MONDE

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RÉSUMÉ

Je propose d'élargir la question posée l'atelier sur "La cartographie assistée par ordinateur et le Tiers-monde." J'aimerais que nous nous posions ensemble le problème de l'implantations des nouvelles technologies de communication dans les pays du Tiers-monde.

Dans un premier temps, je vais tenter de situer la technique de la cartographie assistée par ordinateur parmi l'ensemble des technologies qui constituent ce que je me plais à appeler la télémediatique. Cette expression, plus large que celle de télématique, utilisée en France, recouvre cet ensemble de moyens nés du mariage à trois des télécommunications, des médias et de l'informatique. Il s'agit d'un monde nouveau, fruit de la numérisation des signaux de télécommunications, de la miniaturisation des médias, et de la banalisation de l'informatique. Nous allons survoler ce monde en faisant les liens entre ces technologies dont le mariage n'est pas encore tout à fait évident aux yeux de tous et qui permettent d'utiliser un nouveau langage, le scriptovisuel. Ce langage marie la graphique, telle que définie par le cartographie français Jacques Bertin, et le graphisme et peut premettre de faire le lien entre les cartographes et les utilisateurs des données contenues dans les centres, que ce soient des chercheurs en sciences humaines ou des "décideurs," technocratiques ou politiques.

Dans un second temps, je vais proposer un nouveau modèle de coopération internationale qui rejette le concept de transfert technologique pour le remplacer par celui de l'interaction technologique. Pour ce faire, je vais analyser et rejeter les schémas linéaires qui considèrent la coopération comme un transfert de biens ou de savoir entre un donateur qui a tout et un récipiendaire qui n'a rien. Je vais présenter et rejeter les schémas cybernétiques qui considèrent la coopération comme un moyen d'atteindre des objectifs de développement prédéfinis par le donateur en fonction de l'image qu'il a, lui, du récipiendaire et de ce qu'il croit être son bien. Je vais plutôt proposer de considérer la coopération comme un système ouvert d'interrelations des Etats entre eux, compte-tenu des spécificités de chacun et dont l'échange de savoir et de savoir-faire rend possible des interactions positives.

Dans un troisième temps, je vais analyser les conditions nécessaires pour que les nouvelles technologies de communication puissent s'implanter dans les pays en voie de développement. La première condition qui vient naturellement à l'esprit est celle de la formation. C'est une condition nécessaire mais non suffisante. Dans le cas des nouvelles technologies, cette formation doit mettre l'accent sur la capacité de s'en servir et non seulement sur tel ou tel type d'utilisation, de cette façon on évite de transférer des modèles mais on facilite l'apprentissage technologique.

La seconde condition est celle de la nécessité de mettre en place des infrastructures minimales. Les nouvelles technologies sont de plus

en plus simples d'opération, elles requièrent de moins en moins d'énergie et sont de moins en moins coûteuses, mais n'ayons pas d'illusions, elles doivent s'appuyer sur des infrastructures complexes. Les réseaux de télécommunications qui supportent des terminaux légers et conviviaux sont eux mêmes coûteux et élaborés. Les services "après-vente" exigent un ensemble de ressources humaines et matérielles. Enfin, la troisième condition, souvent passée sous silence, est la nécessité d'un environnement administratif valable; mon expérience en Afrique me démontre qu'une grande partie des problèmes soi disant techniques sont en fait des problèmes administratifs.

En conclusion, nous nous rendons compte que les problèmes du Tiers-monde ne se règleront pas de facon linéaire et que la cartographie assistée par ordinateur peut être un excellent champ d'apprentissage de l'implantation de la nouvelle technologie dans les pays du Tiers-monde.

GENERAL TRACK SESSIONS: DIGITAL INTEGRATED MAPPING SYSTEMS

THE NATIONAL DIGITAL CARTOGRAPHIC PROGRAM OF THE U.S. GEOLOGICAL SURVEY

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ABSTRACT

The National Mapping Division of the U.S. Geological Survey is actively adopting computer technologies to support its mission of collecting and distributing cartographic and geographic data for the United States. Digital methods are becoming increasingly important in the mapmaking process, and the demand is growing for digital data bases that link base category data to other physical, social, and economic data. Production of data for a national digital cartographic data base at 1:24,000-scale is well underway and complete small-scale planimetric coverage of the United States has recently been completed at 1:2,000,000-scale. During 1983 work was initiated in cooperation with the Bureau of the Census to produce an intermediate-scale data base at 1:100,000-scale.

The Department of the Interior established a committee to coordinate all digital cartography activities being conducted by its component bureaus. Also in 1983 the Office of Management and Budget issued a memorandum requiring Federal agencies to coordinate digital cartographic activities to improve the use of such data and provide a framework for proper management. The U.S. Geological Survey has also established a procedure to develop digital cartographic data standards for issuance by the U.S. National Bureau of Standards, and as the first step in that process, several of the in-house documents that have been developed for collecting and managing digital cartographic data have been published.

INTRODUCTION

In recent years the disciplines of cartography and geography have undergone a rapid and striking reorientation as the techniques for digital collection and manipulation of cartographic and geographic data have emerged from fledgling laboratory procedures into dominant and driving forces that now pervade the disciplines. This reorientation has accelerated since the late 1970's with rapid advances in minicomputer and microcomputer technology and a steady downward trend in hardware prices that have placed digital spatial analysis capabilities within the reach of ever-increasing numbers of earth scientists and land managers (McEwen, 1983). Digital techniques have provided a variety of new and powerful capabilities to collect, manipulate, analyze, and display spatial data.

The National Mapping Division (NMD) of the U.S. Geological Survey (USGS) is actively adopting computer technologies both to support its mission of collecting and publishing cartographic and geographic data at a national level for the United States and its territories and to fulfill Federal requirements for a national digital cartographic data base. The USGS through the NMD has the objective of preparing and making available multipurpose maps and fundamental cartographic data, and has concentrated its efforts on base category data as found on topographic maps, such as hypsography, hydrography, transportation systems, and major cultural features. (Southard and Anderson, 1983; Starr and Anderson, 1982).

OVERVIEW

During the 1970's, as the body of knowledge in digital spatial data analysis grew, it became apparent that fundamental cartographic data were needed in digital form to serve as a reliable reference base (Guptill, 1978). In addition, it was anticipated that increasing use of automated equipment and digital cartographic data would improve the timeliness and flexibility of map preparation with a possibility of eventually reducing overall costs.

The requirement for a digital cartographic data base had been recognized by 1976 by the (then) Topographic Division of the USGS. It was projected that this would become the single largest USGS data base with an estimated content of about 10^{14} bits of data. Digital cartographic activities in the USGS had proceeded cautiously as compared with developments occuring in some national mapping organizations worldwide. This has been fortuitous since many mapping organizations were applying computer-assisted cartographic methods that largely replicated sequential concepts of map preparation, without recognizing the need for topologic structuring of data and the desirability of embracing the emerging concepts of geographic information systems.

A Digital Applications Team was formed in 1977 to focus in a single group the ongoing activities within NMD and to perform further research, development, and applications. The Team goal was to develop a prototype capability to digitize, manage, and distribute cartographic data representing the content and detail of the standard USGS 1:24,000-scale topographic map. Two advanced concepts emerged: one, that files produced for the proposed National Digital Cartographic Data Base should be topologically structured, and two, that an extensive set of attribute codes would be required for the extremely high level of information contained on a map. These two concepts were adopted, and in 1978 the USGS began collecting base category digital cartographic data in an operational program. The now-familiar digital line graphs (DLG's) and digital elevation models (DEM's), corresponding to the content and accuracy of standard 7.5-minute quadrangle maps, were the primary products of the program (McEwen and Calkins, 1982).

The USGS land use and land cover mapping program has been underway since the early 1970's and production of digital data began in 1973 in response to increasing demands by natural resource managers. The Geographic Information Retrieval and Analysis System (GIRAS) was developed to handle the digital data produced. A major feature of the GIRAS software is the emphasis on topology and attribute coding.

Other programs begun by the late 1970's included development of a Geographic Names Information System (GNIS) and a national small-scale digital cartographic data base. The objective of GNIS was to build a digital data base of all names used on the 1:24,000-scale USGS Topographic Map Series. Collection of data for a national small-scale digital cartographic data base was begun in 1979 from the 1:2,000,000-scale sectional base maps of The National Atlas of the United States of America; the first phase of this project was completed in mid-1982.

In 1979 the Secretary of the Interior directed the USGS to include digital mapping in the National Mapping Program and to address other agencies' needs for data. The NMD formed a Digital Mapping Program Steering Committee which prepared a report that established the following guidelines for future actions.

- o Create, maintain, manage, and distribute the national cartographic and geographic digital data base for multipurpose needs;
- o Assist Geological Survey divisions, other Federal and State agencies, and others in developing and applying spatial data;
- o Coordinate digital cartographic and geographic activities and provide leadership to the Federal Government in the development and application of spatial data;
- o Implement digital techniques in cartographic and geographic operations; and
- o Establish a major capability for digital geographic and cartographic research and development.

Digital cartographic and geographic data were to be considered standard products of the National Mapping Division and procedures for distribution would be developed to ensure public availability of data consistent with the Survey's policies for the release of computerized data. Digital data production during Fiscal Years 1980 and 1981 would be primarily directed to the following types of data:

- o DEM data meeting 7-m root-mean-square accuracy,
- o Topologically structured DLG data for boundaries and the public land net at 1:24,000-scale,
- o Land use/land cover data at 1:250,000 and 1:100,000-scale,
- o The 1:2,000,000-scale data base, and
- o The Geographic Names Information System

Other types of data would be considered in response to firm requirements or to evaluate experimental techniques.

A strong in-house research capability would be developed to address the basic and applied research problems facing the

Division. Since the state-of-the-art in data base management and computer technology did not permit an optimum implementation of a cartographic and geographic data base, a phased development strategy was adopted to provide an optimized data base by the 1990's.

FEDERAL POLICY DEVELOPMENTS

During the 1980 budget review process the USGS requested an increase in funding to establish a digital cartographic program, and the Office of Management and Budget (OMB) requested that studies be conducted to justify such a program. One study conducted for the Office of Science and Technology Policy (OSTP) (Donelson, 1980) resulted in the following conclusions:

- o A national digital cartographic data base is justified,
- o The requisite program should be centralized in the Geological Survey,
- o There is sufficient demand for digital products to support a self-sustaining program.

Evidence from visits to State agencies and private companies showed unanimous desire for (1) universal standards and (2) uniform coverage; these two points became the basis for a Federal program. The report concluded that only the Federal government could establish and promulgate universal cartographic standards. Also, it was concluded that this would not occur unless the Federal government was directly involved in the production and data management process. To establish standards, provide uniform coverage, and create a national data base becomes logically a Federal responsibility.

As recommended in the OSTP-sponsored study, OMB directed the USGS to conduct a market survey to determine the depth and viability of the public and private market for digital cartographic products. This survey identified a robust and growing series of activities using computer-aided design and geographic analysis techniques but concluded that the private market was not currently favorable for full cost recovery in the public sale of basic data. The market currently responds to high-priority special projects of limited scope in which basic data are collected at minimum cost and only with sufficient accuracy and completeness to satisfy the project objectives. The basic data are frequently discarded and seldom satisfy multipurpose use. In 1981 Senate Bill 1280 was introduced in the 97th Congress, to establish a revolving fund in the Department of the Interior (DOI). This fund would be available, without fiscal-year limitation, for financing the production and distribution of digital cartographic data at uniform standards, developed by the USGS, under the direction of the Secretary of the Interior. Congress has not acted on this or any similar legislation and has chosen to continue to appropriate annual funding for digital cartographic activities.

The Senate Subcommittee on Energy and Mineral Resources requested the U.S. General Accounting Office (GAO) to conduct a study to develop further information on the nature and extent of computer-mapping activities in the Federal government. Their report (U. S. General Accounting Office, 1982) called attention to the undesirable effects of duplicative computer-mapping programs and recommended more vigorous action by OMB and DOI to meet federal data requirements.

In October 1982 the Secretary of Interior issued instructions to the Solicitor, Assistant Secretaries, and Heads of Bureaus in the DOI regarding the production, storage, access, and distribution of digital cartographic data of the United States land areas. The directive states:

> The Department has established a digital cartography program in the Geological Survey to provide a focal point within the Federal Government for the production, storage, access, and distribution of digital cartographic data of the United States land areas. * * *

The responsibilities assigned to the USGS were as follows:

- o Establish and administer the National Digital Cartographic Data Base (NDCDB) to provide for storage, access, and distribution of base categories of digital data developed through federally funded programs. These data shall meet established standards and specifications and be developed for approved categories;
- o Chair the Interior Digital Cartography Coordinating Committee;
- o Be the primary producer of digital cartographic data for inclusion in the NDCDB; and
- o Develop a national cartographic data program based on the requirements and priorities of Federal and State agencies and other users of digital cartographic data.

Several meetings of the Interior Digital Cartographic Coordinating Committee (IDCCC) have been held and the first semiannual report prepared. The report indicates that several actions have been taken as recommended by the GAO report and that an increase in funding for the USGS Digital Cartography Program has been forwarded to OMB as part of the Fiscal Year 1984 Budget request to Congress. Spatial data activities and expenditures in DOI bureaus were summarized together with listings of equipment available for digitizing, editing, plotting, and displaying or manipulating data.

On April 4, 1983, the Director of OMB issued a memorandum for the Heads of Executive Departments, Establishments, and Independent Agencies on the subject, "Coordination of Federal Digital Cartographic Data Programs." The OSTP and GAO reports had both cited the need for a OMB circular that would coordinate the digital cartographic activities of Federal agencies and assure that the USGS had the authority to produce data and enforce standards for a national digital cartographic program and to report Federal activities to OMB. Excerpts from the memorandum follow:

> Purpose. The purpose of this memorandum is to initiate a process to bring about coordination of the digital cartographic activities of Federal agencies. * * *
>
> Federal Interagency Coordinating Committee on Digital Cartography. In order to improve the use of digital cartographic base data within the Federal government and to provide a framework for its proper management, I am establishing an interagency coordinating committee. It will be chaired by the Department of the Interior, and will consist of representatives of at least the following Departments and agencies:
>
> | | |
> |---|---|
> | Department of Transportation | Department of Commerce |
> | Department of Defense | Department of Energy |
> | Department of Agriculture | Department of State |
> | Department of Housing and Urban Development | Department of the Interior (Chair) |
> | National Aeronautics and Space Administration | Federal Emergency Management Agency |
>
> Other agencies with activities or interest in digital cartographic base data also should be represented, and may do so by contacting the Director, U.S. Geological Survey. * * *
>
> In the performance of its duties, the committee should consider the needs of potential users of digital cartographic base data outside the Federal Government and the users of end products built on the base data.

The first meeting of the Federal Interagency Coordinating Committee on Digital Cartography, established by OMB, was held on May 27 and was attended by representatives of 39 agencies. It served to convene a steering committee of the primary agencies cited in the OMB memorandum and to create the necessary subcommittees to carry out specific tasks.

DIGITAL CARTOGRAPHIC DATA STANDARDS

As the application of computer technology to the disciplines of cartography and geography has burgeoned in recent years, so has application of automated methodologies in kindred disciplines within the earth sciences (Frederick and Anderson, 1983). Recognition by Federal agencies of the pressing need for standardization of data elements and representations used in all automated earth-science systems resulted in the issuance of a Memorandum of Understanding signed in February 1980 by the National Bureau of Standards of the Department of Commerce and by the USGS of the Department of the Interior.

Under the terms of this agreement and the specific tasks that are part of the National Mapping Program, the NMD has assumed responsibility for developing and maintaining cartographic and geographic data elements and their representation standards for use in the Federal establishment.

In an effort to fulfill this role, standards documents have been assembled with explanatory text into USGS Circular 895. The circular describes some of the pertinent issues relating to digital cartographic data standards, documents the digital cartographic data standards currently in use within the NMD, and details USGS efforts to define national digital cartographic data standards. There are currently seven chapters:

- A: Overview and USGS Activities
- B: Digital Elevation Models
- C: Digital Line Graphs from 1:24,000-scale maps
- D: Digital Line Graphs from 1:2,000,000-scale maps
- E: Land Use and Land Cover Digital Data
- F: Geographic Names Information System
- G: Digital Line Graph Attribute Coding Standards

Ultimately, the effectiveness of any standard is the degree of acceptance accorded by the user community. This acceptance, in turn, depends upon the responsiveness of the standard to demonstrated needs. Individual users will bear some temporary inconvenience and cost of adhering to a newly instituted standard if it is perceived that the benefit to the community as a whole promises an eventual return exceeding the initial investment of time and effort. Recognizing the need to involve the user community in the digital cartographic standards process, the USGS is actively supporting the work of the National Committee for Digital Cartographic Data Standards (NCDCDS) (Moellering, 1983).

Established in January 1982 and operating under the auspices of the American Congress on Surveying and Mapping, the NCDCDS consists of a steering committee and working groups on (1) Data Organization, (2) Data Set Quality, (3) Features, and (4) Terms and Definitions. The membership consists of professionals from Federal, State, and local agencies; private enterprise, and the academic community. The stated goal of the NCDCDS is to provide a professional forum for all involved public agencies and professional individuals to express their opinions, assessments, and proposals concerning digital cartographic data standards. The Committee will be requested to review USGS standards as represented by Circular 895; after sufficient time for circulation, discussion, reformulation, and comment, they will be submitted to the National Bureau of Standards for consideration as Federal Information Processing Standards.

USGS DIGITAL CARTOGRAPHIC AND GEOGRAPHIC DATA

Digital elevation data are produced and distributed in the form of DEM's corresponding in coverage to a standard USGS 7.5-minute topographic quadrangle. DEM data is also distributed as digital terrain tapes (DTT's) and arc-second DEM's corresponding to 1:250,000-scale topographic maps. Currently, the majority of the 7.5-minute DEM's are created using digitizing orthophoto equipment and consist of elevation values spaced at regular 30-m intervals and referenced in the Universal Transverse Mercator (UTM) coordinate system. The standard DEM format, however, does provide for randomly spaced elevation values and a variety of coordinate referencing systems.

The 7.5-minute DEM's are archived in the NDCDB according to two distinct levels of vertical accuracy: (1) less than 7-m vertical root-mean-square error (RMSE) and (2) 7- to 15-m vertical RMSE. The 7-m vertical RMSE was determined to be a reasonable and attainable standard under a variety of terrain conditions and instrument constraints using 1:80,000-scale high-altitude aerial photographs.

The USGS also distributes digital elevation data produced by the Defense Mapping Agency from 1:250,000-scale topographic maps in the form of digital terrain tapes (DTT) and arc-second DEM's. Digital terrain tapes were produced by the DMA by digitizing the contours, ridgelines, and drains from 1:250,000-scale topographic maps. Each DTT has elevation data points at 0.01-inch spacing for a $1^\circ \times 1^\circ$ block that corresponds to the east or west half of the source 1:250,000-scale map. Arc-second DEM's are produced by the DMA by updating and reformatting existing DTT's, where feasible, and by acquiring additional data where DTT coverage is nonexistent or inadequate. Elevation values are spaced at intervals of 3 seconds of arc, referenced horizontally in latitude and longitude coordinates. Like DTT's, arc-second DEM's represent $1^\circ \times 1^\circ$ blocks corresponding to the east or west half of the source 1:250,000-scale map, except in Alaska, where the block size varies with latitude.

Digital planimetric data are produced and distributed in the form of DLG's. Two major DLG data bases are currently produced: (1) large-scale DLG data digitized from 1:24,000-scale USGS topographic quadrangles and (2) small-scale DLG data digitized from the 1:2,000,000-scale sectional maps of The National Atlas of the United States of America. A third program is now being initiated in cooperation with the Bureau of the Census to produce DLG data from the 1:100,000-scale map series. The basic applications of DLG data are to support automation of the cartographic processes and automated spatial data analysis.

The DLG file structure is designed to accommodate virtually all categories of planimetric data represented on a conventional line map. Point, line, and area data types are accepted. Each distinct data category (such as boundaries, hydrography, and transportation) is stored as a separate file or subfile in the NDCDB. The data are classified at one of three levels according to the editing, enhancements, and spatial structuring performed on the files. The attribute coding scheme is open ended and can be expanded.

The small-scale DLG data were digitized to meet the expressed needs of the USGS and other user agencies for a complete small-scale national data base. These DLG data files are available in both a topologically structured format suitable for use with geographic information and spatial data analysis systems and a simplified graphics format (information defining topological structure is omitted) designed especially for automated graphics production. Both formats include feature codes assigned to facilitate automated production of base maps and special-purpose graphics at scales ranging from 1:2,000,000 to 1:10,000,000. Coverage is nationwide, and the data are stored in 21 multi-state regional blocks: 15 for the conterminous United States, 5 for Alaska, and 1 for Hawaii.

Digital land use and land cover data are derived from land use and land cover and associated maps (1:250,000- and 1:100,000-scale). The source maps depict land use and land cover in polygon format, and the digital data are accordingly structured in a highly compressed arc-segment/polygon format to facilitate digital manipulation and analysis using the GIRAS computer programs (Mitchell and others, 1977). A separate digital data file is created for land use and land cover and each of four associated data categories: (1) political units; (2) census county subdivisions; (3) hydrologic units; and (4) Federal land ownership. In tandem, the digital land use and land cover data and the GIRAS software constitute a functional geographic information system suitable for automated analysis of a variety of resource and planning problems.

Digital geographic names data are collected and archived via the multipurpose GNIS software and data base (Orth, 1980). The GNIS consists of five distinct data bases: (1) The National Geographic Names Data Base is the primary data component of the GNIS and consists of descriptive information pertaining to all named features (except roads, communication towers, and triangulation stations) found on the maps of the USGS Topographic Map Series. (2) The USGS Topographic Map Names Data Base contains descriptive information pertaining to the official names of the individual map sheets in the USGS Topographic Map Series. (3) The Generic Data Base is structured to serve as a research tool and as a depository for descriptive text information for the GNIS. A total of 61 feature categories (designators) are defined and cross-referenced to specific types of features found on published maps. (4) The National Atlas Data Base contains descriptive information pertaining to the geographic names found in the index of _The National Atlas of the United States of America_. (5) _The Board on Geographic Names Data Base is a listing_ of all domestic geographic names decisions rendered by the Board on Geographic Names since 1892.

CONCLUSION

There are many aspects to the national digital cartographic program; most have evolved during the past decade from concentrated research, development, and applications, and from direct extrapolation from conventional graphic processes. The once-experimental concept of computer-assisted cartography has reached a mature form that is operational and cost effective for many applications. The process for creating a 1:24,000-scale data base is firmly in place. A 1:2,000,000-scale base of planimetric data of the entire country is complete and available in two formats. The generation of a 1:100,000-scale data base of national scope is commencing through a collaborative effort with the

Bureau of the Census, and the well-known 1:250,000-scale digital terrain data bases continue to be maintained and disseminated. Also, the land use and land cover digital data base is being increased each year and maintained in conjunction with the associated GIRAS analysis software. Digital geographic names data are used for a variety of operational and research tasks, and the quality and quantity of data is continuously improving.

An increased awareness of the importance of digital cartography in the Federal Government has caused several important actions to occur in the past 3 years. The OSTP-sponsored study of 1980 concluded that there is substantial worth in a national digital cartographic program but that further management and definition were required. The GAO study of 1982 further identified a number of important facts and recommended more vigorous action by DOI and OMB.

At OMB's direction, USGS conducted a market survey to determine the depth and scope of the public and private market for digital cartographic data. The study identified a number of viable and rapidly growing activities but a large, mature market that would support a national program in the absence of public funding was not discovered.

One of the most significant actions to result from these various government sponsored studies was the OMB mandate to the Federal agencies to coordinate digital cartographic activities through an interagency coordinating committee chaired by the DOI. Furthermore, the DOI has charged the USGS with the responsibility for coordinating all digital cartography activities for its component bureaus.

Understanding production requirements and applying uniform digital cartographic standards are paramount to all coordination efforts. In an effort to assume the lead in the formulation of standards and develop the NDCDB, the USGS has published Circular 895 which describes various aspects of digital cartographic standards.

Some of the challenges in digital cartography have changed from a decade ago, but many still exist. We must continue to refine the data collection/data base creation process, promulgate uniform standards, and demonstrate the application of spatial data in the solution of the many earth science problems that face us. Perhaps the largest immediate challenge to the mapping community is to develop and manage the technology required to provide user orientated geographic information systems that are suitable for integrating and analyzing the large mass of spatial data now available to the earth science community.

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HYDROGRAPHIC CHARTING

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ABSTRACT

This year the Canadian Hydrographic Service (CHS) is celebrating its one-hundredth's anniversary. It is a significant year in other aspects as well. It marks the beginning of an effort, albeit limited, towards the realization of the electronic chart. Although not an entirely new concept, the electronic chart has had to wait for the appropriate technology to appear. The year also marks the commencement of activity toward the 2nd generation of cartographic systems which will be based upon 32 bit minicomputers. Although the fundamental characteristics of the system won't change, it is planned to provide better facilities for interactive compilation from digital source data and to provide and plan for the deployment of computer assistance throughout hydrographic charting.

The paper reviews the step by step development and application of digital techniques to nautical chart production. It discusses the capabilities and limitations of the current systems, the plans to overcome them and the rationale for moving from the 16 to the 32 bit computer.

Digital computers and the related technology are providing new and useful tools for the cartographer, but the construction of the chart will, for the foreseeable future, continue to rely upon the skills and intelligence of the cartographer. It is the aim of the CHS to make these tools as effective as possible within that framework, and at the same time to extend and broaden their application. Even though the basic techniques have been established as being sound, extending the use of the systems will continue gradually. This limits the expenditures needed to buy the equipment but also allows the users time to adjust to the new ways.

The success and acceptance that have been achieved, so far, are due to the gradual transition which has allowed users to become comfortable with the digital equipment, given them time to learn how to integrate the new techniques into their work and to become familiar with the strengths and weaknesses of the new technology. A large scale introduction, assuming we had known how to do it, would likely have been disastrous. This policy will continue and although it may slow down the application and use of the computer-assisted methods, it greatly increases the probability of having systems that are effective and will contribute to the chart production process.

The evolution of the electronic chart in the next decade will have a significant impact on the format and method of constructing the chart, but this will also be a gradual process dictated not so much by technology but by other factors such as the need for international standards for exchanging and presenting the digital chart data, by the availability of the digital information, possible legal implications, user acceptance, cost, and the ability of agencies to respond.

NATIONAL OCEAN SERVICE AUTOMATED NAUTICAL CHARTING SYSTEM

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BIOGRAPHICAL SKETCH

Kirby Gean is the Staff Cartographer for the Systems Development Branch. The Systems Development Branch is responsible for the design, development, and implementation of automated systems supporting the National Ocean Service's nautical cartography. Mr. Gean is responsible for quality assurance of marine digital data which is being processed for inclusion in the National Ocean Service Automated Nautical Charting System (NOS/ANCS) data base. He prepares requirements and specifications for charting applications software, and developes procedures manuals for the automated cartographic systems as they are transitioned to operational use. Mr. Gean's background has provided him with an authoratative knowledge of digital data collection, processing and automated cartographic applications.

ABSTRACT

The implementation phase of the NOS/ANCS required changes to original cartographic concepts and methodologies which had been developed for data handling and maintenance of nautical charts. As with many developmental projects, the transition from the drawing board to operational use (blueprint verses reality) often encounters unforeseen problems. The ability to quickly assess these problems and incorporate changes for resolution is as important to the successful implementation of a system as is the original system design. The NOS/ANCS, through continued development, now can support the maintenance and production of nautical charts. Concepts and methodologies will be discussed with emphasis on some of the problems encountered and resolution of those problems.

INTRODUCTION

The National Ocean Service (NOS) has as one of its primary missions -- the maintenance and production of approximately 980 nautical charts, containing approximately 3,000 assorted panels, insets, and extensions, covering the coastal waters of the United States, the Great Lakes, and U. S. territories.

A NOS study initiated in 1970 concluded that an automated cartographic capability would be essential if NOS were to maintain its suite of charts with current information on natural and man-made changes and that increased throughput of such marine information would not be possible in a timely manner without the use of computer-supported data acquisition, processing, storage, maintenance, and graphics. The automated data storage, data maintenance, and graphics associated with nautical chart production is NOS' present concern, NOS having already implemented and transitioned to operational use an automated data acquisition and processing capability for hydrographic surveys.

Of the three areas: data storage, data maintenance, and graphics, the methods originally conceived for maintenance of nautical charting data, have collectively undergone the most significant changes since implementation of the NOS/ANCS. Changes have been incorporated in digital data collection techniques supporting the creation of the data base; in new digital data collection methods required for maintenance of the data base; and in the hardware used to interactively edit data comprising the data base.

BACKGROUND

The NOS/ANCS was developed in house by NOS through an outside contract with the Planning Research Corporation. The NOS/ANCS provides on-line disk storage for nautical chart data published by NOS and provides cartographers with the capability to interactively maintain nautical charts via color-graphic work stations. The NOS/ANCS also supports post-maintenance reproduction of nautical charts.

Central Site and Work Station Hardware

The central site portion of the system contains two model V76 Sperry Univac computers operating in a master-slave relationship. Software allows either computer to act as a stand-alone master in the event of a malfunction of the other. Each computer has 128K memory and is presently configured for dual access to five 300-megabyte disk drives. Additional disks will be added as data are made available. Other peripherals supporting each computer include three 9-track tape drives, a card reader, a line printer, and an operator's console. The central site as configured will support ten color-graphic work stations, each connected to the central processors via a high-speed data cable.

Two prototypes of ten planned work stations have been implemented. Each is driven by a model V76 Sperry Univac minicomputer with 160K memory and is supported by two 58-megabyte disk drives for local files, one 300-megabyte disk drive for data storage, a four-color vector refresh "edit" display screen, a monochrome storage "reference" display screen, a graphic hardcopy device, and a digitizing table.

Data Base Structure

The data base is geographically oriented. A feature is stored only once. Accompanying attribute information tells how each feature is to be depicted on the various charts. This technique eliminates redundant storage, which in turn decreases the size of the data base. Single feature representation prevents conflicting depictions of features within an area of overlapping charts. Also, when a feature is deleted from a chart through cartographic decision or is superseded by new information, it is easily deleted from all other charts because it is represented in our data base only once.

The Data Base Management System (DBMS) used in the NOS/ANCS allows direct access to records on the disk. To make the storage scheme more manageable, the Earth's surface has been subdivided into one degree by one degree squares. Each degree block is defined as a master record to the DBMS. Near the shoreline, where data are more heavily congested, a further refinement is made to the degree block subdivisions. In these areas, a master record represents an area that is five minutes by five minutes square.

A variety of data records represent the different types of features. A group of these records is required to represent one feature. A discrete feature (a symbol represented by one coordinate) for instance requires a minimum of four records to be stored. The first record, called the base data record, contains information about the type of feature, its data base origin, its charted status, and its geographic position. The second record in the sequence,called the compilation fact record, tells which charts the feature is to appear on and how it is to be symbolized and rotated. The next record contains the geographic positions, characteristics, and charted status of any nomenclature which accompanies the feature. The last record describes the actual text which appears on the chart supporting the feature.

Lines are similarly represented. The first record contains information about the type of line, its data base origin, its charted status, and the geographic position of the beginning of the line. The second record (compilation fact) tells which charts the entire line or part of the line appears on. The last record, repeated, contains the actual geographic positions of the line, eight coordinates per record. Compilation fact records created during editing are inserted in the coordinate record sequence to denote the beginning and end of line segments within the line feature which are either superseded or temporarily turned off (not to be charted) on individual overlapping chart panels.

Data Base Creation

The data base was created by digitizing the suite of NOS published charts, supplementing the digitization effort by researching and converting to digital form past and current graphic and textual source documents describing navigational aids, landmarks, hazards, and other easily researched features.

Prior to the collection of currently published information from the chart, 3200 active hydrographic surveys representing 28,000,000 soundings were digitized to form the nucleus of the data base. These surveys are to be used for chart reconstructions and new chart construction and will also be used to replace soundings previously manually applied to charts and subsequently digitized from those charts. The survey data is currently being used to develop and test automated contouring and sounding selection routines. These routines will be used in the future to process new surveys.

Currently, the charted features for the Gulf of Mexico, the East Coast to North Carolina (including Puerto Rico and the Virgin Islands), and the Great Lakes have been collected and loaded into the NOS/ANCS data base to support automated chart maintenance activities. Selected charts from each of these areas are presently compiled and maintained on the system.

Data Flow/Application

The application of new data using the NOS/ANCS is straightforward. New data to be applied must be converted to digital form. If the data comes in a graphic form, it is converted to a machine readable form on the graphic digitizer system. If the data is descriptive, it is keypunched and transferred to magnetic tape.

The original design outlined new data application to be performed on the information in the data base in the following manner.

Data received by NOS for automated chart maintenance is given a preliminary review to determine charting applicability. If determined to be useful, information specific to the document: date, originator, data type, geographic limits of the document and the nautical chart compilation team responsible for application of the data along with other information are keypunched for inclusion in the Source Registry File (SRF) resident on the central site disk. The SRF is an accounting of all documents entering the NOS/ANCS used for chart maintenance.

The new source document (graphic or textual information) is forwarded to the appropriate compilation team where data from the document are digitized and keypunched. The data are then processed for inclusion in the New Data Holding File (NDHF) repository also resident on the central site disk

The cartographer prepares a punch card retrieval request to extract the published information from the data base along with any new documents which reside in the NDHF. The retrieval deck contains data fields qualifying the data requested, by geographic window, charts, and data type.

The SRF is queried during request processing to determine if the new data documents requested are resident in the NDHF, and the request is processed for syntax errors. If no errors are evident, a copy of the data requested is sent to the work station where additional processing is done enroute to format the data for interactive editing.

The cartographer logs onto the work station, registers the largest scale chart upon which the new data falls, creates displays for each chart or portion of chart requiring edit, and applies the new data, composited with the current published information on the screen, to all overlapping charts.

After editing is completed a reviewer logs onto the work station to review the application. If the application of new data is correct, the reviewer initiates an update to the central site data base. The edited copy is sent back to the central site to replace the original published data and any information superseded during the work session is written onto an archival tape to be stored.

The edited data can then be retrieved to tape and subsequently used to prepare reproduction negatives on the NOS/ANCS laser plotter.

PROBLEMS AND NEW APPROACHES

Initial Data Base Creation

One of the first tasks to be accomplished before implementation of an automated mapping/charting system, is the creation of the data base to which corrections will be made. An early attempt to build the NOS/ANCS data base by digitally recollecting the current depiction of the nautical chart from previously applied source documents proved to be time consuming and labor intensive. Personnel resources and funding were not sufficient to overcome the problems encountered to digitally recapture the data from original source documents, tie the linear data together, and process the piecemeal collections.

New Approach. Since the published nautical chart is a legal document, having undergone extensive edit and review, the decision was made to research easily found information from previously applied source documents, e.g., navigational aids, landmarks, and hazards, and to digitize the rest of the chart to acquire the remaining data required.

Other than "chart oriented nomenclature", all other data found through research or digitized from a larger scale chart would not have to be recaptured on the next overlapping smaller scale chart. This saves time and avoids redundancy.

Redundant capturing of data from smaller scale charts was permitted in cases where linear features were greatly generalized because of extreme scale differences. These small scale charts were digitized in their entirety to avoid a "postage stamp" appearance when larger scale chart data are plotted on the smaller scale chart base. Processing software distinguishes between large and small scale features in the data base. Software routines are being developed to generalize linear features without degrading the accuracy of the line.

The approach, that of digitizing existing published information, hastened initial data collection activities and eliminated the labor intensive research and evaluation that would have been necessary had we recaptured original source information.

New Data Application To The Data Base

New data documents, entering the NOS/ANCS were to be collected in their entirety by digitizing graphic information or keypunching textual information.

NOS receives charting information from approximately 60 sources: federal agencies, state and local governments, foreign countries, and the private sector. The original concept was to provide the cartographer at the work station with the entire digital copy of the document from which the cartographer could make evaluations and selections of features for application to the chart. The entire content of the document was to be preserved for future reference for making new charts and for legal purposes. The original concept specified that the data base content would be document oriented within the geographic scheme.

It was recognized at the outset that hardware and resources would have to be dedicated to the task of new data collection. Source documents received by NOS are diverse in content and format. The task of digitally collecting all the information from new source documents proved to be very labor intensive. To preserve the exact character and content of each source document, extensive review of the digital conversion was required.

The time, resources, and expense involved in collecting and transforming graphic and textual data to digital formats, was grossly underestimated. To compound this problem, NOS has recently recognized two other important considerations. NOS is unsure whether it can digitally capture documents and manuscripts compiled by others outside the agency, process these data, and guarantee that they represent exactly what the originator of the document intended? In addition, it is questionable whether the data base should be considered a repository for original documents, to be used by the originating office at a later date?

The data entering the data base undergoes extensive software processing: point elimination of linear information to reduce storage requirements, and elimination of certain nonchartable data specific to the compilation of the original document. Therefore, it has been recommended that the original concept of capturing the entire document and digitally preserving it requires more study. The shear magnitude of digitally converting documents of varying formats, many with insufficient control or nonstandard control, has required extensive set up time for digitizing and has made it necessary to consider an alternate approach to new data collection.

New Approach. The new document, after being registered and initially evaluated to determine charting acceptability, is forwarded to the compilation team responsible for its application. Team cartographers evaluate the document and determine whether the data are to be digitally collected or immediately applied to the nautical chart. Certain factors are considered in his decision:

- amount of features on the document
- criticality of the data
- type of control on the document
- scale of document/scale of chart to which the document is to be applied
- availability of resources for digitizing
- print cycle of charts to which the document is to be applied
- the estimated time required to digitize the document

If the data from the document can be quickly digitized or keypunched, the data necessary for chart maintenance are collected and entered into the NDHF. If not, the document is applied to the chart compilation manuscript and these corrections are digitized. The data corrections are identified as originating from the new source document.

Applying data first to the chart manuscript eliminates extensive digitizing set up time, captures the data after cartographer evaluation, captures only the data needed for chart maintenance (if linear information, properly generalized, tied to published lines, and restituted.) This approach also eliminates work station application time for line editing. Most importantly, NOS cannot wait for digitizing and processing functions to be preformed on new source documents before evaluating them for critical situations which must be extracted and forwarded for inclusion in the Notice to Mariners. It has proven to be a more timely approach to apply the new source document to the chart manuscript concurrent with this evaluation.

Additional Problems Associated With New Data Application. The document approach, that of digitally collecting the entire contents of a document and sending it to the work station for subsequent application, overtaxed retrieval processing and storage capacity at the workstation.

The geographic window of many new documents covered such a large geographic area that to bring them and the published information to the work station encumbered data application.

Additionally, to preserve the integrity of the data base, the system will "lock out", or make unavailable to other cartographers, any portion of the retrieval area being edited, for the duration of the compilation session. The area locked out is the union of the limits of the new documents and the area specified by the cartographer. Some documents will lock out very large areas of the data base making the system very cumbersome for other cartographers.

Resolve. To alleviate the space problem, larger disks were added to the work stations. The large document problem was resolved by effecting software changes to allow partial retrieval of the contents of a document. Prudence on the part of the cartographer in his request for data also helps keep retrievals small. Although more retrievals are required to apply large documents, large areas of the data base are not "locked out" for long periods to other cartographers wishing to apply documents, and scheduling of work station sessions does not log jam.

This approach somewhat destroyed the original concept of management reporting based on full document application and requires a greater awareness on the part of first line supervisors who must now report features applied as well as partial documents applied. However, this approach significantly increased throughput. In the future, the new document retrieval approach (total contents or portion of) will possibly be abandoned in favor of automatically retrieving all new data within the geographic window requested for work station edit activity regardless of the number of documents residing in the NDHF.

Work Station Enhancement

The work station has undergone extensive changing: hardware, software, and methodology for data application on the color screen.

Originally, the work station environment allowed only minimal interaction via the keyboard interface. Early thought assumed that properly evaluated, digitized, and processed data would arrive at the work station clean and error free, be correctly geographically positioned per control on the original document, and require only minimal editing to apply the data to the current published chart. Limited functions allowed straight line connections of linear features, rotation and movement of some symbols, transactions of features to published or archived status, and allowed supporting functions to query the contents of feature records.

Methods/Software. Preliminary studies indicated that extensive editing would be required of linear features and less editing required of other data types. When the cartographer got on the work station after the system was tested as conceived, to perform compilation activities, it was found that the work station did not support the cartographer in the manner he/she was accustomed to in the manual application of data.

Production use of the work station provided a more realistic barometer for determining where extensive data editing was necessary. We found that most work station activity centered around maintenance of discrete features and charted nomenclature which supports the feature. Linear data revisions, although not as substantial in quantity, presented problems because of initial limited editing capability.

Enhancements. Software enhancements to the cartographic capabilities originally developed include:

- complete nomenclature (text) editing: creation, placement, and graphic display
- complete line editing capability: line creation, joining, closure, deletion, vertex manipulation, segmenting
- capability to edit feature record fields to correct errors introduced during initial data base creation and load processing
- data entry and feature record creation at the work station to bypass extensive processing of small amounts of data through the NDHF
- bulk editing of features within polygons, qualified by data type, feature classification, charted status, and symbolization.

Other enhancements being developed include the capability to append comment records to features where recording the reasons why a feature was edited in a certain way might clarify post-edit research. Also, a record will be created and appended to any feature moved at the work station. This record will contain the edited position of the feature. The original position as given or captured will be retained for historical reasons.

Hardware. Another area of concern, which NOS has taken steps to improve, is the graphics/interface at the work station. Our current edit screen is of the vector refresh type. The amount of data displayed on the screen exceeds capacity of the refresh buffer, forcing the cartographer to increase the zoom factor (enlarge the scale of the display) to eliminate excessive data from view. This results in a smaller edit window on the chart to which corrections are being performed. The keyboard interface, which requires numerous keystrokes to initiate and control editing, proved to be cumbersome and slow, forcing the cartographer to step completely through chained editing sequences.

NOS has procured color raster graphic work stations and is currently effecting software development to eliminate the graphic display problems. NOS is also developing a hierarchical/menu system which can be displayed on the edit screen alternately with the graphic data. This approach will eliminate the menu pad and the menu area which must be reserved on the digitizing table seen on some other systems on the market.

Central Site Data Base Edit Capability

Another area of concern is the edit capability, lacking presently, of the data resident on the central site disk packs. There has been a need to edit large amounts of data prior to it being sent to a work station. The mass data collection effort along with the complex task of processing the information introduced some errors in the data which, if sent to the work station, would greatly encumber the editing process. Also, it was recognized that if the cartographer could manipulate the data at the central site he/she could eliminate some tasks formally thought to be within the jurisdiction of the work station environment.

New Concept. The one major capability desired at the central data base above the ability to correct data, is the need to assign features in mass to a newly designed chart. Presently, features must be assigned to a new chart, one feature at a time, at the work station. The bulk edit function recently developed for editing features at the work station is an improvement, but can only mass edit features which are displayed on the edit screen.

With central site data base edit capability, a new chart or series of charts could be interactively developed by editing the parameter information files describing geographic chart limits. The data within the new limits would be mass assigned to the new chart or qualified by specific data types. The new chart would then be sent to the work station for embellishment and/or removal of undesired features which are not charted due to scale factor. NOS is presently developing this capability.

Archival System

The original design required an off-line archival library system to store all features which were subsequently removed from the chart during work station edit sessions. This archival file was designed to support cartographic research of past chart maintenance applications in lieu of the pick and shovel effort now used in searching through files and drawers to find original source documents.

Features from source documents were to be stored in the active data base if published on at least one chart and stored in the archival file off-line, if superseded. The archival file was to be document oriented. Data written onto the system archival tape during data base update from the work station would, at intervals, governed by the archival tape capacity, be written onto tapes in the library indexed by the document's identification number previously assigned during initial document registry.

We found that the logistics of updating document indexed tapes, which continually increased in number, to be labor intensive. Providing a dumping place for archival features by document identification did not provide the cartographer with all the needed historical information specific to a particular printing of the chart.

New Approach. To improve the capability to extract historical information from the archival file, NOS has abandoned the original concept of storing superseded information off-line by document identification in favor of storing data by chart identification.

Graphic re-creation of a past printing of a chart will be more easily achieved if corrections applied to a chart are stored in the archival library along with the published representation for each printing of the chart. The listings retrieved in support of the graphic will provide the cartographer with an historical accounting of documents applied and editing performed. NOS is presently developing this capability.

CONCLUSIONS

The importance of post-developmental efforts cannot be over emphasized. The concepts of the NOS/ANCS geographic-oriented data base are advanced. NOS is massaging the design as conceived to incorporate changes brought about by rapidly advancing technology and cartographer needs for efficient, timely application of marine information to the chart.

METROCOM: HOUSTON'S GEOGRAPHIC INFORMATION MUNICIPAL MANAGEMENT SYSTEM

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ABSTRACT

In September 1978, the Houston City Council approved the Department of Public Works Director's request that his department be authorized to embark upon the development of an interactive facility data management system, dubbed METROCOM (METROpolitan COMmon). In November 1978, the City Council further authorized the City's Tax Department to participate in this same project.

Since that time, the City's digital graphics/data base consultant has expended 316 man-years in developing the METROCOM Data Base. Of this effort, 121 man-years were devoted to digitizing the data and 55 man-years to system design and software optimization. The METROCOM system recently has been installed in the City Hall and now represents the largest municipal data base of its kind in the USA. This article presents a brief history of the project and discusses some of the many lessons learned.

INTRODUCTION

Houston's METROCOM system consists of an integrated collection of spatially-related municipal data accessible to all City departments. The METROCOM data base resides on mass storage devices which are available for instant inquiry by City offices. Output capabilities include a high-speed line printer, digital and electrostatic plotters, and CRT displays with associated hard copy devices. The key to the METROCOM system is geographic location. All data stored in the system are indexed to digital versions of the planimetric maps which the City has produced and continues to produce, using photogrammetric techniques. This continuous planimetric map covers some 1,760 square kilometers (680 square miles) and is overlayed with ownership and land-use information on some 554,000 parcels, as well as complete information on the water, sanitary, and storm sewer systems, the road network, and bridges servicing a population of approximately 1.7 million.

COMPUTER SYSTEM

The interactive graphics system which the City has chosen for its consultant's use in building and maintaining the METROCOM Data Base is Synercom Technology's INFORMAP system. This system uses the Digital Equipment Corporation's PDP 11/70 minicomputer with an RSX-11M operating system. Figure 1 shows the configuration proposed by the consultant

PROPOSED METROCOM SYSTEM CONFIGURATION

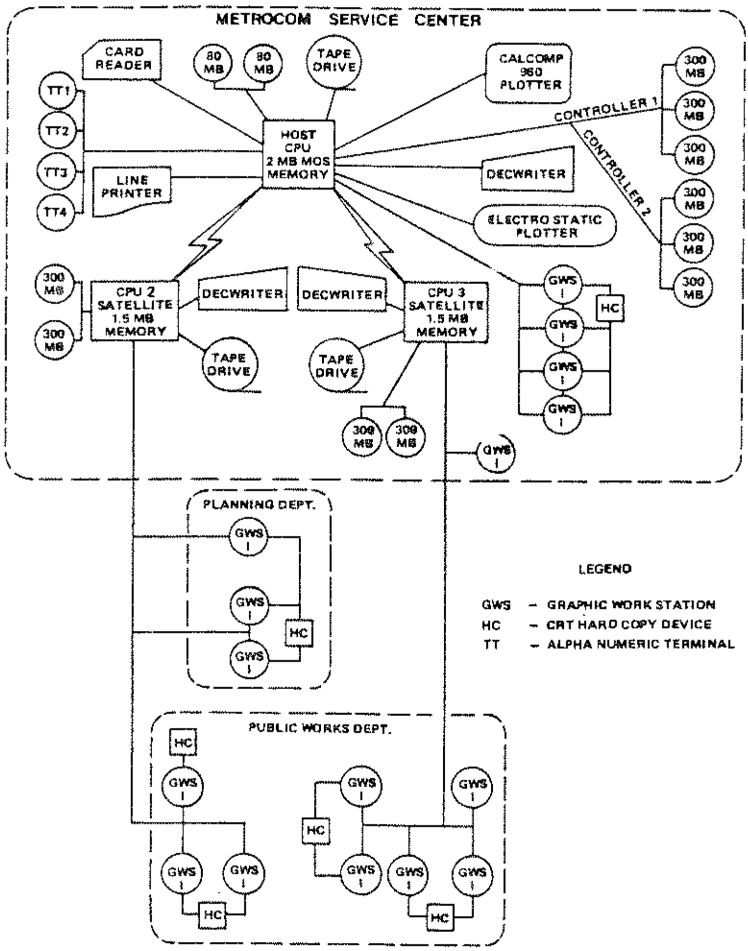

Figure 1

for installation in the City Hall. It consists of three PDP 11/70 minicomputers and 16 interactive graphic workstations. One PDP 11/70 will serve as host for the entire system. It will be dedicated to the task of managing the master METROCOM file and supplying data on request to the satellite systems through a DECNET™ data link. The host will also control the digital and electrostatic plotters as well as an array of other peripheral input/output devices. Present planning calls for the METROCOM system to have a disk storage capacity of 3.2 billion bytes. This will be achieved by using ten 300-megabyte disk drives and two 80-megabyte disk drives.

Eight interactive graphic workstations and one PDP 11/70 computer will be dedicated to the Department of Public Works. Three graphic workstations will be dedicated to the City's Planning Department, which will share the second satellite PDP 11/70 with the Department of Public Works. By using this distributive processing arrangement, the physical size of the specialized departmental files have been kept within reasonable limits. This concept also allows each department to access more rapidly that data which it frequently uses and to protect data of a restricted nature. Four graphic workstations will be retained in the METROCOM Service Center which will be responsible for hardware and software maintenance and master file updating.

OPERATIONAL INTEGRATION

The METROCOM system is not as yet a fully operational system. Tasks designed to make the system fully operational and scheduled for accomplishment in 1983 include the following.

- Transferring the system's three PDP 11/70 CPUs, 16 Synercom Technology Graphic Workstations, and other associated peripherals to an operating environment within City Hall.
- Networking this equipment and other City-owned computer systems.
- Training City personnel in the use of the system.
- Documenting operational procedures.
- Developing long-term system maintenance procedures.
- Planning for the expansion of the system to include data required by other City departments.
- Developing specific applications for the various City Departments.

As this article goes to press, the first of the two satellite CPUs and eight graphic workstations are being installed at City Hall. The host CPU and many of the peripherals are scheduled for installation in January 1984.

A date for the installation of the second satellite system has not been set.

COMPUTERIZED GEOGRAPHIC BASE

The foundation stones for the METROCOM Data Base are the more than 5,000 brass survey markers which have been implanted at intervals of approximately 610 m (2,000 ft.) throughout the Houston Metropolitan area (Gale, 1970). The coordinates of these survey markers have been computed from Second Order, Class II Horizontal and Vertical Surveys, using National Geodetic Survey procedures and specifications (Federal Geodetic Control Committee, 1975). Horizontal positions are adjusted using the NGS Traverse Program while vertical positions are adjusted through use of the NGS VERT 02 program.

The 1:1,200 scale (1 in. = 100 ft.) maps which form the basis of the geographic base were originally compiled using 1:6,000 scale (1 in. = 500 ft.) color aerial photography acquired with a cartometric quality camera. All maps were compiled to the National Horizontal Map Accuracy Standard of 1/40-inch at map scale for 90 percent of well-defined points.

The 1,530 map sheets produced before March 1979 were photogrammetrically revised using 1:12,000 scale (1 in. = 1,000 ft.) color photography prior to digitization on a graphic workstation. An additional 32,800 hectares (81,000 acres) were mapped at a scale of 1:2,400 (1 in. = 200 ft.), while orthophotos at a scale of 1:1,200 (1 in. = 100 ft.) were used to capture the planimetric detail of the large industrial sites along the Houston Ship Channel.

While most map revisions in the early stages of the project were performed using conventional (nondigital) mapping techniques, future updates and new mapping will be compiled directly from color aerial photography using a direct digital mapping system such as WILDMAP®. The next revision of the geographic base had been scheduled for 1983, at which time approximately one-third of that base was to have been updated; however, funding restrictions have delayed this revision until 1984 when the revision will most likely be accomplished in conjunction with the new mapping of recently annexed areas.

The complete METROCOM land base consists of some 2,700 map blocks, each covering a land area of approximately 65 hectares (161 acres). Each map block is edgematched to all adjoining and diagonal sheets. All map blocks are subdivided into 10 layers (annotation, roadways, railroads, drainage, sidewalks, fences, driveways, parking lots, buildings, major cultural features such as bridges, dams, power plants, etc., and miscellaneous cultural detail). The entire land base is stored as a continuous map on a single 300-megabyte disk pack. For more technical information on the mapping program, the reader is referred to Hanigan (Hanigan, 1979).

COMPUTERIZED CADASTRAL SYSTEM

The second major subsystem of METROCOM is the real property ownership system. This system consists of a graphic inventory of all land parcels, both exempt and nonexempt, within the territorial limits of the City and the Houston Independent School District. (The boundaries of the two are not coterminous.) These digital files contain all the information needed to graphically represent approximately 554,000 land parcels, their deeded dimensions, and, where appropriate, their acreage.

The graphic segment of the real property ownership system was developed by fitting the best available data for each parcel to the computerized land base on a block-by-block basis rather than by using the sophisticated interactive geometric routines contained within the Synercom Technology's computer system to individually position each parcel. The graphic files of the real property ownership system also include the information needed to draw the city, county, and school district limit lines, subdivision boundaries, historic land survey lines and city, county, state, and federal rights-of-way. The nongraphic attributes stored in the computer for each land parcel are referenced to an apparent centroid which has been assigned to each parcel. These centroids can be graphically portrayed as the parcels are displayed on a CRT or plotted on a hard-copy map.

The nongraphic attribute information was obtained from two disparate sources. Current ownership data and other directly related information were obtained on magnetic tape for bulk loading into the interactive graphic system through a subcontract with a local title company. Property attributes relating to land use, the value of the land, and improvements thereon, as well as the nature and character of the improvements themselves, were obtained from a mass appraisal firm contracted for the reappraisal of all real property within the City and the Houston Independent School District. This information was bulk loaded into the METROCOM system as approved by the City and provided by the mass appraisal firm to the consultant. The reader is referred to Table I for a representative listing of the property characteristics available to the City's department in the METROCOM system.

TABLE I - REPRESENTATIVE PROPERTY CHARACTERISTICS

Land-use classification and neighborhood code
Tax account number
Names of all property owners and their percent interest
Service address of all parcels
Legal descriptions such as subdivision name, block, and lot number
Deeded and calculated acreage
Square footage of improvements
Date and price of last sale
Assessed value for land and improvements
Reference to appraisal review history

TABLE I (Cont'd)

Number and type of rooms (residential)
Style and type of residence
Existence of carports, garages, swimming pools, easements
Type of foundation and exterior walls
Type of heating and cooling system
Roofing material
Commercial structures: frontage, location, and parking availability codes
Year constructed and/or remodelled
Reference to outstanding building permits

COMPUTERIZED FACILITY MANAGEMENT SYSTEM

The third major subsystem of METROCOM is the facilities management system. This system consists of a graphic inventory of all City-owned utilities. The graphic segments of the facility management system were developed from existing engineering plans and plats on file with the Department of Public Works. During the data collection and analysis phases of the project as many as 36 people were involved in inventorying, collating, and reviewing over 40,000 sets of plans and 25,000 land development plats. (No attempt was made to field verify these data.) From these documents, those engineering drawings considered to be the most current and accurate were selected for entry into the facility management system. As each drawing was digitized, the information contained on that drawing was assigned a confidence factor indicating the level of confidence which the data evaluators believed could be placed on the source documents.

As part of the data collection process, the inventory of all plans and plats on file with the Department of Public Works was computerized and geographically indexed to the DIME (Dual Independent Map Encoding) file provided by the City's Planning Department. This index will be maintained as a permanent feature of the METROCOM system.

Included in the facilities management graphic files are sufficient data to prepare 1:1,200 scale overlays of the City's network of roads and bridges, the complete water, storm sewer, and sanitary systems, as well as the distribution network for the City-owned Magnolia Park Gas Company. In addition, the facilities management system contains an assortment of nongraphic attributes related to these utilities, as well as the City's streets and bridges. The latter information was supplied in large measure by the State Department of Highways and Public Transportation for bulk loading into the METROCOM system. The reader is referred to Table II for a representative list of the nongraphic attributes associated with the facilities management system.

TABLE II - REPRESENTATIVE FACILITY CHARACTERISTICS

Bridges:	Deck material, design load, reference number, length, width, number of spans, span material, span type, and vertical clearance.
Roads:	Classification, curb status, number of lanes, agency responsible for maintenance, width, and type of pavement.
Manholes:	Various invert elevations, type construction, size of manhole cover, utility serviced.
Lines:	Flow elevations at each end, type of material, shape, size, status (proposed, existing, abandoned).
Devices:	Number, type, size.
All:	Date digitized, source document number, evaluator's confidence level.

COMPUTERIZED LAND-USE SYSTEM

Although not designed as a land planning system, the METROCOM system can be used as such, as is evidenced by the map shown at Figure 2. This map was prepared by combining the graphic ownership mapping data with the land-use data available in the system (see Table III). These latter data were acquired under separate contract as part of the City's mass reappraisal program and bulk loaded into the system late in 1982.

TABLE III - LAND-USE CODES

Principal Category	Subcategories
Residential, Private	11
Residential, Commercial	4
Commercial	60
Industrial	17
Institutional and Special Purpose Buildings	12
Communications	2

EFFORT

The magnitude of the conversion effort can be sensed from the data given in Table IV. This table summarizes the effort expended by the City's consultant between late 1978 and the end of 1982 in accomplishing the design and development tasks associated with the METROCOM system. The table does not include the time expended on the preliminary studies and the pilot project, nor does it include the effort expended by the subcontract photogrammetric firms and the title company responsible for researching and verifying property ownership records and preparing same for digitization.

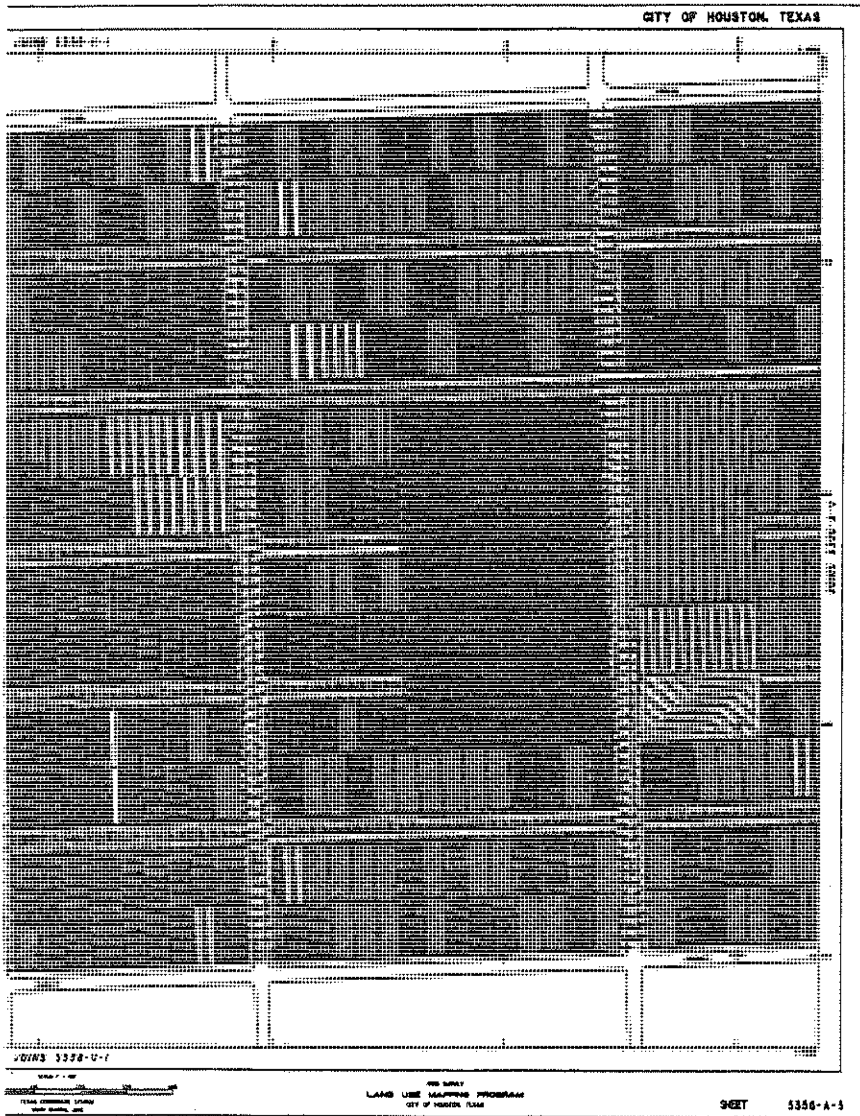
CITY OF HOUSTON, TEXAS
LAND USE MAPPING PROGRAM
SHEET 5356-A-5

Figure 2

TABLE IV - METROCOM EFFORT (Man-Years)

	Organization*	Collection	Conversion	Data Processing**	Quality Control
Land Base	5.5	5.8	31.0	8.0	7.9
Real Property	11.8	14.2	52.1	27.4	3.5
Facilities	14.3	68.5	37.5	19.7	9.0
TOTALS	31.6	88.5	120.6	55.1	20.4

*Organization includes time spent on liaison with the City, project administration and supervision, and personnel recruiting and training.

**Data processing includes system design, programming, computer operations, and plotting.

An analysis of these data shows that the preponderance of the consultant's effort, or 47.1 percent (149 man-years), was devoted to the facility system. The ownership system accounted for 34.5 percent of the effort (109 man-years), while the land base required the other 18.4 percent (58.2 man-years). Organizations or persons contemplating such a project might note that the data collection effort for the facilities was almost twice the conversion effort. Were the hours expended by the various subcontractors on the collection of the real property data available, this same ratio would undoubtedly exist there, too.

LESSONS LEARNED

The over 300 man-years of effort expended by the consultant have taught everyone associated with the project innumerable lessons. Among the more cogent are the following.

- The availability of a staff skilled at organizing and managing a project of this magnitude is as critical, if not more critical, to its success than the availability of a staff skilled in interactive graphics technology.
- A well-designed and carefully executed pilot project is an absolute necessity.
- Heavy and continuous client involvement is a must throughout the project.
- A carefully phased project is to be preferred to a massive turnkey project.
- Innovative, project-oriented software can materially speed and simplify the conversion process; therefore, early emphasis should be given to the size and quality of the system's design and soft-ware development staff.

- Even with a well-executed pilot, the data collection, evaluation, and preparation tasks will exceed even conservative estimates. Nonetheless, these tasks must be thoroughly accomplished if the completed system is to be credible.

- Consistent work flow is critical. Data collection, evaluation, and preparation must stay at least 30 and preferably 45 days ahead of the conversion task.

- The nature of much of the work involved is such that experienced engineering technicians are soon likely to lose interest in the data collection, analysis, and preparation tasks, yet their experience is vital to the timely and economical completion of the project. These tasks might better be done by the client whose data are being processed.

- Early and continuous quality control by technically knowledgeable, well-trained, highly motivated personnel will save more than it will cost.

- The quality control staff must be large enough to ensure rapid turn-around; otherwise, the entire project schedule will quickly deteriorate.

- Subcontractor capabilities should be thoroughly investigated and tested during the pilot project. This is particularly true when the local situation requires the use of subcontractors whose prior knowledge of digital mapping, data processing, and Geobased Information System technology is limited.

SUMMARY

Houston's METROCOM system combines, on a heretofore unknown scale, high-order ground surveys, photogrammetrically developed planimetric maps, and modern techniques of digital cartography and data processing in a common interactive municipal management system.

When fully operational, the interactive nature of METROCOM will allow Houston's municipal planners and managers to explore alternative solutions to the pressing problems caused by the City's rapid expansion over the past decade. METROCOM will also reduce the cost of City operations by replacing currently inaccurate, inconsistent, and duplicative filing systems with a centrally maintained geographically oriented file of accurate and consistent data.

To the author's knowledge, the METROCOM system represents the largest application of computer graphics technology to date within a municipal environment. The work done on the METROCOM system has shown that this technology is capable of improving the manner in which municipalities manage their base, real property, and facility mapping systems. The project has also shown that the implementation of a system such as METROCOM is not a trivial task. The proper application of this technology requires tight management, skilled personnel, a significant expenditure of resources, and a considerable period of time.

While not yet all things to all people, Houston's Metropolitan Common Digital Data Base should serve for years to come as an exemplary model of a comprehensive mapping and municipal data management system.

ACKNOWLEDGEMENTS

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METROPOLITAN TORONTO INTERMUNICIPAL MAPPING

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ABSTRACT

Metropolitan Toronto has established a MAP DATA CENTRE to store and exchange the survey and mapping data generated by it's departments and those of it's six constituent municipalities. The system is to be the foundation for an urban information system. Each department has retained responsibility for it's own mapping. Several have re-evaluated their needs. The Metro Central Mapping Agency's mandate has been redefined to include the MAP DATA CENTRE and input of control networks, index maps at 1:10 000 (3 m), and minimal base maps of street lines, curbs, railways and shorelines at 1:1 000 (0.3 m). The history of reasons for co-operative action is examined.

INTRODUCTION

In 1979 the Municipality of Metropolitan Toronto, in co-operation with the six Local Municipalities (5 cities, 1 Borough), undertook a review of the surveying and mapping systems being used and found them lacking. The problem was not the surveying and mapping, rather it was the management of the resultant data and its integration with related records.

It was found that the trend towards using computer assisted methods for surveying, drafting, mapping and design was inevitable. Further, it was evident that potential benefits would be lost and costs wasted if action was not taken to retain, correlate and distribute the resultant digital data via a common storage and exchange system.

This system is to be operated as part of the MAP DATA CENTRE. It is to serve as the foundation for an urban information system. Individual users will be connected, through their workstations, to the Map Data Centre and later to their own jurisdiction's computer. Eventually the centre should incorporate translation and communication systems to network the various computers together.

The spacial identifiers, co-ordinates and neighbourhood, will be used to help relate the data in the existing function files and data bases. The data is to remain under the control of the responsible functional groups. As needed they will reorganize or replace their functional files to take better advantage of the total system.

MAP DATA CENTRE

The purpose of the common storage and exchange system is to provide, in a flexible structure, an ordered stock of geographical data that can flow freely to departments, utility agencies, the public etc. They can then perform studies and prepare customized maps, plans, designs, surveys, graphs and reports. The MAP DATA CENTRE is therefore a warehouse, central library or data base type of service at the wholesale level.

One of the roles of Metropolitan Toronto is to provide wholesale services to it's constituent, municipalities and the community. For example water is purified by Metro and distributed by pumping stations and large mains to the local municipalities. They in-turn distribute the water to the individual buildings. The reverse flow applies to sewers. Similarly, Metro provides the expressways and arterial roads while the local municipalities provide collector roads and local streets.

The MAP DATA CENTRE was established as a Metro Service in the Central Mapping Agency (CMA), a section of the Management Services Department. It's operating costs are covered out of general revenues as nonrecoverable costs. No charge is made to users for the storage or exchange of the common geographical data, nor for the links to their files. A user may, however, store additional unique data at his own cost. The CMA is about to install the centre's computer system, disk storage devices,system and user support terminals, and a training workstation. In the meantime, data is being stored on other computers.

DATA INPUT

Establishing a central warehouse is not he same as manufacturing the parts. The responsibility for surveying and mapping still rests with the individual departments and utilities. By sharing data, each department can, in the long term, lower it's costs. In the short term, increases in costs are required to satisfy the input standards set by the MAP DATA CENTRE.

Input involves digitally tracing, by one means or another, each map feature. In addition, intelligence must be added by correlating features to their neighbours, attaching graphic and nongraphic attributes and linking the features to other files.

Departments can offset some of the increase in cost by avoiding some of their current costs. If for example, street and curb lines have been input and are maintained by the Roads Departments, then other users can avoid the cost of surveying these features. A more critical examination of project requirements may reveal features previously shown but not required; for example private patios, sidewalks etc.

Costs can also be avoided by eliminating traditional functions that do not contribute to the long term goal. For example, once map features are digitally traced they can be easily plotted, thereby eliminating manual tracing and scribing. Users are therefore encouraged to convert to the digital system and avoid traditional tracing costs.

It is to a department's advantage to minimize the transition time, to share data, to be selective concerning the data they elect to input and maintain and to avoid unnecessary work. As there are both cost increases and potential to avoid costs, it was agreed that each department would continue to pay for it's own surveying and mapping.

Under the co-operative system established, each department and utility incurs costs on a voluntary pay-as-you-go basis and only utilize the MAP DATA CENTRE when they feel it is to their benefit. As a result, each department is re-evaluating and re-organizing it's mapping programs and identifying the map data they will input and maintain.

REVISED MAPPING PROGRAMS

Metropolitan Toronto has re-evaluated the CMA's control surveying and mapping program. As a result, the agency's mandate has been updated.

As noted, the storage and exchange system and related standards, quality assurance, data base administration, user training, plus system and user's support services, are part of the Agency's DATA CENTRE.

CMA is to continue to set control surveying and photogrammetric mapping standards, to provide quality assurance over contracts and to physically maintain the control networks. In addition, data regarding the bench marks (6,000 +), control stations (14,000 +), aerial photos and photo control points are to be stored in the MAP DATA CENTRE.

The Agency's index mapping program was revised. The traditional index maps are being replaced by two series with overlays. A minimal map, at a representative scale of 1:100 000 (30 m), for displays smaller than 1:25 000 and a topographic map, at a representative scale of 1:10 000 (3 m), for displays from 1:2 500 to 1:20 000. The 1:10 000 series will include Statistic Canada street segment and block face data, Metro Planning's polygons and links to a main frame geographical referencing system. Standard maps will be plotted and microfilmed at 1:10 000 and 1:100 000 for over the counter distribution.

The 20% Metropolitan contribution to the updating (re-mapping) of the 1:500 scale base maps, a joint program with the local municipalities, is to be phased out. Instead CMA will input a minimal base map, at a representative scale of 1:500 (0.3 m) for displays larger than 1:2 000. This series will include curb lines, railways, shorelines etc. and the base for a numerical cadastre of all road and street lines. Maintenance for some of these features (i.e. curbs), may be assumed by others. Standard 1:1 000 maps will be plotted for over the counter distribution.

Contracts have been issued to private mapping firms for 1/3 of the index maps and 1/10 the 1:500 minimal base maps. The street line locations are being calculated with the assistance of private surveying firms. The Central Mapping Agency has been renting both a Wild Leitz Synercom and an Intergraph workstation and is currently preparing to install it's own stations.

The Metropolitan Toronto Public Utilities Co-ordinating Committee (MTPUCC), is responsible for the large scale composite underground utility map series. They have re-evaluated their program and are testing alternate proposals.

Their program is funded by contributions by the various utility agencies. The project has been traditionally under-funded and only a limited area has been mapped. However, the MTPUCC has served as a catalyst for finding ways to avoid maintaining a special series of composite maps. In the short term, with it's limited funds, MTPUCC Has engaged CMA to input utility data and plot 1:500 composite maps. Eventually each utility agency is to use it's own workstations to input and maintain the location of it's own plant. In most cases, satellite systems will be installed for facilities management. To implement their systems some utilities propose to input their network, and the related nongraphic data, as an overlay to the 1:10 000 (3 m) series. As the 1:500 (0.3 m) data is available, it will be input, linked to the nongraphic data and used to upgrade or replace the 1:10 000 overlay.

Some local municipalities have also reviewed their mapping programs. The City of Toronto (population 678,000) is in the process of installing a turnkey computer graphics system. It is to be used for mapping, engineering, architectural and business graphics. Toronto is starting with 2 workstations and the expected demand is 20 stations by 1988. This system will be linked to their mainframe AMDAHL computer, which is also used by Metro. It will also be connected, as a satellite, to the MAP DATA CENTRE.

The City of North York (550,000) has already precalculated the subdivision and zoning limits for one third of the city. The City of Scarborough (445,000) has converted it's 1:500 aerial mapping program to digital and is considering installing a workstation for input of it's sewer network. The City of Etobicoke (293,000) is considering installing a workstation next year for maintaining a streets inventory and preparing contract drawings. Senior representatives, usually Commissioners of Works, of the City of York and the Borough of East York, along with their counterparts, from the other local municipalities and Metropolitan Toronto form the intermunicipal Mapping Liasion Committee. They co-ordinate mapping activities through a technical committee on computerized mapping.

HISTORY OF CO-OPERATION

Metropolitan Toronto was established in 1954, as a federation of the local municipalities to provide them with regional services. The Council is composed of local council members. Local independence is reduced each time Metro is given more authority. Intermunicipal controls surveying, mapping and geographical systems were not designated as Metro responsibilities by the Providence. Rather, they came about through co-operative action and recommendations of the municipal engineers.

In 1957, the local engineers needed a common datum to integrate their separate sewer systems. They asked the Metro surveying staff to establish the basic network and agreed to convert to and complete the bench mark network. By 1960 a start had been made on a common horizontal control network, and in 1965 on the large scale base mapping series, with derived maps at smaller scales. Computer programs were developed for network adjustment, geometric calculating, road design, digitizing, plotting and data management.

In 1968 a report was submitted to Metro Council, by the Public Utilities Co-ordinating Committee, suggesting the establishment of a Central Mapping office and a start on computerized mapping. Council formed an intermunicipal committee of surveyors and engineers to review these suggestions. This was followed by a staff committee. In 1974 an intermunicipal Central Mapping Advisory Committee was formed. The Central Mapping Agency, starting in 1975, was to provide common control surveying and photogrammetric mapping standards, quality control of contracts, maintain the control network, and provide map storage and distribution services. In addition, the agency prepared index maps, photomaps (1:5 000) and administered Metro's 20% share towards the intermunicipal large scale mapping program. These central services were all provided at Metro's cost.

In 1979 the Advisory Committee recommended that it's name and role be changed to a Liasion Committee, that the Agency be moved from the Roads and Traffic Department to a Management Service Department, and authority be granted to proceed with the problem definition phase of a computerized mapping and information system. This was followed in 1981 with authority to proceed to the mapping design and implementation phase. The computerized mapping program is to be operational in 1984. Some day, in the future, the urban information phase will follow.

This is a long story but it serves to illustrate that it is the human & administrative areas that are of the most concern when establishing an intermunicipal program. There is a basic inertia in all systems, a resistance to change and a concern over losing local automony and control.

Co-operation started because there was a need for a common bench mark system. It was expanded when photogrammetric large scale base mapping started. It was consolidated to allow aerial mapping contracts to be quality controlled by a central group. It is being expanded because of the need to share each others data during these times of restraint. There must be an external force to change inertia.

Time is needed for ideas to evolve and gain acceptance. It is now necessary to view data (information) as a resource to be managed, to include geographical data as a basic resource and to accept computerized mapping methods and equipment. More time is required before intermunicipal sharing of digital data will be realized and accepted. It will be sometime after that before an intermunicipal urban information system is accepted,

MAP PRODUCTION

The implementation phase of the project has started. The initial data levels have been defined. They are compatible with the mapping systems being leased and those used by our mapping consultants. One system required the symbols and lines to be on separate levels and the other required the use of a separate level for each feature type that may be displayed separately.

A table of feature codes have been prepared for topographic mapping. They will be cross referenced to the National Standards for the classification of Topographic Features. The codes identify the feature type, non-graphic attributes, the data level and default non-graphic attributes. Basic feature codes are used by those digitizing the data directly into a turn-key system. (e.g. 410, road, curbed). Detailed codes are provided for those preprocessing the data before inputting it into a turn-key systen. (e.g. 412-road, paved, curved and 413-road, paved, straight). During preprocessing buildings can be squared, building extensions can be joined to the main building, steps calculated, driveways joined to road curbs etc. This latter method is used by some mapping consultants for stereoplotting and will be used by our staff for digitizing table.

A unique number is assigned to each building, manhole, hydrant, etc. as they are input. The first digitized point per feature is used as a text mode. A plot can then be prepared showing the feature and its number. Attribute data will then be bulk loaded by relating the unique number to existing records (e.g. - address and tax data).

The initial contracts for 1:500 topographic mapping required the mapping contractor to provide all the detail he had supplied when preparing traditional maps. Subsequent contracts have minimized the detail thus reducing the cost for input and maintenance.

The street lines are coordinated by performing calculations, on the main frame computer, using a combination of dimensions off old subdivision plans and the co-ordinates off survey plans of lot corners. Each street and city block on a subdivision plan is assigned a number. The distances and bearings (with appropriate minus signs) are coded, in a clockwise direction, around each block. The lot and street numbers to the right and left are also coded. The loop is closed to detect any coding of plan errors.

Ties across the streets are added, along with the coordinates of the corners. The plan is adjusted. Where necessary, several plans are adjusted simultaneously. All the input data is retained. At a later data more accurate coordinates or lot dimensions may be substituted and the plan readjusted.

Co-ordinates are then calculated for text modes for the street names, lot numbers, plan distances and the calculated dimensions. The data is then transferred to the mapping system. The text node for the lot number will be used as a paracentroid for the lot's attribute data. As all the mapping systems, in use in Metro, support the Intergraph Standard Interchange Formate (ISIF) it is being used for data exchange.

The geographical referencing system (GRS) is being developed to allow users to cross reference their files by means of commonly available identifiers (e.g. street name, address, tax number). The map system uses coordinates but these are transparent to the user. The system is being developed by reconciling data in the Statistics Canada AMF files, the Regional Planning files, Assessment files, and the map data. Initially the coordinates for each parcel will be the block face coordinate. Eventually the file will also contain the paracentroid for each parcel. The lots, as subdivided, are often further divided and therefore the lot and parcel paracentroids may not be synonymous.

The GRS data is being stored in tables linked by pointers. For example, the street segment table contains:

- pointer to node record of beginning node,
- pointer to node record of ending node,
- pointer to last recorded segment record which also involves the beginning node,
- pointer to last recorded segment record which also involves the ending node, and
- pointer to master street name record.

Each node is threaded to all segments in which it is involved. Each street segment is connected to it's nodes and to other segments involving the same nodes. The block faces are also connected to the nodes. Tables, are also being prepared listing the last recorded nodes and blockfaces in each 1000 m X 1000 m grid cell. The polygon records will also be defined by reference to its nodes. In addition to maintaining the GRS files on the mainframe, the data will also be stored in the map system. As new streets are added the map data base will be used to update the GRS files.

THE PROTOTYPE LAND INFORMATION SYSTEM FOR THE CADASTRAL PILOT PROJECT IN COLOMBIA

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ABSTRACT

A prototype land information system is being developed for Colombia as part of a pilot project which is carried out jointly by the National Research Council of Canada (NRCC) and the Instituto Geografico "Agustin Codazzi" (IGAC) of Colombia. The pilot study is performed for a 2 000km^2 test area containing topographical features, land use patterns and soil types which are representative of the entire country. The system components, the on-line photogrammetric information acquisition procedures, the field identification and data collecting techniques, as well as the data bank functions are discussed in the paper. The results of the pilot project will be used to define the specifications for a country-wide cadastral land information system.

INTRODUCTION

A cadastre when established as an integrated multipurpose land information system is a fundamental tool for the diagnosis of economic and social conditions in a region or a country and an indispensible information base for the preparation of plans and programs for specific development projects. The importance of adequate and reliable information, offered by a well-organized cadastral system becomes more evident with the increasing need for very careful monitoring and programming of the economic development of a country.

The developments in computer technology related to the management of information have changed the traditional concepts about the storage, retrieval and manipulation of information in cadastre. The exploitation of powerful functions provided by this technology for the establishment and maintenance of a collection of data that can be shared among a number of applications is steadily increasing the potential for more efficient management of information in integrated, multipurpose cadastral and land information systems. However, the characteristics of these information systems do not depend solely on the organization and capabilities of the data management systems. The quality of an information system depends to a high degree on the quality of the stored information itself; that is, on the accuracy, reliability, integrity and completeness of the data. These characteristics of the overall quality of the metric and semantic information depend on the techniques and processes used for the acquisition of data. In cadastral information systems, organized as geocoded systems, the files of fundamental concern are those containing the metric information. They are the geometric framework and the carriers of all the semantic information. The acquisition of all the metric information and some of the semantic information for the establishment of cadastral systems is best accomplished by photogrammetric methods and techniques. The choice of processes and the choice of instruments for the performance of these processes will depend mainly on the criteria for accuracy, integrity, completeness and reliability of the information, and on the factors related to the economical constraints, time constraints, and constraints imposed by the human resources. The contemporary computational photogrammetric techniques and the associated analytical, hybrid and automated instruments offer a selection of versatile and flexible means for the acquisition of information required for the establishment and maintenance of cadastral information systems. The combination of advanced photogrammetric methods and information management methods represents a basis for the development of powerful and efficient integrated multipurpose cadastral information systems (Jaksic, 1981).

The "Pilot Project Cadastre Latin America" is a consequence of the interest of Latin American countries and especially Colombia in the development of these information systems and in the upgrading of existing cadastral systems of limited capability which were originally established mainly for taxation purposes.

The general objective of the pilot project is the establishment, in a pilot zone, of a prototype cadastral system based on the implementation of modern concepts, methods and technology, which will allow for testing and analysis of procedures for acquisition, processing, presentation and exploitation of information and ultimately for the definition of detailed specifications for the country-wide implementation of the new Colombian cadastral system. In the frame of Latin American cooperation the results of the pilot project will be made available to other Latin American countries embarking on the establishment of similar cadastral systems (Gonzalez-Fletcher, 1980).

The project is conducted jointly by the Geographical Institute of Colombia (Instituto Geografico "Agustin Codazzi") and the National Research Council of Canada. It is financially supported by the Colombian and Canadian governments. About two thirds of the project budget is supplied by the Colombian National Department of Planning and the Colombian Ministry of Finance and Public Credit and one third by the Canadian International Development Agency.

The project evolved in two phases. The first phase, completed in the summer of 1983, has been concerned with:

- selection and establishment of the pilot zone (test area) for the project,
- design and the execution of flight plans,
- densification of ground control by on-line analytical triangulation and block adjustment,
- selection of procedures and preparation of instructions for the field interpretation,
- collection of semantic information related to the chosen set of attributes (e.g. land use, property owners),
- collection of information on soil classes,
- definition of the set of final cadastral and cartographic documents and specification of techniques for their generation,
- establishment of a prototype system for photogrammetric compilation of information,
- specifications for the procedures for information management,
- definition and establishment of the hardware and software for the information management component of the prototype system.

The second phase, presently in course, is concerned with the overall consolidation, analysis, enhancement and optimization of the established cadastral system, comprising the following activities:

- analysis and enhancement of procedures,
- detailed study and improvements of field and office information compilation techniques in areas of various economical and social significance (e.g. rural and urban areas),
- analysis and enhancement of techniques for generation of necessary documents,
- analysis of information management components of the system (e.g. software modules for maintenance and revision of records and for generation of documents),
- quality analysis and the specification of quality control procedures,
- definition of specifications for the country-wide implementation of the cadastral information system.

The primary designed objective persued in both phases of the pilot project is the development of a generalized information system which can grow both in size and capability without major restructuring. A modular approach has been chosen for the fundamental hardware and software structure of the system (including the photogrammetric hardware and software components). Consequently any of the system components can readily be replaced by an either simpler or more sophisticated version and new options can be added both in hardware and software with minimal disruption to the system. This allows for an orderly growth of the system and enables the use of the system at different levels of complexity.

SYSTEM COMPONENTS

The equipment for data acquisition, data processing and display of information, which was installed at IGAC as part of the pilot project, comprises the following:

Analytical Plotter

The analytical plotter (US-2) is intended primarily to provide the control coordinates for the production of stereo-orthophotos and digital elevation models, and the digitizing and mapping of cadastral information. The dedicated computer (PDP 11/34) of the instrument will, during the second phase of the pilot project, be connected to the data bank computer to allow the acquisition of digital data for areas such as cities and towns, requiring higher accuracy boundary information. The data acquisition will be carried out under the control of the data collection software, developed as part of the pilot project.

Orthophoto Production Equipment

A Gestalt Photo Mapper II system is used for the production of orthophotos, stereomates and digital elevation models. The system, which is based on automatic image correlation, consists of a scanning system, an image correlator and two printing units for simultaneous recording of the orthophoto and stereomate images. The height data used for the generation of the stereo-orthophotos are recorded as a regular grid of elevation data (grid interval 182 μm at the scale of the original photo). For a typical stereo overlap the system provides therefore approximately 600 000 height values which are used for the plotting of contourlines on a computer-controlled plotting table.

Stereocompilers

Four Stereocompilers are available to collect the digital information from stereo-orthophotos. Easting and Northing coordinates and Heights are recorded for the cadastral boundaries and the land use pattern outlines. Beside their use for definition of land units in the data bank they are also used for cartographic presentation, area calculation, and calculation of the maximum and the minimum heights and terrain slopes within a parcel, which are an important source of information in a land information system. In addition to providing information on elevation, stereo-orthophotos allow for a precise definition of the boundary information by stereoscopic interpretation.

The Stereocompiler offers the possibility of plotting a manuscript on a transparent overlay on the orthophoto, during the digitizing process (van Wijk, 1982). The operator observes the plotted lines superimposed over the stereoscopic model, which provide him with an up-to-date record of the digitized information and reduces the chance of errors in the digitized data due to double digitizing and omissions. The transparent overlays are also used to indicate the digitizing windows as part of the preparatory stages of the data collection process.

The Stereocompilers are on-line with the data bank computer and each one is equipped with an alphanumeric terminal which provides a communication link between the operator and the computer and allows the data acquisition to be performed under computer control.

Digitizing Table

A Gentian Hi-state digitizing table with a 90 cm x 120 cm digitizing area is used for digitizing soil type boundaries from field interpretated orthophotos and may, in the future, be used for planimetric updates and revisions. The table is connected to the data bank computer so that all the digitizing operations can be performed in the on-line mode of operation.

Data Bank Computer

A PDP 11/44 minicomputer with a RSX-11M operating system is used for the data bank system of the pilot project test area. The central processing unit has a memory capacity of 1 Mbyte, is equipped with two 10 Mbyte disks and a dual drive magnetic tape unit. Peripherals also include a VT 100 terminal, a DECwriter, a Tektronix interactive graphical terminal for editing and a small XY plotter for graphical presentation of parcel information.

The computer has a sixteen channel multiplexer. Two channels are used for each of the four Stereocompiler digitizing stations (one for the computer alphanumeric terminal and one for the digitizing system), two for the XY digitizing table, and one for each of the four above mentioned peripherals. The remaining channels are available to include the analytical plotter in the on-line data acquisition system.

Plotting Table

A Data Tech plotting table controlled by a Nova 3 minicomputer is used for the plotting of contourlines from the GPM generated digital elevation models and cadastral information obtained from the data bank system. The plotting is done in an off-line mode of operation using data stored on magnetic tape.

Additional Equipment

Additional instruments provided to IGAC for the pilot project include a number of field stereoscopes to be used in the field for the identification of parcel boundaries on the stereo-orthophotos.

Also five Minicompilers are available for interpretation and simplified plotting based on stereo-orthophotos. These instruments consist of a stereoscopic observation system and are used in conjunction with a conventional light table. They can accommodate stereo-orthophotos at map scale and are intended primarily for interpretation and graphical recording of soil type boundaries.

DATA ACQUISITION

The photogrammetric data acquisition process is based on photographs taken at various scales which are selected depending on the density of information to be collected and the accuracy required. Modern wide-angle cameras are used for the aerial photography and photo scales vary between 1:50 000 and 1:6 000. The smaller scales (up to 1:10 000) are used for the acquisition of data for the rural areas. For these areas the scales of line and orthophoto maps, produced as part of the pilot project, range from 1:25 000 to 1:2 000. Urban areas are photographed at scales 1:20 000 to 1:6 000, depending on the size of the town. Map products for these areas may be at scales of 1:5 000 to 1:1 000 (IGAC, 1980).

The photogrammetric data acquisition process consists of different stages, which are briefly described as follows:

Aerial Triangulation

The control points needed for producing the stereo-orthophotos, the digital elevation models, and for the digitizing and plotting operations are marked on the photographs and determined by on-line aerial triangulation developed at NRCC for the analytical plotter. The subsequent block adjustment is also based on software developed at the NRCC. The orientation parameters, derived from this operation can also be used directly on the Gestalt Photo Mapper for the relative and absolute orientation process. In this case the ground control points, derived from the aerial triangulation, are used to verify the quality of the orientation procedure.

Production of Stereo-Orthophotos and Digital Elevation Models

The stereo-orthophotos and digital elevation models are produced by automatic image correlation on the Gestalt Photo Mapper. The orthophoto and the stereomate are recorded simultaneously on the two printing stages. X-parallaxes introduced in the stereomate permit three-dimensional interpretation and the derivation of terrain heights from the stereo-orthophotos. Providing that the orthophoto and the stereomate are produced from the two different photographs of the stereo overlap, small details such as buildings and trees can be interpreted and measured three-dimensionally.

The X-parallaxes in the stereomate are generally generated according to the base-to-height ratio of the stereo-overlap. For areas of high relief, which are common in Colombia, a smaller X-parallax to height ratio is often used in generating the stereomate image. This results in smaller image displacements in the stereomate and reduces the image quality problems occasionally encountered in areas with large elevation differences.

The orthophotos are enlarged to the required map scale (2 to 5 times magnification) and combined into orthophoto mosaics according to the cadastral map sheet system. This allows for convenient use of the orthophotos in the cadastral regional offices and offers the possibility of a systematic sheet by sheet revision process.

The accuracy of the XYZ coordinates derived from the stereo-orthophotos and the elevation data of the digital elevation model, generated by automatic image correlation in the GPM system, was tested in various experiments. A standard coordinate error of 40 µm at the scale of the original photographs is considered to be typical for the system (van Wijk, 1979).

Field Identification

Enlarged orthophotos and stereomates are used for identification of the cadastral information in the field. Special cadastral survey teams mark the parcel and field boundaries on the orthophotos based on information obtained from the cadastral recorda and provided by the property owners. In addition information on cultivation types, buildings, road, classifications, drainage patterns etc. is indicated.

A copy of the orthophoto mosaic with the interpreted information, is kept in the cadastral regional office aa an up-to-date cadastral record. One copy is returned to IGAC in Bogota to serve as a guide for the digitizing operation.

In addition to the above mentioned field interpretation data, information on parcel name or address, ownership, owner identification, cadastral value, date of change in ownership, etc. is collected for each parcel on special forms. The cadastral identification number is used to correlate this information with the field interpretation data on the orthophotos.

Soil types are identified by specialized soil survey teams, involving field inspection as well as laboratory analysis. The soil boundaries are marked on the orthophotos for subsequent digitizing. The stereo interpretation of the terrain surface, offered by the stereo-orthophotos, has been recognized to contribute to the accuracy of the interpreted soil type boundaries.

The orthophotos offer certain advantages over regular aerial photos in field interpretation because they represent the terrain in orthogonal projection. The orthophoto scale is uniform and straight boundary lines appear straight in the orthophoto image despite terrain elevation differences. This will allow to take advantage of simple tape measurements to define boundary points which cannot be directly interpreted in the photographs.

Digitizing

The data acquisition is based on individual parcels and is carried out according to the field interpretated orthophotos. All data, pertaining to a certain parcel, such as its boundaries, cultivation outlines and buildings, are digitized before proceeding with the following parcel. Strings of coordinates form closed polygons, made up of different segments (Linders, 1983). Segments are parts of boundary lines located between points common with adjacent parcels or land use units. For parcels extending beyond the window which delimits the area to be digitized in a stereo model, polygons are closed with a "virtual" segment along the window.

The digitizing is carried out "on line" under computer control, so that the measured model coordinates can be transformed into the ground control coordinate system in real-time and are used as such during the entire data acquisition process. The on-line procedure also offers the possibility of using the same string of coordinate values in segments shared by adjacent parcels or fields. The operator defines such a segment as "old" and identifies it by pointing at its end points and one intermediate one. The original segment then becomes part of the polygon. The segment file in the computer memory consists consequently of a unique set of segments which can be used repeatedly to form different polygons. A special code is used before the digitizing of a segment is started to indicate whether the segment is new, old, virtual or internal, the last expression being used for segments common to two different cultivation types within a parcel. At the end of each segment a code is used to indicate whether the last segment point is a new one or whether it has already been digitized as part of a different parcel or field. These features, combined with the condition that all data make up closed polygons, ensure that each digitized point has only one set of coordinates so that double points and lines are avoided in the graphical representation of the digitized data. Each boundary point is defined in the data bank by a single set of coordinates, even when such a point occurs in different parcels or cultivation fields.

The four Stereocompilers are used for the digitizing of the cadastral information from stereo-orthophoto transparencies for rural areas and possibly the smaller villages. The analytical plotter will be connected to the data bank computer to allow the digitization of the cadastral information in built-up areas such as cities and towns.

As mentioned before, the Stereocompiler offers the possibility of producing a graphical overlay of the digitized information on the orthophoto. The operator observes this graphical record superimposed over the stereo model so that it provides an up-to-date record of the digitizing process. A previously digitized segment will, for example, be recognized and can consequently be identified as "old". Windows are marked as a preparatory step on the overlays to assure that the required overlap is obtained for the data digitized in adjacent models.

The graphical record observed by the operator during the digitizing process reduces the chances of errors, omissions and double digitizing. Also, the data acquisition software provides real-time verification on polygon closure. The digitized data are therefore of good quality and there is no need to provide the operator with other editing facilities.

The final editing is carried out as an off-line operation, performed only after the different models have been joined. Special software has been developed for the purpose and a Tektronix interactive terminal is used. This terminal also enables monitoring and checking the progress and the quality of the digitizing operation. A disadvantage of the off-line editing is that, in the case of serious omissions or errors, the stereo-orthophotos may have to be set up again in the Stereocompilers to complete, or correct the data. The orientation process on the Stereocompiler, however, is simple, consisting merely of aligning the orthophoto and the stereomate on the image carriers and remeasuring the ground control image coordinates. This normally can be done in about five minutes.

The soil type boundaries are digitized in a separate operation using the XY digitizing table. In order to incorporate the soil information into the parcel structure of the data bank, a polygon overlay procedure will be required. The necessary software for this procedure will be incorporated during the second phase of the pilot project.

Data Files And Automatic Plotting

The cadastral attribute information on parcel description, ownership, cadastral value, etc... are entered on magnetic tape, independently of the digitizing process. The parcel identification number, entered together with the attribute and digital information, serves to correlate both types of data. A possibility is provided to update, delete, correct or add to the cadastral information and the corresponding B-tree structure.

All data corresponding to one cadastral unit - usually a municipality, is combined into one file and stored on magnetic tape. A computer-controlled plotting table is used to plot the digitized data. The plotted information, together with the contour lines, derived from the GPM digital elevation models, and the soil type boundaries are used for cartographic processing and representation in the form of conventional cadastral line maps or orthophoto maps.

DATA BANK FUNCTIONS

The cadastral attributes and digital information on parcels, land use and soil types are stored in records which are part of indexed up-to-date files. In the pilot project this information is collected for approximately 20 000 parcels. The records for each parcel contain information such as the cadastral reference number, parcel name or address, name and identification number of the first owner, area, value, cultivation types, types of buildings, dates of changes in ownership, and names of additional owners. The files are a multi-level and multi-key type, with information retrieval based on the B-tree structure. The three keys, selected for data retrieval, are:

- the parcel's cadastral reference number,
- the first owner's name,
- the first owner's identification number.

At specific times, possibly at the beginning of each calendar year or quarter, the cadastral information in the up-to-date files is preserved for future reference in another file, called snapshot file, with the intention to preserve historical information. Not necessarily all the information contained in the up-to-date files will be copied into the snapshot files.

In addition to the up-to-date and snapshot files a transaction file is kept in which all changes concerning the parcel and ownership are entered. A new transaction file will be started each time the snapshot file is produced so that the snapshot file and the transaction file together can provide up-to-date information between the dates of the last snapshot file and the following one.

Information from the data bank system is produced by a report generator. Listings of cadastral information can be printed for individual parcels.

Also all parcel numbers, names of first owners and part owners can be listed. Together with the information on individual parcels a graphical certificate can be generated showing all digitized parcel data in the ground coordinate reference system. The certificate is bordered by a window around the parcel. Also plotted are the cadastral and cultivation field boundaries for neighbouring parcels within the window. The certificate lists the parcel area and the areas for the different fields, together with the codes and types of cultivations. Also included are the minimum and maximum heights and terrain slopes, calculated from the digitized XYZ coordinates.

A set of commands will be incorporated to locate and list parcels with specific characteristics such as crops, irrigation, construction, area and value. These commands form a part of the query language package, that will include function libraries dealing with polygon overlays, to be incorporated in a later phase of the pilot project.

CONCLUDING REMARKS

The data collection for the pilot project area is presently in full process and information on accuracy, editing requirements and production rates will be collected. The experience obtained so far has demonstrated the suitability and versatility of the stereo-orthophoto technique for the acquisition of cadastral information. This is particularly true for an organization such as IGAC which has regional offices in twenty cadastral districts across the country. The simplicity of the technique and the instrumentation, such as the Stereocompiler, offers the possibility to carry out the digitizing of the information at the regional offices without the need for highly trained photogrammetric technicians. The collection of the digital data at the regional level would be a logical and desirable solution for processing the field interpretation data, which, presently, are already being collected by the regional offices. The aerial triangulation and the production of stereo-orthophotos and digital elevation models would remain to be carried out centrally at the main office.

The configuration of the data bank information acquisition and processing system installed as part of the pilot project is capable of handling the data for one of the cadastral districts. Based on the results of the pilot project similar systems may be installed in the regional offices so that the information will be directly available to the various regions which, for a cadastral information system, is an important asset.

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FROM PENCILS THROUGH PULSES TO MAPS
INTEGRATING A DIGITAL MAPPING SYSTEM INTO A MULTI-DISCIPLINE ORGANIZATION

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ABSTRACT

Choosing and integrating a computer based mapping system into an organization, especially a multi-disciplined organization such as McElhanney, is a formidable challenge. Each of the three main disciplines of surveying, engineering and mapping have specialized requirements differing from other disciplines as well as a multitude of task oriented requirements within the discipline. The overall requirements of each discipline is examined, some task oriented requirements within the disciplines are illustrated, a brief description of the system hardware/software is provided. The method of integration of the system into the company and into each discipline of the company is examined, specialized applications to accomplish specific tasks are illustrated. Special emphasis is placed on the particular methodology used for the collection, editing and output of digital photogrammetric data in a previously conventional mapping organization dealing with a wide range of client disciplines and their divers requirements. Outside forces over which the company has no influence but which directly affect the operations of the company are examined and observations made. Some conclusions are drawn and a few thoughts and ideas formulated and offered for comment.

CARTOGRAPHIC POTENTIAL OF THE BUREAU OF LAND MANAGEMENT GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

The use of geographic information systems in the Bureau of Land Management has increased significantly over the past five years. Major requirements for inventory and planning decisions for managing resources on public lands in short time periods has caused managers and resource specialists to re-evaluate analysis techniques, resulting in a greater reliance on automated systems.

Applications as determined by Bureau project needs have emphasized statistical analysis output from GIS's rather than graphic output. Although the Bureau's GIS has graphic output capabilities, its use is limited to display graphics and compilation manuscripts for thematic maps. While thematic mapping is a major portion of the Bureau of Land Management Mapping Program, there is also a large requirement for a standard specification map series called the Surface and Surface/ Minerals Management Intermediate Scale Map Series. This series portrays land and mineral ownership data on a scale of 1:100,000 on the USGS topographic base. These maps must meet National Map Accuracy Standards. Currently all production phases of these maps are produced using traditional color separation techniques in a manual mode.

Since the requirements of most resource projects handled by the Bureau's GIS dictate that land and/or mineral ownership information be collected for most project data bases, the beginnings of a cartographic data base have developed. The purpose of this paper is to analyze the needs of the Bureau in terms of a cartographic data base, determine the suitability of the Bureau's GIS software as a potential automated cartographic system, and finally to make recommendations concerning needed enhancements to the system. The topics covered will include:

I. Description of BLM's Geographic Information System
   A. Data Entry System (ADS - Automated Digitizing System)
   B. Data Analysis (MOSS - Map Overlay Statistical System)
   C. Graphic Output (COS - Cartographic Output System)
   D. Hardware

II. Bureau GIS Applications
   A. Analytical Output
      1. Resource inventories
      2. Resource planning
   B. Graphic Output
      1. Compilation manuscripts for thematic maps
      2. Black and White thematic maps
      3. Color thematic maps

III. Suitability of ADS/MOSS as a Cartographic Data Base
   A. Point Coordinate Format
   B. Projection Handling
   C. Accuracy

IV. The Bureau's Mapping Program Requirements
   A. Thematic Mapping
   B. Intermediate Scale Mapping Program
      1. Compilation of ownership data layer
      2. National Map Accuracy Standards
      3. Traditional color separation techniques

V. Required Enhancements to Software and Hardware Environment
   A. Geographic Integrity
   B. Interactive Compilation
   C. Plotting Capability

SIDEC - UNE BANQUE DE DONNÉES ÉCOLOGIQUES GÉOCODÉES FONCTIONNELLE À HYDRO-QUÉBEC

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RÉSUMÉ

SIDEC (Système intégré des données écologiques de la Côte-Nord) est une banque géocodée d'information qui a été mise sur pied en 1979 pour répondre aux besoins créés par l'inventaire écologique de la Côte-Nord. Cet inventaire a été réalisé selon les normes de l'inventaire des terres du Canada et a couvert un territoire d'une superficie de 200 000 kilomètres carrés. Les données générées sont les contours de quelque 55 000 cellules, réparties sur soixante-cinq (65) feuillets cartographiques à l'échelle du 1:125 000. Celles-ci constituent les données de base, soit les données de niveau I. Les données du deuxième niveau sont fournies par la suite et constituent essentiellement des regroupements de cellules; ce sont les régions et districts écologiques. Les informations de troisième niveau sont générées par le système lui-même et constituent sa principale raison d'être. Elles se résument par le calcul d'une classe attribuée à chaque cellule. Celle-ci est calculée par le moyen d'une clé d'interprétation utilisant les données stockées et conçue par le spécialiste intéressé (ingénieur, biologiste).

Le caractère manuscrit des informations écologiques composées de 13 500 fiches descriptives de systèmes écologiques comportant chacun quelque 35 descripteurs alphanumériques de format variable a posé certains problèmes. L'entrée de données en format libre a été effectuée directement à partir des fiches descriptives de système et un programme de validation suivant la méthode de l'analyse syntactique a été développé.

La digitalisation des coordonnées spatiales des systèmes écologiques a été accomplie en utilisant la méthode de gravure de contour et de lecture optique.

Une fois l'entrée complétée, une phase de compression et de ré-alignement des données spatiales ainsi que de re-codification des données écologiques a été entreprise.

Des programmes de traçage et de remplissage de surfaces ont été développés pour produire des cartes interprétées reproductibles. Le produit final est obtenu par procédé photo-mécanique en utilisant les cartes tracées par le système SIDEC directement pour le tirage des négatifs et l'impression couleur sur acétate.

L'informatisation de l'inventaire écologique de la Côte-Nord a permis une réduction des coûts de production de cartes thématiques de l'ordre de 15 à 20 fois en plus d'augmenter considérablement l'accès aux données de cet inventaire.

ABSTRACT

SIDEC (système intégré des données écologiques de la Côte-Nord) is a geocoded information system created in 1979 as a processor of the St-Lawrence North Shore ecological survey. The survey was undertaken and completed in concordance with the Canadian Lands classification guidelines and covered a 200 000 square kilometer area. Generated information consisted of the spatial coordinates and ecological description of some 55 000 cells dispersed within 65 maps at a scale of 1:125 000. These informations are the basis of SIDEC and are defined as the first level of information. The second level of information is the grouping of these cells within ecological regions and districts. SIDEC generates the third level of information which is essentially a capability class attributed to each cell; this is done by means of an interpretation key developed by the interested specialist (engineer, biologist) and based on the other two levels of information.

Certain problems arose during the treatment of the handwritten ecological informations comprised of some 13 500 field data sheets each containing 35 alpha-numeric descriptors in variable format. Free format input was used and a validation program based on syntactical analysis was developed.

The cells spatial coordinates were digitalized using a scribing and optical scanning method, and once completed, a phase of data compression and re-alignement of the spatial coordinates as well as a recodification of the ecological data was undertaken.

Mapping and area-fill programs were developed for the production of interpreted and reproductible maps. The final product is obtained by photo-mecanical process using the maps generated by SIDEC for direct production of negatives and color acetates.

The development and operation of SIDEC has achieved a reduction in production costs of thematic maps to the order of 15 to 20 times and has considerably increased ease of access to the St-Lawrence North Shore Survey.

INTRODUCTION

SIDEC (système intégré des données écologiques de la Côte-Nord) est une banque géocodée d'information qui a été mise sur pied en 1979 pour répondre aux besoins créés par l'inventaire écologique de la Côte-Nord.

En effet, l'expérience acquise lors de l'utilisation des données de l'inventaire écologique de la Baie-James avait démontré la complexité et les coûts importants liés à l'utilisation des résultats de ce type d'inventaire.

Nous allons donc d'abord décrire les principales caractéristiques de ce type d'inventaire, les besoins qu'il crée en terme d'utilisation et enfin, présenter les moyens informatiques utilisés pour répondre aux besoins. Nous terminerons par un bref regard sur les coûts de développement et d'opération et les développements futurs.

L'INVENTAIRE ECOLOGIQUE

L'inventaire écologique intégré est une méthode d'inventaire du territoire relativement nouvelle qui vise à éviter les cartographies multiples et sectorielles dont les résultats sont toujours difficiles à intégrer. C'est-à-dire qu'il s'agit d'éviter d'obtenir autant de cartographies différentes qu'il y a de spécialités, d'autant plus que la simple superposition de cartes thématiques différentes ne suffit généralement pas à dégager les relations recherchées entre les variables.

Ce qui est proposé par l'école australienne (Christian et Stewart, 1968), méthode par la suite adoptée au Canada (Wiken, 1981), est de reconnaître des surfaces jugées homogènes et où la relation entre les variables est déjà connue.

Puisque la méthode a été conçue essentiellement pour l'inventaire de grands territoires, le travail se fait sur photographies aériennes à l'échelle relativement petite, généralement 1:60 000 sur lesquelles on reconnaît des "landforms". Pour chacun, on assume une séquence de textures et de drainages. Ce sont des "patterns" de "landforms" que l'on cartographie à l'échelle du 1:125 000. Les autres variables sont considérées comme dépendantes de celles-ci, sauf le climat régional qui est reconnu en recherchant les variations dans les chronoséquences végétales pour un même type de surface.

L'échantillonnage du terrain vise (1^o)- à élaborer les clés de photo-interprétation pour reconnaître les types de surface et(2^o)- à déterminer les différents stades de végétation caractéristiques de chacun. On obtient ainsi l'information de base ou de premier niveau.

Par la suite, un traitement de cette information est effectué par l'équipe d'inventaire en vue de détecter le climat régional et ainsi de définir les régions écologiques et les chronoséquences pertinentes à chaque région. Les districts sont des regroupements d'unités basés sur le relief et les dépôts. Cette information générée à partir de la première, l'organise en vue d'une utilisation ulrérieure et constitue l'information du deuxième niveau.

Le troisième niveau est celui de l'utilisateur, donc celui qui nous concerne plus particulièrement. Il s'agit, pour l'utilisateur, de générer, à partir de l'information de base, les cartes thématiques qui l'intéressent. Ceci se fait généralement en élaborant une clé de potentiel combinant d'une façon plus ou moins sophistiquée les états d'un certain nombre de variables retenues. L'élaboration de la clé peut aussi utiliser l'information provenant de d'autres inventaires, fauniques par exemple. Le tableau I est une liste non-exhaustive des clés réalisables à l'aide de cette méthode d'inventaire.

TABLEAU I

Nature des interprétations possibles pour l'aménagement du territoire à l'aide de l'inventaire écologique (tiré de Jurdant *et al*; 1977)

AGRICULTURE
- Aptitude des sols pour l'agriculture
- Aptitude des sols pour diverses cultures
- Risque d'érosion du sol
- Identification des problèmes d'aménagement

FORÊT
- Aptitude des sols pour la production de matière ligneuse
- Aptitude des sols pour diverses espèces ligneuses
- Difficulté de plantation
- Coût de reboisement
- Coût de production des plantations
- Potentiel de régénération naturelle
- Espèces agressives après coupe à blanc
- Espèces agressives après feu
- Risque de chablis
- Traficabilité

RÉCRÉATION
- Attrait du paysage
- Potentiel récréatif des lacs et rivières
- Aptitude pour la récréation dans la nature
- Possibilité pour terrain de camping
- Possibilité pour lac artificiel
- Possibilité pour sentier, infrastructure, etc.
- Possibilité pour centre de ski
- Possibilité de reboisement esthétique

FAUNE
- Aptitude pour la faune terrestre
- Aptitude pour la sauvagine
- Aptitude pour la faune aquatique
- Production potentielle de plantes utiles à la faune

EAU
- Capacité de rétention en eau des sols
- Qualité de l'eau

INGÉNIERIE
- Potentiel pour diverses activités relevant de l'ingénierie

ZONES ÉCOLOGIQUEMENT SENSIBLES
- Délimitation des zones

La fiche de système écologique contient des informations manuscrites définissant de façon détaillée la surface délimitée par une ligne pleine ainsi que les surfaces des sous-systèmes aquatiques délimitées par une ligne pointillée.

Chacun des systèmes écologiques cartographiés sur le territoire possède une fiche de système écologique unique, mais la correspondance entre fiche et système cartographié ne peut se faire que par analyse visuelle puisque dans bien des cas on peut trouver plusieurs systèmes écologiques identiques en définition, où la seule différence est l'emplacement spatial.

DEVELOPPEMENT INFORMATIQUE

Pour bien identifier chaque fiche à son système, nous avons intégré un système de numérotage où chaque système écologique est assigné un numéro séquentiel unique et où chaque sous-système ou aquatique est assigné un numéro séquentiel de sous-système. Ainsi, nous arrivons à identifier sans ambiguïté chacun des systèmes cartographiés.

Le processus de numérotage consiste à retrouver via une analyse visuelle la fiche correspondante au système écologique numéroté. Une fois repérés, les numéros de système et de sous-système sont ajoutés directement sur la fiche de système.

Une fois le numérotage d'une carte écologique terminé, les fiches descriptives de système écologique sont vérifiées pour repérer des caractères illisibles qui sont corrigés, permettant ainsi une réduction des erreurs de lecture lors de la perforation des données.

La perforation des données se fait directement à partir de la fiche manuscrite en format libre où le seul champ fixe est le numéro de système écologique. Etant donné le caractère hautement variable d'une fiche écologique, les directives de perforation ne prévoient aucun champ de longueur fixe. Au contraire, la fiche est divisée en plusieurs blocs d'information, chacun se terminant par un point. Si le bloc d'information est vacant sur la fiche, il n'y aura qu'un point de perforé. Chacun des blocs d'information peut aussi contenir plusieurs sous-blocs d'information, chacun séparé par une virgule. Si le bloc d'information ne contient qu'un sous-bloc d'information, aucune virgule n'est perforée.

Le produit de la perforation est un nombre variable d'enregistrements pour chaque fiche écologique à valider.

Le programme de validation écrit en PASCAL se base sur une méthode d'analyse syntactique où la position logique d'une information prime sur sa position physique. A chaque fois que la position logique d'une information ne correspond pas aux conditions programmées, un message d'erreur est généré et le programme ne se préoccupe plus de valider les enregistrements de cette fiche en particulier. Aussi la validation se fait par passe jusqu'à l'élimination de l'ensemble des erreurs.

Le deuxième sous-ensemble de SIDEC concerne les informations spatiales de la cartographie écologique, soit les limites géographiques des systèmes écologiques cartographiées au 1:125 000 qui doivent être digitalisées et mises en relation avec les données alphanumériques.

Une copie vermillion à ligne blanche est prise de la carte écologique par procédé photomécanique, copie qui fait ressortir toutes les informations cartographiques en blanc sur un fond de couleur orange. Ensuite, les contours des systèmes écologiques et de leurs sous-systèmes sont gravés avec un instrument pointu pour enlever la couche blanche et rendre les contours transparents.

Après vérification que l'ensemble des contours ont bel et bien été gravés, la carte finalisée est positionnée sur un lecteur photo-électrique à tambour.

Le processus de digitalisation fonctionne par réflexion. Si un contour a été gravé, alors la lumière émise par le faisceau traverse la carte et il y a réflexion. Chaque point d'une carte est donc allumé ou éteint.

Le produit de la digitalisation est une matrice binaire qui est ensuite transformée par le truchement d'un logiciel de conversion matricielle en un fichier de segments, un segment étant l'ensemble des coordonnées (UTM) par laquelle passe une ligne entre deux (2) points d'intersection.

Ce fichier nous est transmis avec un fichier de correspondance contenant essentiellement les numéros des sous-systèmes aquatiques et leurs numéros correspondants de segments.

SIDEC étant un système basé sur des informations spatiales comparativement à des systèmes à information linéaire ou ponctuelle, les segments appartenant à un sous-système aquatique doivent être repérés et ordonnés pour constituer le contour total d'un polygone. De plus, les coordonnées d'un contour doivent être comprimées pour limiter au strict nécessaire le nombre de points à traiter.

La reconstitution d'un polygone est accomplie en trouvant chacun des segments appartenant à un polygone et en déterminant leur séquence physique.

La compression des coordonnées vise deux (2) buts. Premièrement, une réduction en nombre des points en ne conservant qu'une coordonnée au cinquante (50) mètres carrés. Ceci nous donne une précision physique de quelque deux cents (200) points au pouce. Nous croyons que cet ordre de précision opérationnelle est le mieux adapté aux limites, premièrement de la technologie d'impression matricielle et deuxièmement, de l'acuité visuelle.

Le deuxième but est de réduire l'espace nécessaire pour l'entreposage d'un polygone en gardant la première paire de coordonnées en valeurs absolues tandis que les autres coordonnées du polygone sont transformées en valeurs relatives où chaque point peut prendre l'une des huit (8) directions en fonction du point précédant.

Ces deux (2) opérations permettent une réduction de l'ordre de dix (10) de l'espace utilisé pour entreposer ces polygones en comparaison avec les polygones avant traitement, composés d'un nombre n de coordonnées en valeurs absolues.

De plus, le ré-alignement des coordonnées au cinquante (50) mètres carrés permet une compatibilité absolue avec le format DIPIX des images LANDSAT et nous offre de façon plus pragmatique l'utilisation éventuelle des informations issues d'un traitement numérique des images LANDSAT.

Les données alpha-numériques des systèmes écologiques sont ensuite recodifiées en valeurs numériques et entreposées dans une structure relationnelle de banques de données. Le concept relationnel a été retenu parce que les blocs d'information apparaissant sur la fiche descriptive de système ne sont pas nécessairement accédés à chaque analyse des données en plus de se prêter particulièrement bien à une structure rectangulaire de sous-ensembles.

Des spécialistes concernés développent des clés d'interprétation des données écologiques du système SIDEC qui sont ensuite programmées dans un langage évolué. Une fois appliqués aux données écologiques, ces programmes obtiennent une pondération ou classe de potentiel pour chacun des polygones du système.

La carte ainsi pondérée est tracée autant de fois qu'il y a de classes de potentiel, chacune des sorties contenant uniquement les polygones complètement noircis et appartenant à une même classe. Dans le cas de la clé de potentiel pour l'habitat de l'orignal qui assigne un maximum de cinq (5) classes aux systèmes écologiques, cinq (5) sorties complémentaires sont produites par le logiciel de traçage.

Ces cartes tracées constituent le matériel de base et le produit final du système SIDEC. Le tirage de négatifs et l'impression par procédé photo-mécanique sont accomplis directement à partir de ce produit.

La production traditionnelle des cartes de potentiel à partir des informations écologiques de l'inventaire de la Basse Côte-Nord était accomplie par du personnel qui appliquait directement la clé d'interprétation à la fiche descriptive de système écologique. Une fois le polygone classifié, sa surface était coloriée à la main. Le produit final était ensuite obtenu par procédé photo-mécanique.

Dépendant de la complexité de la clé d'interprétation, ce travail nécessitait entre deux (2) et quatre (4) jours par carte au 1:125 000. En tenant compte de l'ensemble du territoire à interpréter, le coût minimal par production traditionnelle était de 30 000 $ par clé d'interprétation. Ce coût élevé contribuait à l'inaccessibilité de l'inventaire.

Le coût total de développement et de mise en opération du système SIDEC est de 215 000 $, l'équivalent de la production manuelle de sept (7) clés d'interprétation de l'inventaire écologique et 8% du coût total de l'inventaire. Compte tenu du caractère quasi permanent de l'inventaire écologique de la Basse Côte-Nord, nous estimons qu'à long terme, quelque cent (100) clés d'interprétation seront développées.

Présentement, douze (12) clés d'interprétation ont déjà été développées et intégrées au système SIDEC.

CONCLUSION

Le coût minimal de cartographie automatique pour une clé d'interprétation sur l'ensemble du territoire en question est de 2 000 $. Ceci signifie une réduction des coûts de production de la cartographie thématique de l'ordre de quinze (15) fois en plus d'augmenter considérablement l'accès aux données de cet inventaire et de réduire de façon radicale le temps nécessaire pour mener à terme une étude thématique.

TABLEAU II

Produit	Coût total	Coût par carte 1:125 000
DEVELOPPEMENT		
. Inventaire de la basse Côte-Nord	2 500 000 $	38 461 $
. SIDEC		
- Ressources humaines	121 425 $	1 868 $
- Digitalisation des contours	22 750 $	350 $
- Perforation des données	10 125 $	155 $
- Frais d'ordinateur	60 000 $	923 $
Total (SIDEC)	214 300 $	3 296 $
PRODUCTION		
. Production thématique manuelle	30 000 $	462 $
. SIDEC		
- Programmation d'une clé d'interprétation	660 $	10 $
- Exécution de la clé	335 $	5 $
- Traçage des cartes thématiques	1 005 $	15 $
Total (SIDEC)	2 000 $	30 $

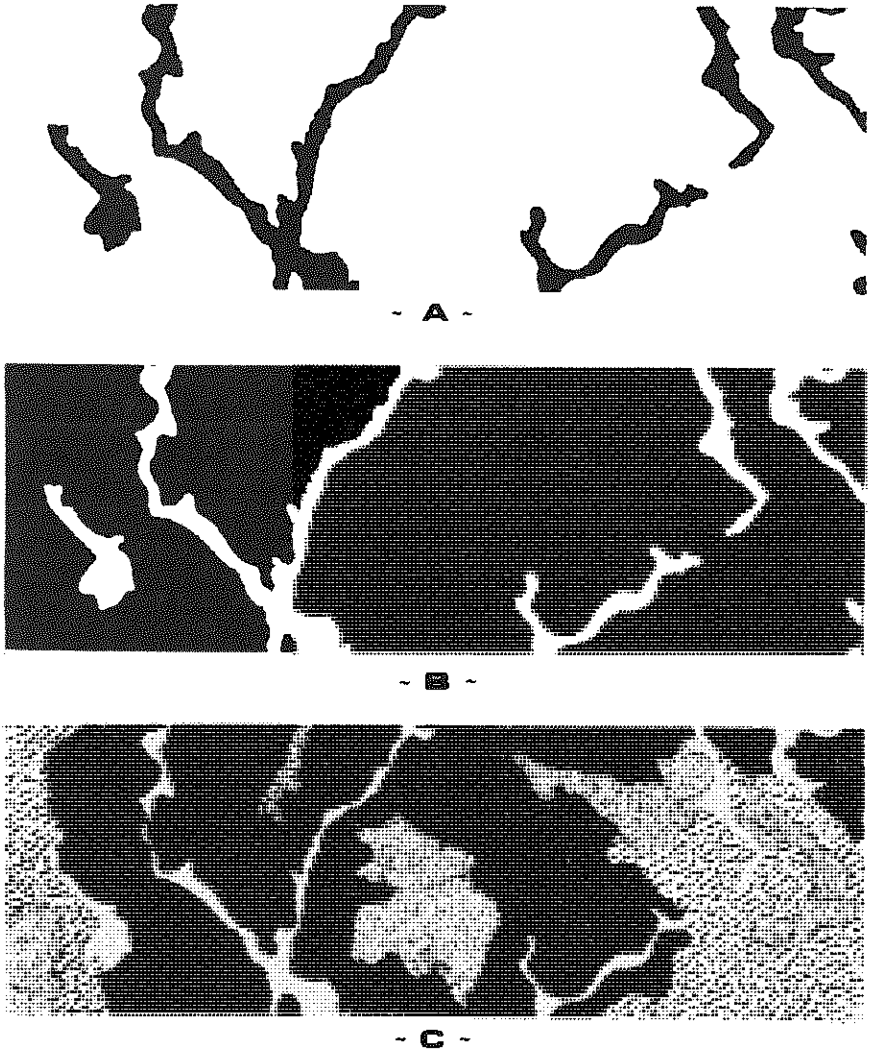

Figure 1. Les étapes graphiques de la production automatisée des cartes thématiques. En A, le positif à surfaces noircies tel que produit par la traçeuse numérique; en B, un négatif produit par procédé photomécanique, et en C, la carte thématique produite par superposition de cinq négatifs différents et de trames appropriées.

Figure 1. Three steps leading to final thematic maps. Subfigure A, shows area-filled contours as produced by a graphic printer; subfigure B, is a negative copy obtained by a photo-mechanical process and, in subfigure C, is the final product made by an overlay of five different negatives coupled with the appropriate screens.

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A DATA STRUCTURE FOR RESOURCE MAPPING WITH CARIS

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ABSTRACT

This paper describes the resource mapping capabilities of CARIS, the Computer Aided Resource Information System. In particular, it outlines the data structure and describes some of the algorithms used to process polygons.

INTRODUCTION

We will define a resource mapping system to be one whose main function is to maintain a land resource data base to serve planning, management and cartographic purposes. The maps to be produced include the conventional topographic, thematic, and special purpose maps such as hydrographic charts.

Being more than just a computer-aided drafting system, a resource information system also maintains topological relationships. One particularly important relationship is polygon relationship since many data, such as population, soil, forestry etc., are polygon-related and many thematic maps consist purely of polygons. We refer to these maps as polygonal maps.

CARIS (Masry, 1982) is a Computer Aided Resource Information System based on Digital Equipment Coporation's (DEC's) PDP 11 hardware and its time sharing operating system RSX11M. The peripheral devices include refresh-type color graphics terminal, digitizer, photogrammetric stereo plotter, flat-bed and drum plotters, disk and tape drives, and console terminal. Each station is stand-alone and is capable of interactive digitizing and editing (Figure 1). The first stations of CARIS will be delivered to the Land Registration and Information Service (LRIS), the Council of Maritime Premiers, Canada in the fall of 1983.

The integration of CARIS at the University of New Brunswick is the joint effort of members of the Surveying Engineering Department, the Computer Science Department, and an industrial firm - Universal Systems Ltd.

The design of CARIS is based on concepts similar to those which have been in use in some digital mapping systems in Canada for a number of years. Two of these systems are: the Canadian Geographic Information System (CGIS) (Lands Directorate, 1973) which deals mainly with polygonal maps, and the Canadian Hydrographic Service system which deals with production of charts (Furuya, 1973).

Some of the properties of CARIS are as follows.

1. The system provides the capability of topographic, hydrographic as

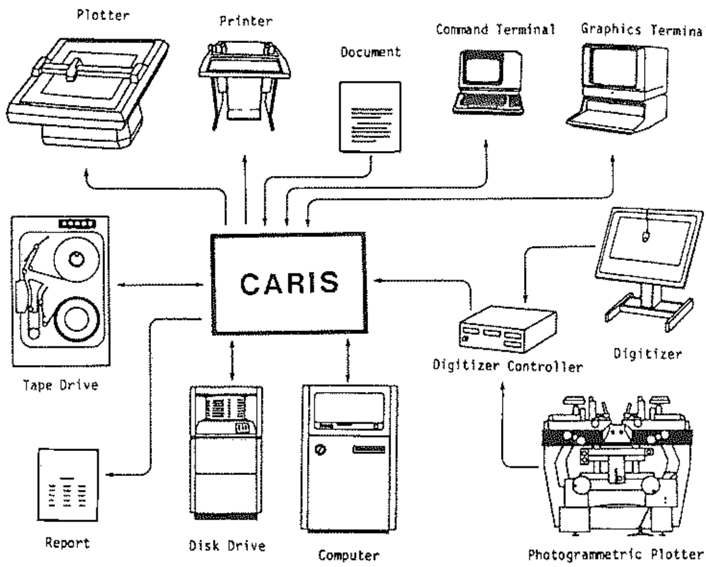


Fig. 1 - The CARIS Environment

well as polygonal mapping. The topographical and topological information can be displayed simultaneously or selectively, and they can both be edited interactively with equal ease.

2. Data can be entered from survey documents, maps, or stereo models. Lines can be represented either as absolute coordinates or in a compressed form. All coordinates can be converted in real time to ground.

3. Polygonization is done automatically. A number of topological erros can be detected by software. The errors can be corrected using the interactive graphics editor.

4. The data structure is flexible enough to allow future expansion to accomodate new demands in mapping. It is efficient enough to satisfy most interactive queries within two seconds.

5. The system is capable of handling very dense lines (as much as 700 points per line) without significant degradation in response time.

6. A data management package is provided to handle attribute data which can be linked to the graphics.

7. Map sheets can be combined, windowed, or changed in scale and projection.

In the rest of this paper, a description of the data strucutre will first be given to show how topographical and topological data can be represented. This is followed by a description of how the polygon sides are digitized and how the polygons are formed automatically using the CARIS programs. Finally, a few algorithms will be presented to illustrate some applications of the data structure.

DATA STRUCTURE

We will first describe a graphics data structure to serve interactive editing of topographic data and then demonstrate how the data structure can be extended to include topological information as well.

Graphics Data Structure

The files for editing are stored as random access files on disk. They can be consolidated to a sequential file on tape or disk for archive and interchange purposes. This sequential format is called the interchange format.

The basic graphic elements of a topographic map are lines, names, and symbols. Each graphic element is associated with geometric as well as attribute data. The geometric data defines the location and shape of the graphic element whereas the attribute data gives relevant non-geometric information such as feature identification, ownership, etc. In the CARIS system, geometric data for lines can be in absolute coordinates or compressed with directional coding using eight discrete directions. All the transformation parameters required to convert from the file coordinate system to the ground system is stored with the map files.

Even with compression, most of the lines are so long that each will need thousands of words to store. In order to allow in-core processing of geometric data, each line is segmented into convenient pieces each of which can fit into a core-buffer. These line segments, being the basic logical element of the graphics data structure, are composed of a descriptor record (Figure 2) and a data record which is collectively known as a DAD (Descriptor And Data). Each descriptor, and hence each DAD, is given a unique identification called the descriptor number. Since these descriptors belong to graphic entities, we will sometimes call them graphics descriptors to be specific.

The data record stores the information required to plot the graphic entity. For example, the data record of a line contains coordinates; that of a name contains the location, slope and ASCII code of each character in the string. The descriptor record stores a geometric summary of the entity such as the bounding rectangle together with some vital attribute data such as the feature code and the source number. The feature code is an alphanumeric code chosen by the user to name the feature whereas the source number is a signed integer ranging from -32768 to 32767 to serve as an additional identifier. One application of the source number is to identify the survey document from which the feature was compiled from. When a map has mixed topographical and topological information, the source number is also used to differentiate between the two types.

Since a continuous line may consist of a fair number of DADs, and these DADs can be scattered over the disk; pointers are kept in the descriptor record to link them together.

The descriptor records are fix-sized records with identical format for each graphic type, but data records are variable-sized with different format for each type. A data code in the descriptor identifies the graphic type so that its associated data record can be interpreted correctly. Some common codes are: one for a line represented by absolute coordinates, three for a compressed line, and seven for a name.

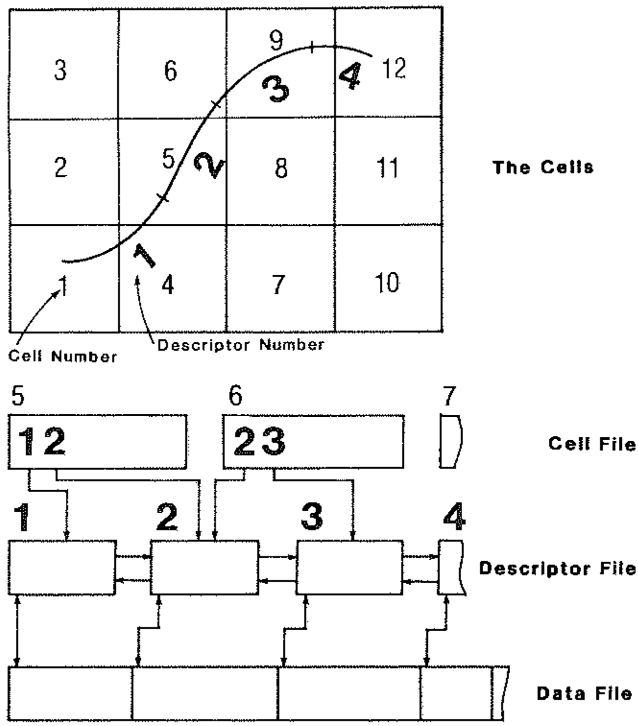


Fig. 2 - The Graphics Data Structure

Because of the fundamental differences between a descriptor record and a data record, it is convenient to store them in separate files: the descriptor records in the descriptor file and the data records in the data file. Another set of pointers is therefore required in the descriptor record to point to its data record in the data file. It should be noted here that the pointers relating the descriptor and its data or relating one descriptor with its neighbours are doubly linked to provide maximum search speed and to reduce the risk of loosing data due to corrupted pointers.

We have now discussed two levels of the CARIS edit file hierarchy: the descriptor file followed by the data file at the lowest level. There is yet one level, which we will call the cell file, above the descriptor file.

Each map is divided into square cells with each cell having a record in the cell file. The entries in the cell record are descriptor numbers of the graphic elements within or passing through the cell. With this structure, it is possible to localize most search operations to a limited number of cells. As we will see later, this cell structure helps in the design of efficient algorithms to process polygons.

When converted to the interchange format, the cell file is dropped and the descriptor and data files are merged. Moreover, all the pointers in the edit files are also inactivated during this conversion and will be reconstructed when being converted back again to the edit format.

Topological Data Structure

A topological data structure contains the relationships between one geometric entity and another. In a polygonal mapping application, we are particularly interested in arc-to-polygon relationships (how the lines are related to polygons) and polygon-to-polygon relationships (how one polygon is related to another).

The two main types of graphic element in a polygonal map are lines and names. The lines form outlines of polygons and the names form display labels of polygons. In order to make the lines easier to manipulate, we adopt the convention of many topological data structures to restrict the extent of each line from one node to another; a node is simply the meeting point of two or more lines. Such a line will be called an arc in this paper (Figure 3). The terms chain, segment, edge or boundary are sometimes used to refer to the same topological entity in other literature. Being a line, an arc is a collection of DADs. A special type of descriptor, an arc descriptor, is created to store important information about an arc such as its length, its bounding rectangle and pointers to relate this arc to polygons. An arc descriptor is linked to the start of the first graphics descriptor of the line forming the arc (Figure 3). All the descriptors belonging to arcs, including the arc descriptor, have a negative source number. Other descriptors which are purely of topographic nature have a positive source number. The automatic polygon builder only process descriptors with negative source number, while the graphics editor is capabable of handling both topological and non-topological descriptors.

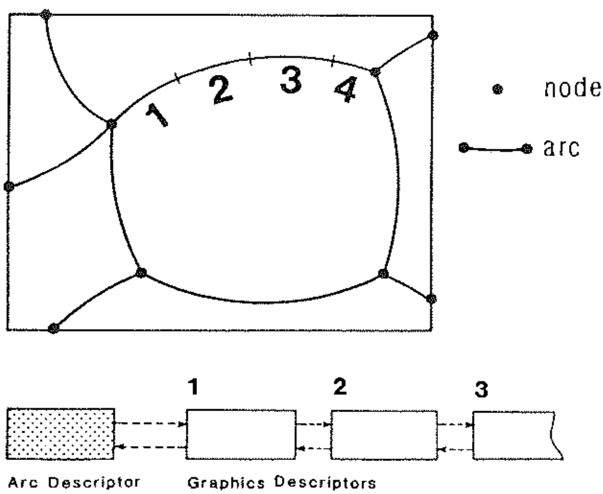
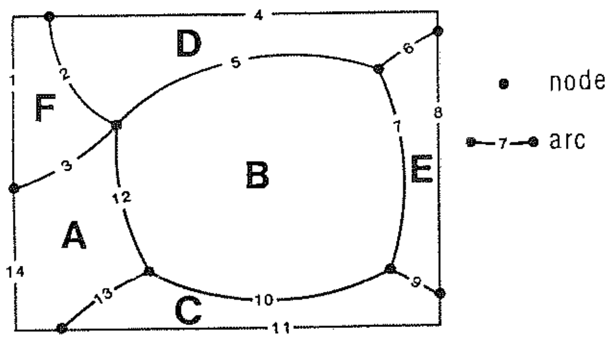


Fig. 3 - Arc and Graphics Descriptors

One method of relating arcs to polygons is to create an inverted file in which all arcs belonging to a polygon are stored in a list (Figure 4). There are two disadvantages of using this scheme. First of all, since each arc belongs to exactly two polygons, each arc entry must be duplicated. Unless a complex system of pointers is used, the modification of the arc lists can be cumbersome. Secondly, the total neighbourhood relationship of polygons cannot be obtained easily. The total neighbours of a polygon not only include those sharing the same arc, but also include those sharing the same node. For example, the



Polygon	Arc List
A	3, 12, 13, 14
B	5, 7, 10 12
C	9, 10, 11, 13
D	2, 4, 5, 6
E	6, 7 8, 9
F	1, 2, 3

Fig. 4 - Polygons Represented by Arc Lists

neighbours of polygon B in Figure 4 are A, C, D, E and F. The arc list described above does not readily reveal neighbours, such as F in Figure 4, that only share a common node. We therefore decide to employ a structure that does not involve such a list. In the CARIS structure, each arc descriptor contains two polygon pointers and two arc pointers. The two polygon pointers point to the left and right neighbouring polygons; each of the two arc pointers points to one of the many possible incident arcs at both ends of the arc. These arc pointers form a circular list of arcs around each node linking all arcs incident on a node in an anticlockwise order. The pointer at the start of the arc is called the first next incident arc pointer and that at the end of the arc is called the second next incident arc pointer (Figure 5). It is easy to see that this circular list can be used to quickly locate all neighbours of a polygon. The method by which these pointers can be used to relate arcs to polygons will be discussed in a later section.

A fourth file, the polygon file (Figure 5), is used to store polygon-related information including the area, an interior point, the polygon label, the bounding rectangle of the polygon, a pointer to one of its component arcs, and a number of pointers to preserve the polygon-to-polygon relationship. For instance, a pointer is used to relate an enclosing polygon to one of its islands, one to relate an island to its enclosing polygon, one to relate one island to another and to relate polygons within compound islands which are islands consisting of a number of polygons in themselves. In addition to these, a pointer is used to relate the polygon to its attribute record in an attribute file which is maintained separately by DATATRIEVE, a DEC program for data management. The attribute file is the fifth and last file in the CARIS topological file system.

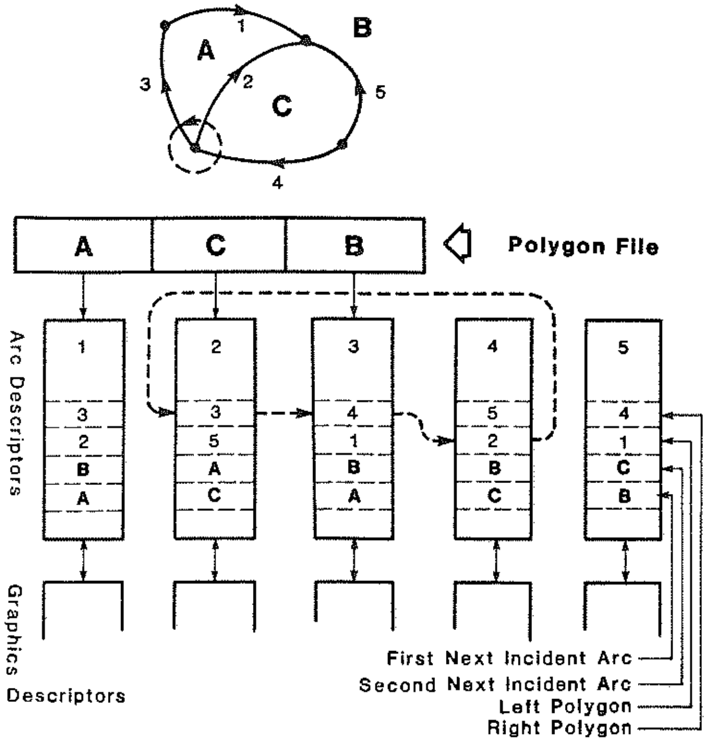


Fig. 5 - The Topological Data Structure

PROCEDURE FOR DIGITIZING AND FORMING POLYGONS

Polygons are not digitized explicitly, that is, the digitizer operator does not have to finish the perimeter of one polygon before proceeding to the next. The only requirement for the operator is to digitize all the arcs from node to node in any sequence. Other than this, the only other required operation is to digitize an interior point together with an optional user label for each polygon, again in a random sequence. The formation of polygons and the association of interior points to polygons are done automatically by software.

There are two programs used in the polygonization process. The first one, the Arc Linker, looks for nodes in the file and builds circular arc lists around them. Arc ends are automatically snapped at the same time.

Topological errors detected at this stage are mainly node order errors. Nodes of order less than three are suspicious and are therefore flagged in the graphics with an error number which is cross-referenced to a hardcopy list giving details of the error (Figure 6). This helps the user to easily locate these detected errors while in the editing package and to correct them.

The user will iteratively arc-link and edit the arc file until it appears clean to the Arc Linker. This will help the next polygonization program to work more efficiently and reliably. It should be noted that at each iteration, only those arcs affected by the previous edit will be processed by the Arc Linker. The processing time of this program, therefore, is proportional to the number of errors detected during the previous run.

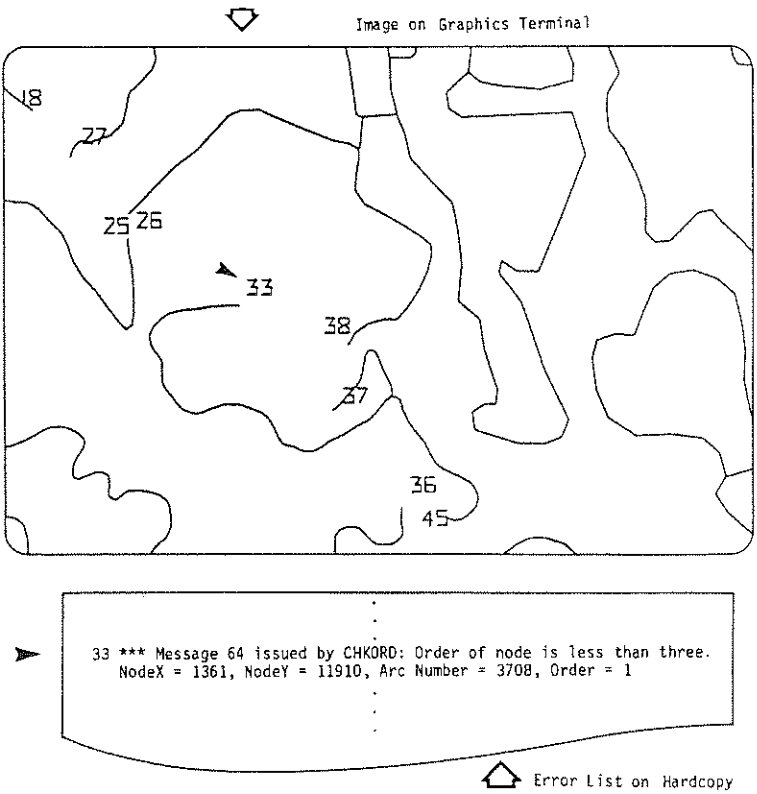


Fig. 6 - Error Messages from the Arc Linker

The second and last program to run is the Polygon Builder. It uses the circular list around each node produced by the Arc Linker to build the polygon file. It also resolves the island relationship and relates labels to polygons. Polygon-related errors such as unlabelled polygons, thin polygons etc. are detected at this stage. Again, the graphics editor can be used to correct the problems. Since the circulr lists around nodes might have been disturbed by editing, the Arc Linker and the Polygon Builder have to be executed again after the edit.

A Polygon Checker is provided to check the integrity of the topological data strucutre produced by the polygonization programs.

ALGORITHMS TO PROCESS POLYGONS

It is not the intention of this section to describe a full collection of algorithms in a polygonal mapping system. Instead, only a few among them are discussed here mainly to illustrate the capabilities of the data structure.

There are two type of algorithms: type A is for building the topological data structure from the raw arc file; type B is for retrieval after a clean topological data structuure has been established. All type A algorithms described here assume the topological data structure is partially complete. In particular, the circular lists of arcs around each node and the left and right polygon pointers for each arc are known.

Algorithm to Retrieve Arcs of a Polygon

This is a type B algorithm that can be used to retrieve the component arcs of a polygon given its number.

1. From the polygon record, read the first component arc of the polygon.
2. Read the arc descriptor record of the first component arc. Note which side the polygon in question is related to this arc.
3. If the polygon is to the left of the arc, use the first next incident arc pointer to get to the next component arc. If the polygon is to the right, use the second next incident arc pointer.
4. Read the descriptor record of the next component arc and pick the other component arcs using the same rules as in step three.
5. Exit if the first component arc is again reached.

This algorithm always collect arcs of a polygon in a clockwise sequence.

Algorithm to Associate a Label with its Polygon

This is a type A algorithm which solves the point-in-polygon problem for each digitized interior point and its polygon label.

1. Determine the cell enclosing the polygon interior point.
2. Of the four orthogonal directions to the border of the map (up, down, left, and right), pick the shortest path.
3. Extend a finite half line from the interior point to the closest border along the shortest path.
4. If there is no arc pointed to by the current cell record, move over one cell in the direction of the finite half line and repeat this step.
5. If there are arcs pointed to by the current cell record, determine if any of these intersects the finite half line. If an intersection is found, the enclosing-polygon problem is solved since the left and right polygons are known for each arc. If no intersection is found, move over to the next cell in the direction of the finite half line and repeat from step four.

An enclosing polygon will eventually be found for a point unless the point is outside the map.

Algorithm to Visit all Connected Arcs

This is a type A algorithm which can be used to collect all polygons connected to a given one. This is useful in setting up the pointers relating all polygons on a compound island.

1. Allocate a "connected" list to contain all connected arcs. Also allocate a stack. Initially nullify both the list and the stack.
2. Pick an arc to start. In the case of using this algorithm to collect all connected polygons, use the first component arc of the given polygon.
3. If the arc is not in the connected list then do the followings:
   a. Spawn two adjacent arcs from this arc (the two arcs pointed to by the first and second next incident arc pointers).
   b. Push the two spawned arcs into the stack.
   c. Declare the arc as being connected and put it in the connected list.

   If the arc is already in the list, ignore it.
4. Pop one spawned arc from the stack.
5. If the stack is empty then stop, else repeat from step three.

At exit, the connected list contains arcs connected to the initial one. To obtain the polygons connected to the given one, simply read the arc descriptor record of each in the connected list and note their left and right polygons.

CONCLUSION

A data structure that can be used for both topographic and polygonal mapping has been presented. From our experience, the data structure is flexible and efficient. It is suitable for interactive editing and on-line query of the land resource data base. Moreover, it can be extended to include network and three-dimensional structures. Its capability of mixing different types of information in the same file offers great potentials in land resource information management.

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A DIGITAL CARTOGRAPHIC INFORMATION UTILITY

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ABSTRACT

This paper will evaluate the potential of the National Ocean Service (NOS) Automated Information System (AIS) digital cartographic data base as marketable information commodity. The evaluation will stress the mutual benefits that government data base agencies and the public can share. A sampling of a few government cartographic data bases depicts how duplication of data collection and subsequent maintenance can be significantly reduced. Moreover, a wider range of users would be serviced because the digital mode supplements the present paper map or chart dissemination media.

This paper also presents a possible user-source agency interface to make the information cartographic data base a reality. The interface suggested requires a threefold approach. First, released AIS digital test data would have user restrictions by copyright and would require user fees. Second, the selected AIS test data would be made available to a network of depositories with existing digital data maintenance and disposition capabilities. Third, the depositories would provide user feedback to the NOS as well as test data manipulations or non-AIS supplementary data that the users may have.

INTRODUCTION

Although manual cartography remains the predominant mode of map compilation, automated mapping is becoming increasingly important and will eventually replace pen and ink in dominance. Automation offers greater flexibility in collection, manipulation, and storage of data with resultant cost reduction in combined compilation and reproduction. Moreover, there is a potential information utility or source agency-user interface between the growing number of digital cartographic data bases supporting this automation and the recipients of the information. At present, the large volume of integrated digital latitude and longitude points referencing symbology or defining locations on the earth's surface has not had effective interagency exchange, and many private users do not have access to digital cartographic data for applications not addressed in published maps.

People are touched by map products everyday. Service industries use maps or charts for delivery of people or goods. Recreational activities employ cartographic products. Public and private planning enterprises base many decisions on cartographic publications. These uses exemplify the great many people who use and benefit from maps and justify the development of a cartographic information utility. Digital mapping data provide the ideal medium for this utility. However, a dissemination infrastructure is needed to make collected digital cartographic data available to all potential users. The critical elements missing to complete this dissemination are consistent computer mapping standards to encourage information exchange, information storage and disposition facilities, and a comprehensive marketing policy for digital mapping products. In combined form, these elements constitute a cartographic information utility which can be developed by analyzing current digital cartographic data collection perspectives, investigating the basis for mutual benefits in data sharing, and suggesting potential dissemination and marketing procedures.

CURRENT DATA COLLECTION

The Federal Government collects vast amounts of cartographic digital data in the United States. Table 1 differentiates three principal federal digital cartographic data bases by function, unit, scale, structure, and format. The comparison criteria serves only as a point of departure to view how real world digital cartographic data bases lock themselves into their own applications preventing mutual benefits in data sharing. The lack of access to combined digital cartographic data stored in these government data bases has forced numerous state governments and private companies to independently collect their own. Further analysis of the data base differentiation points to the need for value-free digitization whenever feasible and standardization in data storage and retrieval formats.

COLLECTOR	FUNCTION	UNIT	SCALE	STRUCTURE	FORMAT
Defense Mapping Agency (Holland 1979, DMA 1982)	Digital Terrain Elevation Model (Three Levels)	1°x1° Blocks 15'x15' Cells 7½'x7½' Cells	1:250,000 1:50,000	Hierarchical Hierarchical Hierarchical	Overlays of graphically oriented elevation values with relative accuracy determined by level
National Ocean Survey (Moses, Passauer 1979; Swisher 1981)	Nautical Chart Automated Information System	1°x1° Blocks 144 Cells	Scale Independent	Hierarchical	Chained record types with latitude and longitude of symbology matched to data base array
United States Geological Survey (Stephens, Domaratz, Schmidt 1979)	National Small-Scale Cartographic Data Base	1°x1° Blocks	1:2,000,000	Hierarchical	Topologically structured and graphically oriented data sets

TABLE 1: SAMPLE DIGITAL CARTOGRAPHIC DATA BASES

Collection perspectives and functions are closely related. The United States Government Accounting Office noted that several federal departments, using United States Geological Survey (USGS) digital data for their own unique uses, acknowledged problematic duplication but condoned it for fear that any corrective action would jeopardize their own function (United States Comptroller General 1982). Insufficient overlap in source agency and end user data collection perspectives and applications has hindered digital data set standardization. The Defense Mapping Agency Digital Terrain Elevation Data Base is used or missile penetration planning. The Automated Information System (AIS) is primarily used for production and maintenance of nautical charts. USGS National Small-Scale Data Base supports use emphasizing terrain, drainage, and cultural digital data.

Unit and scale considerations of digital cartographic data base design affect decisionmaking in ways not always anticipated. Unit and scale do not solely define relative accuracy and spatial relationships respectively; they also reflect the bias of the data collector in the projected use of the digital data and create problems in passing it between large- and small-scale representation.

Perhaps the most important consideration is that both the government and private sectors have not agreed upon the standards for digital cartographic data structure, format, and coding which would be most desirable if they allowed reasonable access to each other's digital data. Current diversity within hierarchical organizations not only discourage interagency exchange but actually inhibits new applications evident from a holistic view of all available digital cartographic data resident in a universally accepted hierarchy.

BASIS FOR DATA SHARING

The fragmentation in both the conceptualization and actual collection of digital cartographic data underscores the need for cooperative effort to bring about reduced duplication with lower collection costs and optimal data availability to stimulate new applications. There is an urgent need for ethics and values in digital cartographic data collection and a definitive federal policy to guide data structure and format. The data collection must be as close to value free or unbiased as possible. The policy must impose leadership and direction in cartographic data set definition.

The idea of "componentiality" applies to value-free cartographic data digitization (Cooper 1979). Each data collector must view itself as a component of a larger entity. Data collection must keep in mind the ultimate value as part of a whole while still honoring singular function. The source agency which is most concerned with a particular data type should be responsible for its collection to the extent that not only is its agency need satisfied but other uses are represented as well.

NOS practices "componentiality." One of the most critical functions of a nautical chart is to portray the shoalest water depth to ensure boating safety. However, the totality of the hydrographic portrayal supports other nonnavigation applications like bathymetric contour mapping which has proven helpful in fishing, environmental impact studies, and offshore oil exploration. Shoreline is still another nautical chart data type that lends itself to interagency use. Shoreline is digitized from the largest nautical chart coverage available but is filtered by point elimination software for use at smaller scales. The elimination procedure compares point data to a spline curve to generate a best fit facsimile line with less points at a selected scale. Labor intensive digitizing at smaller production scales is replaced by flexible use of existing digital data enabling reduced core storage overhead and increased map throughput.

Leadership in cartographic data base policy has recently been proposed in United States legislative bill S.1280 which designates the United States Department of the Interior as the lead agency in formulation of a National Data Base. The bill also attempts to establish a revolving fund to make government mapping products self-sufficient through cost recovery (United States Comptroller General 1982). The intent of this proposal is indeed welcome. However, no lead agency can effectively manage, in conceptual form or in standard digital data format, cartographic uses not represented in its own product line. Reconcilement of individual source agency needs remains a problem. To date, little progress has been made.

Despite obstacles, the search for interagency coordination and agreement of acceptable digital cartographic standards continues. Perhaps the most significant advances will come from source agency and end user debate. One such forum is the National Committee for Digital Cartographic Data Standards (DCDS). DCDS is a designated committee of the American Congress on Surveying and Mapping whose purpose is to develop a workable model versatile coding system acceptable to all users of digital cartographic data (Moellering 1982). NOS participates with membership on each of the four working groups of the committee studying the issues of data organization, features, definition, and quality. This research underlines NOS' commitment to standardizing cartographic symbology and coding between its charting divisions as well as international digital cartographic data exchange between itself and its Canadian counterpart.

DISSEMINATION AND MARKETING

Magnetic tape and cassettes will inevitably replace paper in future marketing of existing and new mapping products. Recent reexamination of NOS chart distribution favored using the system approach to review if not change present marketing strategy because of environmental impact on charting products (Maloney 1983). There is a growing realization that current digital cartographic nautical chart data are undermarketed. However, legal obligation to boating safety restricts wholesale release of the data. Nautical charts are continuously being updated. The magnetic tape or cassette would only represent an image at a point in time and not necessarily the latest correct representation. Still another consideration is the medium itself. The digital mode is invisible to the user and may contain parity errors, fatal tape errors, or missing data. Most important, NOS has the legitimate concern that users will manufacture digital mapping products for uses contrary to the Services' legislated responsibility for boating safety.

The previous problems are being studied and possible copyright law may be enacted restricting the use of released nautical digital cartographic data. The question of user fees is also being addressed. Full recovery of nautical charting costs will be an important factor in fee assessment. USGS charges $26 for a magnetic tape of digital data from its small-scale data base. However, this high price has not received warm reception (United States Comptroller General 1982). There has been limited release of AIS digital data in printout form. The listing form alleviates the problems associated with the invisible digital medium, restricts mapping reproduction for unauthorized uses, and makes the data more affordable to the end user. However, digital cartographic data must be made available for purchase in order to improve automated charting via user feedback, stimulate new applications, and realize full cost recovery for the source agency.

The National Geodetic Survey Division has begun sale of selected projection computations which run on the Hewlett Packard 97 and 41CV programmable calculators. Each program sells for $10. With copyright and carefully spelled out disclaimers and appropriate dissemination vehicles, AIS data could be made available for public sale.

Universities or libraries with sufficient data base storage could house portions of pooled or selected source agency digital cartographic data on a test basis. In time, designated depositories could become connected in a network of regional service centers. Whatever infrastructure is chosen, the key is to make use of the expanding personal computer market and relational data base technology.

The number of personal computers in the United States today is estimated at 1.9 million. By 1990, 10 to 15 million home microcomputers are predicted (Westin 1982). This would provide 30 to 50 million potential new consumers of digital cartographic data. This is a realistic projection because terminals and accessory digital plotters are now becoming increasingly more affordable to communities, schools, small businesses, and many home users.

The relational data base model provides the ideal interface between the source agency and the end user. It requires no artificial constructions and allows the user to literally piece together his own view of the real world from available digital cartographic data. Figure 1 illustrates how the user may look through pooled digital data and then rearrange record relationships in tabular fashion to suit his own needs. Once the digital data are placed in the depository by geographic position and data type, the user is shielded from the source agencies' formats, access methods, and storage management techniques.

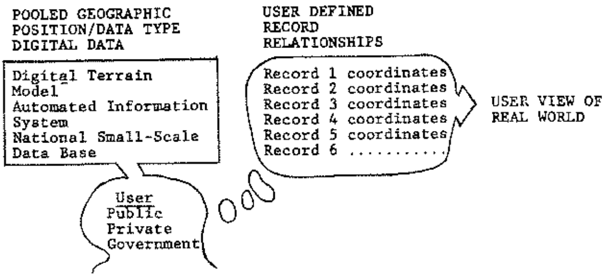

FIGURE 1: POTENTIAL SOURCE AGENCY END USER INTERFACE

The critics of the relational approach fault the complexity of the system. The logical or symbolic operations performed on the digital data by mathematical means are viewed as too costly and time-consuming. Most critics also feel that successful relational methodology is contingent on new hardware developments. In reality, the complexity is transparent to the user, and present terminal and plotter technology affords successful implementation. In addition, the cost and time of mathematical manipulation can be controlled by restricting the number of user defined record relationships allowed.

CONCLUSION

The great potential of automated mapping is undeniable. However, to realize the capabilities that this medium promises, digital cartographic data collection needs an unbiased approach with mutually acceptable standards in structure, format, and coding. This cooperative effort based upon source agencies viewing themselves as components of a digital cartographic data community can provide data sharing to stimulate new cartographic application and reduce costly data duplication as well as instill data policy direction and collective support of a designated lead agency that no legislation in itself can do.

The possible end user-source agency interface suggested, using NOS digital data as an example, is an attempt to make the potential use of stored digital cartographic data tangible rather than conceptual. The active part that NOS plays in both the digital cartographic data community and in exploring full dissemination of its own digital data serves notice that a digital cartographic information utility is indeed possible.

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SELECTING DIGITAL MAPPING EQUIPMENT FOR LRIS

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ABSTRACT

LRIS was seeking an automated mapping system which would meet two basic criteria. The first requirement was that the system produce maps efficiently. The second requirement was that the system be amenable to polygon type manipulation by downstream users of the data. These requirements were initially seen to be in conflict. This document outlines the process used to select a system which met both criteria.

INTRODUCTION - THE AGENCY AND THE PROGRAM

The Land Registration and Information Service (LRIS) was started 10 years ago by the three Maritime Provinces. It is an agency of the Council of Maritime Premiers. The program covers all three provinces and provides for:

- 1) survey control monumentation;
- 2) medium and large scale base mapping;
- 3) property mapping; and
- 4) assistance in establishing provincial land titles systems.

The program was originally considered a four phase program. The latter phases, a land titles system and a land information system were perceived as the ultimate goals which justified the heavy initial outlay on monuments and base maps. It is now recognized that these initial outlays have proven to be cost-beneficial in their own right.

As already mentioned, one of the major LRIS activities is base mapping. Medium scale maps (most at 1:10 000) have now been produced for the entire land mass in the Maritimes. The current inventory is orthophoto mapping with some sheets available in line map format as well. Larger scale line maps (1:10 000 to 1:4 800) have been produced for the urban areas.

Some years ago, it was obvious we would eventually do base mapping digitally. Our experiences in the selection process may be interesting to others in the mapping field about to purchase digital equipment. This paper attempts to describe that selection process.

It is perhaps worth noting that, despite the fact that no effort is being made to promote them, there is a substantial growth in "information systems" now taking place in the Maritimes. Providing a good consistent base for that information, whether it be conventional hard copy maps or digital base map data, has been the catalyst for this informal development of information systems.

When we started the process of selecting digital base mapping equipment, we were aware that the equipment chosen would have a significant effect on how efficiently digital data could be used by others. We were also aware, though, that preoccupation with selecting equipment for an "information system", rather than for base mapping could easily lead to unacceptable inefficiencies in our base map production. This paper also attempts to describe how these influences affected our choice.

STEPS IN THE ACQUISITION PROCESS

We used seven basic steps in the process needed to acquire digital base mapping equipment:

1. Get approval for money for the equipment.
2. Prepare a Request for Proposals (RFP) and send it to all interested vendors.
3. Evaluate the responses to the RFP sent in by prospective vendors and select a "short list" of vendors to be benchmarked.
4. Perform Benchmark Tests.
5. Compile the results of the Benchmark test, comparing strengths and weaknesses of the different systems, to decide with which vendor(s) to negotiate.
6. Negotiate contract terms with remaining vendor(s), get best price, determine attitudes about service, investigate financial viability of vendor, evaluate other risks.
7. Select a vendor and sign the contract.

REQUEST FOR PROPOSALS

Our Request for Proposals was prepared in the April to June period of 1981. It was a time-consuming process, mostly because it was the exercise which forced us to decide, in considerable detail, exactly what we required in a digital mapping system. We had to examine our manual procedures and determine how many of them should be automated. We knew enough about the market to understand that there were no systems which had all the features which we would like to have, so we had to go through the process of deciding which features were absolutely necessary and which were merely desirable.

Further complicating the issue was the business of checking with the users. Seminars were held in each Provincial capital. Long discussions took place on the necessity of having a system which would handle "polygon" information efficiently. Many of our "downstream users", particularly of the resource series, were probably going to require a system which could treat polygons and the related attribute data simply and efficiently. How important was it for us to have a system which could also handle downstream problems? Would it be sufficient if we simply bought a system which could translate its data into a format suitable for a system which did handle polygons? Would the data be suitable at all for downstream users if it was pure "line" data (as is normally the case with base mapping systems)? In short, how much efficiency would we have to sacrifice in data collection to provide that data in a format which was most suitable for other users?

Our investigations showed that there were two "families" of systems. One was line based and the other was polygon based. It seemed that base mapping was done most efficiently on a line based system.

We felt that a translation program for data produced on a line system to be used by a polygon system might be a very difficult, if not impossible, thing to produce. We decided to treat polygon manipulation as desirable rather than necessary in the Request for Proposals.

The Request for Proposals was sent out on June 15, 1981 to about twenty vendors who had previously indicated an interest in receiving it. A copy of our RFP is now available publicly for the cost of copying. (However, it is a document specific to LRIS needs. Moreover, in the final analysis, the exercise of deciding for oneself what to put in the RFP is highly educational.)

We tried to limit the number of vendors replying to the RFP, primarily because we knew it would cost them about $5000 each to prepare proposals. There is, however, no practical way to refuse to accept a proposal. Moreover, in retrospect, it seems several companies may have done it to gain experience. Most withdrew fairly early in the process.

EVALUATING RESPONSES TO THE RFP (AUGUST 1981)

We received six responses to the RFP. Most showed considerable thought and appreciation of our problems. We engaged consultants to help our project team evaluate these responses and determine which should be "benchmarked" to determine if they could really deliver all that they proposed. After a sometimes heated one day meeting, we decided to indicate to three of the firms that we would consider them as potential vendors if they successfully passed our benchmark test. All three of the vendors accepted the invitation to be benchmarked.

BENCHMARKING (NOVEMBER - MID JANUARY, 1982)

Designing the benchmark test and preparing the documents associated with it proved to be a time consuming task. It was necessary first to decide which features were essential and which were merely desirable, and then to devise some way to get the vendor's system to demonstrate these features.

The different test steps were organized to make the benchmark test go as quickly as possible, and the raw input data that was to be used in the test was prepared. The benchmark document, together with sample maps and typical stereopairs, was sent to vendors about a month in advance. We visited each vendor to explain in detail what would be required of the benchmark test and to emphasize that data should be compiled before the test was begun.

We told the vendors that different stereopairs (ones that would tie with those sent earlier) would arrive with the benchmark team, and that these would be compiled at the time of the benchmark. (The benchmark document is also available to those who could use it. Like the RFP, it was written specifically for LRIS needs and should be treated as such.)

The actual benchmark was done by a team consisting of 2-3 consultants, one staff member, and one member of the LRIS Board of Directors. Technical staff from LRIS were also on hand to advise the benchmark team members on how easily the equipment could be operated.

The team spent about a week "benchmarking" each vendor. Two days were spent testing features important in compilation, two days testing features important in editing, and the final day, plotting, catching up, and testing data base features. Each item in the benchmark document was evaluated and rated. We tried to determine the computer time required for various steps, in order that some estimate could be made of how much volume the system could handle. We were unable, however, to obtain satisfactory proof of volume production from any of the vendors. (Eventually they did, however, guarantee a volume level.)

The benchmark exercise is a costly one for the vendors as well as the purchaser. We had assumed it would cost each vendor about $15,000 to $25,000 to be benchmarked. The vendors were only too well aware of it, once they saw the proposed benchmark test. In the final analysis, only one vendor gave us an estimate of their cost - $40,000 to $50,000.

EVALUATING THE BENCHMARK RESULTS (END OF JANUARY, 1982)

At the end of the benchmark exercise there was a meeting of the benchmark team to rank the importance of each feature mentioned in the document, and to assign a value indicating how well the system performed each feature. These weighted results were added and then the total values for each vendor compared.

At the end of the benchmarking exercise, only two of the original three firms remained. Both were "big names" in the industry. While their strengths and weaknesses differed, the weighted results of our tests done in October and November of 1981 were almost identical. It was concluded that either one could do the job.

With the results of the benchmark test in hand, we went on to address several other factors important in the selection of a vendor: 1) local and international service reputation, 2) financial viability of the firm, 3) direction of the firm in hardware and software developments, 4) training programs, and 5) price.

Neither firm was eliminated after consideration of these criteria, but their strengths and weaknesses in each area were kept in mind during the contract negotiations.

(Our benchmark results are not available.)

NEGOTIATING THE CONTRACT TERMS (JULY - SEPTEMBER, 1982)

We opened negotiations with the two firms by asking for a quotation based on their equipment, training provisions and maintenance terms. Each vendor began negotiations by sending us their standard contract. We countered with our contract - a customer oriented document which had been drawn up by a utility in Western Canada and which had been the basis of their contracts with each of the vendors.

In addition to the provisions in this contract we added one major provision of our own - that the vendor be prepared to guarantee a level of performance reliability, and that this reliability standard would be maintained even when all the stations we ordered were in use at the same time and that this performance standard would not be deteriorated by hardware or software maintenance problems. This provision, in effect a guarantee of a production level, was eventually agreed to by both vendors.

The negotiations took about 3 to 4 months and were conducted as openly as possible. Each vendor was kept aware of the position of the other vendor on most matters. Certain items were, of course, confidential for technical reasons, but these were minimized, partly by virtue of the fact that the internal workings of their systems are "black-boxed". We had several negotiating sessions with each vendor, and finally got to the point where we were prepared to recommend a vendor to our Board of Directors.

SELECTING A VENDOR

This recommendation to our Board of Directors was based on several factors:
1) performance on the benchmark test;
2) reliability of the firm;
3) potential for downstream users;
4) likely ability to provide maintenance locally;
5) price;and
6) ability to tailor software to meet our needs.

However, just at this point it became obvious that things were moving too smoothly. Following an election in Nova Scotia, the Government put a freeze on all capital expenditures. It was not clear if this freeze extended to the Nova Scotia portion of funds in our budget. Discretion seemed to be called for so we treated the announcement as a freeze, regardless of their intent. It was nine months before that web became untangled and we were free to move.

In the meantime, a local vendor indicated he was ready to be benchmarked. Because the vendor was local, and showed much promise (polygon based, stand-alone units) we decided to benchmark his system, using the same procedure as with the previous vendors. (Systems analysts, return to step 2 at this point.) The other vendors were informed of this decision.

This system did very well on the benchmark test. Our standard contract was signed with the newcomer in April 1983, for delivery of equipment to start in September 1983. We expect to be in full production by April 1984.

The system we chose was CARIS (Computer Aided Resource Information System). Its software is composed of modules from several agencies, including "GOMADS" from the Canadian Hydrographic Service, some software from the Canadian Geographic Information System, some software written at the University of New Brunswick (UNB) and some software from Digital Equipment Corporation (DEC). It is based mostly on DEC computers with a microprocessor-based controller developed at UNB.

This system was particularly appealing to LRIS. It was designed principally for cartographic and geographic application. Each of the workstations is used on a stand-alone basis. The system is designed to handle polygon-type information in the same file as cartographic information, a feature which holds real promise for the continued development of land information systems in the Maritimes. In short, it will handle our production efficiently and, at the same time, allow for eventual use by those downstream users whose needs are polygon oriented.

The system is being installed at our Surveys and Mapping building in Summerside, Prince Edward Island. It will have 3 to 5 workstations connected to existing stereoplotters, and 3 or 4 edit workstations using digitizing tables. We expect to produce 350 to 450 map sheets each year on the system. The system will cost $1.5 - $2 million, including about $400,000 for a large precision plotter.

CONCLUSIONS

1. The benchmark process has definite merits:
   - It forces the customer to define its needs.
   - It provides reality about how well any system will do what you want it to do - a reality that may not come easily from salesmen's talk or demonstrations.
   - It provided an objective base on which to compare systems.

2. There are also drawbacks to the benchmark process:
   - It is a costly exercise for both the customer and the vendor. Staff time and travel dollars add up quickly, especially if consultants are used as part of the team. LRIS budgeted 10% of the final cost for the exercise ($200,000). It ended up costing us about $150,000.
   - It is a time-consuming process. New versions of software and hardware were announced or released between the benchmark time and the time that a system could be delivered.
   - The capacity of any system is not easily measured. LRIS used consultants partly to help get a fix on likely volume capabilities. In the final analysis we knew that the system would produce maps but not how many.
   - It measures only the ability of the system and equipment to perform certain functions. It does not measure the firm's reliability, service performance, the likely direction in their software and hardware development or their ability to tailor software satisfactorily. These things are at least as important as the one-time ability to perform on a benchmark test.
   - Although it is a mechanism for defining needs, our perception of the importance of certain features changed as the benchmark exercise progressed. The weighting values assigned to each step in the benchmark would be different if it were done today.

3. Taking these things into consideration, LRIS was satisfied with the benchmark process. An investment of up to 10% of the purchase price is not out of line for a good benchmark. Our staff gained valuable experience during the benchmark process and we are willing to share that experience with others.

ACKNOWLEDGMENT

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THE FLORIDA PILOT DIGITAL PRODUCTION PROJECT - A COOPERATIVE VENTURE BETWEEN THE U.S. BUREAU OF THE CENSUS AND THE U.S. GEOLOGICAL SURVEY

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ABSTRACT

The U.S. Bureau of the Census is currently planning to use computer-generated maps both during the enumeration of the 1990 Decennial Census and for publication with the resulting data. These maps will be generated from the cartographic subsystem of the Topologically Integrated Geographic Encoding and Referencing (TIGER) system, a geographic information system which is being developed by the Census Bureau to coordinate all geographic aspects of the next decennial census.

This paper describes the pilot production project of the U.S. Bureau of the Census and the U.S. Geological Survey to collect, encode, and structure 1:100,000-scale digital data for the State of Florida as the first step in creating the cartographic data base. Each task assigned to either the Census Bureau or the Geological Survey is presented in terms of its impact upon the project as a whole, along with a detailed description of the methodology devised to accomplish the task. In addition, the paper serves as an interim report on the progress of the project, and the coordination between these two federal agencies to create this cartographic data base which will be usable for both census and general-purpose cartographic applications.

GENERAL TRACK SESSIONS: PRACTICAL APPLICATIONS OF COMPUTER-ASSISTED MAPPING SYSTEMS

THE PRODUCTION OF AUTOMATED CHARTS OF EUROPE (PACE) PROJECT

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ABSTRACT

The Production of Automated Charts of Europe (PACE) Project involves the application of automation techniques to the production of a well established group of small scale aeronautical charts. The aim at the outset was to provide the cartographer with a range of tools and procedures that would result in an improved service to the user and reductions in costs. The system was designed to incorporate continuous maintenance of data in addition to the computer assisted output of chart separations at different scales. Emphasis was placed on a simple approach where digitising, interactive editing and plotting facilities could be integrated with the existing processes and flow-lines. No attempt was made to automate every element of the task and manual solutions were accepted if they proved to be more cost effective. A review after three years work on the project shows that virtually all the objectives have been met without significant difficulty and numerous products have been favourably received by the user.

INTRODUCTION

The Mapping and Charting Establishment RE (MCE) is responsible to the Director of Military Survey, United Kingdom for the production of a wide range of maps, aeronautical charts and related information for use by the Armed Services. Since the late 1960s computer techniques have been used to assist production processes wherever practicable (and cost effective) and automated cartographic procedures are now well established. Much of the resources of MCE are currently devoted to wholly digital work but there is still a very important requirement for the traditional paper product. Since 1976 considerable effort has been devoted to the application of automation processes to the preparation of small scale aeronautical charts.

The first MCE 'automated' air chart was published in 1978 and covered part of Arabia (Macdonald 1979). Experience in this relatively sparse geographical area enabled us to shift our attentions to the much more difficult theatre of NW Europe and introduce, for the first time in a major UK Military Survey mapping programme, a system of continuous maintenance. The concepts developed for the early work have been continued, with emphasis on an approach where computer assisted digitising, editing and plotting facilities are used as tools in the overall cartographic process. This paper describes the key elements of the system with details of the benefits, problems and future developments.

THE REQUIREMENT

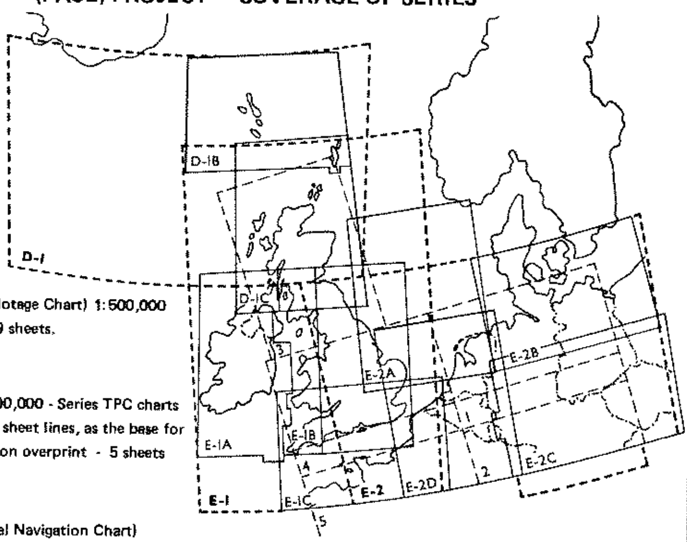
The Director of Military Survey UK has the responsibility for production of a number of topographical air charts in Europe for use by the Royal Air Force. For many years MCE has been tasked with production of

Series TPC (Tactical Pilotage Chart) at 1:500,000 scale and Series ONC (Operational Navigation Chart) at 1:1,000,000 scale on a cyclic revision basis.

Work on these very large format productions (58" x 42") has always been demanding because although the scales involved are small in cartographic terms the requirements for content are particularly complex and specifications are amended fairly regularly to suit the needs of the user. It must be stressed that these productions are intended to cover a range of applications and are as such, prime examples of cartographic compromise. The niceties of design are, quite correctly, subordinated to the stringent needs of the aviator. The task for the cartographer is to supress some of his traditional ideas concerning aesthetics and concentrate on depicting the very detailed specification with accuracy and as much clarity as practicable.

Charts covering Western Europe involve additional difficulties. In what is arguably the densest area of cultural detail in the world, change is relatively frequent and as can be seen from Fig 1 the sheetlines are overlapped to provide optimum operational coverage. This pattern of sheet distribution causes considerable difficulties with regard to revision and inevitably results in inconsistencies between adjoining charts with different generation dates.

PRODUCTION OF AUTOMATED CHARTS EUROPE (PACE) PROJECT - COVERAGE OF SERIES



D-1B — Series TPC (Tactical Pilotage Chart) 1:500,000 - the basic coverage - 9 sheets.

3 — Low Flying Charts 1:500,000 - Series TPC charts are used, with different sheet lines, as the base for a complex air information overprint - 5 sheets

D-1 — Series ONC (Operational Navigation Chart) 1:1,000,000 - derived from the Series TPC information - 3 sheets

Fig 1

In an attempt to overcome some of these problems and provide a significantly improved service to users in this extremely important geographical area, MCE carried out a study in 1979 in which we set out to show that the auto carto techniques used for TPC/ONC work in Arabia could be extended and applied to European production. The report on this study was accepted by Directorate of Military Survey, MCE was authorised to proceed and the new programme was commenced in February 1980 with data capture at 1:500,000. After early adjustment of the chart coverage the overall requirement for the Production of Automated Charts Europe (PACE) Project was established as 3 ONC Charts, 9 TPC Charts and 5 Low Flying Charts (LFC) - versions of the TPC base on different sheetlines.

It was accepted from the outset that a considerable investment was necessary to digitise the basic chart data and to some extent, the coverage was selected, and restricted, to take account of the resources that could be spared for the programme. Revision cycles were established that made provision for completely new first editions (replacements for current products) and the start of a programme for second editions of each chart, within four years. It was understood in the beginning that all the benefits of the proposed system would not be realised until the second edition phases. (Benefits are discussed later in this paper.)

THE BASIC PRODUCTION PROCESS

It is important initially, to examine the broad changes to the production line which have taken place with the introduction of automation. The traditional, 'conventional' process was essentially serial in nature - research for suitable source material was followed by cartographic compilation, drafting and the reproduction processes. Any derived production such as the LFC (reformatted from TPC components) and the ONC (recompiled from the component TPC charts) followed in due course. Revision work for any product was accomplished by recommencing the cycle - research, compilation, etc. One significant weakness of this long drawn out process for very large sheets in busy geographical areas, covering numerous countries, was the effect on currency and compatability. A European TPC could take about 2 calendar years in the pipeline, the ONC had to follow after the publication of at least four TPC charts - edges, overlaps, detail densities and specification were often out of step.

The PACE approach is a parallel process with research and compilation, including updating, treated as a continuous function with drafting, including automated plotting, undertaken as necessary. Once TPC coverage is available, output for LFC and ONC work can be commenced without significant additional research or compilation activity.

The key element in this changed procedure is the continuous revision process (described in more detail later). There is little point in digitising large quantities of data in order to output various charts unless provision is made for regular maintenance. This concept is fundamental to the PACE system and when the entire coverage is held in digital form as a data base or perhaps more correctly, a data bank, it is possible to output any of the charts, at any chosen time interval, with up-to-date content. The problems of overlaps and differing detail densities disappear in that the data base is contiguous and to a uniform compilation standard. The currency difficulties are also minimised as the TPC/LFC and ONC products can theoretically be produced in any order and at variable intervals with the latest version of the specification.

Broad details of each of the production stages are given below:

Research

The collection and analysis of a wide variety of source materials was a considerable task at the outset. The effort applied has now been significantly reduced to meet the needs of the updating system. New material, in the form of mapping, digital air information, etc is supplied to the compiler at regular intervals.

Compilation

This task was particularly demanding during the initial data capture phases as the compiler had to take into account more than one series as eventual output from the data base. Compilation extractions were produced from 1:250,000 source maps supplemented by a variety of other scales and types of information. These working units, although keyed to the 1:250,000 coverage, were generalised manually to suit the specification requirements of the 1:500,000 (TPC) and 1:1,000,000 (ONC) products. Ideally 1:250,000 data capture would have been preferred but we were anxious to complete first over cover in an operationally acceptable timeframe and minimise scale change (generalisation) problems. All features were assigned a six digit code, the sixth being used as a scale identifier - separation of data for use at different scales is very simple. The compatibility/density/ edge matching activities were extensive and required great care as we were determined to build this new data base to a very high standard in terms of both consistency and accuracy. The compilation effort was reduced significantly when first time cover of the whole area was completed in 1982 and the maintenance system commenced.

Digitising

Prior to this stage the research and compilation activities differed very little from the conventional approach, except for the added complexity of considering more than one product at a time. Compilation traces were digitised either by the compilers on manual tables or on semi-automatic devices (see "equipment"). Data was captured in point mode (as few coordinates as necessary) and held in machine coordinates coupled with essential plotter system commands - the format is uncomplicated, flexible and easily transformed or otherwise manipulated for a variety of functions. A series of verification and editing stages were performed before the data was lodged in the working data base.

Colour Separation

This heading embraces the automatic plotting of detail for a selected product ('windowed' from the data base for any particular area) and the manual preparation of relief shading, masks and other miscellaneous items. Most of the data is plotted, including almost all text and much of the air information component, but no attempt is made to automate every element - if an item is cheaper to produce by hand, that is the way it is done.

Reproduction

The outcome of the plotting and manually generated components is a set of conventional positives. These are combined and turned to negatives as necessary to produce a proof copy on plastic and eventually, printed copies using the percentage dot process in six colours.

EQUIPMENT

MCE has assembled a wide range of minicomputer based devices to meet numerous digital/auto carto requirements. We have always considered that relatively free-standing systems best suit the 'computer controlled cartographic tools' concept and that software development should, in the main be assigned to a Contractor with a specification from the production staff as to the precise requirements. This broad philosophy has worked over the years and we have successfully tuned our facilities to meet our needs. All systems incorporate a high degree of flexibility in order that we can respond quickly and efficiently on a wide range of product requirements. Brief details of the major facilities used in the PACE project are given below.

Digitising/Editing

Two main systems are used for data capture and editing both developed and installed by Laser-Scan Laboratories Limited, Cambridge, UK. The first, a cluster of manual digitising tables and interactive editing stations is linked to a VAX computer. The system software for both capture and edit functions is powerful and versatile and is used by MCE for many applications. The editing sub-systems (LITES) are equipped with both colour (1024 line) and monochrome VDUs and the extensive display facilities are particularly suitable for the updating/revision/correction of the complex PACE topographic data. MCE was involved in the cartographic application development of the second capture system - the Laser-Scan Fastrak. (Howman and Woodsford 1978), (Antell, 1982) This laser based line following digitising/editing/plotting device has significantly increased throughput of data for PACE and other digital products.

Plotting

A range of verification/edit plotters are utilised in MCE. Most of the PACE work is run on a Calcomp 1051 drum with satisfactory results. Finishing plotting of all PACE colour separations is undertaken on Ferranti (Scotland) Master Plotters. These machines, although old, produce excellent results on film using a photo light head which incorporates 64 exchangeable symbols. The very comprehensive plotting control software enables us to draw virtually any symbol or line pattern required, direct from drive commands inserted at data capture stage. Selection of detail, lineweight or symbols can be decided at run time and amended easily at any point. The only real shortfall in our plotting capability is the relatively slow speed of the finishing plotters. As output requirements increase, this area of activity can cause bottlenecks and we are currently actively seeking a solution. To this end, Laser-Scan have been funded by Military Survey to develop a new, fast laser device based on the methods employed successfully for plotting on Fastrak systems. New hardware and a sophisticated software package should be available in October 1983.

THE MAINTENANCE PROCESS

As mentioned earlier, a vital element of the PACE system is the continuous revision process. With the introduction of computer based techniques and the ability to update existing data rapidly such an approach is practicable and essential in order to obtain maximum benefit. It is also significant, that to revise chart data in small bites is much cheaper in the long run than to research entirely anew every few years - in our experience, 'revision' on this basis turns out to be 're-compilation' with all the attendant delays in supplying our customers' needs.

The process used for PACE is relatively straightforward and involves research staff, as part of their normal activities, identifying new information which updates the latest reference hard copy of the data base. New information is despatched to the compiler at regular intervals (generally monthly) and the aim is to cover the whole area systematically so that no country will be more than six months out of date at any one time.

New information is compiled in the form of overlays to the existing data, showing additions and deletions. Amendments are executed on the LITES interactive edit station using the colour visual display and the master working data base is updated accordingly. Careful documentation of change dates is essential and the data base records and chart histories are meticulously maintained.

Because the data base is held in component form (ie, by chart separations in the main) it is relatively easy to output check plots of any part or group of features, at any time. The compiler can therefore, still operate in his traditional mode, with a paper copy, in order to verify his inputs and monitor the contents of the data base.

PRODUCTION PROBLEMS

The basic steps and techniques developed at the outset are now proven and have served well for the PACE project. There were worries in the beginning concerning staff attitudes to the changing pattern of requirement for traditional skills; where drafting diminished and compilation and machine operation increased. These fears proved groundless - once trained, compilation teams have found the very demanding multi-series approach challenging and satisfying. The use of automated plotting techniques is a considerable advantage from a management point of view - machines draw very well and allow us to use our limited human resources for high quality subjective work, such as compilation, which the computer cannot undertake.

There were, inevitably, some problems in the early phases of the project. The study stage underestimated the quantity of large scale source material that was eventually used. The training of compilation staff took longer than was envisaged and the extent of requirements for supervisory, quality assurance work were not fully understood in the preliminary trials. Despite experience in Arabia we still had to follow a learning curve for the very much more complex work in Europe and there were some delays, against our schedules, for the basic area data capture phases.

Accepting that these early deficiencies are now behind us and the programme is well advanced, it is clear that there are still a few residual difficulties.

Project Management

This very complex project needs careful supervision and management to cater for the peaks and troughs of the many stages - estimating and quality control are particularly demanding. One rather significant aspect concerns the use of automated equipment - despite all the advantages there is one drawback - we are now machine dependent in some instances and management has lost a little flexibility compared with the conventional cartographic processes - machines do sometimes break down and generate bottlenecks in the system!

Scale Changes

Data produced for Series TPC at 1:500,000 is used for the ONC at 1:1,000,000 without filtering or smoothing (data densities are reduced based on the feature coding/scale identifiers). This system works well in almost all cases and only very infrequently is it necessary to 'double digitise' - produce two versions of an element of detail to suit individual scales. Generalisation is much talked about in auto-carto circles but few answers to scale changes emerge. The difficulty in the PACE data is really one of displacement - the traditional problem of fitting too much detail into a small geographical area, which we generally overcome by using interactive editing techniques to adjust the data base alignments and content to suit the different scales, prior to plotting the separations. Although this subject must be given consideration in automated production it is not too serious provided that a purist approach is not pursued - local adjustments of detail can be accomplished without serious penalty to the overall system - manually if necessary.

Data Complexity

The PACE project has special problems not encountered in earlier work. Very heavy cultural detail is overlayed with a particularly complex air information component. Despite the fact that we now hold much of our air data in digital form, the clashes of text and symbols necessitate a great deal of manual involvement, with some impact on schedules. The problem would be worse with a totally conventional process but we have gained less from automation assistance on this aspect to date than we would have wished.

Many observers of this system expected problems with the technicalities involved in the digital processes and with data storage. Neither of these aspects have proved to be troublesome. As already mentioned, our equipment was designed and tuned to suit our preferred methods and minor changes to procedures are relatively easily accomplished. The entire data base for the PACE system is held on a working disc of about 80 mb and the security back-up magnetic tapes amount to a handful - not a cause for worry at all in MCE. No serious technical difficulties occur with regard to the digital processes - as described earlier the problems concern traditional cartographic and management factors rather than equipment performance or data storage.

BENEFITS

As intended from the outset the real benefits to be derived from the PACE system concern the user:

Response Times

The major benefit is without doubt, the facility to produce rapid output from a current data base as required. Many of the old currency problems should disappear and printed stock of new editions could be made available in a matter of months from tasking instruction compared with 1 - 2 years for a conventional product.

Flexibility

Existing sheetlines can be altered easily to accommodate new requirements - LFC sheetlines have already been changed during the production cycle, to take advantage of this facility. Specification changes can be effected relatively easily by output of new components - any variation or selection of symbols and features is practicable.

Quality

The base detail for TPC was compiled and digitised with great care and a high quality data base now exists. Positional accuracy and data selection consistency were major points of concern during the data capture stages and will ensure that any future output, for any product, is maintained at the same standard. Periodic amendment of original components in the traditional process resulted in serious degradation of quality due to re-drafting and photo-mechanical copying. This no longer applies as repeated output from a plotter can be maintained at a constant standard. Overlap problems between sheets and inconsistencies between series aud editions will be minimised.

There are of course, benefits within Military Survey also:

Costs

The initial data capture task and output of the first PACE editions will cost approximately the same in man hours and calendar time as the equivalent manual, traditional process. The advantage is that a data base now exists and the maintenance programme will be significantly cheaper. Products derived from the TPC base (LFC and ONC) cost roughly 60% less for the base detail than with manual techniques and the revision process, using interactive editing, is from 40 - 60% cheaper in cartographic effort.

Utilisation of Staff

As mentioned earlier, the adoption of automation assisted techniques has enabled MCE to utilise expensive skills to best effect and to maintain a high standard of interest. Considerable numbers of staff have now gained exposure to the auto-carto world through involvement in this project and this background is valuable for other applications.

RESULTS TO DATE

The complete data base is now held in working disc form with back-up magnetic tape copies, is readily accessible for any purpose and is under continuous modification as new data is received. Five TPC charts have been published, the remaining four new editions are very close to completion, one LFC is about to be published, the other four will be during 1983, the first ONC (E-2) will be printed by September 1983 and the remaining two will go to print before the end of 1983. Preparation for the PACE revision output is well under way and the first sheet was commenced in June 1983.

The published charts in this programme have been well received and it should be noted that the appearance of these automated products is virtually identical to that achieved in the traditional way - the methods employed in preparation are transparent to the user and no attempt has been made to influence the preferred presentation to accommodate computer assisted techniques. It is also of interest, that as well as providing the source for output of numerous charts as its prime function, the PACE data base has been used by many other customers for a variety of display facilities. The data base is held in a simple format with an effective directory system and manipulation to suit other purposes has not been difficult or costly.

THE FUTURE

The entire process involved in the project is under review and subject to refinement at all times. There are a number of ways in which the system could be advanced:

Extension of the Area

This matter has been under review for some time. It is primarily a question of resource priority - as already mentioned the initial data capture for a new area represents a significant investment. There are no technical constraints on extension of the existing coverage to embrace further geographical areas.

Other Outputs

From the outset the PACE system was designed to allow a variety of products to be output within the 1:500,000 to 1:1,000,000 scale range. It is easy to plot different map symbols and lineweights from those used for TPC/LFC/ONC from the basic data and there is potential for further production economies by extending the process to encompass other series.

Intensification of Data

It is feasible to enhance the basic 1:500,000 data base with insertion of (say) 1:250,000 digital information thereby extending the range of products that could be supported. Such an approach would of course increase some of the generalisation/displacement difficulties experienced with scale change.

The PACE system is very much a live project and small but significant improvements are regularly introduced by the production teams. Other components (eg, relief shading) will probably become candidates for computer assisted solutions in due course and changes to our users' requirements will also necessitate reappraisal of techniques from time to time. The remaining problems on aspects such as air information depiction provide a stimulating challenge to all involved.

CONCLUSION

We have moved a long way since our early work with automation of aeronautical charts in Arabia and our original philosophy, concepts and ideas on processes have proved to be generally sound. Despite some ups and downs, the transition into the PACE project was broadly as envisaged, this unsophisticated approach to production of a major chart series has been effective and we are confident that the significant benefits forecast will be achieved. There are numerous clever approaches proposed for automation in cartography not all of which ever come to fruition. We believe our straightforward, hands on attitude to computer assisted topographical map and chart production has something to offer and could be applied to many other map series.

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PRODUCT/MARKET MATCHING SYSTEM: A COMPUTER-ASSISTED APPROACH TO TOURISM PLANNING

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ABSTRACT

The purpose of this paper is to describe Tourism Canada's computer-assisted product/market matching system. Product/market matching is a simple concept: matching market requirements with product attributes. The system designed for Tourism Canada is intended to facilitate the planning of tourism development and marketing activity. Intended as a direct application of auto-cartographic capability to planning needs, the system's major components are a Quadtree structure for storing map data and a Graphic System to incorporate the major processes of the product/market match system.

INTRODUCTION

Over the last decade, the complexion of tourism has changed dramatically - in Canada and elsewhere. The accelerated economic growth of the sixties and early seventies spurred a boom in travel activity, characterized by random and extravagant consumption. In light of this relatively indiscriminate demand, there was little or no competition among suppliers of travel services and facilities. This rush to prosperity was interrupted by two energy crises in the seventies with growth slowing to a halt by the beginning of this decade, manifest in the recent recession.

This changing economic reality was accompanied by a shift in social values. Environmental concerns rose to the fore of social consciousness. Quality once again became a principle of consumption. Conservation has become a firm commitment rather than a temporary inconvenience. Together these factors have produced a consuming public which is more discriminating and more conscious of value for money. Moreover, this new demand pattern is considered fundamentally different in that its impact will last and not automatically reverse with economic recovery.

For the tourism industry, the new consumption pattern has constrained the growth of demand. On the supply side, the corollary has been an expansion of competition. Quality of plant, competence of personnel, level of service, price, location, additional amenities and variety have all once again become crucial variables to the health of the tourism trade. This competition extends globally. Every country in the world has a tourism industry and for most it is an important sector. Industry health in a given country is, in many ways, a relative phenomenon.

To the Canadian economy tourism is extremely important. Representing $16.5 billion annually, tourism accounts for over 5% of national GNP. Over 100,000 businesses and more than 1 million jobs are directly associated with tourism. As this tourism income filters through the economy, a further $28 billion is generated in indirect jobs and income. Clearly, the health of the industry is a national concern. The federal government, through Tourism Canada, regards the tourism sector as a vital instrument of economic development.

THE NEED FOR A PLANNING SYSTEM

If Canada is to expand its share of the increasingly demanding tourism market, planning is key. Tourism plant takes time to put in place, necessitating planning not for the present but for the future. In contrast with the scattered and disjointed tourism facilities characteristic of the industry's past, the current concept for tourism development is destination zones. These zones are specific, but not rigidly prescribed, geographic locations of potential for tourism development based upon significant tourism factors (Gunn, 1982). Product/market matching can be used to identify these destination zones.

Fundamental to planning under the destination zone concept is the ability to identify those locations where there exists the potential for a critical mass of plant and service which addresses market demands. If a critical mass can be developed in such locations, a synergy may be effected which will, in turn, facilitate self-sustained growth towards a fully developed destination area.

To assess the potential of comparable locations and markets, crucial planning elements must be evaluated. Locational factors include environmental features, recreational potential, existing infrastructure and myriad others. Against these evaluations must be applied a layer of market factors, such as demographics, economic forecasts, leisure trends, income levels, changing tastes, education and others. Gridding these two sets of factors should reveal those destination zones suitable for tourism marketing and investment planning.

Tourism planning in Canada's public sector is done by both the provincial and territorial governments and by the federal government. The objective of this planning has been to encourage sensible economic growth of the tourism industry through marketing and incentives to private tourism investment. Into this planning process must now be integrated the concept of destination zones. However, without sufficient regard for optimizing development in a national or regional context, the relatively independent efforts of different levels of government can result in a series of competing opportunities. The challenge is to develop a practical planning system which will not only identify potential destination zones, but which will facilitate better tourism marketing and development decisions leading to coordinated and balanced growth of the tourism industry in Canada.

THE RESPONSE

Tourism Canada, the federal government agency responsible for tourism development and marketing has taken up this challenge. For several years, Tourism Canada has been moving towards a product/market match capability. Since the early 1970s, Tourism Canada has been steadily creating several major data bases and a new planning system which will facilitate coordinated tourism development. A major step has been the creation of a national inventory data base (under development since 1980) which is a key source of information on Canadian events, attractions and accommodation facilities. To complement this product information, Tourism Canada has conducted numerous market research studies in Canada, the U.S. and several overseas countries which provide useful insights into attitudes, perceptions and preferences of specific market segments.

This information serves as an invaluable tool by which comprehensive and rational proposals for tourism development initiatives can be developed, especially when a national or regional perspective is required. The product/market matching system now under development is a major integrative component of the planning process.

A search of technological literature revealed that while many computerized systems exist, none are specifically configured for tourism planning. A systematic approach to this process was required. Tourism Canada contracted DPA Consulting Ltd. of Ottawa to undertake a four phase process to design and develop a system suitable to these planning needs.

In terms of technology, Tourism Canada's product/market matching system will be a first for Canada's tourism industry and puts Canada in the forefront of high technology applications to tourism planning.

THE PRODUCT/MARKET MATCH CONCEPT

The product/market matching model is not a new one. Other industries and government bodies apply variants of the model in specific contexts. Conceptually, product/market matching is very simple: to match market requirements with product attributes.

At Tourism Canada, "matching" is defined as a two step process aimed at achieving "macro" and "micro" analytical goals. Macro analysis involves the identification of opportunities. For example, given the attributes of a tourist market segment, those locations in Canada (or a region of Canada) can be identified which most closely match the known or perceived needs. Similarly, given the attributes of the tourism product, those market segments most likely to be attracted to the destination can be identified. Alternatively, and key to tourism planning, market segments and locational data can be correlated to identify those improvements which are required to make the location attractive to the segment. At a broader level, tourism attributes of other countries can be evaluated against market preferences to assess Canada's competitive position.

Micro analysis is the subsequent detailed financial and economic assessment of specific development opportunities or plans in a particular location. For example, how the tourist market will be shared among competing facilities, the projected financial performance of a proposed tourism project or development plan, the estimated impacts (direct, indirect or induced) and net economic performance of a proposed project.

The system being developed for Tourism Canada provides the capacity to simultaneously consider the many spatial attributes representing tourist activities or plant descriptors. Moreover, computerizing this process will provide the flexibility required to respond to ever-changing product and market factors.

By level of analysis, the macro analytical process will be phased into operation first. This is a relatively new process in the tourism industry. The macro analysis will use a series of maps representing different aspects of the tourism product in conjunction with market preference criteria to identify, via an overlay process, the location of the product/market match. This spatial representation is a critical

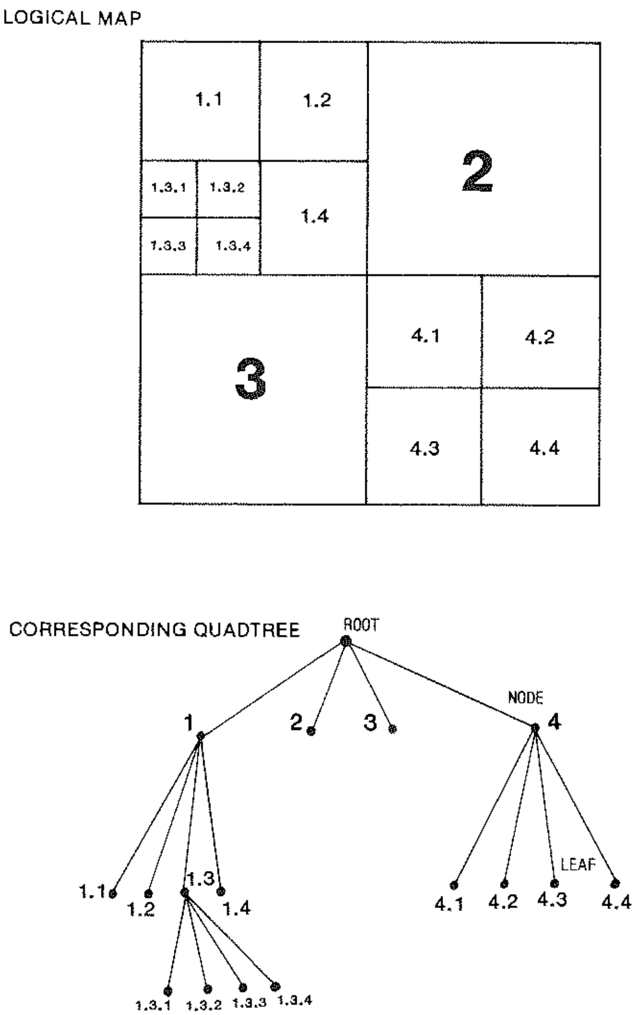

FIGURE 1 SCHEMATIC DESCRIPTION OF QUADTREE

dimension of the destination zone concept of tourism planning.

SYSTEM OVERVIEW

The hardware configuration for the product/market match system includes a Spectrix micro-computer with an M6800 micro-processor, a 30 megabyte hard disk, a Matrox GXB 1000 color graphics board and peripherals for input and output. Major software components include a Quadtree structure approach to store map data and a Graphics System which incorporates the major processes of the product/market match system.

User Interface

The product/market match system is completely driven by a set of menus which are displayed on the terminal screen in a sequence controlled by the user. The menus are designed to aid the user in generating the various available reports (at the macro or micro level) and the desired map overlays (applicable to macro analysis only). At any point in the system, numerous 'help' screens are available upon request to supply additional details relevant to the current display. Also accessible at any point are inquiry screens concerning colour codes (a list of colours with their corresponding codes is displayed), map keys (a list of map keys in hierarchical order, alphabetical order or by category as specified by the user is displayed) and map IDs (a list of map codes and corresponding map titles that contain all map keys specified by the user is displayed).

Quadtrees

In order to store maps into memory, an image representation with minimal storage requirements is necessary. The quadtree is extremely efficient in that it deals with entire regions instead of single pixels (coloured points on the screen). The quadtree is physically similar to a binary tree in that a node, "the father", is subdivided into more nodes and so forth. The only major difference is that the father node of a quadtree is subdivided into four nodes as opposed to two for the binary tree. Figure 1. schematically describes the conversion of an image to the corresponding quadtree. In order to create the quadtree, a square image is subdivided into four equal quadrants. If a quadrant consists entirely of one attribute (or colour), then the corresponding node becomes a leaf and is assigned a colour code. As Figure 1, illustrates, nodes 2, 3, 1.1, 1.2, 1.4, 4.1. 4.2, etc. are all leaves that would contain the colour code of the area which they represent. If by examination it is determined that a quadrant does not contain a unique attribute (or colour), then the quadrant is further subdivided into four more quadrants and the process of examination is repeated.

Notation for a quadtree is as follows:

1) The root of a quadtree is the node from which all the nodes expand. The root is unique in a quadtree.

2) A leaf is a node with the characteristic that it has no sons, thus it is not further subdivided. A leaf is often referred to as a terminal node.

3) All other components of the tree are simply called nodes.

If an image has large quantities of small areas and points of different colours, such as maps, then a simple matrix representation of each point of the image can require considerable amounts of memory space. Consider a colour screen consisting of 1024 x 1024 pixels (coloured

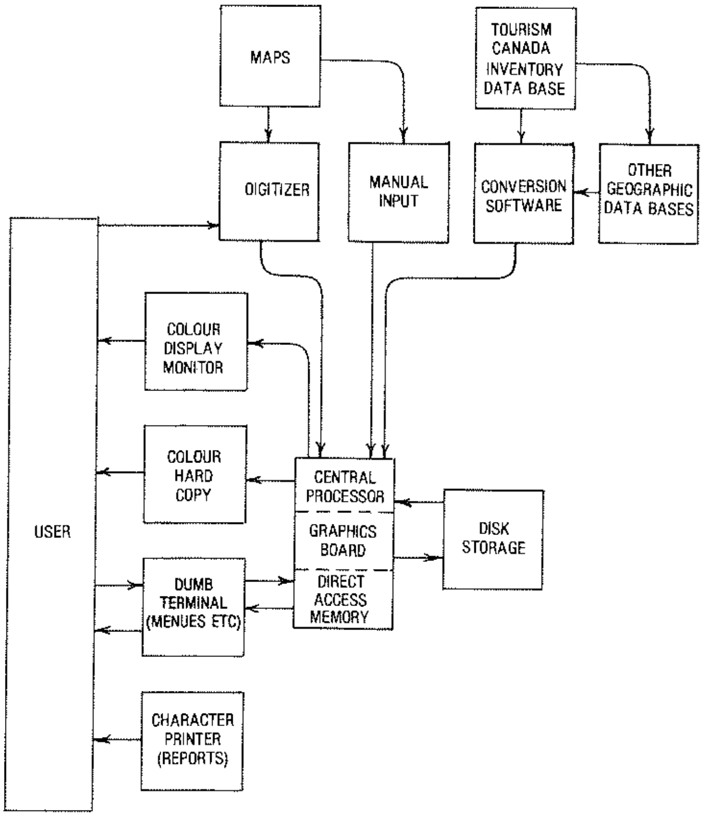

FIGURE 2 TOURISM CANADA COMPUTER SYSTEM DIAGRAM

points), then it is realistic to assume that a matrix representing this image could occupy in the order of 1 Megabyte of memory. That is obviously unacceptable since most micro-computers cannot address more than 1 Megabyte of memory, and the overlay process deals with three images simultaneously: the two original maps and the resulting map. The selection of the quadtree image representation is of significant importance for the storage and image processing efficiency of the graphics system. While the specific storage and processing time efficiency will vary depending on the complexity of the images being represented, analysis suggests that on average the quadtree approach will reduce storage and processing time by a factor of 10 over the pixel by pixel method.

The first major discussion of the use of quadtrees explained the idea of the quadtree and proved the advantages of such a storage method mathematically (Hunter, 1978). Further developments were made expanding the concept of the quadtree into codable algorithms (Samet, 1981). However, most of the existing literature considers black and white as the only possible colours in an image. For the Tourism Canada system an enhancement was required to this methodology to distinguish between as many as 256 colours, each colour representing a different combination of intensity of blue, green and red.

Input/Output

Figure 2. represents the product/market match computer system. The major input to the system comprises a variety of maps of Canada and its regions. Each map represents either an attribute, such as weather conditions, accommodation, distance from airport, etc. or a breakdown of Canada into counties, census divisions or other meaningful sub-regional zones. Base maps can be created through a manual digitizing process or they can be created automatically from Tourism Canada's inventory data base which is geocoded. The following information is associated with all maps:

1) A map identification number for retrieval purposes;

2) A map title;

3) A set of up to five map keys (key words to describe the map), again for retrieval purposes;

4) A legend describing the sections of the map;

5) A colour shceme, where each legend item corresponds to a different colour.

Three devices are used as principal output media. Firstly, a terminal where the interaction between the system and the user takes place. Secondly, the colour monitor where maps or reports can be displayed. Finally, the colour printer where hardcopy maps are reproduced according to the user's request.

Process Description

Figure 3. illustrates the system data flow. The Graphics System contains seven main processes described as follows:

P1. Map Management System. This system is an interactive process used to retrieve and store tree representation maps in the Map Library, and to store or update information on the maps in the Map Library Dictionary. The process also includes the creation of rasters used by

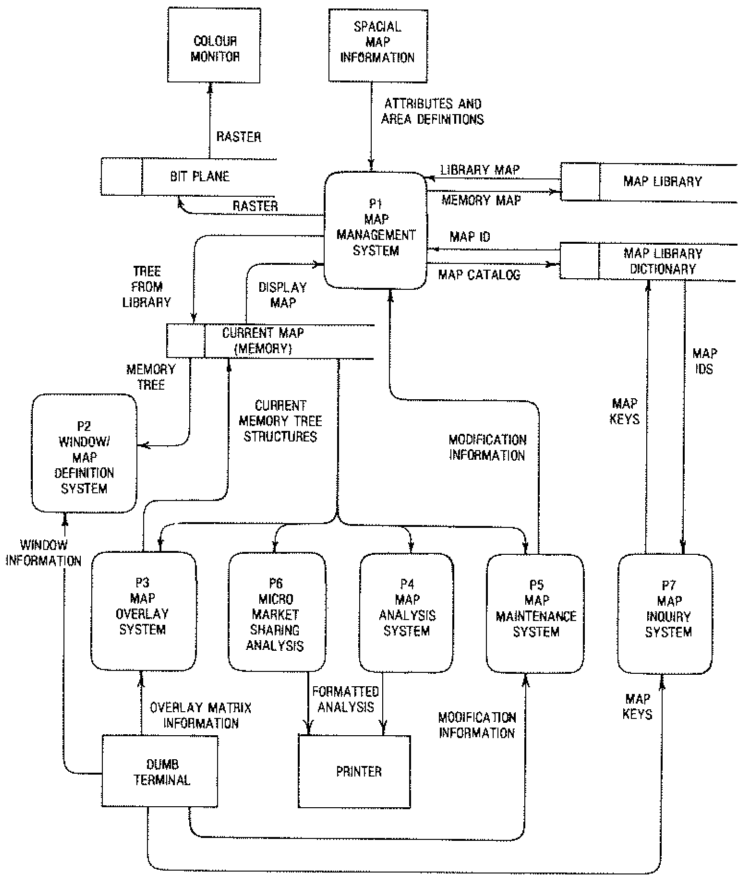

FIGURE 3 **DATA FLOW DIAGRAM — OVERVIEW**

the display process.

P2. Window Definition. In general, the entire map of Canada is not required for analysis. In this case a 'window' can be defined; that is, a rectangular subdivision of the original map or a predefined zone (e.g. a tourism zone - Cape Breton). Only the area covered by the window will be affected by subsequent map manipulations and considered in analysis until a new window is defined. The size of the window can be increased, but cannot exceed the boundaries of the map of Canada, or decreased to cover only a few square kilometres.

P3. Overlay Process. The overlay process is the basic tool for macro analysis in the product/market match system. When an overlay is requested (only two maps can be overlayed at a time), a default legend for the resulting map is displayed and may be modified if desired. A standard overlay matrix is generated and it may also be changed. (The entries in this matrix represent the legend items in the two original maps.) After the overlay is made, the resulting map may be stored in the Map Library or discarded.

P4. Map Analysis System. This process will perform an analysis of a single map or will perform multiple map correlation analysis. The process will use maps as input and will generate a series of formatted reports to be output on a printer or other device. These reports are made at the macro level.

P5. Map Maintenance System. This process will perform certain maintenance tasks on the map that is currently displayed. This process is interactive, using the current map as input along with modification parameters specified by the user and modifying and updating the map and the map representation structure with the appropriate changes.

P6. Micro Market Sharing System. This process will evaluate the suitability of a particular market segment within each zone and estimate the zone's market share, i.e. number of visitors. The general purpose of this process is to estimate the impact of the increase of resources in a particular zone (e.g. a new hotel) on the market share.

P7. Inquiry System. At the user's request, this process will assist the user by displaying map IDs and titles, map cataloguing key (used to identify a map with characteristics), and colour codes.

BREADTH OF SYSTEM APPLICATION

Originally conceived as a planning tool for tourism product development, system capability could eventually extend to many applications. Once development opportunities are identified through macro analytical map overlays, micro analytical processes can be applied to evaluate competing options. For tourism marketing, the ability to correlate product attributes and market preferences will permit more targetted and selective marketing campaigns. As a continuing, operational application, the product/market match system will be a tremendous asset to Tourism Canada's toll free 'hot line' through which travel counsellors provide information to thousands of travellers in Canada annually.

Once refined and tested by Tourism Canada, the system may be made accessible to multiple clients within government and to private sector tourism investors and developers. Eventually, if certain constraints are overcome (outlined below), direct access may be available to tourism consumers. This latter application could involve the installation of compatable hardware and transmittal software in the domestic and international offices of Canadian government departments. Prospective visitors can then access the product/market match system directly for detailed information with which to plan their trips. Other on-site installations under consideration may be international conventions and exhibitions, enabling visitors to access the system and thereby encouraging them to extend their stay in Canada. In interaction with consumers, the system will have data capture capacity allowing all consumer inputs to be stored in memory, thereby providing a large base of actual data for further research and analysis.

APPLICATION CONCERNS

Two primary areas of concern have been identified to date regarding the product/market match system. The first is a very fundamental concern regarding the ability to 'match' product and market information as they are presently in the data bases. For example, product information is often defined in terms of 'hard' or physical attributes (e.g. location, type of amenities, capacity, etc.), while market preferences are often defined in 'softer' terms (e.g. visitors wanting a 'hospitable', 'exciting', 'quality' holiday). The level of matching will be relatively restricted in the early phases of system use until product and market information can be defined in more comparable terms (apples and apples) or until an appropriate indexing system can be devised.

The second area of concern regards future direct access to the system by consumers. The hardware at the receiving computer terminal must be capable of quickly generating hardcopy maps of high quality, that is, in multiple colours with sharp definition. Ensuring the availability of hardware with this capacity for speed and quality involves considerable expense. Another concern is associated with using one software package for transmitting data to the variety of hardware configurations throughout Canada and the rest of the world. Direct consumer access will be restricted until these system component issues are resolved.

CONCLUSIONS

The product/market match system promises to be a great advance in tourism planning techniques. The system can move from aggregate analysis of Canada as a whole to site-specific analysis of very discreet areas. The particular cartographic techniques employed in this system have substantially enhanced the ability of Tourism Canada to efficiently and comprehensively assess tourism opportunities and thereby help the federal government contribute to the more rational economic development of a vital industrial sector.

ACKNOWLEDGMENT

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GEOCARTOGRAPHICS - A GRAPHICAL SERVICE FOR STATISTICAL DATA

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ABSTRACT

Geocartographics services have been available to the Census and other areas within Statistics Canada for over ten years, and have been provided to other government and private agencies on a cost-recovery basis since 1979. Beginning with basic digitizing, plotting and thematic mapping capacities for geo-coding and portraying Census data in 1971, these services have evolved to include complex thematic maps, graphs, maps to support collection of census and survey data, and reference maps for demonstrating the geographic structure of statistical data.

This paper traces the evolution of these products and services, and highlights significant systems acquisition, development and adaptation activities. Current activities, trends and future possibilities are also discussed.

INTRODUCTION

Statistics Canada, as the national statistical agency, must collect, process and disseminate vast amounts of socio-economic statistical information. Almost all of this information can be graphically represented, and much of it is also spatially referenced and therefore amenable to cartographical display. With the advent of computer technology and the development of computer graphics capabilities, Statistics Canada began exploiting this technology.

A TRADITION OF SERVICE

Geocartographics can trace its beginnings back to the late 1960's with the development of the Geographically Referenced Data Storage and Retrieval System (GRDSR) for the provision of ad hoc tabulations of micro data from the Census of Population.

Building and maintaining the necessary cartographic framework for the GRDSR System required specialized equipment and methodology to digitize cartographic features such as streets, rivers, etc. By 1974, this activity had been extended to digitizing the boundary files and the street networks of the 33 urban centres in Canada with populations 50,000 or more. Work began by using an off-line digitizer and by 1976 computers and software were acquired to permit on-line digitizing and editing. These acquisitions also included cathode ray tubes and hard copy attachments for displaying cartographic data.

In 1970, a small drum plotter was acquired mainly to produce edit plots to support GRDSR digitizing. With the increased workload foreseen for the 1976 Census, a faster and more accurate plotter was purchased. It permitted not only edit plots but medium quality camera-ready outputs for graphs, diagrams and maps. At the same time, a stand-alone interactive design and edit station was acquired to permit creation, update and edit of drawings. This has been used subsequently for charts, forms, PERT diagrams, organization charts, machine configuration diagrams, etc.

Organizationally, the activities of acquisition, development, support and operation of the equipment were part of the Spatial Systems Section of Census Processing Division consisting of the:

- Spatial Research and Development,
- Spatial Data Display,
- Geocoding, and
- Geofile Units.

In 1979, the first two units and the machine operations function were combined to form the Geocartographics Subdivision with the task of serving not only the requirements of Census but those of other parts of Statistics Canada and users outside the Department as well. It was located with other central computer-related services in the Systems and Data Processing Branch of Statistics Canada. Concomittant with this broadening of the client base was a shift in emphasis from mainly research and development for Census to production services built upon the earlier developments. In subsequent years, the group grew in number from 6 persons to a peak of 40 and is currently operating with a staff of 30.

In developing the Geocartographics services, software was acquired and/or improved. Included was software for:

. conversions of map projections (EMRTABS, SYSBET, PILLAR);

. interactively compiling, editing and updating maps and digital geographic base files (AUTOMAP);

. cartographic display of statistical data (SYMAP);

. compilation of maps and graphics (GIMMS);

. digitizing and editing of polygon segments (GUESS);

. graphics (Tell-A-Graf); and

. block adjustment (KRATKY).

Much of this software was acquired to operate on the large central computing facility at Statistics Canada. GUESS and AUTOMAP, on the other hand, were implemented on minicomputers supporting on-line digitizing. In 1981, a large minicomputer was acquired to meet most of the interactively oriented processing needs. Since this computer needed only to deal with aggregate statistical data and geographic data, it did not require the high security of the Department's facility which holds micro data. Thus it is anticipated that this computer will be able to link to others outside the Department, thereby permitting sharing of cartographic data. In 1981, Geocartographics acquired colour graphics terminals and a colour hard copy device (a Matrix camera for 35mm slides or 8 x 10 prints or transparencies). In addition, with lower cost devices now available, users throughout Statistics Canada could acquire their own colour terminals and utilize central services for high quality work.

It can be seen from this brief background that the Geocartographics Subdivision has evolved over the past decade in many ways. With respect to personnel, the staff has grown from a small number of professionals to a larger interdisciplinary team of geographers, cartographers, mathematicians and computer specialists. Production responsbilities have necessitated the addition of cartographic draughtspersons, computer and equipment operators and software support persons to the team. The hardware has been augmented to enable production volumes and to take advantage of current technology. Software has been extended and increased to support production and further development of the product line. The trend has been increasingly to the acquisition and implementation of packages with relatively less in-house software development. The range of services and clients has expanded from specific support to Census of Population to the complete cartographic and graphic support required by an entire national statistical agency and to the provision of such services to other agencies.

GEOCARTOGRAPHICS SERVICES

The Geocartographics Subdivision addresses areas such as cartography, graphics, storage and retrieval of geostatistical data, geography, man/machine communication, geographical data entry and display, and consulting. The full range of current services can be described as follows:

<u>Computer-Assisted Graphics</u>
This covers a wide variety of graphical presentations that can be derived from statistical data stored in the computer. These include pie charts, histograms, line charts, scatter diagrams, etc., in which the computer, through software, calculates the size and placement of the graphical components based on the specifications of the user.

The graphics packages available are enhanced by software for colouring, shading, graph layout and text. Together with appropriate hardware (medium quality plotters, graphics terminals), quality output can be produced suitable for publications or for slides.

Computer-Assisted Cartography

An area of particular interest to a statistical agency is the production of thematic maps to display geostatistical data. There are four types of thematic map products:

- Choropleth Mapping;
- Dot Mapping;
- Proportional Symbol Mapping; and
- Three Dimensional Mapping.

Computer-Assisted Geography

As an adjunct, capacities were developed or acquired to permit manipulation, generalization and analysis of geographical and geostatistical data. Software systems include map projection transformations, generalization, area and centroid calculations, and classification of data.

Computer-Assisted Drafting

In addition to mapping and graphics, a computer-assisted drafting capability permits the user to interactively design and edit forms, diagrams, charts and other artwork. Such applications have included organization charts, PERT charts, and layouts of computer communications. Recent work has included the evaluation of systems for computer-assisted preparation of floor plans especially suited to the dynamic open office concept in current use in government buildings.

Geocartographic Data Entry and Edit

Hardware and software are required to capture and edit geocartographic data such as shorelines, boundaries, streets, and points of interest. A typical system consists of a digitizing table to allow entry of XY coordinates, an alphanumeric terminal to enter feature codes, a graphic terminal to display the graphic and facilitate editing and an interactive computer facility to control the data capture and the editing. Software available provides the ability to identify and handle points, lines and polygon segments and to construct whole polygons from polygon segments.

Geocartographic Data Display

Two moderately high resolution drum plotters are being operated to support all the previous services. Edit quality plots are produced by ballpoint pen on paper while publication quality (including colour separations) are usually produced employing a lighthead on photographic film.

In addition, maps and graphs can be displayed on black and white or low to medium resolution colour graphics terminals interacting with our larger computers. An electronic camera hooked to the terminals can permit medium quality colour hardcopy of what is on the screen.

Geocartographics Systems Development

In order to develop and support these services, a team of software specialists has been formed and computer systems have been acquired and/or developed and enhanced. Design activities have focused on developing and enhancing modules for geostatistical products and improving the interfaces between our various systems and between systems and users.

Some specific developments include the automatic generation of double line streets from Area Master Files, improved interactive editing, and text placement.

Geocartographics Computer Processing Service

With the acquisition of a large minicomputer, the Geocartographics Subdivision supplies processing to a wide variety of users. Some users have acquired their own graphics terminals, small plotters and microcomputers, and Geocartographics provides a host system with hardware and software on which they can do their own processing.

Geocartographics Consultation and Support

The multi-disciplinary specialists gathered into the Geocartographics Subdivision, through their experience and knowledge, constitute a unique resource. Within Statisics Canada they render advisory and support services over the whole range of geocartographic activities. In addition, they participate in technical committees, task forces, and work on interdepartmental and international committees (e.g. SORSA, AUTO CARTO VI).

PRODUCTS OF GEOCARTOGRAPHICS

As Geocartographics has evolved it has had some notable achievements and products of which a few will be discussed here. Some of these products could constitute the subject of separate papers.

Thematic Maps for Census of Population

For the 1971 Census of Population, some statistical maps were produced using line printer hardware and SYMAP-based software. Later more sophisticated hardware such as pen plotters and software such as GIMMS permitted the production of higher quality thematic maps.

Since most Canadians now live in cities , thematic maps of metropolitan areas on various themes were expected to be of wide interest. For the 1981 Census, thematic atlases of the larger CMA's (Census Metropolitan Areas)"in Canada will be published portraying 34 themes at the CT (Census Tract) level.

Agriculture Atlases

The 1976 Census of Agriculture data was used to produce an atlas of statistical maps to illustrate various themes. This publication containing 113 maps without statistical tables and quickly sold out both printings. Reaction was extremely favourable and another atlas for the 1981 Census of Agriculture is being produced. This publication differs from the earlier one in that it contains more textual analysis, fewer maps but a large number of graphs.

Mortality Atlases

A two volume Atlas of Mortality was produced as a joint project of Health and Welfare Canada and the Health Division of Statistics Canada based on mortality information compiled by 1976 Census Divisions. Volume 1 contained rates due to cancer in the major anatomical sites. Volume 2 depicted general mortality with 34 maps showing spatial variation of major causes of death. The source of information was death certificates for the period 1966-76. These volumes were highlighted in the August, 1982 Canadian Geographic magazine and the national news.

Volume III is currently in production. It illustrates mortality at various localities in Canada and, in this case, proportional symbols are used to illustrate mortality.

National Forestry Inventory Atlas

In 1982, the Forestry Statistics and Systems Branch (FSSB) of Environment Canada published "Canada's Forest Inventory" which included 10 national maps of various forestry Thesemes. The choropleth maps were notable because of the large number of collection units (50,000) which were digitized and displayed. This required extension of the capacity of the mapping systems to handle the scale and volume of the data.

Cartographic Boundary Files

In order to produce maps such as those for Census of Population, Census of Agriculture, Mortality, and Forestry, geographical boundary data is required. For Census, this meant Census Divisions for all Canada and Census Tract boundaries for larger metropolitan areas. For Forestry, this includes forest regions which would generally concentrate on less populated areas.

Such boundaries, especially those relating to the Census, constitute a product in their own right. For 1981, the Census Divisions of Canada and Census Tracts for 12 major metropolitan areas have been packaged into cartographic summary tapes (CARTLIBS) and these are marketed to academics, researchers, and technically sophisticated clients who then can produce their own thematic maps.

Reference Maps

Reference maps serve as a bridge between statistical data and the geographical framework. In 1981, Geocartographics, in conjunction with manual drafting staff in Geography Division, produced the 1981 Census Subdivision Reference Maps which illustrate for users the areas reported on the Census. This project provided an opportunity to digitize major shorelines and to develop algorithms and systems to place text and point symbols on maps and interactively manipulate them.

Collection Mapping

Production of double-line street maps of collection units to support household surveys (Census of Population, Labour Force) are a labour-intensive task. A semi-automated approach could increase efficiency, improve compatibility of products, and reduce error. Accordingly, a prototype system was developed for 1981 Census from which 200 enumeration area collection maps were produced. From field tests, these were found to be operationally adequate and won general acceptance.

In preparation for the 1986 Census a "production" system is being developed which already shows much lower cost and higher throughput than the prototype system. It is anticipated that about 1200 CT maps containing 8000 enumeration areas will be produced with the automated system. In addition, these maps can find application for other household surveys and possibly other agencies such as Canada Post and the Chief Electoral Officer.

FUTURE DIRECTIONS

The future directions for the Geocartographics Subdivision will be determined by past performance, current perceptions of demand, environment, technology, and the future as it actually unfolds.

The past is prologue. This paper has outlined the evolution of services which have grown apace with hardware and software advances. In the late 1960's, at the beginning of this evolution, it appeared that cartographic systems (both hardware and software) would have to be custom developed. The cost of developing a custom system however, became prohibitive and the delays unacceptable. Now the design of systems is more a matter of integrating existing hardware and software components to perform the task at hand.

The early 1970's could be characterized as the "gee whiz" stage where prototype systems were producing useful quality products and unbounded optimism pointed to completely automated mapping. The booming economy was willing to provide funds to support such endeavours. However, concrete production results were expected by the late 1970's. The development of the earlier part of the decade was expected to be bearing results but some of the earlier expectations and promises were not yet being realized. In the early 1980's restraint and recession have cut off much of the support needed to sustain development and, as a consequence, the emphasis is on production. We have gone from unbridled optimism to the cold reality of demonstrating that earlier investments were worthwhile.

Trends

In the early 1980's, some trends are evident which will heavily influence the directions for automated cartography services in government.

- people costs continue to rise even in an era of 6 and 5.

- computer cost, especially hardware, continue to fall. Current home computers are as powerful as some mainframes of a decade ago.

- demands for information and graphical portrayal of it will increase in this post-industrial "information" society.

- user expectations, in terms of quality, flexibility and responsiveness also will continue to increase. Graphical quality from automated systems must satisfy the requirements of the most discriminating user.

- availability of data will increase with "Freedom of Information" and the rise of videotex systems.

- innovation may address these problems but few resources will be available for development. Long term developments will continue to be discouraged because of the rapidly changing underlying technological base and the problems in funding which will dictate the need for a rapid pay-off.

- Government in Canada is dropping its previous leadership role, yet the private sector is not yet picking it up.

These trends, while making our job more difficult, should be regarded as a challenge for the future. Although the original ground rules and external conditions will continue to change, these conditions present opportunities to apply the burgeoning technology in the numerous areas where tangible results can be achieved rapidly.

Scenario for the Near Term Future

How do these trends affect the ability to service the needs of a national statistical agency? The following general scenario appears reasonable for the near term:

- demand for information will continue to grow rapidly, yet Statistics Canada will have to meet these increased demands either within current resource constraints or through cost recovery.

- dissemination of statistical information to the public will tend to be more graphical and cartographical in order to convey this greater volume of information in a digestible form to a wider audience. Detailed tabulations will be still needed by the researchers, but these users will most likely request summary data in digital form rather than in published form.

- computer technology will be expected to help us carry out these tasks but computerized systems will undergo close scrutiny to determine if they are really delivering what was promised.

- more rapid responsiveness to requests for information can be expected including an on-line "map-on-demand" and "graph-on-demand" capability.

- increased analysis of statistical data can be expected and this will result in a requirement for graphs and maps to facilitate "browsing" and analysis of statistical data.

- more integration and transfer of geographical data between agencies can be expected so that needless duplication can be avoided and costs kept down. This will necessitate standardization of interfaces to permit such transfers and development of generalization concepts to allow the use of detailed digital data at smaller scales or lower resolution.

- management will increasingly use graphical portrayal of information for decision-making, organizational charts, floor layouts, PERT and CPM charts.

Effects

The effect of such a scenario on a service such as Geocartographics would be the following:

- systems, including both hardware and software must be refined and improved to produce maps and graphs at a yet lower cost and faster response. For a central service, this means maintaining and improving current services and keeping hardware and software current. It also means moving towards on-line "map on-demand" and "graph on-demand" capabilities.

- cheaper commercial hardware and software will enable users to acquire their own work stations for low to medium quality work and the central facility's role will include advising on system selection, assisting in maintenance, providing a host system for larger tasks, providing a central repository of geostatistical data and rendering consultative services to support these users.

- the demand for geostatistical data will require its collection, purification, storage and retrieval for users. Standards and procedures for data exchange will have to be developed and implemented to permit accessing data of other agencies and integrating various data sets. This also involves assessing the accuracy and resolution of the data and advising on its suitability for various uses.

- overall geographical data requirements will require more interdepartmental planning.

- anticipation of future demands and possibilities will require that research and development continue even in a period of restraint. Areas of investigation could include:

  - improvement of data entry and edit;
  - integration of spatial data from a variety of sources;
  - providing greater support to publications;
  - support of video text;
  - provision of dial-up access to non-confidential data;
  - user friendly packages for graphical and statistical analysis and presentation;
  - converting addresses to geographically referenced codes ("geocodes");
  - computer-assisted districting;
  - application of remote sensed data;
  - communication effectiveness of graphs and maps;
  - refinement and implementation of further statistical mapping techniques such as cartograms, flow maps, three dimensional presentations, polygon overlay;
  - geostatisical modelling (including overlay and network analysis techniques);
  - improving storage, retrieval and integration of geostatistical data.

The priorities for any research and development project will be determined by the relative importance of the study to the user and the rapidity by which benefits can be realized. Additionally, projects having a broader impact should enjoy greater attention.

SUMMARY

Geocartographics has developed from a service dedicated to the Census to one which supports the whole range of activities of our national statistical agency. This has been made possible by advances in computer technology and the growing awareness and heightened expectations by users of the capacities and possibilities that exist.

The use of graphics will increase because of greater demand and availability of computer systems. Current technology and economics will allow more and more users direct access to facilities. Geocartographics will provide those services which are most cost/effective with a central system. In addition, they will maintain geostatistical data bases for mapping and support departmental graphical activities with necessary research and development.

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APPLICATION OF A GEOGRAPHIC INFORMATION SYSTEM (GIS): INDENTIFICATION OF RESOURCES SENSITIVE TO ACID DEPOSITION

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ABSTRACT

The Minnesota Acid Deposition Control Act, passed in March 1982 required the Minnesota Pollution Control Agency (MPCA) to publish a list of Minnesota resources sensitive to acid deposition by May 1, 1983. The Land Management Information Center (LMIC) was contracted by the MPCA to provide geographic information and computer support for the identification process. Models were constructed to identify areas in the state which may be sensitive to acid deposition. The models incorporated inputs from a variety of sources including 1) 40 acre and square mile parcel information stored on the GIS at LMIC, 2) field measurements of water chemistry, 3) advice from experts, and 4) public reactions. To address the wide variety of inputs and to quickly supply maps of model variations, LMIC staff utilized the GIS software EPPL6, the statistical package MINITAB, and the DBMS, INFO. Information was frequently manipulated with the DBMS and statistical package and integrated with geographic information. Four models of sensitivity to acid deposition were developed. LMIC produced maps of the model results and lists of communities which contain sensitive areas.

INTRODUCTION

The Land Management Information Center (LMIC) is a section of the Minnesota State Planning Agency. The Center was created to meet the demand government agencies have for accurate geographic information about Minnesota. To meet that demand the center maintains a number of geographic data bases including a statewide forty-acre data base about Minnesota resources, as well as a number of software packages to manipulate and display this information. Funding to maintain and expand these capabilities comes from grants, general appropriations, and a service bureau which responds to clients' needs on a fee basis.

One of the clients is the Minnesota Pollution Control Agency (MPCA). The Minnesota Acid Deposition Control Act of 1982 requires the MPCA to identify areas potentially sensitive to acid deposition and then to adopt a control plan to deal with the problem. The Act required the MPCA to publish a map and list which identifies areas sensitive to acid deposition by May 1, 1983. The Land Management Information Center (LMIC) was contracted by the MPCA to assist in the identification process. The process included: 1) technical review, 2) publication of preliminary map and lists of sensitive areas, 3) public hearings, and 4) the publication of a final list of sensitive areas.

BACKGROUND

Acid deposition is a recently recognized and highly visible environmental problem. The identification of resources or areas sensitive to acid deposition must be examined when addressing the deposition problem. Sensitivity of areas, both aquatic and terrestrial, has been closely linked to soil and geologic features, watersheds, land use, and vegetation (Twaroski et al 1983), (Thornton et al 1982), (Colwell et al 1981), and (Galloway and Cowling 1978). The sensitivity of a lake to acid deposition depends on the movement of precipitation through a watershed and the ability of both terrestrial and aquatic components of the watershed to neutralize acid. Lake akalinity is an indicator of the ability of a lake and watershed to neutralize acid, i.e. its sensitivity. A lake with low alkalinity has a low buffering capacity and, therefore, may be sensitive to acid deposition (Thornton et al 1982). Unfortunately, sampling each of Minnesota's 15,000 lakes is economically infeasible. Therefore, a model to identify areas of sensitivity is needed. The sensitivity of a lake or aquatic ecosystem to acid deposition can be modeled by comparing lake alkalinities to features of the surrounding area or watershed.

PRELIMINARY MODEL

The preliminary model of sensitivity associated sampled lake alkalinity with watershed characteristics. Four study areas were chosen to develop the model. The study areas were all over 800 square miles (2200 sq. km.) in size and represented much of the variation watershed characteristics may exhibit within the state. Lake alkalinity for 300 lakes were obtained from field samples and entered into the computer with INFO, a relational data base management system. Inputs considered in the modeling process were soil hydrologic and chemistry features, bedrock geology, depth to bedrock (640 acre resolution), land use and forest cover (40 acre resolution). To address the differences in resolution of model inputs the data was compared on a watershed basis. Initially, percent coverage of features for each watershed were correlated with lake alkalinities. This correlation process compared percent coverage of watershed features with alkalinity of lakes in the watershed. This process involved the GIS, EPPL6 (Environmental Planning and Programming Language 6), the statistical package MINITAB, and INFO data base management system. Correlations were low but did indicate watershed feature-alkalinity relationships. Composite maps of watershed characteristics and lake alkalinities were created for the study areas. These allowed MPCA staff to visually analyze information. The correlations and information from visual inspections were used to create an overlay model with EPPL6. This model had a data resolution of 40 acres even though some inputs had a lower resolution. The model identified two classes: sensitive and nonsensitive. The model was created by overlaying land use, soil, geologic and land form characteristics. The overlay process assigned equal importance to both the sensitive class and nonsensitive class. The model was run for each study area and the entire state.

The model was reviewed during its development by a technical review committee made up of scientists from industry, the state, and general interest groups. The review process required production of 1) statistics about acreages of sensitive versus nonsensitive areas, 2) scale maps of the models for visual inspection, 3) scale maps of model variations. One model variation produced was to exclude land use from the model.

Upon completion of the preliminary model, stable base maps of modeled sensitive areas for the state were produced at a scale of 1:500,000 and the DBMS INFO was used to produce a list of all communities in the state which contained sensitive areas. The list of communities was published because it effectively aggregated the sensitive areas to a managerial level and addressed resolution problems. These were made available for public comment and review.

MODIFICATIONS AND ALTERATIONS

The MPCA held numerous review meetings with scientific experts and with the general public. During this time numerous variations of the models were developed and mapped for display. At this time, it was also decided to expand the study area to include much of central Minnesota. This required the location of 1,000 more lakes and the assignment of their lake alkalinities. The lake locations were determined in three ways: 1) digitizing by tracing lake borders, 2) assigning lakes numbers to parcels which contained water, or 3) from Landsat analysis. Composite maps of the lake alkalinities and watershed characteristics were then produced for visual inspection by the review committee. The process took approximately three weeks to complete.

The model developed from the increased data base was then lebeled an aquatic sensitivity model. Because the model was created from such a wide variety of sources and data resolutions, it was closely inspected for inaccurate assignments and adjusted accordingly. For example, a model alteration would be required if no lakes appeared in a watershed or if all lakes sampled in a watershed had high alkalinities.

The question of terrestrial system was thought to be different enough from aquatic systems to deserve its own model. A model for peat was created because of the importance recently placed on peat as a major natural resource in Minnesota. A process for combining the three models was also explored.

FINAL MODEL

The final aquatic model had the same general inputs as the preliminary model. Modifications were made concerning land use and forest cover. Minor watersheds which had to be altered were identified and corrected. In addition, another level of sensitivity was added to the model. A flow chart of the final model is displayed in Figure 1.

The terrestrial model was created by combining land use, soil, and land form features. This model had three levels of sensitivity: nonsensitive, potentially sensitive, and highly sensitive.

The final peat model was created by identifying peat resources within the state and assigning them a class of moderate sensitivity.

A final composite model was created by combining the three sensitivity models. This model placed greatest importance on high sensitivity, less importance on potential sensitivity and least importance on nonsensitivity.

Maps of the final models and a list of communities which contained sensitive areas were completed for the MPCA before the required date of May 1, 1983. A copy of the final composite map is displayed in Figure 2.

Figure 1

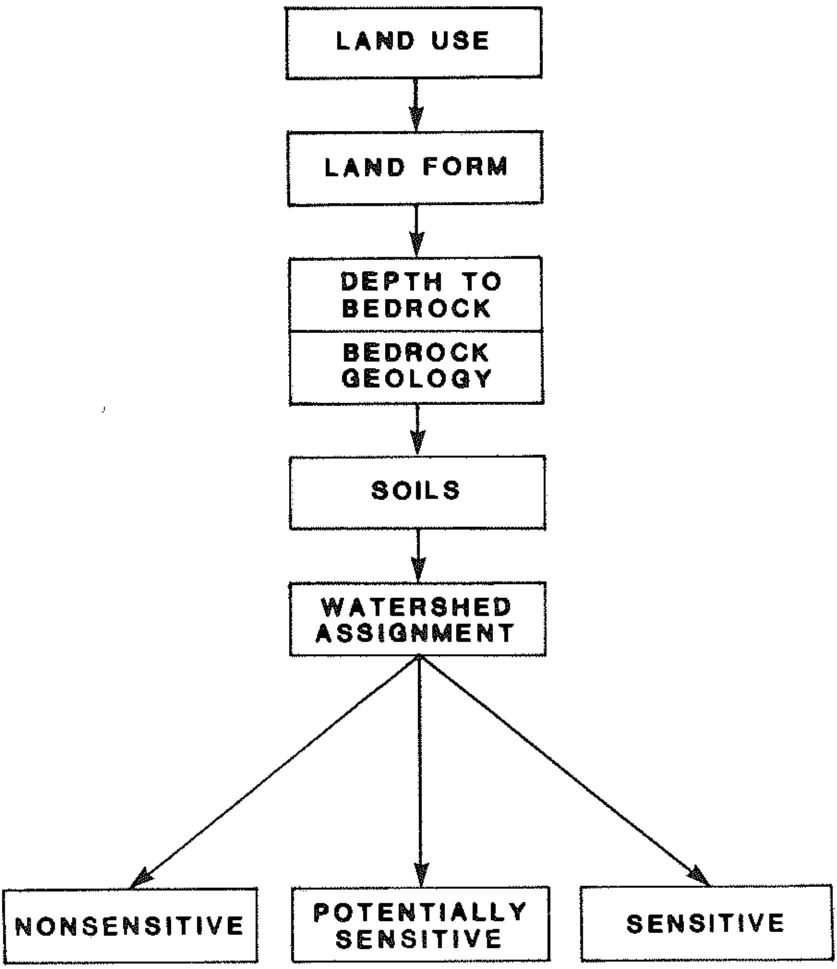
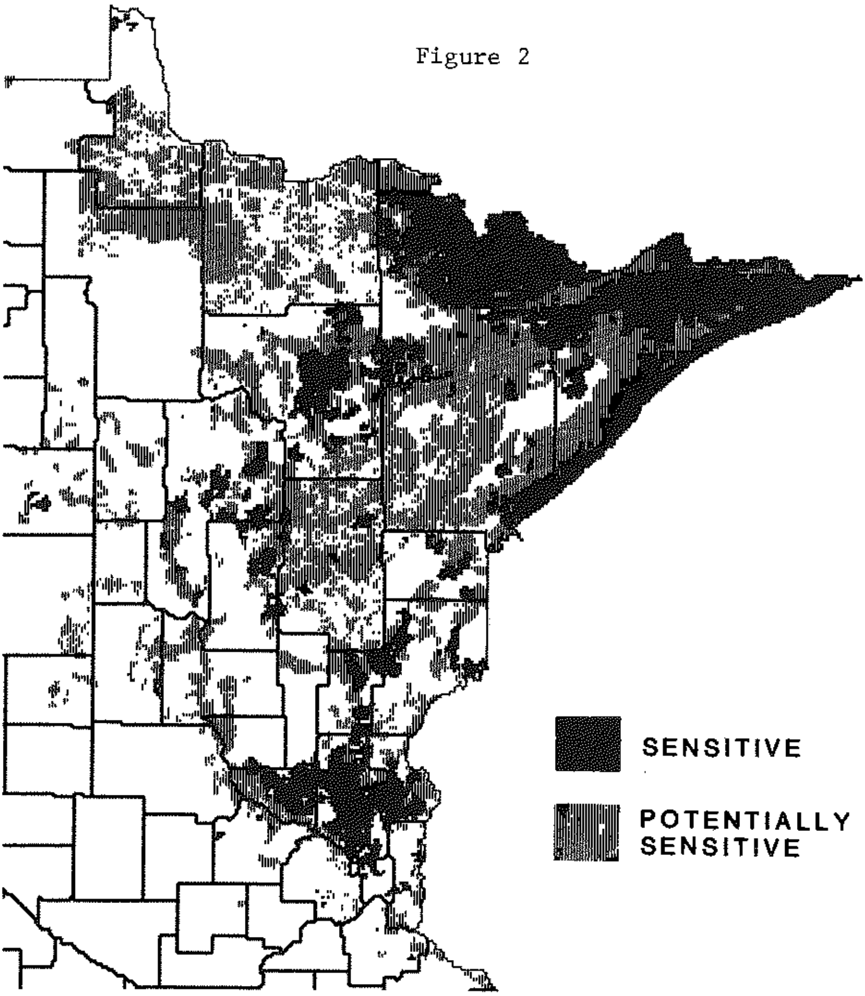

LAND USE
LAND FORM
DEPTH TO BEDROCK
BEDROCK GEOLOGY
SOILS
WATERSHED ASSIGNMENT
NONSENSITIVE
POTENTIALLY SENSITIVE
SENSITIVE

Figure 2



CONCLUSION

The service bureau of the Land Management Information Center provides decision makers and managers the opportunity to utilize the systematic capabilities of a geographic information center. Some of the more significant aspects of the study are as follows: 1) A computer-based system was utilized in the execution of a major piece of legislation; 2) utilization of a variety of data entry techniques provided the means to efficiently obtain the most and best information available; 3) manipulation of geographic information with EPPL6 allowed a quick response time for map analysis; and 4) use of a statistical package and a relational data base management system in conjunction with a geographic information system expanded the analysis and report procedures significantly.

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INTEGRATION OF VECTOR AND GRID DATA BASES IN B.C. FOREST INVENTORY

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ABSTRACT

The data base of the Inventory Branch, B.C. Forest Service, consists of over 6000 forest cover maps and their descriptive statistics. Since 1978, this data base is being loaded into an Interactive Graphics Design System (IGDS). Although the polygon overlay processor available on IGDS is operating well, production was seriously impacted owing to the magnitude of the data especially when several themes had to be base overlaid. In order to solve this problem, a grid-based thematic overlay technique was developed and details of its application are described in this paper.

INTRODUCTION

The Inventory Branch of the B.C. Forest Service is required to develop, compile and maintain the inventory of forest resources over an area of approximately 52 million hectares, including the management of the data base, the annual update of resource maps and associated data files, and the continuous monitoring of forest depletion. The Branch is also charged with assessing the actual and potential effects of changing patterns of land use and any of resultant shifts in environmental values.

The forest inventory data base was developed during the past 15 years and has a replacement value of over $100 million. This data base consists of over 6000 forest cover maps and their descriptive statistics. The main purpose of the data base is to provide area summaries by forest types and administrative boundaries, as well as to combine the area summaries with the appropriate volume information in order to report on total timber volumes in terms of a wide range of biological and management criteria. In the traditional forest inventory data base, area and volume summaries are available only by previously defined physical and legal boundaries, such as management units, regions, compartments, ownership, and others. However, the 1978 provincial forest registration requires reports and summaries on forest resources by boundaries previously not defined. In order to meet this requirement, the forest inventory data base was set up on an IBM computer under the MARK IV data management system. Area and volume statistics, as well as the entire list of forest cover descriptive parameters, are available through this system to the resolution of approximately 400-hectare grids. At the same time, the Inventory Branch acquired an Interactive Graphics Design System (IGDS) from Intergraph Corporation, for the purpose of managing the forest inventory data base in a flexible manner (Hegyi, 1982).

While the map production and update phase of the work became considerably more efficient through the use of IGDS than through conventional means, serious operational problems were encountered in the polygon overlay processing component. In order to overcome this problem, a grid-based polygon overlay processing software package was developed and interfaced with the vector data base. In this paper, the operations and integration of these two data bases are described.

OPERATIONAL ENVIRONMENT

The inventory data base consists of over 6000 forest cover maps (6' latitude by 12' longitude at 1:20 000 scale), each containing eight levels of overlays or themes: (1) forest and range types, (2) forest inventory administrative boundaries such as compartments and inventory zones, (3) forest management boundaries such as timber supply areas and blocks, (4) 1000 m x 1000 m grid areas in terms of U.T.M. projections, used for data management and retrieval purposes, (5) ownership boundaries, (6) Forest Service administrative boundaries such as Forest Regions and Forest Districts, (7) previous forest planning boundaries such as public sustained yield units and subunits, and (8) boundaries of reserves. Each thematic overlay is made up of polygons and their associated descriptive statistics. For example, the forest cover theme consists of approximately 500 polygons per map, with attributes describing species composition, age, height, crown closure, density, history, environmental sensitivity and other relevant ecological criteria. Each map requires approximately three megabytes of storage on the Interactive Graphics Design System (IGDS).

Before 1978, the development and maintenance of the inventory data base was carried out on manually draughted maps and the descriptive statistics were set up on a mainframe IBM computer. Polygon areas were determined through dot counting and, for quality control, areas were balanced within approximately 400 hectare grids and the relevant data were available in machine readable form.

In order to meet the requirements of the new 1978 forest legislation, that is, capability of providing summaries in terms of boundaries previously not defined, the 400-hectare grid summaries were utilized in the creation of a geo-referenced data base. Consequently, the forest inventory data base is available on a mainframe IBM computer under the MARK IV data management system and individual polygons are referenced to the geo-locatable 400-hectare grids.

While the grid area data base provided an efficient system for managing the existing forest inventory data, the problem of updating maps on an annual bases still remained to be solved. Therefore, in 1978 the Inventory Branch acquired an Interactive Graphics Design

System from Intergraph Corporation. This computer assisted mapping system consists of two PDP 11/70 computer subsystems, one with .75 and the other with 1 megabyte of intel MOS memory, two 300-megabyte and two 80-megabyte disk drives with removable disks, 10 design digitizer stations, one CALCOMP 960 plotter, two Tektronix hard copy units, a card reader and printer, and other relevant peripheral equipment. The system is currently operated by a staff of 42, utilizing two shifts. Map production is at an average of 800 maps per year, which is twice the previous manual rate without an increase in the number of staff.

Current computer mapping demands are fully utilizing the available system and future requirements indicate a need for upgrading. At the same time, the IBM mainframe processing and storage costs are seriously impacting the fulfillment of user requirements. As a result, the Inventory Branch is in the process of acquiring a VAX 11/780 computer with 4 megabytes of memory and adequate storage and peripheral devices. In addition, plans are in preparation to integrate two micro computer systems into the operations, primarily for the purpose of performing front end processing.

CREATION OF DATA BASE

The forest inventory data base currently utilizes most of the 63 IGOS levels, separating such details as aerial photo centres, topography, toponomy, cadastral survey, forest type polygons and their descriptions, etc. The process of digitizing is completely automated by combinations of IGDS and user-developed algorithms integrated to produce maps and reports. Map labels describing forest types are entered in batch mode through the attribute file and are placed at the text nodes associated with the unique polygon numbers. Areas of the closed forest type polygons (complex shapes) are calculated and the result is entered into the attribute file. The graphic designs or maps are plotted on mylar, from which prints are made for distribution. Currently, two types of manuscripts are digitized: the existing 1:15 840 maps with imperial labels and the new 1:20 000 series with metric attributes covering the reinventoried areas.

The final step in the preparation of inventory statistics is the merging of map-related data with those obtained from samples. The computer assisted mapping system provides area summaries by polygons, as well as by aggregated forest types, and average timber volumes for these polygons or aggregates are obtained from a combination of aerial and photo samples.

Because the creation of the forest inventory data base involves overlaying the eight themes described earlier, and the data associated with each map sheet is in excess of 3 megabytes, the Polygon Overlay Processor (POP) supplied by the vendor was put to a vigorous test. Although the available POP software of the vendor works and is technically correct, it was found to be largely system demanding and time consuming to such an extent that map production was seriously impacted. Therefore, we decided to explore alternative ways of performing this important task.

VECTOR OR POLYGON DATA

A problem which is not trivial for polygonal maps is that of verifying the map, that is ensuring that all points are in precisely one polygon or in correctly nested polygons. This is a major problem with very complex maps. Checks such as summing the areas of polygons are useful in identifying the existence of an error: however, they are not infallible and do not locate the position of the problem area(s). To ensure the complete integrity of a polygonal map, it is a time consuming and costly process.

A common requirement in computer assisted mapping is the calculation of the areas of polygons. In this process, it is not sufficient simply to calculate the area within the polygon of interest; it is also necessary to check for nested polygons, that is to check if other polygons are contained within the polygon in question, and then to perform the necessary adjustment. While the original calculations are straightforward and linear in cost, the nested polygon solution is complex. A further expensive operation is the overlaying of various polygonal maps to produce another polygonal map with the area computation of resultant polygons. The production of the map of the overlays is straightforward; simply, it involves the realignment of the plotter to plot over other themes. However, to compute the areas, new polygons must be formed. Software solutions are available, but they tend to be slow and easily confused by erratic data.

GRID DATA

Given the problems with polygonal data as described previously, examination of the grid data concept was undertaken. The objective was to increase overall production throughput by reducing the effort required to verify and manipulate map data (Barrodale and Sallaway 1982).

Calculating areas for grids consists of counting the grid points for each polygon and multiplying by the area represented by each point. The nested polygon problem is handled at the grid production stage. This simple process computes areas to the resolution of the grid. Overlaying two grid maps involves some housekeeping such as the manipulation of relevant attribute combinations; otherwise the process is straightforward. Polygonal overlap can be detected during the grid production stage. Nested polygons can easily be separated from problem overlays. Areas of the map which do not fall within a polygon can easily be identified by scanning the resultant grid. Map verification is straightforward and is valid to the resolution of the grid.

A common complaint about maps derived from grids is that they tend to have unpleasant "staircase" boundaries which are unacceptable. This was not a concern here, because the maps are drawn from the original line data in vector form. Area calculation is then carried out by grid overlay. In this regard, the most critical problem is accuracy; this revolves around the choice of grid spacing. A small enough spacing will give sufficiently correct representation of the data. It may, however, significantly increase the storage required and, as a result, the computation time for grid production and manipulation is also increased. On the other hand, a large grid spacing may return unacceptable accuracy for areas. A critical factor in determining the required spacing is the shape of the polygons. Errors in accuracy occur at the perimeter of the polygons only; long narrow polygons tend to have higher errors than do square or circular ones. Close examination of inventory maps indicated the frequent occurrences of long and narrow polygons, hence resulting in grid spacing that may be unacceptable.

Another difficulty in the use of grids is data redundancy. As previously indicated, the grid spacing must be small enough to represent appropriately the data in locations of much change. In areas where the data varies slightly, many grid points may end up having the same value, hence redundant data may be stored. Consequently, it was determined that storage requirements could be minimized by utilizing the technique of run-length encoding.

An overhead incurred in the use of the grid format is that of producing the grid itself. This problem has been extensively investigated in many applications. By combining techniques from a variety of applications, a method was formulated which is considered capable of reducing this overhead to an acceptable level.

INTEGRATION OF VECTOR AND GRID DATA

The results of some preliminary investigations indicated that the integration of vector and grid data may be feasible. Hence, a prototype system was developed with the following results.

Using a grid spacing of 20 metres, the areas of over 90 percent of the forest cover polygons were within .2 hectares of their polygonal equivalent. These results were found to be acceptable, although the cost of storing each grid value was found to be excessive. Thus, the run-length encoding technique was introduced, resulting in approximately a 90 percent reduction in storage requirements. This process records the data by a series of pairs, the first of which contains the number of repetitions, while the second records the value to be repeated. The process of converting five maps from polygonal to grid format, overlaying and calculating areas for all levels took approximately 13 percent of the time estimated for achieving the same with polygonal data, that is 40 minutes instead of 5 hours. This prototype system clearly indicated that the use of grid data is preferable to polygonal data in the area calculations of forest cover and related themes. Therefore, the prototype system was turned into production mode and has been running successfully since April 1982.

Given the successful implementation of the integrated vector/grid systems, it became obvious that certain production related benefits could be attained. For example, the Planning Branch of the Ministry of Forests requires map displays based on combinations of forest cover attributes. This was achieved by defining boolean operations on attribute types and ranges. Themes were colour coded via a look-up table and displayed on an ink-jet plotter.

Further examination for productivity improvement resulted in the feasibility of eliminating the requirement for producing and storing vector polygons. A system is presently being produced by PAMAP

Graphics Ltd. which will take non-intelligent strings of vector data and automatically produce grid based polygons. Extensive production throughput improvements will result from this initiative.

CHALLENGES

Beyond the mandate of the Inventory Branch to capture the map data in digital format, lies the demand to supply timely and accurate updates. The requirement for identifying and mapping change detection has been deemed feasible with the aid of satellite image analysis. The current technical achievements in this technology, that is improvement in resolution and the ability to view the earths surface through most climatic conditions, has provided resource managers with a tool of almost endless dimensions (Hegyi and Quenet 1983).

The introduction of grid processing into computer assisted mapping facilitates integration with satellite image data. In an operational environment, it is anticipated that an IGDS operator would be able to view a thematic image of the change in forest cover superimposed on outlines of stand boundaries. The synchronization of the system cursor to the correct geographic representation and then interactive digitizing of the change boundaries, will result in the update of forest cover maps.

An obvious extension to this concept may be the matching of the two raster representatives, resulting in automatic update of changes in forest cover maps.

Complete integration of satellite image data to the forest inventory is expected to provide enormous productivity benefits.

CONCLUSION

The acquisition of a computer assisted mapping system by the Inventory Branch has resulted in increased efficiency in the production and continuous update of forest cover maps. The development of a grid-based thematic overlay process resulted in extensive production throughput improvements, and it also expanded the scope of digitized thematic data utilization, especially in the areas of thematic colour map production and the automatic update of digitized maps through satellite image analysis techniques.

ACKNOWLEDGEMENTS

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ROLE OF A GEOGRAPHIC INFORMATION SYSTEM IN THE MANAGEMENT OF NATIONAL PARKS IN THE ATLANTIC REGION

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ABSTRACT

The development of a Natural Resource Management Process within the National Parks Program of Environment Canada has significantly increased the demand to manipulate and rapidly consult comprehensive information sets describing the resources of the parks. Techniques have been developed for the collection and compilation of large hard-copy data sets describing the physical and biological resources in each park. Most of this information is spatial or map based.

The application of computer based technology to the management of these data sets has been ongoing for the past four to five years. The nature of the data to be managed has necessitated the use of a particular type of data management system, that is, a Geographic Information System (GIS). In this case, the Canada Land Data System, developed and maintained by Environment Canada, has been applied to the problem.

This paper deals with the ongoing work in the Atlantic Region, within the Department of Environment, to apply this GIS to the Resource Management Process in the National Parks. Information needs, decision nodal points, information flow, system capabilities, costs and benefits are dealt with. Actual uses and applications within the process are described and the basis for expanded application to this process is presented.

INTRODUCTION

The Resource Management process within Parks Canada is "directed toward the maintenance or modification of the biotic and abiotic resources of a park in order to achieve a stated objective of preservation and or use". The basis for this process is information - the kind of information that describes the biotic and abiotic resources within each park. The acquisition of this information is a very time- consuming and costly process, which in many ways never really stops. However, the acquisition phase should be only a small part of the information cycle; with the largest part being the management, analysis and application of this information within the resource management process within the park.

The information which is so crucial to resource management has one very significant characteristic: it is spatial or geographic in nature. Most, if not all, are displayed on or referenced to maps.

During the past two decades, there has been considerable effort expended in the development and design of a new form of technology, commonly referred to as Geographic Information Systems (GIS). The technology is based on advances in computer applications, the development of digital mapping and the growth in sophisticated Data Base Management Systems.

This new form of technology has significant potential to solve an old problem inherent in this, as in many other, resource management processes. The problem to which I am referring is that of information storage, management, analysis and retrieval; particularly of the extensive spatial data required in the process.

The objective of this paper is to examine the application of a Geographic Information System to this problem within the context of the resource management process within the National Parks of Atlantic Canada.

THE NATURAL RESOURCE MANAGEMENT PROCESS

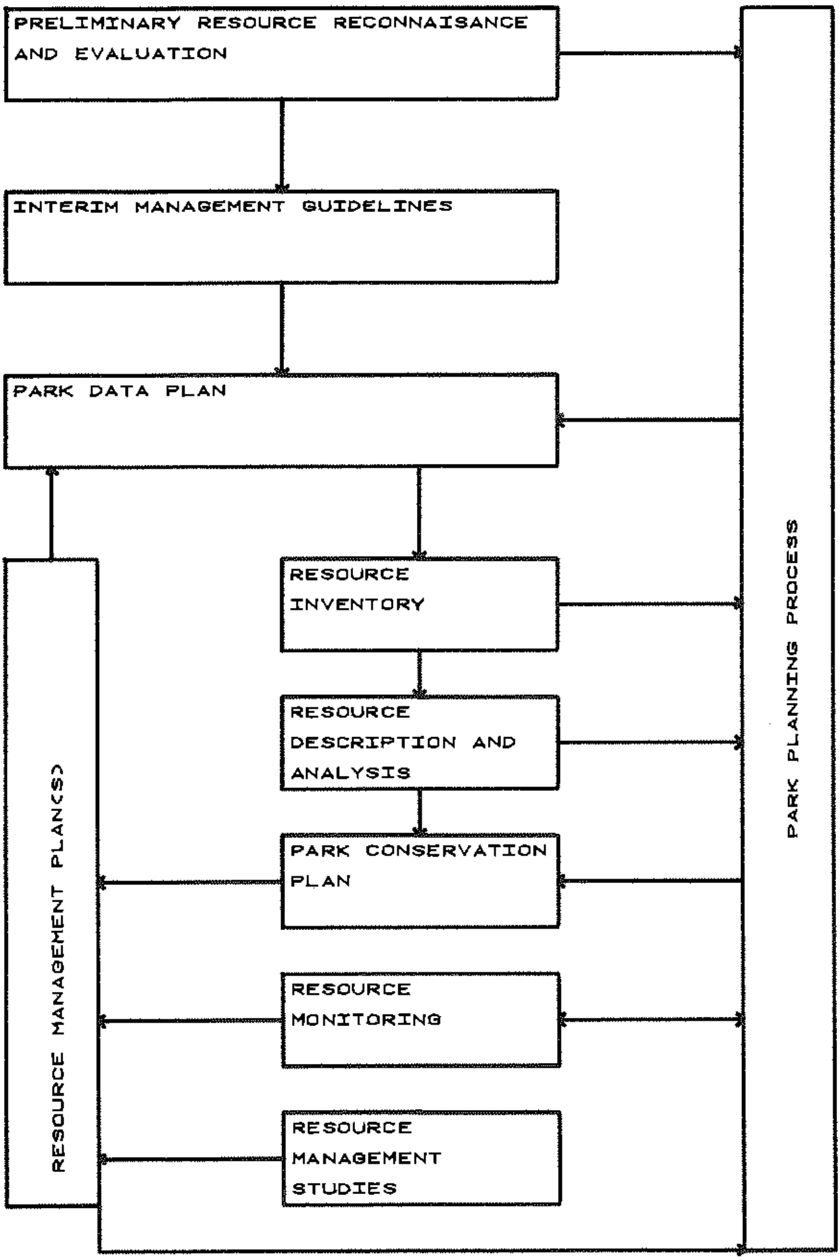
Within the National Parks program of Environment Canada, the Natural Resource Management Process (NRMP) is clearly laid out in a manual entitled: Natural Resource Management Process Manual. This management process runs in tandem to and feeds into the Planning Process for National Parks.

There are nine components to the process:

1. Preliminary Resource Reconnaissance and Evaluation;
2. Interim Management Guidelines;
3. Park Data Plan;
4. Resource Inventory;
5. Resource Description and Analysis;
6. Park Conservation Plans;
7. Resource Monitoring;
8. Resource Management Studies;
9. Resource Management Plans.

The relationship between these various components is shown in Figure 1. The process is a dynamic one which to all intents and purposes should pass through the first five stages fairly early in the history of the park. During these early phases, the Interim Management Guidelines are extremely important and depend upon synthesis from the Preliminary Resource Reconnaissance and Evaluation. The information pulled together at that stage must suffice until the Resource Inventory can be completed and the Resource Description and Analysis (RD & A) carried out. The RD & A is the most complete synthesis of resource

FIGURE 1. NATURAL RESOURCE MANAGEMENT PROCESS



information to be carried out and as such provides the basis for Conservation and Management plans drawn up further in the process.

Information Needs and Decision Points

In considering the role of a GIS in the Resource Management Process it is important to analyze both the information needs of this process and the key decision points where the information is most needed and in what form it is needed. By examining the management process in this light, it is possible to identify the role that a GIS can play.

The principle information needs of this process include mapped descriptions of the natural resources of the park. In general, this need is met through the compilation of Ecological Land Surveys. The methodology for these surveys is well described in the document Ecological Inventories in National Parks (Parks Canada, 1980).

The output of such surveys, however, are maps of medium to high complexity (greater than 500 units/map) with extensive lists of descriptors to accompany each map. The scale and format varies considerably from park to park. These maps are the principle source of information regarding the natural resources in the park. The process requires that this information be manageable and manipulable. Individual components of the information must be accessible and cross comparisons of information are necessary. In addition, a great many of the natural resources do not lend themselves well to being plotted as areas on maps, but as specific point features. These features may be specific habitat (nesting sites) or natural features (waterfalls). This type of information must also be dealt with within the process.

The ELS and point data play a key role in the RD and A along with resource related data collected during the Preliminary Resource Reconnaissance and Evaluation. That data will include a wide array of mapped information and purely descriptive textual information (all reports prepared in park area). The process requires, therefore, a series of information types: the first describing the resources in map form depicting area, points, linear features, etc.; the second illustrating data on specific resources, detailed site descriptions, etc.; and the third outlining general process oriented data which applies to the various ecosystems of the park as process information rather than site descriptive information. In all cases, information on a temporal basis is needed where monitoring has been identified as necessary.

Equally important, in the process is the location of decision points, when the need for information reaches a peak level and what form the information is required in. These are the factors that determine the demand side of the overall equation that dictates the role of a GIS in this process.

Within the Natural Resource Management process for National Parks, there are a number of points at which information must be available and in a certain form.

The point of maximum information manipulation occurs in the Resource Description and Analysis. The requirement to access and manipulate information varies considerably within different parts of the process. Although not a distinctly quantifiable variable, the relative magnitude of the need can be estimated within a range of high, moderate, and low. This estimated range is illustrated in Figure 2.

There is an immediate peak early in the process which coincides with the initial resource reconnaissance and evaluation phase. The actual demand for information access diminishes during the development of the interim management guidelines (which are based on the analysis done in the Resource Reconnaissance and Evaluation). Information access is at its lowest during the development of the park data plan on the resource inventory. The resource inventory is a time of data collection and does not involve information retrieval and manipulation. The need to retrieve and manipulate climbs to another peak during the Resource Description and Analysis. It is during this component of the process that the greatest amount of synthesis of information occurs. The analysis that occurs here will provide the major contrihution to the Park Management Plan. In addition, Park Conservation Plans are based on the synthesis of the RD and A. Further stages in the process draw upon the Park Conservation Plan.

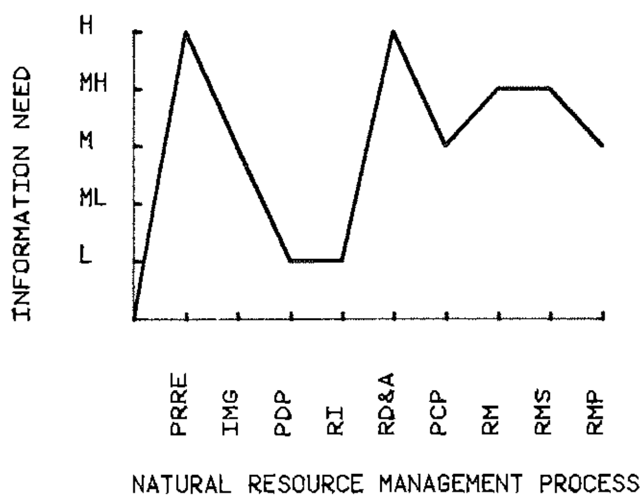


FIGURE 2 INFORMATION NEEDS IN THE RESOURCE MANAGEMENT PROCESS

THE GEOGRAPHIC INFORMATION SYSTEM

The GIS which has been applied to the spatial data management needs endemic to the resource management process is the Canada Land Data System. This is a general purpose GIS maintained within Department of Environment (Canada) by the Lands and Integrated Programs Directorate. The system is set up to handle very large data sets in an efficient manner. It operates in an IBM 370 environment and has unique input characteristics in that it uses an IBM Scanner to digitize maps.

Output from the system for the Natural Resource Management Process is obtained through a remote graphics station located in the Atlantic Regional Office of the Lands and Integrated Programs Directorate and through remote terminals (non graphic) in the parks. The graphics station is based on Tektronix hardware and is configured as shown in Figure 3.

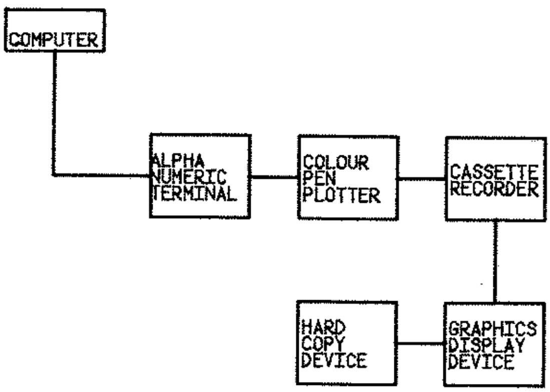


FIGURE 3 LOCAL GRAPHICS STATION CONFIGURATION

Application of the GIS in the Natural Resource Management Process

During the past five years, a series of data bases have been constructed on CLDS for Parks in the Atlantic Region. The data sets which have been constructed are based on Ecological Land Surveys. This type of survey incorporates the various descriptors of the resource; physical and biological components are ascribed to a given area of land according to interpretations performed on various remotely sensed images.

The data bases that have been constructed for Parks Canada generally include one polygon coverage, one point coverage and one line coverage. The polygon coverage has the bulk of the descriptive information attached to it. A typical list of the type of information which attaches to these is given in Table 1.

TABLE 1 LIST OF VARIABLES

VARIABLE	DESCRIPTION
LSYST	LAND SYSTEM
LTYPE	LAND TYPE
TOPOG	TOPOGRAPHY
STYPE	SOIL TYPE
STEXT	SOIL TEXTURE
DRAIN	DRAINAGE
SLOPE	SLOPE
ASPEC	ASPECT
SHYDR	SURFACE HYDROLOGY
VGASS	VEGETATION ASSOCIATION
VGTYP	VEGETATION TYPE
VGSPC	VEGETATION SPECIES
MAMAL	MAMMAL DISTRIBUTIONS
BIRDS	BIRD HABITAT

The parent files which accompany these data sets generally deal with specific features, both man-made and natural. These include such things as houses, interpretation points, waterfalls, nesting sites and so on. The line files are put in as simple graphic files to present linear features such as roads, trails, utilities, drainage patterns, etc. These linear files are used as background material on plots of polygons and point features. They allow the user to store his base map along with the polygon and point coverages.

Use of the Biophysical Data Bases in the Natural Resource Management Process

It is important to keep in mind the nature of the resource management process and also the fact that the established parks are entering the process at a point beyond the initial phase. For many of these parks that has been at the Resource Inventory phase. This phase is a period of low demand for retrieval. It is a period of low demand for retrieval. It is a period of data collection and compilation. At the completion of the inventory, some parks moved to storing the inventory on CLDS while others waited until the demand for retrieval had increased. The next point in the process at which demand for retrieval increases substantially is in the Resource Description and Analysis (RD and A).

Within the RD and A, park personnel must perform substantial synthesis of the information contained in the resource inventory. This involves a considerable amount of map manipulation, tabulation of areas, comparison of resources through cross-tabulations, etc. These functions are all quite labour intensive and thereby, quite costly.

In the Atlantic Region, most of the national parks are presently preparing or have just completed their RD and A. in those cases where data bases exacted on CLDS the system has been used as one of the tools to manipulate the data. In those cases where the data was not on a GIS such as CLDS, the RD and A project has been set up to include the input of the data to the system (including one park considered to be too small to warrant the expense). CLDS will then be used as a tool in the compilation of the RD and A.

CLDS is used to produce a number of products for the RD and A. These include both tabulations of data and custom plots. Table 2 illustrates an example cross-tabulation for Terra Nova National Park. In Figure 4, an example plot is shown, characteristic of the type that might be developed for the RD and A.

The primary use of the system at this stage in the process has been for the maintenance and storage of an ELS data base, and for the retrieval of select portions of that data set and the plotting of information selected. This output feeds into the overall analysis performed by the park personnel.

TABLE 2 CROSS TABULATION FOR A NATIONAL PARK

VEGT1 \ LSYST	A	B	C	D	E	TOTAL
	AREA IN HECTARES					
BAK	22	0	0	0	0	22
BAR	0	0	23	252	255	530
BAT	410	0	0	79	0	489
BOM	590	252	7	109	181	1139
B00	395	64	199	397	0	1055
BS-M	3839	2853	364	6661	2416	16133
CA-BF	116	45	16	45	12	234
CL-BS	177	0	0	0	0	251
TOTAL	5449	3214	609	7543	2664	19853

There are costs associated with the use of the system. These can be broken down into two major groupings:

1. The cost of creating the data base;

2. The cost of accessing and analyzing the data.

The cost related to setting up the data sets vary depending on the size and complexity of the data. In some

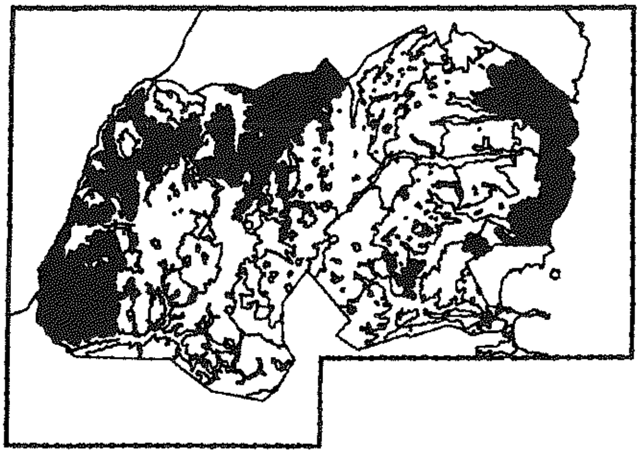


FIGURE 4 DISTRIBUTION OF RED SQIRRELS IN CAPE BRETON HIGHLANDS NATIONAL PARK

cases, a park could be handled on two map sheets with relatively high density data. The input costs associated with such a data set are in the range of $3,500 for incremental costs and an additional 40 percent on that figure for overhead and manpower costs (=$1,400) for a total of $4,900. In contrast, a data set for a park containing nine map sheets of lower density came to approximately $8,500 and the associated overhead and manpower costs $3,400 for a total $11,900.

The cost of retrieving data from these particular data sets runs in the order of $100 to $150 per hour. An hour's worth of time is sufficient to produce five to eight reports and an equivalent number of plot files. The net cost per hour will depend on the number of reports and plots generated. Each individual report or plot costs approximately $10 to $15.

Further Use of the GIS

Application of the GIS and the data bases so far has primarily focussed on the development of RD and A's in the Atlantic Region. This is far from the only possible application of the GIS and its data base. The retrieval capabilities of CLDS will be of significant use throughout the process in response to special requirements such as, environmental assessments, special resource management problems, emergency situations. These types of use cannot be categorized in any single part of the resource management process. They will create short term randomly distributed demand periods over the life of the park.

There are also additional periods within the process at which the GIS will prove extremely useful. Resource monitoring will involve the collection of additional information on any given set of resources. The analysis of this information to establish trends will be greatly facilitated by the GIS. As already mentioned resource management studies both, those that were planned and those that arose out of necessity will be greatly facilitated by the GIS. All of the analysis carried out with the GIS will feed into the overall Park Planning Process.

Summary

GIS technology is growing rapidly and has been applied successfully in many cases. However, in many cases, we are still striving to work out the logical techniques which seem so obvious on the surface but are often difficult to implement. It is fair to state actually that the greatest challenge is not the development in the technology, but; as is the case with most computer technology, it is in the development of procedures and interfaces for the use of the technology within the administrative and management processes within which we work. That will be the ongoing challenge with CLDS in the future - to work out how to implement this tool in the manner in which it is needed.

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ONTARIO HYDRO'S CARSS SYSTEM

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ABSTRACT

Legislation and public outcry for thorough and comprehensive environmental assessments reinforced a need to record, store, manipulate and analyze large volumes of geographically referenced information. The computerization of this information was the only feasible method for handling large volumes of information. Ontario Hydro recognized this need in the field of transmission route selection and started developing a system, Computer Assistance in Route and Site Selection, in 1972. The system was originally to be used for projects covering large geographic areas (20,000,000 ha) using grid cells of 2 km x 2 km. Recently, two major projects, that used CARSS, were successfully defended at an Ontario Environmental Assessment Board hearing. One of the projects was 4,500,000 ha with 35 data maps recorded, another 50 data themes were derived from the original 35, and over 300 possible alternatives were identified and examined.

APPLICATION OF COMPUTERS TO CARTOGRAPHIC PROCEDURES IN CANSIS

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ABSTRACT

The Canada Soil Information System (CanSIS), developed by Agriculture Canada, consists of a cartographic and a data management subsystem. Maps are digitized manually as they are scribed for printing. Various types of computer generated cartographic output are produced; ranging from complete thematic maps to derivative, interpretive, and single factor maps. Over the past few years, the number of map retrievals has increased from a few demonstration plots to over 300 per year. A major area of activity is the development of file integration procedures. For cartographic data this entails the preparation of computer legends, illustrated here for three counties of Ontario. The output includes simple tabular reports of areas or map symbols possessing specified attributes as well as interpretive maps showing basic computer-generated plots or plots enhanced by cartographic processes. Costs are presented for the example maps and reports. The challanges facing CanSIS include; developing the ability to communicate with other soil and geographic information systems, meeting the demand for quantity and variety of output, minimizing the costs of data storage, and training the user to interact with the system.

INTRODUCTION

The Canada Soil Information System (CanSIS) was developed by the federal department of agriculture in cooperation with provincial departments of agriculture and universities, to provide a comprehensive national data bank of soils and related data. It consists of a cartographic subsystem and a data management subsystem. CanSIS is directed to two types of users; information users who require output reports for planning and analysis, and system users, who collect, input and analyse data and manipulate the data to produce final reports.

OVERVIEW

The cartographic subsystem of CanSIS was designed for data input; not automated cartographic map production in the conventional sense. Maps are digitized manually at the same time as they are scribed for printing to avoid duplication of effort. Four digitizing-table work stations are used to input data to a minicomputer. Data are transferred by tape from the minicomputer and loaded into an IBM mainframe computer located at a service bureau for full processing and storage. When the data are edited and 'clean' the computer files for each map consist of a single thematic coverage for one map sheet. There is no provision within the computerized cartographic file to merge adjacent map sheets or to amalgamate one thematic coverage with another.

Various types of output are produced from the cartographic files; such as, complete map identical to the input manuscript, interpretive maps, derivative maps and single factor maps. Most interpretive, derivative or single factor maps involve a simplification of the line and symbol data.

The computer generated output consists of only the thematic lines and symbols. For research and preliminary investigation purposes, these plots are frequently adequate; however, final maps can be enhanced by normal cartographic procedures such as combination with base map information, screening or colouring areas etc. The cartographic subsystem of CanSIS has been designed within a cartographic production framework; the input requirements are identical to those required for conventional cartography; the output products fit the requirements of intermediate steps of cartographic production.

All maps produced by the cartography section of LRRI are input into CanSIS and become part of the national archive. To date approximately 700 maps have been input and the current data collection rate of 150 maps per year has been maintained for the last three years.

Over the past few years, the level of map retrievals has gone from a few demonstration maps to production of over 300 computer generated derived maps for the 82-83 FY. The data selection and plotting procedures to produce simplified maps for specific applications or interpretations have gone from experimental to routine.

SPECIAL CAPABILITIES, APPLICATIONS, AND ASSOCIATED COSTS

A major area of activity in CanSIS has been the development of file integration procedures. For the cartographic files, this has been accomplished by preparing integration files called computer legends. In these computer legends a selection of data from the cartographic file (excluding the large volumes of data associated with polygon boundaries) is written to a standard data file for ease of access and manipulation. The objectives and content of legend files vary with the nature and number of maps being combined and with the accessibility of associated data. At a minimum, the legend file contains the information associated with each map symbol i.e. area on the map represented by the symbol, number of occurences, properties and attributes represented by the map symbol and a link to the full cartographic file so that any aggregation of legend information can be represented in map form. The content of a legend file map be broadened to include data from a number of maps (allowing intergration of the information contained on the maps but not the actual lines), information from other files of CanSIS, interpretations, and reference keys to other computerized data records. The results of any analysis done from a legend file can be represented either in cartographic or tabular form. For many applications the tabular output is sufficient when used in conjunction with the original map. Access to this type of output is readily available across Canada using a simple alphanumeric computer terminal.

Examples of integrated reports and maps for the southern portion of Ontario illustrate the flexibility of the legend system.

The actual costs associated with digitizing the soil survey maps* for Huron, Ontario and York county (six map sheets) are shown in Table 1(a).

A single computerized legend has been prepared for these three counties, to facilitate the integration of data for retrieval. The computer charges associated with defining the legend and loading the data for one map sheet are summarized in Table 1b. These charges do not include the labour cost involved in legend preparation which will vary depending on the nature and complexity of the map and symbols. The costs of keying the data have not been included nor have the costs for any iterations required to correct errors.

Data for other digitized Ontario soil survey maps can be easily added as the need arises. In addition to combining all the information from the soil maps, the legend also contains an approximate CLI agricultural capability rating, a generalized CLI agricultural capability rating as used by the land evaluation project at the University of Guelph, and a link to the soil names file of the data management subsystem of CanSIS.

The land evaluation project made use of the legend to prepare simple tabular estimates of the areas of land which have various attributes specified in the legend. In table 2 the areas of Huron County are summarized by general CLI class and by soil series in order to give estimates of the absolute upper limits of land areas for comparison with the areas of equivalent land cleared and available for agriculture. The data for these tables was output on-line in less than 10 minutes at a cost of approximately $12.00.

The cartographic capabilities of CanSIS were used by the land evaluation project to produce simple derivative maps showing the single attribute soil series (Figure 1). In addition, the land evaluation project conducted analysis to assess the importance of soils of similar quality for particular uses. Their assessments and interpretations could be related directly to the computer legend because they defined soils of similar quality on the basis of groupings of CLI class (as illustrated in Table 2(b)). It was a simple matter to merge their interpretation with the legend file and then link it back to the full cartographic files to generate interpretive maps showing the location of specific land evaluation land types (Figures 2 and 3).

The major costs of data handling are those associated with initial data input. Once the data are'clean' the costs of manipulation are relatively small. Manual enhancements involving cartographic production time vary with the type of final product required. The cost differential between the basic computer generated product (Figure 1) and the two examples of manually enhanced maps (Figures 2 and 3) clearly illustrates how significant these costs may be.

SUMMARY

The CanSIS cartographic system embodying cartographic files for

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*Soil surveys have been completed for all of Southern Ontario. In many cases, these surveys were carried out prior to 1960 and the reports and maps are now out of print. As the information is revised and maps are reprinted, they are digitized and stored in the Cartographic file of CanSIS.

separate maps and a legend file for integration provides a cost effective tool for data manipulation and analysis. Data can be represented either in tabular or cartographic fashion. The computer generated maps can be directly integrated into cartographic production procedures to produce polished, finished products.

The development of a full scale land use and planning tool implies capabilities beyond those currently available in CanSIS. These include the abilities to window or merge maps, to display and edit maps on a graphic computer terminal, to overlay map information, and to have direct interactive capability to relate point or site data to map or polygon information. In CanSIS, the feasibility of developing some or all of these capabilities is being evaluated. In cases where it is impractical or not cost-effective to duplicate capabilities in existence on other systems, a data exchange format will be used to transfer data to other systems.

CHALLENGES FOR THE FUTURE

Amongst the challenges facing CanSIS, one of prime importance is the ability to communicate with other soil and geographic information systems. This communication involves the direct transfer of data to and from CanSIS. Projects now underway in CanSIS deal with defining input requirements so that an acceptable format for incoming data can be achieved. In addition, work is underway to establish the various output format possibilities to transfer cartographic data from CanSIS to other systems. Beyond this direct level of transfer, communication is necessary with other agencies (federal and provincial) as they develop similar and parallel systems so that where possible similar or compatible formats are adopted and needless duplication is avoided.

Another challenge to CanSIS falls in being cost-effective in the production of maps and reports to meet users' requests. This requires major effort to meet the growing demand within the restrictions of manpower and budget. Associated with this challenge is the recognition that as quantities of data grow, so do the costs of data storage and the management problems associated with manipulating large data files. Special attention must be directed towards making the actual data as accessible as possible without jeopardizing its integrity.

Training the user to interact with the system is a third major area of challenge. There is an increasing requirement for good understanding on the part of the user, not only of the data but also of the computer system required to carry out the desired data manipulations. Increased effort and attention is being directed to the preparation of training and development sessions to develop a level of understanding and expertise adequate to allow individual users to access and use their data for their specialized needs. Only in this way can users get exactly the output needed. They will understand how the reports are prepared and they can use the information in applications for which it is appropriate.

ACKNOWLEDGEMENTS

The assistance of Miss C.L. Atkins and Mr. B. Edwards and his staff in preparing the figures and their costs is gratefully acknowledged.

Contribution No. LRRI 83-37

Table 1. CanSIS data input costs for maps of Huron, York, and Ontario Counties.

(a) Cartographic

Map	Map Density		Costs			
	Lines	Symbols	Labour	Computer	Materials	Total
York N	1826	670	$288.66	$109.84	$29.70	$429.14
York S	2474	1108	523.78	263.18	42.35	829.31
Ontario N	2328	863	299.30	193.22	24.75	517.27
Ontario S	3477	1704	780.33	554.09	44.00	1378.42
Huron N	4103	1322	798.14	452.22	52.80	1303.16
Huron S	4005	1271	684.12	501.14	52.80	1238.06

(b) Legend

Computer Definition procedures (one iteration)	$15.50
Loading data from one map sheet (York N)	$14.11

Table 2. CanSIS Tabular Data Output for Huron County

(a) Soil series of Huron County and the area occupied.

Soil Series	Area (ha)
BERRIEN	13706
BONDHEAD	18823
BOOKTON	1332
BRADY	2849
BURFORD	12133
DONNYBROOK	14639
DUMFRIES	4232
FOX	204
GILFORD	2150
GRANBY	2936
GUERIN	50
HARRISTON	80473
HURON	44367
LISTOWEL	19597
LYONS	145
PARKHILL	11010
PERTH	46593
TEESWATER	10500
TOLEDO	1935
WAUSEON	1232

(b) Area of Huron County grouped by aggregations of the CLI agricultural capability class

Group	CLI capability classes included	Area (hectares)
I	1, 2D, 2F, 3F, 2M, 2T	232,347
II	2W, 3W	49,518
III	4W, 5W	6,318
IV	3T, 4T	4,232

Table 3. CanSIS data output costs for interpretive maps of Huron County.

	Data manipulation in computerized legend Computer Cost	Plot Tape creation Computer Cost	Preliminary Plot (labour & materials)	Manual Enhancements (including drafting and photomechanical labour and materials)
Basic Computer Plot Soil Series Map (Figure 1)	$4.51	$25.99	$22.39	
Computer generated map with manual enhancements Land Evaluation Land Types York County (Figure 2)	4.24	24.75	21.28	$290.62
Computer generated map with manual enhancements including patterns Land Evaluation Land Types for Huron County (Figure 3).	3.97	23.65	20.65	1053.08

Note 1: All costs are for production of complete county maps (2 map sheets in CanSIS).

Note 2: Charges for TSO for job submission are not included.

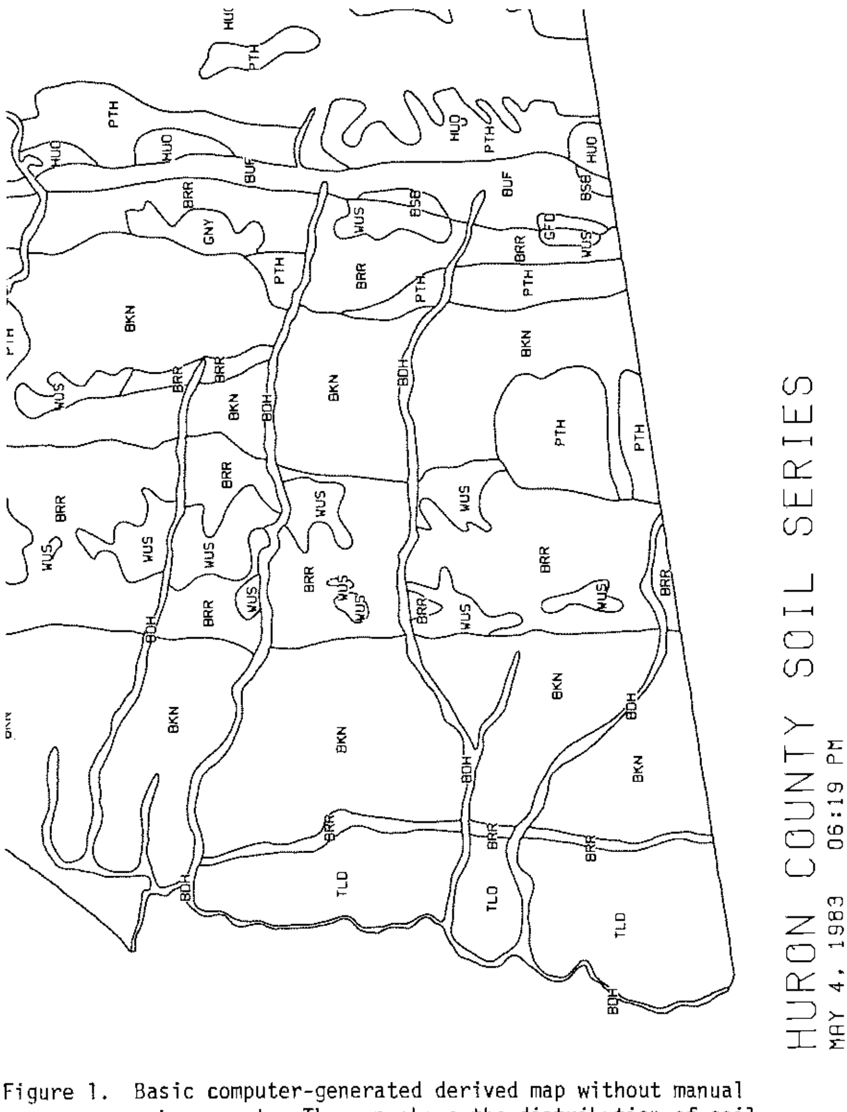

Figure 1. Basic computer-generated derived map without manual enhancement. The map shows the distribution of soil series in Huron County (Section shown covers the southwest corner of the county).

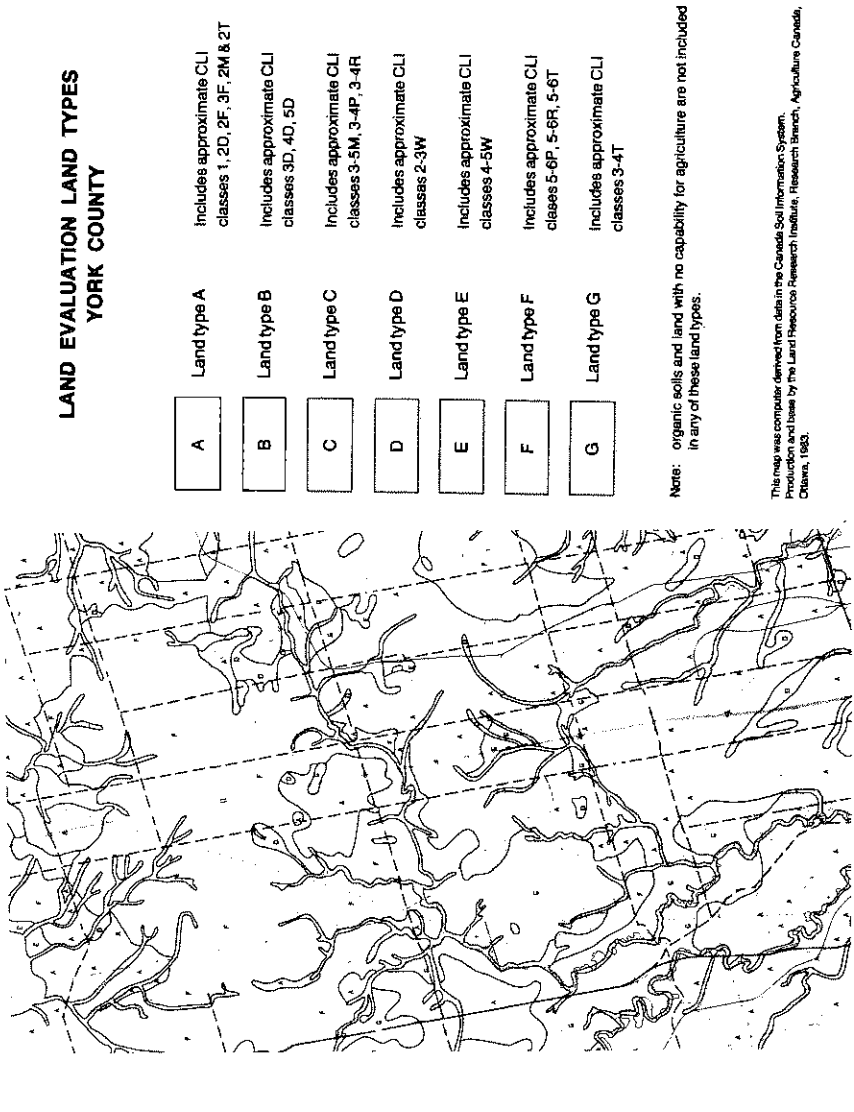

Figure 2. Computer-generated derived map enhanced to show base map data. Other enhancements include a scale changes and joining of two map sheets. The figure shows the location of land evaluation land types in a portion of York County.

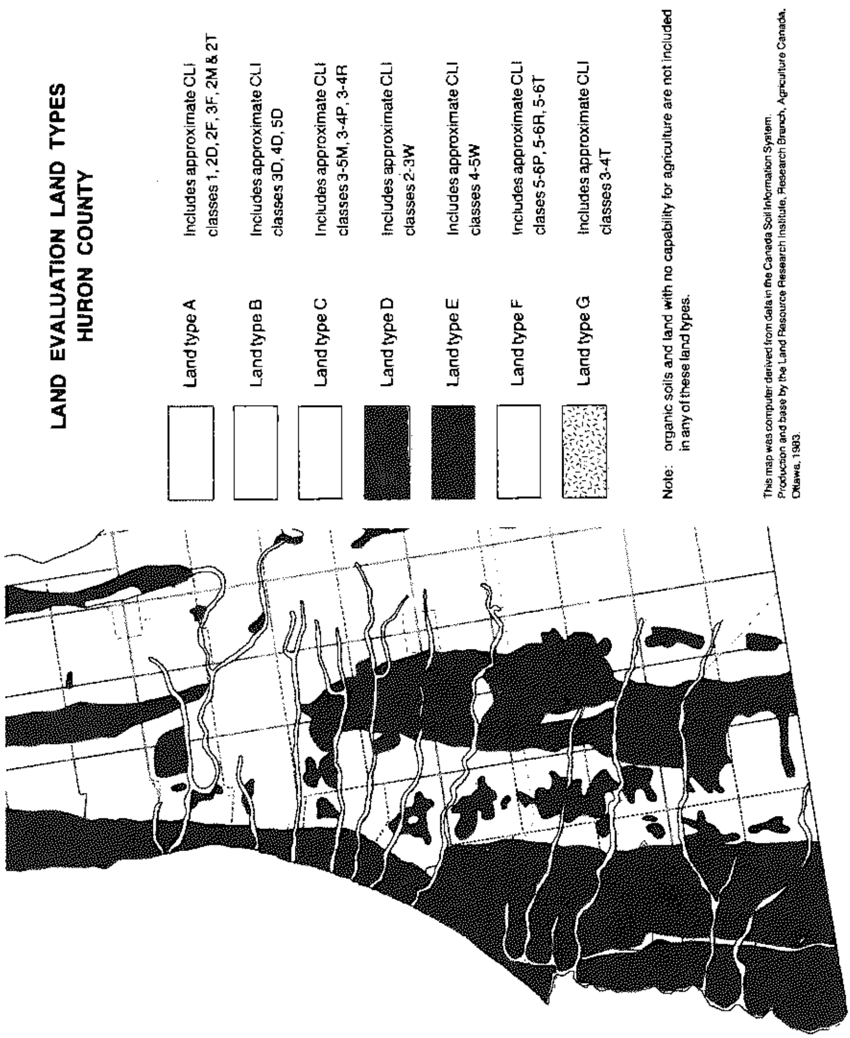

Figure 3. Computer-generated derived map with enhancements as in figure 2. This map is further enhanced by patterns to show the various classes of thematic data. The figure shows the location of land evaluation land types in the south-west corner of Huron County.

COMPUTER MAPPING DEVELOPMENT AT THE CITY OF CALGARY

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ABSTRACT

The City of Calgary has implemented a computer mapping program in order to fulfill some of the City's major cartographic and geographic information needs. This program involves the cooperative efforts of several City Departments. Departmental data are mapped as overlays on a precise base map created directly from calculated survey coordinates. The ownership/tax parcel base map and data linkage capabilities are central to much of the program operation. Other applications include land use classification, utilities, addressing, assessment and transportation. In the future, other Departments will be adding their cartographic and geographic data to the mapping system. System development plans include increased data base capabilities, analytical functions and extended mapping functions. Expansion into other Departments will also necessitate distributed graphic input, display and output capabilities. This paper discusses the development and implementation of the mapping program, as well as the organizational aspects of the program operation. Present methodology, status and benefits are detailed, and future plans and challenges are discussed.

INTRODUCTION

As the City of Calgary has grown, it has experienced a rapid increase in cartographic and geographic information requirements. There are over 60 map series produced manually in the City. Some of these maps contain similar information. They all use some form of a City base map. This situation results in much duplication of effort, particularly with respect to the continual redrafting of the City base map.

In the 1970's the city recognized this problem and developed plans for the coordination and automation of this mapping effort. The implementation of computer graphics methodology is well underway. The base maps were the first to be automated. Other mapping applications and data linkage facilities are following in a phased implementation.

THE COMPUTER MAPPING PROGRAM

Calgary's computer mapping program involves several City departments. The program is based on a system whereby a single digital base map is created and departmental data are mapped as digital overlays on this base. This procedure eliminates redrafting of the base, and assures compatibility of map data across departments. It also allows for multipurpose and distributed use of data traditionally used and maintained for only one function.

The legal base map is produced by the Engineering Department, utilizing data supplied by the Province. This base map is then transmitted to the Data Processing Department. There, the ownership/tax parcel base map information is overlaid on the legal base. A composite base map consisting of both the legal survey data and the parcel data is used by other departments, such as the various utilities. The parcel mapping project contains information and facilities linking the parcels to the City street network and to related data bases.

All computer mapping activities within the City are based on Intergraph interactive Computer Graphics equipment. The Engineering Department and the Data Processing Services Department each own a PDP 11/70 based system with several graphic work stations. Currently map files are moved between systems manually, but direct communication links are planned in the future.

The major computer mapping activities of the City are coordinated by a Computer Assisted Mapping Steering Committee. This committee consists of the Directors of the major departments involved in computer mapping activities. The committee provides direction and guidelines for the operation of the program.

THE LEGAL BASE MAP

The first computer mapping activity started in the City of Calgary was that of creating the Legal Base Map. In 1980 the City began the production of a digital series of cadastral base maps under an agreement with the Province of Alberta. The series consists of approximately 1000 map sheets of a 600 x 800 metre format. The maps are prepared based on a recomputation and reconciliation of all registered survey plans, using field ties between the registered plans and the new survey control network. The Province performs the computation step and the production of the final base maps is done by the City (Piepgrass, 1980).

The Province supplies the City with lot and block corner coordinates and blockface data in digital form, along with copies of the manuscript map sheets. The survey points and blockface lines are automatically loaded into a graphics design file along with the legal lot frontages in both metric and imperial units. The base map files are then completed using the information contained on the manuscript map sheets. Street names and hydrographic features are also inserted. After thorough editing, the base maps are forwarded to the Province for a review cycle. The legal base map is created by the Engineering Services Division of the Engineering Department.

Calgary's base map series production differs from the automated mapping systems of most other cities in that the maps are created directly from the geographic coordinates computed by the Province, rather than from digitized data, aerial photography, or other sources. The X-Y coordinates are measured from the equator and the 114 meridian in the 3 degree Central Transverse Mercator System. All dimensions are held to 1/25 of a millimetre to provide exact metric to imperial conversion. The scale of the digital maps is set at 1:1 ground scale. This is possible due to the precision at which the mapping system can store graphic data.

THE PARCEL BASE MAP

The Parcel Base Map Series depicts all ownership parcels, as opposed to legal surveyed lots, in the City of Calgary. The Parcel Map is produced by the Computer Mapping Section of the Data Processing Department. It is created in exact correspondence to the Legal Base Map. The basic Tax Parcel Map Product consists of a digital map and an associated data base. The data base contains information about each parcel in the City. Other facilities allow for linkage of parcels to the City street network and related data files. The Parcel Map is an overlay on the Legal Base Maps, but is partitioned by sections, rather than cadastral sheet boundaries. There are currently 195 sections covering the City of Calgary, containing more than 160,000 parcels.

Contents of the Parcel Map

The Parcel Map is basically an ownership parcel and address indicator map. As such, it contains the following major features:

Parcel Boundaries	These are the property lines as opposed to the surveyed legal lot lines.
Parcel Addresses	Each parcel has a unique address.
Municipal Addresses	A parcel may have additional or alternative street addresses.
Parcel Areas	The areas of all parcels are automatically calculated.
Roll Numbers	Obtained from Assessment files.
Building Names	

Street names and block numbers are indicated, as obtained from the Legal Base map. An underlay of Legal Base Map information is also supplied, including lot lines, lot numbers, and lot frontages.

The Parcel Data Base Capabilities

The major data relating to each parcel are not only displayed graphically, as outlined above, but are also stored in a data base associated with the map. This data base is an important feature of the Parcel Mapping facility, providing greater information capabilities. Each parcel has a data base entry. The data base is attached to the graphic file via an Intergraph facility, so that for any given graphic parcel, data base information may be retrieved and displayed. The data base capabilities may also be used without accessing the map itself.

The parcel is the basic entity of the data base. For each parcel the following information is accessible:

Parcel Address	This is the unique parcel address.
Street Name	The full name and quadrant of the street is indicated.
Parcel Coordinates	Coordinates of an interior "text node".
Roll Number	The roll number is obtained through a batch run matching parcel addresses to the assessment file.

Parcel Area	The area of all parcels is calculated at once in a batch run, and inserted in the data base.
Section Number	This may differ from the section on which the parcel appears.

Information relating the parcels to the street network of the City is also contained in the data base.

Any of these data may be retrieved for any given parcel. Different users of the Parcel map are interested in different data items. Therefore, various versions of the parcel map are distributed to users, each indicating different data items. These data items are retrieved and displayed for the creation of the particular map of interest only.

Creation of the Parcel Map

The Parcel Map is created using the Legal Base Map information supplied by the Engineering Department and legal ownership descriptions obtained from Assessment. The basic operations involved in the creation of the Parcel Map are as follows:

1. The Legal Base Map files, which are metric sheet based, are merged to form sections, the basic area units used for City mapping functions.

2. Parcel boundaries are created by copying the surveyed lot lines to the parcel map file and editing the linework to form the parcel lines. The parcel boundaries are determined from legal descriptions obtained from the City Assessment Department and Land Titles Office.

3. Once the linework for the parcels has been completed, the parcels are converted to individual polygon entities and data base entries are created for these parcel polygons. The process of creating the polygons is done primarily from the mathematics of the linework by the system itself. The operator provides one point inside the area which is to become the parcel polygon. From this single point, the system finds the nearest side, and follows the boundaries until the polygon is closed. This procedure is possible because of the precise placement of the lot corners (Mayhood, 1982). A data base entry for each parcel is automatically created at this time. Location information including street segment, blockface, section and coordinate information are picked up automatically and inserted in the data base along with the parcel address.

4. Other parcel attribute information is added to the data base later, including the assessment roll numbers and the parcel areas. Additional graphic data include municipal addresses, building names, road closures and plan numbers.

The production of this digital Parcel Map differs from the approaches taken by many other municipalities. The major difference involves the direct use of land title information constructed on a legal base. The creation of parcels in this manner is possible because the legal base is precise, having been created from calculated coordinates. This methodology for the creation of the Legal Base and Parcel Base maps involves capture of data at point of origin, thus resulting in accurate and precise base maps (Somers, 1982).

Figure 1 is a portion of a completed composite base map, indicating selected legal and parcel base elements.

Site Map Information

An important aspect of address information maps in the depiction of sites consisting of multi-family residential, commercial and institutional developments. Such sites contain private roads and buildings with individual addresses, although the parcel containing the site may be large and have only a single address. The detail of these sites is not normally available on City maps. This information is quite important, however, to emergency services, taxi and courier services, utilities, other City departments and the general public.

The first problem involved in mapping such information is that of obtaining it. The Addressing Section of the City has gathered site map data from a variety of sources including utilities, developers and various institutions and developments.

Given the cartographic quality of these sources, mapping the information on an accurate base map presents a problem. The current methodology is to fit the boundary of the site into the precise boundary of its parcel and then to adjust the site contents according to relative location. The contents of the site are not expected to be highly accurate with respect to coordinate location. The major objective in the portrayal of sites is to position the roads and buildings relatively correctly with respect to location, orientation and size, and to show the addresses clearly.

A third problem arises in the production of hardcopy maps including such sites. Different users and output scales require different information to be displayed. A flexible product has been developed, utilizing the level features of Intergraph drawing files. Large scale maps can be produced using the building outline level with or without an overprinting of the complex name. Small scale maps can be produced using the complex name level only.

Data base extensions are being considered that would allow entry of individual condominium or multi-unit dwellings as entities related to the basic parcel.

APPLICATIONS MAPPING AND MAP USE

Many City departments, as well as outside parties, use the City base maps. Some City activities are parcel, or address based, and would use the Parcel Map as a resource, reference, or link to other address related data. This is accomplished via the street network and location information in the parcel data base. Many functions would add or overlay data to the Parcel Base, thus augmenting the parcel data bank. Such a situation would facilitate access to a variety of parcel related data.

Utilities

The utilities use a combined base map. The legal base information is required for their primary records, while the Parcel base data is necessary for drop lines and billing. A joint utility mapping effort is being coordinated by the Engineering Department. That department will distribute the composite base map in digital form to each of the utilities. Each utility will map its own records on this base

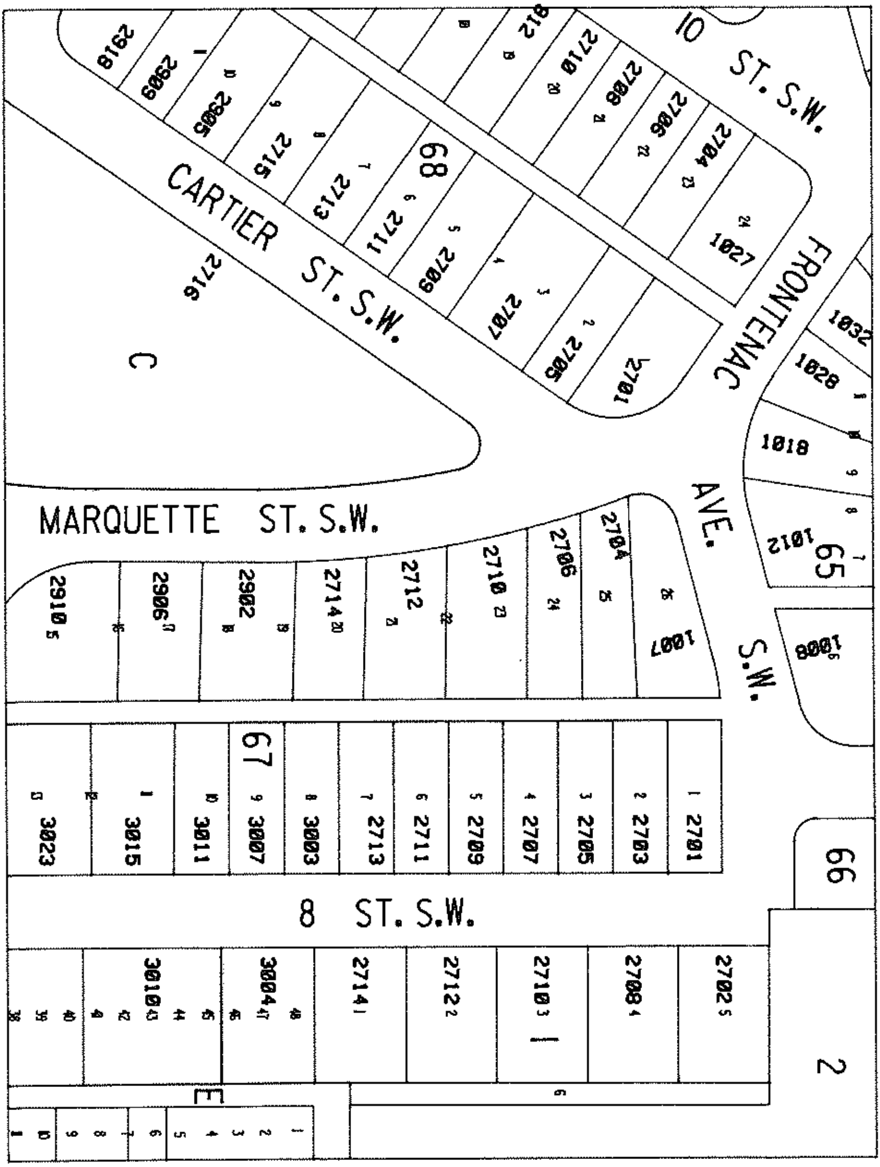

Figure 1. Base Map

Street names, lot numbers, parcel boundaries and parcel addresses are indicated.

according to its operational needs. Specific utility data will be fed back to the Engineering Department by each utility as a digital map file. The Engineering Department will then create and maintain a common utility map from this information. This procedure will make available a central utility map for use by the City, all utilities, and other parties concerned with utility locations.

The City Electric System was the first utility to begin records mapping. Primary underground, overhead, and communications are their first efforts.

Addressing Section

The Addressing Section of the City is a major user of full address information maps. That group currently maintains paper address maps manually but a full set of plots of the digital Parcel Map will replace their current map record system. Address maps are used as a resource for their work in maintaining and adjusting City addresses and for servicing the public. As the central authority on address information, the Addressing Section updates address and parcel information for input to the Computer Mapping Section.

Assessment

The most common and the largest revenue producing entity that the City Administration deals with is the taxation parcel. Thus, one major use of the Parcel Map will be in conjunction with functions dealing directly with the parcel for assessment purposes. The Assessment Department is interested in the graphic representation of their operational location data in a computerized format. Maps produced for this purpose display all address information including section, street name, block number, parcel address, municipal address and building name (see figure 2). The development of area and roll number display was also developed largely for Assessment use.

Planning Land Use

The Planning Department is concerned with two types of land use mapping - Land Use Classification and Actual Land Use. When these map data are represented as polygons, polygon overlay operations can be performed. This operation would allow analysis of Land Use Classification vis a vis Actual Land Use.

Additional Applications

Many other City Departments are becoming involved in the automation of their mapping activities. The benefits of such a conversion lie mainly in the maintenance of the map. The Transportation Department will be converting their bus stop and sign inventories to the computer mapping system. These maps will be linked to a data base containing inventory information currently maintained manually, such as bus stop equipment and characteristics. Bus routes will also be added to the system. Other current departmental applications include the mapping of ward and polling subdivision boundaries, census tracts, and Police neighborhoods.

MULTIPURPOSE MAPS

The basic objectives of the computer mapping program are to centralize the maintenance of a city base map to a single source, thus

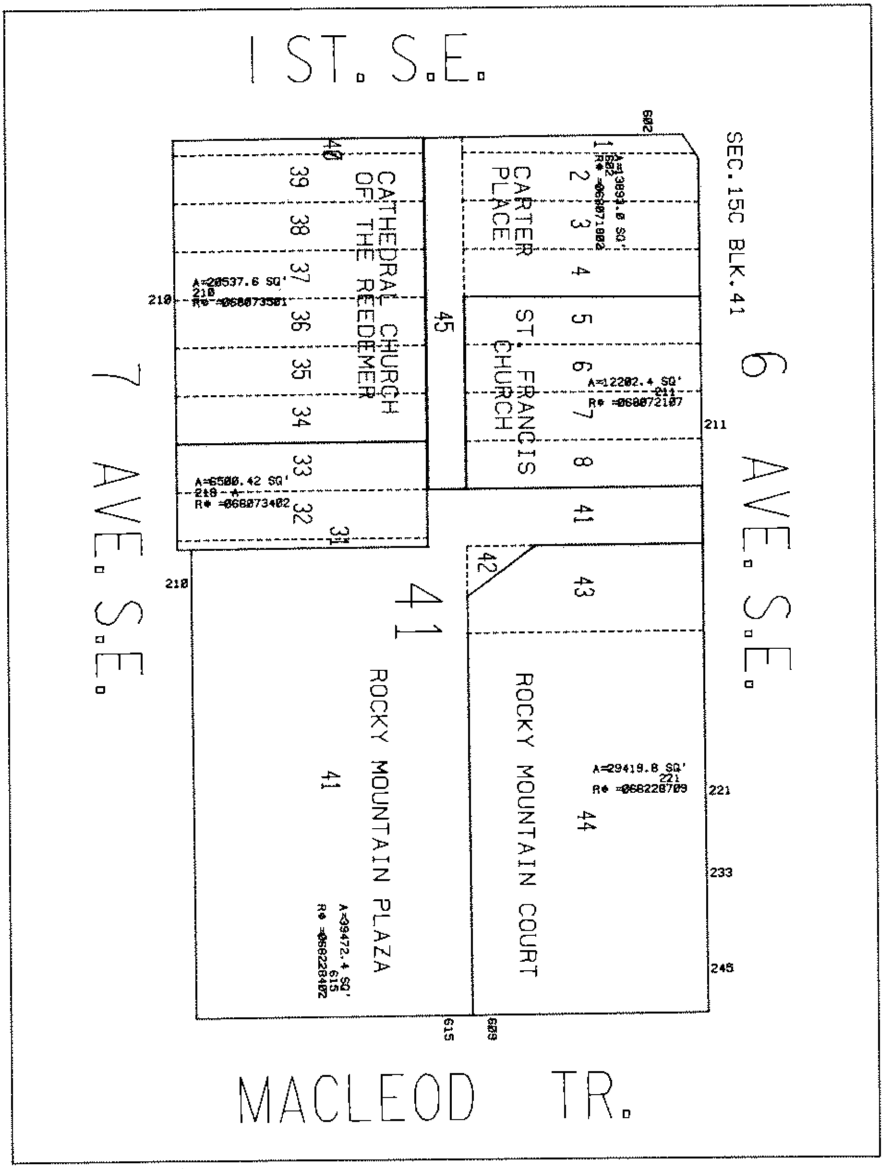

Figure 2. Assessment Map

Roll numbers, areas, building names and municipal addresses are indicated in addition to lot lines and numbers, parcel boundaries and addresses, street names, and block numbers.

eliminating duplication of effort and facilitating map maintenance, and to promote multipurpose use of digital map information. Different users have different needs, so the maps must be as flexible as possible.

A major feature of the Intergraph systems mapping facilities is the division of each graphic file into 63 separate levels. As many as 3 read only reference files can also be displayed along with the primary file. This allows great flexibility in map design. The City has made use of these features by arranging for each Department to maintain its own separate files, while using other files, including the base maps, as reference files. This allows access to other Departments' data, but protects it from inadvertent damage. Each map itself is designed to make use of the level structure. In general, each type of data item is contained on a separate level, thus enabling display of selected information.

Digital map overlays created by one department may also be of use to others. The standardization of graphic data onto a single base makes data compatible between departments, and the centralization of the information on the computer makes it more readily accessible.

Different users require the display of different data elements from the data base. For example, Assessment needs roll number and area included on each parcel along with a small parcel address. The Addressing Section requires larger addresses to be printed, with no roll numbers and areas. Both groups use the same Parcel Base Map graphic but require the printing of different data elements. Separate maps are printed for each group, displaying the elements of interest to them and in a format suitable for their needs. The use of the system data base display capabilities, selective level display, and time of output options allow for this flexibility.

STATUS OF THE MAPPING PROGRAM

Many applications of computer mapping in the City are well underway. The legal base maps will be current on January 1, 1984. The Parcel Base will come fully on-line shortly after that. Planning has nearly finished its land use classification mapping activities and Electric has several record mapping series partially complete. Assessment, Addressing, Police and other departments are using various forms of the Parcel Map.

Future plans include augmentation and enhancement of the Parcel Map and Data Base. Other departments will begin adding their information to the system once the base maps are completely on-line.

CONCLUSION

The benefits of the automation of the City's mapping efforts include reduction of duplicated effort, simplified map maintenance, use of a single centralized base map and increased ease of access to data, among others. The Legal Base and Parcel Base mapping activities involve data capture at point of origin, resulting in accurate and precise base maps. The conversion of current mapping activities to an automated system will take quite a while, but once it is done, maintenance of the maps is more efficient. Automation also requires a great amount of initial funds, although the net savings are certain in the future. Current economic constraints may slow the implementation of computer mapping methodology in the City, due to high initial costs. The program has demonstrated, however, that the benefits are worth the costs in the long term.

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THE UTILIZATION OF COMPUTER-ASSISTED TECHNIQUES IN THE COMPILATION OF NAUTICAL CHARTS

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ABSTRACT

Rapid developments in electronics and computer technology in the past fifteen years have had an important impact on the field of hydrographic surveying and the production of nautical charts. In order to assist in the construction of nautical charts, the Canadian Hydrographic Service (CHS) began developing its computer-assisted cartographic systems over a decade ago and has since implemented successful applications of highly accurate drafting, digitizing, and interactive editing systems. Today, three regional offices and headquarters utilize computer assisted methods to aid many of the traditional manual drafting techniques. As hydrographic field data becomes increasingly available in digital form, computer-assisted compilation techniques will be increasingly utilized. This paper discusses problems and factors in the implementation of computer-assisted methods in nautical chart compilation - an aspect of chart production relatively untouched by the computer revolution in the CHS.

1. THE CHS COMPUTER-ASSISTED CARTOGRAPHIC SYSTEM

1.1 Introduction

In the Canadian Hydrographic Service, the computer-assisted cartographic system is utilized in four ways. A compiled charts is (1) digitized, (2) edited, (3) processed, and (4) plotted. The computer systems have been developed to aid the cartographer in the process of chart production, and to expand with future production techniques. There is one stage in chart production which does not incorporate computer technology, but is now being studied in order to determine the feasibility of implementing computer-assisted techniques: the compilation of nautical charts. This paper attempts to define some guidelines regarding the questions "when may computer-assisted techniques be effectively used in chart compilation?", and "what are the benefits and disadvantages of using computer-assisted techniques in compilation?". To create a context for the remainder of this paper, a brief overview of present CHS methodologies is required.

1.2 Data Structures

There has been a great deal of effort spent on the design and development of an optimal data format. The formats now used are fast and efficient for use on mini-computers. The primary data structure used by digitizing and processing software is called INTERCHANGE or NTX FORMAT. This format is designed for the efficient storage, and sequential processing of digital nautical chart data, primarily on magnetic tape. It handles symbols, soundings, linework, and text, in both symbolized and unsymbolized form.

This format facilitates easy conversion to a second major data format which, although is comprised of the same data types, is a disk based data structure designed for extremely fast response time on one of the key components of the current system, the interactive editing system.

1.3 The Digitizing Station

Several systems are used to convert graphics to digital form. As most hydrographic field data received by cartographic production units are still graphics, digitizing is a major step in the production process. This is expensive in terms of time and cost, and since this paper deals with this area, it should be briefly described as it stands today in chart production.

The hardware used in digitizing is of a conventional configuration of mini-computer, digitizing table, system console, user command console, and three scribing cursors specially designed for digitizing nautical chart information. The digitizing software, which is CHS developed, digitizes directly onto disk.

1.4 The Editing Station

At the completion of digitizing, the digitized data is moved to a second computer system for interactive editing and compilation. The hardware on such a system again consists primarily of a mini-computer (increased disk capacity), tape transports, TEKTRONIX 4014 vector display, digitizing table, assorted terminals, and a CALCOMP 960 pen plotter.

The data transferred to this system are built into a GOMADS file. GOMADS is an acronym for Graphical On-line Manipulation and Display System, and is the CHS developed interactive editing system. It is capable of adding, deleting, moving, and changing symbols, text, soundings, and lines. The data is drawn on the TEKTRONIX 4014 graphics terminal at a wide variety of magnifications, in its entirety, or selectively, according to numerous parameters. Features in the digital data file may be pointed to by means of the cursor on the digitizing table (an accurate pointer), or by a joystick control on the 4014. GOMADS output may be stored on magnetic tape or in another disk file.

1.5 Data Processing

There are several other cartographic software packages used in chart production. MOSAIC is a program which was designed to emulate the manual mosaicking process, where the field sheet data and other source data are brought together to form a single source. Although it is not used fully in in this capacity today, when all data is available in digital form, it will be capable of replacing the manual mosaicking process. This allows changes in many parameters, including scale, projection (including spheroid and scaling latitudes), windowing, sounding units, but most importantly, it registers a chart to geographic coordinates before building a GOMADS file. Although the MOSAIC Program is not presently used to its full potential, as computer-assisted compilation becomes a reality it will be an integral and very powerful component of the chart compilation process.

STARS, an acronym for "Symbolization, Transformation And Reformatting System", is the name given to the software which converts NTX data to symbolized form. Until STARS is run, the data consists merely of solid lines of no specific lineweight, in order to facilitate faster processing. STARS reads each record in a user file and searches a MASTER file for associated drafting specifications, which includes lineweight, symbology, symbol disk, etc. A symbolized chart file may be drawn on CALCOMP plotters, or TEKTRONIX 4014s or built into a GOMADS file like any other chart file, although processing of a symbolized file usually requires more time.

Throughout all these production steps, several other utilities are used for checking the validity and integrity of the data, and for copying and separating the data.

1.6 Plotting

During the production process the cartographer must occasionally plot the chart data, for checking and verification purposes, either in symbolized or unsymbolized form. Pen plotters are excellent for very fast verification checks, but tend to be inaccurate due to the high plotting speed. A graphics terminal is also good for quick visual checks of part of the data, but the complete file can only be displayed at an extremely small scale, no hardcopy is produced. For highly accurate checking, the cartographer may submit his data for reproduction on film at any time during the construction of a nautical chart. Two in-house flatbed plotter utilizing lighthead projectors are used to draw these accurate plots.

Regarding cartographic presentation, an important aspect of plotting is the grid size of display devices such as plotters and CRTs and of input devices such as digitizers, which directly affects line smoothness. Because such equipment is based on a relatively coarse .002" grid structure, the creation of smooth lines is difficult. This becomes most evident after drafting, where the resolution of linework on film increases, allowing other weaknesses show up. The opportunity to improve the smoothness of linework arises as the data is being prepared for plotting. Since the plotting systems are based on a much finer grid structure than on the pen plotters, digitizing system, or CRT, a smoothing algorithm has been implemented which uses what is called a "lookahead" method, to create a more cartographically presentable line. The grid size of the KONGSBERG plotter is 0.0004", and the GERBER grid size is 0.0001", an increase over the other devices of 5 and 20 times, respectively.

2. COMPILATION OF NAUTICAL CHARTS

The objective of cartographic compilation is to collect all available source information, select data which may appear on the final product, develop depth contours and generalize linework. Due to the increasing amount of digital hydrographic field data becoming available, and the evolution and anticipated demand for new types of cartographic products such as the "Electronic Chart", it is felt the compilation process could greatly benefit from computer assisted techniques. Data collected in digital form would allow us to handle much more information, producing charts in a more efficient manner and reduce the amount of digitizing, which is a time consuming process. The major steps in the current methodology require:

1. gathering graphic source data
2. photomechanically reduction to final chart scale
3. mosaicking to a base
4. generating a compilation blueline for sounding selection, contouring and generalization

Alternatively, the projected methodology for computer assisted compilation is to:

1. gather graphic source data and digital data
2. digitize source data, at any (larger) scale
3. digitally reduce, etc. and concatenate all sources to base
4. contour using automatic contour generators OR plot on film and produce blueline, manually develop contours, select soundings, digitize contours and concatenate to digital chart file

The first step in compilation is the construction of a chart "base", which consists of a graduated border, graticule and control points. The manual construction of the chart base used to be a tedious and time consuming task, with a high probability of error. Now it is mathematically generated and drafted on a high quality flatbed plotter, saving several weeks work, and vastly improving accuracy and precision.

The next step is the construction of a "mosaic". Using manual methods, the hard copy source information are photographically reduced to chart scale, cut into small pieces and pasted on the chart base. In the case where source data is in a different projection than the chart, registration and accuracy is questionable. When source information overlap or a new source arrive at a later stage of chart construction, cartographers are often forced to produce more than one mosaic. Any changes to manual mosaics are complicated tasks. In contrast, any changes and additions to "the digital mosaic" are easily implemented, at any time in the production cycle.

Concatenation of digital source files into a digital mosaic can be done via the MOSAIC Program or the GOMADS interactive editing system. GOMADS is usually the most convenient method when all the data are not available at the same time. MOSAIC can also be utilized to convert sounding units and to assign unique numerical values to each file for easy identification.

In 1977, a special project was initiated to determine the feasibility of using the computer-assisted cartographic system as a compilation tool. Chart 8015, Funk Island and Approaches, off the east coast of Newfoundland, was selected for this project. Several different types of source information were used, and were easily brought to common scale and projection. The final chart specifications were approved only when compilation of the chart was almost completed, but since the information was already in digital form, it was easy for the MOSAIC Program to change the projection and limits.

Whenever possible, the source data being mosaicked should extend 2-5 cm beyond the chart neatline. This will allow last minute adjustments to the chart limits and will also improve the accuracy of contouring at the edge of the chart.

It is essential that the digital mosaic be carefully checked and approved. Theoretically checking can be done on the CRT screen (GOMADS), but it is more convenient to work on hard copy, where all the areas in question can be clearly marked. It is common practice for checking to be done by an individual who was not involved in the production of the document. In the CHS, checking is done by professional checkers who examine, correct and eventually approve the job. After all corrections are made and questions are resolved, the digital file is updated via the GOMADS interactive editing system.

Once the cartographer is sure that the mosaic contains the correct and complete source data, the next phase, which is called "compilation drafting", can be started. This includes the following aspects of compilation: contouring, selection and generalization.

In the manual processes, a mosaic is photomechanically reproduced as a blueline on a scribecoat. This manuscript is utilized by the cartographers equipped with engraver to develop contours and select soundings and other features.

While producing the experimental Chart 8015, the first step was to develop contours, select soundings and other hydrographic information on sources photographically reduced to chart scale in order to imitate digital source data. There were several benefits to this approach. First, at a scale close to that of the final product, it was possible to visualize what this final product would look like. Therefore it was easier to select a reasonable number of soundings and apply some generalization to line work. Secondly, there was a significant saving in digitizing time. For example, a field sheet reduced five times will contain only 20% of the original line length. The soundings were over-selected in order to establish sufficient background which would allow some changes and modifications at a later stage. Approximately three times more information was selected than was required for the final output. Nevertheless, during the editing-compilation stage, it was still necessary to go back to the original source materials to confirm and re-select additional soundings or re-position the contour lines. Once selection of the data and the development of the contours was completed, the individual sources were digitized. These digital source files were registered and the sounding units converted to metric values, and then concatenated into a digital mosaic for data selection and editing. The main computer-assisted compilation process was the deletion of data, previously marked on hard copy, that was not required for the final chart presentation. Film positives were produced at the completion of the compilation-editing phase.

Contours on nautical charts are needed primarily to satisfy the navigational needs of the mariner, and therefore may differ from the presentation on other types of maps, because the basic function is to provide depth information rather than shape information. The major objectives of contouring nautical charts is to emphasize critical shoals, to provide general bathymetric coverage, to provide space for navigators to plot positions and courses, to define the limits of critical and significant depths and to describe the nature of the bottom.

CHS charts have been produced in metric, contoured format since 1976. The basic difference between these two formats is that on the newer charts there is a smaller number of representative soundings and an increased number of bathymetric contours. Additional bathymetric contour lines on Canadian charts are justified by the increased amount of depth information supplied by modern hydrographic surveys. This type of format also gives a much clearer picture of bottom configuration.

In 1981 the CHS began investigating the possible implementation of contour formatted field sheets and automated contouring techniques. Tests and experiments conducted to date have been promising for hydrographers, who in the future, may produce this new field document on board survey ships. This concept involves a more dense selection of depth contours and less soundings. If implemented, this will have a great impact on chart production procedures. The cartographer will no longer be involved in contour development, their function will be selection, smoothing and generalization of contour lines supplied by the survey. This should simplify the compilation process.

Several contouring programs are now being tested and evaluated, and the results are encouraging. There are two basic techniques used in automatic contour generation. One requires the creation of an artificial grid system, the other develops contours from a triangular network based on depth measurements. Our task is to select the programs and the algorithms which can be used effectively by both hydrographers during construction of a field document and by marine cartographers at the chart production stage. The program should be fast in execution, compatible with machines used by the CHS offices, should produce digital files in a format compatible with CHS systems, be easy to use, flexible enough to allow users the ability to select the type of information they require. This is particularly important for cartographers during the compilation processes because they will request only those contours which will appear on the printed chart. The most important objective is to have the program generate the correct output. Smooth, accurate and precise lines require less editing.

Under the present system, contouring should be performed on the "mosaic", as this is the concatenated form of all available sources. This method is used during the manual compilation, and also, during the experiments with chart 8015, it was established that by using this method, the cartographers in most cases will simplify their work, avoid some of the problems associated with connecting lines derived from separate sources, and be able to apply proper generalization when compiling linework.

The most common range of magnifications during the interactive editing is 4 to 8 times the chart scale. At this magnification the portion of the document that can be displayed on a 19 inch CRT screen is not large enough for proper data interpretation. During compilation, cartographers often have to change the selection, modify the linework, apply different generalization, etc. To maintain a uniform presentation throughout the chart, they have to see "the complete picture". Therefore, the development of depth contours directly on CRT display via GOMADS system seems to be an impractical approach and it is preferable that a hard copy be utilized.

Situations occur where only a small part of a compiled chart is available in digital form, this part should be automatically contoured, plotted and manually mosaicked with the remaining source data. When the opposite situation occurs, it might be beneficial to digitize the hard copy source and concatenate it into a digital mosaic for future contouring. The average source document may contain tens of thousands of points of information such as soundings, bottom quality samples, land features, etc. In some cases only 1% or less is selected to be charted, but this selection is vital.

One of the most difficult and complex operations is selecting soundings. The purpose of sounding selection is to choose from the available source data an adequate amount of depth information indicating the dangers to navigation by showing the available draft and to portray the general configuration of the sea bed. Because both the nature of the bottom and the nature of the source data varies considerably from chart to chart, cartographers are presented with an ever-changing set of circumstances as they attempt to apply the rules and conventions of sounding selection. For this reason, the introduction of a fully automatic sounding selection does not seem to be realistic at present. In the future however, if the new presentation of contour formatted field sheets is accepted, then sounding selections will be greatly simplified because only critical and significant soundings would be shown.

Computerized techniques can significantly aid interactive sounding selection. In very dense areas the program should be able to reduce the amount of depth information on the screen, for example, by deleting some deeper soundings in the situation where two or more depths overlap each other. The operator should be able to request a search for the specified depth values on the viewing area or through the complete file. By selecting a range of depths the program can drastically improve the interactive contour interpolation as well as the selection of significant and representative soundings. The same program should be able to select the shallowest or the deepest sounding on the viewing area, or select only a specified range of depths. The GOMADS interactive editing system is a perfect tool for this type of work. All background information should be flashed on the CRT screen and the cartographer, by placing the cursor on the appropriate sounding will make a selection. A colour display is a necessity. Selected data will be flashed in one colour and background information in another. Grouping the soundings according to depth and displaying each group in different colour would simplify the selection.

It should also be mentioned that during data selection, the cartographer should never delete any information. The background information should stay intact, available for future use in case there is a need to change or modify the output. After the compilation is completed, only the selected data will be symbolized and plotted on film to produce reprographic overlays.

Source documents are usually larger in scale than the constructed charts. In order to portray all information required for the chart, the amount of information has to be greatly generalized. Rules for generalization are similar to those used with manual-visual techniques and will include exaggeration, minimization, omission and selection of the features. Again, it would prove beneficial for the cartographer to have a hard copy on which all areas in question will be identified and their corrections indicated. Because of the complexity and difficulty in defining these problems mathematically, the present generalization process used in the construction of nautical charts will not be fully automated for a long time.

Poorly digitized lines have to be edited interactively on the CRT screen. GOMADS has proven to be an excellent tool for this type of work. It is usually advantageous for the cartographer to have a hard copy of the file on which poor quality linework can be identified. These cosmetic changes to the digital chart file can be done at any time during chart production. This is not a unique compilation function, and has been successfully used for the last seven years.

3. CONCLUSION

Experiments with chart 8015 and other charts produced utilizing computer-assisted techniques have indicated a promising future for computer-assisted compilation in the Canadian Hydrographic Service. However, it has also indicated the presence of the greatest challenge yet, in creating a cartographic tool that will enable cartographers to easily merge, manipulate, and select or reject large amounts of hydrographic, and other source data. The data must achieve digital form as quickly as possible, ultimately right from the initial hydrographic survey. Because of increased use of digital processing at the compilation stage, much if not all of the huge amounts of survey data could be handled and used in chart production. Such a system must be able to accurately emulate sounding selection and contour development according to strict existing standards, either automatically and/or interactively. Design decisions should be based on what the cartographer knows the final product will look like, by using colour displays to draw the data in standard nautical chart colours, and by displaying various combinations of data.

By using digital data as much as possible, developing a system that is reliable, accurate and easy for cartographic personnel to use, and by allowing fundamental design decisions early in the production path, the final nautical chart should reach the maritime community faster, and be a generation advanced in cartographic accuracy.

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GENERAL TRACK SESSIONS: COMPUTER-ASSISTED SUPPORT FOR DECISION-MAKING

STRABO - AN ALTERNATE GIS APPROACH TO DECISION-MAKING FOR PLANNING APPLICATIONS IN DATA SCARCE ENVIRONMENTS

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ABSTRACT

This paper discusses an alternate Geographic Information System approach to data-poor spatial analysis problems. The approach, which has been called the Strabo Technique, is based on a modified Delphi methodology and is well suited for those decision-making applications in which spatial data is unavailable and/or unattainable. Although the technique is a candidate for a wide range of uses, the paper concentrates on the potential impact that it has for resource development within the framework of lesser developed countries. Here one often finds decisions and plans being made in a vacuum of reliable spatial data to the detriment of the development objectives. The Strabo approach, alone or in association with other GIS functions, presents a relatively inexpensive and simple solution to a number of these problems. The emphasis is on the methodology and applications rather than physical systems since Strabo can be considered both machine and software "independent".

INTRODUCTION

Often, when spatial decision making problems are considered, the under-pinning assumption is that relevant data or information is already available or at least attainable. How best to process this data; how reliable is the information; what data structures are most appropriate; how to interpret the results-these, <u>inter alia</u>, are the usual topics of discussion. But, what of the problems associated with unavailable data or, at best, information which would be extremely expensive to acquire? These problems are common in all manners of spatial planning applications, but are particularly exacerbated in development planning in the World's Lesser Developed Countries. It is towards these problems and these applications that this paper focuses. It describes an approach for gathering, analyzing, and interpreting spatial information in data scarce environments which might otherwise have been omitted from the planning process.

THE STRABO PROCESS

Strabo is the name, attributed by Poiker in 1975, to a process which finds its roots in the Delphi methodology. The differences in the approaches were significant enough to suggest that a new name was necessary. Strabo, the name of a famous Greek geographer/cartographer, was selected to represent the relationship to geographical applications as the oracle of Delphi represented the knowledge of wise men.

The Delphi approach to problem solving was developed in the late 1940s by the Rand Corporation. Its basic thesis is that "experts" tend to arrive at a concensus of opinion after several feed-back iterations. It was originally developed as a forecasting device for the American military but as interest grew, so did its range of applications. It underwent several major modifications in philosophical approaches, the description of which extends beyond the scope of this paper. In the late 1960s, Delphi was extended from a forecasting device to a general method for opinion assimilation and evaluation. The use of this approach experienced its share of criticisms from a number of avenues (see Sackman, 1974), but by and large the utility of the technique has been widely accepted, and it is recognized as a powerful tool for "structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (Linstone and Turoff, 1975).

In its broadest sense, the method may be defined as a series of steps towards solving a problem for which hard data is either unavailable, unattainable, or unreliable. Typical problems would include forecasting social "indicators" such as human attitudes and values, or predicting major technological developments. The first and probably most critical step is to identify a number of "experts" who are familiar with the subject of the problem to participate in the investigation. The knowledge base of these "experts" has been a focus of much attention by the critics of the approach. A thorough review of these concerns will not be considered here. Having selected a group of "experts", the process is to provide each with a set of questions which they have to answer with quantitative estimates . After being weighted by a confidence factor, the responses are tallied and a set of descriptive statistics are then prepared to summarize the responses. The results are returned to the participants along with an indication of where they stand relative to the group as a whole. The respondents then re-evaluate their opinions, prepare new responses, and begin the process anew. This may require several iterations; however, seldom is it repeated more than two or three times. Increased repetitions are time consuming and tend to promote a false type of consensus among the participants (Luscombe and Peucker, 1979).

Strabo takes a similar approach but instead of requiring a quantitative response, the participants are asked to respond with spatial information, usually a map. Of course this can be used in conjunction with a "normal" Delphi approach, but the fundamental difference is in the type of data provided in the response. The summary descriptive statistics become composite maps, again weighted by the confidence level of how certain the respondent is in his/her answer.

Respondents are asked to complete at least one of two types of maps - the first is an Attribute Map describing some characteristic of a study area, and the second is a Confidence Map describing the certainty with which each participant is able to respond to the Attribute Map. The Confidence Maps serve as weights for the responses of the participants and can be manipulated by the study director as appropriate. The Confidence Map essentially defines the respondent's perception of his knowledge surface.

Strabo is by no means the only attempt at applying a Delphi-type approach to spatial planning applications; the uniqueness of Strabo lies in the type of responses provided by the process participants. A number of spatial studies have included a Delphi component, but the participants respond to planning or development alternatives already existing in mapped form. Their spatial understanding of the problem and their perception of the knowledge surface remains unmeasured, but these are crucial if their input is to be considered heavily. Frequently, planning or development alternatives are arrived at through conventional Geographic Information System analysis (e.g., Comarc, Dames and Moore, ESRI, among others); Delphi is then applied to the "solution" and the results are fed back into the overall planning process .

USING THE STRABO METHODOLOGY

Why or when should a Delphi-based, spatial methodology be considered in the planning process? Several situations may arise which would favor the adoption of these techniques.

i. We can consider those situations in which it is beneficial to include public opinion in the decision making process. This case is rather straight forward. It provides an inexpensive data input to the problem which might otherwise have been ignored.

ii. The techniques can be applied to forecasting spatial impacts of policies or programs. The advantage over most quantitative, spatial, forecasting models is that it considers the qualitative and subjective elements in the analysis. For example, what are the long term social-spatial impacts of an inner city redevelopment project?

iii. They can drastically reduce the extent and cost of more traditional data collection processes. To illustrate, evaluations of resource potential can substantially diminish the area in which more detailed analysis would be required. If the objective were to locate oil reserves, a group of "expert" geologist might, through this process, reach a concensus about the areas which have the highest potential for development. Exploration could be limited, initially, to those areas thus reducing the chances of drilling dry holes (Barry, et al., 1970).

iv. A fourth situation in which the techniques hold promise is that of providing spatial information presently unavailable for an area and which would be extremely costly or impossible to collect. For example, if it is necessary to develop a water supply system for an urban area, one would have to consider the spatial distribution of a number of social indicators. Not always is this information readily available, nor is it always possible to afford the time or cost to collect the requisite data adequately.

IMPACTS FOR DEVELOPING COUNTRIES

The degree of sophistication in data collection, management, and analysis ranges widely amongst the Lesser Developed Countries. Some have well established data collection programs; however, they often lack the ability to manage the vast amounts of data or to effectively analyze the information in preparation of their development strategies. The results are typically sub-optimum programs. Others lack even the basic spatial information on which to build an integrated, comprehensive development plan. Yet, development projects are identified, prepared, and implemented.

To alleviate some of the problems experienced by the Lesser Developed Countries, several options are worth considering. Where appropriate, the introduction of spatial analytical capabilities within á Geographic Information System framework should be integrated into the overall development planning process. Likewise, the creation and maintenance of spatial data bases at relevant scales should be encouraged and supported. These, however, must be viewed as long-term solutions - and even then, only to a small number of their data analysis problems.

Major data collection and analysis programs are very expensive - requiring already scarce resources within the LDCs. The Strabo

Technique, used in "isolation" or in concert with other spatial analytical methodologies, would provide an alternate approach to the problems. Reliable spatial data for large scale development projects can be easily and inexpensively obtained through this process. It may not be feasible, for example, to conduct an urban survey in an LDC city of 5 million to support an Urban redevelopment project, but the necessary information about the social and economic structure of the area may be derived from a concensus of the "experts".

The applications of the approach are not restricted to any development sector-it can be used equally well in urban planning and development projects, agricultural redevelopment programs and mineral explorations, among others. It does not, in itself necessarily replace existing approaches to development decision making, it augments them; however, it does have the power to stand alone as a planning tool in the absence of other approaches.

CONCLUSION

The Strabo Technique applies a different approach to spatial problem solving than most other techniques or methodologies. It empasizes the information derived from a concensus of opinion of "experts" rather than from existing hard data or from spatial modelling attempts. Because the emphasis is on the approach, rather than specific functions, the Technique is both machine and software independent. Many existing "geographic information systems" can perform the types of operations and manipulations required to do a Strabo study.

The Technique has a wide range of applications in the spatial decision-making process, but it lends itself particularly well to the data problems in the Lesser Developed Countires where decisions have often been made in a data vacuum. It provides a mechanism for establishing and analyzing information which otherwise would be omitted.

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THE USE OF LARGE SCALE INTERACTIVE MAPPING SYSTEMS IN A DECISION SUPPORT ROLE

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ABSTRACT

Decision support systems are integrated hardware and software packages used by managers to aid in making semi-structured decisions. Large-scale interactive mapping systems are designed to collect and manage geographic data bases. Experience in the automated mapping industry has indicated that large-scale interactive mapping systems have not been used in a decision support role because of inadequacies of the user interface. Operators of these systems tend to be highly trained individuals possessing a technical background, thus eliminating managers as system users. Improvements to the user interface focusing on conceptualization and control aids should allow decision makers to use interactive mapping systems as decision support tools. Recent attempts at user-friendly systems such as the Domestic Information Display System (DIDS) have shown that development work in this area is both feasible and justifiable. Development in the areas of low-cost inquiry terminals and improved command structures is needed to provide decision makers with a friendly user interface.

INTRODUCTION

Decision Support Systems (DSS) have been actively used and researched by the management science community since the early 1970's. The body of knowledge and experience accumulated about this subject has shown that DSS have traditionally conveyed information in tabular form and have not been able to convey geographic information in the form of maps. In fact, graphics of any form have only recently been introduced into DSS. Large-scale interactive mapping systems can, if developed in a manner suitable to DSS applications, solve many of the problems encountered by previous DSS relating to their lack of display capabilities for geographic information. This paper will explore the requirements of a DSS in the context of mapping systems, cite problems being encountered by DSS users, examine the applicability of large-scale interactive mapping systems to DSS, and suggest further development for these mapping systems to facilitate their use in a decision support role.

DEFINITION

Any study of DSS and their relationship to mapping systems should begin with a definition of these two products. A DSS is an integrated system of computer-based products, both hardware and software, that is used by managers to aid their decision making in semi-structured decision tasks (Bennett, 1983). Two key concepts, support of management decisions and semi-structured decision tasks, should be stressed at this time. It is important to note that a DSS does not replace managerial judgments but instead aids the manager in making these judgments. This is not to say that a computer system is incapable of supplying a single best answer to a managerial problem. If the problem at hand is highly structured and the associated decision making process can be described in detail before the decision is made, then it is a programmable problem and the system can supply an optimal solution. Examples of these structured types of decisions are the calculation of accounts receivable, budget analysis, and inventory control. If, however, the decision making process cannot be described in detail because of the need for non-quantifiable data, then this semi-structured decision cannot be made but can be supported by the computer system. Examples of semi-structured decisions are the selection of industrial site locations, long-term forecasting, and the determination of target product markets.

A large-scale interactive mapping system is primarily designed for the collection, management, and display of geographic data. Note that the purpose of these systems is not just the manipulation of maps, as is the function of automated drafting systems, but the management of a large geographic data base composed of graphic as well as attribute information. Every item of data in such a data base has, in some way, a spatial element that ties it to a geographic location. This geographic association may take the form of a record describing a piece of equipment at a known location such as a transformer for an electric utility company or may be a collection of data describing a polygonal area such as a tree stand for a forest products firm. Due to the interactive nature of these systems, they provide immediate on-line access to their data bases and should be able to support semi-structured decision tasks that require geographic data.

REQUIREMENTS

Studies of the decision making process and of existing DSS have shown that there are common requirements a DSS must meet in order to be effective. The four most often cited requirements (Carlson, 1983) are:

1. DSS must provide specific graphical representations to assist the decision maker in conceptualization and a frame of reference for using the DSS (e.g., maps, bar charts, histograms).

2. DSS must support multiple paradigms since different types of decisions require different types of decision making processes.

3. DSS must provide memory aids to the decision maker (e.g., an electronic scratch-pad, recall of past reports, etc.).

4. DSS must provide control aids to help the decision maker control the DSS and facilitate its use as a decision making tool (e.g., English language commands and error messages, menus, etc.).

A common thread running through all four of these requirements is the dependence upon a well-designed "friendly" user interface. The DSS field has stressed research and design on the user interface and has made recent advances toward developing user-friendly systems. Typically, 60 percent of the software for interactive DSS applications is devoted to code related to the user interface (Bennett, 1983). Large-scale interactive mapping systems, on the other hand, have not stressed the user interface as highly as DSS. Software for a typical interactive mapping application will only devote 35 percent of its code to the user interface. It seems obvious that, if mapping systems are to function in a decision support role, the user interface must be much more highly developed.

PROBLEMS

Due to the heavy dependence upon a well-designed user interface for a successful DSS, the majority of problems reported by current users relate to inadequacies in this area. For instance, existing DSS do not provide the graphical representations that decision makers need for semi-structured decisions (Carlson, 1983). Tabular data is entirely adequate as a system response to a structured decision process since a single best solution can almost always be represented in this manner. However, when a range of alternatives is necessary as a system response, as is the case with semi-structured decisions, the provision of graphical representation becomes paramount. If the decision has a geographic element, such as the selection of a new facility site, the graphical representation must be in the form of a map. This problem relates directly to the first requirement of a DSS: the need to provide specific graphical representations.

A second problem cited by DSS users relates to the general "user-friendliness" of the system. The target user for most DSS is the manager or decision maker. Logically, this person should be interfacing with the system directly, without the need for expert advice or extensive training. This unfortunately is not always the case. Many managers employ a consultant or "middle-man" to operate the system instead of using the system itself as a decision making consultant (Gorry & Krumland, 1983). This problem is especially acute in instances where interactive mapping systems are being used to provide decision support material. Due to the complexity of the user interface, operators of these systems are almost exclusively individuals possessing a highly technical background, thus effectively eliminating managers as system users. This problem relates to the fourth DSS requirement: the need to provide control aids.

APPLICABILITY

Interactive mapping systems can resolve some of the inadequacies of DSS simply by the fact that they are both interactive and have the ability to display maps. However, in other aspects they are greatly lacking as decision support mechanisms and need to be developed to meet the requirements of DSS. As previously stated, the requirement that a DSS provide graphical conceptualization aids has not been satisfied by most of the current systems on the market. Interactive mapping systems are capable of providing the user with map displays on a timely basis and, if equipped with the proper software, can generate a full range of thematic and statistical (i.e., choropleth) maps. Managers, when faced with a decision that is spatial in nature, normally use data presented in the form of maps, tables, graphs, and pictures when analyzing the problem or selling the proposed solution to the affected parties. The decision maker carrying out these tasks is accustomed to working with ideas presented orally and in a written form on paper, transparencies, and slides. If we want to design computer-based tools that will support the decision maker in these tasks, we must consider the characteristics of the intended user and the nature of the tasks carried out (Bennett, 1983). Along these lines, interactive mapping systems must be given the ability to display bar charts, histograms, pie charts, and other graphics familiar to managers in addition to the ability to display maps.

Most interactive mapping systems, whether by design or default, meet the DSS requirement of supporting multiple paradigms. A good DSS will not impose process upon the decision maker when a problem is semi-structured, thus allowing the decision maker to arrive at a solution independent of system-induced bias. Many DSS ask the user explicit questions, the answers to which determine the next presentation. Typically, there are far too many possible combinations of user actions to make a question-asking approach feasible (Bennett, 1983). The ad hoc nature of queries and commands presented to users of mapping systems avoids this pitfall, although often at the expense of user-friendliness.

The third requirement of a DSS, providing memory aids such as an electronic scratch-pad, can also be satisfied by interactive mapping systems. Systems organized in a manner similar to Synercom's INFORMAP System, where there is a provision for separate working and permanent storage areas, are particularly well-suited to this task. Under this type of organization the data base is kept in a permanent storage area in which the data can be viewed, extracted for reporting and tabulation, or copied into working storage. No direct modification or editing or data is allowed in permanent storage. Working storage functions as a scratch-pad area where copies of user-defined geographic areas in permanent storage may be placed. Once in working storage the data can be edited, added to, deleted, and generally manipulated to test results of "what if" scenarios. Data in working storage can be saved for future reference or deleted after a conclusion has been reached by the decision maker using the system.

Providing control aids, the fourth requirement of a DSS, is an area where interactive mapping systems are in need of vast improvement. Much of the power of a well-designed user interface lies in the capability to present information in a variety of forms. The same statistical data placed on a map, shown in a graph, or shown in tabular format can lead to different user insights. Assuming that a user may want different representations of the same data at different times during the decision making process, the user requires a high degree of control over the presentations. This control must be "high-level" to be attractive to a decision maker since most managers do not want to interrupt problem-relevant thinking processes to cope with computer-imposed details (Bennett, 1983). High level control can be provided through the use of English language commands, menus, or a combination of both. A manager should be able to sit down at a terminal; query the system for a map using simple placenames and terms describing spatial relationships such as size, distance, adjacency, etc.; and view the map on the terminal screen. Currently, this is not possible with any widely available large-scale interactive mapping system. Error messages are another aspect of the user interface that needs improvement. Managers quickly learn whether a system is a friend or a foe when they make errors. A friendly system should give an informative message and provide help in correcting the error. Current use of error messages like "INVALID PARAMETER" mean little or nothing to a manager, much less a programmer, and can be loosely translated as "something is wrong, and this is a wild guess at what it is" (Brown, 1983).

Attempts have been made to overcome the aforementioned problems and develop a mapping-based DSS. One such example is the Domestic Information Display System (DIDS), an interactive, menu-driven software system that produces single and bivariate choropleth maps on color television monitors of socioeconomic data by county and congressional district at the national and state level and by census tract for standard metropolitan statistical areas (Dalton, 1979). The system is highly interactive and can produce a color map display within seconds of the selection of a data item from a menu. Continued use and evaluation has proven it to be a reliable and easy to use system that can be operated by non-technical staff. The menu-driven user interface is easy to comprehend and simple to use. A novice can produce a meaningful map using the default parameters in a matter of seconds. More importantly, it is also easy to utilize the options to alter the colors and class intervals, select windows on the data, or highlight a particular class (Cowen, 1982).

DEVELOPMENT

As previously stated, the decision maker must be given aids to conceptualization of the problem and control aids over operation of the system. These are paramount to the achievement of a friendly user interface. On a systems level, this interface can be viewed as a function of both hardware and software. The hardware aspect of the user interface may encompass a vast body of components but for the purpose of this paper will be limited to the terminal or workstation. Virtually all of the large-scale interactive mapping systems on the market today supply workstations as the primary, and often the only, interface between the operator and the system. These workstations are designed for a specific purpose: the entry and editing of a geographic data base. They are also designed for a specific type of operator: an individual with a technical background who is familiar with concepts common to the fields of cartography and drafting. A typical workstation consists of a digitizing table or tablet, a free-floating cursor, a keyboard, and two CRT monitors. Recent products offered by Synercom and other companies have relied upon high-resolution color raster monitors and have included local processing capabilities to off-load the CPU. These workstations perform quite well within the bounds of their designed tasks but are not suited to the type of user interface required of a DSS.

A terminal for DSS applications needs to be smaller and less imposing than the typical workstation. Ideally it should be desk top size, thus fitting easilyin the decision maker's office environment. It need not feature the sophisticated display capabilities of a typical workstation but should include a low or medium-resolution color raster monitor on which text and graphics can be easily overlayed. Like the workstation, the DSS terminal requires local processing capabilities to provide high response times and the ability to operate as either a stand-alone system or in a network with the main CPU. In this manner, a large number of terminals can be supported without significantly degrading the overall system performance. Since the terminal will not be used for data entry or editing, but will be used to query the data base, a digitizing table is not necessary. However, some form of graphic input device such as a lightpen, joystick, or mouse is required to allow the user to interact with the system through the utilization of graphic menus. Finally, the terminal must be relatively inexpensive. In today's market a typical workstation can range in cost from $50,000 to $100,000. A realistic cost goal for a DSS terminal would be $5,000, with $10,000 being the upper limit based on the amount of local processing involved. A terminal with the capabilities described above, when integrated with an interactive mapping system, could easily satisfy the hardware requirements for a user interface that is friendly enough for use by managers.

Many companies in the computer mapping industry are currently developing low-cost inquiry terminals that conform to the definition of a terminal for DSS applications. While this is encouraging, the development of software for the user interface is lagging far behind the development of hardware. In some respects, software is more critical to the provision of a friendly user interface than is hardware. Managers will not utilize the decision support resources of a mapping system unless the command structure is clear, concise, and easy to learn. The use of menus is one method of providing this type of command structure. Although mapping systems currently provide menus, their development is still at a rudimentary level. A successful menu approach should be based on a hierarchical tree structure such that the first menu displayed is the most general and allows the operator to select a number of more specific sub-menus. Each successively lower branch on the menu tree would allow the operator to specify more detailed or application-specific commands. Many software packages for personal computers have taken this approach and have proven to be effective in providing a friendly user interface.

Another type of command structure that has been ignored by the computer mapping industry is the use of English language commands. Commercial software packages for data base management systems typically take this approach by providing a conversational command language that allows the user to retrieve information, design reports, and perform arithmetic operations, all with a simple English-like vocabulary and syntax. Common commands in a data base management system such as SELECT DATA FILE, DESIGN FORMAT, and CALCULATE could easily be applied to a mapping system. Users would then be able to select a given geographic area of interest, choose the colors and symbology for a display, and retrieve statistical information based on the non-graphic attributes in the data base. A conversational tutorial, similar to the computer aided instruction courses offeed by DEC and other suppliers of commercial software packages could be used to teach the manager how to use the mapping system in a self-paced, friendly manner.

CONCLUSION

The computer mapping industry is presently facing the challenge to develop large-scale interactive mapping systems that can be used as decision support tools, as well as for collecting and managing geographic data bases. Research conducted within the management science discipline has pointed the way for this development and has supplied a wealth of information on the requirements for a successful DSS. By studying the problems encountered by current DSS users, the mapping industry can avoid many of the common pitfalls attributable to a poorly designed user interface. Pilot projects and studies such as DIDS support the premise that the use of mapping systems in a decision support role is not only feasible but is attractive to the user community as well.

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AN INTEGRATED DATA BASE FOR MINERALS AND ENERGY INFORMATION ON PUBLIC LANDS

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ABSTRACT

Questions often arise about the availability on the public lands of the United States of both fuel and nonfuel minerals that are of strategic and critical value. Providing answers to such questions has involved various Federal agencies that collect, analyze, and manage resource data. However, these data often are widely dispersed and are not readily analyzed because of the variability in format and map scale.

The ability of geographic information systems to combine point, line, and areal data for answering relational-type questions has been widely documented, although the establishment of a particular data base presents its own unique problems. The U.S. Geological Survey is developing a geographic information system consisting of information on Federal surface ownership, Federal subsurface mineral rights, location of actual mineral occurrences and (or) known potential, and formal restrictions to mineral development. By utilizing information already in existence or soon to be collected by other agencies, this geographic information system should be able to provide answers relating to mineral availability on public lands.

INTRODUCTION

The stewardship of Federal lands is more than the opening or closing of such lands to development. Federal lands belong to all Americans. The scenic beauty, recreational opportunities, wildlife habitat, and mineral, biological and water resources are all part of the wealth of Federal lands which must be managed for the public good. Though the concept of multiple use guides management decisions, the question of priorities often results in controversy and conflict.

The resolution of conflict depends on objective resource data balanced against public priorities. The determination of public priorities is a political process. Resource assessments are the responsibilities of scientific and land management organizations. The U.S. Geological Survey

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(USGS) has served the public for over 100 years by collecting, analyzing, and disseminating information about the Earth, its processes, and its water and mineral resources. Other agencies such as the Bureau of Land Management (BLM), the Bureau of Mines, the Fish and Wildlife Service, and the Forest Service also provide resource data and assessments of Federal lands.

A FEDERAL MINERAL LANDS INFORMATION SYSTEM

One national priority is the development of mineral and energy resources. History and politics have determined the ownership pattern of Federal lands. Geologic processes have determined the occurrences of mineral and energy resources. Where the two coincide is of great interest to the Federal government and its land management agencies. Questions arising about the availability on public lands of both fuel and nonfuel minerals that are of strategic and critical value are an important component of the development of an overall resource management policy of the Federal government. The various Federal agencies that collect and analyze resource data and manage land resources have provided answers to parts of the availability questions. Pulling these data together in some meaningful form has proven difficult in the past because of the dispersal of data and the variety of formats and presentations.

The objective of the U.S. Geological Survey's Federal Mineral Lands Information System (FMLIS) is to integrate, in digital form, diaparate data which are compiled and published at different map scales and in different formats to be used as a tool for land management and policy decisions at regional, State and national levels. These data include the location of Federal surface land ownership, subsurface mineral rights, energy and mineral resource occurrence and potential, and federally mandated or formal restrictions to mineral development. In addition, base cartographic data are included for location and analysis purposes.

Sources of Data for FMLIS

Data for FMLIS come from a variety of sources. The primary source of Federal surface ownership, subsurface mineral rights, and Federal restrictions to mineral development is the land records of the Bureau of Land Management. These data are kept on Master Title Plats, Use Plats, and historical files at the township level. Records cover all federally owned and managed land as well as those lands for which the Federal government has a subsurface interest. Currently, BLM is developing an Automated Land and Mineral Records System (ALMRS). This system will automate the land recordkeeping process for BLM by allowing them to input records in digital form and retrieve data in both tabular and graphic format. USGS is working closely with BLM on the development of ALMRS and selected ALMRS data will be incorporated into FMLIS.

Mineral occurrence and potential information will be obtained from the USGS Geologic Division's Mineral Resources Data System (MRDS), Conterminous U.S. Mineral Assessment Program (CUSMAP), Alaska Mineral Resource Assessment Program (AMRAP), and Wilderness Area mineral assessments, as well as mineral information from other sources and agencies. These types of data are presented in various scales and formats which necessarily will impact the types of data analysis and output.

Geographic Information Systems

Geographic information systems (GIS) provide the ability to integrate and analyze spatial data. They are a combination of hardware and software designed for the capture, analysis, and display of geographic information. Such systems are frequently applied to natural resource management problems.

A GIS can be divided into three basic modules corresponding to data input, analysis, and output. Each module is distinctive and, to a large extent, characterized by its hardware. Data input is commonly from manual digitizing tables or raster scanning systems. Data output is through graphic display devices or x-y plotters. Data analysis is normally performed on a general purpose computer and, in this case, it is the software rather than the hardware that is distinctive.

There are two principal types of GIS. One uses grid cell or raster-based data. The second uses data in vector form and there are several versions within this type such as arc/node or full polygon formats. Manually digitized data are usually in a vector form but can be converted to a raster form. Data from scanning systems are normally in a raster form but can be vectorized although it may be a relatively expensive process. Vector systems can often produce higher quality output graphics with more "realistic" line detail. Raster systems generally have a lower quality of output graphics but can perform a number of analyses more rapidly and efficiently than vector systems.

Geographic information systems incorporate a broad range of functions essential to the manipulation and analysis of spatial data. Since much of the data comes from maps that may vary in scale and (or) projection, it is essential that the system be capable of changing scales and projections and registering the maps. Because the data input process is not perfect, it is necessary for the system to provide editing facilities that allow the data to be examined and corrected. Various systems do contain certain error detection capabilities for some types of data such as ensuring that polygons close at a point. Normally, data input is required for each theme individually so that each map goes through the process of digitizing, editing, and entry into the data base. This process of building the data base is the most tedious and time-consuming and yet one of the most critical steps in the application of geographic information systems.

Once the data base has been constructed a new set of functions come into use. A key function is that of overlay which allows the user to combine two or more sets of data to produce a new set. In raster systems, this is a relatively simple process but, in vector systems, it is a much more difficult process which few systems are able to perform effectively. In any system, this is the critical function for the integration of the data prior to analysis.

In the analysis phase, functions are called upon to select, retrieve, display, window, zoom, tabulate areas, measure distances, and so forth. It is at this stage where interactive systems are most beneficial. Up to this stage, the difference between batch and interactive systems is not significant. However, when the user has the ability to rapidly analyze his data interactively, examine alternatives, and test hypotheses, the benefits are substantial.

The display of data is essential to the analysis process but, once the results have been determined, a final set of products is commonly needed. For these, it is often desirable to have a higher quality output with greater use of color and symbolization and more attention to format than is necessary for the analysis phase. Some systems provide additional capabilities to meet these needs that can greatly assist users in dealing with decision makers.

In the initial stages of the Federal Mineral Lands project, several different systems will be examined, both raster and vector, to determine their relative strengths and weaknesses.

MEDFORD PILOT PROJECT

A pilot project was planned to test the concepts of FMLIS. The area of the Medford, Oregon, 1:250,000-scale quadrangle was selected because Federal surface, subsurface, and restrictions data were available from BLM's 1:100,000-scale Surface Mineral Management status maps covering the Medford quadrangle. USGS has a CUSMAP report for Medford and extensive point data from MRDS. A second pilot area will be tested in coordination with BLM in the Silver City, New Mexico-Arizona quadrangle to determine the working relationships between BLM's ALMRS project and the FMLIS. The Medford pilot project could not utilize ALMRS data as none were available; however, the pilot project did demonstrate the overall concept of the FMLIS and provided insight into data analysis and output techniques.

The concept of FLMIS was tested by posing a series of land management and mineral development policy questions of the data base. Such questions included:

(1) Which Federal agencies own and (or) manage land in the area and where do the lands occur?

(2) Where does the Federal government have subsurface mineral rights?

(3) Which federally owned and (or) managed lands are restricted or withdrawn from mineral development by Federal law?

(4) What minerals occur or have a known potential for occurrence, and where do they occur?

(5) What is the coincidence of Federal surface and subsurface ownership?

(6) What is the coincidence of subsurface mineral rights and restrictions to mineral development on land owned and (or) managed by a particular agency?

(7) On what federally owned and (or) managed land does a particular mineral occur where the Federal government has subsurface mineral rights and there are no Federal restrictions to mineral development?

The ability to manipulate the data base to derive the answers to these and other types of questions demonstrates the viability of the concepts proposed by the Federal Mineral Lands Information System.

The work for this particular pilot project was performed at the EROS Data Center (EDC), Sioux Falls, South Dakota. The FMLIS-Medford pilot project used spatial data on the Medford study area, coupled with the GIS analytical capabilities of the Interactive Digital Image Manipulation System (IDIMS) made by Electromagnetic Systems Laboratory. The IDIMS is designed for manipulation, analysis, interpretation and processing of a wide variety of image data. In general, analytical processing is performed on images in raster form. The heart of IDIMS is a Hewlett-Packard 3000 minicomputer with a multiprogramming operating system. Images in digital form can be input directly into IDIMS. Mapped data must first be digitized in vector form and then converted to raster format. Tabular numeric data may be entered directly via tape or terminal. Most processing may be performed by the non-programmer using software modules written specifically for IDIMS. For display, data may be sent to color electronic displays, character printers, and plotters.

The FMLIS data base, consisting of registered raster images of the Medford area and associated text and numeric data, is handled by two subsystems of IDIMS. One of these, the Earth Resources Inventory System (ERIS), is a software package for the integration and analysis of earth resource data in tabular form. The data may come from IDIMS image data, digitized data, or input directly by the user. Using ERIS, the user may manipulate data files, perform calculations, create new files, and generate descriptive statistics of the contents of these files. The second IDIMS subsystem for handling tabular data is the Image-3000 system. This system has many of the features available in ERIS with the exceptions of a limited IDIMS interface, yet has more flexible report generating capabilities.

The ownership and restrictions data were digitized from the BLM 1:100,000-scale Surface-Mineral Management Status maps.

The mineral occurrence and potential data were obtained from MRDS files and the Medford, Oregon, CUSMAP report. The data, once digitized in vector format, were rasterized for processing and analyis on IDIMS. Hard copy display products were produced on an ink jet plotter, a laser beam film recorder, and a flatbed plotter. However, the real value of a geographic information system is the ability to manipulate and analyze data rapidly and display output on a CRT.

CONCLUSION

The Federal Mineral Land Information System is still in a developmental phase. The Medford pilot project provided helpful insight into the problems of data collection, data capture and manipulation, and some analysis techniques. There are still a number of areas which need to be addressed such as:

(1) The ability to incorporate BLM's ALMRS data.

(2) The best type of geographic information system to employ.

(3) The most efficient combination of data formats; that is, raster versus vector.

(4) Appropriate map scales for data presentation in relation to the types of questions asked.

(5) The roles of other Federal agencies in the Federal Mineral Lands Information System.

As the system evolves in response to the needs of Federal agencies, the above concerns become more critical. The key to the success of FMLIS will likely be the flexibility of the system to handle a variety of spatial data in a format acceptable to a number of computer systems. FMLIS will then provide a basic set of information which could be expanded upon, as needed, by others who have a need to deal with information at a finer degree of detail.

INTERACTIVE GRAPHICS SYSTEMS IN LOCAL GOVERNMENT MAPPING: THE ACHIEVEMENTS AND CHALLENGES

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ABSTRACT

The first system of the turnkey interactive graphics system genre was installed for mapping in a local government almost 10 years ago. Since that time, 100 or more others have been installed and more are being sold every day. The purpose of this paper is to explore the achievements and problems which have been experienced by those using this technology for mapping in local governments and to pose certain challenges for the future based on those experiences. The paper will review the technology among mapping users, identify exemplary installations, identify the primary applications, discuss the common problems which have been encountered, and note trends which are emerging. Among these issues are the revolution which is occurring in local government mapping, the problems of existing source materials and the extent of user friendliness among systems. The issues will be discussed as they relate to practical applications in land information systems. Based on these experiences, the paper will present a series of challenges for improved utilization in the future. It will discuss the serious problem of initial data conversion, the potentials for attribute and graphic linkage, the future of direct user operation of the systems and the potential support for multipurpose cadastres.

INTRODUCTION

Interactive graphics systems have begun a revolution in local government mapping operations. Automation of mapping, like automation of just about everything else, is seen as a way to improve productivity and reduce costs. Until the advent of the minicomputer-based interactive graphics system, however, the cost of map automation was just about prohibitive for local governments, and so the potentials for productivity were meaningless. With the availability of relatively low-cost technology about 10 years ago, the door was opened to mapping automation. Today that opening seems a floodgate with new systems being acquired almost daily.

Although the first local government systems were installed almost 10 years ago, we still do not have much experience in the full life cycle of these systems. The systems themselves function as well or better than expected and significant improvements in the technology have taken place over the 10 years. But conversion of map data for an entire city or county to digital form is such a tremendous task that few places have actually completed even an initial data base. The benefits of an automated system do not begin to accumulate until at least a substantial portion of the data base is converted, so most systems in operation today are not yet at their peak efficiency.

In addition to the improvements in worker productivity that are possible through use of automated systems, they can also provide substantial benefits by reducing or eliminating redundant map maintenance activities and by bringing flexibility to map production. In many communities, a new subdivision may be plotted separately on 10 or more individual maps in as many organizations. A central automated system is capable of providing the various specialized maps to those same organizations through a single update operation. The cost savings here can be substantial. The flexibility of an automated system in producing various sizes, scales and combinations of features from a single base to meet individual requirements is also very cost effective.

THE SYSTEMS AND THEIR APPLICATIONS

The systems which are the focus of this paper are a genre of interactive graphics computer systems supplied by various vendors. The systems are typically sold as "turnkey" packages, including hardware, software, training, documentation and maintenance. They are generally built around a sophisticated general-purpose minicomputer and include large-volume disk storage units, a magnetic tape drive, a system console, one or more graphic work stations and a plotter. Each graphic work station consists of one or more high-resolution graphic display devices, a digitizing table and cursor, and a keyboard.

These hardware devices are controled by a comprehensive repetoire of software, including an operating systemm, graphics package, data base management system, FORTRAN and/or other compiler, macro language and utilities. These components are integrated into a system which is very easy to operate with most commands being issued interactively by means of menus.

The predominant application area for acquisition of interactive graphics systems in local government is maintenance of base maps. What is included in a base map varies from place to place, but generally includes streets, parcels and often utility facilities. These maps are usually entered into the system with as high a precision as is practicable, though cost considerations have generally ruled out acquisition of new, very high-precision maps. Because of the long lead time in converting a detailed, accurate base map to automated form, many organizations have begun more general mapping in parallel to provide useful visibility for the system. GBF/DIME-type files have been created or loaded to support thematic mapping of planning and administrative data.

In addition to the local governments themselves, private and public utilities have been a major customer for interactive graphics systems for mapping. In some cases, a local government and one or more utilities in the area have jointly acquired a system. The utilities are also using the systems for map maintenance. In this case, in addition to streets and property boundaries, the facilities (water, sewer, electric or gas lines; valves; transformers or other facilities) of the utility are also entered with as high a precision as practical. The utilities on the average seem to have more resources and possibly a greater requirement for precision and so have entered higher quality data during conversion.

Local governments have also used the attribute data storage and computational capabilities of the systems to perform geographic analyses. Such things as political redistricting, service area definition and areal crime analyses have been performed on the interactive graphics systems.

Because of their common role as the primary mapping organization in a local government, the Public Works Departments have tended to be the predominant user organization; though, somewhat surprisingly, Planning Departments have been very active in leading the local government into acquisition of an automated mapping.

Although the systems typically have computer-aided design (CAD) capabilities to support engineers in designing bridges, roads and utility facilities, very few local governments are making use of these features. A reduction in the cost of map maintenance is the main goal at present, with improved timliness and flexibility important by-products.

EXEMPLARY INSTALLATIONS

As stated earlier, there are now about 100 interactive graphics mapping installations around North America. Of the 100, however, the majority are relatively new and have not achieved enough to provide valuable insight. The one observation from these newer installations is that the latest systems built around computers with 32-bit architecture offer significant capability improvements over the older systems. Adding microcomputers for local processing at the work stations has also supported the improvement in system performance.

Of the mature installations, all have important lessons to provide, but a few exemplify these lessons particularly well. One of the best documented experiences is that of the City of Milwaukee, Wisconsin. Milwaukee began in 1977 with a carefully planned and well-documented pilot project. An M&S (now Intergraph) system was leased for 6 months and a sample of maps was digitized.

The pilot was used to test procedures, verify the practicality of the technology and estimate costs for full data conversion and operation. The pilot was evaluted and judged successful. The system was acquired and the full implementation program was begun. The main application was to be the conversion and maintenance of the engineering base. The City undertook conversion of the data base itself and estimated it would take 2 1/2 years to complete. In 1982 the staff produced a report summarizing the activity to date in which they reported that conversion was taking about twice as long as estimated and would take 5 years to complete.[*] In the meantime, however, the system has been successfully applied to planning and management functions ahead of schedule. Thematic map production and spatial analysis have been very useful to the City and have contributed to the system's credibility in political circles.

One of the important problems encountered by Milwaukee, as well as other system purchasers, is that of obsolescence. This is an area of rapidly changing technology in which, though systems continue to function, the vendors exert great pressure to upgrade to make their maintenance and support task easier. In Milwaukee's case, a long-awaited upgrade turned out to be to the last sale of the current model; and so, unfortunately, another upgrade can be expected sooner than usual.

Another early installation, one that encountered serious difficulty, is Virginia Beach, Virginia. This was one of the first few local government installations and, like Milwaukee and other early purchasers, Virginia Beach set out to digitize the maps itself. Virginia Beach is also a

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1 Huxhold, William; Richard Allen; Randolph G. Schuind. An evaluation of the City of Milwaukee Automated Geographic Information and Cartographic System in Retrospect. Presented at Harvard Computer Graphics Week, July 1982.

very large city geographically, and so conversion took about 8 years. Unlike Milwaukee, it did not have the good fortune to win political allies through thematic mapping or other early applications, and so was faced with a crisis over the extensive time before operating productivity would be achieved. Luckily, the automated mapping operation survived that crisis and productivity will be enhanced with the acquisition of an upgraded system.

Perhaps the most highly publicized of the installations has been Houston, Texas, where a very different approach was taken. Unlike the prior two cities that developed their data base internally from existing map sources, Houston spent several millions of dollars in aerial photography, new map production, conversion to digital format, and system acquisition. Using a contractor, the calendar time required for conversion was reduced significantly. Acquiring new map products also provides Houston with a high-quality data base, something not all organizations have achieved. For those who can afford it, both of these approaches--contract data conversion and high-quality sources--are desirable. One important point to consider in this approach is to ensure sufficient management and customer involvement in the product. The contractor should not be sent off to build the data base unattended. The local government has people with knowledge and expertise that will be important in compiling source materials, and successful use and maintenance of the data base will benefit from an understanding of its development by its users and maintainers.

Another interesting location is Burnaby, British Columbia. Burnaby has developed a successful mapping operation built around an interactive graphics system also. A relatively high-precision map has been converted to digital form. The reason I note Burnaby here, however, is because it began as a multi-organization project. The Burnaby Joint Utility Mapping Project (BJUMP) included the utilities (B.C. Hydro & Power Authority, B.C. Telephone Co.) along with the Municipality of Burnaby. Multiple use of automated systems is an especially cost-effective approach. The two major costs of an automated system are the basic computer system (e.g., CPU, disk, software, etc.) and the digital conversion of the base maps. The incremental cost of additional work stations and conversion of overlays is relatively less expensive. This means that, with multiple user organizations, the major costs can be amortized over a broader base with a relatively low additional cost per user added. In addition to the direct cost break, the sharing of mapped data achieves byproduct benefits through reduction of redundant map maintenance activities and elimination of inconsistencies among the maps of related organizations.

ACHIEVEMENTS

The achievements of this technology are still incomplete. Probably the most significant achievement to date is the stirring of a revolution in mapping operations. The interactive graphic technology has made automation of mapping technically and financially feasible and automation is now being achieved, planned or discussed in most large-size and many medium and smaller jurisdictions around the United States and Canada. In comparison to this psychological achievement, the tangible achievements are less substantial. There are few locations where operations have been completely or even substantially converted to automation. The lead time for data conversion is long and the technology is new, so few have been through the whole cycle. As with any other panacea--it isn't. The systems work and can perform most of what they are promoted to be capable of. There are very real problems in using them fully, however (discussed below). It is safe to say that virtually all who are involved with the technology and know the realities of its use have a positive opinion of it, though most would do things a good deal differently if they had it to do again.

A significant achievement of the builders of the systems is that they have built systems that are truly user-friendly. The systems are easy to operate by pointing at menu commands and locations on a map or display screen. The combination of interaction and visual display allows most persons to easily understand how to operate the system. An operator can be trained within a few days and will become very proficient in a few weeks. Experience has shown that personnel from virtually all levels of sophistication can learn operation, though those with an understanding of the maps seem to make the best digitizer operators.

The systems are capable of entering, storing and plotting map features with an extremely high level of accuracy and precision. In fact, the limiting factors here are not the system but the source materials and the operators.

A virtually endless repetoire of formats, annotation and symbology is supported by systems so that the unique requirements of virtually all users may be satisfied easily.

The automated linkage of graphic images with their attribute characteristics stored in a data base has been achieved in an operating environment. One can select, retrieve and display graphic images (e.g., parcel boundaries) on the basis of their attribute values (e.g., all parcels over 5 acres and valued at more than $50,000) and can report the attributes of selected images (e.g., a parcel identified with the cursor on the display or all parcels within a graphically defined area). This capability is very powerful, opening and wide range of applications.

In summary, there are successful applications that have improved productivity, reduced redundancy, and in other ways improved local government mapping.

PROBLEMS

For mapping, the single most serious problem with use of interactive graphics systems--or any other automated system for that matter--is the task of converting the paper, mylar, scribe, linen, or whatever media, source maps to digital form. This is a very time-consuming and costly endeavor. It has proven to be more time consuming and costly than originally estimated in virtually every location that has accomplished a large amount of conversion, often by orders of magnitude. Numerous techniques and technologies, including automated scanning, have been tried in various places with the final result that it is still time consuming and costly. Part of the problem is the magnitude of data that resides on the maps of a local government, part rests with the level of precision and accuracy required to meet mapping requirements, and part is a result of the quality of source materials. Most local governments in North America have not yet developed really accurate, high-precision maps. Though Canadian cities may surpass those of the United States, in general there is still a good bit of effort required in either country to organize high-quality source materials.

A second problem that is beginning to emerge now is obsolescence. Interactive graphics, like all other parts of the computer industry, has been undergoing rapid changes and improvements in its technology. Because of this, organizations are finding they must upgrade not only to take advantage of the latest improvements, but to be eligible for maintenance by the vendor. The recent major shift to computers of 32-bit architecture has changed the industry significantly. Vendors are cutting development and support of 16-bit systems. Some locals are getting caught in the upgrade-or-lose-support syndrome. This will become a greater problem in the near future.

Other problems that have been encountered include insufficient maintenance support, especially when the site is not convenient to a vendor maintenance location and internal organizational conflicts.

"Turf battles" have emerged, in some cases between the mapping and data processing organizations or between rival mapping organizations. In some cases the introduction of this dedicated, special-purpose, minicomputer system directly into a user organization such as a Public Works Department has been met with resistance by the Data Processing Department. It has represented a break in the mainframe monopoly that was controlled by Data Processing, sometimes considered a dangerous precedent and threat. Also, it has often put the user in direct control of the system, another threat; and it has given the user access to system support by a vendor rather than the Data Processing staff.

Rival mapping organizations, such as the Public Works and Assessor Departments may see the system as a threat to their individual control or separate map set. While this represents redundancy in map maintenance that should be reduced or eliminated, each may feel its maps are superior and that it should be the controlling organization. There may also be a background of past difficulties or a past attempt at manual centralization that exaserbates the problem.

TRENDS

A few important trends are emerging in this field as newer installations learn from the experiences of others and as the technology evolves. An important trend by the newer installations is contract data conversion. Rather than attempt to digitize the city or county on the few work stations that can be afforded and taking years before production operation is achieved, newer locations are contracting with service companies to create all, or at least part of, the initial data base more quickly in a high-volume production environment.

Linkage of attribute and graphic data is now a common goal. Most vendors are now supplying systems capable of storing and linking both sets of data, allowing retrieval and processing of graphic images on the basis of their attribute values and the retrieval of attributes for specified geographic areas. Ironically, this is countering the logic of the original shift from a shared mainframe to a dedicated mini for graphic processing. Attempts are being made at networking graphic and mainframe data base systems, but to date most are batch movement of data sets from one system to the other, not on-line query of a base on one system from the other.

In the technology sphere, the trend is definitely to 32-bit processors, microcomputers in work stations, refresh raster displays, and even color graphics displays.

CHALLENGES

Based on the potentials that I have observed for this very useful technology and the problems that hinder its effectiveness at present, I offer the following challenges for the future.

The first challenge is for the development of a practical, cost-effective data conversion technology. The most promising technology seems to be scanning of some type. Many have offered scanning as "the solution", but to date no truly effective system is in widespread use. Laser scanning seems to be the most effective current approach, though it still requires considerable editing or processing to produce a satisfactory digital file.

A second challenge is for the development of a true real-time interface between the graphics system and the attribute data bases of the operating organizations. Most organizations have a mainframe or minicomputer system that contains extensive data bases such as assessor parcel files, road inventories, and utility customer and facilities files. These have logical relationships with the maps of the graphics system with which they should have a direct on-line connection. The dilema exists between the efficient processing of transactions on the current computer system and the heavy input/output load of a graphics system. If too much attribute data is stored in the graphics system, as is the current trend, its processing and maintenance will disrupt the interactive graphics processing. If, on the other hand, graphics processing is added to the current data base system, the graphics input/output transactions will bring that system to its knees. The solution appears to lie in an effective interface between the two systems that will allow each to perform the functions it is best at while allowing the benefits of linking the two sets of data.

A third challenge is for evolution to direct user operations of the mapping systems. As they are presently used, the systems are an automated replacement for manual drafting, producing a very similar map product that is used in the same way as the products of the manual operation. The power of the computer system to support and enhance many of the map use functions is not yet being tapped. As hardware costs drop and map data bases are completed, more and more actual map use can move to the automated system. Rather than even flexible plotting of paper maps for use, users can obtain a work station (inexpensively now with terminals capable of emulating work stations) and perform whatever function (e.g., response to an inquiry, computation, overlay, etc.) is required directly on the system. This evolution will improve timliness and quality of work and will reduce production costs. The user-friendliness of most current systems will allow inexperienced users to learn operation in a short time

The final challenge is for application of the technology to the support of multipurpose land records or information systems. There has been a great deal of discussion and publication of concepts and techniques for multipurpose cadastres. It seems to be generally agreed that this is a worthwhile concept, but in terms of practical application, it remains just a concept. The graphics systems offer what could be a key component in making multipurpose cadastres a reality. The ability to provide each user/participant with individual maps, scales, symbols, data, etc., while combining all into a central data base, makes sharing and multi-use much more practical. Each organization can have essentially its own operation with little sacrifice to the common operation. This has been one of the main roadblocks to successful multipurpose systems and it is one that we can now begin to overcome.

CLOSING

In closing, I will say that the jury, or at least the Supreme Court, is still out on the final verdict regarding the overall effectiveness of interactive graphics systems for local government map automation. There have been many, and a growing number of, system acquisitions. Few, though, are at a fully operational level. Data conversion has been slow, so only older systems have achieved substantial conversion; and these lack the latest technological improvements. It appears that it is an important innovation that will improve productivity and flexibility, reduce redundancy, and add intelligence to map images through graphic/attribute linkage. As with other things, the salesmen and advocates are probably overstating the value, but even discounting those statements, this is a very valuable technology that outshines manual mapping operations in many application areas.

PROJET EXPÉRIMENTAL DE REPRÉSENTATION GRAPHIQUE AUTOMATISÉE DE DONNÉES AU MINISTÈRE DES TRANSPORTS DU QUÉBEC

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RÉSUMÉ

La plupart des inventaires techniques et des données budgétaires sont emmagasinés au ministère des Transports du Québec dans des banques de données informatisées. La gestion de ces informations peut donc se faire de façon rapide et efficace. Par contre, l'analyse et l'interprétation de ces données se font encore à partir des méthodes conventionnelles de cartographie manuelle. Afin d'améliorer la planification de ses interventions et d'assurer une meilleure prise de décision, le ministère des Transports a décidé de procéder à un essai de représentation graphique automatisée de ses données. Pour ce faire, il s'est adressé à la firme CRAR Inc. (Consultation et Recherche en aménagement régional) qui avait déjà produit une base géographique géocodée; celle-ci avait été conçue pour la planification du transport des écoliers. L'entente de service intervenue entre les deux parties comportait deux niveaux de réalisation graphique: d'abord, la cartographie des inventaires techniques, tels que les courbes, les pentes et les volumes de circulation, puis l'illustration de scénarios de planification dans le temps, en vue d'optimiser les interventions de construction et d'entretien du ministère des Transports. Les résultats du projet se sont avérés concluants tant du point de vue de la qualité de la représentation visuelle que de l'efficacité avec laquelle l'information est traitée graphiquement.

INTRODUCTION

Le ministère des Transports recueille sur les routes du Québec une foule de données qui fournissent une image du réseau routier tant sur le plan de la géométrie, de la qualité structurale, de la capacité que de la sécurité qui y prévaut. Celles-ci permettent de mieux planifier les projets de construction et d'entretien du Ministère.

La plupart dea inventaires techniques et des données budgétaires sont emmagasinés dans des banques de données informatisées. La gestion de ces informations peut donc se faire de façon rapide et efficace. Par contre, malgré le caractère éminemment spatial des données de transport, l'analyse et la planification reposent encore sur des listes de données informatisées et sur quelques documents cartographiques produits manuellement. Lorsqu'il s'agit d'analyse de projets en vue de prise de décision, la cartographie manuelle peut devenir très limitative. Les cartes sont produites à échelles fixes et selon des paramètres prédéterminés qu'il est impossible de modifier sans encourir de trop longs délais de production. De même, les recoupages de données pour en étudier les interrelations ne peuvent être réalisés que sur demande, impliquant selon la complexité du travail, une période plus ou moins longue de compilation et de rédaction cartographique.

INVENTAIRE DES BESOINS ET DES RESSOURCES DISPONIBLES

Conscient de cette situation, le Service de la statistique, mandaté par les autorités du ministère des Transports, a procédé à la création d'un comité intraministériel, dont les objectifs étaient d'inventorier les besoins des différentes directions en matière de graphisme numérique et de système d'information à référence spatiale, et de faire des recommandations suite aux besoins énoncés et à l'inventaire des ressources disponibles.

Le rapport du comité intraministériel conclut que l'analyse des projets routiers, leur planification et leur programmation pourraient être améliorées si les analystes avaient accès à des systèmes d'information automatisés à référence spatiale. Afin d'appuyer ses conclusions, le comité recommanda de procéder à un essai d'application des données du Ministère à une base géographique automatisée.

L'inventaire des ressources disponibles fit ressortir l'existence d'un système incluant une base géographique d'une grande partie du territoire québécois. Il s'agissait du système GALILÉE développé depuis une douzaine d'années* par la firme CRAR Inc. (Consultation et Recherche en aménagement régional). GALILÉE se définit comme étant un système d'information automatisé à référence spatiale pour fins de gestion scolaire au Québec. Sa fonction première est d'assister les régisseurs des commissions scolaires à mieux planifier le transport des écoliers.

Présentement, la base géographique du système GALILÉE est implantée à l'échelle de 23 commissions scolaires régionales du Québec, touchant au-delà de 90 commissions scolaires locales et couvrant quelque 750 municipalités. Ainsi, plus de 30 000 traits du réseau routier (rues, routes, rangs, etc.) québécois ont été géocodifiés et ils sont maintenus à jour en ordinateur par les commissions scolaires régionales concernées. La partie complétée de la base géographique de GALILÉE correspond actuellement à près de la moitié des municipalités du Québec. La numérisation de la base géographique de GALILÉE fut faite à partir de documents cartographiques produits par le ministère de l'Energie et des Ressources du Québec et le ministère des Transports du Québec. Les régions urbaines denses ont été digitalisées à partir de cartes aux échelles 1:1000, 1:2000 et 1:5000; les régions péri-urbaines aux échelles 1:5000 et 1:10000; les régions rurales aux échelles 1:20000, 1:40000 et 1:50000. La base géographique de GALILÉE comprend plusieurs niveaux d'information: les limites des commissions scolaires, les limites municipales, le réseau routier numéroté de même que le réseau routier non-numéroté et sa nomenclature. La conception et le contenu de la base géographique semblaient donc pouvoir répondre aux

* Sous sa forme d'entreprise universitaire (1970-1980/à Sherbrooke) et sous sa forme d'entreprise privée (1980-1983/à Québec).

besoins du ministère des Transports du Québec.

LE PROJET EXPÉRIMENTAL

En avril 1983, un contrat de service visant à vérifier l'applicabilité des données du ministère des Transports à la base géographique de GALILÉE fut accordé à la firme CRAR Inc. Le contrat comportait deux niveaux de réalisation graphique: d'abord, la cartographie des inventaires techniques, tels que les courbes, les pentes et les volumes de circulation, puis l'illustration de scénarios de planification dans le temps, compte tenu de différentes politiques d'investissements, en vue d'optimiser les interventions de construction et d'entretien du ministère des Transports.

Le projet débuta à la mi-avril et son achèvement était prévu pour la fin juin 1983. L'échéancier du projet comportait quatre étapes majeures.

1ère étape: adaptation de la référence spatiale du ministère des Transports à la base géographique de GALILÉE

L'information recensée par le ministère des Transports étant surtout de type linéaire, celui-ci a adopté comme repère spatial dans ses banques de données la clé hiérarchique route-tronçon-section. Chaque route est divisée en tronçons qui sont eux-mêmes subdivisés en sections, selon des critères d'homogénéité spatiale.

Pour sa part, la base géographique de GALILÉE fut constituée selon le modèle hiérarchique municipalité-trait-segment.

Il fallait donc faire le lien entre la référence spatiale utilisée au ministère des Transports et celle qui servait d'assise au système GALILÉE. Finalement, cette opération s'avéra relativement simple et CRAR n'eut qu'à établir une correspondance entre son fichier municipalité-trait-segment et le découpage routier route-tronçon-section du ministère des Transports. Chaque route-tronçon-section n'était en fait que la sommation de un ou plusieurs municipalité-trait-segments de GALILÉE; CRAR n'eut donc besoin d'aucune digitalisation pour créer le nouveau fichier géographique qui devait servir de carte de base pour les applications thématiques.

2ième étape: préparation des fichiers statistiques

Le projet prévoyait la réalisation de dix applications thématiques. Le ministère des Transports dut préparer un fichier de données par application thématique, selon les spécifications de GALILÉE, les regrouper sur bande magnétique et les transmettre à CRAR.

3ième étape: adaptation des logiciels graphiques de GALILÉE au projet du ministère des Transports

Cette étape regroupait les travaux de validation des fichiers géographiques et statistiques, et de développement des symbolisations appropriées aux représentations thématiques demandées par le ministère des Transports. Dans certains cas, le Ministère désirait conserver le même type de symbolique que celui utilisé sur ses documents cartographiques manuels, dans d'autres cas, le projet expérimental visait à développer de nouvelles formes de représentation cartographique.

4ième étape: production des applications thématiques

La région pilote qui avait été choisie dans le cadre de ce projet expérimental était celle du district de Cookshire, dans la région administrative de Sherbrooke.

La carte de base. Le projet prévoyait d'abord la production d'une carte de base détaillée à l'échelle 1:125000 du district de Cookshire, sur laquelle on distinguerait les limites du district pilote, l'identification et les limites des districts qui lui sont contigües, les limites et la nomenclature des municipalités à l'intérieur du district pilote et, finalement, les réseaux routiers numérotés et non-numérotés selon des représentations distinctives.

Les applications thématiques. Elles étaient au nombre de 10, la plupart à l'échelle 1:125000, et leur réalisation comportait deux niveaux de représentation graphique. Il s'agissait d'abord de la cartographie simple des inventaires techniques du ministère des Transports. Les thèmes suivants avaient été choisis, soit pour leur intérêt, soit pour leur degré de complexité cartographique:

- courbes sous-standards
- pentes critiques
- qualité structurale du réseau routier
- volumes de circulation
- localisation ponctuelle des accidents
- fréquence et gravité des accidentes
- programmation régionale des travaux de construction routière
- couches d'usure

Le second type de représentation graphique concernait la cartographie de scénarios de planification des interventions de construction et d'entretien du Ministère. Ces scénarios étaient représentés par les thèmes suivants:

- évolution du coefficient de roulement (1982-1986-1991)
- proposition de travaux d'entretien

Les réalisations cartographiques de ces deux derniers thèmes, de même que celles des thèmes de la localisation ponctuelle et de la fréquence et gravité des accidents, étaient inédites et constituaient une première au ministère des Transports du Québec. Les six autres thèmes faisaient déjà l'objet de représentations cartographiques produites manuellement.

BÉNÉFICES ESCOMPTÉS

L'acquisition d'un système d'information automatisé à référence spatiale suppose des coûts de développement et d'implantation relativement élevés. Par contre, ceux-ci devraient être compensés favorablement par les nombreux avantages qu'il peut offrir. Qu'il s'agisse simplement de la rapidité de production et de mise à jour des inventaires de données techniques du Ministère, sans compter l'élimination des erreurs de compilation et de transcription qui peuvent se glisser dans les documents cartographiques produits manuellement. Les données nécessaires à la planification pourraient ainsi être cartographiées pour permettre une interprétation et une analyse visuelle souvent inexistante actuellement. La cartographie automatisée rend aussi possible la production rapide de documents graphiques adaptés à des projets d'étude spécifiques: on peut ainsi définir une région précise à cartographier, en déterminer l'échelle, selon les besoins, et même afficher sur une même planche deux ou plusieurs variables pour en analyser les interrelations - que ces données soient de même nature (transport/transport) ou de nature différente (transport/socio-économie) -. Finalement, le traçage automatisé permet de produire des documents cartographiques de qualité différente, selon les besoins de l'utilisateur: des simples cartes d'analyse exécutées très rapidement, ou des cartes de qualité supérieure pour présentations spéciales, conférences, etc.; il est même possible de réaliser directement sur table traçante des séparations de couleurs pour fins d'impression.

CONCLUSION

Compte tenu du court laps de temps et du budget minime dont nous disposions pour réaliser le projet, les résultats cartographiques se sont avérés concluants tant du point de vue de la qualité de la représentation visuelle que de l'efficacité avec laquelle l'information statistique fut traitée graphiquement.

Le projet expérimental a permis de mettre au point la conceptualisation et le développement nécessaires pour un district du ministère des Transports. Ces techniques de représentation graphique sont directement applicables aux mêmes activités du Ministère sur le reste de son territoire. Cette réalisation est toutefois conditionnée au préalable par l'extension à l'ensemble du territoire québécois de la base géographique du transport scolaire.

Après avoir démontré avec ce projet expérimental que la base géographique de transport scolaire pouvait répondre adéquatement à plusieurs des besoins du ministère des Transports, nous croyons que cet outil pourrait également répondre à d'autres besoins d'organismes qui doivent traiter des données spatiales. Ce champ de développement reste ouvert et mérite d'être exploré davantage.

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THE GEOSUPPORT SYSTEM: GEOPROCESSING IN NEW YORK CITY

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ABSTRACT

The Geosupport System is New York City's first interagency effort to make automated geoprocessing available to all city agencies for use in service delivery, revenue enhancement, and planning and analysis activities. The approach we have taken in New York is to integrate manual mapmaking, geographic base file maintenance, and application development into a unified system, eliminating the error prone systems of the past. The project was made possible by technological developments in computer graphics, theoretical developments in geographic base file concepts (viz. GBF/DIME) and extensive local experience in address standardization and matching techniques. Current applications include a project with the Board of Education to determine student eligibility for bus passes based on walking distance to school, and and a project with the Bureau of Electrical Control for maintaining streetlights.

INTRODUCTION

A city has special data processing needs because most of its operations, from collecting taxes to collecting garbage, are geographically based. While automation advanced rapidly in New York City agencies during the 1970's, this automation followed the patterns established in the private sector. No special techniques were devised for processing addresses, or, in other words, for automating geographical activitities. City administrators often find themselves sitting frustrated at a computer terminal, unable to obtain information necessary to efficiently manage city operations.

The Geosupport System in New York began with the realization that special techniques had to be invented for processing geographical information. We realized that geographical locations had to be treated as data, to be processed, massaged, digested and regurgitated as is any other data in an information system. Although no such system existed, other cities had been trying to solve the same problems that confronted New York, and these tools were available to us:

- interactive computer graphic systems to maintain a digitized map
- GBF/DIME file concepts
- geoprocessing software
- telecommunication packages developed in the private sector for commercial data processing

The Geosupport System was able to integrate these tools into a unified system, so that when a water main breaks, when a streetlight is repaired, when a traffic sign is installed, the information can be located on a computerized geographic base file which simulates a map. City agencies can use this file to track complaints, send out work crews, make reports by geography, route service delivery, etc.

The following is a brief summary of the development of the Geosupport system, a description of the system, and examples of current applications.

DEVELOPMENT OF THE GEOSUPPORT SYSTEM

Several factors contributed to the development of the Geosupport system. The development of GBF/DIME technology coupled with the digitization of the Census Bureau's Metropolitan Map Series for New York City made the integration of mapmaking and geographic base file maintenance possible for the first time. Thus, instead of updating a geographic base file by means of textual data entry procedures, it was now possible to display the image of the file as a computer map and update it graphically, allowing for greater speed and accuracy of maintenance. Another factor which contributed to the development of the Geosupport system was that by the late 1970's, computer graphics systems had sufficiently decreased in cost to become attractive to municipal governments.

In June 1981 the city approved City Planning's proposal to:

- purchase a computer graphics system to maintain the GBF/DIME as the standard New York City geographic base file.
- employ staff to update and enhance DIME and to combine DIME technology with city-developed geoprocessing software to support geographically related operational applications of city agencies.

COMPONENTS OF THE GEOSUPPORT SYSTEM

The Geosupport System consists of two major components: geographic base file maintenance and application-callable access software. The GBF/DIME is maintained on a Digital Equipment Corporation VAX based graphics system installed at City Planning. The system was purchased from Synercom Technology. Geoprocessing reference files are generated for use on IBM mainframe-compatible computers on which user agencies' applications are installed. Geoprocessing access software previously developed at the Finance Department has been incorporated and expanded to provide the functions delineated below.

The system provides both batch and online (CICS) access. The online access is modularized to allow user agencies to easily incorporate these functions into their applications, which are written by the user agencies themselves. In effect, the Geosupport System provides all the geoprocessing functions required by user agencies.

Functional Operations

a) Address normalization - processes a computer-readable address into a standardized format to make it available for matching purposes. Street names are normalized by recognizing their components, expanding the relevant ones and dropping ordinal suffixes. For example: "Park Ave S" is normalized as "Park Avenue South", and "W 75th Str" is normalized as "West 75 Street." The house number, if present, is also normalized by zero filling, hyphen removal, etc. to generate a standard format for matching purposes.

b) Address validation - matches the normalized address against the already normalized entries in the Street Name Dictionary to verify the existence of the entered street name; determines inclusion of house number within a valid range of house numbers for a given street; verifies the existence of an intersection or on-street-high and low cross street combination.

c) Geocoding - associates a standard numeric street code with the entered street name; designates street code combinations for locations such as intersections; associates higher level geographic areas such as community district and census tract and block with a specific address or location.

Location Input Formats

The Geosupport System currently processes three types of input formats in both the online (CICS) and batch versions of the software. They are as follows:

a) An address - i.e., house number and street name.

b) An intersection - i.e., two cross streets.

c) A street segment - i.e., "on" street and the two nearest cross streets, for example Broadway between W 42nd St. and W 43rd St.

Each of the input types is normalized, validated and geocoded utilizing references to the geoprocessing reference files generated from DIME. In the online system, address validation occurs at data entry time, thereby preventing an operator from entering incorrect geography into the system. The information is also immediately geocoded per user specifications.

CURRENT APPLICATIONS

The following is an in-depth view of two applications of the Geosupport System. The first application is typical of those which are developed and implemented by user agencies. The Bureau of Electrical Control developed its own project which makes use of the centralized geoprocessing facility of the Geosupport System.

The second application, the Board of Education project, required use of GBF/DIME's xy coordinates and more highly sophisticated software development which was beyond the capability of the user agency. In this application the Geosupport staff became more involved in project development.

First Application: Streetlight Maintenance System

The Bureau of Electrical Control is responsible for maintaining and operating the city's 320,000 street and park lights. The Bureau has contracted with private firms to repair the lights and has partitioned the city into eight contract zones, with each zone being awarded to the contractor with the lowest responsible bid.

The city has extablished a complaint center to receive citizen calls requesting light repairs in their neighborhoods. City operators enter the identifying information at a terminal and transmit a work order to the proper contractor via a computer printer located at the contractor's offices. The contractor repairs the light and enters repair information into the system via the contractor's own terminal.

The Geosupport System provides the Bureau with the following capabilities:

a) The system determines the proper contractor given the location of the light.

b) When given a house number and street name, the system automatically provides:

- the nearest cross streets to help the contractor find the light

- the zip code and census tract so that the contractor can batch the work orders and thereby increase efficiency by scheduling nearby work orders for the same crew and day.

c) Identifies duplicate complaints via geographic matching so as to avoid multiple trips to the same site.

d) The system enables retrieval of information geographically, allowing flexible input formats to respond to citizen complaints, work crew inquiries, and management requests.

e) The system determines the Community District , which enables the agency to report service delivery by neighborhood.

Implementation of the Streetlight Maintenance System has provided substantial benefits to the city in the form of lower competitive bids from contractors, higher productivity, and increased control by the city over contractor performance.

Second Application: Board of Education

New York City subsidizes transportation costs for 350,000 public and private school children by providing bus and subway passes and yellow bus service. Eligibility for this subsidy is based on the student's walking distance to school and on the grade level, as follows:

Grade	Distance
K - 2	1/2 mile
3 - 6	1 mile
7 - 12	1 1/2 miles

The geographical unit of eligibility is a street segment, that is, a stretch of street between two consecutive intersection. For example, if any point on a street segment is more than 1 mile from a particular school, then all children in grades three to six of that school who live on that segment are eligible for subsidies.

In order to determine eligibility, the Board of Education had contracted with private concerns to draft street maps which delineate the three distance zones for each school. The zones had been determined either by planimeter measurements of maps or by pedometer measurements in the field. When streets were opened, closed, or renamed, the maps for the affected schools would have to be redrafted. Drafting maps just once a year for the city's 2,000 schools costs over one million dollars. For this reason, eligibility has largely been determined at each school based on the judgment of the teacher or school secretary charged with the responsibility.

The State of New York funds a portion of the transportation subsidies provided to the school children. An audit conducted by the Board of Education last year revealed that the State has disallowed 50 million dollars in subsidies over the past five years. Clearly, a more accurate method for determining student eligibility for transportation subsidies had to be found.

Since eligibility determination is based on the minimum walking distance to school, with paths defined as sequences of street segments, it is an ideal application for a computerized map. Therefore, the Department of City Planning, in cooperation with the Board of Education and the city's Office of Management and Budget, developed and automated eligibility determination system using the GBF/DIME. This system consists of three components: the GBF/DIME, a shortest path algorithm and geoprocessing software.

The first component of the Geosupport system is New York City's GBF/DIME file. The preliminary version of this file, created by the New York City Planning Department for the Census Bureau in 1978, and subsequently digitized in 1980, was not sufficiently accurate nor comprehensive to be used in the eligibility system. Much effort was put into correcting the street names and address ranges, adding missing segments, updating the file with changes in the city's geography since 1978, and adjusting the x,y coordinates. Existing designations for non-street features such as railroads and bodies of water proved useful but enhancements were also required for foot bridges over highways and pedestrian blockage information.

The second Geosupport system component is a shortest path algorithm formulated by the Dutch computer scientist E.W. Dijkstra. This algorithm was adapted to the GBF/DIME file to determine which street segments fall within the 1/2, 1, and 1 1/2 mile distance criteria for each school. The program provides three lists of ineligible schools for each street segment in the city corresponding to the three distance criteria, creating a geoprocessing file called the Pupil Eligibility Directory.

The third component of the system is the geoprocessing software to process the individual students' addresses and access the Pupil Eligibility Directory in order to determine the students' eligibility. The geoprocessing software used for the eligibility system is the same as that used for other projects so as to maintain compatibility.

The Pupil Eligibility system allows the Board of Education to:

a) Validate students' addresses at data entry time to prevent incorrect information from entering the system.

b) Accurately determine eligibility by computer rather than by subjective judgment.

c) Update eligibility geography by computer when street changes occur, avoiding the tedious process of redrafting school eligibility zone maps. In a future enhancement, we plan to plot a double line eligibility street map for each school. (The GBF/DIME is currently stored as a single line map.)

It is anticipated that implementation of this system will reduce the disallowance generated by the next state audit from 10 million dollars to a negligible amount.

Other applications include:

Department of Transportation (Traffic) - The agency maintains a computerized inventory of the city's one million traffic signs and utilizes the Geosupport System for its sign repair and replacement system. Future development will include coordination of the placement of traffic signs with instances of traffic accidents.

Department of Transportation (Highways) - A system is being established to monitor street excavations by private utilities, plumbing contractors, etc. Such monitoring enables DOT to determine responsibility for street cave-ins caused by inadequate repairs after excavations. It also enables DOT to coordinate the scheduling of utility escavations with street repair scheduling.

Department of Environmental Protection - a complaint system similar to the one described above for streetlight maintenance is being established to generate work orders for water and sewer problems, catch basin blockages, air and noise pollution complaints, etc.

Office of Management and Budget/Fire Department - A joint project between these agencies used the Geosupport System to correct addresses from a file of 200,000 Fire Department permit holders. The purpose of the project was to increase the billing returns and provide accurate information to local Fire Department units on hazardous waste storage.

In summary, any city agency wishing to use the online or batch geo-processing system is provided with documentation and consultation with Geosupport staff. Furthermore, any agency that needs to contract with outside data processing services is provided with documentation to be incorporated into their Request for Proposals. This enables potential data processing vendors to make lower bids, since a significant portion of the application system is already written.

CONCLUSION

It is the intention of the Geosupport System to provide city agencies with a full spectrum of their geoprocessing capabilities from software to centralized geographic base file maintenance. The application development is done by the user agency. Geosupport staff provide users and potential users with documentation, consultation and training services. Implementation problems and suggestions for new development are discussed at Geosupport Users Group meetings. This structure allows the City Planning Geosupport staff to devote its resources to geoprocessing software development and file maintenance, where they have the expertise, while user agencies can concentrate on their specific applications.

As the system proliferates throughout the city government, adherence to geographic standards and compatibility between agency applications is fostered. The Geosupport System will significantly enhance both the city's operational efficiency and its capacity to control, analyze and plan its activities.

We have learned much from developing this system. Most importantly, our experience has borne out the commonplace that a computer system is only as good as the data it contains. Therefore, most of our effort has gone into correcting and updating the GBF/DIME for New York City. The next step is to develop techniques to allow an administrator to get answers from a computer to such "simple" geographic questions as:

> What activity has my department had on 5th Avenue between 31st and 59th Streets last week?
>
> If I draw a box on a map on a computer screen circumscribed by 1st Street to 5th Street and Avenue A to Avenue D, what demographic patterns and housing activity do I find?

This will lead us to the fifth generation of geographic information systems.

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THE ROLE OF QUALITY INFORMATION IN THE LONG-TERM FUNCTIONING OF A GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

A geographic information system requires a method to maintain its contents over the long-term. This process must handle quality components along with the data directly depicted on a map. Quality information includes lineage records, accuracies of position and classification, integrity of data structure and temporal reference, among other things. The quality component informs users of suitability for their applications, and it also offers distinct advantages to data producers with responsibility for long-term maintenance. Quality information is not currently maintained by most available software. New data structures and algorithms will be required to meet this need.

BACKGROUND: TWO OUTMODED MODELS OF MAPS

The development of automation in cartography has finally progressed beyond the stage of marvelling that a computer can make a map. Maps produced by the computer should no longer seem novel, even to the layman. Yet, the digital age has come with a crab-like stride. Computers get faster and storage gets bigger. Resolution and accuracy of many devices improve, but our ideas do not keep up with material progress. There are two attitudes about maps which deserve particular attention because each, in a different way, hinders full exploitation of automated cartography.

Model 1: The Map as Graphic Artifact

Maps have a tangible reality as graphic images. The images consist of symbols used to represent spatial information, both position and attributes. As an automated drafting machine, a computer can plot back a stored map that mimics the traditional product. This achievement may be useful in a limited way, but a pantograph does not deal with the information portrayed by the map -- the reason for making a map in the first place.

Concentration on the graphic product alone has trapped cartographers for years. Just as any group hates to admit ignorance, cartographers in the past abhorred blank spots. The heraldic beast may have vanished, but conjecture and surmise are still packaged into a slick graphic presentation that obscures the variations in our knowledge. We have developed expectations, such as smooth contour lines, which are not always supported by adequate evidence.

Model 2: Data Structures based on Spatial Logic

Pleas to examine information content as the basis for digital data structures are not new. At the first AUTO-CARTO, I gave a paper showing the impact of different data structures (Chrisman, 1974). The topological model I advocated has received full theoretical treatment by now (Corbett, 1979). While the theoretical work may have convinced a few, the model has been adopted mostly to solve practical problems.

I am still convinced that the topological approach to map information is necessary; I am no longer convinced that it is sufficient. The topological abstraction is linked to the graphic elements of the traditional map. The model links points, lines and areas according to their tangible connections. The topological relationships have an undeniable role in the internal consistency of the map information, but all other relationships are considered "attributes" for thematic mapping or record keeping. This formulation does not have the flexibility to handle certain relationships which are crucial to the long-range functioning of a geographic information system.

LONG-RANGE FUNCTIONING OF A GEOGRAPHIC INFORMATION SYSTEM

The term "geographic information system" (hereafter GIS) is almost dangerously vague. Software is sold as a GIS which may only amount to a computer-assisted drafting station. I would like to reserve the term for a complex type of software which can handle the whole life cycle of spatial information.

Duecker (1978) has identified an important distinction between routine and non-routine systems. Non-routine covers the single purpose, one-shot data base effort, while routine implies an established mechanism to maintain the data for the foreseeable future. In the early years of automation the non-routine had to be dominant due to the experimental nature of the technology. Much of the current GIS software reflects its origins in these non-routine projects; after a massive input phase, the data is considered to be static. Virtually all software with academic and government origins follows this pattern. GIRAS (Mitchell and others, 1977) is an example of a government project with ambitions of Retrieval and Analysis built into its acronym, but the realities of data base production gobble up most resources. The GIRAS data, like many similar projects, consists of a snap-shot of land use. The data structure has no need to record how each line is determined because the same process applies to all.

As a further example, the ODYSSEY system is finally being marketed by Harvard as "Harvard's GIS". While the nomenclature may be necessary for marketing, I tried to make a distinction while it was being developed (Chrisman, 1979). The software was designed as a collection of processors to manipulate geographic information. These processors still represent the state of the art for their special functions, but ODYSSEY does not perform all of the data base management functions implied in the broader term GIS.

More provocatively, I would assert that no available commercial software provides a full GIS. While ODYSSEY and GIRAS and other non-commercial developers at least adopted the clarity of the topological model, many commercial groups considered it too complicated (these statements will not be found in corporate literature, but come from personal communication). The commercial groups are responding to the profession's attachment to the map as a graphic product. Yet, in the real meaning of an information system, the computer must have more structure to its data base than merely replotting cartographic spaghetti.

My definition of GIS is strict and my conclusion is that no real GIS has yet been implemented. Hundreds of systems have been installed, increasingly for routine processing. At first the task is similar to a one-shot project; the backlog of parcel maps (or whatever) must be digitized (Hanigan, 1979). Eventually, these operations plan to switch to routine maintenance. In a refreshingly frank paper, a group working for the City of Milwaukee has discussed the process of getting past the input phase (Huxold and others, 1982), and they specifically mention the underestimation of the maintenance aspect. The current tool is the graphic editing station which assumes that maintenance will mirror the old cartographic process. In the rest of this paper I will try to demonstrate how this concept of routine functioning is inadequate.

QUALITY INFORMATION: A MISSING COMPONENT

A full-fledged GIS can not simply record spatial data, it must also store and understand how these facts are known. This component can best be described as the data quality dimension of a data base. Quality information provides the basis to assess the fitness of the spatial data to a given purpose, and it also provides the handle for long-term maintenance.

The quality of cartographic information seems an obvious concern. An "accurate map" is part of the popular mythology of cartography, but the profession spends little time on this problem. Few map users notice (or would even care about) the lack of a National Map Accuracy statement at the bottom of a topographic map.

As in many other situations, the development of automation has forced a reevaluation of received opinions and accepted practices. Perhaps, the graphic nature of traditional maps precluded some abuses. Numbers in a data base create an illusion of accuracy and the computer opens new ways of potential abuse. The quality of digital data is an integral part of the information content of the data base. New data structures will have to evolve to encode the quality component, particularly for long-term, routinely maintained projects.

Quality information is not a synonym for positional accuracy measures, although some groups see little else that affects quality (Canadian Council on Surveying and Mapping, 1982). In a standards effort for the U.S.A., the American Congress on Surveying and Mapping's National Committee for Digital Cartographic Data Standards (NCDCDS) (Moellering, 1982) has established a Working Group on Data Quality, as one of four working groups. The next few paragraphs summarize the deliberations of this group (Chrisman, 1983), but they are interpreted in a framework of personal opinion which does not necessarily reflect the views of the working group.

In the opinion of the working group, the foundation of data quality is to communicate information from the producer to a user so that the user can make an informed judgment on the fitness of the data for a particular use. Within this goal, the first responsibility of a producer is to document the lineage of the data. A lineage report traces the producer's work from source material through intermediate processes to the product. In many cases, cartographic agencies have procedure manuals and other documents which contain the relevant information, but this information is not usually considered of great public interest. For example, the description of computer processes and data structures for GIRAS appeared in the widely-disseminated Geological Survey Professional Papers (Mitchell and others, 1977), while the description of the compilation procedures for the project was placed in the Open File Report series (Loelkes, 1977). In this case, at least the lineage can be constructed from public records. In the case of smaller mapping agencies (at the county or municipal level that accounts for a large proportion of the annual cartography budget, [see Larson and others, 1978]), lineage information may be in the memory of one person, and retirement wipes the slate clean.

Beyond a narrative of lineage, a quality report should include quantitative meausres to help a user evaluate applicability. Since geographic information has attribute and temporal components, along with positional ones, each component should be evaluated. This conclusion of the working group rejects the findings of its Canadian counterpart, which saw fit to ignore all but the positional component:

> "... 'up-to-dateness' has been interpreted by the Committee as 'date of cultural validity'. As applied to digital topographic data, 'Completeness' was deemed impossible to quantify by the Committee; instead, it was proposed that the list of feature classes actually contained in the file be furnished." (Canadian Council on Surveying and Mapping, 1982, p. 6)

In contradiction to these findings, temporal information can be subjected to tests (eg. field checking photo-revisions). The more dramatic problem is the blindness to "completeness". It is not enough to list the feature codes used. It is necessary to evaluate how consistently features were assigned to classes and how exhaustive the classes were in the actual context. Contrary to the Canadian committee's statement, procedures to evaluate classification accuracy are widespread in remote sensing and other fields (eg. Fitzpatrick-Lins, 1978; Turk, 1979), while evaluation of logical integrity of a data structure is a fundamental and valuable outgrowth of the topological model (Corbett, 1979). A broad coalition of disciplines must contribute to the components of quality assessment.

Arguing the relevance of temporal and attribute components does not reduce the importance of the positional component. The Canadian draft standards, as well as the efforts of the American Society of Photogrammetry (Merchant, 1982), provide a solid contribution. Still, most work has concentrated on "well-defined" points, and the extension to more complex natural features may involve additional issues (Chrisman,1982). Furthermore, estimates of error in position need to be converted into a form which relates to the user's application (eg. bounds on areas).

The Working Group forsees a range of testing procedures, falling along a continuum of rigor, to evaluate quality in each component. The least rigorous "tests" may merely represent deductive estimates. Under controlled circumstances (such as appropriate sampling applied to similar map sheets), a deductive estimate could provide the user with adequate information at a much lower cost to the producer. At intermediate levels of rigor, testing would compare the data to internal evidence or to the source document. The most rigorous test requires an independent source of data of higher accuracy.

From this discussion it is clear that the National Committee for Digital Cartographic Data Standards is operating inside a charter from a traditional cartographic agency. The emphasis is on a data base product which largely replaces the map graphic product. Certainly standards are needed to ease the distribution of digital data. However, some of the largest impacts of investigating data quality will rebound on the producer.

Quality Information Serves Producers

Whereas the NCDCDS and other national standards efforts have focussed on transmitting information to a user to evaluate aptness for an application, the same quality information should serve the producer as well. Recording how information was obtained is a normal cartographic function which has moved into digital applications without great reexamination. For instance, the Houston METROCOM project creates a "sheetless" map, but records source and some undefined quality assessment for the original sheets (Hanigan, 1983). While the input sheet correctly identifies the origins of the data, quality information will not remain forever tied to these units. In maintaining Houston's parcel map, updating will be sporadic and scattered. Each update has a different pedigree which should be recorded. Over the years, the process of maintenance will fragment the lineage and quality information.

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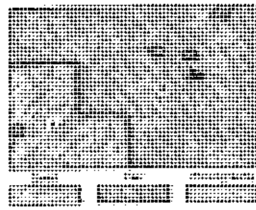
Prepared by the Army Map Service (SNTT), Corps of Engineers, U. S. Army, Washington, D. C. Compiled in 1955 from: Bangka 1:50,000, Directorate of Military Survey, Sheets 35-XXVIII-B and 36-XXVIII-A. 1944; Sumatra, 1:100,000, Topografische Dienst, Batavia, 1918-25; Sumatra 1:200,000 Topografische Dienst, Batavia, Sheets A and B, 1924; Netherlands Hydrographic Chart 52, 1951; USHO Chart 1266, 1944; Indonesian Hydrographic Chart 104, 1951. Names processed in accordance with rules of the U. S. Board on Geographic Names. Road classification should be referred to with caution. The reliability of vegetation information is undetermined. Names for symbolized populated places are omitted where information is not available or where density of detail does not permit their inclusion.

RELIABILITY DIAGRAM



A. Medium scale topographic maps, controlled ground survey, 1911-20.

B. Medium scale topographic maps reconnaissance survey, 1913-23. Planimetry revised from 1944-45 aerial photography.

Figure 1: Lineage and reliability information from AMS 1:250,000 sheets in Sumatra, Indonesia

Many map sheets show a "reliability diagram" as a part of the legend, displaying an important evaluation of quality variations (see Figure 1). In a digital era, this "diagram" should be an overlay, registered to the rest of the map and integrated into the data stucture. Spatial variations in quality can go to the entropic extreme of a separate evaluation attached to each data item. In an application such as navigation or military intelligence with a high premium on reliability, this complete disaggregation is normal. At this limit, the storage of quality information expands from a negligable single figure per sheet to occupy a large fraction of the data base. Adding one word per coordinate, or fifty percent of file bulk, is a dramatic threat to system performance, but some sort of quality information may be fully justified.

This discussion has established the general nature of quality information. The following sections will provide some examples of the reasons why the quality component is necessary to the long-term functioning of a digital data base.

Centrality of Control to Positional Quality

A cartographic data base is distinguished from other computer applications mainly due to the representation of physical space. The special focus on spatial properties does not deny the relevance of tabular (attribute and temporal) data; it merely accepts the spatial problems as peculiar and critical.

In the construction of a map, the nature of geodetic control has a direct impact on positional quality. To some extent, control is an eternal verity akin to motherhood and apple pie. Yet, no agency can invest in first order control for all coordinates of interest. Control is expensive and must be used parsimoniously. Though new technology for geodetic surveying (eg. Counselman, 1982) may revolutionize the field, it will still require hard economic choices. Some advocates of the multipurpose cadastre place the geodetic network as the initial phase. This grand densification of control can be demonstrated in a few current projects (eg.

Bauer, 1976; Hanigan, 1983). Massive investment does help bring a project up to a higher standard of quality, but it does not avoid a fundamental problem. Change in control is inevitable. No matter how complete the original network, new coordinates will trickle in due to normal progress and unrelated projects. In the long-term management of a GIS, it will be necessary to readjust coordinates to account for changes in control. Data structures and procedures for these adjustments must be developed.

The impact of change in control will be a distortion of the preexisting coordinate system. This distortion can be seen as a displacement field or surface. This field represents the displacement distance and orientation as if measured directly from a "rubber sheet". Rubber sheet distortions might be recognized as a form of witchcraft or as a pragmatic necessity in automated cartography, but there is little discussion of alternative algorithms and data structures to perform them. Petersohn and Vonderohe (1982) demonstrate that the choice of adjustment model (affine versus Helmert's projective) makes a difference in the result. Usually a programmer picks a method for numerical ease, not specific relationships to systematic errors.

Beyond numerical properties, there is a need for a data structure to manage the distortion surface and the control network. Hybrid data structures, such as those proposed by Brassel (1978), may provide the most likely alternatives. However, in many cases, the distortion of new control is not a simple surface effect. Many measurements are made relative to others, such as the linkage of property lines to section corners in the Public Land Survey. In the data base, an absolute coordinate may be recorded, and the relationships would not be recorded. A full GIS must find a method of dealing with dependencies between data items. Some relationships may be spatial and properly handled by surface data structures, while others may require explicit encoding.

To summarize, control is a foundation for positional accuracy, but it is bound to be readjusted from time to time. Any long-term information system must have procedures and data structures to carry out the readjustment in a manner which fits the nature of the measurements.

Quality in classification

Quality in attributes can take many forms, but it is representative to restrict attention to the case of nominal attributes -- the problems of classification. Apart from terrain and geophysical applications, the overwhelming majority of GIS applications concern some type of discrete phenomena. Topographic feature codes, place names, geocodes, parcel identifiers, land use types, all fall into the same broad group. The discussion above of the NCDCDS work mentions some procedures to examine the accuracy of attributes. These methods have been developed for the one-shot application so typical of current projects, particularly those using remote sensing. In addition to these procedures there is a need to develop methods applicable to the multi-layered environment of a full-fledged GIS.

For example, a GIS may have a topographic component showing rivers and streams. It may also include a floodplain determination (usually from a different or derivative source). The data structure of the GIS should be informed of the set relationship implied between a stream and its floodplain. This should ensure that each stream has a floodplain (or an explanation for not having one). In addition, logical impossiblities, such as rivers meandering in and out of their floodplain, should be detected. A GIS should be able to check for many attribute errors by using one layer to check another. Multi-layer comparisons demand efficient polygon overlay procedures which are not available in many systems.

Some elements of quality in classification have a map form, which can be most clearly demonstrated in the practices of remote sensing. A remote sensing classification can be unsupervised where only statistical parameters are used, but often supervised procedures are used. Supervision requires an operator to select some areas as typical of a target class. In order to document the derivation of a supervised classification, the locations of these areas, or training sets, is necessary. Once a classification is developed, it can be verified by a testing procedure such as a "ground truth" sample. In general, for any classification procedure, it is important to know where it has been developed and validated. Training sets and ground truth samples may be acquired to perform a hidden function, but they should become another layer in the complete GIS.

Temporal Effects

Cross-validation of sources provides a powerful tool, but it demonstrates a major difficulty in quality assessment. Many have commented that polygon overlay leads to spurious results, such as the mismatch of river and floodplain mentioned above. The problem may not be the fault of the overlay process, but in the original sources. Many layers which are fed into a GIS are not fully comparable with the others, yet the comparison has to be made somehow. Some problems of comparability can be assigned to positional inaccuracy or differences in classification, but many also involve time. The most likely explanation of the river/floodplain inconsistency is that the two maps represent different, valid maps from different years. After ten or fifty years a river may move far enough to create the logical impossibility. Time, then, is an important component of quality information. Proper use of temporal reference could help explain these anomalies and ensure a reasonable resolution of the problem. Furthermore, the long-term maintenance of a GIS should lead to simultaneous updating of features so that inconsistencies are avoided.

In some cases, a GIS records not just a single map layer, but its evolution over time. At any one time a traditional map coverage (as recorded by a topological structure) should be available. Basoglu and Morrison, for example (1978), constructed a hierarchical data structure which gave each boundary a time component. While this approach can be constructed to give a proper result, it requires very careful manual data entry.

The quality of temporal data can be subjected to the same analysis applied to spatial represetation. Since time can be divided into many periods, it is impractical to test exhaustively. An alternative approach would create a polygon map using all lines from all times. This network will identify all the entities with a distinct history. By assigning temporal codes to these areal entities, there is only one map to check for completeness, plus a simple check for historical validity for each area.

SUMMARY

Space, time and attributes all interact. Quality information forms an additional dimension or glue to tie these components together. Innovative data structures and algorithms are needed to extend our current tools. No geographic information system will be able to handle the demands of long-term routine maintenance without procedures to handle quality information which are currently unavailable.

ACKNOWLEDGEMENTS

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GENERALISATION AND ERROR IN SPATIAL DATA BASES

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ABSTRACT

Many of the implications of generalisation in computer cartography have been assessed in terms of computing efficiency and visual effectiveness. Minimised storage, display and plotting times are viewed positively. There are, however, important adverse effects in the use of geo-coded features and digital cartographic data; effects which relate to the nature of digital geocoding, digitising accuracies and other error sources. The resultant error has considerable impact on the validity of automated retrieval methods such as point-in-polygon. A set of simulations were carried out on a data base of 23000 industrial establishments in N.W. England, using error-banded retrieval techniques. The effects of generalisation highlight potentially serious geocoding and retrieval errors.

The 115 polygonal units shown in Figure 1 form the 100 Employment Office Areas (EOAS) in North West England used as a geographic base for industrial establishments by the North West Industry Research Unit at the University of Manchester. They are a typical set of units used to partition the continuum of space into more manageable structures, essentially for administrative purposes. The units vary considerably in topographic size, from the very small EOA of Walton (89) to Lancaster (107), differences reflecting not their suitability for spatial analysis but simply the result of administrative convenience whose ideal is that such units should not have too wide a variation in the totals of establishments or workforces within them. The boundaries are merely a result of processes of administrative containment. Their statistical disadvantages have been identified in the contexts of spatial autocorrelation, the modifiable areal-unit problems, or by reorganisation of the data according to impartial units such as grid cells. The latter, though laudable, requires that data be available at a sufficiently fine level for restructuring, and assumes that confidentiality constraints permit such an operation. Usually, however, spatial data are gathered by governmental agencies at local regional and national levels, and these agencies view geographic space as being partitioned not into statistically impartial units but into the administrative structures they know and love. Whatever the relative merits and disadvantages of irregular units they do provide information in a format primarily useful for administrators, and spatial analysts must use them to best advantage.

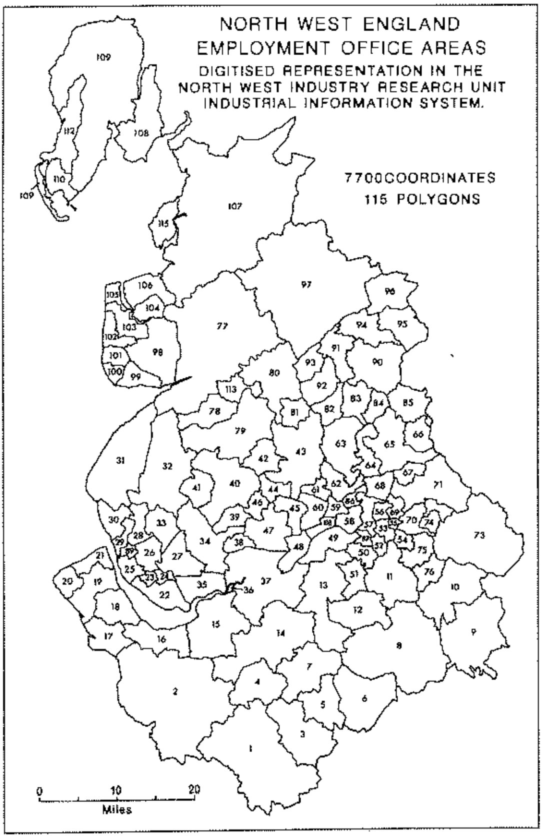

Figure 1

If the problems only were statistical then those building geographic information systems would have relatively little to worry about. However, there are potentially serious error problems, readily identified in the literature, but few of which have been tested empirically for their total effects in automated spatial retrieval. This is somewhat surprising considering the claims that computer cartography is a highly refined and accurate science. Bickmore (1982) notes various attempts towards scientific processes where any process within it involves a mathematical formulation and algorithmic expression. Dudycha (1981, p. 116) examined 'the computer revolution in cartography' and Morrison (1980, p. 7) even claims that 'cartographic products produced by computer-assisted technology can usually be made accurate to the resolution of the machine hardware used to produce them.' Various authors in Rhind & Adams (1982) support such views, yet they conflict markedly with authorities such as Jenks (1981), or Boyle (1982, p. 3) who argues that 'in my opinion we have failed during the 1970s.' A major reason must be that of inadequate investigation into error processes, a fault identified by Goodchild (1977) and elaborated by Poiker

(1982, p. 241) who notes 'the absence of any notion of precision and accuracy' in computer cartography, which he argues 'is like a person with the body of an athlete in his prime time and the mind of a child;' Goodchild (1980a, p. 192) examined accuracy for raster data, stating

> The accuracy problem would be simple if measurements for digital data could be checked directly against their true, real world values. But this is not normally possible. In general accuracy must be predicted from the digital data alone, by making assumptions about the true data.

Such assumptions relate to data usually 'captured' from published paper maps (with all their imperfections), using highly sophisticated hardware.

Poiker's 'body of an athlete' is largely undisputed. Without doubt the hardware of computer cartography is becoming faster, cheaper, and more accurate in a mathematical sense. What seems less easily agreed is the 'mind of a child,' which here is examined in the context of misuse of error-prone cartographic data. The sizes of the EOAs in Figure 1 do not reflect the numbers of establishments within them - not surprising and Tobler's (1979) suggestion of a 'transformational view of cartography' should motivate more to think in other metrics than raw topographic domains. In the context of EOAs the topographic size is more indicative of dispersion - the larger the EOA the more dispersed the establishments - and this has been confounded by the ravages of time and industrial recession to give wide variation in establishments and employment totals. EOA 107 (Lancaster) had 209 recorded manufacturing establishments in the database with an average employment of 34, whereas the much smaller EOA of Manchester (57) had 2367 establishments, averaging an employment of 11. The topographic boundaries pay scant regard to the thematic variables, yet it so often is the case that the topographic dimension is the primary mode of geocoding. A standard approach uses an orthogonal grid framework to geocode boundaries (usually as segments/chains, nodes, features, points) and utilises retrieval algorithms such as point-in-polygon to extract requisite locations. Considerable research has gone into optimising the search time of such algorithms, by refining software codes and structuring databases to minimise disk accesses. Both approaches seek to utilise the power and numerical accuracy of the computer more efficiently. The eventual cartographic precision, however, is determined by the quality of input data and types of usage. Jenks (1981) highlights various error inputs of digitising, and Chrisman (1982) assesses the error components of maps, though their studies are relatively recent. Early work on retrieval by point-in-polygon was concerned mainly with execution speed (for example Aldred 1972, Nordbeck and Rystedt, 1972). Baxter (1976) seems to assume inherent geocoding precision when stating that for any retrieval process 'the user merely states the precise coordinates of ...' the features in question. There can be no precision in map-derived data particularly since so many boundary features used are artificial lines that cannot be verified for ground truth. Precision also is underplayed by the Department of the Environment's (1973) extensive document on geocoding, which states as a matter of fact that 12 figure Ordnance Survey coordinates will give a ground resolution of 1 metre on the ground and that this will be 'adequate for most Local Authority data processing purposes.' Furthermore, they claim

> "It is normally possible to establish point-coordinates by eye using 1:1250 maps within an accuracy of around plus or minus 5 metres. When digitising equipment is used to generate coordinates electronically, the accuracy is improved to within plus or minus 1.5 metres" (DoE 1973, p. 93) In spite of the fact that the same human eye is guiding the digitiser cursor! Given a 1mm line on a 1:1250 map, a paper map with potential maximum stretch of 5%, the line would have a maximum distortion of 0.0625 metres on the ground. The 1mm line itself represents a direct width of 1.25 metres and the potential ground truth is 1.3125 metres. The 'human frailties' (Jenks, 1981) of digitising would add further error to this (for a statistical evaluation of error distributions see Chrisman, 1982) and there is little chance that the 1 metre resolution would be achievable. It seems logical to regard all digitised lines as being error-prone. Finer digitising would involve a futile attempt to transmit computational precision of the machine to the vagaries of cartographic representation.

There is also another, and very variable error component related to geocoding and digitising. Aldred (1972, p. 5) regarding digital polygon representation, notes 'the accuracy of this representation for curved shapes being dependent upon the number of vertices used.' Goodchild (1980a) quotes the paradoxical situation whereby greater generalisation in digitising gives less accuracy but the smaller volume of data allows faster processing. He also argues (Goodchild 1980b, p. 89) that cartographic generalisation may vary from map to map on the same scale. Even on a single map the digital sampling error will be distributed unequally - lines that are straight will have relatively low error components, while crenulate lines will be seriously error-prone. These differences are worsened by effects of unit size, particularly since the smaller sized spatial units in this study contain disproportionately high numbers of establishments. Thus local error factors will exacerbate global errors.

Smedley and Aldred (1980) examined these error sources. They note that the translation of a continuous line on a map into a digital summary involves a radical change in dimensionality. Of the infinity of possible points along any line, digitising samples but a few. Shapes become simplified, lines have their paths generalised, and to confound all of these there are the human problems in digitising. In spite of a growing range of hardware at the upper end of the market - line-followers, scanners etc

- much digitising still is undertaken using conventional tables, and the majority of existing line files are so derived. In Universities, Local Authorities and Research Organisations, digitising has been the poor relation in geographic information processing. Reasons are not difficult to isolate, since it is a tedious, time-consuming and exhausting process with a low reward value. It is easy to impress with a multi-coloured computer map, much less so with a slide of clean digitised outlines. It has been a case of out-of-sight out-of-mind and this mentality has been one reason for insufficient appreciation of problems of resolution and reliability in retrieval situations.

One technique for assessing geocoding and retrieval error is the 'epsilon' distance of Perkal (1966). Perkal used a band of error (distance epsilon) about a cartographic line as a means of generalising the line objectively. The technique works as efficiently in reverse if, for example, one simple value of epsilon is seen in the context of the representative fraction of a map. If the scale is 1:50000 and the width of a line 1.2mm then the line cannot be measured to a ground precision of better than 60 metres. Figure 2 shows an epsilon error band placed above EOA 77 (Preston). The black lines are the digital representation and because of the various error processes a band of error is assumed to exist.

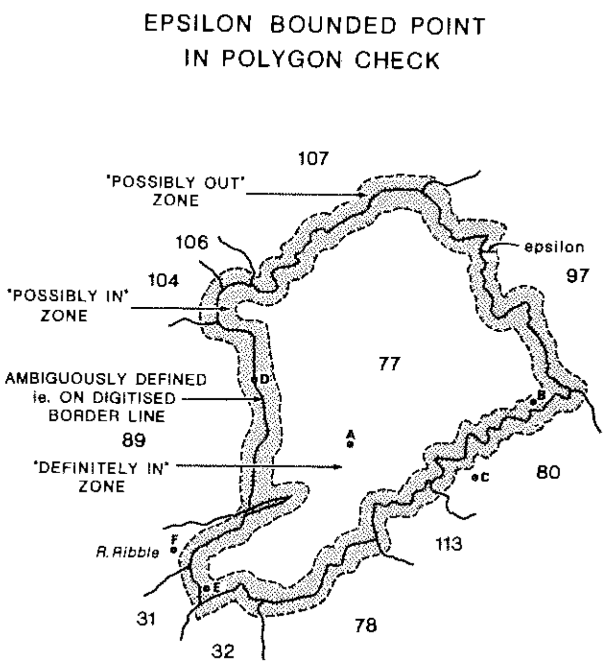

Figure 2

The area contained within the confines of the band now has four sectors. 'Definitely in' is the core of the area within the error tolerance. 'Possibly in' records a point which is within the digitised confines of EOA 77 but the error band makes inclusion uncertain. Beyond the digitised line is 'possibly out' where points are geocoded as being in a neighbouring area but technically they could be EOA 77's members erroneously geocoded, mis-classed because of digitising error, or both. Lastly, an establishment may be geocoded actually on a digitised line. The chances of this may seem remote, but they do occur and few algorithms allow for this - Douglas' (undated) being one of those that does. Thus on Figure 2, point A will be exclusively assigned to EOA 77, and point C to EOA 80. Point B is possibly in 77 and therefore possibly out of 80. Point D is ambiguously defined being on the border of 89 and 77. Point F is a more complex situation and will be discussed later.

An epsilon bounded point-in-polygon check can be carried out easily using a combined point-in-polygon and point-in-path check, where the width of the path is twice the value of epsilon. It is important that a point-in-polygon algorithm be used which specifically checks for ambiguity. The value of epsilon will be application dependent (see Chrisman 1982, for statistical arguments), but if it highlights a large percentage of doubtful assignments then a different approach to automated spatial retrieval would be necessary.

To evaluate the effects of the error process an initial test was carried out in 1982 on 780 initial entries in the NWIRU database. These industrial establishments provide a readily identifiable epsilon of 0.7071km because they are geocoded by the Department of Industry to a 1 kilometre grid square resolution. This may sound somewhat coarse, but some manufacturing units can have sites in excess of one square kilometre. Additionally, it is standard practice to assign a single coordinate pair to spatial features of areal extent because coordinates can be stored easily with other data, and they minimise retrieval time. Point geocoding is simple and direct, but it is not used for any methodologically sound spatial reason; simply because the characteristics of digital computing dictate it. Now that extremely powerful processors are becoming more common, it may be feasible to propose a reconsideration of geocoding practice. After all, current methods are the results of compromises and constraints determined by technology that is now decidedly out of date. Current practices are throwbacks to earlier days, although given the large amount of investment in these practices a reconsideration would not be entirely appreciated.

The 780 test points were not chosen with any particular areas in mind, although they did cover an area of eastern Manchester with EOAS of varying sizes; EOAS 73, 76, 11, 53, 57, 58, 68, 67 and 71 bounded the zone. EOA 73 is a large, almost circular area whereas 55 is small, and 70 has a promontory which would be almost all within the epsilon band. All the 780 points were tested against every EOA for various levels of epsilon so that sudden declines in accuracy could be identified. Starting with a classic point-in-polygon search 23 of the 780 were flagged as ambiguous, 2.95% of the total. With an epsilon of 0.1km 7% of all points were in areas of doubt: 100 metres is less than the ground-thickness of a line on most administrative maps and, given statistical tolerances of 5%, indicates that careful checking for erroneous geocoding is increasingly important. At 0.2km 20% were doubtful, a large increase, and for epsilons of 0.3cm to 1km the percentages in doubt were 23, 27, 35, 44, 50, 52, 56 and 61.

At an epsilon of 0.7km only some 50 percent of the 780 locations are uniquely assignable to one area. A worrying aspect is that the percentage loss is not equally distributed between the EOAs 71 and 73, which are large and which do not have many inflections, are least affected. At an epsilon of 1km they had respective losses of 32 per cent and 33 per cent. In the final NWIRU data base, these were to have 709 and 17 establishments respectively. Compare this situation with areas 55 and 56 which suffered 100 per cent doubt at epsilons of 0.5 and 0.4km respectively. These smaller units, which, as mentioned previously, tend to contain more than their 'topographically fair' proportion of establishments, are most at risk from cartographic error.

Overall, the initial trial highlighted a need for careful appraisal of cartographic error in digital spatial retrieval. First, the areas which are most affected by epsilon are the smaller areas, areas which are often those units of most importance in a geographic information system. They are the urban areas wherein most activity is concentrated. Second, shape has an effect of its own which can compound the effect of unit size. A small unit which has considerable elongation quickly would totally fall within the doubtful areas of the error band. Third, the rate of error may also be a function of establishments locating near administrative boundaries.

The test area was examined further to see what the effect of epsilon would be on employment totals, not just on numbers of establishments. An alarming range of values occurred for average employment per establishment using only 'definitely in' establishments. Interestingly, the deviations were not necessarily highest in the smallest-sized units. This simply is because of the variation in size of employment of establishments, and it only requires one large employer to be in the zone of doubt and the averages for the particular areas affected will vary markedly. One possible counter-argument to this would be to put faith in the presence of spatial autocorrelation. This would view the epsilon error very much as a case of swings and roundabouts, whereby the establishments that EOA 11 'loses' to EOA 8 are offset by those which EOA 'gains' from EOA 8. Therefore, a further simulation was carried out using 1980 total employment and, instead of excluding the doubtful establishments the possibly in and possibly out establishments were included. Only EOA 73 remained unchanged at an average employment of 33. The smaller areas, however, suffered badly: EOA 53 had averages ranging from 4 to 14.91 and 56 from 9.7 to 15.5.

Here the error problem was attacked by 'hedging one's bets' and rather than ignoring establishments in the error band, including all of them on either side of the border. There is a greater chance, perhaps, of ironing out some of the error by a neighbourhood factor, but it could be argued that this is no more than a cynical spatial lag whereby some of the establishments in the areas nearest neighbours are being used in an attempt to reduce the variability induced by epsilon error. In this case the greater the value of epsilon the greater the smoothing, and ironically, therefore, the bigger the error term the less the error will be visible in the smoothed data. Further, some EOAs started to 'gain' employment at an alarming rate and the results did not warrant any further consideration.

The outcome of the initial testing on the 780 points was that a decision was made to validate the entire data base. The possibility of error was far too high to be ignored. The results of the entire epsilon testing of the data base at 0.7071km are listed in Table 1

TABLE 1 FULL DATA BASE (22,798 ESTABLISHMENTS) EPSILON ERROR RESULTS AT 0.7071 KM

	Category		Percentage Affected
1.	Possibly out definite		1.5
2.	Possibly in		4.35
3.	Unassignable		1.4
4.	Possibly in/out		29.8
5.	Possibly in/out 1		6.72
6.	Ambiguous		1.19
		Subtotal	44.96
7.	Uniquely assigned		55.04
		Total	100.00

The categories bear some explanation. 'Possibly out definite' refers to those establishments which, using conventional point-in-polygon retrieval, would be missed altogether. This sort of case occurs along coastal areas where, because of the establishment geocoding to 1km resolution, the grid intersection lies out in the sea. Only the possibly out epsilon can pick this up. However, since there is no other EOA to which the establishment can be assigned, it can be uniquely assigned to the EOA for which it is 'possibly out.' Category 2 is similar - the establishment is possibly in an EOA but there are no other EOAs for it to be 'possibly out.' Referring to Figure 1, this could involve establishments at the margins of EOAs 8, 9, 73, 71 and so on. Again, they are uniquely assigned. Category 3 is unassignable. On Figure 2, location F is one such example, since it is beyond the error tolerates of all surrounding EOAs. Category 4 refers to establishments which are flagged as possibly in one and possibly out of another EOA. Category 5 notes those which are possibly in one and possibly out of more than one other EOA and 6 refers to those establishments by chance geocoded on the digitised boundary. The establishments flagged in Categories 3 to 6 were all checked against detailed records and local street maps in a time-consuming but important check as to their correct EOA. In a large number of cases this check indicated that traditional point-in-polygon retrieval would have been manifestly unreliable and would have produced classifications of establishments which at times bore little resemblance to the truth. At e = 0.7071km the 'definitely in' category only will include some 60 percent of establishments and workforce. It is useful to note that the number of establishments closely follows the trend of workforce and that the numbers of establishments can be used as a reliable surrogate for other key variables.

The end result of the NWIRU's concern with map error and spatial retrieval was a considerable amount of checking and manual validation but a data base which verified as 100 per cent accurate at the level of Employment Office Areas. For any aggregation or combination of EOAs this consistency can be maintained. Since every establishment is uniquely assigned, it seemed useful to include the EOA assignment as an extra item of data for each record. This extra item of data then was converted into a link list format so that each establishment points to the next establishment in the same EOA, so facilitating very high speed retrieval of information without further recourse to point-in-polygon and all the error that it entails. Clearly, not every spatial search will be along the lines of a neat aggregation of EOAs and it must be accepted that irregular area retrieval will be necessary at some stage. For the moment, users can be given three statistics for each such search - these relate to 'uniquely in', all establishments within the digitised boundary, and the total using the autocorrelation effect. Using existing programming styles and retrieval techniques, this seems, at present, to be the most logical provision. Nevertheless it does point to important, and indeed urgent, future research into <u>Intelligent</u> Geographic Information Systems: systems which can be provided with basic ground roles of spatial inclusion/exclusion that go beyond the crude mechanical techniques in use today. Already Image Analysis researchers are examining developments in 'Context Analysis' which will help to classify satellite imagery using statistical classification techniques, tempered by behavioural inputs from human operators; behavioural inputs which the system learns and will implement automatically at a later date. Such developments will be needed in Spatial Information processing before Geographic Information Systems can operate with the subtlety of a researcher rather than being a brute force speeding-up of repetitive and tedious operations.

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TOPOLOGY AND THE CONCEPT OF THE STATISTICAL SOLID

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ABSTRACT

A major disadvantage in automated construction of three-dimensional graphic displays lies in the facility with which such figures may be represented and re-represented. One can 'move around' in a virtual space, to view the object or surface from a variety of viewpoints and scales. Three-dimensional viewing techniques have been widely used for display of geographic terrain; they have also been applied to design and manufacture of solid objects. The statistical analogy to terrain representation is the smoothed, often fishnet surface by which single and multivariate relationships are commonly illustrated. Such surfaces have been applied to illustration in diverse sets of decision-making tasks, for example, in optimizing facility locations on a land-value surface.

The construction of a statistical solid is much less commonly used as a visual tool in spatial decision-making, but has been used to depict metric relations in cluster analysis and in multivariate regionalization techniques. Statistical solids may also be useful to illustrate topologic relationships. It is proposed that the visualization of such relations may facilitate their interpretation; and further, that computer generation of such displays will provide a means to 'move around', to explore all facets of the multidimensional framework. Ronald Atkin's development of A-Analysis, or Polyhedral Dynamics, provides a guide for construction of the topologic relations. This paper will discuss techniques for illustrating these relations in a graphic framework, and suggest possible applications useful in decision-making tasks.

ADVANCES IN GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

Research into spatial information systems has disclosed that geographic information systems (GIS have lagged behind important developments in computer science, information theory and interface design. Basic data structures such as vectors, strip trees and quad trees are discussed. Summaries of the properties of hierarchical, network and relational DMBS are given. Recent development of a relational spatial data base with variable-length and matrix records (RSDB) is described. RSDB has the capability to add the benefits of network and hierarchical DBMS to the relational system. The enhancement of information content is seen as a new function of the DBMS, making the topology and numerical attributes of features available with their coordinates. Improvements in data management and information content are seen as necessary for achieving the final goal, the improvement of the human interface. Any mode of interaction (keyboard, cursor movements, voice, etc.) should be available to the user for any application; and the choice should not be dictated by the particular query or data type.

INTRODUCTION

Geographic information systems (GIS) have received considerable attention recently, and are a central topic in this AUTO-CARTO SIX conference. The ones that have been created vary in type, from mere descriptions of methods of organizing data, to complete systems of hardware and software for creating digital geographic data bases and for mapping from them. As the implementation becomes more complete and definite, the scope of the system tends to become limited. This is natural enough; the mere task of naming and classifying geographic features is a large one, and the task of creating a comprehensive geographic data base for a province or country is so formidable that it has never been fully accomplished.

Recent research by the authors has disclosed also that the designs and implementations of geographic information systems have lagged behind developments in computer science, including information theory, data base management theory, and interface design. Three basic improvements to GIS are considered in this paper. One is the design of a DBMS with the flexibility of the relational system added to the speed of other types. Another is the enhancement of the information content of the basic data by including the semantics and topology; that is, by improving the data model. The third is the improvement of the human interface with the system; and when this aspect is interpreted as broadly as it should be, it is really the most important goal of GIS development.

THE DATA MODEL

The basic data model of most GIS is a list of feature names, with instances of the named features located by coordinates. This simple model contains no help for the user in either semantics or topology of the features.

The need for help with semantics is exemplified by the word "contour". Most cartographers will give it the meaning of a representation of a level line, but even in strictly geographical usage it may mean the outline of the areal feature or of the plane projection of a solid figure. Another example is the word "road". There are many different types of roads, even if the meaning is limited to something that carries vehicular traffic; but consider the meaning "a place, less enclosed than a harbour, where ships may ride at anchor." This takes us all the way from topography to hydrography, and makes it evident that context must be appreciated by the system.

The data model must also take topology into account, to some extent at least. In the strict mathematical sense, the topology of geographic features and combinations of features depend only upon their 'connectivity'. For example, a sphere and a cube are topologically similar or homeomorphic, as are a contour line and the outline of a lake. These are simply-connected solids and surfaces. An example of a multiply-connected solid is a doughnut; and of a surface, a lake with islands. It will be convenient to extend the notion of topology to include the comlexity of geographic shapes. A simply-connected surface (one with no holes) may still have a highly complex outline. One way of quantifying complexity of a shape is to determine the masimum number of intersections of a general straight line with the outline of the shape. We will also include under topology the properties of adjacency and intersection of like or unlike features.

Geographic Data Structures

A large class of geographic data is that which names, encodes, describes and locates topographic features. However, topography is only one branch of geography, and geographic data may belong to many other branches such as human geography, meteorology and so forth. When all such branches are included, geographic data structures and formats may take on any conceivable complexity. For the time being, however, we will consider the data structures that pertain only to information that is associated with topographic mapping, and to thematic mapping that requires a topographic base.

With this limitation, GIS must handle the following feature elements:

a) Points;
b) Lines (open-ended);

c) Outlines (closed polygons);
d) Areas (groups of adjacent area elements).
The data structures consist of these elements along with the data that are required to locate, identify and describe the feature to which they pertain. The data structures may also carry some topology, the simplest type being that which relates the elements above to one another; for example, the data structure for an area may carry references to the lines which delimit it, and to the nodes in which these lines intersect.

The data structures of existing GIS are quite simple. They deal with an individual point as a name or code with a set of coordinates; a line as a coded list of coordinate sets; and an area as a coded set of lines, or as a coded set of area elements, each of which may carry a vector of properties. There are other types of data structure, such as run-length encoding, that are used within some GIS without being shown explicitly; and there are others to be described below that do not appear to have been applied at all.

Run-length encoding. Run-length encoding is a means of condensing the information carried by a raster image or a rasterized thematic map (Figure 1). When a particular type of area element or pixel is first encountered in a row-by-row traverse of the image, that pixel is given an opening flag. If a number of pixels with identical properties are then encountered sequentially, they are counted; and a closing flag is given to the last of them. Only the positions and codes of the flagged pixels and the counts are stored. The storage and the reproduction of an image or thematic map is greatly simplified by this technique, if the homogeneous areas are mostly large compared to the size of the pixel. The flagged pixels are also available for drawing line maps from an image, and a converse process can be used to create images from line maps.

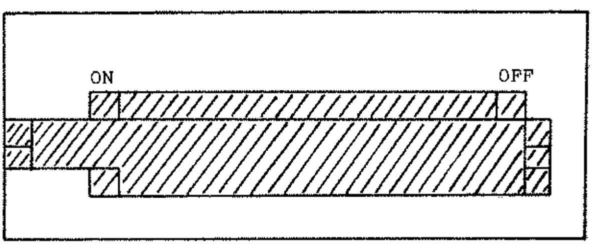

Figure 1: Run-length Encoding

Strip trees. The strip tree is a data structure for storing linear features. Consider a line (Figure 2a) that is made up of many points, and assume that it contains many more points than are required to define the line to the desired accuracy. (This situation arises often with stream-digitized lines.) A rectangle is computed that encloses all the points of the line and that is bisected by the straight line joining the end-points. The width of the rectangle is twice the distance from the straight line to the point of the original line that lies farthest from it. The half-width is calculated, and if it is within the required tolerance for locating the line, the job is finished and the straight line is taken as the representative of the original If not, two rectangles are computed on the sections of the line defined by the end-points and the point that lies farthest from their join (Figure 2b). The process is repeated until the half-width of the enclosing rectangle is within the tolerance for defining the line.

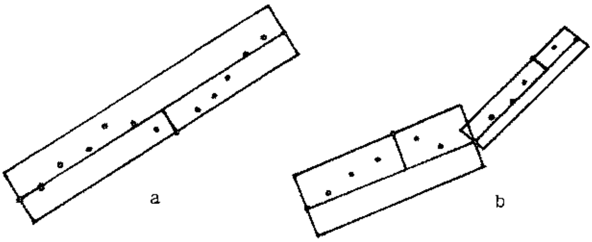

Figure 2: Strip Tree

The resulting data structure is called a strip tree because it can be stored as a tree (a balanced B-tree, for example). Different levels of generalization correspond to the different levels in the tree, making it easy to generalize at different levels from the same data source. The storage requirements are economical under the conditions assumed, but of course there is overhead associated with the structure that may not be justified for some applications.

Quad trees. The Quad tree offers a similar method of condensing the information in raster images (Figure 3). The image is first divided into sections with numbers of rows and columns that are integral powers of two. A section is then quartered, and each quarter is tested for homogeneity of the pixels it contains. If a quarter is homogeneous,

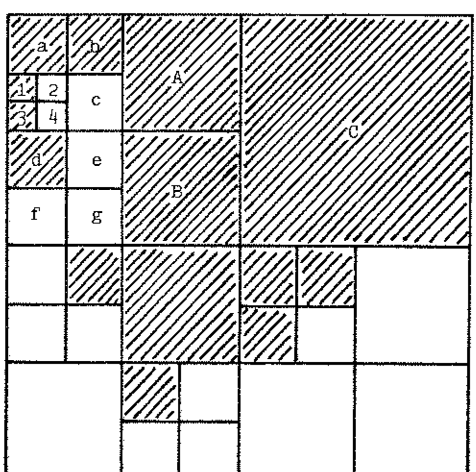

Figure 3: Quad Tree

it is stored as a unit. If not, it is quartered again. The process is continued until all quarters are homogeneous or until they become individual pixels. Once again, a B-tree may be used to store the image, and the economy of storage and recovery may be great. A processed Landsat image is ideal for this type of manipulation, while a raw image will ordinarily not justify it.

Semantics of Geographic Feature Representations

Specific geographic features are represented in GIS by symbols that may be words, letters, numerals or graphics. The semantics of these symbols refers to the meanings that they convey, and is therefore of the greatest importance to the user of geographic information. Individual symbols should convey unequivocal information to broad classes of users. Groups of symbols may convey more information than is contained in the individuals; one example of this being the information on slope and aspect that is carried by sets of contour lines. Another is the idea of population density and land use practices that are given by the clustering of house symbols. These examples show how the semantic value of symbols is related to the experience and understanding of the user.

The user of a data base must be able to enter symbols to initiate data base action, and must be able to understand the symbols that are returned from data base query processes. The accuracy of this two-way communication is crucial, and careful data base design is required to minimize the confusion that can arise from misunderstanding of the symbols, whether they represent commands, data input, or returned data or graphics. If words are being used to make queries concerning geographic features, the words must have exact meanings in the context of the specific data base. Inexactness of definition in such common words as 'contour' and 'road' has been pointed out above.

The design of a high-level query procedure for a GIS should include some artificial intelligence to resolve simple context problems such as these. Large amounts of processing overhead are required to accomplish this, using natural language queries, and the user must still understand the effects of the semantic structures of his queries. A simpler solution is to require the user to determine the type of object desired and to formulate a specific request for it.

To assist in the identification of the specific object desired within a data base, the object is often assigned attributes. The attributes can themselves be objects, but they serve the purpose of descriptive adjectives. The use of attributes narrows the definition of the object and allows for the selection of the specific information required. For example, the user can specify the exact type of 'road' that is required. Otherwise, the entire range of objects covered by the term 'road' may be selected, and their attributes can be examined separately.

Topology of Geographic Features

Present geographic information systems provide only the very simplest of topological information, if they provide any at all. It may be possible to derive the topology of features from their coordinate data, but for many important and simple topologies the derivation may be expensive or even impossible. In such cases the topology must be derived at the time of feature digitization, and it must be carried with the coordinate data in the data base. For ease of recovery of information, the topology should carry the coordinates.

Common topological relationships. The following is a list of important topological relationships, more or less in order of their complexity:

a) Connectivity of vectors: Present GIS often carry contours, roads and other vectors as disconnected and unrelated strings of point coordinate sets. For example, a given road has connection to near and distant roads and places. Such information has inherent connectivity that can be important, and it is difficult to recover once it has been lost.

b) Connectivity and adjacency of areas: Areas are stored as sets of raster points, or more commonly as closed polygonal outlines. In the latter case the unity of an area is assured by the data format, but in neither case is it known from the basic data format whether two areas touch one another. Some polygonal data structures, such as the SDTC data transfer format which has been adopted by several Canadian government agencies, carry this information by labelling each section of a polygon with the codes of the areas that it separates. It is also possible to label each node of a polygonal structure with the codes of all the areas that meet at that node.

c) Intersection: Intersection of features is an important property that is not presently provided. One example is the intersection of linear features such as roads and streams. This information would allow mapping all culverts and bridges on a road system. Another example is the intersection of areas, such as wetlands with proposed construction zones. There are many examples of interesting intersections that are now determined laboriously or not at all.

d) Proximity: Proximity of linear and areal features is more difficult to determine than adjacency, but may be just as important. Two examples will be given. In forestry, we might have the query "What areas of mature timber lie within one kilometre of a given proposed road system?". The military might ask "What areas of tree cover lie within 2000m of a proposed line of advance?". It is clear that the answers to many such queries cannot be included in the basic data structures, but the data base management system should provide the answers at reasonable cost of time and money.

Topology and graph theory. The following sections will just introduce the idea of handling topological relationships by means of graph theory. Actual physical objects have area, volume and shape, but their map representations are points, lines and polygons which can be considered as purely geometrical and topological objects. If topological questions are to be answered, however, the topology of the features must be carried in the data base. For example, if the task is to find a route between A and B by following roads, representing roads as a linear network allows efficient solutions. It is also possible to take into account such factors as bearing strength, width and surface status as constraints in the route selection. It is vital, however, that the network be connected; it would be difficult or impossible to find a route from A to B if the roads connections were not made, or if they were interrupted by bridges.

The topology of features that can be considered as linear can be modelled by connectivity graphs. The graph may be a map-like representation, perhaps with the scale distorted (like a subway-car station map), or may be a computer-stored abstraction of the network. The nodes of the graph are intersections and connections of roads to bridges, ferries and the like. The arcs of the graph represent sections of the road and the connecting features. Note that for pure topology the coordinates of the nodes and the lengths of the arcs need not be specified.

The topology for areal (polygonal) features can be modelled by adjacency and incidence graphs. An incidence graph is topologically homeomorphic with the line-drawn map of the features. That is, the arcs represent the boundaries between adjacent polygons, and the nodes or vertices represent the points where three or more polygons meet. The degree of the vertex is the number of polygons that meet there, and, at the data capture level, the question of whether all the polygons are closed can be answered by examining the degrees of the vertices.

An adjacency graph looks like the incidence graph turned inside out. A vertex represents a polygonal area, and an arc represents a pair of adjacent polygons. Adjacency graphs can be used to determine whether a possible path exists across terrain which has been classified into passable and impassable areas, for example. For simple maps the question can be answered at a glance, but detailed representations of complex terrain require the adjacency-graph approach.

In all the cases above, the topology can carry positional and descriptive information. The vertex of an incidence graph may carry the coordinates of the point where the polygons meet, and the arcs may carry the descriptions and the areas of the adjacent polygons. Left and right identifiers may be carried also. The great virtue of the graph representation in the computer is that all the theorems and methods of graph theory may be applied to derive new and important relationships of features.

A GIS interface consists of the hardware and software which allow the user to interact with the geographic data base. Ease of user interaction is one of the major goals of GIS design, so that the interface must provide a simple conceptual model of the interaction. It must also contain an English-like query language that is easy to learn, and integrity checks on the user's actions to ensure smooth interaction. One goal of interface design is to make it unnecessary for the user to have an intimate knowledge of what the data base contains or how it is structured. Most GIS offer some on-line help, but the interfaces tend to be designed for particular applications by a particular class of user. The following sections give a brief description of the components and requirements of a graphical interface for entering, retrieving and editing geographic data.

The User's Actions

The actions to be carried out by the user are:

1. Entering and editing graphical entities (points, lines, polygons, symbols, groups, text, etc.);
2. Data base interaction (retrieval, update, create, delete, etc.);
3. Saving images, printing images;
4. Modifying the display space.

Lines symbols, objects and all other stored items have to be referenced so that the user can identify them without ambiguity.

Control Objects

The interactive interface programs are controlled with the assistance of control objects, including the following:

1. A spatial window for displaying spatial information;
2. A text window for displaying text data such as error messages, for information selection by interaction with the data base, and for requests by the user;
3. A menu space for different menus.

When using a pointing device a cursor should be displayed to indicate position on the display. When the user moves from one control object to another, the cursor should change appearance to indicate this transition.

A scale indicator should always be visible on the display. This may take the form of a displayed scale fraction or of a divided and annotated scale line.

It is understood that the user will receive some form of feedback to all actions. In may cases, this will consist of the movement of a cursor on the screen. In other cases it may be in the form of a text message.

Command Modes of the Graphics Interface

The graphical interface includes a workspace, which contains a small subset of the data base at any one time. Five explicit modes of operation are suggested for the graphical interface. Three of the modes are interactive, the other two are used when leaving the editor:

1. edit - add to or delete from the graphical information in the display state. This will involve an update to the workspace.
2. show - involves querying the workspace. If the information is not found in the workspace, the data base is searched and the required material is transferred to the workspace for graphical or textual display. The default mode upon first initiating the graphical editor will be 'show'. The reason for this is that upon initialization the display screen is blank. It is therefore probable that the graphical editor was invoked to show spatial objects, which may then be edited or just viewed.
3. select - involves querying the workspace or the data base (if the required information is not in the workspace) and presenting the data to the text window. Depending on the amount of data being returned, it may be necessary to increase the text window size. Redirection of the data to another device is also possible. It will be possible to transfer the results of a 'select' into a 'show' request without repeating the query under show mode.
4. stop - exits from the graphical editor. The changes made in the workspace are incorporated into the data base.
5. abandon - stop the graphical editor. The changes in the workspace are abandoned and do not affect the data base.

In general, the command language should consist of as few explicit modes as possible. An explicit mode is one that must be invoked by the user, by changing from another mode with an explicit command. For example, to delete from the screen of the graphical device, the user could be required to enter a DELETE mode. Options within DELETE mode would likely be presented to the user at that time. To exit DELETE mode, the user would be required to explicitly abandon the mode and enter another one.

The user must always be aware of what mode is in use, and it is easy to become confused if too many explicit modes are available. ON the other hand, if there are very few modes, the number of commands on the screen at one time become excessive. A good compromise must be reached in grouping the commands into modes.

DATA BASE MANAGEMENT SYSTEMS

Hierarchical Data Bases

The most common type of data base for GIS is the hierarchical data base, illustrated in Figure 4a. It is most suitable for data that occur naturally in hierarchical form; for example, data organized by municipality within county within province within country. Data from any one of the root nodes may be recovered rapidly by a search down through the branches. In many GIS, the depth of the hierarchy is not great, and large files of data can be recovered quite rapidly.

Hierarchical systems break down when it becomes necessary to recover related information from many root nodes. While the complete data set for any one census tract, for example, may be readily available, it is quite a different matter to answer such a query as "What is the proportion of home owners to renters in all census tracts within four given counties?". Each root node representing a census tract must be located and queried individually; a very slow prodess.

Network Data Bases

A network data base is shown diagrammatically in Figure 4b. Such a base makes it easy and fast to recover related information, if the relationships have been built into the network. The recovery of specific large blocks of data may also be fast, but once again the paths of navigation through the base must be known. Network data bases are not easy to modify and are not easily understood by the user.

Relational Data Bases (RDB)

A diagram of a relational data base is given in Figure 4c. The RDB looks simple in the diagram, and it looks simple to the user also. The simplicity is deceptive because a

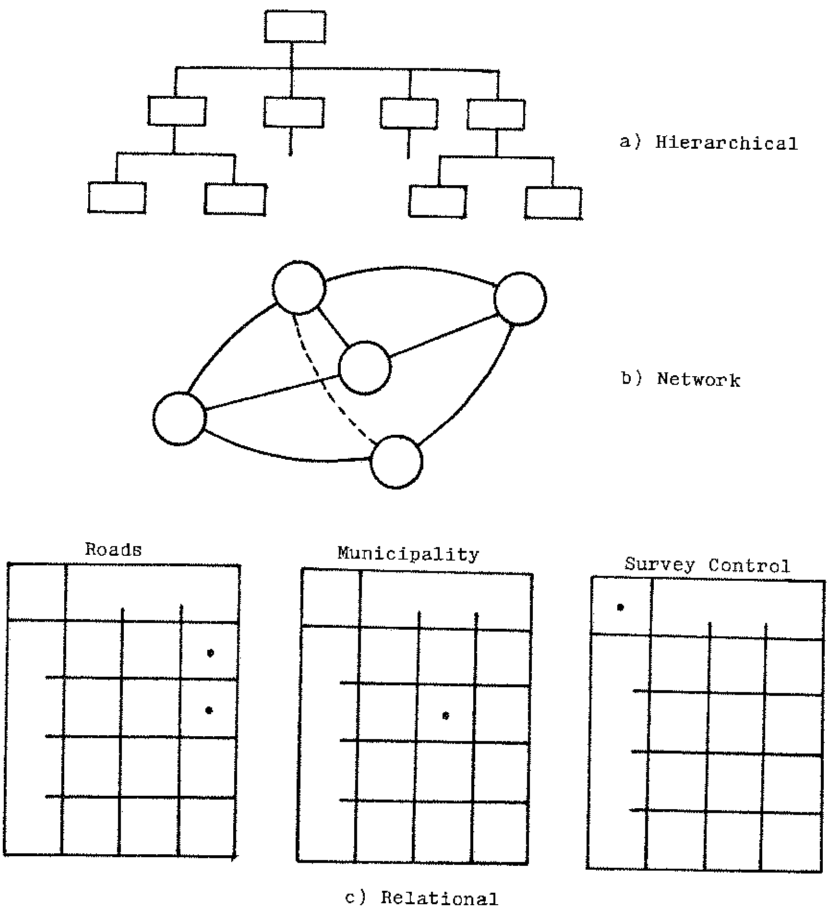

Figure 4: Data Bases

highly developed relational data base can embody all the complexities of a set of hierarchical and network data bases.

The elements of the RDB are relations, domains and tuples. In the simple tabular representation, the relation is the table, the domain is the column, and the tuple is the row. The more general terminology is necessary because the domains and tuples, in relational data base practice, may be numbers or symbols unrelated to any physical quantities. In many cases the relation represents a type of object, the domain an attribute of the object, and the tuple an instance or example. Relations may be indexed on any attribute, providing fast recovery of the instances of that attribute. Links can be established from any element of a relation to other relations. The paths of navigation must be known, as for the network D.B., but modifications are made more easily. Joins between relations allow any types of related information to be selected. Joins are reasonably fast and useful only if the relations have been suitable indexed for the purpose.

RSDB - A Master Relational Data Base

The common relational data bases used in business contain records of fixed length. This is satisfactory for systems of moderate size because it does not take too many characters to specify any employee's name or to enter any sum of money, for example. In large business systems, and particularly in geographic systems, data often occur in large masses which must be recovered all at once. A topographic map may contain several million data, with one or more millions in the contour file alone. A Landsat image with perhaps 15 million pixels, each carrying four bands of colour data, is another example that must be recovered quickly.

Collins & Moon Limited has recently developed the central components of a Relational Spatial Data Base (RSDB) with variable-length and matrix records, to handle problems of the types above. This capability makes it possible, within the relational data base, to simulate network data bases with their fast recovery of related material, and hierarchical data bases with their easy addressing and fast recovery of large blocks of data.

CONCLUSION

Future geographic information systems will take advantage of modern developments in interface technology, in information theory, and in data base management systems. This paper has stressed the consideration of topology and semantics, and the need for new interface design. The most important recommendation is the creation of a comprehensive relational data base to respond to user queries, with the capabilities of fast access to massive files, competent response to queries, and flexible management of different forms of geographic data.

AN EXTENSION OF MAP OVERLAY CONCEPTS USING AN IMAGE PROCESSING SYSTEM

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ABSTRACT

In the process of site and route selection, varying types of spatial data must be assembled, evaluated, and compiled. Traditionally done by hand, this task has been significantly expedited through the use of computers. Using a raster image processing system, Gibbs & Hill has developed a group of computer programs which search an array of maps for specific combinations of most suitable factors for potential site location. Suitability is commonly expressed according to an interval scale; that is, all ascending levels of suitability, from least to most suitable, increase by equal numerical intervals. Although the interval scale is prevalent in site selection studies, it is not the only numerical expression of variations in suitability, and perhaps not the best. Two alternatives are examined in particular: one determined by the ratio between consecutive values, and a second by the logarithm of numbers in the interval scale. In comparison to the interval scale, the alternatives offer probably a more realistic expression of variations in suitability, as well as greater resolution in the results.

I. INTRODUCTION

Site selection incorporates the analysis and compilation of many individual maps, each of which describes a different characteristic, whether physical or socio-economic. All data elements are registered to the specific geographic locations they describe and are stored in the computer. Additional data may be derived from the combination, or overlay, of two data base elements. The result of the overlay provides information not adequately represented by either of the input maps. The concept of overlaying maps may be extended to include a much larger number of attribute maps in a single operation.

The overlay process is central to the analysis in site selection studies. Siting applications can range in diversity from siting small, highly specialized retail establishments to vast areas in which to store toxic wastes. A set of input maps may be searched for specific combinations of most suitable characteristics or for areas that would prohibit their selection as potential sites. These characteristics, or attributes, must be initially defined. They must also be expressed in a form which allows comparisons of suitability to be made among all of the input maps. To simplify the process, suitability is typically expressed in whole numbers less than ten.

Recent developments in computer graphics hardware have encouraged the search for more efficient ways to process site selection analyses. Maps have traditionally been stored in computers as strings of x,y coordinates, which can very simply drive line plotting devices. Reductions in the costs associated with computer processing and storage have encouraged the development of the Multiple Map Matrix Analysis (3MA) software on a raster image processing system. This software allows maps to be input, sorted, and analyzed as rectangular arrays, or matrices, of area units. Each area unit can range in size from square yards to square miles.

Several features of the raster image system influenced the 3MA software development: first, any input map may contain more than 300,000 discrete area units, or pixels. Any pixel on an input map can be assigned a value ranging from 0 to 256. Multiple map overlays can yield a potential range in summation values from 0 to 65,536 (or 256^2). The summation may be completed in a matter of minutes, regardless of the number of discrete areas depicted on each input map.

The development of the 3MA software emphasizes the use of the computer as a powerful "adding machine." Its programs allow maps of virtually unlimited complexity to be input to the system and then analyzed with any user-defined suitability scale. Since the summation is completed quickly, it encourages experimentation with alternative suitability scales before making a final site selection.

This paper proposes several such scales which seem to more appropriately express variations in suitability. The emphasis of the analysis may be placed on deriving more accurate numerical representations of suitability, without being restricted to those that are easy to calculate by traditional methods. Following a general discussion of the process, the scales are compared in both hypothetical and actual site selection situations.

II. THE INTERVAL SCALE IN TRADITIONAL SITE SELECTION

Site selection analysis depends on the ability to measure differences in suitability and express them in numerical terms. Measurement is usually made according to one of four types of scales: nominal, ordinal, interval, or ratio. From nominal to ratio, the scales increase in complexity and the amount of information they can represent, at the risk of greater confusion. Before computers were used to perform map summation, increased information was often sacrificed for less confusion and computation ease. The four scales are briefly discussed below.

1. Nominal -- This scale is based on a binary classification of attributes. That is, all pixels on a map are assigned values of either "suitable" or "unsuitable". Sometimes called a categorical scale (Hobbs and Voelcker, O'Banion), this classification reflects only qualitative, not quantitative, differences between two mutually exclusive levels of suitability.

2. Ordinal -- In this scale, areas on a map are ranked

in terms of suitability. Although the ranks may be identified by numbers, they reflect only comparative differences. Thus, only Boolean operations such as greater than, less than, or equal to are valid. All arithmetic manipulations are invalid.

3. Interval -- Numerical expressions on an interval scale go beyond ranking suitability levels to exhibit known differences or internal relations in suitability between areas on the map (Muercke). Scale values are defined in terms of an arbitrary origin, and express how much one level of suitability differs from another. This makes addition and subtraction, as well as the Boolean operations valid. Multiplication and division are limited to constant terms, since these preserve the relative differences between suitability levels.

4. Ratio -- The ratio scale is identical to the interval scale except that the numerical expressions of suitability are based on a non-arbitrary origin. This gives an intrinsic meaning to the numerical expression itself. All operations, arithmetical and Boolean, are valid. Multiplication and division are not restricted to constants, and may be used with variables as well.

When the nominal scale is used in site selection studies, all "unsuitable" pixels on the input maps may be assigned a value of zero, and all remaining "suitable" pixels a value of one. If the value on each pixel is summed with the values on the corresponding pixel on all other maps, those pixels on the resulting map made up of only one values among all input maps define the "most suitable" areas. Those with only zero values result in the "least suitable" areas. All other pixels on the resulting map, whose sums are made up of combinations of zero and one, represent areas of intermediate suitability. Although all input maps are binary, the resulting map can have three gradations of suitability: "least suitable," "intermediate," and "most suitable."

The binary classification of input maps represents the simplest case, but generally oversimplifies real-world variations in suitability. Input maps usually provide a variety of areas which can be ranked in order of suitability. The nominal scale can therefore be expanded to an ordinal scale of more than two levels of suitability. Five levels, for example, can be expressed as:

5 excellent
4 good
3 fair
2 poor
1 unsuitable

As the adjectives indicate, these levels represent qualitative differences in suitability. The numbers express rank only, not numerical differences, (between "good" and "excellent," for example.) If a study includes the summation of four maps with these five levels of suitability on each, the resulting map would contain a maximum of 17 different levels (sums equalling 4 through 20) from a theoretical maximum of 625 (5) possible combinations from the four input maps.

The least suitable (sum=4) and most suitable (sum=20) levels can each result from only one combination of suitability levels on the input maps (i.e., 1+1+1+1 or 5+5+5+5). Site selection studies, especially those which sum more than four maps, often do not yield an area that combines "excellent" levels on all input maps. It is therefore necessary to look at areas which combine mixed levels of suitability. Unlike the levels of maximum and minimum suitability, each intermediate level, (with sums equalling 5 through 19), can result from a variety of combinations of input factors. The value of 19, for example, can result from four combinations: 5+5+5+4, 5+5+4+5, 5+4+5+5, 4+5+5+5. Their aggregation into a single level implies that all areas with the value of 19 have identical suitability. In reality this is rarely the case. Beyond the top few levels of final suitability, much larger areas on the resulting map are aggregated into a single level, which generalizes the results more than is often desired for site selection studies.

In part for these reasons, siting studies often assign a weighting factor to each input map which reflects its importance relative to all other input maps in the analysis. Weights are typically expressed according to a ratio scale, in numbers ranging from zero to one, with a sum equal to one. The suitability value for each pixel is then multiplied by the weight assigned to the entire map before summation.

Because the weighting factors are fractional numbers, their multiplication by whole-numbered suitability values increases the number of levels in final suitability, thereby reducing the amount of aggregation on the resulting map. This creates an impression of greater resolution in the results, allowing analysts to more easily identify potential sites. The desire to compute a single measure of site suitability has prompted many studies to weight and add together ordinal numbers in violation of measurement theory (Hobbs and Voelcker). By definition of the ordinal scale, multiplication by a weight factor (or by any other factor) is invalid and thereby compromises the results achieved. Summation without the use of weighting factors must also be approached with caution since it implies that areas of the same rank on different maps have identical suitability. This may, of course, be true, but is more often assumed to be true than actually tested. It is therefore important to consider the comparison of equal ranks between input maps before beginning any analysis.

III. ALTERNATIVE SUITABILITY SCALES

The above discussion points to the need for expressing variations in suitability using numbers which better describe the differences between successive suitability levels. This may be done using an interval or ratio scale of measurement. By definition, multiplication by weighting factors does not compromise the integrity of either type of scale.

The ordinal scale mentioned earlier could conceivably be used as an expression of interval or ratio differences in suitability. The distinction between its use as an ordinal or interval scale of measurement is not always clearly defined in site selection studies. In this paper, it is therefore referred to as the ordinal/interval scale. The scale offers the advantage of a numerical progression that is easily recognized, as well as numbers, usually single-digit, that are easy to sum. For the purposes of comparison in this study, the scale has been expanded to nine levels of suitability which are expressed with a constant interval of 10 between 10 and 90. This does not change the characteristics of this scale, but merely serves to clarify the numerical differences between it and the alternative scales. Although the absolute numerical difference between successive levels remains constant at 10, the intervals that these numbers represent range from 100% between the bottom two levels, to 12.5% between the top two levels of suitability (see Table 1). The most suitable level is therefore only slightly better than the next most suitable level. Value scales in the physical world would seldom, if ever, be described by such a sequence of numbers.

Differences in suitability may be more aptly expressed by a constant ratio of difference between successive suitability levels. The magnitude of the ratio is based in part on the threshold interval at which humans can perceive a difference between two stimuli. The determination of this value goes beyond the scope of this study, and is therefore arbitrarily defined at 32%. The values of this scale, called the ratio scale in this analysis, are shown in Table 1.

Table 1

Suitability Values	Ordinal/Interval Scale			Ratio Scale			Pseudo-log Scale		
	Value	Diff.	%	Value	Diff.	%	Value	Diff.	%
Excellent	90			90			95		
		10	12		22	32		5	6
. . .	80			68			90		
		10	14		16	32		6	6
. . .	70			52			84		
		10	17		13	32		6	8
. . .	60			39			78		
		10	20		9	32		8	11
. . .	50			30			70		
		10	25		7	32		10	17
. . .	40			23			60		
		10	33		6	32		12	25
. . .	30			17			48		
		10	50		4	32		18	60
. . .	20			13			30		
		10	100		3	32		30	
Unsuitable	10			10			0		

A second scale is based on the perception of differences in values for continua such as length, duration, numerousness, area, weight, and loudness. Rather than describe value differences by a constant ratio, the scale of subjective magnitude (i.e., what humans perceive the magnitude of the stimulus to be in comparison to its actual magnitude,) approximates a power function of the physical stimulus (Stevens and Galanter). Thus, if suitability levels are defined in proportion to their discernability, the interval of difference between successive levels of suitability decreases with increases in suitability. The numerical values could be defined according to a logarithmic scale, such as the one called the pseudo-log scale in Table 1. The values were obtained by calculating the base 10 logarithms of the numbers 1 to 9, multiplying them by 100, and rounding to two figures. The exponent of the power function has been rather arbitrarily defined here in base 10, since its value varies according to the phenomenon being measured (Stevens and Galanter).

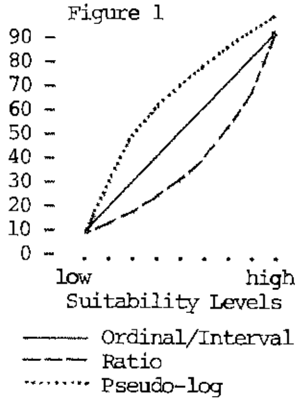
These scales attempt to represent only two of many alternatives to the ordinal/interval scale. As such, the ratio and pseudo-log scales can be viewed as prototypes of a family of scales with similar properties concerning variations in suitability. The most appropriate interval of difference for the ratio scale and the most appropriate exponent for the pseudo-logarithmic scale would be the topic of further research. For this study, the emphasis is on determining how these types of scales behave in general in comparison to the traditional ordinal/interval scale. Their characteristics are reviewed and compared, first in a statistical sense and then in a siting study which follows.

IV. QUANTITATIVE CHARACTERISTICS

Figure 1 presents of the numerical differences between the three suitability scales. Each scale value is plotted against equal increments of suitability. Values on the lower end of the pseudo-logarithmic scale are spaced farther apart than on the upper end. The opposite is true of the ratio scale. This could imply greater resolution in the results of map summation on the low end of the pseudo-log scale and on the high end of the ratio scale.

In a summation of four maps with nine levels of suitability on each, the resulting map could have up to 6561, or 9 , distinct combinations of suitability. Many of these combinations aggregate into the same summation level, so that the number of distinct suitability levels on the resulting map is much smaller than 6561. A hypothetical four map overlay, where every possible combination may result, is used to compare the number of distinct suitability levels and the frequency with which they can occur between the three scales.

Figure 1



Four maps are generated based on a three by three matrix, so that each square is assigned one of the nine levels of suitability:

1	2	3
4	5	6
7	8	9

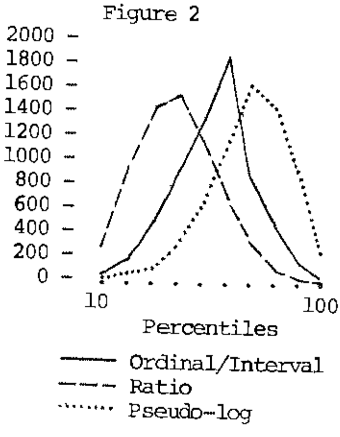
The pattern of the first map was repeated at progressively reduced scales on three other maps. All suitability levels occur in equal amounts on every map and overlay on all levels of the other maps. Out of 6561 possible combinations, the total number of distinct suitability levels is:

33 on the ordinal/interval scale
192 on the ratio scale
185 on the pseudo-log scale

Already, both the ratio and pseudo-log scales represent a six-fold increase in resolution in final suitability over the ordinal/interval scale.

The distribution of the total number of possible combinations of resulting suitability, shown in Figure 2, also varies between the three scales. The ordinal/interval scale produces a normal distribution of combinations throughout the range in suitability. Fewer combinations fall into the upper part of the range using the ratio scale. Using the pseudo-log scale, fewer combinations fall into the lower range. Greater resolution in high levels of suitability may therefore occur with the use of ratio-scaled levels of suitability. On the other hand, greater resolution in low levels of suitability can result from logarithmically spaced levels in suitability on the input maps.

Figure 2



It is important to look at the cause of the increase in resolution. This may best be explained through an example two-map overlay. Using the ordinal/interval scale, an area which combines most and least suitable levels (90+10) on the input maps has the same final suitability as another area which combines two intermediate (50+50) levels. With the ratio scale, most and least suitable levels (90+10) have a higher final suitability value than two intermediate levels (30+30).
This again implies that the ratio scale emphasizes higher levels of suitability. The lower levels of suitability are emphasized using the pseudo-log scale, because highest and lowest levels (95+0) result in a lower final suitability value than two intermediate levels (70+70). This relationship holds true for every pair of combinations.

On the basis of this discussion, one might conclude that the ratio scale could be more appropriate for differentiating between highly suitable areas to determine the most suitable one. The pseudo-log scale could have potential in applications that require sensitivity to lower levels of suitability.

V. CARTOGRAPHIC APPLICATIONS

The hypothetical four map overlay described above distributes the suitability levels evenly throughout each map. In commercial or industrial facility siting studies however, suitability levels are rarely distributed in equal amounts over each of the input maps. More often, areas of highest suitability are least plentiful on each input map. Progressively larger areas are associated with lower levels of suitability.

This was true for the input maps of a siting study performed by Gibbs & Hill for the government of Nigeria. Seventeen input maps were analyzed in order to locate potential sites for secondary steel manufacturing facilities. The input factors covered a variety of information including climate, vegetation, rainfall, and population density, as well as proximity to navigable rivers, railroads, educational facilities, airports, and the electrical power distribution grid. The analysis was initially performed using the ordinal/interval scale and a set of weighting factors, which described the relative importance to the client of each input factor.

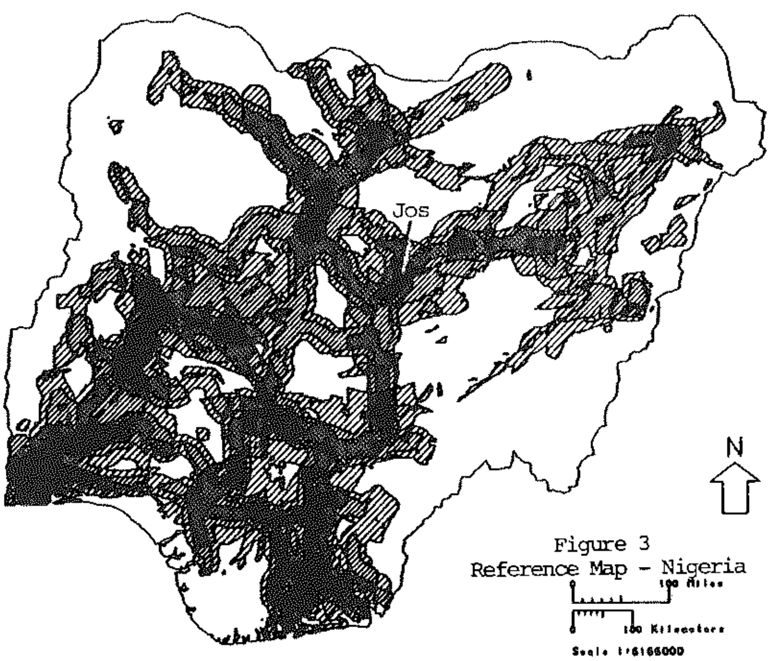
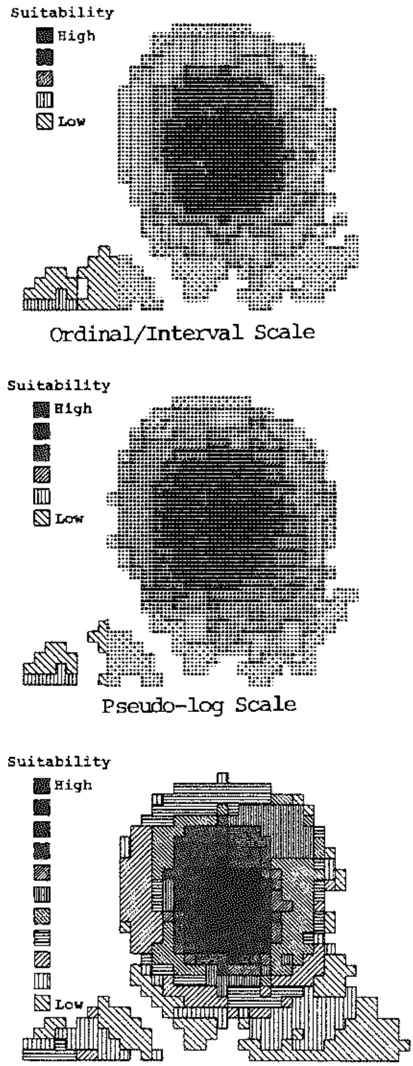


Figure 3
Reference Map - Nigeria

The maps are reanalyzed here without the weighting factors, using the three scales described in this paper. An area in the vicinity of the city of Jos, shown in Figure 3, is used to indicate the difference which results from using each of the three scales. Although this area falls approximately 10% below the maximum resulting suitability level, it is selected for presentation here because it includes a range of levels on each of the input maps. For graphic clarity, every five levels of final suitability are aggregated, producing the resulting maps in Figure 4.

Figure 4



Ordinal/Interval Scale

Pseudo-log Scale

Ratio Scale

The results are consistent with the discussion in Section IV. The interval scale yields the fewest levels of differentiation within the range of suitability levels. The pseudo-log scale offers only slightly greater differentiation. In comparison to these two scales, the ratio scale offers far greater differentiation. The results are attributable to both the nature of the analysis and of the different value scales. The analysis seeks to identify sites with most suitable characteristics. The ratio scale therefore offers the greatest resolution in the high end of the range in suitability. The pseudo-log scale causes greater aggregation on this end, and is instead more appropriate in analyses which seek to identify those areas that are unsuitable as potential sites.

VI. SUMMARY AND CONCLUSIONS

The results presented here describe only specific examples of suitability scales and therefore reflect the preliminary nature of this analysis. The pseudo-log and ratio scales can be considered as isolated examples of an entire spectrum of logarithmically and ratio-scaled progressions. Even within the limitations of two-digit numbers to describe these scales, there are many more possible expressions of suitability than are feasible to test. The wide variety of input maps and analysis objectives defy an empirical approach to testing all possibilities. Because of this, it is also not possible to generalize numerical expressions of suitability to a single, all-purpose scale that can replace the traditional ordinal/interval. Instead, suitability scales should be considered specific to the analysis they describe, and should not be readily applied to other studies. The values of the suitability scale and the relationships between them should be carefully determined between client and analyst at the outset of the study. The ratio and pseudo-log scales of this paper provide guidelines for alternative, possibly more accurate approaches to representations of variations in suitability.

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OVERLAY: A RELATIONAL DATA BASE MANAGEMENT SYSTEM FOR SPATIAL ANALYSIS

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ABSTRACT

We present the background to the software product OVERLAY, a relational data base management system intended to support a class of applications requiring the ability to phrase and process complex queries against both spatial and attribute data. These applications include:

- resource management such as insect and pest control, forest harvest planning, and oil reservoir analysis.
- demographic studies and market research.
- digital image analysis.
- biomedical research.

The capabilities of OVERLAY are for the most part complimentary to Computer Aided Draughting and Cartographic systems, and are distinguished as an analytical tool by the query facilities and the underlying mechanisms which provide for uniform treatment of spatial and attribute data. The development of OVERLAY has required investigation into a number of seemingly unrelated areas, most notably:

- the representation of spatial data.
- supporting logical operations against spatial data in a consistent manner.
- defining a complete data manipulation language consistent with both spatial and attribute data.

This paper will outline our work towards the implementation of a data manipulation language, the core of OVERLAY, in domain relational calculus.

LE GRAPHISME CARTOGRAPHIQUE ASSISTÉ PAR ORDINATEUR COMBINÉ À UNE BASE DE DONNÉES ALPHANUMÉRIQUES: UN PUISSANT OUTIL D'ANALYSE

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ABSTRACT

The geographers know very well the graphic analysis essentially based on combinations of draftings or graphic figures and very often express their results with graphics. We often say that a drawing is worth a thousand words. On the other hand, everybody knows the analysis power of a computer if we know how to program it to process the millions of necessary operations to obtain the anticipated results. Let us imagine the combination of those two remarquable tools in one; we will then have a faster tool, more powerful, more flexible: the integrated data base operated on a computer. The author explains the new analysis power of the computer assisted cartographic graphics combined to an alphanumerical data base with a few simple and varied examples such as election lists, forestry parcels or electric circuits: henceforth, mapping becomes the most powerful tool ever thought of.

INTRODUCTION

Tous les gens connaissent bien ce qu'est une carte. C'est un document graphique de haute qualité qui illustre un thème pour un territoire donné.

Les gens connaissent aussi l'amoncellement de papier expulsé par les salles d'ordinateur avec des listes interminables de noms et de colonnes de chiffres à effrayer n'importe quel comptable. Les géographes en particulier sont conscients de la longueur de temps nécessaire pour traduire ces listes en une représentation simplifiée et correcte de toute cette information. Jusqu'à ces dernières années, les seules tentatives pour aider les cartographes à accomplir ce travail fastidieux aboutissaient à fabriquer une sortie d'imprimante ayant plus la forme d'un cartogramme que d'une carte. Quel est donc ce problème si crucial qui ne puisse vraiment pas être solutionné? C'est le lien entre des éléments graphiques de qualité et les attributs alphanumériques de ces éléments.

En effet, le lien entre les éléments graphiques et leurs attributs constitue le problème, et maintenant la solution, à cet ennui de compilation des données nécessaires à la fabrication d'une carte. Si ce lien existe et qu'il est bidirectionnel, c'est-à-dire pouvoir à partir des éléments graphiques fabriquer des listes d'attributs d'une part et à partir des attributs alphanumériques, fabriquer des éléments graphiques de qualité d'autre part, il est dorénavant possible que le cartographe se fasse assister par l'ordinateur pour fabriquer les cartes dont il a besoin pour transmettre ses informations et se servir de cet outil pour des fins d'analyse. Cet outil remarquable existe: c'est la base de données intégrée exploitée par l'ordinateur.

Nous allons maintenant illustrer de quelles façons ce nouvel outil a été exploité pour résoudre des problèmes d'analyse en cartographie à l'aide de quelques exemples dans quatre domaines différents de l'activité cartographique:

- carte électorale
- carte forestière
- toponymie
- circuits de distribution électrique.

CARTE ELECTORALE

Les cartes électorales sont toujours le résultat d'une série importante d'analyses et d'essais laborieux. Par exemple, pour passer la limite d'une circonscription électorale à un endroit plutôt qu'à un autre, il faut tenir compte de facteurs très variés comme:
- l'environnement physique:
  - . regrouper les gens qui ont les mêmes problèmes (route, eau, chaleur, etc.)
  - . tenir compte des obstacles naturels (chaînes de montagnes, cours d'eau, etc.)
- l'environnement culturel:
  - . regrouper les gens de même origine
  - . regrouper les gens de même idéologie
- le nombre:
  - . ne pas dépasser un nombre déterminé de personnes dans une circonscription tout en s'y rapprochant le plus possible.

Partant de cela, il est facile de s'imaginer bien d'autres contraintes qui peuvent être intégrées et résolues par ce mode de traitement.

Les mêmes problèmes se présentent pour chacune des divisions de la circonscription électorale jusqu'à atteindre la plus petite unité: la section de vote.

Mais le document graphique publié n'est pas le seul document nécessaire au bon fonctionnement de la journée de votation. Il faudra en outre fournir des indicateurs de rues (listes des rues, rues par secteur de vote et même par section de vote) et des listes électorales (listes de votants par section de vote). Tout cela exige un travail énorme de compilation, d'analyse et de vérification.

La carte, en soi, n'est pas trop complexe à produire c'est lorsqu'on tient compte des analyses de population que cela se complique. Prenons un exemple classique: une série de condominiums se bâtissant dans un quartier résidentiel. Cela amène 1,500 habitants de plus sur une rue. Il faut donc tenir compte de ce changement majeur local et déplacer en conséquence les limites des sections de votation. La méthode classique déplace arbitrairement la limite pour répartir la nouvelle population. Après coup, on analyse, listes en main, l'impact de cette nouvelle division sur la population des sections de vote. On recommence ainsi jusqu'à atteindre la division la plus tolérable. Un autre exemple serait le développement d'un nouveau quartier résidentiel ou le remplacement d'un quartier résidentiel par des édifices à bureaux.

La base de données intégrée nous offre beaucoup plus de souplesse que la méthode traditionnelle. D'abord, la carte servant de base et de support aux données alphanumériques peut être mise à jour et retracée dans des temps très courts (moins d'une heure dans la plupart des cas pour un document de travail). Ensuite, la base de données alphanumériques, rattachée aux éléments graphiques, peut elle aussi se mettre à jour rapidement si des rues s'ajoutent, changent de noms, disparaissent etc., comme dans le cas des votants qui changent d'adresse ou qui s'ajoutent ou disparaissent. Mais le plus ennuyeux de tout cela, sans une base intégrée, c'est le changement de limites d'une circonscription ou d'un secteur ou d'une section de votation.

Classiquement, il faut corriger la carte (qui à force d'être corrigée devient vite un document illisible), refaire les indicateurs de rues qui «indiquent» les rues ou parties de rues faisant partie de tel ou tel secteur de vote, et finalement fabriquer les listes électorales (listes de votants/section de vote). Il faut donc presque tout refaire à la main. Et nous n'avons absolument pas tenu compte de la population impliquée; si on s'est trompé il faut recommencer à la main encore une fois.

Comment la base intégrée peut-elle nous aider en plus de refabriquer la carte complète en une heure et de mettre à jour la base alphanumérique? Elle nous permet, par ces mises à jour rapides d'effectuer des analyses qui nous permettront d'évaluer la pertinence des limites électorales établies avant de fabriquer les cartes et listes. Les analyses peuvent être du type «graphique d'âge/sexe/section de vote versus la circonscription électorale complète» cela nous permettant de constater les disparités d'âge et de sexe à l'intérieur de la circonscription. La même analyse peut se faire, au besoin, sur les revenus, le statut de propriétaire/locataire, l'origine ethnique, le nombre d'enfants, etc. Cela permet donc de fabriquer à temps une carte électorale adéquate.

CARTE FORESTIERE

Un deuxième exemple où la base de données intégrée ouvre des horizons jusque là inaccessibles, est le domaine des cartes forestières.

Le problème classique est la confection d'une carte des polygones des différents types de végétation; à cela, bien sûr, devra se jumeler une base de données (souvent des listes-papier) contenant des informations de superficie, de volume de bois, hauteur d'arbres, dépendance administrative, etc. Cela est important de tout compiler une première fois mais comment répondre à la question: où sont tous les polygones contenant des épinettes de 25 ans dont le diamètre est de moins de 10 centimètres, dans des forêts concédées à telle compagnie? Les listes seront là pour nous indiquer que ce sont les polygones numéro tel et tel et il faudra rechercher ces polygones sur toutes les cartes d'inventaire (travail ardu et souvent trop long pour être exploité en temps voulu «épidémie»).

La solution interactive s'impose et nous force vers la base de données intégrée. Qu'advient alors la question de tout à l'heure? L'ordinateur recherche pour nous les éléments graphiques dont les attributs alphanumériques ont été énoncés et nous les indique sur l'écran en quelques minutes. Une copie d'écran de 30 secondes et vous voilà prêt à affronter votre problème avec toutes les armes souhaitables. Vous faut-il plus de renseignements (les listes conventionnelles)? Un rapport peut être imprimé dans les mêmes délais que tout autre système. Dans le cas d'analyse d'hypothèses quant à telle ou telle maladie, épidémie ou croissance anormale, un grand nombre de cartes et des listes peuvent être fabriquées en des temps très courts permettant des interventions plus rapides et efficaces.

Enfin, un autre avantage et non le moindre de ce mode de traitement est, ici encore, la mise à jour. Un feu, par exemple, et tout le bel inventaire traditionnel est faussé. Le mode interactif de traitement d'une base de données intégrée permet de fabriquer un nouveau polygone autour de la région brûlée (sur l'écran bien sûr) et d'attribuer à tous les éléments qui s'y trouvent l'attribut «brûlé à telle date»; toute la base est ainsi mise à jour en quelques minutes et prête à toute nouvelle exploitation ou interrogation.

Cela ne vaut-il pas mieux que de colorier à la main un document non reproductible et souvent périmé une fois terminé?

TOPONYMIE

Les noms géographiques s'attachent à des surfaces bien définies par définition. Alors pourquoi doit-on toujours s'attarder à des listes n'illustrant pas de quoi on parle (combien peuvent s'imaginer la grandeur du lac Mistassini si on n'en montre pas une image relative à une surface connue), ou à des cartes sur lesquelles il faut chercher le nom en question pour savoir de quoi on parle? Où sont tous les lacs «LONG» de la province de Québec? Cela apparaît impossible à trouver par méthode traditionnelle.

Pour résoudre ces problèmes les gens multiplient les échelles de cartes avec des grilles de repérage jumelées à une base de données permettant de retrouver, avec ces coordonnées, les différents éléments géographiques portant un nom.

Imaginons un peu le problème dans une région plus restreinte comme celle d'une agglomération de municipalités. Plusieurs rues de ces municipalités peuvent porter le même nom et cela devient vite un cauchemar pour un organisme qui tentera de contrôler l'appellation des lieux. Où sont les rues «St-Jean» par exemple? A part quelques chiffres indiquant des coordonnées, cela ne veut pas dire grand chose-sur l'importance de ces voies de circulation.

Une solution nous est spontanément proposée par l'exploitation interactive d'une base de données intégrée. Il ne s'agit que d'attribuer aux éléments graphiques confectionnant les cartes exploitées les attributs noms, nature de l'élément, superficie etc. et la base intégrée est formée. Tout cela ne se fait pas sans difficulté bien sûr et la plus grande objection sera l'acquisition des données numériques formant la carte. Il n'est cependant pas nécessaire de démarrer avec une carte complète au tout début. Un départ modeste avec des acquisitions constantes et surtout des mises à jour régulières ne manqueront pas de donner les résultats escomptés.

Alors nous pouvons répondre à nos questions de tout à l'heure et afficher en quelques secondes tous les lacs «LONG» de la province de Québec ou d'une région plus restreinte de la province et en fabriquer une copie tout aussi rapidement.

Ce qui est toujours intéressant, dans ce système, c'est la possibilité au plutôt la facilité de mise à jour des données. Le lac «LONG» «un tel» change-t-il de nom? Il ne s'agit que de changer l'attribut de cet élément graphique et la base de données est prête pour de nouvelles exploitations et interrogations.

CIRCUITS DE DISTRIBUTION ÉLECTRIQUE

Un dernier exemple d'utilisation d'une base de données intégrée vise un domaine encore plus spécialisé: les circuits de distribution électrique.

Dans ce cas, plusieurs problèmes de représentation et d'analyse sont bien connus des organismes de distribution électrique mais nous en retiendrons seulement deux:

- localisation des bris
- balancement des phases.

La localisation des bris d'appareillage de distribution fait l'objet d'installation complexe permettant de connaître où s'est produite l'interruption sur les grandes lignes de transport. Cependant la distribution locale ne jouit pas d'autant d'avantages. Souvent les réparateurs se déplacent à l'endroit du manque de service et cherchent visuellement les causes de panne suivant la distribution à rebours. Bien sûr, il existe un dessin des circuits de distribution avec la description «théorique» de l'appareillage (voltage, puissance, etc.) mais ces dessins ne sont souvent pas à jour étant trop nombreux et trop longs à refaire.

Alors comment balancer correctement les phases si les renseignements concernant le réseau de distribution n'est pas à jour? Un système interactif pouvant montrer l'état actuel du réseau de distribution local est d'un grand secours pour déterminer les points névralgiques du réseau et surtout les appareils impliqués. De plus, connaissant l'état actuel du réseau, si l'information qualitative de l'appareillage est intégrée à ce dessin, il est facile d'en retirer l'information et de balancer les phases. Un cas assez fréquent peut ici servir d'exemple.

Un quartier résidentiel se développe et il faut l'alimenter. Il faut aussi prévoir une alimentation d'urgence au cas où la première source deviendrait inutilisable. Alors en dessinant les deux réseaux sources de ce nouveau quartier et le réseau du quartier et en y attribuant toutes les informations pertinentes on pourra prévoir facilement les implications de charge des deux réseaux et installer l'appareillage nécessaire.

Tout cela est déjà très bien mais qu'arrive-t-il de l'analyse de charge réelle du réseau? C'est là que la puissance de la base intégrée exploitée interactivement prend toute son importance. C'est là que le balancement réel du réseau s'effectuera réellement.

Souvent la méthode d'analyse est basée sur une image théorique du réseau sur cartes perforées auxquelles on attribue les paramètres d'opération réels comme puissance, voltage, facteur de puissance etc.. De là, une liste de l'appareillage est formée en tenant compte de facteurs de proportionnalité et des pertes théoriques pour déterminer les puissances réelles «théoriques» dans chaque branche du réseau et les puissances et voltages disponibles à chaque client. De là des actions théoriques sont prises pour corriger le réseau et une nouvelle liste est formée. On recommence ainsi jusqu'à satisfaction avant de passer aux changements pratiques du réseau.

Avec la base intégrée, l'état du réseau et tous ses paramètres sont connus et il est simple d'en analyser une partie ou une autre. De plus, si on veut effectuer des changements théoriques à titre d'essai, il est simple de modifier le dessin et les attributs qui y sont accrochés interactivement et d'en exécuter une nouvelle analyse.

CONCLUSION

Les quatre exemples cités ont tous plusieurs points en commun:

- des informations graphiques de grande qualité (carte...)
- des information alphanumériques
- des besoins de mise à jour rapide des deux types d'information
- un lien constant entre les informations graphiques et alphanumériques
- nécessité de listes et de dessins ou cartes à différentes échelles
- une souplesse d'analyse la plus grande possible pour permettre la prise de décision dans les temps requis.

Ces exigences nous font rapidement prendre conscience que les méthodes actuelles de travail ne sont plus adéquates et d'autres solutions s'imposent. La représentation graphique demeure, dans tous ces cas, l'élément le plus important d'analyse ou de visualisation de l'état de la question ou du transfert d'information. Cependant, cette représentation ne peut être fabriquée suffisamment rapidement pour accorder tout le support souhaitable.

En jumelant la partie graphique à la partie alphanumérique dans une même base de données intégrée, il devient alors possible, nous l'avons vu, de fabriquer non seulement la représentation graphique nécessaire (carte ou autre) mais aussi toutes les listes décrivant avec tous les détails souhaitables les arrangements graphiques en question et cela dans des temps requis.

Assistée de cette façon, la cartographie ou la représentation du territoire devient alors l'outil de représentation et d'analyse le plus puissant jamais conçu.

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A HIGH RESOLUTION MICROCOMPUTER BASED COLOR SYSTEM FOR EXAMINING THE HUMAN FACTORS ASPECTS OF CARTOGRAPHIC DISPLAYS IN A REAL-TIME USER ENVIRONMENT

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ABSTRACT

For purposes of experimentation on the human factors of real-time, color, cartographic display, we have configured a high resolution microcomputer based image display system. The system provides the basic image device for a series of studies aimed at examining the practical use of color on cartographic displays. In the paper we examine: human factors and color display, the graphics hardware, and some initial experiments involving the human factors aspects of using real-time, color displays for purposes of spatial problem solving through the performance of map use tasks.

At present, computer-generated cartographic displays represent a significant aspect of spatial decision support systems which operate in an environment of large volumes of data and which utilize graphic displays as a method of presenting data in a timely and organized manner for rapid decision making. It is important to realize that the production of map displays and the performance of map analysis tasks are significant aspects of these systems.

Map use, however, is normally considered a labor intensive task conducted by a user who possesses significant expertise in cartography (this is often an incorrect assumption). In this sense, it is presumed that the map user can accomplish the required goal in some extended temporal domain with or without the advantage of a display which has been designed to induce a visual information performance that is typified by speed and accuracy. The utility of such a presumption is debatable but not unreasonable when the object of perception is a traditional "manuscript" map (such as a topographic, climatologic or geologic map). Conversely, when the map is a thematic map that is designed to convey the spatial variation of a limited phenomenon or a set of real-time phenomena for purposes of spatial decision making, the speed and accuracy of map task performance is extremely critical.

To date, there has been little analysis of the types of display design that could provide useful task support for reaching accurate and timely decisions based on visual inspection of computer-generated cartographic displays. Furthermore, the lack of this information coupled with the current technological transformations, which have passed cartographic representation into the arena of real-time digital graphics, provoke a serious human factors problem. The resolution of this problem will require an interdisciplinary approach since there is a significant dearth of research that blends cartographic and human factors theory in such a manner as to provide a useful, diagnostic tool for the effective design of maps for real-time decision making. Cartographic literature, for instance, examines theoretical mapping requirements within the context of the perception and use of maps, but in a traditional use format; that is, a somewhat leisurely interpretation of printed maps symbolized in a normally achromatic format. Conversely, human factors literature, while providing information on the perception of real-time, computer-generated displays, offers few guidelines related to products with the complexities and presentational requirements of maps. In this context, it is frequently the case that computer-generated cartographic displays do not serve the purpose for which they were created, are poorly rendered, and equally poorly designed and understood. New research on the interface between maps, map task performance, and the capabilities of digital display systems is a pressing demand, and one that cannot be satisfied by researching existing literature.

BACKGROUND

The key to the utility of maps is that thematic material is organized within a spatial framework and the organized material is "perceived, understood, retained, and retrieved better than comparable but unorganized material" (Haber, 1981). During the mapping process the cartographic designer enhances the basic image organization that results from spatial structure by selecting graphic techniques and design dimensions that further organize the image elements, or by providing legends and guides to help viewers categorize the spatial variations and display elements (Dobson, 1981).

The cartographer, when creating the map image, acts as a image organizer by attempting to mix graphic elements to create a balanced, harmonious display with a suitable figure-ground relationship. It is, unfortunately, the case that during this process most cartographers act in an idiosyncratic manner creating each display uniquely and often based on prior episodic experience with other displays. These decisions are based mainly on intuition, convention, or a sense of artistic balance; and are rarely subject to human factors of any particular set of decisions that lead to the employment of specific graphic elements (symbols, tint screens, etc.)

With the advent of digital cartography and readily available real-time color display capabilities, non-cartographers have begun to create real-time map images (virtual maps) which are to be used in high performance situations only to find that substantial literature on the use of cartographic design to organize color displays does not exist for either real-time digital displays or even the analog printed map. Furthermore, extended examination of the literature on color perception created by human factor specialists reveals that the perception of color symbols on maps or map-like displays is a critical research area that has been neglected (e.g., Christ's comprehensive review of color literature (1975) reveals on three studies with map-like stimuli.) The lack of interface between the cartographic requirements for the representation of spatial data and the human factors related to efficient map use reflects a critical gap in display design guidelines that contributes to continuing inefficiencies and inaccuracies in the use of real-time cartographic displays. Further, this gap will prohibit the emergence of high performance map reading that reflects the merging of the visual capabilities of users with the display capabilities of systems.

The key to understanding the design requirements of the cartographic display lies in appreciating the visual processing needs of the map reader. The visual processing of marks and signs of cartographic displays, however, is not a trivial perceptual task and involves extremely complex processing. Unfortunately, the problems that automated mapping poses for cartographic information processing cannot be understood, much less solved, unless consideration is given to map creation and utilization as two components of a coherent process. It is only through consideration and understanding of both of these subprocesses that we can evaluate the integrity of various methods of mapping data as a means of communicating spatial information.

In a general sense, cartographic communication includes map making, map use (map reading, map analysis, map interpretation, and map appreciation). More specifically, cartographic communication involves two transforms. The first transform generates the map from the input data, while the second derives information from map use. The situation becomes more problematical when we consider that the processes involved in the transformation from the data to the map and from the map to useable information are subject in the former case to constraints of method (both technical and conceptual) and in the latter case to human factors limitations generated by the perceptual abilities of the human visual information processing system. In this sense, cartographic communication requires assessing cartographic theory to determine the appropriate forms for mapped elements and, concurrently, preparing the cartographic message within the known constraints of human factors theory that may influence the visual processing of spatial cartographic data. When the output map, which results from these processes, is to be a virtual display on a CRT, numerous additional factors concerning both cartography and the processing of visual information make the information transfer more complex and a study o- the visual processing of computer-generated cartographic symbols more imperative. This is especially true in real-time map displays where no human review and edit of the display is possible before it is presented to the user.

CARTOGRAPHIC REPRESENTATION IN A COMPUTERIZED ENVIRONMENT

Digital mapping is concerned with the methodologies and techniques of mapping in an automated environment. The processes of computer mapping represent rational, mechanical decisions leading to the manipulation of the data to be represented. The manipulations, however, must be tailored to match the long established functions of the map within the context of cartographic theory and the processes of human communication. In this sense, although digital mapping appears to be a technological extension of current cartographic practice that requires few fundamental changes in the traditional conception of the mapping process, the structure of manipulating cartographic information for digital processing does require that more attention be paid to the nuances of cartographic theory than is the case in manual production. In an effort to provide an insight to the complexities of automated cartography and to clarify the relationship between mapping and the manipulation processes that are necessary to map with computers, the types of processes that typify digital cartography are discussed in Appendix B. Of more significant concern, is the fact that cartographic representations in real-time display environments are increasingly being symbolized with color as an active graphics variable. While the use of color does not pose significant computational problems, its effectiveness as a display variable that can positively influence visual processing during map use remains unclear.

Unfortunately, both the human factors and cartographic literature that relate task performance to the graphics characteristics of displays lacks substantive information on the basic issues that are of critical importance to the understanidng of map use tasks performed on displays presented in color either in a normal or computer-generated environment.

THE USE OF COLOR WITH CARTOGRAPHIC DISPLAY

While cartographic displays have much in common with other graphic representations, some of the presentational concerns in cartography are unique in respect to the design and use of other types of displays. In addition cartographic displays are used for purposes and tasks significantly different from those common to non-spatial displays. An examination of the human factors and associated color use literature, however, reveals few instances of experimentation that deal either with cartographic displays or map performance tasks. As consequence, much of the information that does exist is of questionable use when the stimuli are maps and the task requires a search of map information.

As an example of this mismatch in the literature, let us examine some commonly held notions about the limitations on the information processing of color stimuli.

1. The utility of colors is limited for code sets greater than six, since beyond this limit it is hard to identify various hues (Hauesing, M 1976; Hurvich, 1981; Krebs et al, 1978.) In addition, it is assumed that employment of a large number of codes will result in erroneous (misdirected) visual fixation, and, as a result of this, an inefficient search (Carter and Cahill, 1979).

   As is commonly acknowledged, the utility of general guidelines is a function of the task difficulty and the nature of the task. In most cartographic situations the stimuli (a map) is accompanied by a legend which serves to define the categorical significance of the graphic elements used to define the symbolized items on the display. In this case, one would expect that the color code would be quite large (certainly larger than six) and yet still effective in task performance since the addition of a legend serves the purpose of an "anchoring stimulus" and helps to stabilize color matching decisions made by the maps reader.

   In addition, color is used on maps for three distinct purposes: first, it serves to paint the distribution of the mapped variables; second, color is used to disassociate background (geographical space) from the distribution (thematic space); third, color is used for annotation (grids, lettering, etc.) that is explicitly a part of the spatial framework but not an active (data/target) part of the display. In these cases, color is used as an organizer and effects the hierarchical partition of the image element by representing conceptually distinct events. This linkage between color and types of events, coupled with the use of symbol legend may allow the use of color codes on maps that are extremely large in respect to non-map stimuli.

   Further, it is usually the case that the mapped distribution (the targets) are presented in a redundant format such that both color and a secondary variable (such as size) both represent the same information. This technique allows further extension of the color code.

The purposes for which the map will be used may also serve to usefully extend the number of active colors on the display. For example, research dealing with the mapping of bivariate statistical distribution pairs off hues, thus permitting the mix of the two variables in a spatial location, to determine the mix of colors involved. Although the resulting display makes absolute color identification quite problematical (due to the extremely large number of blends that can be generated), variations in the mixes provide those interested in establishing spatial patterns, a unique tool for observing subtle changes in the spatial behavior of the mapped variables.

2. It is commonly held that when color is not a positive graphic variable (that is, when it is used as background), it may act as a distractor (e.g. Krebs, et al, 1970). On maps, as with most displays, only a limited number of the graphic marks on the display are of active interest at any moment. Map background information, while not a positive display variable, does serve to organize the image into types of information (image and attribute data) and helps define the spatial organization of the display. If the colors attached to the geographical aspect of the display are chosen on the basis of a harmonious, color relationship, the decision effectively promotes a figure-ground segregation that speeds the task performance and may influence the accuracy of the performance.

3. While various studies have shown that color perception in peripheral vision is quite poor (Hurvich, 1981; Kinney, 1979; Teichner, 1979), the utility of peripheral vision during task performance is rarely the function of a single variable. As mentioned previously, mapped variables are usually portrayed in redundant form. For example, symbols might be differentiated on the basis of color, shape, and size -- with size being an active variable that reflects the numeric magniture of the data, while shape and color often indicate category. In this situation, the color difference is complimented and enhanced by the size and shape differences, and eccentric location within the visual field is not a negative factor. Obviously, the situation is determined by conspicuity, and one of the significant differences between maps and other stimuli is the design of conspicuity inherent in the combined graphic elements of the image. In addition, one must consider that maps are spatial displays which provide a distinct visual organization that requires a structured examination. In this sense, the entire concept of peripheral-central target location loses some of its importance during search since the nature of the geographic framework requires an areal search of the displayed unit. As a consequence, the position of the visual cue is an inferior performance variable due to the requirements of map search.

4. It is commonly accepted that symbols shown in color must be larger in size than black-and-white symbols in an identical presentation in order to be accurately discriminated (Christ, 1975). In the cartographic situation, however, we are often faced with a simultaneous display of multivariate data which may be mapped to determine the locational differences in a qualitative sense. If the mapping seeks to distinguish the nominal differences between the data, cartographic theory requires that the symbology convey to the reader only the fact that the data are categorically different (nominal representation) and not that the data can be distinguished on importance of rank (ordinal representation), or

magnitude (interval/ratio representation). In this situation, the cartographer must design a set of symbols who's "look" distinguishes one symbol from another. At the same time, the "look" must not explicitly or implicitly infer magnitude or rank. That is, the symbol must be of the same size and weight, and differ only in a qualitative sense.

In situations where there are a number of variables to be represented, this is a trying design task since the number of alternative graphic marks of uniform weight are soon exhausted. On the other hand, solving this problem with symbols that can be colored to indicate their qualitative differences can be accomplished quite easily, and usually with smaller-sized symbols than in an achromatic case, since the symbols can be filled with a color rather than rendered with an embedded design such as some orientation of line work to distinguish it from other items in the spatial matrix. In this case, it seems obvious that color symbols need not be larger than black-and-white symbols in an identical presentation. This distinction is especially important to cartographic applications due to the nature of the scaling and projection transformations that are required to display data. The efficient use of space and symbol size are one of the most problematical cartographic design areas, and the application of color in display design has long been regarded as one of the most efficient methods of interfacing methodological constraints and the requirements for accurate map task performance.

The creation of color cartographic displays requires that the display designer be familiar with the various aspects of color theory and the psychological human factors response of user to chromatic displays. Unfortunately, the literature on color theory is quite obscure for general application, while the documentation of human factors studies is so stimulus dependent as to be of limited applicability to the designers of chromatic cartographic displays. In addition, the application of these findings to the perceptual processing of cartographic displays is further clouded due to the spatial nature of the data display. The map presents problems of context, complexity and simultaneity that are not present in most other displays. Drawing analogies between maps and other stimuli, however, is an especially precarious activity, and indepth experimentation with maps as stimuli and map interpretation of the operant task will be required to successfully utilize color maps.

PLAN OF RESEARCH

General Goals and Method

The overall aim of the proposed research is to determine the most appropriate methodology for the design of real-time color cartographic displays so that speed and accuracy of map task performance can be significantly increased. A major thrust of the investigation is to determine reliable and prompt coding and presentational mechanisms for the display of spatial data in virtual map format. In the normal cartographic situation, symbols are differentiated on the basis of size, shape and color (being rendered with some combination of hue, saturation and lightness). There is, however, little information about the effectiveness of these codes on the normal performance of tasks based on cartographic displays, and significantly less information is available relating to their effects on high-speed task performance based on computer-generated, color, cartographic displays.

As a consequence, it is desirable to establish a utility function that will indicate those basic thresholds of these variables necessary for minimal performance. In addition, it is necessary to examine the performance benefits that result from increasingly distinctive combination of these variables in order to find operating parameters that will provide a more optimal performance ratio.

The basic approach used in the proposed experiments utilizes classic methods of cognitive and experimental psychology: the measurement of response times and error rate. These methods are well adapted to the major aim of the research which is to increase the speed and accuracy with which map use tasks are performed. The underlying assumptions of the method of measuring performance is that the time a person takes to make a response reflects task difficulty or complexity. When a given component of the display is altered, the change in reaction time will reflect the contribution of that component to the solution of the particular task. The task performance, however, will also be measured by the accuracy of response, since time measures alone prompt the subject to respond for speed at the expense of accuracy (Wickelgreen, 1974). As a consequence, error rates will be examined to insure that accuracy is constant across conditions or positively correlated with reaction time.

HARDWARE

For purposes of experimentation on the human factors aspects of real-time, color cartographic displays we have configured a micro-computer based image display system. The system is based on a Northstar Horizon 8 bit, S100, host which houses the Scion MicroAngelo Color System. The host is driven by a Z80A processor and is equipped with 64K bytes of ram, two quad density mini-floppy drives and a 10 M byte hard disk with a 5 M byte fixed and 5 M byte removable (cartridge) capacity.

The graphics system consists of 18 MicroAngelo MA512 graphics boards. Each board is configured as an independent Z80A based computer with 32 K bytes of display memory and a resident 6 K byte operating system. In addition, the system is equipped with a MicroAngelo Polette board (with three banks of 256 byte high speed statisran (45NS) for the hardware color hook-up table) which ties the individual bit planes together to generate a specific color for the current pixel. The displayable resolution of the system is 512H X 480 and the image is displayed on a Hitachi 2719C-11 color monitor (720 H X 540 V capacity).

The system as configured, can be used to generate up to 16.8 million "colors" and display a maximum of 256 colors simultaneously. Eacg MA 512 functions as a bitplane with a display memory (bit map) of 512 H X 480 V pixels. The resident operating system on each board provides response to over 70 graphic commands which include: Polygon fill, fade, vector, point, circle, fuse region (rectangle) look, blink, etc. The onboard software can be accessed directly or through the resident color interface which is a relocatable subroutine library featuring a uniform command protocol. The RCI is written in microsoft F80 Fortran and is linkable with any . Rel compatible object file. In addition, the system software provides a powerful color editor for composing (using either the R6B or the HLS color models) and archiving colors. A subsystem of the color editor is devoted to screen editing in order to define the
of boards and colors into organized transparencies which can be displayed and acheived.

Because of its architecture, the MicroAngelo system does not place computing load on or require memory space from the host. Rather the host and the MicroAngelo operate in parallel which provides a responsive and covenant graphics system.

The stimuli and the tasks used in the experiments are uniquely interfaced with both the presentational and interpretational requirements that are common to accepted cartographic practices. The strength of the experiments, then, is that the data that will result from the experiments will be directly applicable to developing and understanding the interfacing of the graphic characteristics of color displays and the effect that they have upon effective human performance of specific map interpretation tasks. The availability of such knowledge will lead to further understanding of the nuances of communicating spatial information with maps and, also, result in immediate benefits related to the creation of real-time and near real-time displays especially in the area of increasing the speed and accuracy with which map interpretation tasks are performed.

Specifically, the research will provide:

1. A comprehensive examination of the multi-disciplinary literature currently available dealing with the generation and human perception of both monochromatic and color cartographic displays. Similar information has been collected for non-spatial displays (Silverstein and Merrifield, 1981) but no such critical examination of existing knowledge is available pertaining to display of spatial data.

2. A determination of the relative advantages or disadvantages of various figure-ground (foreground-background) color schemes with respect to the performance of specific map reading tasks. In addition, the results of the experiments will allow a critical assessment of whether or not background color is a distractor during visual search.

3. Analysis of the degree to whic redundant coding enhances the speed and accuracy of symbol search on real-time displays. Evaluation of the redundant coding schemes used in these experiments will provide a more efficient method of portraying targets and, as a consequence, enhance the visual search of real time displays of spatial data.

4. An evaluation of the influence of increased display complexity on the performance of visual search tasks. The experiments are designed so that the stimuli employed increase the complexity across the experimental design, ranging from a skeletal map for the initial experiment to a complex display (including a grid and a transportation network) for the final experiments. In addition, the targets used in the experiments increase in complexity from univariate to multi-variate with the appropriate graphic representations varying from non-redundant to redundant graphic variables.

5. Recommendations concerning the dynamic alteration of targets or display elements as a means of enhancing the speed and accuracy of target search. Experiments on the winking/blinking of targets and the fading of the information on other image planes will allow an examination of the effects of selectively manipulating graphic variables as the display is being searched.

Overall, the research will provide benefits which will increase the speed and accuracy of visual search performed during the use of real-time, color cartographic displays. In an indirect sense, the results of the research should provide information that will generate a display requiring less effort to search than that which is common in conventional displays. It is felt that this benefit will result in a less rigorous visual search procedure, produce an improved psychological outlook in persons performing these types of map use tasks and that these benefits will, in turn, generate significant increments in task performance.

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GENERAL TRACK SESSIONS: RESEARCH AND DEVELOPMENT IN AUTOMATED CARTOGRAPHY

COMPRESSION AND COMPACTION OF BINARY RASTER IMAGES

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ABSTRACT

The raster scanning of large line-art images common in cartographic applications yields large binary images which must be stored and processed with the utmost efficiency. Although known data compression techniques have been effectively applied in this technology, the computational resources required to process these images are on an escalating trend as the processing logic becomes more sophisticated and the demands on raster scanning systems continue to grow. Recent developments at Canada Land Data Systems have shown that further reductions in both storage requirements and processing time can be achieved by utilizing more specialized image compression and compaction techniques. A new technique for reducing the resolution of binary images with no loss in topography and minimal loss in topology has been developped. This new technique is based on an existing line thinning algorithm and offers great savings in both the storage requirements and processing time required to process large binary line-art images.

INTRODUCTION

The increasing demand for digital data in computerized geographic information systems has led to the introduction of systems for automatic data capture. Commonly known as <u>raster scanning systems</u>, these systems make use of optical scanners as the primary mode of input. Instead of manually digitizing the data sources, the original map document is converted, by hardware, into an array of numbers representing the positional distribution of optical density within the image. Hence the map document is represented as a rectangular grid, or <u>raster</u>. For each raster element, or <u>pixel</u>, the grey-level intensity of the corresponding area is known. By defining a light/dark threshold, the grey-level image thus produced can readily be converted into a <u>binary raster</u> image depicting only the presence or absence of lines. The major focus of this paper is in the storage and processing of these binary raster images as it applies to cartographic or geographic information processing applications.

Binary raster images resulting from the scan of conventional map reproduction material are bulky and contain much superfluous information. Unlike manual digitizing, the total area of the map document is converted to digital form, including blank areas, marks and scratches and other unwanted information normally disregarded by the digitizing operator. The computational task of extracting the wanted information from these digital images and of performing the raster-to-vector conversion required for most vector-based geographic information systems is non-trivial. Hence the efficient storage and manipulation of these binary raster images is an important consideration in the design of any raster scanning system.

This paper is based on recent studies performed at the Canada Land Data Systems (CLDS), Environment Canada in cooperation with the Norwegian Computing Centre. These studies, which focus primarily on the efficiency of existing algorithms, were performed in preparation for the replacement of a somewhat antiquated but well-proven raster drum scanner. Although the upgrading of the scanning hardware itself should increase the efficiency of the operation, it is also recognized that considerable effort must be devoted to increasing the subsequent software efficiency to cope with the increased volumes of data produced by current-day scanners.

CONVENTIONAL DATA COMPRESSION TECHNIQUES

The result of the raster scanning process is a large array of grey-levels in which each pixel is typically assigned a value ranging from 0 to 255 (one byte per pixel). The raster representation of a typical NTS map sheet (60 cm. by 80 cm.) requires of the order of 192 million pixels when scanned at a grid resolution of 50 microns (.002 inches) or 768 million pixels at 25 micron (.001 inches) resolution. To put this in perspective, the grey-level representation of this image at 50 micron resolution requires approximately 6 times the storage capacity of a full-scene Landsat MSS image containing all four bandwidths. Fortunately, the greater part of this data is redundant and the storage requirements of the image can be reduced significantly through conventional data compression techniques. The text that follows describes, in chronological order, the most commonly used techniques to reduce the volume of these raster images. These three common techniques include thresholding, run-length coding and skeletonization. Other compression techniques which will not be described here include information-theoretic methods (Rosenbeld and Kak, 1983) and hybrid raster-vector techniques (Peuquet, 1982).

Thresholding

The first step in reducing the storage requirements of a grey-level image is to convert it to a binary image depicting only the absence (white areas) or presence (black areas) of lines or areas. This operation, commonly known as thresholding, reduces the storage requirements of the image to a single bit per pixel, thereby reducing the overall storage requirements by a factor of eight if the grey-level values were contained in a single byte. Thresholding simply requires that all pixels below a given light/dark threshold value be re-assigned to zeroes (0's) and all others above this threshold to ones (1's). The selection of the proper light/dark threshold value is normally made on the basis of a grey-level histogram which shows the absolute and relative frequency of each grey-level value for a particular image (or subset of a particular image). Alternatively, for constant source material, the light/dark threshold could be determined on a trial and error basis.

Thresholding is a trivial computational task which should be performed as an integral part of the scan process by the scanning hardware. Ideally, one should be able to scan a small sample portion of the document in continuous-tone grey-level in order to determine, through histogram analysis, the appropriate light/dark threshold. The scanning operation could then be re-initiated with this threshold value fed in to trigger automatic thresholding of the image during the scanning process. Some scanning systems still output the entire grey-level image which must then be temporarily stored on some external device (normally magnetic tape) and subsequently re-read by thresholding software. The time required to simply write and read this enormous volume of data can significantly impair the overall scanning operation.

Run-Length Coding

The binary image produced from thresholding the grey-level image is significantly reduced in volume but still contains large clusters of zeroes (0's) for line-art images along with large clusters of ones (1's) for solid area images. Further data reductions can be achieved by taking advantage of these clusters. Run-length coding is a popular data reduction technique used in image analysis and is especially advantageous when used with binary images common to cartography. Using this technique, the image is reduced row by row (or column by column) by identifying long runs of 0's or 1's which occur throughout the image. In its simplest form, this technique encodes a two integer value for each run, the first representing the length of the run and the second representing the pixel value of the run. For binary images the pixel value of the run requires only one bit of storage whereas the storage requirements for the length of the run are often dependant on the total size of the image in the direction of the run. If the storage allocated to encode the length of the run is large enough to accomodate a run across the entire length of the image, the value of the run need not be encoded as the only two possible values (0 and 1) will alternate. Another coding scheme used for binary images encodes only runs of 1's. In this a this approach, the 2-integer sequences represent the row (or column) position where the run starts and the length of the run.

The type of run-length coding used in a particular scanning system is very much dependant on the record formats and data structures used to store the image and the type of accesses done to retrieve all or part of the image. These in turn have often been dependant on the manner in which the actual scanning is performed. Systems using drum scanners have a tendency to store the image on a column by column basis, run-length coded in the circumferential scan direction. Scanning systems employing flatbed scanners have a tendency to store swaths of the image, run-length coded in the direction of the sweeping and perpendicular to the direction of the scan. Likewise, drum scanning systems seem to favour the scan-line approach to the raster-to-vector conversion requiring column by column access to the image whereas flatbed scanning systems tend to favour the patch by patch approach requiring patchwise access to the image.

Run-length coding serves well to reduce the storage requirements of binary raster images with no loss of data. Unfortunately, run-length coding in most cases is unidirectional and does not offer any data compression in the direction running perpendicular to the runs. The other drawback of run length coding is that most processing algorithms require that the run-length codes be expanded to full raster format prior to subsequent processing. Hence run-length coding in most cases is only advantageous to reduce storage requirements and does not generally reduce processing time.

Skeletonization

Skeletonization is a further means of reducing the data contents of a binary raster image. In this process all black pixels (1's) which are not required to preserve the topography (presence or absence of lines or areas) or topology (relationships between lines or areas) are removed (changed to 0's) from the image. In the case of solid area images, this results in the removal of all interior black pixels and the retention of only those pixels which define the outline of areas. In the case of line-art images, lines are reduced to single pixel width where each pixel represents either an inner-line-point, an end-of-line or a node.

Skeletonization of binary line-art images is a very resourceful computational task primarily due to the large number of pixel neighbourhood analyses required and the iterative nature of the process. The skeleton of a line-art image is normally derived through a process known as line thinning, a process which involves the successive erosion of the line edges, from all directions, until the lines have a single pixel width. Perhaps one of the most efficient line thining algorithms is that derived as part of the ARLIP software package in Bonn, West Germany (Kreifelts, 1977 and Woetzel, 1978). The line thinning process in this algorithm is reduced to a systematic inspection of the 3x3 neighbourhood of all black picture elements to determine, through pre-defined table look-up, whether or not the pixel can be removed without breaking connectivity of lines or creating "holes" in the original linework. The raster is divided into four partitions, so that pixels from one partition cannot be neighbours of each other. This, combined with a quasi-parallel application of the operator allows for multiple logical passes of the thinning process in one physical pass of the image. The algorithm also yields a "marked" skeleton whereby nodes or line junctions, inner-line-points and ends-of-lines are separately identified as a by-product of the thinning process.

The ARLIP algorithms (or variations of) for line thinning and raster-to-vector conversion are quite common in drum raster scanning systems. Unfortunately, the algorithms expect strip by strip access to the binary raster image and are not easily adapted to the patch by patch access dictated by flatbed scanning systems. Furthermore, the algorithms, as originally conceived, require that run-length coded strips be fully expanded to their raster representation prior to processing.

A NEW APPROACH TO DATA COMPACTION

At this point we deviate from the conventional techniques of data compression to introduce a new approach to binary raster data compaction. Specifically, we look for an algorithm which could serve to reduce the resolution of a binary line-art image with little or no loss of information. Such an algorithm, if applied first to the binary raster image, could reduce the storage requirements by a factor of four on each pass and significantly reduce the computational time required for run-length coding (and decoding) and skeletonization.

The general approach to reducing the resolution of a binary raster image is to map a 2x2 pixel quadruple into a single pixel whose value is derived by some pre-defined decision criteria. The decision is simple when the 4 pixels in the quadruple are all zeroes or all ones; the difficulty is in choosing the new value of a quadruple with mixed zeroes and ones. On one extreme, one could set all mixed quadruples to ones, thereby conserving topography at the loss of possibly many topological relationships. Conversely, one could set all mixed quadruples to zeroes, a process which runs the risk of destroying topography thereby generating new topological relationships between broken or erased line features. Other approaches such as taking the average value, randomly selecting ones or zeroes or any other method based solely on the contents of the 2x2 pixel window present a threat to both topology and topography. The algorithm we have formulated looks beyond the 2x2 pixel window to guarantee topography and, unless physically impossible by lack of resolution, to preserve the topological relationships found in the original binary image. A brief background and statement of assumptions will be presented first, followed by the general formulation of the algorithm.

Background and Assumptions

The rational behind our choice of algorithm is heavily based on current raster scanning practices, especially those involved in choosing the optimum resolution for the scanning process. Scanning resolution on most scanning devices is normally user selectable and can vary from 25 microns (.001 inches) to 200 microns (.008 inches). The choice of the proper scanning resolution is a critical step in the raster scanning process. Too coarse a resolution will result in line breakages and line merges, a situation which will significantly impair processing operations during the raster-to-vector conversion and the follow-up vector editing and tagging procedures. On the other hand, each time the scanning resolution is reduced by half, the size of the resultant raster image and the computational requirements to treat such image quadruple.

Selection of the proper scanning resolution is based on criteria of both topography and topology. The resolution of the scan must be fine enough to capture the finest of lines. This does not present significant challenge for the scanning of most map reproduction material since all lines are clearly visible to the eye and a resolution of 100 microns is normally adequate to capture most of the features on topographic maps. On most reproduction material however, the spacings between lines is less than the minimum line size and therefore finer resolutions must be used to capture the topology of the image. This phenomenon is perhaps best illustrated in the scanning of contour separation plates which have line widths varying from 100 microns (intermediate contours) to 180 microns (index contours). These plates can be scanned at 100 micron resolution with minimal line breakages, however the spacing between lines becomes infinitely small whenever lines approach the near vertical cliff situation. This causes the lines to coalesce if the grid resolution is not sufficiently fine. In some low relief areas a resolution of 100 microns may be adequate but in most cases resolutions of 50 or 25 microns must be utilized to capture the topological relationship between contour lines. Based on the above one of the underlying assumptions behind our algorithm is formulated, being that, in most cases, the resolution of the binary raster is much finer than the minimum line width. It is also assumed that the algorithm will only be used on line-art images and that the ratio between the number of 1's and 0's need not be preserved.

General Requirements

With these assumptions, we define the basic properties (apart from efficiency) of an ideal data compaction algorithm as follows:

1) Preservation of Topography: No line structures or blank areas between line structures must be completely removed from the binary image, with perhaps the exception of single-pixel areas or holes which may be considered as dirt. Likewise, no new line strutures may be created by the decomposition of existing blank areas or line structures.

2) Preservation of Topology: The connectivity of lines and blank areas between line structures must be preserved. See (Rosenfeld, 1970) for the definition of connectivity in raster images.

3) Preservation of Positional Accuracy: The centre of lines in the aggregate image should, within the limits imposed by the coarser grid resolution, correspond to the centre of lines in the original image.

4) Skeletonization: The resultant aggregate image should correspond to the skeleton of the original binary image.

The above requirements lead to the use of existing line thinning algorithms for the skeletonization of binary images, except that in this case the lines must not be reduced to single pixel width and that some lines may have to be thickened to ensure their presence in the aggregate image. Adherence to requirements (1) and (4) will be improved if pixel deletions are favoured over pixel additions. Assuming still that the lines are generally thicker than the spacings between lines, thinning the edges of lines will aid skeletonization and favour the preservation of narrow blank areas between line structures. The preservation of connectivity can be achieved by utilizing known line thinning operators, based on a 3x3 neighbourhood analyses and used for both pixel deletion and addition. There will however be cases where neither deletion nor addition is permitted, in which case preservation of topography is likely more important than the preservation of connectivity. This may be the case with thin lines separated by narrow spacings. Positional accuracy can be respected if the thinning (or thickening) operator is applied in the quasi-parallel fashion developped as part of the ARLIP algorithms. Only partial skeletonization can be achieved in an efficient manner and total line thinning is likely more efficiently performed on the aggregate image. Favouring pixel deletions over pixel addiions and noting that lines on the aggregate image are only half as wide in pixel notation does however contribute significantly to the skeletonization process. Presumably, the image could be aggregated to such a level that all lines are single pixel width but this may not be the ideal solution as it may not preserve topology.

A Data Compaction Algorithm

The algorithm we have chosen to implement this data compaction technique is heavily based on the ARLIP algorithm for skeletonization, so much so that its software implementation required only cosmetic changes to an existing implementation of this line thinning algorithm.

The partitioning from the ARLIP algorithm forms the grid for our aggregated raster and a 2x2 grid superimposed on the original raster is such that each aggregated pixel contains one pixel from each of the four partitions. In our implementation, only binary pixel values are maintained so that a marked skeleton does not result. Hence our operator is simplified in the sense that we do not have to consider the special cases for ends-of-lines.

The operator is applied to the matrix in the same row and column ordering to allow for multiple logical passes of the operator in one physical pass of the image. The major difference between line thinning and our compaction algorithm is that not all black pixels are considered for possible deletion. Furthermore, if a pixel cannot be deleted for reasons of connectivity, then all white (0) pixels within that quadruple are set to black (1's). The crucial step is in determining which pixels should be considered for possible deletion.

Singular pixels which are part of an all black quadruple (four 1's) are not considered for deletion. Only those pixels contained in a mixed quadruple are potential candidates, except for one special case where the quadruple is predominantly black, i.e. three black pixels and one white pixel. Tests have shown that premature filling may occur if the black pixel diagonally across the white pixel in this special case is considered for deletion. Hence in deciding whether or not a pixel should be considered for deletion, only 4-way connected neighbours within the quadruple are considered. With due respect given to the position of the pixel within the quadruple, only those black pixels (1's) having a white neighbour (0) above or below, to the right or to the left, are considered for deletion.

The process is limited to two passes of the operator, the second pass required only if the special case mentioned above was encountered during the processing of one particular row. The resultant raster consists solely of 2x2 groups of either all black (1's) or all white (0's) pixels and can be aggregated by retaining the pixel representation of any one of the four partitions. The topography of the original image is conserved and very little loss of topology occurs if the algorithm is applied to the proper image, i.e. to line-art images with lines wider than a single pixel.

Program Performance

A Fortran/Assembler version of the algorithm has been implemented on an HP1000 computer for experimental purposes. Due to lack of finer resolution on the available scanner (resolution is fixed at 100 microns), medium and high density contour plates were reproduced at 1.6 magnification and scanned at 100 microns resolutions. Linewidths in the resulting raster image ranged from 3 to 7 pixels with an abundance of single-pixel spacings between lines. Compression of the raster to 200 micron resolution was performed in approximately half the time required for normal skeletonization of the image. No significant changes in topology resulted and the storage requirements for the resultant raster (run-length coded)were reduced by approximately 40%. Processing times (and costs) for the subsequent skeletonization and raster-to-vector conversion were reduced by as much as 75% in most cases.

CONCLUSION

Preliminary figures indicate that our raster compaction is a viable pre-processing technique which could be applied to most raster scanning systems. The algorithm is currently being optimized and is to be implemented on an IBM mainframe for daily production usage. The same algorithm will also be implemented on a micro-based raster editing facility currently being developed for the CLDS. As research continues in this area, it is hoped that algorithms of this nature will one-day be implemented as hardware components of raster scanning devices so that the dream of real-time vectorization can become a reality.

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THE ARC/INFO MAP LIBRARY: A DESIGN FOR A DIGITAL GEOGRAPHIC DATABASE

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ABSTRACT

Geographic Information Systems are systems for the preparation, analysis, display and management of geographic data in electronic form. Even the most minimal of systems include processing and display functions. More capable systems include evaluation functions. To qualify as a full Geographic Information System, data management functions are also required. For these data management functions to operate efficiently, the managed geographic data should be organized into a database of some form.

MAP LIBRARY is the ARC/INFO Geographic Information System's geographic database. It is maintained and accessed by ARC/INFO's LIBRARIAN module. Browsing capability and additional access is provided by the QUERY program. These features, combined with ARC/INFO's processing, evaluation and display capabilities, comprise a full Geographic Information System.

This paper describes ARC/INFO's MAP LIBRARY database structure and QUERY browsing program. The design process for MAP LIBRARY and QUERY is described along with discussions of some of the rejected alternative designs and features.

INTRODUCTION

What comprises a Geographic Information System and what distinguishes it from other types of systems, such a Cartographic Information Systems? Geographic Information Systems perform four general operations: the preparation of geographic data, the analysis of geographic data, the display of geographic data and the management of geographic data.

Preparation includes such functions as digitizing, editing and reformatting data. The purpose of the preparation operation is to take data in a usable form, whether electronic or visual, and convert it into a form usable by the system in question.

Analysis includes such functions as topological overlay, corridor creation and modeling. The purpose of analysis operations is to examine the data with the intent to extract or create new data that fulfills some required condition or conditions.

Display includes all operations that produce graphic output, such as line printer maps or three-dimensional color views. The purpose of display is to visually present data, in either a permanent or temporary media, for examination.

Management is the handling of "permanent" digital geographic/cartographic data. Management operations oversee the storage and retrieval of this data in a consistent and convenient form. This generally requires that the data be organized into a database of some form.

The distinguishing characteristic of a Geographic Information System is the inclusion of all four of the above functions. Figure 1 gives a partial morphology of the various types of systems that operate upon geographic data, characterizing the various types of systems by the presence or absence of these four functions.

As can be seen from Figure 1, ARC/INFO possesses all four of the required functions. The subject of this paper, MAP LIBRARY, is ARC/INFO's geographic database, which is accessed by the LIBRARIAN geographic data management package and by the QUERY browse program (these modules are discussed in some detail, below.) Some discussion is also made of the remainder of ARC/INFO to provide a context for the main discussion. The design process that led to the current design of MAP LIBRARY is traced to provide an example of a geographic database management system. To illustrate this process, the end products MAP LIBRARY, LIBRARIAN and QUERY are described in moderate detail.

System Type	Preparation	Analysis	Display	Management	Example
Geographic Display System			*		DIDS
Automated Mapping System	*		*		POLYVRT/SYMAP
Geo Analysis System	*	*			1972 PIOS
Geo Processing System	*	*	*		GRID
Cartographic Information System	*		*	*	INFORMAP
Geographic Information System	*	*	*	*	ARC/INFO

Figure 1

ARC/INFO can conveniently be broken down into seven modules (see Figure 2):

a. Data Entry. The primary input method for ARC/INFO is ADS (Arc Digitizing System). ADS is a free-form, spaghetti style digitizing system, with entry of attribute data via INFO (see e). Once entered, the digitized input can be 'cleaned' to remove redundant points and sliver polygons, and snap closed small closure errors. Large errors and misplaced arcs may be dealt with by ARC/INFO's digitizer driven topological editor program.

b. LIBRARIAN. This is a suite of programs to manage the MAP LIBRARY geographic database. This includes programs for the insertion and extraction of data from the library, plus commands to report on and summarize the contents of the database. Tape rollout capabilities are implemented to conserve limited disk space.

c. QUERY. This is a program to browse through the MAP LIBRARY. It may also be used as a secondary data extraction tool. QUERY allows the user to examine the database both visually and by listing. Sections of the database may be selected for attention either by spatial criteria or by modeling equation. Quick-look plots and simple reports may be generated on the contents of a MAP LIBRARY.

d. ARC Analysis Software. ARC/INFO has a large core of topological analysis programs. This includes six varieties of overlay (Union, Intersect, Clip, Update, Line-in-Polygon, Point-in-Polygon); variable width buffer generation; network allocation and analysis; feature selection by equation; and merger of adjacent polygons with the same attribute(s). These capabilities may be combined with modeling performed in INFO (see e) to generate a wide variety of topological and other analyses.

e. INFO Relational DBMS. INFO is a commercial database management system produced and marketed by HENCO, Inc. (HENCO, 1983) based on the relational database model (Codd, 1970). All ARC/INFO attribute files are in INFO readable formats, which allows INFO to be employed as a modeling tool on ARC/INFO coverages. In support of its role as ARC/INFO's chief modeling tool, INFO has full computational and manipulative operators and is programmable in its own right. Supported by a numberof ARC utility programs to aid in large manipulations of attribte files, INFO provides a complete aspatial-data handling subsystem.

f. ARC-PLOT. This is ARC/INFO's primary display module (there are, however, a number of specialized and quick-look plotting programs included in the analysis software). ARC-PLOT is the driver for the Tektronix IGL graphic subroutine package, as well as a large number of unique commands for the plotting of coverages. The intent of ARC-PLOT is to provide a plotting system that would allow a novice to produce simple but adequate maps, while allowing the more sophisticated user the power to create whatever is desired. ARC-PLOT can be used either to produce displays on a graphic CRT, or on an external plotter, or to produce a graphic database file for input to COMPOSE (see g).

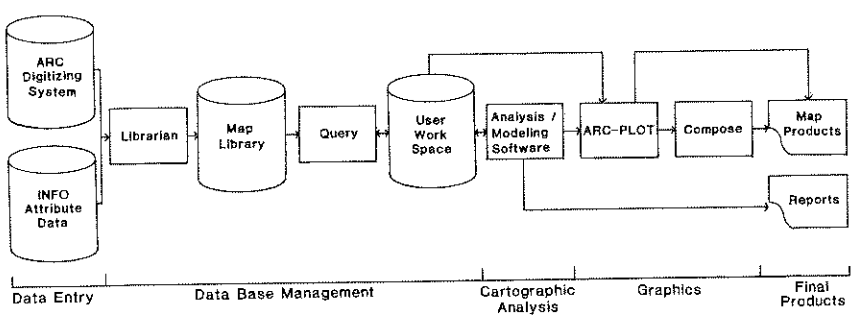

Figure 2

g. COMPOSE. This program is a combined graphic editor and map composition tool. COMPOSE inputs a graphic database file produced by ARC-PLOT, and provides the tools for the user to modify it for proper cartographic appearance. Lines can be moved, symbolizations altered, features added and removed. COMPOSE allows the cartographer or cartographic technician to take a raw topological file and turn it into a finished cartographic product.

The above seven modules comprise, in its entirety, the ARC/INFO Geographic Information System. It can easily be seen how vital to its operation MAP LIBRARY is. The need for a spatial database comes up time and time again when considering potential applications for ARC/INFO.

THE MAP LIBRARY STRUCTURE

The basic unit of operation in ARC/INFO is the coverage, which is the electronic equivalent of a map sheet, containing all the map sheet's topological and attribute data. It was decided, to maintain compatability, to continue this structure into MAP LIBRARY. Thus, at its lowest level, a MAP LIBRARY is composed of ARC/INFO coverages.

The usual place of operation in ARC/INFO is the user workspace. Here, coverages extracted from the MAP LIBRARY are processed by the ARC/INFO analysis software. The user workspace holds the coverages created by user action, such as overlay. This includes newly digitized raw coverages, and coverages waiting for insertion into the MAP LIBRARY.

A MAP LIBRARY is divided spatially into tiles and by subjects into layers. A tile is an arbitrary subdivision of the MAP LIBRARY's data area and while it is usually rectangular (to match a map sheet), it may in fact be of any shape (e.g., the lower 48 United States could be used as a set of tiles). A layer is a map type within the map library. Some examples of layers are: Soils, Administration and Land Use.

A tile will, at most, contain one coverage (referred to as a map section) per layer within the tile's spatial domain. A coverage can provide more than one layer, however. For example, a coverage containing line information (streets) and polygon information (blocks) could hold the data for two layers, streets and blocks.

One of the design goals for MAP LIBRARY was that the database structure should require relatively few auxiliary files (i.e., files used in ordering or accessing the database, but containing no unique data of themselves). A MAP LIBRARY contains two auxiliary files, the Index coverage and the Layer file.

The Index coverage is a map of the tile structure. It is an ordinary ARC/INFO polygon coverage, each of whose polygons correspond to a tile, and can be manipulated as such. The index coverages attribute file contains such information as tile name, presence (has it been rolled out or not) and tile location. In addition, tile level data that the user might wish to perform searches upon can also be stored in the Index coverage's attribute file. Figure 3 shows the basic MAP LIBRARY structure and its relation to the Index coverage.

The layer file is a list of all layers present in the database. It contains layer name, coverage name (all the coverages that compose a layer have the same name, which is not necessarily the same as the layer's), presence and type (point, line or polygon). As the Index coverage provides a spatial index, the layer file provides a subject index.

Certain, not entirely obvious, decisions are embodied by the above structure. The most important such decision is how to handle features (lines or polygons) that cross tile boundaries. The decision was made to break such features at the tile boundaries, and to handle the question of merging them back together exterior to MAP LIBRARY. This path was chosen after observing how the vast majority of geoprocessing is performed. Most users have one, or at most, two standard map sheet series to which 90%+ of their studies are geared. In such cases, that user's tile layout is matched to that map series; hence, in most cases the map sections can be used as is. In the 10%- cases where data across map boundaries is desired, somewhat more expensive map merger processes can be employed. Other schemes which would allow easier merger were considered, but they all required a greater expenditure of time and computing power for the routine extractions.

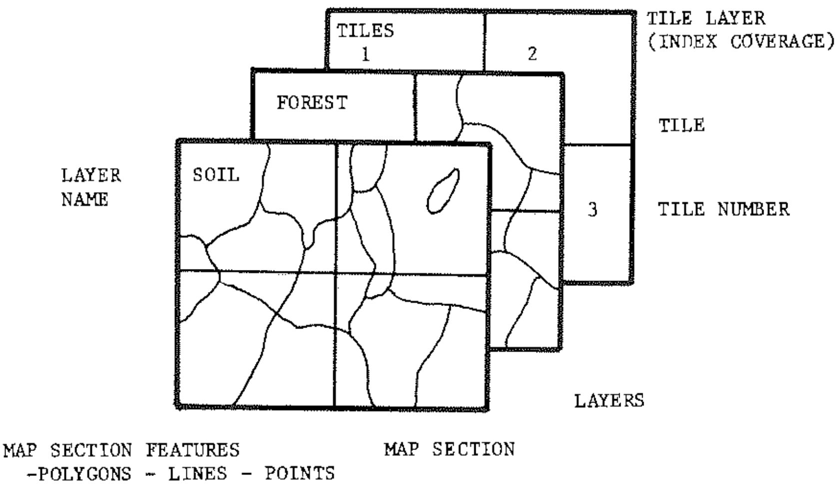

Figure 3

THE DEVELOPMENT OF MAP LIBRARY

People are using Geographic Information Systems to manage larger and larger quantities of data. Five years ago the majority of applications for Geographic Information Systems were small study areas in support of specific projects (with notable exceptions such as CGIS (Tomlinson, 1974). Today, provincial and national scale geographic databases are being constructed. This presents a new challenge to GIS designers, especially in the management and updating of large amounts of spatial data.

This need for data management for larger areas was first recognized at ESRI in the aftermath of a benchmark for the Saskatchewan Department of Tourism and Natural Resources in 1980 (Tomlinson and Boyle, 1981). The need was underscored by installation of an ESRI system to support the New Brunswick forest inventory in 1982. The detailed design for a system to manage large collections of map data was began in Fall 1982.

Briefly, a system was needed for the easy storage and retrieval of digitized and processed data for the moderatly large (hundreds to thousands of quadrangles, tens of thousands of map sheets) quantities which ESRI's users were requiring. The system should allow the extraction of areas, either by map sheet or by polygon. Most importantly, the system should fit smoothly into the user's normal operations, as experience shows anything that does not fit does not get used.

MAP LIBRARY was originally conceived as the digital analogue to the traditional paper map library. It was visualized as an on-line means of storing map sheets so that they might be searched for, identified and 'checked out'. With this image as a guide, design on MAP LIBRARY commenced.

Early on, four general concerns were recognized: data division, searchable information, spatial indexing and data management. Data division is the problem of how the data within the MAP LIBRARY get subdivided for storage purposes. Searchable information refers to the question of how to handle data that a user might conceivably wish to search on or for. Spatial indexing is the technique used for spatially identifying a desired feature. Data management deals with the questions of how inserts, extracts, etc. are to be performed.

During the initial design period, it was decided to divide the data by two criteria: spatial location and subject. Two reasons led to this decision: 1) there are distinct practical limitations on file size on the PRIME 750 ESRI uses for development (files are limited in size to the physical disks and access speed decreases as file size increases); 2) there was good precedent for such an approach (henceforth referred to as 'tiling') (Tomlinson, 1974; Synercom 19??). The question of how to deal with features that crossed the tile boundaries was put aside for later consideration.

Initial Design:

a. Data Division. Data is divided into square or rectangular regions called tiles. A tile may contain 'within' it either a further set of tiles (subdividing that tile) or a set of map sections, these being individual map sheets containing data on one subject (local government, soils, voter registration, etc.) and having spatial dimensions identical to the containing file.

b. Searchable Information. Searchable information is stored within the tiles (as opposed to the map sections) with higher level information in higher level tiles, lower level information in lower level tiles.

c. Spatial Indexing. Spatial indexing information is also stored in the tiles, and it consists of the UTM coordinates of the tile's four corners.

d. Data Management. None designed at this point in time.

After the above design was completed, the next step was to attempt to design how it would appear to the user. This brought up a number of needs, such as browsing, and underlined the need for data management functions.

First Revision:

a. Data Division. The digital geographic database is a hierarchical structure. It may be viewed as an N-ary tree. An N-ary tree is a tree data structure where each node, with the exception of the root node, has exactly one parent and a variable number of sons. The root node would be a 'master tile' which contains the real world coordinates of the data area and pointers to the first level of tiles.

b. Searchable Information. This is essentially the same as in the initial design.

c. Spatial Indexing. This is similar to the initial design, but adapted to the tree concept. The concept of a Visual Index Overlay (VIO) has been added. This is a purely graphic image projected on top of the tile grid to help users visually orient themselves.

d. Data Management. Five data management tasks have been identified and detailed, as follows:

   1. Database browse. The casual examination of database contents.

   2. Examination/Study area selection. The ability to specify a region to which all subsequent operations refer.

   3. Full Extraction. Extraction and merging of specified areas of the database.

   4. Map Entry. The entry of new data into the library.

   5. System configuration and reconfiguration. The definition and alteration of the basic library structure.

The next step in the design process was an initial design of the browse program, QUERY. This in turn led to a reconsideration of the MAP LIBRARY structure in terms of the browse requirements.

Second Revision:

a. Data Revision. The nature of the tile is further defined to specify that each tile is a file directory (a UFD in PRIME terms) and its various contents are individual files.

b. Searchable Information. Searchable information becomes INFO data files, which allows the use of INFO in browse operations. It becomes clear that any particular piece of searchable information may only be allowed to exist at one place - allowing otherwise would endanger database integrity.

c. Spatial Indexing. Spatial indexing is now by means of a standard ARC/INFO coverage referred to as the Index Coverage. Each polygon in the Index Coverage has a unique identifier that corresponds to one and only one data tile. A data tile is a tile of the lowest level that contains map sections rather than pointers to subtiles. Spatial searches and queries are performed by comparison with the Index coverage.

d. Data Management. The browse function will be performed by QUERY which, aside from the different data structures used, will be an expanded and improved version of the old PIOS QUERY program. PIOS QUERY consisted of a mix of database query commands, display commands, and graphic annotation commands.

At this point ESRI paused for an internal review, considering the design against how the rest of ARC/INFO functioned and how users actually employed their data. Two conclusions were drawn. In many ways, the current design for MAP LIBRARY was in conflict with ARC/INFO, and it did not reflect how the vast majority of geographic operations were performed - within the confines of a limited number of map sheets of a uniform series. The design was altered to reflect these facts.

Third Revision:

a. Data Division. The tiling scheme has been sharply altered. Instead of a hierarchy of tiles, there is now one level of tiles - the data tiles. The new scheme avoids the overhead of the old, and is directly addressable through the Index Coverage.

b. Searchable Information. Searchable information is no longer associated with tiles; instead, it is resident in INFO tables stored in a special directory, and pointed to by the index coverage.

c. Spatial Indexing. This is the same as in the second revision.

d. Data Management. A new function, data rollout is defined. As disk space is finite, but map data is not, it is highly probable that sooner or later a MAP LIBRARY will contain more data than it can store on-line at one time. As buying more disk drives is not always a viable alternative, some means of data rollout is required.

   Examination of PIOS QUERY has led to the realization that it is too specialized, and not suitable to use with the MAP LIBRARY. Therefore, a totally new QUERY program will have to be designed and written from scratch.

After the third revision, it was felt that the design had gone as far as it should go as a theoretic exercise. The next step undertaken was a sample implementation of QUERY. It was felt that coding this module would force the solidification of the parts of the design that were still vague. Even if the first version of QUERY produced was so flawed that it would be discarded, the information gained in the attempt would make the effort worthwhile.

The implementation of QUERY caused a number of alterations in the MAP LIBRARY structure (searchable information was completely altered for example). It also greatly clarified MAP LIBRARY's basic form and function, allowing a lot of dross to be removed from the design. The current implementation of MAP LIBRARY is described in the following section of this paper.

LIBRARIAN

The LIBRARIAN module is a set of programs to manage the above described MAP LIBRARY digital geographic database. It has four basic components; Insertion, Extraction, Rollout and Reporting. This paper describes version 1.0 of LIBRARIAN. In time, later versions should add a considerable variety of functions.

Insertion is performed by the INSERT command. This particular command would normally only be used by the database administrator, as care must be taken considering which coverages are placed within the MAP LIBRARY. Before a coverage is inserted into a map LIBRARY it should be cleaned (topologically verified), edge-matched, scaled to real world coordinates (as opposed to digitizer inches) and converted (if necessary) to the standard library projection. INSERT automatically matches the inserted coverage against the Index coverage to determine the tile or tiles in which it is to be placed. If data of that layer already exists in those tiles, a paste-over update overlay is performed.

Extraction is performed by the EXTRACT command. Unlike the INSERT command, EXTRACT can be employed by any user. There are two basic kinds of extraction: the mapsheet extract and the region extract. The mapsheet extract pulls out a coverage that corresponds to a tile in extent. This form of extract is essentially a specialized copy, and is quite fast. The region extract requires that the user define a region polygon (either by digitizing, entering its coordinates or by selection from another coverage) and build it into an ARC/INFO coverage. All the data within this region would then be extracted, and, if from multiple tiles, merged together. After a particular extraction template has been created, it may be stored and used over and over.

MAP LIBRARYs are constructed to allow easy rolling out (removal to off-line storage) of excess or unneeded data onto tape or other exterior storage media. Rollout is accomplished by copying the tile or layer to be rolled out onto tape; deleting the rolled out data; and then using the ROLLOUT command to mark the tile or layer rolled out and to indicate to its new location. Rollout out data can be re-inserted by copying it from tape, and then employing either INSERT or the ROLLIN command. This procedure is also the responsibility of the database administrator.

The status and contents of the MAP LIBRARY can be accessed by use of the CATALOG command. The CATALOG command, meant for use by the database administrator, could be employed by other users as well. The CATALOG command produces simple reports on the contents and history of the MAP LIBRARY. It produces listings of what layers are present in which tiles, what has been rolled out, and to where. Listings can also be produced of various map section additions, and when they have been updated.

References have been made to an individual called the database administrator. A large, shared database requires someone to make such decisions as: what searchable information should be maintained; or, is a particular coverage 'good enough' to be inserted into the MAP LIBRARY. These decisions cannot be made in a casual or off-hand manner; they require consistent approach or policy, best implemented by a single person or small group of people. If an installation maintains several sets of highly disparate data, each set could be organized into a MAP LIBRARY with a separate database administrator for each.

QUERY

QUERY is the MAP LIBRARY browse program and, hence one of the major user access methods to the MAP LIBRARY. Using QUERY, a user can select regions and features from a MAP LIBRARY by either a modeling equation or by overlap with a user-defined spatial object. These elements can be displayed graphically, listed numerically, or output to INFO for report generation. Regions defined in QUERY can be used outside QUERY for extraction from the MAP LIBRARY.

In brief QUERY can:

- List the contents of the MAP LIBRARY.
- Select which map sheets (tiles) are to be in the QUERY working set, either by overlap with a spatial object or by fulfillment of a modeling equation.
- Select which map types (layers) are to be included in the QUERY working set.
- Select which map features are to be in the QUERY working set, either by overlap with a spatial object or by fulfillment of a modeling equation.
- Display (in color, if the terminal allows) the current QUERY working set, in relative scaling, at a user defined absolute scale, or to fit a user-specified arbitrary window.
- Produce plot(s) of the currently displayed map.
- List the selected features' attributes to the screen.
- Write out the selected features' attributes to an INFO file, to make use of INFO's report generation capabilities.
- Add outside (non-database) coverages to the current QUERY working set.
- Interactively measure lines and polygons of interest; determine coordinates of points.

QUERY was designed as the primary casual access method for MAP LIBRARYs. It was also designed as a map production tool for those maps not requiring topological operations (see Figure 4).

Aside from the MAP LIBRARY, the primary QUERY data structure of concern to the user is the collection. A collection is a general catch-all structure that contains various pointers into a MAP LIBRARY. A collection contains four kinds of information:

1. Which MAP LIBRARY it points into
2. Which tiles are currently selected
3. Which layers are currently selected
4. Which features are currently selected.

QUERY deals primarily with two collections: the Subset and the World. The World generally points to the entire MAP LIBRARY, while the Subset is the current working set. The selection commands (TILE, LAYER, RESELECT, ASELECT, NSELECT) determine the contents of the subset, either dropping elements (layers, tiles or features) from the Subset or adding them from the World. If the user is only interested in a particular Subset of the MAP LIBRARY, the World may be set to the Subset; for that user the rest of the MAP LIBRARY no longer exists.

The current Subset may be stored externally to QUERY and later restored. This allows the user to save his

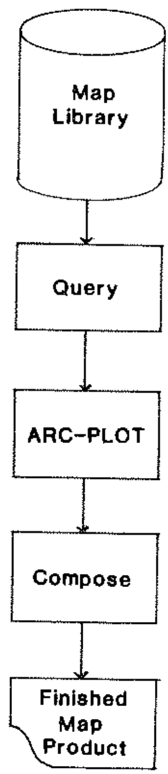

Figure 4

working environment prior to a dangerous action, or to break off a session and continue it later.

Outside of QUERY saved collections can be plotted by ARC-PLOT or converted into sets of coverages (called map sets). Eventually, many or all of the procedures in ARC/INFO will be made to work equally well on both coverages and collections.

CONCLUSIONS

As described above, MAP LIBRARY is a map sheet based on-line geographic library. It is an electronic equivalent of the traditional map library, with retrieval and storage of maps and a catalog that can be examined either by subject or by map sheet number. Unlike the traditional map library, it can do more. It can merge adjacent map sheets, and extract sections of map sheets while leaving the remainder. More importantly, it links directly into a Geographic Information System, allowing a far larger range of actions than mere retrieval.

Properly integrated, a full Geographic Information System (i.e., a geoprocessing system with a geographic database manager) is an extremely powerful land analysis/land management tool. It allows operations that are awkward or impossible on less capable systems, such as producing detailed models on a statewide basis.

This is the direction in which future Geographic Information Systems (and future versions of existing Geographic Information Systems) will have to continue. This would eventually result in a multicapable geographic database management system with full analytical, modeling and graphic capabilities. Such a system would be an <u>environment</u> in which the geographic operations would be performed, with all the files and overhead being dealt with by the system, leaving the user free to concentrate on the actual analysis and products.

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DEVELOPMENT OF
GEOGRAPHIC INFORMATION HANDLING CAPABILITIES:
WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES

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ABSTRACT

The Department of Natural Resources in Washington State is responsible for the management of 3,000,000 acres of uplands and 2,000,000 acres of marinelands. The uplands are largely forested and there are, in addition, areas of grazing and agriculture. The collection and analysis of data for the management of these resources has been an ongoing process for more than twenty years. The department is currently acquiring a new system (third generation to the department) to meet these requirements. The purpose of this paper is to describe the process of identifying information needs and the functional requirements for this geographic information system.

The first inventory system developed by the department utilized hand drafted forest type maps and computer punch card encoding of the timber inventory data. Upon recognition that higher level planning information was required, the department developed its own second generation Gridded Resource Inventory Data System (GRIDS). Resource data were collected for sample locations on a regular grid on a state plane coordinate base. The system provided site specific information for these sample cells and was able to summarize data for statewide planning purposes.

The department began to assess its need to futher enhance its geographic information handling capabilities in 1979. A growing list of planning requirements associated with land management activities prompted a study of the need for the GEOgraphic Multiple use, Analysis and Planning System (GEOMAPS). This study has resulted in a statement of information needs, data requirements and system functional requirements specific to the needs of Washington State. Proposals were received from vendors. System selection was based on the results of a benchmark test administered to three potential vendors.

AN INTEGRATED MAPPING SYSTEM FOR TODAY AND TOMMOROW

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ABSTRACT

Interactive graphics technology can dramatically enhance the productivity of the cartographer and earth scientiest. The high degree of responsiveness and ease of interaction, coupled with a dynamic visual presentation, allow the extensive amount of technical data inherent in the mapping process to be reduced to manageable quantities in forms familiar to the skilled professional. Current technology supports systems which have the flexibility to accept data from a variety of sources, including existing maps, stereo compilers, electronic theodolite instruments, field notes, and remotely sensed data, as well as data in other digital formats. These systems provide the capability to add intelligence to the graphic data and to merge captured information to form a continuous map. Interactive tools are available as a part of these systems, through which data can be analyzed, revised, used for map design and/or generalized and symbolized to produce a wide range of map products. One system which has these capabilities is comprised of hardware and software developed and refined by Intergraph Corporation.

INTRODUCTION

Any integrated mapping system should include capabilities for map data compilation, information management, data analysis, and data revision plus map design and production. There are interactive graphic systems available today which address each of these areas in part leaving the integration of capabilities to the user. However, a few interactive systems have been developed which strive to provide these capabilities in integrated form. One such system is a result of satisfying integrated mapping requirements from over 200 user organizations during a period of 14 years. This system is marketed by Intergraph Corporation. The system is built around the Digital Equipment Corporation VAX and PDP central processors. To accomodate the processing stresses unique to the graphics environment, Intergraph has added a series of specialized processors and peripheral devices to supplement the central processor capabilities. One of the most important of these peripheral devices is a dual screen raster work station.

The following is a description of the mapping capabilities available with this system today and a look into capabilities to be added in the future.

Map Data Compilation

The creation of a digital data base is necessary for any automated mapping application. The creation of digital maps today must take into account traditional requirements of the cartographer as well as space age requirements of our society. Features on maps have traditionally come from actual measurements, photographs or other maps. Thus, a versatile graphics system must allow for the input of data from a variety of sources. Other requirements of map compilation are speed of input-due to the vast amounts of data to be converted to digital form and precision-due to the earth specific needs of many technical users. Intergraph's method of data capture is to interface to a variety of input devices. Most often data capture is provided from a high-precision manual digitizing table (precision=.001 inch) with optional backlighting and a specially designed mapping cursor. Data from aerial photography, another input source, can be digitially recorded directly from analog and/or analytical stereodigitizers. Survey data can also be used directly for mapping by using the portion of the system which accepts survey notes that have been recorded by an electronic theodolite system or keyboard entry of handcoded survey field notes. In addition, the system provides translation of existing digital data from many sources. Each of these data capture mechanisms has associated software which has specialized functions to make the required mathematical corrections or transformations to values being captured. Available software can also feature code the data during the input sequence.

Intergraph's World Mapping System (WMS) is one of the most basic software packages which provides for formation of a continuous map. WMS provides coordinate transformations between different types of map projections. Projections currently supported are: Lambert Conformal Conic, Alber's Equal Area, Equatorial Mercator, Transverse Mercator, Laborde, Indonesian Polyhedric, and Polyconic. In addition it is possible to transform grid coordinates from both UTM and State Plane coordinate systems. Least square transformation software is also provided for merging small areas in the same projection. Data can therefore be automatically compiled into one graphics data base from a variety of map sources thus minimizing storage and time required during the compilation process.

For input of data from stereo-photographs using a stereo digitizer, Intergraph provides a special graphics workstation as well as a Stereo Digitizer Interface (SDI) software package. This hardware-software combination incorporates high resolution interactive graphics for immediate visual feedback of the data being digitized. Several features of the stereodigitizer workstation include voice entry and response and a "through-the-lens" graphics superimposition onto the photo pair being digitized.

Intelligence can be added to digital graphic coordinates by using a software package named the Map Feature Coding System (MFC). This package provides a flexible interface for operators digitizing feature coded maps such that data can be tagged and automatically symbolized during entry. The system includes a standard matrix menu, a voice menu, a symbol and cell library with typical symbology for large scale mapping applications.

The Electronic Theodolite System (ETS) has been designed to give surveyors a way of transferring data collected with an electronic theodolite directly to a graphics data base. The package reads data from the theodolite system and performs a survey adjustment using a compass, transit or least squares adjustment. The main traverse is adjusted then the side shots. Following adjustment a graphics data base of coded elements and elevation points is created for display and final editing with very few actual man hours being spent on the process. In addition to the Electronic Theodolite System, Intergraph has now added an Interactive COGO System (ICS), to its list of available software. In this software, the original "COGO" packages have been enhanced to include graphics capabilities. By combining the mathematical power of this package with the unique versatility of graphics Intergraph offers a tool which is very advanced when compared to earlier coordinate geometry packages.

By combining the hardware and software described above, Intergraph is striving to provide for compilation of a continuous, intelligent database which contains information required for a variety of analysis functions as well as map production. Furthermore, the system has been designed so that compilation can be performed quickly and that data storage requirements are kept to a minimum.

Data Analysis

Digital data bases can be used to analyze real world problems. Techniques for viewing data in meaningful structures and relationships require flexible hardware as well as powerful software. The Intergraph dual display raster screens have a high resolution of 1280 x 1024 which gives a level of detail free of distortion caused by the "jaggies". The right screen can be color with 256 shades in three colors - red, yellow, and blue, which can be combined for a color table of almost infinite color combinations. Color greatly enhances data analysis by highlighting features such as of color fill of contours for the identification of flood planes. In addition to color, segregation of data into subsections for combinational display can speed analysis. The approach used by Intergraph is to layer data into a maximum of 252 overlays. Each overlay can then be viewed independently (analogous to map color separations) on either of the two screens. Multiple views are provided by software division of each screen into four separate sections. This allows simultaneous viewing of up to eight different orientations of any graphic data set. Pan and zoom are also available on the raster screens and make possible quick location of features and map areas in a large data base. Intergraph also provides special application software packages which are designed to focus entirely or in part on data analysis.

A basic need in data analysis is the evaluation of the third dimension (often elevation) in a 3D-database. The Digital Terrain Modeling series of software packages allow for construction, display and manipulation of a gridded or an irregular elevation data base. The package can create a display in several forms including contours, profiles and triangulated irregular network. The resultant configurations or networks can be colored or color filled, shaded and then viewed in 3D from any orientation. These surfaces can then be overlaid over a master data base (for example - contours over profiles) and used for a variety of mapping applications including site design and road construction which includes cut and fill volume determinations.

Another area of data analysis involves polygon processing. The Graphic Polygon Processing Utility (GPPU) software package has been designed to create polygons from an existing data base and then perform various analysis functions on those polygons. The analysis functions performed on polygons include: dynamic island identification, net area and perimeter calculation, polygon intersection (AND, OR, NOT), and minimum distance zone generation. Non-graphic attributes associated with each polygon are interrogated during the analysis function. The result of the function can be non-graphic reports, graphic color delineation, and/or cross-hatching of results.

Data Revision

Data revision is another function required of an integrated mapping system. Recognizably, any newly created data base is likely to contain errors. Location of these errors is a major problem particularly when the data base is large. Visual display in two or three dimensions is very often the only way of identifying problem areas. The Intergraph system provides many functions specifically directed toward visual location of a particular graphic and editing of that graphic. Variable scaling allows the data to be viewed in its entirety or in areas of particular interest which can be dynamically enlarged. The raster pan and zoom feature further enhances the capability by allowing the user to "move" through the desired areas of a graphic data base while viewing it at close range. Color is another valuable editing tool when used to highlight related features to make inconsistencies apparent. For example, coloring a drainage system one color and contours another might enable the editor to pick out contours whose valleys do not coincide with drainage.

Special application software is also designed to facilitate the location and correction of map data base errors or inconsistencies. The Digital Terrain Modeling software provides for conversion of elevation data to profiles. These profiles when viewed in 3D from various attitudes make readily apparent any spikes or holes in the data base which can then be removed if necessary.

The Edge Matching software (EGM) is specifically aimed at locating and correcting inconsistencies. Edge matching is a process which removes discrepencies between independently digitized source maps. The common boundary of the two adjacent maps is the "match line" along which the end points of linear graphics must coincide. The table of criteria used to determine when a match occurs includes overlay, symbology, elevation, map feature code and a set of distance tolerances. If the maps are in two different graphics data sets, options are to match one data set to the other or move end points to an average match point. The process can be executed interactively from a graphics work station.

Once a feature has been located for editing, the Intergraph system provides very powerful means of correcting or adjusting graphic location and symbology or non-graphic data associated with the graphic. The File Processor™ hardware, an integral component of all Intergraph data processing systems, reduces response time by performing user defined searches at disk rotational speed and then transmitting to the host central processor only that data which meets specific criteria for final search. This increased speed makes the graphics software a real time editing tool.

Map Information Management

In mapping applications such as navigational charting, municipal and utility facilities mapping, general topographic mapping, and resource exploration and management, one of the major advantages of computer usage in general and interactive graphic usage in particular is the minimization of storage of duplicate data. These disciplines generally require many variations of data to be produced for one specific geographic area. Providing mechanisms for managing the large amounts of information which is required by these disciplines is one of the more difficult (but essential) areas of an integrated mapping system. By providing the coordinate transformation and map feature coding capabilities mentioned previously with the basic graphic and non-graphic database management capabilities, the Intergraph system today gives the user the ability to create a continuous, intelligent master geographic database.

Through a software package named Drawing Management System users have the capability of tracking each portion of data available in this master database. In addition to this package the Distributed Graphics System (DGS) adds the capabilities of systematically distributing the revision of data to the master and the production of maps from the master. The package provides for coordination of data revision such that the data can be used during the revision cycle and that old data can be retained until revised data has successfully passed through approval cycles. With this package required types of map products can be generated by generalizing the detailed master data to the desired scale, projecting the data from the master to the desired coordinate system, adding textual information to the map from the master non-graphic data base, and symbolizing the data according to type and predefined cartographic rule.

Today even with this level of sophistication in map generation, cartographic license must still be applied using interactive editing before final production of the map to insure conflict resolution, etc. However, in the near future many more automated generation capabilities are planned for this package. In an effort to make the Intergraph system user friendly, special user interaction software specific to each application mentioned above is also available with the system. This software allows the user to manage his information in terminology familiar to his environment rather than requiring extensive computer knowledge on his behalf.

Map/Chart Design

The process of designing new maps/charts with an interactive graphics system can be made easier with the availability of certain tools to supplement standard interactive capabilities. The capabilities of coordinate transformation and data generalization described previously provide for changing existing digital data into the new form required. The standard text placement capabilities of the Intergraph system supplemented with chart design software provide the ability to add text to the map/chart in the font, size, position, and orientation desired. If a new font is required, the extensive font generation software which allows for interactive definition of new fonts can be used. (The system allows for the simultaneous use of 256 different fonts with no restriction on number of characters per font.) Statistical data presentation on the map/chart can be compiled from the master non-graphic data base using capabilities of the non-graphic data base management software. This data can then be presented on the map/chart in the form of a line, bar, and/or pie chart at the desired user scale and orientation using an available software package named Line/Bar Graph.

Another software package called Interpage provides for interactive page composition for use in the preparation of legends, atlas text, etc. This package merges the power of word processing with the power of interactive graphics creation and revision. Using this package, text can be interspersed in the map/chart and/or surround the map/chart. The extensive standard interface format translation capabilities of the Intergraph system allow for translation of existing digital data such that it can be merged into the map/chart being created. Automated name placement from existing gazateers can be accomplished using this capability.

Map Production

Without the ability to output a map in hard copy form, there would be little need for the existence of interactive graphics computing in the mapping process. Since computing has not achieved the physical size, price, or portability which would permit each map user to remain in an all digital domain, hard copy is still a very necessary part of the process. Today, the Intergraph system has the hardware and software capabilities required to interface to over 22 different hard copy output devices. The spectrum of these devices include high precision flatbed pen plotters, photo header plotters, electrostatic plotters, high-speed matrix line printers, and a color camera system. The software which interfaces with these devices allows for rescaling and resymbolization of the map during the output process. By providing this capability the system allows for the use of rapid generalized font presentation during interactive edit with the hardcopy detailed font being used only during the hardcopy phase of production. The spectrum of output devices allows for proof plotting with rapid lower precision devices and print quality output with the high resolution devices. With the hardware and software design currently available in the Intergraph system, as advancements are made in the technology of output devices, these advancements can be easily added to the system.

WHAT WILL BE AVAILABLE FOR TOMORROW

Each day advances are made in creating a more user friendly, automated, and integrated mapping system at Intergraph. The company has a large mapping applications division which monitors requirements of the mapping community and state-of-the-art hardware and software capabilities to derive how to best marry requirements and capabilities to advance the integrated mapping system.

In the near future a map raster scanning system which uses a special array processor designed and built at Intergraph will be included in the map compilation capabilities. This system will allow for rapid, automated digitization of existing maps in raster format. A rapid raster-to-vector conversion process which uses character recognition techniques to minimize data storage requirements and add intelligence to the data during the conversion process will be possible. The techniques which are being studied to provide this capability are much faster than techniques currently being marketed.

Also the special array processor being used in the scanning process will be used in performing coordinate conversion and digital terrain analysis to greatly enhance the speed of that portion of the mapping process. The inclusion of Landsat imagery as a data source for map compilation and revision is gaining increased interest in the mapping community. Intergraph is currently studying improved methods for including this data in the map compilation process.

The capability for automated generation of maps using the Distributed Graphics System described above will be expanded in the future to include as much conflict resolution and other automated capabilities as possible. A tradeoff study is now underway at Intergraph which is striving to discern what the most feasible level of automation the system should try to attain.

In the hardcopy phase, as new devices become available such as advanced laser and high resolution color electrostatic plotters, Intergraph will interface to these devices to add their capabilities to the available system. The company is also studying hardware generated raster fill techniques to include the capability of providing quick half-tone generation. In the very near future, an interface to typesetters from various manufacturers will be available with the system.

SUMMARY

In conclusion an integrated mapping system must have two basic capabilities: first, it must enable digital processing of map data from compilation to production, and second it must be able to process the data in a way that is smooth and comfortable for the user. This, of course, is an over simplification but one which has been made to emphasize the importance of "user interface". Intergraph continues to strive to attain a system for the cartographer and earth scientist. Technical writers are working with applications personnel to develop clear, concise documentation. Standardization is used wherever feasible; for example, common, accepted cartographic terminology, processes, and symbolization are used by Intergraph when designing software interfaces. On-going customer support is a basic policy designed to keep a customer's system functioning and to provide feedback on changes which would help make the system more useful. An integrated mapping system should allow the user to make maps quickly, in a cost effective manner, and in a manner related to accepted cartographic practices.

DIGITAL CARTOGRAPHIC DATA PRODUCTION USING RASTER SCANNING TECHNIQUES

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ABSTRACT

The National Mapping Division (NMD) of the U.S. Geological Survey has the responsibility for building and maintaining a Digital Cartographic Data Base to support the National Mapping Program. A major task that must be accomplished to fulfill this responsibility is the efficient collection and processing of the information contained in the large inventory of published maps maintained by the Division. Production procedures and software are being developed which will enable the NMD to digitize, encode, and structure digital cartographic data collected on the Scitex Response 250 raster scanning system. The production procedures being developed comprise: (1) pre-digital preparation of materials to utilize the color recognition capabilities of the system, (2) improved raster editing; (3) automatic node generation/structuring software; and (4) improved vector tagging/editing procedures.

INTRODUCTION

The U.S. Geological Survey (USGS), as the major civilian mapping agency for the United States, has the responsibility for preparing and making available multipurpose maps and fundamental cartographic information to meet the needs of the National Mapping Program (NMP) and other Federal and State agencies throughout the Nation. One of the major activities of the NMP is the collection and processing of selected categories of topographic information for the creation of a National Digital Cartographic Data Base (NDCDB).

The NDCDB consists primarily of public land net, transportation, hydrographic, and boundary data collected from 1:24,000-scale quadrangle maps; road, railroad, stream, water body, and boundary data collected from 1:2,000,000-scale National Atlas sectional maps of the United States; land use and land cover data and geographic names; elevation data collected as a byproduct of orthophoto production; and 1:250,000-scale elevation data produced by the Defense Mapping Agency. These data files, with the exception of the

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1:2,000,000-scale data which cover the entire country, provide varied coverage of only selected areas of the country. To provide digital coverage of the country at a larger scale, the USGS has begun an ambitious program to create a data base from 1:100,000-scale quadrangles, to be completed during the 1980's. This program is being developed in conjunction with the U.S. Bureau of the Census, which will use the data as the basis for the development of a geographic information system to meet the Bureau's responsibilities for conducting the 1990 Decennial Census.

BACKGROUND

In late 1981 the USGS and the Bureau of the Census formed an interagency task force to review current and projected requirements of both agencies for cartographic products. This review was to be accomplished through the development of a series of research projects which would address the application of state-of-the-art technology to the production of new and updated maps and related graphs, as well as digital products needed to support the National Mapping Program and the 1990 Decennial Census. As a result of this activity the requirement for an intermediate-scale (1:100,000) data base was identified. This data base will be used as basis for the development of the Census's Topologically Integrated Geographic Encoding and Reference (TIGER) system, which will automate many of the geographically based aspects of data collection, processing and map publication associated with taking the 1990 census.

To develop the necessary production procedures and software to accomplish this task, a pilot project was initiated that involved the collection of transportation and hydrographic data from the forty-eight 1:100,000-scale quadrangle maps of the State of Florida. Florida was chosen for this project because it provides a diversity of rural, urban, and coastal areas which will enable the full testing of developed production facilities and procedures.

TECHNICAL APPROACH

The production procedures and software that have been used by the USGS in the past to collect digital data have involved primarily the manual digitization of linework and the keyboard entry of associated attribute codes. These procedures have served to meet initial needs for digital data, but they are labor intensive and would be inappropriate for production on a project of this size. To produce the volume and quality of data that are required in the time frame given, new data collection techniques had to be developed.

The use of the Scitex Response 250 scanning and editing system was determined to be the best available means by which a project like this could be accomplished. However, in order to integrate such a system into a manual production environment presented several technical problems. These technical problems ranged from the preparation of materials for scanning to the development of software that would take unassociated line strings and produce the necessary topological structuring that is required for standard digital line graphs (DLG's).

DATA STRUCTURE

The DLG's produced by the USGS are topologically structured. The DLG concept is based on graph theory in which a diagram is expressed as a set of nodes (points in space) and arcs (line segments connecting nodes) in a manner that expresses logical relationships. Applied to a map, this concept is used to encode explicitly, in the digital data, the spatial relationships of adjacency, connectivity and coincidence between features on the map.

The DLG data structure has presented several problems, such as the requirement for nodes at points where lines change classification and has been of utmost importance during the development of production procedures. The procedures developed to maintain this structure in the resulting data files required the development of both software and procedures for the preparation of input materials to the scanning process.

PRODUCTION PROCESS

The production of the 1:100,000-scale data base is a joint effort between the USGS and the Bureau of the Census. This will be accomplished by: (1) the USGS performing the initial collection and processing of all transportation and hydrographic information using the Scitex system; (2) the Census Bureau performing all attribute coding and structuring of the roads data; (3) the USGS performing all attribute coding and structuring of the hydrographic and other transportation data and; (4) the USGS doing final data verification, testing and storing of the information (figure 1)

Predigital Preparation of Materials

The 1:100,000-scale quadrangle maps that are being used as source material for this project were originally designed with the automated collection of these data in mind. Several changes were made in the way information is symbolized on these quadrangles as opposed to traditional products produced by the USGS. Some of the changes were: (1) the use of solid-line road symbols instead of cased (double line) symbols; (2) minimizing the number of dashed features and replacing them with continuous-line symbols (intermittent streams); and (3) preparing feature separates as opposed to the more traditional color separates. With these design changes the 1:100,000-scale products lend themselves more to digitization using automated techniques than other more traditional products.

The preparation of these materials for automated scanning involves a two-step process: (1) combination of feature separates in the photolab; and (2) the color coding of

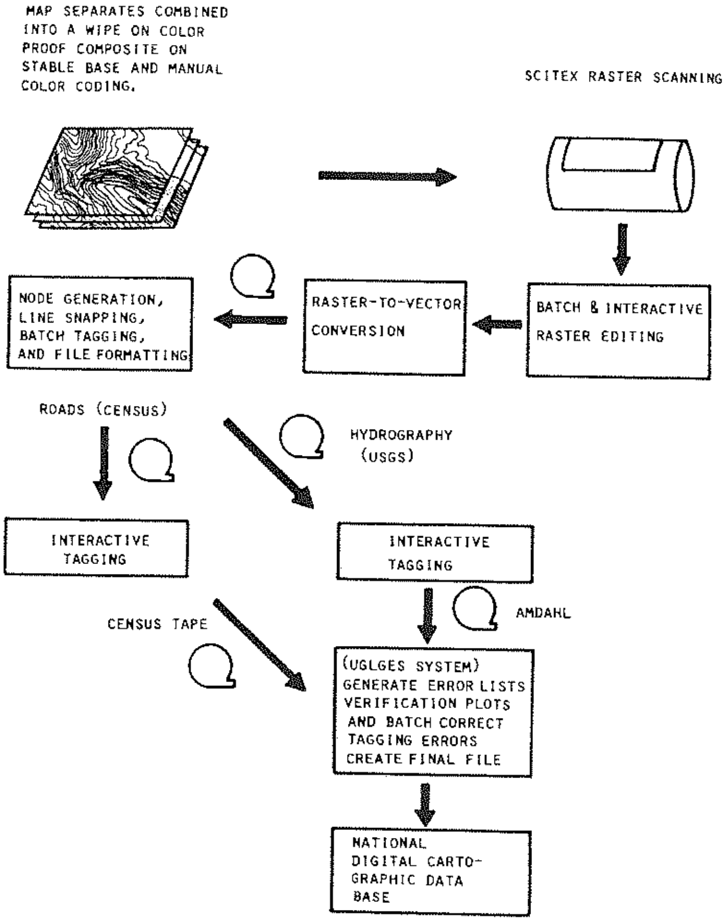

Figure 1. Production workflow for 1:100,000-scale data base

features that require special processing. The photolab processing for the road data involves the combining of two road feature separates on a sheet of stable-base white scribecoat. The hydrographic data require some additional processing because on the hydrographic overlay all features are not lines. Some areal hydrographic features do not have specific limits shown on the map, such as swamp and mangrove. For these features the open-window feature separate is combined with the line data on the white scribecoat. Each window is shown in a different solid color, that is, swamp as blue, mangrove as red. The drainage lines are all shown in black.

Once the photolab composites are made a cartographer will inspect the materials and identify features that will require special operator attention on the Scitex edit station.

The types of special features identified are: (1) airfields; (2) changes in classification of roads or drains that occur at other than intersections; and (3) miscellaneous point features. These features are highlighted with color pens so that the edit station operator can easily identify the feature and process it.

Scanning and Editing

Once the preparation phase has been completed the materials are placed on the Scitex scanner for digitizing. With the exception of a very short set-up procedure in which (1) the colors on the input document are calibrated; (2) the scanning resolution set; and (3) the limits of the area to be scanned are set, the digitizing operation is totally automatic. On an average, 3 to 3.5 hours are required to scan one 1:100,000-scale composite, at 35 points per millimeter regardless of line density or complexity.

Following the successful completion of the scanning operation the following batch and interactive editing procedures are used:

- Postscan cleanup--The first operation performed on all scanned data sets is the deletion of all point features in the raster data base. On the roads overlay this consists primarily of airfield symbols and miscellaneous ticks on the data set neatline. On the hydrography overlay springs, wells, and other point features are deleted. These features are added back to the file during vector editing and tagging of the data. They are deleted during this phase because the Scitex editing and vectorization routines do not handle point features well.

- Preliminary line skeletonization--Following the deletion of all point features, a preliminary skeletonization, vectorization, and re-rastorization of the file is performed. This is a batch routine that does not require operator attention. The sequence of this operation is: (1) If the data set contains areal features to be processed, the colored area representing the limits of the feature is outlined. This is done automatically by using the FRAME command; (2) line features are skeletonized to one pixel in width and converted to vector format using the Scitex raster-to-vector software; (3) the NODECOR command is used to adjust end points of the lines at intersection; (4) the vector-to-raster software re-rasterizes the data set in preparation for interactive editing of the data at the Scitex edit station; and (5) the original scanned file is merged with the re-rasterized file through the use of the PLACE command. The PLACE command is run selectively, so that the thinned lines are selectively placed in different color channels from the original linework. This allows the operator of the editing station to easily identify any errors that occurred in alignment during vectorization and gives a guide for correcting the line.

The above batch process requires from 2 to 5 hours to run depending on the width of the lines that must be thinned and the overall size of the data file.

- Interactive editing--Following the batch process the operator will interactively inspect and edit the data set. This editing involves: (1) correcting alignment errors due to the skeletonization/vectorization process; (2) closing any breaks in the linework; and (3) breaking lines that were marked during preparation of the materials (this procedure indicates to the structuring software, which is run after the data leaves the Scitex system, to insert a node).

- File segmentation--After editing, a mask is created using the editing system that will be used to segment the file. Each file is segmented into 32, 7.5-minute subfiles. This is done due to current file-size limitations imposed by DLG production software. The mask consists of a set of diagonal points (upper left corner and lower right corner) for each 7.5-minute section. This file is stored for later processing.

- Final vectorization--After segmentation, each 7.5-minute section is vectorized and numbered. The number of each subfile represents its position within the overall 1:100,000-scale file. After the file has been vectorized, it is stored on magnetic tape for further processing.

Preliminary File Structuring

At the conclusion of the Scitex processing, the data files consist of a set of unassociated line strings. For these data to be stored in the NDCDB, the file must be topologically structured and the line strings tagged with appropriate attribute codes. To place the necessary node and area points manually on an interactive editing station would be very labor intensive. To reduce the time required for this process, software was developed that creates the necessary nodes and build a preliminary file from the Scitex output.

Currently the structuring software runs on an Amdahl 470 V7 computer and performs the following tasks: (1) node generation and line joining to the nodes; (2) clipping of data that extend beyond the established data set edges; (3) assignment of area points denoting areas which fall inside and outside the graph; and (4) assignment of attribute codes to all lines. The attribute codes assigned are user-selected to reflect the most common feature in the file. In the case of hydrography, the code for perennial streams is usually selected; in the case of roads, the code for fourth-class roads is used. Refinement of this software is continuing and will result in its use on the Division's Perkin-Elmer 3230 minicomputers. This will allow this basic structuring to be accomplished in all of the Division's Mapping Centers.

Vector Editing and Tagging

The editing and tagging of the files produced is the most time consuming and labor intensive part of the current production process. Each separate line segment must be checked to determine if the attribute code assigned during the previous process is valid and, if not, change it or possibly add additional codes to reflect coincidence with another feature or some other situation. The system currently used by the USGS for this purpose is an Intergraph interactive editing system. This system is being used to add all the final attribute tags and any additional structure to the hydrography data sets. The Bureau of the Census has developed a similar process on a different hardware configuration to do the necessary tagging and final structuring of the roads files. More information regarding the Census system is in the paper "The Florida Pilot Digital Production Project--A Cooperative Venture Between the U.S. Bureau of the Census and the U.S. Geological Survey" (Loikow, 1983).

Data Structuring and Verification

Following the completion of the editing and tagging operation, the data sets, both hydrography and roads, are processed through the Unified Cartographic Line Graph Encoding System (UCLGES). The UCLGES system has been used by the USGS for the past 7 years to perform all final data structuring and verification of DLG files. The system performs several logical checks to verify topology and the proper use of attribute codes. Errors are corrected either through the UCLGES batch editing routines or the data sets are returned to the producer (USGS or Census) for correction. When a file is completely verified through UCLGES, the files are archived in the NDCDB. For more information see the paper "An Intermediate-Scale Digital Cartographic Data Base For National Needs" (Guptill, 1983).

CONCLUSION

The USGS has developed production procedures that enable the production of high-quality DLG data files using raster data. These procedures will enable the USGS to meet its goal of producing an intermediate (1:100,000-scale) data base of the Nation during the 1980's. The procedures described above are being used in a production environment. Continued development, however, will improve the overall capacity of the system. The primary areas still being investigated are: (1) improved raster-to-vector conversion software to reduce the time required for raster editing; (2) improvement in tagging software and hardware to increase production; and (3) improved verification and quality-control procedures.

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OPTIMIZING RASTER STORAGE: AN EXAMINATION OF FOUR ALTERNATIVES

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ABSTRACT

The performance of many algorithms in spatial data processing depends on the way in which spatial entities are ordered. The paper defines a general class of problems in which the objective is to preserve as far as possible the spatial relationships present in two dimensions. Applied to a raster, the problem leads to the N or Morton ordering and a new Pi-order is proposed based on a familiar Peano curve. An algorithm is given for defining Pi-order. These are compared empirically and analytically to the conventional row ordering, and a simple variant, using a number of standard images and using a class of indices which includes the spatial autocorrelation measures. The empirical results support Pi-order but the analytic results are mixed.

INTRODUCTION

Consider a set of spatial entities which are to be stored and processed in a spatial data system. In this paper the entities considered are the cells of a square raster, but they might equally be a set of non-overlapping polygons representing census tracts or counties. The order in which the entities are stored and processed is critical in many types of queries and sorting operations. The purpose of this paper is to consider the implications of such an order for storage, manipulation and output. The paper discusses various ways of defining an optimum ordering, indices for evaluating specific orderings, and algorithms for transforming one order into another.

Let the number of entities be n, and let r_i denote the position, or rank, of entity i in the ordering. The vector $\underline{R}$ with elements r_i, i=1,n must be a permutation of the integers 1 through n, and clearly n! such permutations are possible. Now consider a square n by n matrix $\underline{W}$ whose elements w_{ij},i=1,n,j=1,n represent the proximities or spatial relationships between each pair of entities. For example we might let w_{ij} = 1 if i and j are adjacent or share a common boundary, otherwise w_{ij} = 0. Or w_{ij} might be the length of common boundary or a decreasing function of the distance between the entities' respective centroids.

We can now define a class of indices

$$S = \sum_i \sum_j w_{ij} \; f(r_i, r_j) \qquad (1)$$

as measures of the spatial structure present in the ordering R. If f is an increasing function of differences, such as $(r_i - r_j)^2$ or $|r_i - r_j|$, then S can be said to measure the extent to which the one-dimensional ordering R preserves or destroys the two-dimensional spatial relationships present in the set of entities. Examples are given in the paper of cases where it is desirable to optimize S in order to preserve spatial relationships.

Indices having the same general structure are well known in the area of spatial autocorrelation. Both the Geary and Moran indices have this general form (Cliff and Ord, 1973), in each case normalized to produce a measure which is comparable across data sets of different n and $\underline{W}$. As simplified for the case where the entities' attributes are permuted integers, they are respectively:

$$I = 12 \sum_i \sum_j w_{ij}(r_i - \bar{r})(r_j - \bar{r}) / [(n^2 - 1) \sum_i \sum_j w_{ij}] \qquad (2)$$

where $\bar{r} = (n + 1)/2$

$$\text{and } c = 6 \sum_i \sum_j w_{ij}(r_i - r_j)^2 / [n(n + 1) \sum_i \sum_j w_{ij}] \quad \text{(Geary, 1954)} \qquad (3)$$

A low value of c is obtained by ensuring that two entities in close proximity to each other (high w_{ij}) are assigned similar integers. Thus we would minimize c in order to best preserve the spatial relationships present in the two-dimensional arrangement. Similarly maximizing I will ensure a strong correlation between the integers assigned to neighbouring entities. Note that different solutions are expected as the two indices are not complementary (I + c is not constant) except in special cases, for example when the weights are standardized such that $\sum_j w_{ij} = 1$ for all i.

The problem of optimizing I, c or more generally S falls into the general class of quadratic assignment first mentioned by Koopmans and Beckmann (1957). In this paper we consider one version of the problem which is immediately applicable to automated cartography: the question of the optimal method of storing raster data.

RASTER STORAGE

There has been considerable recent interest in the structuring of raster data, since options like quad-trees offer considerable advantage in searching and processing operations (see for example Klinger and Dyer, 1976, Samet, 1981). A given raster data set can occupy very different amounts of storage depending on how it is structured, particularly if run-length encoding is used and if the domain of the data is limited. The traditional ordering of a raster, row by row from the upper left corner (Figure 1a), may be less efficient than other orderings because of its property of rapidly traversing the image from one side to the other. An early and somewhat obscure paper by Morton (1966) described the use of a particular raster ordering in processing the frames of images in the Canada Geographic Information System (Figure 1c). Cells which are close together in space appear to be placed in similar positions in the sequence to a greater extent in the Morton ordering than in the conventional one. Recent papers by Tropf and Herzog (1981) and others have revived interest in the Morton ordering, which is recognized as an example of a space-filling or Peano curve. Any real image is likely to show strong spatial autocorrelation, in other words two pixels which are close together on the image are more likely to have similar data attributes than two pixels which are further apart. So we would expect a raster coded in Morton order to have greater average run length, and thus smaller volume, than one coded in conventional order.

Although Morton order has this intuitive advantage, only one move in two in the sequence is to a cell which is a rook's-case or 4-neighbour, and as the raster increases in size the length of the longest move increases as well. In a raster of 2^N by 2^N cells the longest move is one column and $2^N - 1$ rows (or vice versa). However another member of the Peano family always has the property of moving to a 4-neighbour cell. We will refer to this curve as Pi-order (Figure 1d) and the Morton sequence as N-order in recognition of the basic 3-step moves from which the curves are constructed. Intuitively we would expect Pi-order to improve on the efficiency of both row order and N-order. The comparisons which follow will also include a revision of row-order in which every even row is reversed (Figure 1b). This will be referred to as row-prime order, and also has the property that each move is to a 4-neighbour.

The definition of Pi-order is somewhat more complex than the others. The construction of the curve can be expressed as an algorithm for returning the row number and column number (both between 0 and $2^N - 1$) of a Pi-ordered cell (numbered between 0 and $2^{2N} - 1$) in a 2^N by 2^N array. The algorithm is as follows:

1) Express the Pi-order number to base 4 as a vector of digits $\underline{P}$ with elements $p_i, i=1,N$, 1 being the most significant
2) $\underline{Q} = \underline{P}$
3) $i = 1$
4) If $p_i = 0$, then for $j = i + 1$ to N do:
   if $q_j = 3$ or $q_j = 1$ then $q_j = 4 - q_j$
   end

   If $p_i = 3$, then for $j = i + 1$ to N do:
   if $q_j = 0$ or $q_j = 2$ then $q_j = 2 - q_j$
   end
5) $i = i + 1$. If $i < N$ go to step 4.
6) Let $\underline{X}$ and $\underline{Y}$ be binary representations of the column and row number. Their elements are obtained from the following table:

q_i	x_i	y_i
0	0	0
1	1	0
2	1	1
3	0	1

The four orderings will now be compared in two ways: empirically, in terms of the volume of data generated for standard images, and analytically in terms of the mean difference in sequence between spatially adjacent cells through the performance of each order against S-indices.

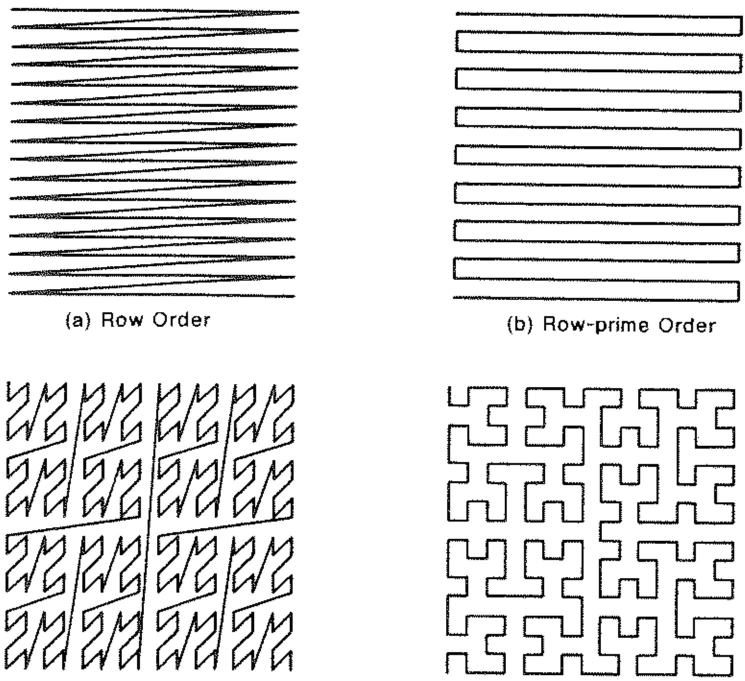
EMPIRICAL COMPARISON

Clearly there is no standard image which can be used to obtain results which are totally generalizable. However several authors (Mandelbrot, 1982, Burrough, 1981, Goodchild, 1982) have argued that surfaces generated by fractional Brownian processes show substantial resemblance to a variety of real phenomena including terrain, to the extent that they support some limited degree of generalization. The surfaces each have the property that variance is a power function of distance, that is

$$E[z(\underline{x}) - z(\underline{x} + \underline{d})]^2 = |\underline{d}|^{2H} \quad (4)$$

where $\underline{x}$ and $\underline{x} + \underline{d}$ are two points a distance $|\underline{d}|$ apart, z is the elevation of the surface, E denotes the statistical expectation and $0 \leqslant H \leqslant 1$ is a parameter. Surfaces with low H are locally rugged but

Figure 1: The Four Standard Orders



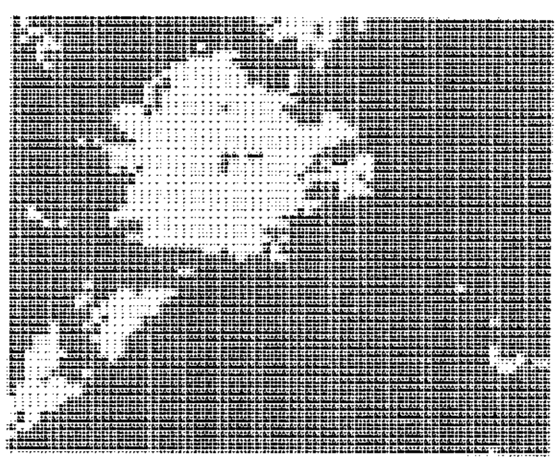
(a) Row Order

(b) Row-prime Order

(c) N (Morton) Order

(d) Pi-order

Figure 2: Example Image Created by Contouring a Fractional Brownian Surface (H=0.5) at the Mean Elevation



show little general trend, while surfaces with high H are locally smooth, but show a strong general 'drift'.

Nine surfaces were generated using values of H ranging from 0.1 to 0.9 in steps of 0.1. Each was then converted to a binary image by taking the mean elevation and coding each cell as either below (black) or above (white). An example is shown in Figure 2.

The results are shown in Table 1 in terms of the number of records required to code the image for each of the four orders. Since the maximum run length in a 2^N by 2^N image is 2^{2N}, each run of black or white can be coded as a record of 2N bits. At H = 0.0 each elevation is statistically independent so the number of runs can be obtained from a standard result, provided the numbers of black and white cells are equal.

For locally smooth surfaces (high H) Pi- and row^1- orders have a clear advantage, with a roughly 60% saving in storage over row-order and a 25% saving over N-order. At low H Pi-order is still the most efficient, but the advantage is small, and N-order appears less efficient than the conventional row-order.

TABLE 1: Data volume for binary images derived from fractional Brownian surfaces

		Order			
	H	Row	Row^1	N	Pi
Contour at mean	0.9	179	116	143	108
	0.8	155	92	123	86
	0.7	168	105	136	85
	0.6	169	106	151	96
	0.5	488	469	580	473
	0.4	398	364	462	378
	0.3	992	972	1050	980
	0.2	1477	1461	1539	1443
	0.1	1796	1779	1882	1707
Contour at median	0.0	2047	2047	2047	2047

ANALYTICAL COMPARISON

It was argued in the first section that the difference between the position in the sequence assigned to one cell and the positions assigned to its neighbours was a measure of the extent to which the sequence preserved the spatial relationships in the two-dimensional arrangement of cells. In this section we consider two S-indices for each of the four orders discussed above:

$$S_1 = \sum_i \sum_j w_{ij} |r_i - r_j| / \sum_i \sum_j w_{ij} \quad (5)$$

$$\text{and} \quad S_2 = \sum_i \sum_j w_{ij} (r_i - r_j)^2 / \sum_i \sum_j w_{ij} \quad (6)$$

S_1 can be interpreted as the mean difference in ordered positions between neighbouring cells and S_2 as the mean square difference. Each element w_{ij} is set to 1 if j is a 4-neighbour of i, otherwise 0.

Table 2 shows the analytical results obtained for S_1 and S_2 for cellular arrays of 2^N by 2^N cells. The expression for S_2 for Pi-order was obtained empirically rather than analytically and must be regarded as an estimate only.

As N becomes large the equations can be compared through the coefficients of their dominant terms alone. It is clear that row, row^1 and N are equal and superior to Pi against S_1, and that the conventional row order is best for large N against the S_2 criterion, since it has a smaller coefficient than row^1-order for 2^{2N}, and both N and Pi-order are dominated by terms in 2^{3N}. Pi-order seems worst on both criteria.

TABLE 2: Analytical results for S_1 and S_2 for the four orders

	S_1	S_2
Row	$(2^N + 1)/2$	$(2^{2N} + 1)/2$
Row-prime	$(2^N + 1)/2$	$(2^{2N+1} + 1)/3$
N (Morton)	$(2^N + 1)/2$	$\frac{5}{126}[2.2^{3N} + 2.2^{2N} + 16.2^N + 7]$
Pi	$[51.2^{2N} + 16.2^N + 16]/[84.2^N]$	$0.195\ 2^{3N}$ + lower order terms

OPTIMIZATION

In this section we consider the possibility of finding orders which optimize S-indices. Branch and bound (see for example Lawler, 1963, Pierce and Crowston, 1971) and a natural selection heuristic (Francis and White, 1974, p.377) were both applied to optimize the Geary and Moran indices to find orders which best preserve spatial relationships. The exact method was used for N=2 and the heuristic for N > 2.

Minimizing the Geary index for N=2 produced two solutions with the same optimum of c = 0.188. The first was row-order, which is consistent with the results obtained in Table 2, since the Geary index is proportional to S_2. Maximizing Moran for N=2 also gave two distinct solutions, with I = 0.729, but neither was the same on any of the four standard orders. For N=3 and N=4 the heuristic algorithm obtained solutions for both Moran and Geary which were substantially better than any of the four standard orders. We conclude that while the four orders behave relatively well, none is an optimal solution. A summary of the performance of the four orders is shown in Table 3, and it is clear that row-order is the best against the Geary criterion and N-order against the Moran.

CONCLUSIONS

Four raster orderings, including the traditional row order, the Morton or N-order, and a new order based on a Peano space-filling curve, have been evaluated against the criterion of preserving spatial relationships. Empirically it appears that Pi-order performs best against fractional Brownian surfaces of varying H, and these are arguably representative of a broad set of real images. Analytically, it appears that cases can be made for row-order, row^1-order and N-order, but that none of the four orders optimize simple measures of efficiency.

TABLE 3: Geary and Moran statistics for the four standard orders

	N	row	row-prime	N(Morton)	Pi
	2	0.188	0.243	0.202	0.368
Geary	3	0.047	0.062	0.074	0.165
	4	0.012	0.016	0.033	0.078
	2	0.667	0.608	0.706	0.545
Moran	3	0.857	0.842	0.881	0.801
	4	0.933	0.929	0.946	0.907

The general framework and measures used in this paper can be applied in a number of other areas. For example the order of U.S. states which minimizes S_1 or S_2 would be an appropriate order for tabulating statistical data, as it would preserve the spatial relationships on the map to the greatest possible extent. Different definitions of $\underline{W}$ could be used to preserve either local relationships within regions, or general relationships within the nation as a whole. Maximizing S_1 or S_2 has the effect of assigning neighbouring entities maximally different positions in the sequence. Such a strategy would be reasonable in the assignment of telephone area codes as it would ensure very different, and therefore hard to confuse, codes to neighbouring zones. Finally one might regard the design of a dart board as being a problem in assigning the integers 1 through 20 to maximize an S index.

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TRIBULATIONS OF AUTOMATED CARTOGRAPHY AND HOW MATHEMATICS HELPS

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ABSTRACT

Many difficulties that arise in automated cartography systems stem from the mathematical innocence of cartographers and programmers. Examples discussed include gaps and slivers in polygon boundary and map overlay files, high updating costs, polygon overlay calculations, islands and lakes in regions, vectorizing raster images, and using database systems. For each example, we discuss how mathematics helps and what particular topics are important. Solutions to problems are only indicated or briefly sketched, because the subject is so broad. The purpose of this paper is to whet the reader's appetite for learning certain topics in mathematics that help tremendously in automated cartography. Finally to aid the interested student, a syllabus is presented.

INTRODUCTION

Errors in digital maps seem to have a survival instinct. Costs routinely exceed estimates and budgets. Sharing data among computer-assisted cartographers is so problematic it is usually avoided. In short, difficulties abound! The application of mathematics, particularly comprehensive mathematical theories, alleviates these difficulties.

The plan for this paper is to consider in turn several common situations in computer-assisted cartography where difficulties are often encountered, and each time discuss how a mathematical approach overcomes or avoids the problem. Such problems include complicated calculations, expensive procedures, and plain inadequacies. Following the examples, a syllabus for the most important mathematical topics is presented.

In each case some particular part of mathematics already provides a solution but that knowledge of the subject is not sufficiently widespread. Solutions are too lengthy to be given in this paper but can be found in the references.

DIFFICULTIES IN COMPUTER-ASSISTED CARTOGRAPHY

A recurring mathematical theme in the following sections might better be regarded as philosophical. It is fundamental and must not be dismissed as academic. It is the <u>ontological</u> question: What exists? Confined to a map the question becomes "what are the elementary objects in this map?"

Failure to answer this question is the source of vexing difficulties. As simple and easy as answering this question may seem, inability to answer it is quite common. The problem is not a matter of resolving details or avoiding minor errors, but rather is related to defining gross categories of objects in the context of a theory of maps. Enter mathematics. A mathematical theory of maps provides those categories and much more, as we shall see in the following examples.

A second recurring concept in the sequel is <u>neighborhood</u>. The common usage of "neighborhood" corresponds well to its mathematical usage. A neighborhood can be small or large but neighboring people and neighboring points are always near to each other in some sense. The mathematical concept is more definite and more abstract but keeping the ordinary meaning in mind won't lead you too far astray. Neighborhoods are fundamental in topology, the branch of mathematics that deals with geometrical properties that remain invariant under deformation. Topology is fundamental in the mathematical theory of maps.

Boundary Traces

Costs of maintainence. A very common method for storing geographic region location is to trace the boundary of each region. The regions may be political jurisdictions, areas of similar land cover, and so on. Usually the most difficult problem is maintaining and correcting the data. Large programs have been abandoned due to the high cost and error proneness of updating boundary traces.

The difficulty with updates and corrections is caused by a very fundamental deficiency in the mathematical approach taken. The deficiency illustrated in figure 1a is that elementary geometrical objects, the points and lines, have not been identified (as they ar in figure 1b). The ontological question lies unanswered. In fact, there is only one boundary line separating A and B, and only one point at which A, B, and C have a common boundary. However, the independent boundary traces weave around each other and no point is common to the boundary traces for A, B, and C, which causes difficulty in updating and gives rise to slivers and gaps (discussed below).

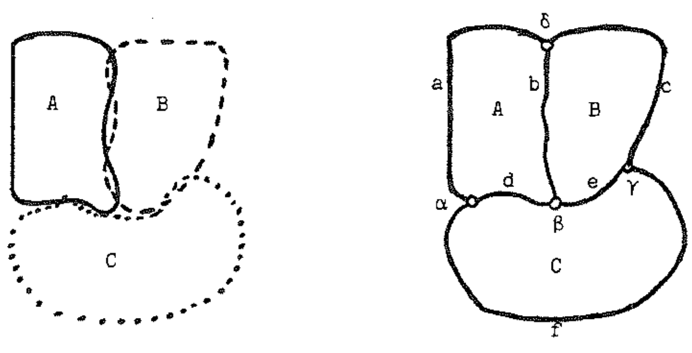


Figure 1(a) Boundary traces for regions A, B, and C.
(b) The same map with elementary objects identified

Independent traces no matter how carefully done will fail to coincide, so that making a change in the boundary of A will always lead to difficulties in making the corresponding change in an adjacent region, say B. The remedy is to actually record single lines and points once and refer to the single record many times. This means digitizing the common boundary separating A and B once and somehow recording the connection with regions A and B and the connection with the B-C and A-C boundaries at their single point of intersection. That is, answer the ontological question first then record data only about objects that actually exist and are distinct. Figure 1b illustrates the solution. Every point is identified and labelled with a lower case greek letter, each line with a lower case roman letter, and each region with an upper case roman letter (as before).

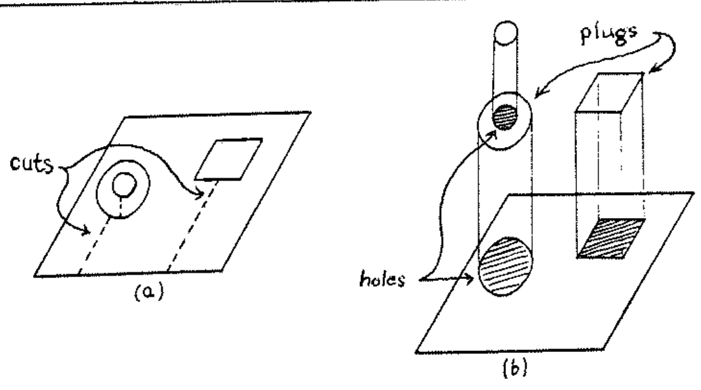
The labels are not necessary, but are shown to specify what elements have been identified.

Slivers and Gaps. A related difficulty is the occurrence of slivers and gaps in plots of boundary traces. These are the small spaces in figure 1a that are eliminated in 1b. To avoid these slivers and gaps in plots, some people merely use a thicker pen, which of course only masks the underlying error. This problem is another aspect of the same deficiency that causes updating to be so expensive, failure to answer the ontological question (What are the ingredients of this map?).

Many people fall into the trap of thinking that precise measurement of coordinates will identify points exactly. But measurements are always subject to error and consequently cannot provide unique identification. What precise measurements can do is make the problem appear less severe, but this is an illusion. It is simpler and better to not fall into the trap at all but to identify the elements and subsequently take one measurement. Coordinates and their proper role are discussed in more detail below.

Islands. A different but still common problem with boundary traces arises because not all regions are bounded by polygons. For example, some have interior islands and lakes, and some features are simply linear, like rivers. The problem is representing such features.

Papers have been published on schemes for introducing imaginary lines to connect components of a boundary and schemes for retracing linear features so that they appear to be bounding empty regions. Figure 2a illustrates such schemes. They become quite complicated as more islands, lakes, and isolated tree structures are added.



Artifical cuts (a) are an unnecessary complication
(b) the solution comes from homology theory
Figure 2.

Here knowledge of topology, particularly homology theory, would avoid the problem altogether. In a sense, the whole problem is invented; it does not naturally arise. Lakes and islands are simply recognized as holes in the surface, and topology teaches us what facts are important to record and which structures are essentially different and which are abstractly the same (this theory alters our answer to the ontological question — holes and plugs to fill them now exist as elements of the map). No imaginary lines are ever needed. Figure 2b shows the topological representation, holes filled with plugs that may themselves have holes.

Overlays and Separates

The cartographic profession has taken the production and registration of separations to a fine art. Many automated systems have attempted to mimic the fine art but suffer deficiencies quite similar to those inherent in polygon tracing. The cost of updates is very high, and slivers and gaps appear and resist attempts to eliminate them.

The cause is the same as before, failure, indeed inability within the scheme, to answer the ontological question correctly. The solution is also the same, take the trouble to answer the question: identify the elements that the map comprises. Overlays present an example of unwittingly answering the ontological questions incorrectly. Map sheets are fundamental objects in an overlay system but they are not in any way related to the message conveyed by the map; overlays and sheets are strictly a matter of convenience in handling paper maps and have no place in an automated system.

The use of overlays in an automated system illustrates that simply mimicking the motions of a manual process does not always succeed. Human geometrical intuition is at work in the manual process but is absent in computers. The remedy, regarded from another viewpoint, is to supply to the computer what humans grasp intuitively in the form of mathematical theories.

For overlays this solution may require more effort than for polygon boundary traces, because the source maps may be separations. In fact, it is sometimes better to encode each overlay separately and use the computer-assisted system to help identify the elementary features, but it is not better to maintain the separate overlays, because the above-mentioned problems ensue. Inconsistencies between the features on one overlay and those on others begin to appear and then accumulate. The weight of accumulated inconsistencies has been the cause for abandoning expensive computer-assisted mapping systems.

Polygon overlay. The so-called "polygon overlay" calculations also present difficulties. Gaps and slivers are generated by nearly coincident lines. This problem was discussed at length above. Another difficulty is just the amount of computing that seems to be required. The problem is to limit the search for coincident or intersecting features to a small number. Here topology again offers a solution. This time the most fundamental topological concept, neighborhood, is the key.

In polygon overlay calculations, the search for intersecting features can be done neighborhood by neighborhood or by considering, in turn, each feature from an overlay as an update, and limit the search to a neighborhood surrounding the feature. Of course you must know in a mathematical (topological) sense just what neighborhoods are, and how to record information about neighbors. All this is thoroughly explicated in combinatorial topology.

Error detection. Discovering errors in maps of any kind is no simple task. In computerized maps the problem is worse than with ordinary maps and is most difficult in overlays. To be sure, error detection is difficult for boundary traces too, but the source of problems is the same as for overlays. The common practice is to examine plots (on paper or CRT) for errors, make corrections (actually changes that one hopes are corrections) and continue until no visible errors remain, no time remains, or no money remains, whichever is first. This method is especially ill-suited to discovering geographic naming errors, that is, errors in delineating various boundaries and labelling with geographic names and codes, such as city names, census tract numbers, or ZIP codes.

Neighborhoods are again the key to using the computer to discover and localize errors. Naturally, the ability to use neighborhood calculations has as a prerequisite knowledge of topology and its applications to system design.

Dual Incidence Matrix Encoding (DIME)

DIME is popular for encoding street maps but is equally applicable to plat maps, county maps, or any map. DIME was devised on the basis of topology and graph theory, and was purposely designed to aid in detecting and controlling errors. It avoids many of the problems discussed above, like gaps and slivers.

Orientation and duality. People do encounter difficulties using DIME, the most perplexing relating to orientation. Surfaces have a property called orientability, which determines whether one can consistently designate "left" and "right" sides to any closed path on the surface. Those who are not familiar with elementary topology are surprised to learn that there are non-orientable surfaces like the Moebius strip, which have only one side. Clerical coding is notorious for swapping left and right and some computer programs have systematically produced orientation errors. The only way to avoid these problems is to understand orientability.

The fact that DIME takes advantage of a geometrical symmetry called duality, as its name implies, leads to a difficulty for those not familiar with duality. In DIME a piece of linear feature (boundary, river, road, etc.) is recorded as a single record also containing information about the immediate neighborhood of the feature in a symmetrical fashion. Figure 3 explains this symmetry in topological terms. Duality depends on the dimensionality of the space; duality in 2-D differs from duality in 3-D but the general idea is the same. The solid line and dashed line diagrams are duals. In 2-D 0-cells (points) are dual with 2-cells (areas): each area in the primal is replaced by a single point in the dual and vice versa. Because of this symmetry, a number of procedures apply equally to 0-cells and 2-cells even though they seem quite different. This is a source of confusion for the uninitiated but a source of efficiency for the cognoscenti.

Poincare Duality

2-D		3-D	
Primal	Dual	Primal	Dual
0-Cell	2-Cell	0-Cell	3-Cell
1-Cell	1-Cell	1-Cell	2-Cell
Boundary	Co-Boundary	Boundary	Co-Boundary

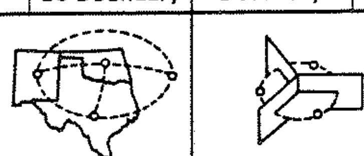
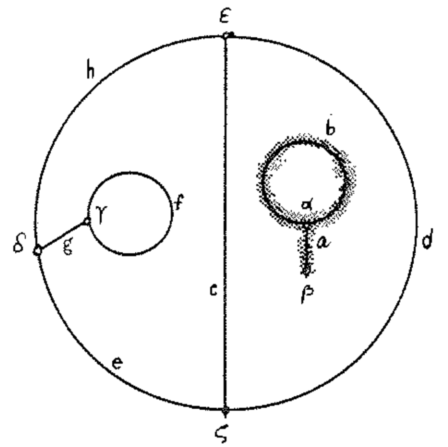


Figure 3

Chaining. The users of DIME files thus have some unfamiliar mathematics forced upon them, and that alone is a difficulty. It is even more difficult to use the plethora of information captured in a DIME file. To make a choropleth map many people make a copy of the file but with orientation reversed, sort the original and copy together (calling the aggregate a NICKLE file) and chain DIME segments around each region to produce a boundary trace file. Chaining presents the most difficulties, especially where there are islands and lakes. A thorough understanding of the Jordan curve theorem (see any topology text) would permit one to dispense with the entire NICKLE-sort-chain process. In case one wants to use a plotting package that demands a boundary trace for input and so is obliged to generate boundary traces, knowledge of Kirchoff's theorem (see Biggs, Lloyd and Wilson in the bibiography) greatly simplifies the chaining algorithm. Figure 4 shows the results of the Kirchoff algorithm. The purpose of the Kirchoff analysis is to isolate distinct parts (components) and within components to classify each element of the graph. Kirchoff invented the method for analyzing electrical networks, but we use it for reducing complex complex cartographic networks to simple sub-elements.



2 components

component I (shaded)

2 nodes (α, β)
2 edges (a, b)
1 cycle (b)
1 acyclic edge (a)

component II

4 nodes (γ, δ, ε, ζ)
6 edges (c, d, e, f, g, h)
3 cycles (f; e-d-h; e-c-h)
1 acyclic edge (g)

Kirchoff's analysis
Figure 4

Any uses of a DIME file are better understood in the context of the algebra of combinatorial topology. The uses include plotting maps, editing, service area definition, transportation modeling, and geocoding. The algebra is based on the boundary and coboundary operators and retrieves neighborhoods of any kind from secondary storage. It is a foundation for every application. A powerful system called 2-D based on this algebra has been implemented on a microcomputer and is in use producing a computer-aided emergency vehicle dispatch database. Using this algebra, 2-D returns police and fire jurisdiction, and nearest major intersection for an incident location specified by address or intersection. This is an example that obviously demands neighborhood searches, but others are often not so obvious.

Triangulation

Partitioning the mapped region into triangles is the standard starting point in topology. It is used in cartography for Digital Terrain Modeling (DTM) and contour mapping. In these applications the elevation at each vertex is recorded and the triangulation is effectively a mesh cast over the surface. The main application in DTM is cut-and-fill calculations for earth-moving projects. Algorithms for interpolating elevations and computing volumes are quite efficient using a triangulation. There are no difficulties at this level but there is of course considerable supporting mathematics.

Conservative extension. Difficulties do arise at another level. If one tries to incorporate the elevation data of the triangulation into another cartographic file or tries to annotate natural features on the triangulation, it becomes evident that not everything in nature is a triangle.

Although a triangulation is the starting point for topology where it is called a simplicial complex, the theory quickly advances to the more general cellular complex, in which the cells are not merely triangles (simplexes) but may be any shape. Likewise in automated cartography triangulations can be generalized into cellular complexes. The advantages are that the cells can be made to conform to natural features and that the theory is conservatively extendible.

The first advantage is easy to understand. The cells can be constructed by adjoining neighboring triangles thus producing a more natural cell and retaining the elevation data of the triangulation. If it is desired, the triangulation itself can be retained as interior structure in each cell describing the cells shape in 3-dimensional space.

The second advantage of cellular complexes is due to the fact that new cells can be built by joining adjacent cells. In contrast, joining adjacent triangles does not return a triangle (see figure 5). The theory and programs for a triangulation are not conservatively extendible to aggregates but for a cellular complex they are. As an example, consider a detailed city map with ZIP code boundaries shown. If the details were all represented in triangles and the programs were made to deal only with triangulations, abstracting a ZIP map would require entirely new programs. For a cellular complex no new programs are needed, because ZIP areas are also 2-cells. This abstract-seeming advantage is a very practical matter in multi-purpose systems and in developing new applications on an existing system.

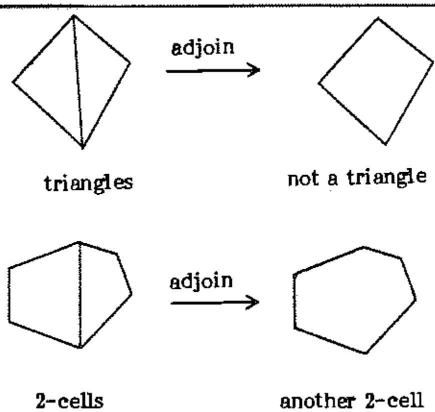


Figure 5

Raster Images, Grids, Hexcells, and Quadtrees

A completely different scheme of storage is to store a picture image or some coarsened version of a picture. A television image is a raster image composed of rows of dots each dot (also called a pixel) having a single hue and brightness. Grid cells are usually coarser than pixels in a raster image but serve the same function. Hexcells, like grid cells tile the plane but in a hexagonal network rather than a square network. Copious storage is needed for all of these methods, and thus techniques to reduce storage occupied are important.

Quadtrees are a particularly efficient method of saving storage for a gridded image.

Picture processing has become a well-known field because of its application to satellite imagery. Contrast enhancement, multi-band spectral analysis, and image editing have all been applied quite usefully in automated cartography. These techniques each demand certain mathematical skills, which confer substantial advantage. The result is a very versatile camera system with some powerful analytic capabilities.

Vectorizing. But treating maps pictorially falls far short of the potential for computer-assisted cartography. For example, analyzing data by political jurisdiction cannot be done on a picture-map; the map content must be understood for the analysis. This is where difficulties arise.

The ontological question in this case is even harder to answer than for overlays and boundary traces, because photo-interpretation is required. Automating this process has never succeeded completely. Some systems "vectorize" the image, but there always remains a large editing job to identify points that should be the same but were interpreted as separate and vice versa. Solving this problem, if it is ever solved, will require considerable mathematical expertise.

Coordinates

To many people, using coordinates and automating cartography are nearly synonymous, and to these people automated cartography is impossible without coordinates. Furthermore, higher precision coordinates are regarded as a sine qua non of higher quality automated cartography.

This is a fallacy and a pernicious one.* The damage is twofold. First, system builders try to use coordinates to identify points thinking that they are somehow cleverly getting both coordinates and identifiers for the price of one. Second, exceedingly expensive programs are initiated to gather coordinates as a preliminary to building and using the entire database, preventing useful programs from being started and forcing some to be halted before ever reaching the useful stage.

Identifiers. Coordinates, being calculated from measurements, are subject to measurement error. This makes using coordinates as identifiers somewhat fuzzy, and in unfortunate cases even high order digits are susceptible to changes. Worse, tracing the history of changes becomes impossible, since points cannot be moved; rather, they vanish entirely and a new point materializes at another location. Trying to get identifiers to do two jobs, their own and carrying data, is a mistake, because ultimately the jobs conflict and there is no space saving anyway. Identifiers must be constant and absolutely distingishable, but data, for example coordinates, must be unconstrained. Data values are variable but identifiers must be fixed and unique. This is the ontological question revisited.

Expensive prerequisites. The second problem, undue expense at the outset, is especially unfortunate because it is so easy to avoid. One need only know enough about topology to understand that a space with coordinates (which must be a metric space) is in fact a topological space, to avoid the initial coordinate gathering expenses. Crude measurements along with an accurate record of the

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* An old aphorism tells why: "It ain't what you don't know that hurts, it's what you know that isn't so."

topological facts, which must be gathered in any case, will suffice. Later, when the system has proven its worth, it can be enhanced with more precise measurements. For a specific example consider a plat map in a computer-assisted cartography system. The important facts shown by a plat map are: who adjoins whom; which adjoiners share a common boundary line, and which share only a corner — in short, topological data. Survey notes show detailed measurements but these are only partially copied over to a plat map. Similarly an automated cartography system can provide a digital plat map, and leave precise coordinates for later concentrating first on correct topology.

To be sure, it is important to digitize and record coordinates. It is also important to provide access to geographic data via coordinates. In addition, more precise coordinates permit more precise and better-looking maps. The important point is that the role of coordinates in cartography, although quite important, is not what is commonly believed. Geometric topology is the subject that clarifies the facts.

Systems of Programs

Automated cartography is realized through computer programs, of course. Systems of programs are formal objects and can be studied using the theory of formalized theories. Nowhere is the formality of computer systems more evident than in relational databases.

There have been attempts to represent maps in relational DBMS's. The relations explicitly stated in the schema in most of those attempts bears little resemblance to the actual geometric relations. One author went so far as to assert that there are so many relations that it is nearly impossible to state them.

Nothing could be further from the truth. The topological theory of maps has only two: boundary and coboundary. Add to these the metrical descriptions of points, lines, and regions, namely location, shape, and surface shape, respectively. These provide a complete representation of the geometry of a map. Five relations isn't so many. And the formalized theory states explicitly what they are. Figure 6 lists the elements and relations of geometry.

Objects	Relations	Metric
0-Cells	0-1 Incidence	Coordinates
1-Cells	1-2 Incidence	Shape
2-Cells		Shape

Topology

Geometry

The Geometry of a Map Requires Only Three Objects, Two Relations and Metrical Descriptions of the Objects.

Figure 6

Failure of sytems analysis. We hear in lecture after lecture and sermon after sermon that the first task in designing a system is to list all the uses of the system. This approach never succeeds in producing a sound system for a subject as demanding as cartography. The first task is to discover or invent a comprehensive mathematical theory that applies, and this requires a great deal more than listing uses. Only within a theory can the ontological question be answered and the list of uses stated in a coherent way.

SYLLABUS

The student of the mathematics of automated cartography will find many texts and monographs on the topics. A few are listed in the references below.

Analytic geometry and in some cases differential geometry are already required for manual cartography. These are needed for using coordinates and computing projections. Picture processing, for example interpreting satellite imagery, requires knowledge of elementary statistics, information theory, and signal processing. These are special topics needed only in a few automated cartography systems. This syllabus includes only topics needed by every system developer.

Topology. Automation requires a deeper understanding of the nature of space than one gains in high school geometry courses. In particular, topology is the subject that reveals the elementary but not obvious nature of space and is essential in answering the ontological question for maps. The most important subjects are:

- Homeomorphism (continuous deformation)
- Complexes
  - Cells (the elementary objects)
  - Incidence (the elementary relations—boundary and coboundary)
- Manifolds (smooth surfaces)
- Orientability
- Duality
- Homology

Graph theory. The 1-dimensional skeleton of a 2-dimensional complex is a graph. Many analytical algorithms needed in automated cartography are graph theoretical. The important topics are:

- Graphs
- Paths and circuits (including Kirchoff's theorem)
- Connectivity
- Planarity (connection to topology)
- Duality (a related connection to topology)

Model theory. Computer systems are formal. Model theory is part of mathematical logic and treats formalized theories and their interpretation. This subject is not well-known even among mathematicians — it is a specialty. Nevertheless, the elementary results of model theory are helpful in building computer systems. The topics are:

- First order theories
- Free and bound variables
- Quantification
- Models

CONCLUSION

We have considered only a few common and well-known cases where applied mathematics alleviates severe difficulties in automated cartography. Many more such examples exist. Quite often very elementary mathematics solves the problem; we saw several cases that only needed a proper answer to the ontological question. Finding a comprehensive theory that applies is the crucial and difficult step. In the context of such a theory the problems vanish or become quite tractable.

For cartography, geometry and especially topology are the theories that organize the subject and illuminate the structure of maps. Graph theory is also quite useful. I hope you are encouraged to learn about the topics in the syllabus. It will make you much more effective as a cartographer or programmer in our field.

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THE APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNIQUES TO VERY LARGE GEOGRAPHIC DATABASES

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Recent years have seen the development and introduction of interactive information systems for applications based on cartographic data by both federal agencies and private corporations. However, these systems have consistently exhibited severe problems with response times and storage volumes for data sets for significant size, as well as rigidity and narrowness in their range of applications. There is, however, an overwhelming need to use extremely large databases containing data integrated from a number of imagery, cartographic and other sources since they represent an essential tool to enable many federal, state and local governmental agencies to adequately perform mandated tasks dealing with a wide range of present-day environmental, resource management and socio-economic problems. The other major obstacle in the development and use of very large spatial databases is that current geographic information systems (GIS) are applicable to only a narrowly defined set of problems; since existing geographic information systems technology requires operation on a predefined data set with "built-in" objects and relationships.

The underlying cause of both problems is that geographic data possesses a number of special characteristics not shared with other types of two- or three-dimensional data which must be taken into account: first, national geographic boundaries (and therefore cartographic lines) tend to be very convoluted and irregular, and subsequently do not lend themselves to compact definition or mathematical prediction. Geographic databases consequently tend to become extremely large. Second, the data in digital form tend to be incomplete, imprecise and error-prone due to both the fuzzy nature of many types of geographic boundaries and the characteristics of the data gathering process. Third, spatial relationships tend to be fuzzy or application-specific, and the number of possible spatial interrelationships is very large.

Spatial data structures or data models which take all of these characteristics into account currently do not exist. However, the combination of artificial intelligence (AI) techniques currently being applied in the areas of non-spatial database management systems and those in computer vision show great potential for dealing with these problems to substantially increase the flexibility and efficiency of geographic information systems, as well as enhancing user-friendliness.

In order to deal with fuzzy entity definitions and fuzzy relationships, knowledge needs to be built into the database system. This would obviate the current need to impose artificial precision onto the data and allow a more natural data representation. This knowledge-base can also be used as a self-checking mechanism to detect and potentially correct data errors. Such a system would be able to answer user queries concerning the relationships of complex objects in a large landscape where the specific query or application cannot be anticipated by (i.e., built into) the system. This flexibility would not only greatly extend the range of applications a single system could handle, it would extend the useful life of a system for a given application as needs grow and change over time. The system would also use its knowledge-base to effectively narrow down the problem's search space with respect to: (1) data retrieved from the large geographic data base and (2) activation of GIS operations on the data retrieved.

The AI portion of a geographic information system may be regarded as an interface between a database management subsystem, representing a collection of manipulative capabilitie and a large collection of data, and the user who has a conceptual view of the data as related to a real world landscape within the framework of a specific problem. As such, the knowledge-based system must be able to deal with each query at various contextual, technical, and functional levels. Performance of the overall system in satisfying the query is dependent, to a large extent, on the system's ability to understand the query and its context. Understanding is assumed to involve a process of new knowledge acquisition before any attempt can be made by the GIS to provide a response to a query which has not been submitted previously. Once the new query is resolved (and a response provided), the new knowledge acquired in this process is stored as a supplemental component of the system's database. The system's knowledge-base is thus continually modified so that accumulated knowledge may be brought to bear upon subsequent queries.

This continuously changing knowledge-base is thus of potentially great importance within a GIS context while simultaneously making the concept a particularly difficult one to implement in view of the characteristics of spatial data. A prototype knowledge-based geographic information system is, however, being presently developed at U.C. Santa Barbara to demonstrate these ideas. A simulation of a very large database for the prototype system will incorporate several application examples. At the foundation of the database for this prototype system are the cartographic data, which include layers of base topographic data at various scales, remote sensed imagery (e.g., LANDSAT) as well as a variety of ancillary data such as land use/land cover, geologic and socio-economic data.

HUMAN FACTORS IN THE CARTOGRAPHIC DESIGN OF REAL-TIME, COLOR DISPLAYS

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ABSTRACT

In the paper that follows a partial framework is developed for analyzing the human factors aspects of real-time color displays. The objective is to analyze areas in which research is needed to provide successful task performance during those activities which typify the preparation and use of cartographic displays.

INTRODUCTION

The problem of the efficiency and effectiveness of spatial displays is becoming more critical since map making has moved into the non-cartographers domain as a consequence of the current technological innovations in color computer graphics and digital cartography. With the increased computational and graphics capabilities available in various systems, and increased demands for pictorial representation of spatial data, cartographic displays are serving a variety of purposes, although often in a perceptually inefficient and ineffective manner. The problems that arise from the use of current display technologies and concomitant decision making based upon virtual maps is that computer graphics has advanced so rapidly that our knowledge of the perceptual and task related aspects of computer-generated, color, map displays has not kept pace with technological developments.

Any investigation into the use of color in a map context should acknowledge that the human factors/color literature provides guidelines in several areas that may be of critical importance to the success of color cartographic display. It is imperative that a strong link between the human factors and map design literature be established in order to enhance the investigation of map task performance. The concepts outlined in the following discussion probe the obvious links between color use, real-time presentation formats, and the presentation of color cartographic displays in a real-time, computer-generated display environment. In addition, examination of these linkages points out the critical unknowns in color cartographic presentations which must be examined in order to provide the capability of high performance during cartographic production or map use.

COLOR SPECIFICATION

In order to use color in a graphics system one must have a means of specifying the attributes of light that will be used to generate the desired perceptual response. In general, the description of the color attributes of a visual display is based on three physical attributes of light or on these attributes corresponding perceptual identities. In terms of the output display device (a CRT) the physical stimulus is defined in terms of wavelength, luminance and purity. Since color is not a direct property of physical energy but a perceptual response by a human to physical energy, no color system exists that takes into account all of the factors that determine a color response. Instead, most color specification systems define color space in terms of three perceptual correlates of physical stimulus termed hue, brightness (luminance) and saturation. For example, the chromaticity system of the C.I.E. specified the quality of light expressed by hue and saturation characteristics (luminance is considered constant). Currently, the 1976 CIE-UCS system is considered the most perceptually uniform chromaticity space for self-luminous spaces (e.g. CRT displays). Conversely, the HSV (hue, saturation, value) or HLS (hue, lightness, saturation) model considers each color to be a pure hue modified by saturation and value (i.e. lightness). Finally, most graphics display devices use the R.G.B. (red, blue, green) color notation system which specifies a color only by a triple of coordinates indicating the intensities of the primaries. None of the color specification methods, however, results in a foolproof or perceptually uniform model of color space (i.e. a space from which the perception of color difference can be derived).

Modeling colors for display, then, can be a frustrating and time consuming task. In addition, the lack of a highly accurate model of perceptual space inhibits development of a precise approach to the exact specification of color in a human factors-task performance context.

COLOR GENERATION AND TASK PERFORMANCE

The CRT normally generates color by combining three monocromatic light sources (red, blue, and green) to synthesize most (but not all) visible colors. By modulating each light source (electron gun) the intensity of red, green and blue are controlled. Changes in the intensity of the three beams creates combinations of the three primary colors. In shadow mask displays each of the beams is targeted to hit a particular set of phosphor dots (arranged in a triad) which, when excited by the electron beam, emit the light of a particular color. The beams are targeted at the appropriate triad by focusing them so that they converge just before reaching the phosphor screen. At this point the beams pass through holes in a shadow mask and diverge so that each beam hits only the phosphor dot that corresponds to the beams color. As a consequence the range of colors available on a CRT display is primarily determined by the possible number of intensity settings. In addition, the range is also determined by whether the method of beam current modulation is amplitude or temporal.

The integrity of color on the display is a function of the convergence of the separate color beams at the display face. Color mixture in the shadow mask CRT is accomplished by spatial synthesis of the triadic phosphors during vision. If beam convergence is inadequate the display may experience: loss of color purity, hue shifts and border fringes or colored symbols. Although limited data exists on the specifics of the interrelationship between task performance and beam convergence in the display it is a well known fact that image misregistration results in deterioration in task performance. It is in this sense that the quality of displays for task performance is partly technical and the first recommendation for system's designers interested in users is to purchase the appropriate, quality display device.

ACUITY, RESOLUTION AND TASK PERFORMANCE

The physical characteristics of the eye generate chromatic aberrations that would lead one to expect that visual acuity and resolution should vary as a function of color. It is clear, however, that with the exception of short wavelengths (the blue portion of the spectrum), fine detail can be seen with equal acuity across the spectrum. That is, using display devices of equal resolution should not result in significant differences in the spatial resolution of red, green or achromatic displays (Nelson and Halberg, 1979). It should be noted that short wavelength stimuli has a negative effect on visual acuity, since the normal eye focuses blue images in front of the retina, and accommodative adjustments may not be sufficient to focus the stimulus. Older users may find this a particular problem since the eye becomes characterized by a restricted range of visual accommodation with increased age (Southall, 1961). In view of these findings, it would be reasonable to assume that the choice of colors for displayed data is irrelevant (in respect to acuity and resolution) with the exception of the avoidance of short wavelength stimuli.

In the cartographic case, however, it would be unusual to find a display in which there were not numerous variables complicating the presentation system by providing a contextual complexity that serves to mask the basic acuity-resolution function. In addition, cartographic presentation is constrained by the fact that connotational color conventions exist. These require certain data to be symbolized in specific hues (e.g., convention requires that some temperature and bathymetric data be rendered with symbols, colored with short wavelength hues). For these reasons, experimentation is required to tell us whether or not the complexity of color cartographic displays complicate the normal acuity-resolution situation and, if so, to establish the utility of various hue relationships in cartographic task performance. In addition, experimentation is needed to estimate the decrement in performance that may occur as the result of using short wavelength colors. Depending upon the strengths of the findings, this could require either altering display conventions, or prompt additional experimentation to find ways of enhancing the signaling power of map symbols rendered with short wavelength hues.

SYMBOL COLOR, COLOR CONTRAST, READABILITY AND TASK PERFORMANCE

Symbol legibility and display readability are functions of a number of complex variables (Gould, 1968; Shurtleff, 1980). In a general sense, the size requirements for a color symbol are dictated by a relationship between image size and color perception. It is apparent that symbol size and contrast are the key to the effective presentation of spatial data. As noted previously, however, the use of space on maps for symbolic display is constrained by map scale as well as the rendering of the myriad data elements are that conventional aspects of map displays. In this case, then, legibility becomes a function of color contrast, symbol color (implicitly), and the nature and degree of color discrimination necessary to perform a specific map reading task.

The colors used to symbolize data appear to have an effect on symbol legibility, although various experiments have been reported that suggest contradictory results. The general result, however, is that symbol legibility seems to be affected by symbol color, background color, and size (Meister & Sullivan, 1969; Ohlsson, 1981). As is normally the case, performance rates for all colored symbols improve as the size of the symbol increases. With respect to cross color performance comparisons, there is limited evidence that colors near the center of the spectrum (green and yellow) are identified more accurately than other colors (Bornstein and Monroe, 1980), while blue symbols appear to impair performance (Shurtleff, 1980).

The influence of color is obviously complicated by the role of contrast and it is thought that color contrast can enhance symbol visibility and promote discrimination between targets. In the cartographic case, contrast must be defined more universally than is normal in color studies since we are interested in the degree to which the symbol is differentiated from either other symbols or its background. In addition, it is normally the case that symbols are represented using multi-dimensional elements (size, color, texture, shape, etc.) rather than a single graphic element. In a purely graphic context, the issue reduces to a complex figure-ground paradigm in which the symbol is designed to be significantly contrasted (using multiple design variables) with spatial information that is considered of less significance. The situation, however, is extremely complex, since the interaction of numerous types and densities of symbols promote an image that is extremely complicated in terms of element definition. Although the interactions of legibility, symbol color and color contrast are complex, it is probable that varying mixes of symbol color, image size and contrast promote extreme signal strength producing effective color harmony and balance in the display. It is also probable that less specific interactions such as those based on esthetics (e.g., color preference) or simultaneity (simultaneous color contrast), increment or decrement the speed and accuracy of task performance on complex displays. All of these interactions limit the applicability of the findings of sanitized color experiments (e.g., color chip comparisons) to the cartographic situation and require more specific yet complex experimentation in distinct application areas.

SYMBOL DENSITY AND TASK PERFORMANCE

Color can be an effective coding device for reducing search time on complex displays. One particular advantage of color is that if there is sufficient contrast between the target color and the color of the background items (momentary or task excluded targets), the number of background items has no affect on search performance (Carter, 1982). This is an important issue since, if there is little graphic differentiation between targets and non-targets, search time increases with the number of background items not of the target color (Carter, 1982). The critical issue in display design, when targets are numerous or locally dense, is to render the symbolic information visually distinct through the use of color and other graphic variables so that they promote symbol conspicuity.

It is clearly the case that the literature lacks studies where information is successfully incremented in terms of both targets and surround. Maps, however, are information rich and any study examining the effectiveness of color on task performance during map use must examine such levels of complexity. This issue is of significant importance since many maps cannot be simplified to the level of complexity normally used in color experimentation. Dynamic displays for a geographic support system that is monitoring the real-time occurrence of transient phenomena would be of limited value if the display drivers were programmed to selectively eliminate target information that would crowd the display or require additional coding. Certain system objectives may require a display of extremely dense information and the only viable solution to this problem is to find methods to effectively display the data regardless of the target density.

DISPLAY CAPABILITIES AND TASK PERFORMANCE

While it is obvious that the nature of the display must be considered when examining computer-generated maps, it should also be acknowledged that these same systems provide graphic capabilities which can also be used to increase the potential for signaling target information. Maps, for instance, are normally considered as static displays and most computer graphic systems merely echo this format although displaying the product as a virtual map on a raster device. It is probable that the dynamic capabilities of these systems can be used to overcome some of the traditional display bottlenecks (contrast, complexity, etc.) and provide unique presentational modes that effectively display target information. Consider, for example, the effects of blinking a target category in a complex display, or even winking a target between colors in the same situation. Abilities such as these may provide the hierarchical differentiation that makes target search successful. A review of the available human factors literature provides little data on the effects of such dynamic manipulation in real-time environments. Such manipulation, however, could be of considerable importance during task performance, and experimentation to pursue the value of this sort of manipulation is critical.

SUMMARY

The effects of computer graphics and color on human performance are highly dependent on the task (Tullis, 1981). The bast majority of studies on the practical application of color have utilized tasks that are far removed from normal map use situations and map interpretation tasks. Because of this omission, the utility of color on cartographic displays remains obscure.

A second factor, the performance of task based on real-time computer-generated displays, seems to provide additional complications in this already murky relationship. In this sense it is necessary for display designers to assess the effects of these and other display characteristics within the context of system capabilities and specific task performance. Many of the differences in the results of color coding experiments that have used similar testing environments have been due to subtle differences in the nature of the operational task. The importance of this distinction raises further questions about the cross applicability of the available literature on color display. There is little debate that the nature of cartographic display and associated map use tasks phenomenally separate these from other presentational modalities and require undertaking of experimental programs to define the design parameters which would be of significant benefit to cartographic displays.

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THE STUDY OF DIGITAL CARTOGRAPHIC DATA FEATURES IN PREPARATION FOR A NATIONAL STANDARD

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ABSTRACT

The Features Working Group of the U.S. National Committee for Digital Cartographic Data Standards has the tasks of studying cartographic feature classification systems and specifying a model that is consistent and comprehensive. Since its inception in August 1982, it has addressed the issues of scale independence, data organization, form of feature definition and basic cartographic data. Six goals for features in a national standard were recommended: independence from symbolization or scale; universality; logical structure; single classes with multiple attributes; explicit definition; and derivation from basic feature sets. A prototype classification system based on five levels is being tested. Future work calls for assembly of feature sets and glossaries, and cost estimates for future standards.

TOWARDS A NATIONAL DIGITAL TOPOGRAPHIC DATA BASE: EXPERIMENTS IN MASS DIGITISING, PARALLEL PROCESSING AND THE DETECTION OF CHANGE

By David Rhind[1], Timothy Adams[1], Simon E.G. Fraser[2] and M. Elston[3]

ABSTRACT

A recently completed topographic data base exists in paper map form for Britain: consisting of 220,000 maps, this set of maps will form the basis of a digital data base. This paper describes recent experiments in three areas which under pin the creation and maintenance of the digital data base. An automated digitising test, carried out by six contractors, is described and the results assessed. Experiments have been made with raster - format data using a 64 x 64 parallel processor to handle OS map data and these are outlined. Finally, research into the determinants of topographic change and its location is described.

INTRODUCTION

Instituting a national digital topographic data base is conceptually simple, especially where good quality, up-to-date topographic maps already exist. The necessary steps are:

(i) ascertain user needs, both in the short- and the long-term.

(ii) encode the map data in a fashion which stores and facilitates retrieval of all the required information.

(iii) construct a library of primitives - a set of software building blocks from which users construct their own applications software to meet their specific needs.

(iv) disseminate the data in a form readily usable on a variety of computer systems.

(v) provide comprehensive yet clear documentation on data and software

(vi) determine where change in the topography is occuring and incorporate it into the data base as soon as possible.

In practice, the creation and maintenance of such a data base is less than trivial. This paper addresses only items (ii) and (vi) in this list but it should be noted that Ordnance Survey (OS) are carrying out work in most of the other areas: for instance, a major user survey has been carried out in regard to 'large scale' digital maps and a similar survey is planned in regard to smaller scale (1:50000 and smaller) maps. Equally, studies are begining of standardisation of data formats, which may be based upon a British Standards Institute draft standard. All of the work described in this paper has been carried out under some form of contract from OS to universities: it all relates to the basic scale maps (i.e. the largest scale map available for any particular area), these being 1:1250 or 1:2500 for about 70% of Britain and 1:10,000 scale for the remaining mountain and moorland areas.

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THE MASS ENCODING OF EXISTING MAP DATA

The large scale OS maps

Efficient mass digitising capabilities are essential if all of the existing basic scale topographic maps in Britain are to be converted into digital form. Table 1 provides an indication of the magnitude of the task and of the progress made by the existing digital pilot production line, in operation since 1972.

Table 1. Numbers of OS maps by map series

Scale	Planned in Series	Already available by digital methods
1:1250 (1/2km x 1/2km)	54,365	7,150
1:2500 (1 km x 1 km)	158,020	10,340
1:10000 Basic (5km x 5KM)	3,659	3
1:10000 Derived	6,522	40
Total	222,566	17,533 (7.9%)

Source: Fraser (1982)

A sample part of an OS large scale map is shown in figure 1. Apart from those at 1:10000 scale, these maps are monochrome, contain many man-made features and show information in a literal as opposed to heavily stylised form; pecked lines are also common. Little height information is shown on 1:1250 and 1:2500 scale maps but the 1:10000 scale maps include contours printed in brown. Adams and Rhind (1981) have shown that on average the contents of the two larger scale maps is as set out in table 20. Between 95 and 99% of the area of each of these maps is not inked i.e. is white space.

Table 2. Average Characteristics for Basic Scale Map Sheets

Features (mean line length)	Map Scale 1:1250	1:2500
Buildings	872	46
Railways	103	10
Road carriageway	377	80
Fences	879	412
Vegetation limits	9	36
Streams	20	82
Road centre-lines	152	56
Total number of features	1428	283
Total number of text characters	1270	395

All lengths are given in cm.

Source: Adams and Rhind (1981)

The mass digitising tests

Adams' (1982) Ph.D. thesis included an account of an experimental study of raster digitising of large scale Ordnance Survey maps. This study was carried out in 1980/81 and included the digitising of one 1/1250 scale OS map sheet on systems in MBB/Kongsberg, USGS (using a Scitex machine), Bell Laboratories and the Oxford Image Analysis Group.

The map sheet was deliberately simplified and no account was taken of feature coding. Thus, whilst a useful first stage, this study could not be regarded as an investigation of mass digitising systems sufficiently comprehensive to plan for the introduction of production facilities. Hence, in midsummer 1982, a project was begun with OS funding to examine the state of the art of mass digitising capabilities so far as almost the full range of OS needs are concerned. This should be seen in the context of the existing manual digitising and interactive editing systems employed in OS productions and of existing Laserscan FASTRAK automated line following digitisers in experimental use within OS (see HMSO 1979, Fraser 1982)

The project involved the preparation of a 'representative' 1:1250 scale map sheet which included all the detail common on OS map sheets with the exception of the embankment hachures. The map sheet was made available to contractors in two forms - as a standing negative i.e. with the high quality, scribed linework of the published map and as the Master Survey Document (MSD), the surveyor's manually inked record of change superimposed on the published document. Comprehensive instructions were given to those participating in the experiment: copies of these are available from OS. In general, participants were encouraged to digitise the work in whatever was the most effective method using their existing systems and were asked to record all times and costs. To avoid the need for participants to learn the OS coding structures, dyeline copies at 1:500 scale of each map were provided on which codes for all linework or point features were marked in colour.

All known manufacturers of automated mass digitising systems were circulated with details of the project, stressing that this bench marking work would be paid for and that it was designed to elicit what were the existing capabilities of the systems. Laserscan Ltd. were included for comparison purposes and used their FASTRAK vector system in Cambridge to digitise the maps; OS also digitised the map in-house using their manual system. Following responses from the potential contractors, the following organisations were sent all the relevant materials:

Broomall Industries Inc. (BII)
Broomall, Pa 19008
USA

Calculo y tratamiento de la
informacion (CTI)
Madrid, Spain

Interactive Systems Corp. (ISC)
Littleton, Co 80120, USA

Kongsberg Ltd.
Maidenhead, Berks, UK

Laserscan Laboratories Ltd (LSL)
Cambridge, UK

Scitex Corporation Ltd.
Herzlia, Israel

Victor Hasselblad AB (who did not take part in the subsequent stages)
Gothenburg, Sweden

All systems other than that of Laserscan were based on raster digitising. All contractors were visited by one of the authors (TAA) over a short time period between October and December 1982: the bulk of the digitising was carried out whilst he was present in each organisation.

Results

The results of these tests are documented at length in an internal OS report containing 'commercial in confidence' data.

The main conclusions however were:

- the only system which produced results suitable for production work in OS at the time of the study was that of LSL;two other systems (Kongsberg and Sci-Tex) had the capabilities of producing graphical results approaching those from the existing OS manual digitising systems.
- none of the systems were yet as cost-efficient as the OS manually based system - at least on the basis of OS accounting procedures.
- the great bulk of the remaining problems related to the software used in the raster systems, rather than the hardware. None of the raster systems tested then had a satisfactory method of linking pecked lines in the existing graphics into continuous lines; recognition of line junctions and preservation of the exact vertices of the angular features common in the basic scale OS maps was often poor (and highly noticeable).
- the addition of feature codes to linework is still a very major component of the whole digitising task.
- very few firms were able to cope with the encoding of the surveyors manually inked corrections to the published maps (i.e. the MSD).
- considerable ingenuity was shown by many of the firms e.g. in setting the most common feature code (fences) as the default value.
- despite the precautions taken (see above), there was a clear 'learning curve' element to the work for the majority of the contractors. Hence their products could be expected to do at least as well in a production environment in OS.
- the situation was changing rapidly and the tests should be repeated periodically.

THE HANDLING OF RASTER TOPOGRAPHIC DATA IN A PARALLEL PROCESSOR

Background

Research by Adams and Smith (1982) attempted to discover the possibilities of handling OS type large scales data in a raster fashion. The work is considered to be pioneering since, as with the developments being made in the US Army Engineer Topographic Laboratory (Babcock 1978), much of the work is being carried out on, and taking advantage of, a true parallel processor.

The research by Adams and Smith has taken two approaches: first utilising raster data which have been generated by software from a conventional vector-based digital file and, second, using data which have emanated from a raster scanning device (see the previous section)

The ICL DAP Parallel Processor

The basic notion of a parallel processor - a computer which can execute the same instruction on many data items simultaneously - has been known for many years. There have been several processors of this type built, most notably the Goodyear STARAN and the ILLIAC IV. Although the ICL Distributed Array Processor (DAP) is similar in nature to these machines, it has two important differences: there are 4096 processing elements in the DAP as opposed to 256 and 64 for the STARAN and ILLIAC IV respectively and the processing elements (PEs) are one-bit processors and hence limited in their applications. All except bit manipulations must be handled by software. Each PE can perform two basic operations - one-bit addition and a one-bit broadcast of data to one of its four neighbouring row and column PEs.

For purposes of computation, the DAP can be described as comprising:

(i) 4096 store planes of 64 x 64 bits;

(ii) the Activity plan (A-plane) of 64 x 64 bits - this is one of three planes comprising the PE. The setting of a particular bit in the A-plane instructs the associated PE to perform a given instruction; if the A-plane bit is unset then the PE remains idle and ignores any given instruction. The use of the activity plane has much importance in array processing; it acts as a 'mask' to determine whether each individual PE acts as an instruction or lies dormant;

(iii) the Quotient and Carry planes (Q and C planes) of 64 x 64 bits - these two planes complete the three in each PE. There are two basic operations which can be performed with these planes; the first is to add the contents of a store plane to the contents of the Q-plane (element by element) with the resulting sum being placed in both the Q-plane and the store plane with the carry bits set in the C-plane where necessary. The second operation involves shifting all the bits in the Q-plane one grid interval in the same direction. For example, the case shown below is a cyclic shift north- each row in the matrix is moved one position north.

$$\begin{matrix} 1 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{matrix} \longrightarrow \begin{matrix} 1 & 1 & 1 \\ 0 & 1 & 0 \\ 1 & 1 & 0 \end{matrix}$$

A DAP-based topographic data system

Adams (1982) has described the structure of an integrated system for processing raster-based OS data on the DAP or its successors. In essence, each 40 x 40 cm map sheet is considered as a maximum set of 109 4096 x 4096 binary arrays, there being 109 feature codes which are used by OS (though only c.35 appear in each map). Software was written in DAP FORTRAN to break down these large arrays into 64 x 64 DAP images and to store the data hierachically: hence no data is stored for a 64 x 64 pixel area in a map if, at the next level up in the hierachy, no bit is set for the corresponding cell area. Other software permits extremely rapid generalisation of the data from one resolution to another. Moreover, the detection of parcels bounded by continuous lines is also very rapid: in one test case using the point propagation capability, the DAP located 1677 such parcels in a map sheet, transferred them to secondary store and 'painted' them out in the main file in 3 seconds of CPU time. Though difficult to provide meaningful comparisons, speeds of 1000 times an IBM 370/168 were achieved for such operations.

Such parallel processing, especially if intimately linked to the high quality graphics now under development, seem likely to make wholly new cartographic data base manipulations a practical possibility. Three possible applications are set out below.

Use of the DAP-based system as a geographic index for any data sets.
Suppose one is interested in finding where in Britain certain conditions obtain, such as deciduous forest or elements represented by OS feature code 30 (fences). Two obvious strategies exist: the first is to hunt through geographically detailed data for all of Britain (a monumental task). The second is to search on a hierarchical basis. Conventionally this would involve inspecting a small scale paper map then moving on to examine larger scale paper maps of selected areas.

considerably through time. Perhaps the most rapid change of this kind presently occurs in 'rurban fringes' where rural land is being converted into housing or in areas of comprehensive redevelopment. Change may occur due to national or to local factors: for example, both the enclosure of farmland in the eighteenth century and urban slum clearance in the late nineteenth century were national in scope. In contrast, removal of field boundaries over the last twenty five years has only occured on a major scale in rural areas where the topography is sufficiently flat to encourage the use of farm machinery. At the extreme, detailed change to houses, such as the building of extensions to the ground floor - and hence detail which would be incorporated on OS plans - is likely to occur most frequently in areas of particular socio-economic status and personal wealth but will also occur most frequently at periods of relative affluence.

In Britain, map revision was for long on a cyclic basis (Seymour 1980). More recently, OS have moved to a continuous revision system and have produced a major internal review of how this is best carried out (OS 1981). In essence, OS now consider two types of change to occur so far as map revision is considered: primary and secondary change.

A map sheet is republished when the total number of 'units of change' exceeds 300. Prior to that stage, changes in topography are held on the Master Survey Document (MSD); this is an unpublished copy of the map sheet held within the Regional Offices onto which surveyors can pen-in the new information as changes occur. The SUSI service (Supply of Unpublished Survey Information) has been popular with customers requiring up-to-date data: in this way, the MSD image is copied on request providing a mechanism for users to obtain the current state of change in any area.

Clearly, some knowledge of the likely overall change in the topography of the country is an essential prerequisite to the allocation of manpower resources and, where an objective is to 'capture' new detail as soon as possible after it is built, some procedure for estimating the most likely locations in which this change will occur is desirable. So far as we know, no formal study has ever been published on the relationship between map revision and topographic change. This is less surprising than it might at first appear since most countries are still primarily concerned with map creation, rather than revision. Nonetheless, we cannot pretend that even in Britain we <u>know</u> the determinants of changes to be mapped.

To provide intelligence on the location and volume of changes we can <u>anticipate</u> using several sources of information:

(i) historical evidence of change
(ii) information from planning authorities
(iii) projections of national and regional accounts
(iv) known changes in relevant legislation
(v) data derived from the maps themselves
(vi) the land use or land cover character of the mapped areas

These sources are discussed in more detail in Rhind and Adams (1983)

Modelling Change

As a consequence of their need to plan manpower allocation, OS have awarded a contract to SCPR and to Birkbeck College to build a model for predicting change. This is being achieved by categarising the map

Such a strategy is not adequate: maps at different scales do not contain the same information. A DAP analogue of the latter can be built from the 'bottom-up' and inspected from the 'top down'. Hence an n x n array for presence/absence of this variable is examined in parallel covering all of the country (if n = 64, the mesh size, d = 20 km). For all mesh cells set to true, an n x n mesh is stored describing the same presence/absence at d/(n-1) km, the process being repeated iteratively until appropriate resolution (set by the input data) is attained. On this basis, access to all of the areas in Britain, at resolution of large scale (e.g. 1/10000 scale) maps could be obtained by examining only three levels in the hierarchy.

The generation of vectors in link and node structure. Previous OS experience of generating links and nodes from the existing 'spaghetti' DMC files was less than totally successful: the many complications inherent in the way OS have encoded the existing map sheets (largely designed for graphic purposes) rendered the vector-based software complex and slow running: yet there is clearly going to be a need for more structured data (especially in the longer term) than that currently provided.

An alternative approach based on rasterising binary format data is to fill 'polygons' using the DAP by rippling out from an arbitrary chosen starting point until pixels set to be 'on' in the mask are reached. The boundary of this 'sub-parcel' (Adams and Smith 1982) can then be vectorised and the area painted out; once all such polygons have been thus treated, breakdown of the polygons into segments with left/right codes could be carried out.

The automated recognition of features. Coding attributes onto line work and checking the results is a major element in the existing OS production of digital maps: coding raster data with the same attributes, given the lack of colour used in the 1/1250 and 1/2500 scape maps, is extremely time-consuming. Previous work on the DAP gave some promise that certain features (e.g. buildings) could be coded automatically, though it seems very unlikely that the full range of 109 OS feature codes could be recognised in this way. A hierarchical approach to feature coding could usefully be investigated - a set of primitive codes could be generated using the DAP and, where more detail is required, it would be supplied by user interaction.

PREDICTING WHERE TOPOGRAPHIC CHANGE IS LIKELY TO OCCUR

Background

The totality of Britain has already been mapped at the largest set of scales which, for present user needs, comprehensive map coverage is needed. As we have seen in earlier sections, this has been achieved by creating a set of plans at 1:1250 and 1:2500 scale covering about 70% of the 240,000 km^2 of the country and the remaining areas being covered by maps whose largest scale is 1:10000. Comprehensive photogrammetrically-derived contour information for the whole country will be completed by circa 1984 and made available on a single set of 1:10000 scale maps, some being basic scale and some derived from basic scale maps. Thus the future task facing the British national mapping agency is not 'where to map?' but rather 'where to direct effort to correct the maps?'. We know from historical evidence that change in the landscape which needs to be incorporated in maps is generally man-induced but takes place at very different rates in different parts of the country; moreover, in any one area the rates of change vary sheets in the country and then running two surveys within a sample of all the map sheets to provide a 'base line' and then a quantitati- statement of change in each map area. Surveyors also define main land use types in each map area. The first survey or perambulation was carried out in August/September 1983, the second being scheduled for one year later. The sample derived was a stratified one based primarily on population density and percentage of households which were 'owner occupiers' in populated areas and was broken down by map coverage at 1:1,250 1:2500 and 1:10000 scale. Respectively, some 1366, 1251 and 416 $1km^2$ areas are being perambulated at these scales.

The selection of the sample was based upon a machine-readable list of the names of all basic scale maps provided by OS. Population and household characteristics were linked to the maps in populated areas by drawing upon the 1971 Census of Population statistics available by 1km grid squares (HMSO 1980). Even acknowledging the inherent problems due to out-of-date census data, this is believed to be the first attempt to tie together map characteristics, determinants of change and rates of change in the topography. Results will be published as they become available.

CONCLUSIONS

In certain respects, OS has problems and priorities which differ from many other national mapping agencies, largely through the concentration on very large scale maps. Nonetheless, the problems involved in mass digitising and in sifting, reorganising and linking massive raster data sets are common to many such organisations. The move towards detecting change is also likely to become a problem in other countries. Hence the results of this study have relevance for other organisations.

ACKNOWLEDGEMENTS

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None of the opinions expressed, however, should be taken as necessarily representing anyone other than the authors.

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Figure 1 Part of OS 1: 1250 scale map SK7518SE (a vector plot)

OVERVIEW OF AUTOMATED CARTOGRAPHY EFFORTS AT DMAAC

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ABSTRACT

The application of computers and computer assisted techniques to support current and future (thru 1988) requirements for chart production at The Defense Mapping Agency Aerospace Center (DMAAC) is discussed. Topics discussed include: Digital Paneling (computer assisted technique for reducing large scale map source to a smaller scale control projection); computer assisted chart symbolization for chart products, Digital Landmass System (DLMS), a data base containing Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD) to support charting requirements and the computer generation of relief information from DTED data. Control, data collection, editing, chart compilation, chart revision, color separation, symbolization, and printing can be enhanced or accomplished by automated processes. Also considered is the development and continual evaluation of a Digital Cartographic Applications Data Base (DCAD) to provide this center with a capability to support advanced digital mapping requirements. The DTED and DFAD data currently produced by DMAAC are used to support advanced aircraft simulators and navigation systems requirements.

INTRODUCTION

The Defense Mapping Agency Aerospace Center (DMAAC) has the responsibility to meet an ever increasing number of different Mapping Charting and Geodesy MC&G requirements. The charting program primarily consists of the Series 200 (S/200) and the Navigation and Planning (NAV/PLAN) Charts. Special charts are produced for NASA, Air Weather Service and many other users. Most of these charts and navigation products are produced using traditional cartographic methods[3]. The traditional chart production process (i.e., feature selection, paneling, compilation, symbolization, negative engraving, etc.) requires manual, labor intensive skills. Therefore, a significant portion of DMAAC's production resources are devoted to assuring that these products are kept current with user's needs. Obsolescence comes from either or both of the following reasons: The charts no longer meet current accuracy requirements; and the information provided is outdated. Thus, DMAAC has established a need for accurate up-to-date cartographic information in a digital format readily transformed to meet specific charting requirements. Specifically, DMAAC has the requirement for a Digital Color Separation Production Process to include the collection, maintenance and exploitation of a data base of product independent digital cartographic information. The data base must contain not only lineal features in a line segment noded digital format, but also sufficient textual information to support utilization requirements for a "Family of Charts" (FOC) production process. This paper discusses DMAAC's current, proposed and future efforts for automating chart production processes to include the development and implementation of a Digital Cartographic Applications Data (DCAD) base for chart features in a standard linear format (SLF).

TRADITIONAL COLOR SEPARATION

The traditional color separation techniques for chart production require manual paneling, compilation and negative engraving. These manual, labor-intensive processes are prime candidates for computer assisted color separation techniques. The Domestic Series 200 program was selected as the first candidate for automated color separation at DMAAC because of the large number of charts produced each year. S/200 charts are produced at a scale of 1:200,000 and are used by air crews for general planning, in-flight navigation and training. After collecting the cartographic source package, the cartographer begins highlighting, on USGS 7-1/2" quadrangle sheets, those planimetric and hypsographic features selected for portrayal on the 1:200,000 scale chart. The cartographer performs a sheet to sheet match and the highlighted cartographic source is then scaled against the projection and photographically reduced to 1:125,000 scale. The film positive photo reductions are paneled to the 1:125,000 scale projection. This serves as a panel base from which final planimetric, hypsographic and special feature manuscripts (i.e., Contour Drainage, Roadroad, culture, etc.) are drafted. The manuscripts are drafted at 1:125,000 compilation scale, then photo reduced to the final 1:200,000 chart scale and imaged on scribe cote. The negative engraver then color separates and symbolizes the various chart features manually on the scribe cote. The engraved scribe cote (color separate) is used for making the lithographic printing plate[2].

<u>Objectives for Automating the Traditional color Separation Processes</u> - The objectives for automating the traditional color separation processes are: (1) To improve existing production processes, (2) Standardization, (3) Quick response to users needs, (4) Cost Savings (Maintenance), and (5) Movement toward an all digital, softcopy production system. The aim is to improve existing production processes through automation, to develop and implement a Digital Cartographic Applications Data Base (DCAD), and to implement an all digital softcopy production system by the mid to late 1980's.

CURRENT DIGITAL PROGRAMS

DMAAC is producing prototype charts from digital data. The digital data for these charts are collected, edited, and color separated in-house by the Automated Graphic Digitizing System (AGDS). The current digital color separation production scenario at DMAAC is shown in Figure 1. The AGDS collects line center data and generates line segments which are "tagged" by the operator with an appropriate Graphics Line Symbolization System (GLSS) code. The cartographic features from the digital data are symbolized according to chart specifications and plotting instructions for them are generated off-line by the GLSS software. Application of the GLSS software can save 50% of the man-hours normally used by the negative engraver for building lithographic color separation plates. Tagged digital data from the AGDS is archived for later chart revisions[4].

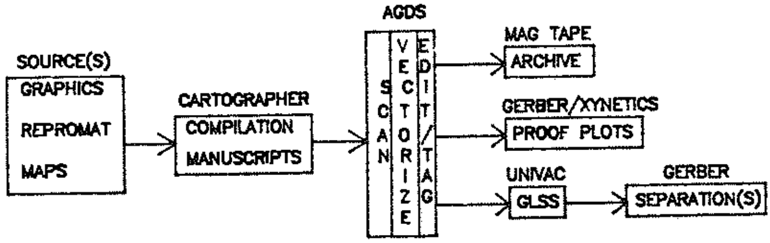

Figure 1. Digital Color Separation

Automated Graphic Digitizing System - The AGDS system is designed for data collection, interactive editing, and color separation of compilation overlays or selected feature lifts. The three main subsystems of the AGDS system are: the scanner, the vectorizer, and the edit/tag (Figure 1) subsystem. The laser scanning subsystem is used to scan compilation overlays outputting the data in raster format. The vectorizing subsystem converts the raster data to vector format. Once the scanned overlays are in vector format, the data are input to the edit/tag subsystem. The cartographer at the edit/tag subsystem has the capability to interactively edit the data, create sub files from the data (i.e., select feature lifts, compilation overlays, etc.), and to mathematically transform the separate overlays to the compilation projection base (Digital Paneling). Common points between the individual overlays and projection base are used for controlling the overlays to the projection and the cartographer can digitally transform the overlays to the projection. He then interactively inserts unique feature identification codes (FIC) to features according to their unique color separation. For example, drainage would be displayed on the blue color separation whereas cultural features would be displayed on the black separation. The color separations correspond to the colors for the lithographic printing plate. The FIC, or tag number corresponds to a specific set of previously defined instructions for feature symbolization. Table 1 is an example of the procedures and symbol pieces required to symbolize a non-perennial drain[4].

Table 1. Symbol Specification File

Feature Identification Code	Conformal Non-Conformal	Type of Symbol	Lineal (blank) Flash(F)	Symbol Size (inches)	Symbol Line Weight (inches)
4347	CON	DASH		.193	.007
	CON	SPACE		.029	.000
	CON	DOT	F	.007	.007
	CON	SPACE		.025	.000
	CON	DOT	F	.007	.007
	CON	SPACE		.025	.000
	CON	DOT	F	.007	.007
	CON	SPACE		.029	.000

After the data has been color separated at the edit/tag subsystem, an output tape is generated for off line chart symbolization by the GLSS software.

Graphic Line Symbolization System - The GLSS software is to provide the cartographer with a chart that shows cartographic features, such that one feature can be easily distinguished from the other. The GLSS software converts line centered data to a specific product format which depends upon the chart specifications being used for the final chart compilation. The product format is generated by a graphic film (photo) plotter[4].

Film Positive Separates From GLSS - To this point, the collection and processing of digital cartographic data through AGDS and GLSS systems have been discussed. Now let's view a composited subplot taken from a full scale production chart. Figure 2 presents a symbolized plot for the following color separations: contours, drainage, roads, railroads, and radar significant analysis code (RSAC). Each separation encompasses the same geographic area. The cartographic features for each separation are plotted according to chart specifications. Figure 2 shows a composite registration of the film positives.

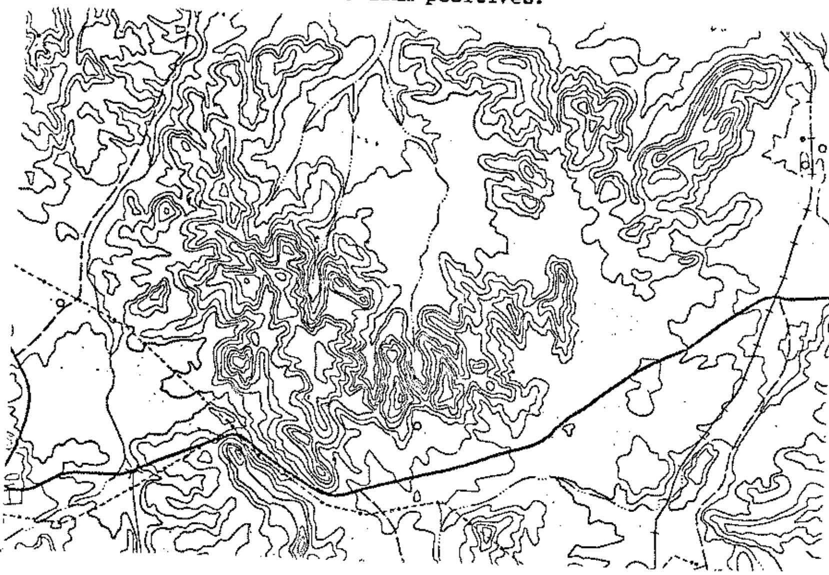

Figure 2. Composite of Separations

The symbolized film positives from GLSS eliminate the need for the negative engraver to extensively hand engrave symbology on scribe cote. The engraved scribe cote is used for making photo negatives for creating a lithographic press plate[4].

Savings For the Negative Engraver - By eliminating the need to manually engrave most chart symbology, the negative engraver can save 60% of the manhours he would need to engrave the chart. For a particular prototype production chart, the engraver time required to scribe symbology and prepare the chart for printing was 430 manhours. To color separate the same prototype chart using digital data and GLSS software for symbolization required only 170 manhours from the negative engraver. Additional savings would be made for smaller scale, larger format charts[4].

Digital Landmass System (DLMS) - DMAAC is currently producing digital files of Feature Analysis Data (DFAD) and Digital Terrain Elevation Data (DTED). These digital files are combined to form the Digital Landmass

System (DLMS) and are used to support advanced aircraft simulators and navigation system. The DLMS data base contains two major types of data, elevation data and physical feature data.

DTED - Elevation data is collected by either automatically scanning profiles from a photogrammetric model on an analytical stereo plotter or by digitizing contours (AGDS) from an existing map[1]. Photogrammetric methods are used to collect the majority of DTED compiled for the DLMS in DMA. Interpolation of collected elevation data yields a uniformly spaced grid of elevations in accordance with DLMS specifications for DTED[5].

Cartometric methods for DTED production are based on AGDS collection of map/chart contour manuscripts. Similar to photogrammetric methods, interpolation algorithms for converting vectorized raster contour data to final DTED matrix form are based on weighted radial averaging methods for points surrounding matrix posts. Contour data is likewise enhanced with geomorphic information (e.g., stream beds, ridges, etc.) to preserve the integrity of terrain forms[5]. Collected data is then transformed, via post processing on the UNIVAC 1100 Series computer to the DTED matrix format.

The role of Digital Cartography is increasing at DMAAC. In areas where a suitable data base exists, contours are generated from Digital Terrain Elevation Data (DTED). Cartographers use a computer program which constructs contours from a rectangular array of elevation points at specified increments of latitude and longitude. A smoothing algorithm automatically eliminates noise and bias errors which enter in the collection process. Generalizing selectively retains the geomorphic character of the surface while thinning the elevation data for compilations at smaller scales. Finally, the contouring algorithm converts the elevation matrix data to linear contours. The advantages of computer drawn contours are threefold. (1) Man/Machine hours are reduced, (2) we are able to take advantage of the digital terrain elevation data base, and (3) there is less requirement for cartographer interpretation of topography.

DFAD - The associated feature data file holds digitally encoded descriptions of culture and landscape features within the terrain region. Most feature types are represented by polygonal boundaries and descriptor tables. The table includes coded information such as surface type (e.g., forest), predominant makeup (e.g., deciduous trees), and average height. Some features such as bridges, dams, walls, and pipelines are specified by line segments, while others, such as towers and certain buildings are specified as point locations with feature heights included. Header records containing index and reference information are used to relate descriptive information to corresponding geographic locations of features. Detailed DLMS data content is described in reference 6,[5] "Product Specifications for Digital Landmass System (DLMS) Data Base."

DFAD Specification Upgrade for Charting Requirements - The DFAD specifications are being updated to support charting requirements. The scale at which these data are collected must be sufficiently large so that it will support all charting products. Special emphasis must be placed on the collection of roads, railroads, cultural features, and drainage. Attribute data for features of the DFAD data base must be of such detail to insure successful retrieval for charting.

Advanced Edit System (AES) - The AES in Figure 3, was developed as an interactive editing system for editing symbolized color separation data in final plotter format prior to final plotting. The AES can also be used for editing digital features from various other formats. It is anticipated that DCAD data will be edited on the AES system for revision, and recompilation of the 200,000 scale aeronautical charts.

PROPOSED AND FUTURE DIGITAL PROGRAMS

Softcopy Production - DMAAC is escalating the automation of the charting process and expects to achieve an all digital softcopy production capability by 1988 (Figure 3) to include the establishment, as appropriate, of uniform procedures relating to the collection, screening, evaluation, editing, symbolization, retrieval and exchange of digital source and production data. It is anticipated that the concept of digital color separation and data base development will necessitate some minor changes in product specifications and compilation procedures. Existing charting specifications for DMA products were developed in an era devoid of automation. These specifications need to be reevaluated for redefinition of certain cartographic rules to maximize the savings that are possible through automation while maintaining effective communication to the users[3].

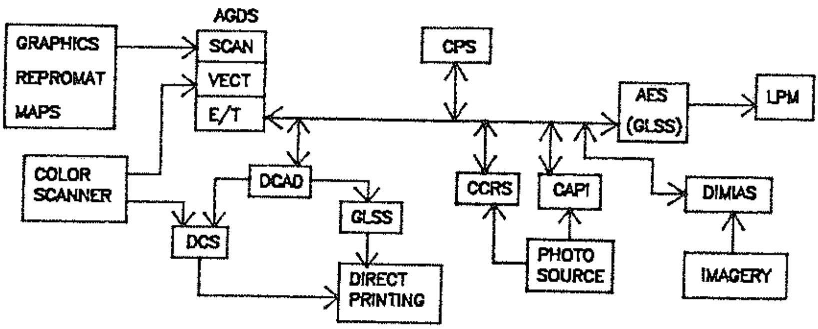

Figure 3. Proposed Production Scenario

Table 2 lists currently identified developmental efforts to support this proposed softcopy production system.

Table 2. Developmental/Efforts to Support Softcopy Production[3].

I System Capabilities

- Advanced Edit System (AES) to support preparation, editing and plotting of symbolized digital map color separation data.
- Cartographic Compilation/Revision System (CCRS) to provide a capability to simultaneously work with graphic, photographic and digital data.
- Clustered Carto Processing System (CPS) will provide a set of interrelated automatic and interactive functions to accept digital data from AGDS, CAPI, DIMIAS, and perform various transformations on the data.
- Computer Assisted Photographic Interpretation System (CAPI) for integrated photo interpretation/mensuration/compilation to support DTED, DFAD, Digital Vertical Obstruction Data (DVOD) and automated charting.

- Digital Interactive Multi-Image Analysis System (DIMIAS) is used primarily to analyze and extract landscape features from digital imagery in a semi-automated mode.
- Digital Chart System (DCS) to be a new generation of auto carto hardware/software to accomplish maximum exploitation of the planned Digital Cartographic Applications Data (DCAD) base.

II Support Hardware

- Color Scanner for rapid digitization and separation (by color) of symbolized cartographic feature data portrayed in DMA chart and source materials in multi-color lithographic format.
- Digital Laser Platemaker to provide a capability to go directly from digital data to pressplate.
- Direct Printing to combine text and digital color separation data and directly print in a variety of colors in a single press run with no reproduction copy or plate preparation.

III Data Base

- Digital Terrain Elevation Data (DTED) is a digital file which is a subset of the Digital Landmass System (DLMS). DTED is composed of terrain data with elevations stored in a matrix referenced to mean sea level, with horizontal positioning referenced to the World Geodetic System (WGS-72).
- Digital Feature Analysis Data (DFAD) is a digital file which is a subset of the DLMS system. It described the physical characteristics of the three -dimensional surface described by the DTED.
- Digital Vertical Obstruction (DVOD) is a digital file consisting of vertical obstructions referenced to WGS-72.
- Digital Cartographic Applications Data Base (DCAD) is a data base of chart features in a standard lineal or segment-noded format (SLF). DCAD is a combined product specification which will satisfy DFAD, DTED, DVOD and automated charting requirements.

IV Support Software

- Software for Auto Carto to provide advanced contours to matrix.
- Matrix to contour and line data thinning.
- Auto Carto Feature ID to support product compilation i.e. automatic tagging of cartographic features.
- Line generalization for automatic adjustment of chart detail for product scale changes.
- Universal transformations and adjustments.

Data Base Requirement - Regardless of the complexity of the above mentioned production processess, the creation of an off-line Digital Cartographic Applications Data Base remains as one of the largest hurdles to be overcome prior to implementation of an effective Automated Charting production process. The many systems within the proposed production process of Fig. 3 would currently be limited in their effectiveness for lack of a common standard format which would allow data exchange between those systems not directly interfaced. DMA is developing such a Standard Linear Format (SLF) for efficient interchange of digital data. Such a format could be the logical basis for DCAD, and for this paper, DCAD and SLF will be synonymous[3].

In the past, the charting, DTED, DFAD and DVOD programs have been separate and legitimate programs because each had its own requirement and production schedule[3]. Typically though, DMAAC requirements for charting, DFAD, DTED and DVOD could all be derived from the same basic control and source materials. The CAPI system is expected to provide this capability to achieve all four requirements in a single pass. It would produce common data elements, to the extent practical, in terms of cost and time available, when digital data is required to support multiple products over the same geographic area. Such a production process would capitalize on redundent production requirements, provide source and product commonality and subsequently minimize proliferation of production and maintenance software. DCAD has two basic design objectives: 1) To store a string of data only once, no matter how many features it may be a part of (segment/node format). 2) To accommodate multi-product and multi-series charting requirements[3].

The segment node format of DCAD will have inherent advantages over the polygon (enclosed figure) format currently used for DFAD data storage. The polygon format does not identify nodes of feature segments. The whole feature (Fig. 4) can be identified only as a segment. Thus, DFAD features sharing a common boundary were overlapped to insure coverage. This procedure was developed because, at that time, only manual digitizers were available for data collection and the capability to digitize a single common boundary for adjacent features was impractical. Manual overlap could be eliminated in off-line post processing of the digital data but often resulted in the subsequent computer generation of overlap slivers or fictitious gaps in the digital data and additional processing was required to eliminate them, where possible. The line segment noded format would eliminate this problem, avoid double storage or common boundaries, simplify update and correction, and be responsive to thinning and generalization algorithms.

It is feasible to develop a storage format designed to accommodate these requirements. Such a design would include the following[3].

1. Header information to contain descriptive information or attributes of the data set.

2. Data sets to accommodate feature and line segment information.

   a. Feature information (Table 3) identifies the unique features which make up the data set. Specifics on feature data content would depend upon the product specification.

   b. Line segment information (Table 3) contains the actual coordinate strings for the segments which make up each unique feature. All features which include a segment would be so identified.

3. Free text information to further define or uniquely qualify data as required.

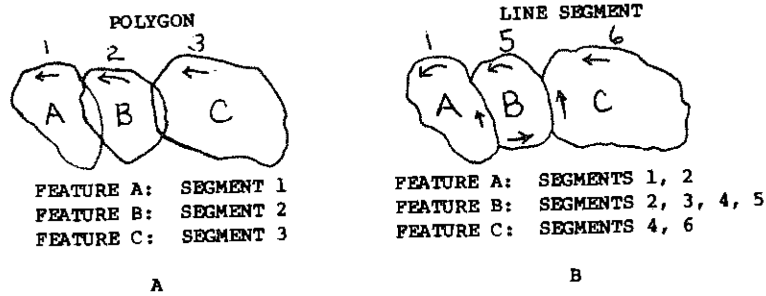

Figure 4 Data Base Formats

Table 3. Line Segment Data Sets

FEATURE	SEGMENT
. . . FEATURE A #SEG = 2 F*/SEG 1** F/SEG 2 FEAT B # SEG = 4 R/SEG = 2 F/SEG 3 F/SEG 4 F/SEG 5 FEAT C . .	. . . SEG 1 FEAT COUNT = 1 FEAT A # POINTS IN SEG $X_1, Y_1, Z_1,$ . . . Xn, Yn, Zn, SEG 2 FEA COUNT = 2 FEAT A FEAT B # POINTS IN SEG $X_1, Y_1, Z_1,$ . . . Xn, Yn, Zn, SEG 3 FEA COUNT = 1 FEAT B . . .

* Direction of segment(Forward (F) on Reverse (R)).
** Segment list is ordered to track the feature boundary.

CONCLUSION

Automated Charting at DMAAC is approaching production status. Equipment and systems projected to support future auto carto production requirements, through the decade of the eighties, have been defined and are in development. To support these future requirements, DMAAC is developing for implementation a Digital Cartographic Applications Data (DCAD) base to support charting requirements where digital data is available. Relief information would be generated from DTED source; chart feature data would be derived from DCAD.

To satisfy charting requirements using DCAD as source, additional software development is needed. Algorithms are being investigated and will be developed to support the filtering, generalization, displacement and symbolization requirements of multi-series, multi-scale charting. The cartographer should also have the option to output the final color separations to a laser plater maker for lithographic printing or to exercise a computer algorithm which will composite all separations for the direct printing process (raster color printing technique). For the immediate time frame, digital cartographic data for input to DCAD must be collected using various collection equipments and sources. Computer systems, software, and procedures such as: Digital Paneling, AGDS, GLSS, Gerber/Xynetics Proof plotting, and Gerber photo plotting will be the current main stays for automated charting.

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AUTOMATED CARTOGRAPHY SYSTEM RESEARCH AND DEVELOPMENT

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ABSTRACT

The technological marriage between photogrammetric processing and interactive graphic systems has produced many benefits, particularly digital mapping. With data now readily accessible by computer the application of digital technology has produced significant cost savings over traditional methodologies. For example, a simple engineering application of using automated profile and cross-section routines on an interactive graphics terminal enables the design engineer to select an optimum pipeline alignment for the parkland regional sewer trunk. The production of digital maps is a relatively straight forward process. The utilization of this data in practical applications lends itself to a certain amount of ingenuity. Whilst both these production tasks are valid in themselves, the most important component of any map is the underlying information, for example - soil type, vegetation, owners name, depth of mineral deposit, diameter of pipe ... etc. Geographic information systems are data management tools that efficiently process the immense reservoir of data attached to a map image. The decision maker must be able to interpret and evaluate this attribute information in a cost effective manner before reaching a final decision. A software package has been developed which has the characteristics of allowing the user to interrogate any existing data bases. It is totally device independent for report generation and graphics output, functional module architecture, menu driven, operating on virtual system architecture. A typical land use application is outlined comparing traditional information retrieval times with the developed software application module. Future development work includes microcomputer intelligence, fast graphic processing capabilities and Landsat image processing. Conclusions are drawn between computer-aided mapping systems and geographic information systems.

GENERAL TRACK SESSIONS: EDUCATION AND TRAINING

SOME IDEAS ON MICROCOMPUTER ASSISTED INSTRUCTION

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ABSTRACT

Computer assisted instruction (C.A.I.) is almost as old as computers themselves. Although the computer has become a common facet of our lives, C.A.I. has yet to make much of an impact on our educational system. Today we again hear the claim that C.A.I. will change the way students are educated vis-a-vis the microcomputer. Only time will provide the answer.

Microcomputer assisted instruction can be divided into two classes, stand-alone instructional units and microcomputer-mainframe computer instructional units. The former division has received the most attention up to now, with the latter seldom getting even honorable mention. This paper presents some thoughts on the structure of microcomputer-mainframe computer assisted instruction (M.M.C.A.I). In addition, we have included an outline of such a unit for Introductory Computer Cartography.

INTRODUCTION

Microcomputer C.A.I. has received considerable attention in the popular press over the past several months. A close reading of this material shows that much of the software described was designed for the lower elementary grades, with little available for higher education. This software includes a wide range of drill materials, some simulation situations, and a few economic gaming routines. Since the concepts presented by C.A.I. for the lower grades are much less complicated than those required in the upper grades it is quite understandable that work has focused on the elementary level.

Most of the articles and the various individuals quoted within them referred to the development of courseware (i.e. software), specifically for microcomputers such as the Apple, TRS 80, and Atari. Because of this most of the C.A.I. software available for microcomputers requires no computer power in addition to that provided by the micro. Therefore this software is often referred to as stand-alone C.A.I.

While microcomputer stand-alone C.A.I. offers tremendous potential, at present it also has some very serious limitations. For example, there is little or no advanced level C.A.I. software for many topics such as cartography. Even though mapping software exists for microcomputers, it is similar to that which runs on mainframes. While most of this mapping software is interactive, it is not designed for C.A.I., and even when such microcomputer software is incorporated into a computer cartography course it must be used much like its mainframe mapping cousins.

The future will probably see major changes in microcomputer C.A.I. In fact as microcomputers grow more powerful and the cost per computational second goes down, more and more complicated tasks will be performed on these machines. Yet is there a role that micros can play in higher education today? One possibility is to use the microcomputer as an interface to the more available and powerful mainframe computer programs. In this way each machine could be called upon to perform those tasks which it does most efficiently.

THE MICRO-MAINFRAME CONNECTION

A major advantage of the micro is its interactivity and dedication to a single user. Response time is quite speedy, long a problem with mainframe C.A.I. units. It is also very easy to develop programs which follow the question-answer and menu driven logic used by most C.A.I. units. Finally, there are techniques now available which make it simple to transfer files between micros and mainframes.

Basically the concept uses fairly simple logic. Software to perform a number of tasks is written to run on the micro. This program generates a series of files which in turn are used as the C.A.I. unit. In turn the C.A.I. unit generates and sends the command file used by the mainframe computer program.

The basic control file is generated by a "create" module. For example the create module asks the instructor to:

1. Input the student question;

2. Tell how many options there are for this question;

3. Input the description for each option;

4. The instructor is then asked to input the command strings needed by the mainframe program for each of the options given previously.

The create module continues to cycle until the instructor has entered all of the questions for a specific problem. The module then calls for those commands needed to complete the command file for the specific mainframe computer software desired.

The result of using the create module is a set of questions which presents a specific problem to a group of students (i.e. the C.A.I. unit). As the program is executed, it builds a file based on the responses selected by the student. Upon successful execution of the program the student-generated file is combined with the necessary system commands and the final file is then sent to the mainframe for processing. An extension of the program allows the micro to retrieve the output generated by the mainframe but in most cases other options would be followed.

The basic logic is as follows. The software allows the instructor to set up a problem requiring that the student make a series of decisions which determine the analysis of a set of test data. The instructor has complete control over all of the situations offered the student. Because of this the students can be directed to concentrate on data analysis rather than data collection and program execution, thereby spending more time and thought on making decisions about which statistical tests to perform, the types of graphics to use, how to classify data, etc. Moreover, the students can also be assigned the task of analyzing their own decision making as part of the total project.

The principle advantage of this technique is that it reduces the amount of time spent on mastering non-essential information. For example, how to manually perform the calculation of a standard statistical test or key punching a set of user commands for SPSS is often taught at the expense of learning where and when to apply such tests and how to analyze the results. This tedium of learning "technique" often clouds other issues in quant methods or computer cartography courses and has generated charges that these courses lacked content.

The M.M.C.A.I. technique also allows for the use of non-C.A.I. software, (e.g. SPSS, GIMMS, SURFACE II, SAS, etc.), in a very controlled and programmed way. Learning how to use this sort of software in a generic sense is clearly more important than understanding any one program in detail, for seldom does a student take a job at an institution which has the same kinds of software that were taught in his/her classes.

Using microcomputers and mainframe machines in this way offers instructional and research power. Yet as technology changes,the reliance on mainframes for this type of instruction will probably decline. However if the methodology followed in developing micro-mainframe C.A.I. is sound, it should led to similar but stand-alone C.A.I. units.

A TYPICAL COMPUTER CARTOGRAPHY COURSE

Current computer cartography courses spend a large segment of time on non-cartography topics such as introduction to computers and computer operating systems. This is especially true if the mapping system supports multiple data files, etc. By far the largest amount of time is spent on learning the mapping program itself. Most mapping systems have a unique user language and this language must be learned before a student can begin to produce maps. Thus numerous lectures and projects are desigued to teach students the mapping program's language.

Once students know a program's user language they can begin to learn the system's capabilities (i.e. types of maps possible, how to manipulate data, lettering styles (design), pattern types, symbol styles, inset maps, etc.). This requires substantial time and effort since the creation of varying symbols and patterns, for example, calls for detailed formal description in the program's user language. While such descriptions are not hard to put together, they are different than the procedures followed when making the same decisions in manual cartography and are thus unfamiliar to students.

The creation of data bases is another important area of computer cartography. Creating such data sets or using those generated by others requires that students understand concepts as well as practical applications. GBF's and statistical data sets are required of all computer mapping systems. While instructors can supply data sets, students must understand the logic of their organization and construction if they are to use computer mapping systems once they leave the university. However in many computer cartography courses, time spent on learning the mapping program limits data set construction exercises, with the building of a data set focusing on a single program's requirements or revolving around the generation of a very simple set of data.

Commonly a computer cartography course concludes with a final project which is often used to test the students' knowledge and use of a particular mapping system. Two common types of projects are:

1. Students are asked to demonstrate a program's capabilities by producing a series of different maps using various patterns, letter styles, symbols, etc. or;

2. Students are given a data set (GBF and statistical) and asked to solve a problem or illustrate some spatial relationships.

Upon completion of the final project and other work, most students successfully matriculate the course. Yet just what has the student learned about computer cartography when large amounts of time are spent on learning a specific mapping program's user language and how to use that program's mapping and data manipulation capabilities? In many respects it is akin to teaching different lettering methods in manual cartography (i.e. Leroy, transfer lettering, headliner, etc.). It is necessary to know about such techniques but they should not become the focus of a university level course.

Because of the requirements of the typical computer cartography course students often become so concerned with learning the mapping program that they lose track of what the program can do (i.e. allow the user to map and manipulate data so as to solve problems and illustrate spatial relationships) and how the software is logically constructed.

USE OF MAPPING PROGRAMS IN A PROBLEM SOLVING WAY

A basic introductory computer cartography course should satisfy at least two objectives:

1. Prepare traditional students in the use of the mapping systems so they can incorporate them into their research and problem solving situations;

2. Provide an introduction for students who wish to do research and development in computer cartography.

This paper does not deal with the second objective. But neither of these two objectives can be satisfied if students spend most of their time simply learning how to use a mapping program as is the case in many typical courses.

A much better approach to the first objective would be to demonstrate how a mapping system can be nsed to improve on an otherwise well developed research methodology. Better yet might be to teach students how to construct a research methodology around computer applications techniques. Either approach would be supplemented with materials on user languages for mapping programs, data set logic, and system design theory which would serve to meet the second objective.

Tests or sample data sets are a common way to demonstrate a mapping program's research capabilities. Oftentimes these data sets, including a command file needed to run the mapping program, are given to the student. The student is then asked to modify the command file so as to modify the test data and the resulting maps. This method can produce satisfactory results but it may also create problems if the changes to the command file are complicated. In such cases, the students either have to learn the program's command language or follow very detailed directions.

A very obvious extension of this teaching methodology would be to combine it with the M.M.C.A.I. logic described earlier.

THE UNIT

A M.M.C.A.I. unit, from a student's point of view, might use the following pattern. The student would receive a handout and a floppy disk containing the program for that problem. The handout would contain directions on how to run the program and certain other details about the program and project.

The project begins with the execution of the program. In this very general example, a simple spatial analysis project is presented. Initially the student is asked to prepare a set of maps, coupled with written explanation, which analyze the spatial relationships of four social-economic variables of their choice but within the limits of the program.

Following the short introduction, the student would have to make a series of decisions which relate to the project. For example the following options might be offered:

1. Which area do you want to analyze;

2. Select the data for this map;

3. What type of map do you want to make;

4. What data classification method do you want to use (if needed);

5. Do you want to manipulate your data;

    a. Combine your 1st variable with others;

    b. Generate percentages;

    c. Create densities;

6. Input labels (i.e. titles, etc.);

7. What style of symbols do you want (if needed).

The project could be much more complicated than the outline above. For example, the selection of data type could offer sub-sets of data such as age breakdowns for population and the data manipulation section could offer all of the available mathematical and logical functions.

The program would limit the student map construction to a set number of maps, not enough to prevent experimentation but enough to discourage the use of the shotgun research methodology. The program could also monitor the progress of students by keeping track of how long it took to make certain decisions, to generate one or a set of maps, and to complete the computer part of the project. The disk containing the program and the monitoring information would be turned in as part of the assignment.

CONCLUSION

Part of the programing logic presented here has already been tested in a mainframe C.A.I. program called SPHERE. So too has the microcomputer command file building and the file transfer logic necessary for M.M.C.A.I. All of the work completed up to now suggests that the logic of M.M.C.A.I. is exceedingly implementable. What remains to be done is to test M.M.C.A.I. in a real life classroom situation.

THE MICROCOMPUTER IN UNIVERSITY CARTOGRAPHIC TEACHING

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ABSTRACT

The microcomputer has become an increasingly available and sophisticated tool for both teaching and research. In my remarks I wish to consider my experiences using Apple 2 microcomputers in introductory courses in quantitative methods and computer cartography. I especially wish to emphasize the kinds of available software and the student responses to work with microcomputers.

At this time general purpose geographical information systems are not readily available for teaching use with the microcomputers. Such systems do exist, and the AP-GRID/GRID-APPLE system is very useful; unfortunately, it is very expensive and requires a considerable backup of digitizers and hard disks. A more economical package, Urban Data Management Software, designed for the United Nations for use with the Z-80 processors and CP/M systems is also available. The real limitation for the Apple user is the requirement that each machine have a Z-80 card.

Students are very responsive to the microcomputers in laboratory situations. Much of the tedium of computations and drafting are removed from the experience. While it can be argued that these experiences of a traditional sort are necessary to understand the underlying processes of map creation and data management I doubt that traditional dullness of both quantitative methods and cartography are necessary conditions for understanding. My students have not been programming, with few exceptions. In those few cases the microcomputers have been an excellent avenue for introductory graphics programming. Rather, my students have been software users who have been introduced to quantitative and cartographic concepts through the microcomputer. The immediacy and interactive character of the microcomputer are very attractive characteristics. Even the awkwardness of movement from one software package to another is not a serious disadvantage in the classroom. It is easy for the instructor to set up meaningful laboratory modules and available software distinctly facilitates teaching.

Still, the advent of truly integrated geographical information systems for the microcomputer will enhance an already very positive teaching situation. The microcomputer is now a very useful teaching tool, and looks to become an even more attractive device.

MAPPING WITH MICRO-COMPUTERS IN THE ELEMENTARY SCHOOLS: A REPORT ON THE DEVELOPMENT OF A RESEARCH STUDY.

by

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In this paper the authors describe a research and development programme designed to explore the potential of micro-computers as a means of teaching map concepts and skills to children in grades 2 to 5. Although the research design will be outlined, the focus of the paper will be upon the map reading, map interpretation and map making activities proposed for development and assessment in this project. The cartographic skills and concepts discussed include: scale variations and changes, the measurement of distance, angles, rotations and transformations, changes in perspective, map symbology, distribution patterns, digitizing, projections, pen-up/pen-down procedures, the four colour conjecture, recursive and heuristic procedures, spatial search and pattern recognition. Problems and opportunities relating to the extending and supplementing of the computer language LOGO to meet the needs of this study will be discussed as well.

EFFECTIVE EDUCATION FOR SPATIAL DATA HANDLING: THE CONTINUING QUEST FOR A VIABLE SOLUTION

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The rapid development of computerized, spatial data handling has left undergraduate and graduate instruction in most institutions of higher education far behind. Graduate education, because of its inherent flexibility, has adapted in some cases but nearly all undergraduate programs of instruction fail to supply students with an adequate background for careers in this field.

This paper examines the nature of the demand for graduates generated by developments in this area and provides specific suggestions for patterns of curriculum development which will mesh with those developed by the Association for Computing Machinery (ACM) for computer science undergraduates. The question of laboratory facilities for teaching is examined as well and suggestions presented for a powerful but low-cost configuration which will meet most anticipated needs.

COMPUTERS AND CARTOGRAPHY AT MEMORIAL UNIVERSITY OF NEWFOUNDLAND

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ABSTRACT

In September of 1981, the Department of Geography at Memorial University of Newfoundland introduced a new major program in cartography at the undergraduate level. Consisting of both B.A. and B.Sc. options, the new program joined three other areas of concentration offered within the Department. Following discussions with the Computer Science Department in 1982, joint Major and joint Honours programs in Computer Science and Cartography are also to be offered, commencing September 1983. The overall structure, content and philosophy of these programs is outlined, followed by a more detailed description of the introductory and advanced courses in computer mapping, and how they approach some of the problems of teaching modern map making at the interface of computers and cartography.

EDUCATION RESPONSES TO THE FUSION OF CARTOGRAPHY AND REMOTE SENSING

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ABSTRACT

The imminent fusion of remote sensing and cartographic science raises compelling questions concerning responses in educational programs. This paper examines conceptual and technological affinities of computer-assisted cartography and digital image processing as they relate to education program structures. Challenges arising from declining half-lives of technological knowledge are considered. Foundation structures require careful planning and continuous scrutiny to ensure that they are capable of supporting specialized programs as well as "lifelong learning." Conceptual models to guide the vertical development of programs arising from the fusion of cartography and remote sensing will be outlined.

THE DESIGN OF MAPS FOR TELIDON

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ABSTRACT

Telidon is a videotex system developed by the Department of Communications in Canada. As Telidon is an alphageometric system it has good graphic capabilities. Videotex systems allow the display of maps in a remote data base directly on the home T.V. set using the telephone or cable as a communications device. This technology provides a new opportunity for cartographers but if this is to be realized then some new design challenges will have to be met. To be effective, map design will have to take into consideration the nature of the new technology and the viewer's response to the images displayed. This paper will discuss some of the issues in map design especially those relating to the sequence in which map elements are displayed.

INTRODUCTION

The interactive design and display of maps utilizing the computer is not new but utilization of such systems has been limited by both cost and accessibility. Cost factors have been increasingly reduced by the introduction of microcomputer technology and, together with the advent of videotex technologies, this is increasing potential public access to maps in digital form.

VIDEOTEX TECHNOLOGY

Videotex is a generic term for systems allowing information retrieval and display in graphic or textual form on a video display screen such as a home television set. Videotex technology was developed during the 1970's (Woolfe 1980) and there are two quite different approaches used to describe images; alphamosaic and alphageometric. The utility of videotex technology for cartography is largely determined by which of these two approaches is used.

The alphamosaic approach is character oriented and displays are built as sequential pieces of a picture consisting of 24 rows of 40 characters. Maps and other graphics are constructed from specially identified coded graphic characters fitted together in a mosaic of picture components. Maps produced on such systems are crude and resemble the early line printer maps in their "block-like" character. The greatest resolution possible is 2 x 3 picture elements. (Figure 1).* The display terminal resolution must usually be specified in advance of displaying the data. Alphamosaic approaches are of limited utility to modern computer cartography.

The alphageometric approach is that developed and used in the Telidon system (Bown et al. 1978). Picture Description Instructions (P.D.I's) are used as a coding protocol. Graphics are described by combinations of geographic primitives such as lines, circular areas, rectangles and polygons and both these and the drawing and status commands are broadly similar to the approaches used in many computer assisted cartography programs. The Telidon terminal uses a bit map display memory and every pixel on the display has a corresponding location in the display memory. Unlike various alphamosaic approaches, Telidon can be displayed on any terminal regardless of construction or resolution without the need for special instructions. The current resolution of the P.D.I. codes is 960 by 1280 pixels which is well in excess of the existing home T.V. sets on which Telidon pages are being displayed which have a resolution of 240 by 320 pixels. Alphageometric approaches clearly hold out more promise for computer assisted cartography. (Figure 2).

A major barrier to the construction of maps on videotex systems has been the slowness of input techniques. When Telidon initially came on the market in 1978-79, input was almost exclusively by use of the light pen. This was, and is, totally inadequate as a means of entering maps and has since been replaced by the use of graphic tablets but input is still slow. By early 1981 software interfaces between Telidon and computer mapping programs such as Gimms (Waugh 1980) had been written (Witiuk, Piamonte and Stewart 1981) which allowed the creation of thematic maps on Telidon directly from existing digital data. Interfaces have also been written between Telidon and micro-computer mapping programmes such as M.I.G.S. (Prashker and Taylor 1983). Input techniques still remain relatively slow.

P.D.I. codes can be extended and the Department of Communications is now developing Picture Manipulation Instructions (P.M.I's), and scanning techniques are being explored for input. These developments may speed up the input of map and other graphics. Extension of existing P.D.I. codes and the introduction of P.M.I's will add considerably to the cartographic potential of Telidon as additional manipulations such as scale change, rotation, transposition of images and interactive editing will all be possible. Research is also underway to add a sound element to accompany the displayed image.

In technical terms there are several computer mapping systems which can produce maps more effectively than Telidon, but none which can give the same possibilities for

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*The figures for this paper are in the form of colour slides. The high costs involved make the reproduction of these colour illustrations in the Proceedings impossible.

wide distribution. The hardware required for Telidon consists of a home T.V. set, a telephone or cable hook up, and a decoder. The only element not present in most North American homes is the decoder which in June 1983 cost approximately $1,200. This cost is likely to decline and several manufacturers (e.g., Apple) are already producing videotex boards for the home micro-computer. If interactive videotex systems are going to be in many homes within the next five years, as many authorities are predicting, then it is important that cartography be part of this development. Videotex systems were not specifically designed for cartography and their use and general public acceptance will depend on uses such as shopping and banking from the home rather than on the public use of maps and other geographical information. Such information will have to compete with other subjects on videotex data bases but the potential exists, possibly for the first time, of the widespread distribution of map and other geographical information in digital form. This poses new communication and design challenges.

MAP DESIGN FOR VIDEOTEX

Cartographers have not given much attention to the design and communication aspects of maps on video screens. Videotex provides us with a new opportunity but our knowledge in this area is very limited. New solutions will have to be found and existing research on cartographic communication and design will have to be extended to provide these solutions.

Communication by a T.V. screen is inherently different from that of a published map. This is caused both by the nature of the process of T.V. transmission and by the brain's response to it. The T.V. transmission process is unlike any other medium. There is no actual picture being projected. Television works by electronic scanning in which tiny dots of light are "fired" one at a time across alternate lines of the screen. An image is created every thirtieth of a second - the time taken for two complete "sweeps" of the screen. At any one moment, however, there is never more than one dot of light "glowing" on the screen. We "see" an entire image because the brain fills in and completes 99.99 per cent of the scanned pattern each fraction of a second although the viewer is usually unaware of this. The only actual picture that exists is in the mind of the viewer.

Although each individual viewer has a different cognitive make-up, it has been suggested that T.V. is the special province of the right hemisphere of the neo-cortex of the brain. The neo-cortex is divided into left and right hemispheres connected by nerve pathways. The left hemisphere tends to deal with sequential logic or rational thinking whereas the right hemisphere recognizes spatial relationship and grasps whole contexts. It excells at tasks such as the completion of patterns. Research has suggested that in watching the T.V. screen the left hemisphere often "tunes out", which it does not do for the printed word or image, although this may not happen in the case of all viewers.

This may be due to the nature of the T.V. transmission process described above which is suited to the right hemisphere's mode of processing information through the completion and recognition of patterns. There has also been speculation that the left hemisphere quickly becomes habituated to the scanning dot of the T.V. transmission process and, lacking any need to respond analytically to it, decreases functioning and goes into a non-critical mode.

What is clear is that we are dealing with a very different form of communication than the printed map or the colour slide. Behavioural research on cartography and videotex is very limited. Mills (1981), utilizing the well-known studies by Arneim (1975) and Thorndyke and Stasz (1980), argues that the most effective maps on videotex may be those that distort reality and that fixed cognitive capacities such as visual memory ability may affect people's ability to learn from maps. These studies however are not based on empirical evidence drawn from maps on videotex.

In designing maps for Telidon, notice has to be taken of the nature of Telidon technology and the nature of the transmission devices and processes. These have both advantages and limitations. In addition we must have a greater knowledge of the cognitive capabilities and responses of the viewers. Design research is in its infancy but at least we have learned what <u>not</u> to do. It is not satisfactory to display existing digital maps on videotex. As a minimum substantial modification has to take place and I am now convinced that new design solutions must be found. The emphasis will certainly have to be on what Jacques Bertin (1983) calls "map to be seen" rather than "maps to be read."

There are numerous design challenges to be met and the Cartographic Research Unit at Carleton has been concentrating on two such challenges; the use of colour and the use of sequencing.

COLOUR

Initially Telidon was limited in the number of colours available but the enhancements made to meet the NAPLS standards in 1982 have dramatically increased the colour choice available. (Figures 3-8). A choice of any sixteen colours or shades of the same colour can be made. There is a large literature on the use of colour, but again perceptions of colour from a vibrant image such as a video screen are inherently different from perceptions of other kinds of images. The economics of publishing have increasingly restricted the use of colour in recent years (as these Proceedings show) but with the advent of videotex these cost constraints have been significantly reduced. Some imaginative figure/ground relationships can be worked out (Figures 9-12) and the use of shades of one colour can give the impression of a "continuous choropleth" map as suggested by Waldo Tobler (1973) some years ago.

Colour and figure/ground relationships are also important in relation to the use of text in Telidon. Where text is used extensively, the effect on the viewer's attention span and eyesight can be quite important. Viewers can rapidly tire of certain colour combinations when viewing text for long periods of time, consequently the use of colour for one or two pages may be quite different from that used for longer sequences. Research has suggested that magenta on green, or light blue on blue (Figure 13), are effective colour combinations for longer sequences.

SEQUENCING

Sequencing refers to the order in which elements of a map or other graphics appears on the screen. The Telidon P.D.I. interpreter can access display memory at random and therefore the order of the appearance of the different elements of the map are in the hands of the designer. Maps can therefore be "constructed" on the screen with considerable flexibility. The sequence in which different parts of the map appear will clearly influence the communication process and the challenge to cartographers is obvious. If video images appeal to the right side of the brain as was suggested earlier, then pattern completion and recognition is an inherent cognitive skill to which sequencing will appeal. I consider sequencing the most exciting of the design challenges facing map design for Telidon as it can take into account the nature of Telidon technology, the nature of the transmission device and the cognitive abilities and responses of the users in a comprehensive way. Careful design for this new medium could dramatically improve map communication.

The Telidon instructions allow a built-in wait command so that the designer can control the length of time and attention drawn to a particular map element as the map is being constructed. Telidon also has the capability of making any element on the screen "blink" or "flash", again allowing the map designer to draw attention to any map element or series of elements in turn.

As Telidon is interactive, the viewer can also decide if he or she wishes to cause the construction of the map to be stopped at any time by pressing the pause button on the keypad used to select and control access to pages in the Telidon data base. The viewer can also go forward or backwards in terms of page selection and can abort a page which is found to be of limited interest.

The map designer can also include textual explanations and descriptions during the construction of the map. Mills (1981) argues that more effective use of text can enhance a map or any other graphic by setting the context in which the graphic can be better understood. Text segments could be an important part of the sequential construction of maps.

In essence, the cartographer is involved in a "graphic dialogue" with the user and consequently must give very careful thought both to the substantive information that the map is designed to impart and to the way in which that information can best be communicated. The cartographer, to effectively utilize this new medium, must understand the information to be displayed as fully as possible if an accurate message is to be conveyed.

Experience so far suggests that in general the following sequences for the presentation of any map should be followed:

1. The title of the map should appear. (Figure 14)

2. Keys, legends and other important annotations should be displayed. (Figure 15)

3. The map outline should be displayed together with the substantive geographic information the map is designed to portray. Here the order in which various map elements are displayed or to which special attention is to be drawn is important. In a choropleth map for example, the extreme class intervals i.e., highest and lowest values, might be displayed first with the intermediate values being displayed later. (Figures 16-18)

4. Tertiary annotation should then be displayed.

5. System and routing instructions should then follow.

The assumption made in this suggested procedure is that the communication process will be most effective if the map is built up part by part in a particular way or series of ways. The viewer is finally presented with the "gestalt" after following the construction of the map in the order and at the pace prescribed by the designer. There is, of course, an entirely different approach which could be used. This involves presenting the user with the entire map as quickly as possible and in no special order and then disaggregating the various substantive elements. Some of you may have seen a current T.V. commercial for life insurance where a graphic of a family standing in front of their house is altered by the removal of the schematic diagram of the father, followed by the removal of the house. The message communicated is effective. For some maps dealing with subjects such as loss of farmland or declines in production this might be more effective. These two approaches will have to be tested scientifically in order to measure their effectiveness in communicating information before definitive conclusions can be drawn.

So far this paper has concentrated on the design and communication aspects of maps for Telidon but it is clear that there are implications for both the design of cartographic data bases and of computer mapping systems, and the broad field of cartographic education. Existing cartographic data bases have not been designed to respond effectively to videotex systems and consequently will have to be redesigned before they can be interfaced with videotex systems. Many computer mapping systems may also require modification to increase their utility for videotex.

The educational implications for cartography are also significant. Videotex provides us with a powerful new teaching and learning tool. Currently Telidon is quite slow in terms of the speed at which it draws maps relative to other computer mapping systems. This however can be turned to advantage in a school classroom where students are learning about maps or are utilizing maps in the learning process. There are also implications for the education of cartographers. It is clear that we will have to add a much greater knowledge of cognitive psychology to our education programmes.

CONCLUSION

Telidon technology provides us with a new stimulus to cartographic design and may lead to an increase in our awareness of the need for a "new cartography" in which the linkage between computer assisted cartography and the new communications technologies are more carefully examined.

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COMPUTER MAPPING

and the

TELEVISION WEATHER REPORT

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ABSTRACT

Profound changes are taking place in the way weather forecasts are being presented on television. The meteorologist is no longer restricted to dusty chalk, smudged boards, and childlike abstract drawings to communicate the dynamics of the weather patterns. The marriage of television and modern computer graphics adapts itself logically to modernizing the medium of the message. The wide reach of weather forecasting to the general public at large represents a most important societal contribution of computerized cartography.

WHEC-TV Rochester, employing a McGinnis-Skinner computer graphics system run on a Hewlitt Packard computer, pioneered computer-displayed weather maps for the television report in New York State. A wide variety of displays are possible, including speeded up and slowed down sequences, colour enhanced cloud and satellite images, contour maps of temperature, and so on. Some of the types of maps possible are never, or rarely, used, and some of them have a great deal of potential for such things as news broadcasts.

AUTOMOTIVE NAVIGATION SYSTEMS AND SUPPORT INFRASTRUCTURES

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ABSTRACT

The first on-board automotive digital computer was introduced by General Motors for engine spark control in 1977. In 1981, all domestic General Motors cars incorporated microcomputer engine controls. Since then, there has been a rapid acceptance of microcomputers by automotive manufacturers world-wide. The last six years have seen many innovative applications in production automobiles.

Microcomputers now routinely control over twenty engine functions, shift transmissions, control instrument panel displays, adjust suspensions, speak voice warnings, listen for and execute spoken commands, memorize power seat positions, tune radios, maintain interior climate, monitor maintenance, calculate trip parameters, and perform navigation computations. Automotive navigation systems are not "science fiction." Today, much engineering effort is being applied to take the ideas of fiction and apply the principles of science to realize cost-effective mass-market products. These particular products will have very significant societal impact.

All types of automotive navigation systems have two essential items in common. First, the human interface has to be ergonometrically designed so as to be easily used by the lay person. And ultimately, map data and information has to be loaded into, acted upon, and displayed by the navigation computer. At present, no suitable map data base has been identified to readily and cost-effectively support automotive navigation systems.

The state-of-the-art of world-wide automotive navigation systems will be examined. Current navigation products will be compared. Recently shown future concept cars will be reviewed from the perspective of future navigation requirements. Finally, map data base infrastructure requirements will be explored.

AN EXPERIENCE WITH THE ABSORPTION, DEVELOPMENT AND DISSEMINATION OF SPATIAL INFORMATION HANDLING AND MAPPING SYSTEMS

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ABSTRACT

The paper describes the experience of the Urban and Regional Systems Group-ASUR of the São Paulo Technological Research Institute, in the area of spatial information handling and mapping. The group's role is to study, absorb, develop and disseminate these technologies to governmental and private agencies involved in urban and regional planning. Starting with software developed elsewhere, the group initially sought the development of a comprehensive system. The variety of applications faced has induced the pursuing of a different strategy that was defined vis-a-vis the stability of the application's nature, purpose, urgency resource availability, continuity, user maturity, spatial units, etc... The new strategy presupposes that technology transference can occur at various levels: conceptual, methodological, basic programs, systems and services. This meant, to start with, the establishment of a set of 230 compatible standard FORTRAN subroutines. The specificity of applications and the scarcity, and variety, of graphic hardware suggest that high modularity and thorough method and program documentation may be the key determinants of the strategy success away from comprehensive and expensive turn-key systems.

INTRODUCTION

The "Instituto de Pesquisas Tecnológicas do Estado de São Paulo-IPT" is the State of São Paulo (Brazil) research agency; it is aimed at carrying out technological research and development, technology dissemination and know-how consolidation.

The Urban and Regional Systems Group-ASUR started up in 1977 to meet the increasing needs of applying quantitative methods to urban and regional problem solutions. The group's main objectives are:

- research, develop and disseminate methodologies that contribute to the solution of urban and regional problems;
- supply technical support and specialized services to state agencies and public or private institutions involved in urban and regional planning and administration;
- establish and develop know-how in quantitative methods applied to urban and regional problems.

The group's activities have concentrated mainly in the areas of spatial information systems, urban and regional modelling and urban and regional economy.

In the area of spatial information systems, the group's main role has been to study, absorb, develop and disseminate these technologies to governmental and private agencies involved in urban and regional management and planning.
This paper is aimed at describing ASUR's experience in the area of spatial information handling and mapping which started with the plan of establishing a comprehensive, general purpose software package and later on switched into a new strategy.

INITIAL ACTIVITIES

The group started its activities implementing software developed elsewhere. Typically, the programs were well documented for operation but were deficiently documented about their methodologies. Having a substantial amount of software in this condition and lacking enough resources, it took nearly two years to fully implement an useful set of packages.
That slow and complex job of untangling the programs resulted highly educative; the necessary conceptual and methodological comprehension lead to a very good grasp of its potential applications and main limitations. As a result, research areas, still methodologically obscures, were identified. This fact together with formal studies on spatial information handling ended up pushing forward the development of new programs.
By 1979, a substantial capability of spatial information handling and mapping was already settled and fully utilized to support many ongoing projects at IPT. The software capabilities included:
- retrieving, handling, storing and mapping data referred to points, lines and areas;
- mapping variables representing flows between zones;
- converting polygonal representation of areas into grid representation;
- intersecting zoning systems represented by polygons, assigning convenient codes to resulting polygons;
- elaborating tridimensional histograms and surfaces viewed from various angles, distances and elevations.

Also, auxiliary procedures, like those for data encoding and organization have been developed.

CURRENT APPLICATIONS AT IPT

The variety of spatial information handling and mapping applications at IPT is a direct consequence of the diversity of activities carried out at that Institute. Some typical projects that required support from ASUR were the following:
- Prospective Use of Biomass Energy
  - coding and digitation of municipal contours within State of São Paulo
  - aggregation of municipalities into administrative subregions, administrative regions and Agricultural Regional Divisions
  - plotting maps with pillars representing the evolution

of sugar cane, soybean, wheat, castor bean, coffee and banana plantations and pasturage within the Agricultural Regional Divisions, from 1968 to 1978 (figure 1)

- plotting comparative histograms of above mentioned plantations from 1968 to 1978 for every Agricultural Regional Division (figure 2)

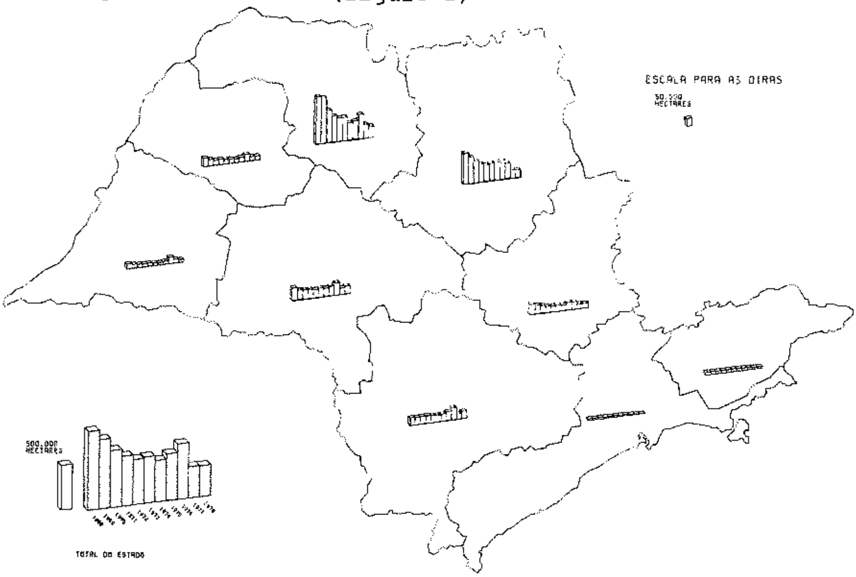

FIGURE 1 - Map showing the evolution of cultivated area for rice plantation in different Agricultural Region Division.

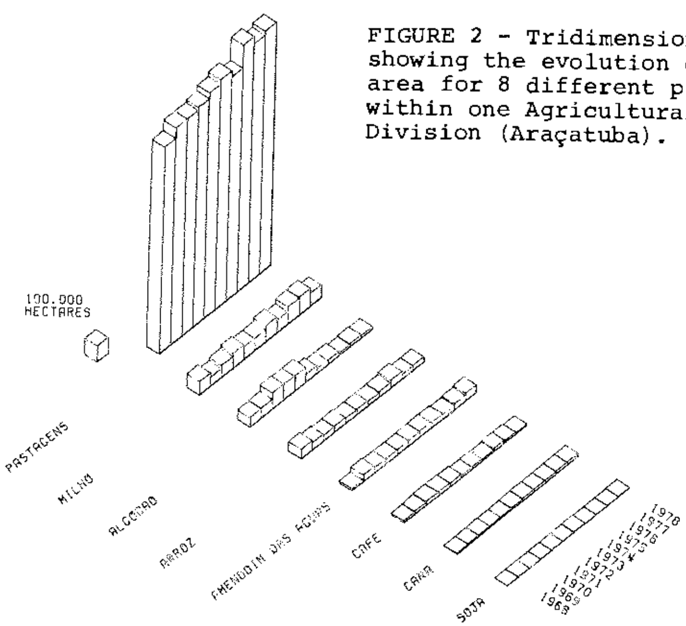

FIGURE 2 - Tridimensional histogram showing the evolution of cultivated area for 8 different plantation within one Agricultural Regional Division (Araçatuba).

- coding and digitation of highway and railway networks in the State of São Paulo
- plotting traffic flow and capacity in the highway network of São Paulo State (figure 3)
- plotting the grid representation of São Paulo State, shading the squares according to reforesting intensity and locating the main processing plants (figure 4)

FIGURE 3 - Traffic flow in São Paulo State higway network.

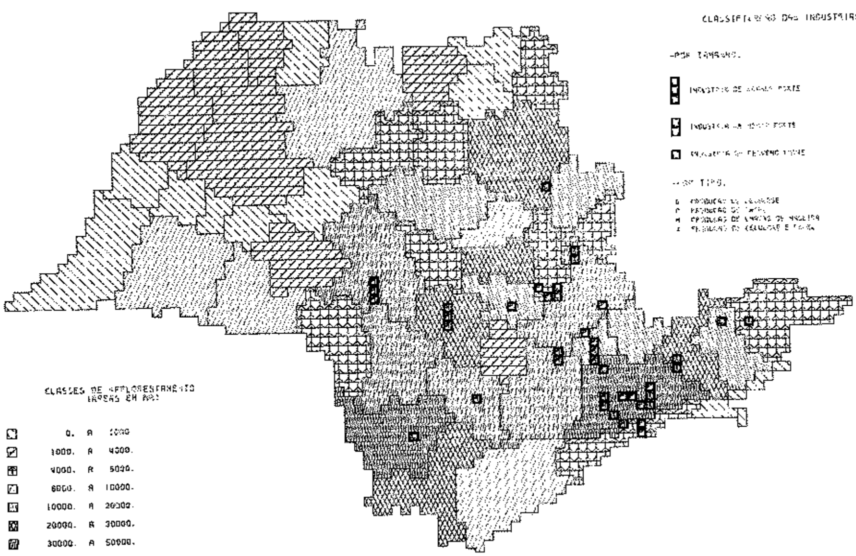

FIGURE 4 - Map showing reforestry classes and main plants within State of São Paulo.

- Transportation Planning System-SPT
  - codification and digitation of municipal boundaries of northern Paranã, southwestern Minas Gerais, southern Goiãs and Mato Grosso do Sul
  - codification and digitation of zones for the State of São Paulo transportation planning system
  - aggregation of zones
  - plotting of zone sets.
- Decision Models for Oil Exploration
  - codification and digitation of geodesic square grid and southern state boundaries
  - plotting the estimated probabilities of oil existence on Paranã river basin (figure 5)

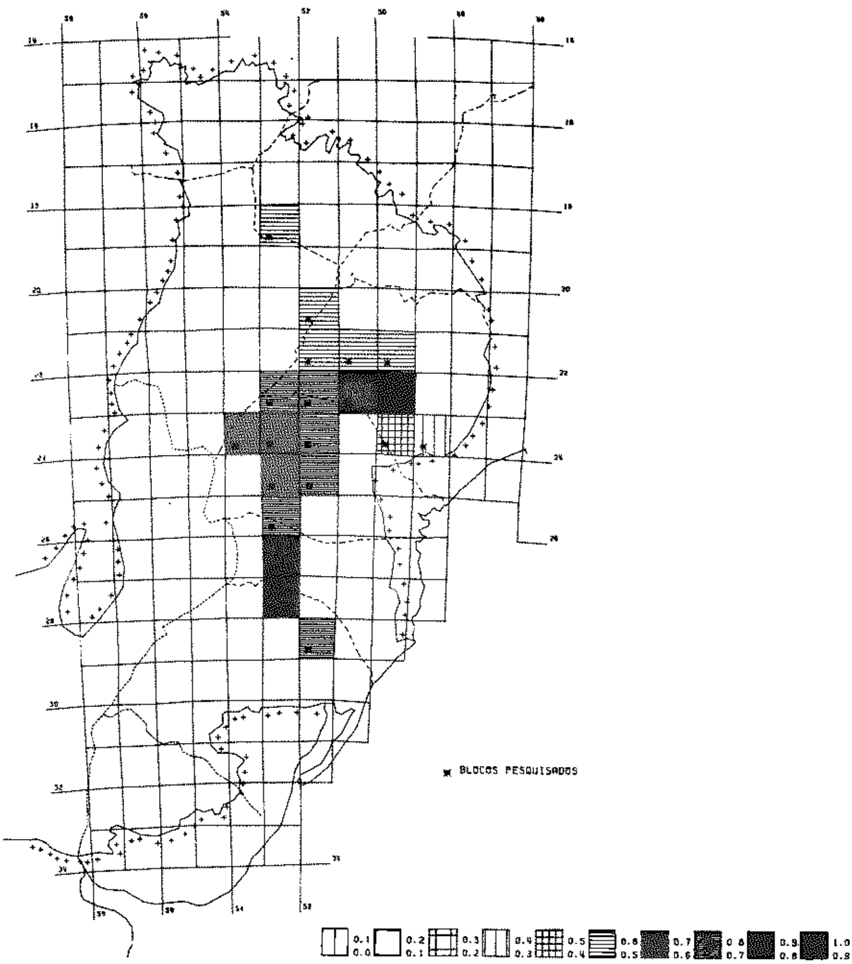

FIGURE 5 - Estimated probability of oil existence.

- Land Revenue and Labor Reproduction in São Paulo
  - aggregation of sub-zones origin-destination into macrozones of transportation and land use model

- plotting of variables (family income, land value, etc.) for every group of zones (figure 6).

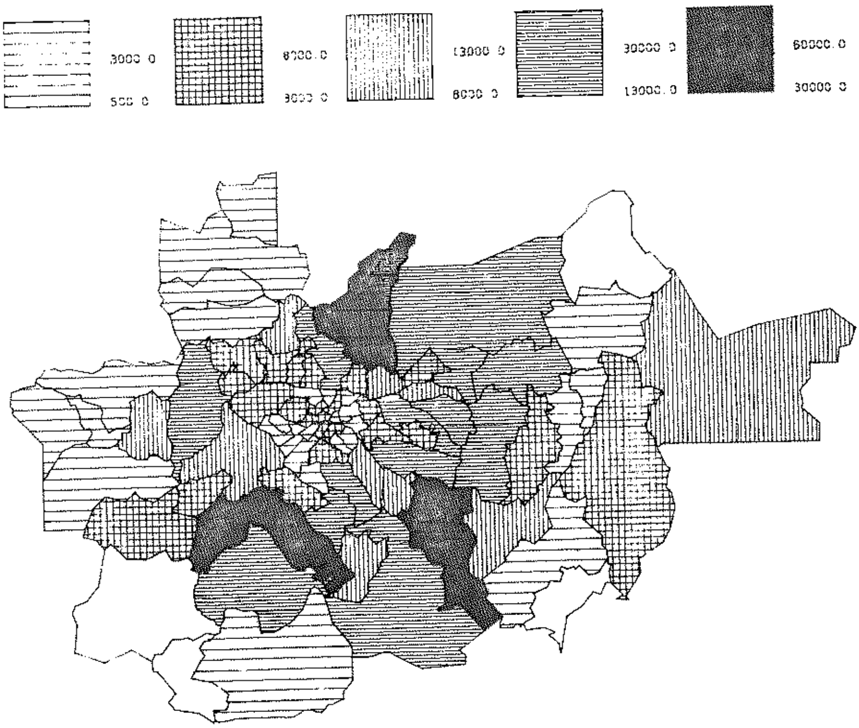

FIGURE 6 - Map showing the number of families living in own residences.

- Methodology for Urban Spatial Information Integration
  - codification, digitation and plotting of census tracts in São Bernardo do Campo
  - polygon aggregation
  - square grid representation of census tracts and their aggregations
  - punctual and square grid representation of blocks and streets
  - point-in-polygon, line intersections, etc.
  - plotting of streets, block centers, census tracts and their aggregation
  - random generation of zoning by aggregation of census tracts (figures 7 and 8).

ANALYSIS

The variety of applications at IPT, due to the diversity of activities carried out, is not typical of spatial information handling and mapping technology users. However, the experience acquired from the applications, including those mentioned above, brought on a new approach to spatial information handling and mapping systems.

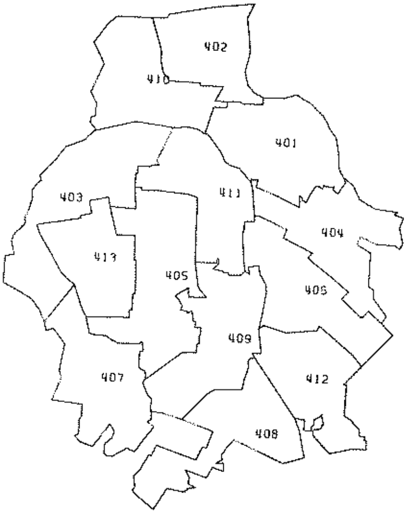

FIGURE 7
Random aggregation of census tracts into 13 zones.

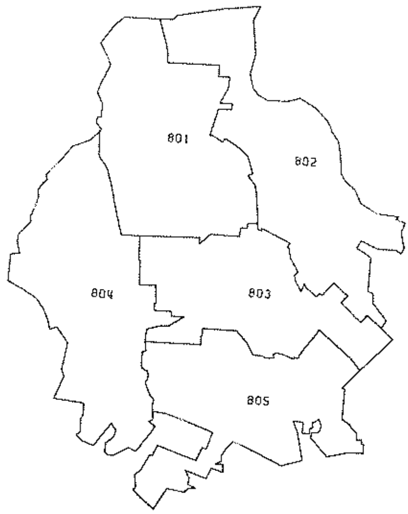

FIGURE 8
Random aggregation of census tracts into 05 zones.

It is very important to consider the many characteristics that reflect any given application; the major aspects are the following:

- objective: the application's objective may range from simple data display systems to very complex spatial information operations;
- nature: the application's nature involves the many different types of processes required like digitation, plotting, etc.;
- spatial units: each application deals with a set of spatial units, e.g., the municipal boundaries for a state agency;
- product destination: each application needs different kinds of output and may include simple plottings, slides, photoliths, etc.;
- display requirements: there are many ways to display spatial information, like thematic maps, shadings, bar diagram surfaces, etc.; each application has its own set of display requirements;
- output urgency: the urgency ranges from "immediate" answer to long period waits;
- available resources: the user has limitations on human resources, hardware, financial resources, etc.;
- continuity: the user may need a single run to get a few outputs or may need permanent processing of spatial information.

These characteristics are usually rather stable for most applications. Therefore, a comprehensive, general purpose, software package that would allow the most assorted operations, and would fit the needs of every user, would certainly penalize them either in processing time or hardware requirements or financial cost. On the other hand, to keep on the shelf one special system for every possible use would be excessively costly.

The key to any application success seems to be the adequacy of the selected technology to the user's environment; the failure of an application imputed to instability of available resources, for example, is likely to be due to improper technology selection which did not consider that aspect.
The importance of aspects like technology adequacy and organizational stability has been realized early in ASUR's existence and a different strategy has been pursued.

ASUR'S APPROACH

Considering IPT's dissemination of technology role, various levels of technology transfer have been set:

- conceptual: covers the very early phase of a project or of a technical group development plan; it involves the learning and organization of basic concepts related to the problem area and to information system technology;
- methodological: covers the articulation of concepts into procedures aiming at certain goals;
- basic software: covers the elements of the methodology formulated as computer programs. This basic software would reflect the basic concepts and basic methodology;
- systems: covers the set of procedures, computer programs and files to achieve certain goals;
- service: covers any type of service received either through specific consultancy or as whole project contracts.

These levels cover a broad spectrum of technology transfer; the users may choose the most adequate level according to his interests or needs; ASUR's operation comprises all the above levels.
At conceptual level, symposia have been promoted (IPT 1981 and IPT 1983). The Simposium on Urban and Regional Information Systems was held on August, 1981 and brought together 115 specialists from 14 brazilian states and eight foreign countries. In addition, courses have been taught at the University of São Paulo both on regular and extension basis.
At methodological and program levels, texts with procedures and software are transferred. To facilitate the task of meeting each user's needs, a high software modularity was achieved by developing and implementing a set of 230 compatible subroutines, written in standard FORTRAN. These subroutines perform the basic functions of spatial information handling ranging from elementary to very complex operations; Appendix I describes that software. Every subroutine is fully documented in relation to program development and use; furthermore, a detailed description of the methods used is provided as well.
Finally, systems and services are developed and provided on demand; as an example, a water network information system (RODRIGUES 1983) has been designed, developed and implemented by IPT for the São Paulo Water Authority-SABESP on a US$ 1.5 million contract.
The new strategy ASUR has been following and the highly modular software available have facilitated the task of meeting each user's needs. It is relatively fast and easy to assemble a system tailored to the applications of any

user; moreover, a substantial gain in efficiency has been attained by designing systems according to the user's available resources (like hardware, personnel, etc.) and, more important, its organizational stability.

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APPENDIX I

The set of 230 subroutines developed and implemented comprises 15 subsets that are described below:

ASUR/APG: this subset contains subroutines for basic support like data input-output.
ASUR/CPT: subroutines for operations involving point sets.
ASUR/CSG: subroutines for operations involving segments, polygonals and networks.
ASUR/CPL: subroutines for operations involving polygons and zoning systems.
ASUR/CRT: subroutines for operations involving grid systems.
ASUR/CTR: subroutines for operations involving tridimensional perspectives.
ASUR/PB1: subroutines that handle graphical devices (thus letting the system be device-independent).
ASUR/PPT: subroutines that plot points using selected symbols.
ASUR/PSG: subroutines that plot polygonals and networks (including link flows and capacities).
ASUR/PPL: subroutines that plot polygons or zoning systems.
ASUR/PSM: subroutines that draw shadings on polygons or zoning systems.
ASUR/PRT: subroutines that plot symbols within squares (in grids or isolated).
ASUR/PTR: subroutines that plot tridimensional perspectives.
ASUR/PLG: subroutines that draw legends.
ASUR/SIM: subroutines that output graphical representations on the printer.

MIGS: A MICROCOMPUTER MAPPING SYSTEM FOR CARTOGRAPHY IN DEVELOPING NATIONS

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ABSTRACT

The use of computers in Third World countries can be difficult and expensive and problems exist of a technical, political and socio-economic nature which are different from those found in the North American context (Taylor and Obudho, 1979). These general problems have hindered the effective introduction of computer-assisted cartography in developing nations. The advent of the microcomputer is radically altering this situation and as a result new opportunities exist. This paper will describe the MIGS system and consider its utility in a Third World context.

INTRODUCTION

The Microcomputer Interactive Geocartographics System (MIGS) was developed by Steven Prashker of Carleton University, as an alternative to the larger computer assisted cartography programs available on the mainframe computer. The system is composed of a modular set of interactive, geocartographic thematic mapping programs, which produce medium to high quality choropleth maps. The systems capabilities also include several automated features such as scales, legends and north arrows, and a versatile text input and plot subsystem utilizing all of the capabilities of the system's graphic plotter.

The MIGS system is written in North Star BASIC, and is composed of approximately thirty programs, none of which exceed 30K bytes. The system resides on a North Star HORIZON microcomputer, a 64K Z80A based machine, and uses two disk drives to sequentially and randomly access the geocartographic data base. Manual digitizing is performed on a Summagraphics digitizer (30" x 40"), and graphical output is plotted on a Hewlett-Packard 7221A flatbed, four-colour pen plotter. Printed output is listed on a regular line printer device, and interactive messages and prompts are displayed on the terminal screen. Figure 1. illustrates the hardware configuration of the system for this kind of application. The total cost of the hardware involved is under $15000.

SYSTEM DESIGN

The impetus for developing this software package was threefold:

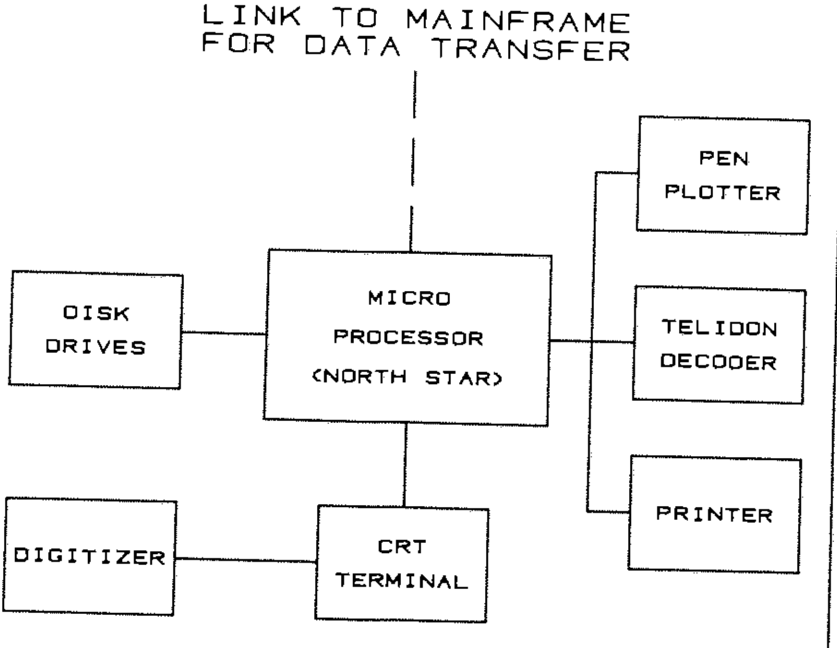

FIGURE 1. HARDWARE CONFIGURATION OF MIGS SYSTEM

1. to implement in a teaching environment, in functions other than a digitizing workstation, a low cost,microcomputer-digitizer-plotter system which was acquired by the Geography Department,

2. to produce a stand alone, turnkey mapping software package that was easy to understand and use by non-technical persons, operating in an interactive mode and

3. to produce thematic maps that are easily tailor-made to the user's specifications.

With this goal in mind, a modular series of user friendly programs was designed which allowed users with no previous programming experience to produce thematic maps. The interactive, stand alone mode of operation was a basic design concept and was implemented throughout all the modules of this user oriented system. User prompts and system messages are displayed on the terminal screen in a simple, comprehensive manner. Locational data is entered from the digitizer, using a menu system, and non-locational data is entered from the terminal keyboard. All data is stored on 5 1/4" floppy diskettes.

The MIGS system is menu driven, with the controller program containing the documentation and main menu. The particular

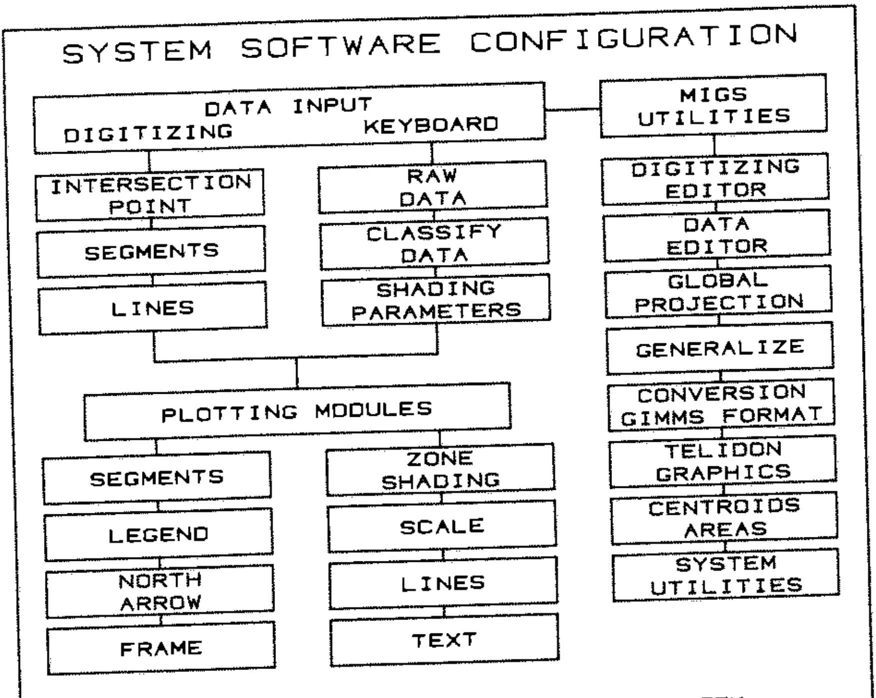

FIGURE 2. SOFTWARE CONFIGURATION OF MIGS SYSTEM

module the user wishes to use is selected from this menu, or from sub-menus. For the novice, a series of HELP documentation is available for the individual program modules. This HELP facility contains an overview of the system and its capabilities, and contains brief explanations on the operation of the selected module. This HELP facility, coupled with the interactive use of instructional messages, is a great aid in guiding the user through the various segments of the mapping system.

CURRENT CAPABILITIES

MIGS is logically configured into three divisions:

Digitizing - Data Input
Utilities - Data edit, generalizing, projection, conversion
Plotting - Graphical output

Figure 2. illustrates the software configuration of the MIGS system.

Currently, MIGS has several facilities for locational and non-locational data input, data output, interactive editing, and data base creation. Locational data is digitized in a format similar to the GIMMS mapping system, using left-right identifiers for the zone segment boundaries. Nodal points are also digitized, with simultaneous output to the graphic plotter for verification. The locational data is then processed, producing base segment and polygon area files. The complete process of base-area file creation is done interactively, with error messages displaying the type of editing, if any, to be performed.

Editing of the locational data base is accomplished by a digitizing-editor software module. Some of its capabilities include:

Addition-deletion of points or segments;
Re-defining segment identifiers; and
Locational correction of nodes

Files are then re-processed to generate correctly edited base and area files.

Non-locational data files are created using a zone data input facility, with the following capabilities:

1. Raw zone data input
2. Data editing
3. Data classification
4. Graphic output parameters

The zone data facility allows a user to classify the raw data into specific levels, up to a maximum of 20. Each level is then given a specific set of graphic output parameters associated with the data, such as:

1. Pen number (from 1-4)
2. Line spacing in millimetres
3. Shading type (single line or crosshatch)
4. Rotation angle of shading lines

Up to one hundred variables per zone can be accessed and classified, with each classified variable being stored on a separate shading file. This shading file is later used as input to the zone shading and legend modules.

The utilities section contains modules for data editing and various other functions such as:

1. Generalization
2. Global projections
3. Conversion to GIMMS input format
4. Centroid and area calculation

The generalization module uses a simple minimum-bounding rectangle tolerance scheme to generalize base and area files. It is a very effective process for point reduction, and is especially useful in Telidon applications where there is a limit on the number of polygon points.

The global projection module provides a facility to transform the basemap onto a sphere in a pseudo-equidistant type of projection. The finished transformation is not unlike Douglas' PILLAR program (Weiss, 1978), and is useful

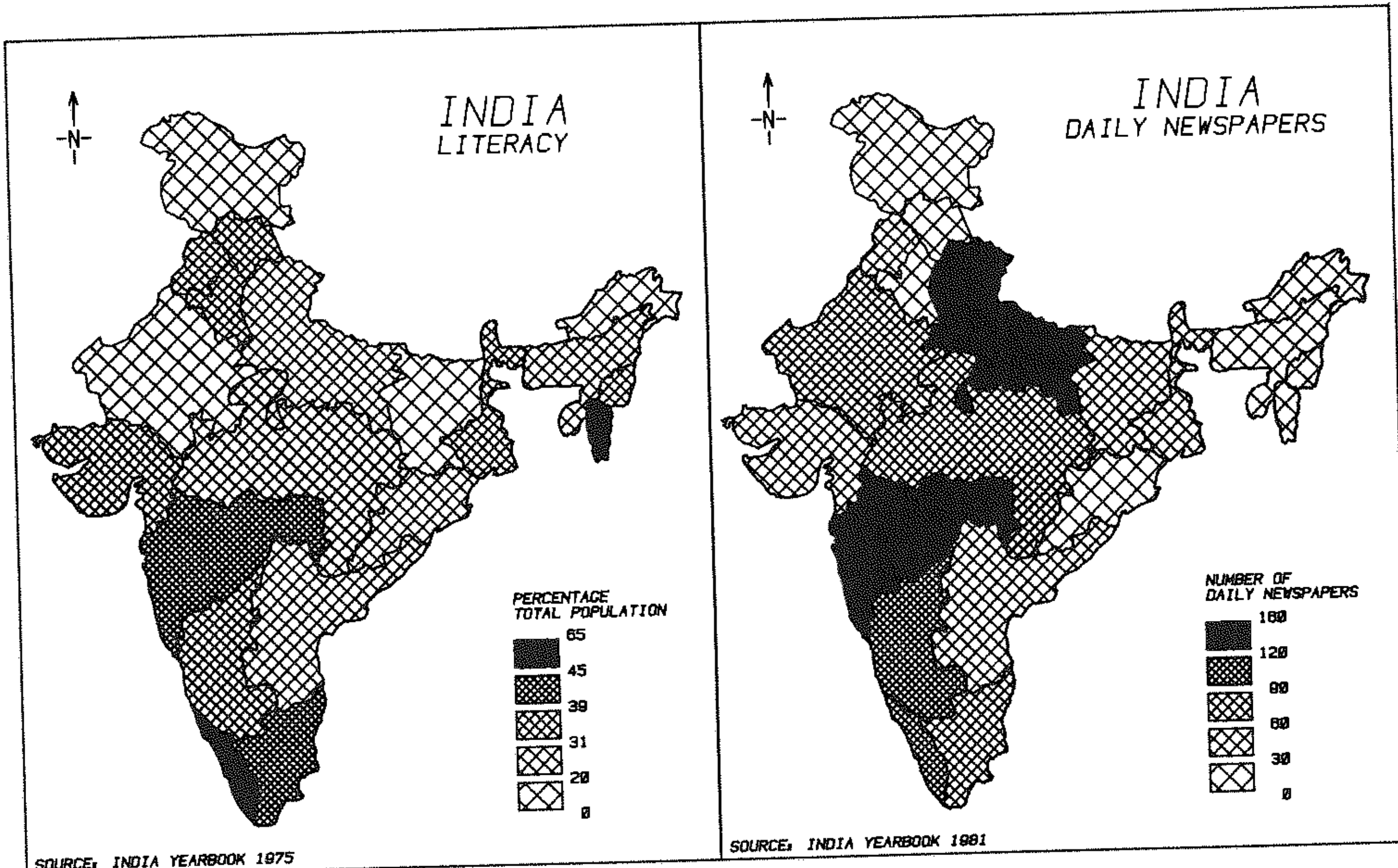

FIGURE 3. AN EXAMPLE OF MIGS HARDCOPY OUTPUT

for displaying spatial data conducive to this type of projection.

The centroid and area calculation module provides a facility to determine centroids and areas of zones. Zone numbers can then be plotted at centroids for zone identification.

The GIMMS conversion module was written as an interface to the GIMMS mapping system. A correctly edited MIGS basefile can be converted into a GIMMS text format file and transfered to the mainframe computer for processing by GIMMS. Thus all digital data bases created by MIGS are completely transferable to the GIMMS system, and currently this is the operational method used in the Geography Department for locational data input into GIMMS.

The plotting section contains all the modules that produce the graphical output. Colour choropleth maps can be generated with transformation capabilities such as scaling, translation, rotation, and global projections. Automated features such as legends, three choices of scale indicators, and six choices of north arrows are available. The comprehensive text input module allows the user to annotate the map and store the text on disk, where it can be edited and reproduced for map originals. Maps can be drawn using felt tip or liquid ink pens, on paper or acetate. Due to the menu driven method of operation, new features can be implemented easily as soon as they become available. Figure 3. illustrates the typical graphical output of the MIGS system, using a liquid ink pen.

CURRENT DEVELOPMENTS

In an effort to maintain MIGS as a geocartographic mapping system using the latest in new technology, current research has been directed in several areas. The first is the implementation of TELIMIGS, the MIGS system in a TELIDON environment. It is now possible, using our existing digital data bases, to generate maps with text annotation, using the the full colour and graphic capabilities of the TELIDON-NAPLPS graphics protocol. Since the NAPLPS protocol is becoming more widely accepted as a standard protocol for information interchange, it was a natural extension that TELIMIGS provide the capability to produce TELIDON-based maps. Because the TELIDON 'page' is sequentially built up of geometric primitives, a whole host of implications arise as to the generation of maps i.e. colour, sequencing of information, information content, resolution etc. It is these cartographic aspects of TELIDON, using TELIMIGS as the map generation system, that are currently being researched. Figure 4. illustrates a map generated in a Telidon format.

The second area of development, in parallel with the first, is the software conversion of MIGS to the CP/M operating system. Specifically, the system is being transferred to an DY-4 Systems' ORION V-D microcomputer, a 64K CPM based machine, using the LST: port for output. This conversion would ensure compatability and transferability to any 64K CP/M based microcomputer with two double density drives and

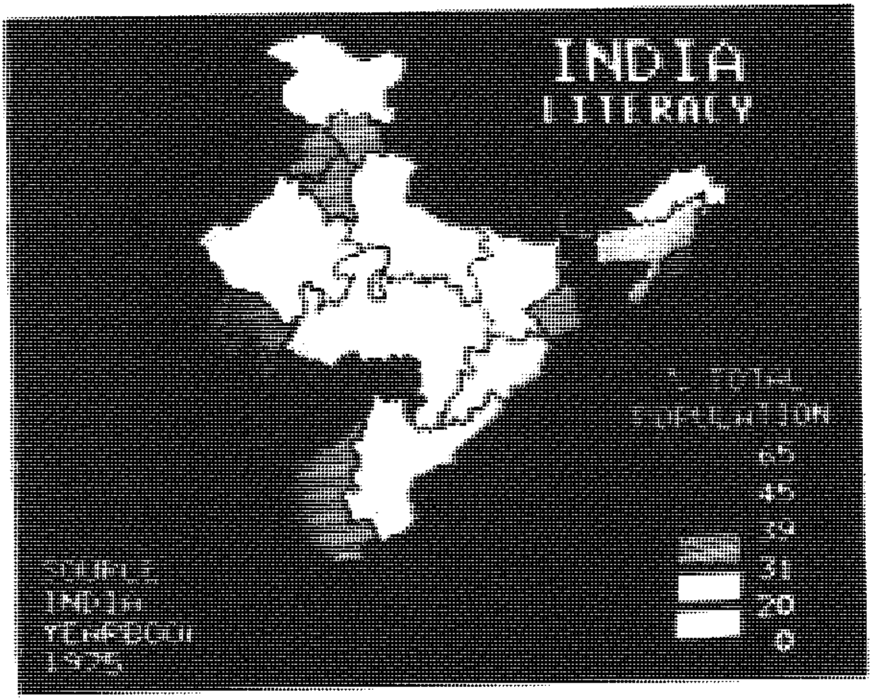

FIGURE 4. AN EXAMPLE OF TELIMIGS OUTPUT
(DIRECT PHOTO FROM MONITOR)

RS-232 serial ports. The language used for the source code is Microsoft BASIC, which is then compiled to provide a considerable speed improvement over interpretive BASIC.

Future enhancements of the system will include:

- computer assisted design of user-defined symbols
- non-locational data manipulation
- pillar-type maps (PILLAR)
- point symbol maps
- contour maps

CONCLUSION

The MIGS system is a small, cost effective method of producing thematic maps, using a minimum of hardware and user expertise. It is one of the few micro-based cartographic mapping systems that can generate TELIDON compatible maps and graphics. It is this ability, coupled with its medium to high quality hardcopy output, that makes it an excellent tool for map production.

Although MIGS was developed in the Canadian context, it is a useful tool for thematic mapping of socio-economic data in developing nations and is already being used for this purpose (Taylor, 1979). The relatively low cost of the system and its ease of use should enhance its applicability in developing nations.

ACKNOWLEDGEMENTS

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KNOWLEDGE ENGINEERING FOR SPATIAL DATA SYSTEMS (KESDS)

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ABSTRACT

PAR Technology has developed a rule-based system that allows the use of probabilistic inferential reasoning in a geographic information systems environment. Like most expert system frameworks, KESDS consists of two main components: an inference engine and a rule base. The inference engine consists of the software for a general mechanism to draw and explain inferences. The rule base is a text file consisting of a set of conditions and actions which provide the knowledge for particular inferences to be made to solve a problem. The task of building a rule base, in the field of Artificial Intelligence, is known as knowledge engineering.

In this paper, we provide an introduction to rule-base building using KESDS. We also discuss the essential components of an inference engine and approaches to building a rule base for specific GIS applications, such as imagery (remote sensing) data interpretation, geographic analysis, and cartographic text placement. Through these application examples, we illustrate the benefits to be gained from using expert systems in a GIS context.

APPENDICES

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Carriere Reynolds
Carto-Quebec
Collins & Moon Ltd.
Commercial and Industrial Development Corporation of Ottawa/Carleton
Commission de toponymie, Quebec
Compusave Inc.
Computer Graphics World
Department of Communications Canada
Department of National Defence Canada
Digital Equipment of Canada Ltd.
Dipix Ltd.
Eikonix Corporation
Exhibit Express
Gentian Electronics Ltd.
Geo-Spatial Research Corp.
GIMMS
Graphic Controls Canada Ltd.
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HASP Inc.
Health and Welfare Canada
Hill Security
Industry, Trade and Commerce Canada
Intergraph Systems Ltd.
International Cartographic Association
International Development Research Centre Canada
Kern Instruments of Canada Limited
Kingsberg-Syscan
Laser-Scan Laboratories Limited

National Research Council of Canada
Northway-Gestalt Corporation
Omnitech Inc.
Ontario Centre for Remote Sensing
Ontario Institute of Chartered Cartographers
Ontario Ministry of Natural Resources
Optronics International Inc.
Photosur Inc.
Prime Computer of Canada Ltd.
Public Archives Canada
Queen's University
Simon Fraser University
Sir Sanford Fleming College
Societé de cartographie du Québec
Spatially-Oriented Referencing Systems Association
Statistics Canada
Systemhouse Ltd.
Technicom Inc.
University of Alberta
University of Ottawa
Urban and Regional Information Systems Association (URISA)
U.S. Bureau of the Census
U.S. Geological Survey
Wild Leitz Canada Ltd.

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