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## Cartographic design and the electronic chart user interface

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The term "cartographic design" customarily has referred to how geographic facts are described in the body and margins of a map or chart. Interactive real-time map and chart displays now force us to go beyond color, content, symbols, and type styles, and consider another aspect of design: the commands and user interfaces required to drive the display and explore the information. This discussion considers the user interface needs of a specific type of real-time geographic information system: the electronic chart display and information system (ECDIS).

All user interface design is important, but the ECDIS poses special challenges for the following reasons.

- Several functions can be performed concurrently. Real-time route monitoring is a continuous ECDIS function. Users may elect to perform other functions (such as planning or updating) in conjunction with route monitoring. Note that monitoring does not recede to the background; the user and the system continue to monitor the situation as other tasks are performed. At any moment, the user might suspend the other functions and refocus attention on route monitoring.
- Many changes to the system cannot be controlled. For example, the animation on-screen is driven by sensor inputs, not by the user. The ship itself is moving. Vessel traffic also is moving. Updates that change the chart database arrive spontaneously by satellite link and must be dealt with promptly.
- Prospective ECDIS users are under pressure to navigate the vessel. A sizable percentage will consider any complexity added by computers to be a nuisance and a risk, regardless of other gains.
- Many ECDIS users will move frequently from ship to ship, and (presumably) from ECDIS to ECDIS. The controls of different ECDISs must be similar, or users must be fast learners and highly adaptable.

The discussion that follows provides a brief overview of ECDIS operations and the proposed display design standards, then proceeds with a discussion of the user interface. Two major points emerge: the real-time nature of the ECDIS gives it special design needs; and standardization efforts should extend to ECDIS commands and command structures for the same reasons that standards are applied to graphic aspects of the ECDIS.

## Overview of ECDIS

An ECDIS supports shipboard navigation by automatically plotting ship's position on a softcopy chart graphic. Ship's position is obtained from GPS; radio navigation systems such as Loran, Omega, or Decca; or dead reckoning. The chart graphic is generated from a digital data base that contains all the information normally shown on a nautical chart. Depending on the implementation, an ECDIS can incorporate overlays of radar and radar targets so a navigator sees his position relative to both charted and uncharted data. Other sensors integrated into the overall system can include depth sounder, speed log, satellite communication systems, and weather receivers (Hammer and Agnew 1991 provide an overview of ECDIS capabilities).

The use of an ECDIS can improve safety at sea considerably. The system warns of such important situations as shallow water, entry into restricted waters, deviation from a planned route, and approach of the next waypoint. Routine portions of the ship's log can be maintained automatically. Updates can be incorporated semi-automatically, requiring human supervision but minimal human involvement.

International efforts are underway to define standards for ocean-going ECDISs. The goal is to permit such systems to be considered the legal equivalent of a paper chart for ships engaged in international and oceanic trade (Obloy 1990 discusses issues of legal liability connected with the development of ECDIS). An equally important goal is to define an exchange format by which hydrographic offices can provide and update ECDIS databases. Kerr (1991) discusses the standardization efforts in detail. Provisional performance specifications have been developed by the International Hydrographic Organization (IHO 1992) and the International Maritime Organization (IMO 1989) and released to member nations for evaluation and comment.

The U.S. maritime community chose to conduct its evaluation by implementing a testbed ECDIS system that conforms to the proposed standards.<sup>1</sup> The U.S. testbed system has been designed and built by Intergraph Corporation under contract to the Woods Hole Oceanographic Institute, using customized software developed on the MicroStation platform and Intergraph workstations (Yeager 1991 and Scott 1992 summarize the project). The testbed system is to be installed on various working vessels in ports around the country to engage the largest possible spectrum of prospective users in the discussions surrounding what an ECDIS should and should not do, and appropriate methods.

Performance specifications are intended to ensure that all ECDISs do improve safety at sea, without necessarily being of uniform design. The Intergraph ECDIS design team chose to treat the experience of designing and developing the ECDIS as yet another test of the performance specifications. For example, were the requirements clear, did they permit technical innovation, and did they resist interpretations that could jeopardize safety? This attitude of experimentation led to a feeling that the design of a user interface for a system as complex as the ECDIS can improve or degrade the safety of a system, just as chart content and presentation are critical to safety.

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<sup>1</sup>The testbed approach also is being used by Germany, the Netherlands, and Norway to evaluate the provisional standards. See Netherlands Hydrographic Office 1991, Norway Hydrographic Office 1991, and German Ministry of Research and Technology 1991).

The IHO Committee on ECDIS provides specifications for most of the design elements of the chart proper. The legibility of the user interface (i.e., contrast and type size) also is addressed. However, the performance specifications leave the organization and wording of ECDIS commands to the discretion of individual developers. This situation is quite understandable. ECDIS technology is immature; the precise limits of the system are not set; different nations and individuals see the technology quite differently; and the research literature provides little definitive guidance on how to enumerate, structure, and name commands. But the difficulty of overcoming these obstacles does not eclipse the need for at least minimal standardization. The rest of this discussion illustrates these points.

### **Cartographic design in the ECDIS**

In many ways, the ECDIS is a cartographer's dream-come-true: the shackles of the paper page are removed to permit chart colors, content, symbols, scale, and legend to be adjusted dynamically to suit a particular task. This new freedom is accompanied by potential costs, however. First, to what extent should a navigator be forced to be his own cartographer? Assuming that cartographic changes are simple and the navigator is content with his new cartographic duties, how safe is it for an untrained eye to design charts of such critical importance? For these reasons, the IHO committee tasked with specifying colors and symbols provided tight constraints on what sorts of chart displays could be considered legal paper chart equivalents.

Table 1 summarizes the specifications for the ECDIS chart display that are provided provisionally by the IHO (described in the IHO "SP-52" document, IHO 1992). Ocel (1992) describes how the Intergraph design team implemented these specifications for the U.S. ECDIS testbed. Because the non-graphic portions of the ECDIS are the focus of this discussion, only highlights are addressed here.

The ECDIS drives an animation of own-ship movement relative to vessel traffic charted information. The animation metaphor to which it adheres most closely is that of the "Stage and Play" (see Gersmehl 1990). The "stage" is the digitized nautical chart, which can be zoomed, panned, re-colored, simplified in content, and queried by either the system or the user. The "play" is ship movement within the charted area, which is driven by the position sensor aboard own-ship, and the targets sensed by the ship's radar system.

The design characteristics of the chart itself are not the focus of this discussion. However, issues of chart design do affect the design of the user interface that controls chart operation and exploration. Most such issues spring from a seeming impasse between hydrographers (the chart creators) and mariners (the chart users). Both share a desire for safe navigation, but differ in their view of what sort of system best supports safety. Hydrographers prefer to minimize navigator control over chart design because of concern that a navigator will remove critical detail when de-cluttering his chart, that he will select a too-small scale in trying to increase the areal extent of the chart, or that his color preferences will impair chart legibility. Navigators argue that they are equipped to determine what chart satisfies a given situation and that constraints prevent exploitation of a powerful technology. Navigators

also voice a preference that the system be easy to learn, easy to use, with a minimal command set; yet also powerful, with almost limitless options to control the system.<sup>2</sup>

More options imply a more complex user interface. A major design goal, therefore, was to provide both simplicity and flexibility by using tiers of control. It was assumed that only users determined to exercise their rights of control would access the lowest tiers. Users content with system defaults could remain on the highest tiers. For example, the U.S. testbed permits users to switch between standard colors and content levels using simple forms that are small enough to remain on-screen with the chart display. But to select or create customized color or content configurations requires that a user summon more complex forms in the lower tiers of control.

Creating a user interface to manipulate chart appearance was the easier part of the design process. This is primarily because all computer users are now accustomed to a mode of usage where the user initiates all system actions. A real-time system such as the ECDIS, whose functions include continual monitoring of external situations in conjunction with user-selected operations, presents new challenges.

Table 1. Summary of IHO and IMO provisional specifications for ECDIS chart design.

Color	Four complete color sets are specified for day, night, twilight, and dusk to preserve night vision but also present good contrast at the altered brightness level.
Symbols	A standard set of ECDIS symbols has been defined, which strongly resemble paper chart symbols. Users are permitted to select from alternative symbols for sector lights, and can adjust the level of detail in the text labels of navigation aids.
Content	The proposed standard ECDIS display content strongly resembles the content of a paper chart. The IMO standard adds that mariners should be able to add to or subtract from the standard display.
Scale	The display scale should be equal to the scale of the paper chart from which the data were compiled. Areas displayed at too large a scale should be hatched with a gray screen. An over-scale warning is to be used if the chart upon which the ship moves is over-scaled. When features compiled from two scales are shown on the screen (as when the ship crosses from one chart to the next), symbols are scaled to be the same size.
Warnings	A required list of warnings is provided, although wordings are not specified.

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<sup>2</sup>McGranaghan (1987) comments that "...vehicle navigation systems with the simplest appearance to the driver will, in the long run, be the most successful" (p. 401).

## User interface design in the ECDIS

The first design challenge of the ECDIS user interface is that ECDIS monitoring activities never cease. Regardless of a user's need to explore the data, plan the next route, edit the current route, update the database, or perform navigational calculations, the chart that shows current situation must be displayed, monitoring commands must remain readily available, and critical warnings must be emitted when needed. The ramifications include problems with "command clutter" and a need to support parallel modes for route monitoring, route planning, and database updates.

A second design challenge is that the primary drivers of the system are inputs from external sensors. The user may be browsing the digital chart holdings when the depth sounders sense dangerously shallow water. Or the ship may be cruising across a chart when updates to that chart arrive via a satellite link. The ability to present these concurrencies coherently to the user is among the greatest strengths of the ECDIS and also the greatest challenge of its user interface.

Even without the concurrencies, the real-time nature of the ECDIS animation distinguishes the ECDIS from animations that do not represent real-time phenomena. In the latter case, a designer's concerns focus on describing and permitting the user to control the dynamic variables--duration, rate of change, and order (as described by DiBiase et al. 1992) or on giving the user a capability to browse the period represented by the animation (as in Monmonier 1992). In the case of the ECDIS, duration, rate of change, and order are represented exactly they occur in the world. The user cannot change the speed or sequence of events and the system cannot provide an overview.<sup>3</sup> User controls over the animation are, of necessity, limited (see Table 2). General "housekeeping" is performed by the system, for example to keep the ship well within chart boundaries when in true motion.

## Standards and guidelines

Extensive international effort has been devoted to standardizing the graphic display of the ECDIS. The standards ensure that basic perceptual limits are observed for color, contrast, and overall legibility. Standards also help users to become familiar with colors and symbols, and therefore to read their charts more effectively. This last point led to a feeling that some standards should govern the wordings of commands, definitions, and warnings.

In early meetings with prospective users, several had expressed concern about the level of effort involved in learning to use the system. This was of particular concern among those who moved from ship to ship, therefore (presumably) from ECDIS to ECDIS. If each ECDIS user interface had a different configuration of forms and menus, different terminology for commands and feature names, and different icons, these concerns would be warranted.

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<sup>3</sup>It is possible to record and re-play an ECDIS voyage; in that case, the animation can be adjusted by selecting a subset of frames from all the frames sampled during the voyage, and by specifying a rate at which frames are displayed.

Table 2. Commands that control the movement of the ECDIS display.

Advance display	Used in true motion to shift the display window along the ship's Course Over Ground vector to show more chart in front of the ship.
Look ahead	Shifts the display window in the direction indicated by 50% of its total width and height.
Return	Resets the chart to display ship's current position (to be used after a "look ahead" command).
New window center	The user selects a new centerpoint for the display window.
Adjust buffer	The user specifies how close the ship can approach the chart edge.
Motion	Changes display motion and orientation. Options are relative motion, which moves the chart under the ship, and true motion, which moves the ship across the chart; also orientation of the display to north up or course up.

Feature and attribute names are an interesting case of new problems being introduced along with new technology. IHO standards require that an ECDIS user can point to a symbol and request a description of the feature it represents. The IHO also provides an object catalog to define allowable features and their attributes. The object catalog uses six-letter code names for features and attributes. If these codes were presented on the user interface, they would be quite unintelligible to users. Obviously, names provided on the user interface need to be in English--the international language used by the maritime community--or in the local language. It would make sense for feature and attribute names to be standardized internationally, just as chart symbols are. The wordings of warnings also need standardization; specific types of warnings are specified in the proposed standards, but wordings are not.

Standardizing the terminology used for feature definitions and warnings would be a relatively simple matter. Far less simple, but arguably as important, is the terminology used for core system commands. Table 3 lists a set of commands or read-outs that all ECDISs are likely to have, along with sample permutations that could occur through the creativity and desperation of developers left to their own devices. The exact names may not be paramount (see Barnard et al. 1989) but standardization and consistency are. A second useful aspect of command standardization is to define standard command categories, which would permit developers to group similar commands in similar ways, and would help users to search efficiently for a particular command on an unfamiliar system. Of the commands in Table 3, "bearing," "distance-to-go," "time-to-go," and "cross-track error" could be grouped in a category "Waypoint."

Table 3. Possible terminology for common ECDIS command phrases.

Bearing	Bearng	brng
Distance to go	Dist ToGo	dtg
Time to go	TimToGo	ttg
Cross-track error	XtrackErr	xerr
Speed over ground	Spd/Grnd	sog
Heading to steer	HdgToStr	hts
Course over ground	Crse/Grnd	cog
Feature definition	Describe	?*?
Navigational calculations	NavTools	calc
Chart annotation	RteNotes	note
Look ahead	Lkout	peek
Edit route	Reroute	rte"

Examples of successful command groupings abound. The most familiar is the Motif-style groupings of the MacIntosh (and MicroStation) user interface. All OSF/Motif users eventually develop an intuitive understanding of the *types* of commands to be found under the standard categories "File," "Edit," etc. Such bare-bones categories could be provided as starting points for developers to structure their detailed designs.

## Conclusions

A paper chart includes a legend and other margin information to provide instruction on proper usage, explanations of chart information, and tools for manipulating chart information (e.g., tide tables, bar scale, logarithmic scale). The design of these data and tools logically fall within the domain of cartographic design. It follows that the display of situational information and the organization of commands to control an electronic chart also fall within the domain of cartographic design.

Most applications of geographic information systems do not have a pressing need to standardize the command wordings and command structures of different vendors. Users are not expected to move from system to system and such considerations as reaction time and potential accidents are slight. The "look and feel" of user interfaces is moving naturally toward standardization, but the content is not.

The real-time complexity of the ECDIS and a critical need for safe operation suggest that guidelines for standardizing the content of the user interface would be extremely useful. Standards are likely to be welcomed by all developers, who then would be freed from the sorts of decisions best made by human factors specialists.

## Acknowledgments

The opinions expressed here are those of the author; however, the work described is the result of a concerted team effort. Of particular note is the work of software engineers Shaun Sewall, Dwayne Miller, and Fred Loewenstein; system engineer Carolyn Ocel; and program manager Dave Scott.

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# The establishment of a thematic map design expert system PC-mapper

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## ABSTRACT

Map is the effective means to analysis and output in GIS, but gaining the high qualitative thematic maps still depends on human experts. This paper introduces the establishment of a thematic map design expert system PC-MAPPER and the realization of it's functions. PC-MAPPER, which suits to different level's users, not only has explain function, adaptive function and friendly interface, but also provid symbol move, note despose and other graphic processing functions. PC-MAPPER is written in PROLOG & C language by the user, and has been provided having pratical value. A number of thematic maps have been made by PC-MAPPER.

## 1. INTRODUCTION

Expert system is the system which can process knowledge and can provide answers on expert's level to questions through inference and judgement. More and more cartographers have realized that it is very important to lead into the technoledge of expert system in cartographic region. PC-MAPPER is a thematic map design expert system which is established on micro-computer by the author.

## 2. THE STRUCTURE OF PC-MAPPER

In order to make the structure of PC-MAPPER more reasonable, the whole work of map design must be examined seriously. By mean of analysising the course of map design, it can be find that different works of map design only concern with different part of knowledges of map design, so the whole work of map design is separated by the author into several task blocks which will be carried out in order. The task blocks are:

- (1). map content (map element) determine
- (2). map element's representation grade determine
- (3). map element's symbol type determine
- (4). area symbol design
- (5). line symbol design
- (6). point symbol design
- (7). map data capture and process
- (8). map drawing and graphics editing

Map content determine is the task block which determines the map elements represented on a thematic map according to map use. Map element's representation grade determine is the task block determining how to represent each element and how to classify and make grade. Map element's symbol type determine is to determine which symbol type ( point,line,area ) should be choose to represent a given map element. The tasks of point symbol design, line symbol design and area symbol design are

seperated into three task blocks because they relate to different part of knowledges of map design and each task block is fairly complex. Map data capture and process is the task block which gains the map data of each map element from map database and make grade to those elements which should be graded. Map drawing and graphics editing task block provides some graphics processing functions which are absolutely necessary for drawing an integrated thematic map. The structure of PC-MAPPER is showed as Fig.1.

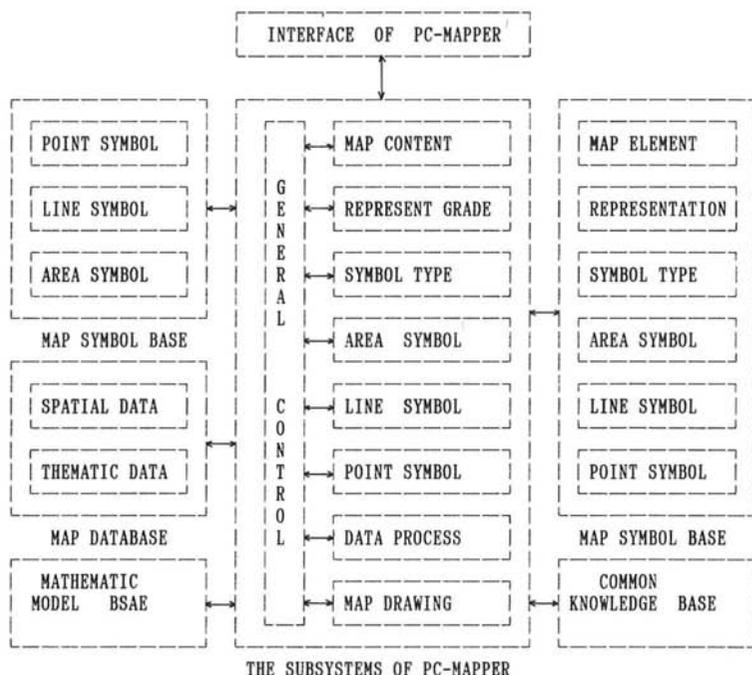


Fig. 1

Each task block is accomplished by an expert subsystem which has an independent reference & control mechanism and a knowledge base. Each subsystem is controlled by a general control mechanism through common knowledge base. This kind of structure reduces the complexity of the expert system, enables PC-MAPPER easily to expand and uphold and raises the efficiency of knowledge operation.

The common knowledge base, which can be used to store the original conditions, middle conclusions and final results of each subsystems, and can also be used to manage the knowledge, is the link of contact with each subsystems. Because each thematic map will relate to a large number of map data, PC-MAPPER should have the support of map database which can be divided into spatial database and thematic database. Great number of conclusions of thematic map design should be represented in the form of graphics, so map symbol base is necessary.

### 3. KNOWLEDGE SUMMARIZATION IN PC-MAPPER

The works which expert system can do is actually the works which man knows how to do. Although there are a number of theories of cartography, such as the theories of map information communication, map model, semiology cartography, visual perception and so on, but these theories are not perfect, especially, it is very difficult to use these theories in practical map design. There are also some expert's experience in many textbooks of cartography, but great majority are still the exposition in principle. So theories should be further completed and experience should be further deepened.

The theory of map information communication is regarded as the fundamental basis of map design in PC-MAPPER, so the affections of map use (user's demands) are considered in all links of map design. The theories of map model and semiology have concrete affections on the works of map design. The author puts forward the concept of representation grade (include nominal, classification, ordinal-grade, interval-grade, numerical-value) instead of the concept of classification and grade in order to describe the abstraction and generality of object.

On purpose to make map symbol type suit to computer assisted cartography, especially suit to thematic map design expert system, determining the map symbol type should not depend on the contents which map symbol represent but only depend on the symbol's nature of map symbol itself. So the author classify the map symbol type into three groups: point symbol, line symbol, area symbol.

The author deems that desiging map symbol can be transformed into determining the values of visual variables. Many cartographers have made reserches on visual variables, and put forward different kinds of visual variables, symbol dimensions, cartographic alphalet etc. In PC-MAPPER, all map symbols are composed of four visual variables which are shape, color, size and pattern.

These above are only a brief introduction about the basic knowledge for map design. Actually, there are even more complicated and more concreted knowledges which will be involved in making concrete map design, however, here will not discuss them further.

### 4. KNOWLEDGE REPRESENTATION IN PC-MAPPER

The knowledge of map design can be seperated into static knowledge and dynamic knowledge. Static knowledge includes mainly objective knowledge and dynamic knowledge is the knowledge solving problems. There is not a common and perfect knowledge representation model up to now, so PC-MAPPER represents the knowledge according to the nature structure of knowledge itself. Thus, static knowledge is represented in the form of frame and logic, which will be transformed into the form of PROLOG language at last. Dynamic knowledges, which are used to reason and control, are represented in the form of rules. e.g., the knowledge about ordinal grade of map element can be represented with a single frame:

```
frame name: ordinal_grade
element name: "boundary"
content: ["country_boundary", "province_boundary", "conuty_boundary"]
map type: ["all"]
```

The frame above can be transformed into a PROLOG clause:

```
ordinal_grade("boundary", ["country_boundary", "province_boundary",
"county_boundary", ["all"] ).
```

The knowledge about how to design area symbol can be represented in PROLOG rule:

```
area_symbol_design:-
  get_area_symbol_order,
  color_or_pattern,
  area_design,
  pattern_color_decision,
  outline_decision.
```

It means that the target of designing area symbol will be accomplished through following steps: first, determine the design order of each element; second, determine which visual variable (color or pattern) should be choose for each element; then, design surface of each area symbol and design pattern color while the area symbol is represented with pattern; lastly, determine the outline of each area symbol.

The original conditions of PC-MAPPER are map use which are cartographic region, map type and map topic, and the last result is a thematic map. So PC-MAPPER and his each subsystem adopt forward reasoning mechanism, because the original conditions are much more simple than the result.

#### 5. THE ESTABLISHMENT OF MAP DATABASE, SYMBOL BASE AND MATHEMATIC MODEL BASE

At present, the map data, which include spatial data and thematic data, are stored and managed by the extern database of PROLOG language. e.g. the datas in spatial map database are represented in the following forms:

```
area_data( area_no. , area_name, area_attr., chain_number, [chain_no]).
line_data( chain_no., chain_attr., point_number, [X-coordinate],[Y-coordinate]).
line_name( chain_no., chain_number ).
point_data( point_no., point_attr., X-coordinate, y-coordinate ).
```

Since PC-MAPPER is established in PROLOG language, map symbol base is established in PROLOG as well so as to suit the mechanism of PC-MAPPER. So PC-MAPPER can control the symbol base directly. Meanwhile, because designing map symbol has been transformed into determining visual variables, map symbol should be called also with visual variables. There are more than 100 kinds of pattern, 19 kinds of line symbol and 33 kinds of point symbol in the symbol base at present. And map symbol base can be easily expanded.

Mathematic model base has different kinds of mathematic models which mainly used to make grade to thematic datas. Mathematic model base is established in C computer language.

#### 6. EXPLAIN FUNCTION AND ADAPTIVE FUNCTION OF PC-MAPPER

When PC-MAPPER finds that conditions or conclusions are wrong or unreasonable, it will provide explain function, that is, give out explanation or WHY explain function while the system shows warning information to the users. The explain function of PC-MAPPER is realized by two kinds of methods which are: 1), put the explain information into control models; 2), establish explain frames in knowledge base and match with the context when the system need providing explanation.

The adaptive function of PC-MAPPER is actually a kind of learning function. To expert system, learning can be regarded as the course of improving system's performance or gaining noticeable knowledge. When the user has modified the conclusions of PC-MAPPER, it means the conclusions of PC-MAPPER can not accord with the user's demands, then the intention of learning has emerged.

The results of learning in PC-MAPPER are the actions which add new knowledge, delete old knowledge, modify former knowledge, arrange original knowledge, etc in knowledge base. The outside appearance of the learning are the changes of some adaptabilities of PC-MAPPER. So after learning by the adaptive function, PC-MAPPER can inference out the conclusions which suit to user's demands under same conditions. The adaptive functions, which reflects the intelligence of PC-MAPPER, can enable the system to consummate it's knowledge base and functions gradually through using the expert system.

## 7. THE INTERFACE OF PC-MAPPER

When PC-MAPPER knows the cartographic region, map type and map topics which are provided by the user, it can accomplish all other works of map design without user's interference. However, the user on higher lever can modify every kinds of conclusions of PC-MAPPER, and the adaptive function can adjust the knowledge base automatically according to the modification.

Because the system's reasoning course generally needn't the interference of the user, the main aspects of the interface are provided to process how to modify the reasoning conclusions by the user. PC-MAPPER has a friendly interface which provides enough reference informations and different kinds of menus which can be operated easily.

Since many conclusions of map design are graphics results, PC-MAPPER shows the conclusions in graphics too. PC-MAPPER provides still the graphic menus and the user can select the shape, color, size and pattern of every map symbol from graphic menus just like operate the ordinary menus. Therefore, it is convenient to do any modifications.

On purpose to make an integrated thematic map, PC-MAPPER's subsystem of map drawing and graphics editing provides many graphic functions, such as symbol modify, symbol move, note despose, map save, map read and so on.

Since PC-MAPPER relates to the most part of works of map design, what mentioned above is only a brief introduction of PC-MAPPER's interface.

## 8. THE APPLICATION OF PC-MAPPER

The thematic map design expert system PC-MAPPER, which is written in PROLOG and C language, can run on IBM/PC(VGA) micro-computers. A number of thematic maps such as "China Political Map" "China Road Map", "China Population Map", etc. have been made by PC-MAPPER, which has proved that PC-MAPPER has many advantages such as inference is rapid, conclusions are right, interface is friendly, operation is convient and easy, and the adaptive function of the system can make the system suit to user's demands. So PC-MAPPER has been proved having practical value.

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# Procedure-independent representation of positioning symbol

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**ABSTRACT** A loss of cartographic phenomena on the map exists at particular position in the real world. Data set describing the phenomena can be illustrated with positioning symbols. These symbols representing various themes are very different from each other so that they are usually drawn by different subroutines. This paper presents a new method with which representation of a positioning symbol is separated from its drawing routine. A positioning symbol is described in this method by a set of structured data and forming criterion. The drawing procedure is only used for converting these data and criterion into a symbol. This method shows its great value when a versatile symbol library is built.

## 1. Introduction

A map is a time-spatial model reflecting the distribution characteristics of a variety of cartographic phenomena in quantity and quality as well as the relationship and variety of them in the real world. This model is not only the materiality (symbol model) and the spirituality (transformation between abstraction and imagination) but also a thinking result and means of human being. Internal thinking model can be transferred to materiality model by a particular symbol system.

Map symbols are not only the results abstracted highly from objects in the real world but also a bridge communicating information between cartographers and map users. Therefore the map symbols can be considered as a graphic language. Cartographers in each country devote themselves to study the designing and drawing method of the map symbols and pay attention to the standardization of map symbols and symbolic language.

Map symbols generally can be divided into three groups: point symbols for adequate representation of local fixed objects, symbols in the form of lines or bands for adequate representation of objects reduced to lines or tracks, and area symbols for adequate representation of objects related to areas or objects which have areal extent. Several authors have addressed the methods of drawing symbols<sup>(1,2)</sup>. It is also possible to produce map symbols with Auto CAD<sup>(3)</sup>

But those methods are procedure-dependent for describing a symbol which is described in mixed form both data and procedure. They show disadvantages in creating symbols. Improvement on that is to separate description of a symbol from its procedure. For producing line symbols there has been an algebraic method<sup>(4)</sup> in which almost all line symbols on maps can be

produced with one operation.

The positioning symbols in this paper is this kind of symbols that can be positioned by one reference point on maps. They may be point symbols, diagrams, pie-charts or histograms. The method recommended in this paper is designed for producing the symbols of this kind.

## 2. Existing methods for drawing the positioning symbols

Cartographic means of expression and cartographic symbols are nowadays means of spatial information spread world-wide, which are able to represent natural, social and economic phenomena on the globe in adequate way. A wide varieties of cartographic symbols can be created by one's brain and hands while an automatic plotter can only draw some formulated symbols. Output of the spatial data on the map is the final step in computer assisted cartography and geographic information system. So the applications of those computer system highly depend on the drawing software in these systems.

Generally, the methods often used for drawing the positioning symbols are as follows:

(1) Symbols to be drawn by hardware which is a plotter with optical drawing head. The symbol plate with variety of symbols fixed in optical drawing head on the plotter could be used to project the symbol on to sensitive papers or films. Symbols on the plate can be chosen by selecting the symbol codes when plotting file is formed.

(2) Symbols to be drawn by software. In this method every positioning symbols can be drawn by plotter controlled with pre-developed drawing procedures. Some symbols, such as individual objects, alphabet letters, Arabic numerals and so on, can be drawn by means of information block. Each of these symbols will be separated into several points within a certain area. Codes of each point in the information block then can be obtained from the location of them. There are two methods for encoding these points either direction codes of moving pen to each point step by step or numeral of grid which must be transferred to direction codes. Some positioning symbols, which could be described mathematically, are drawn by means of procedure. Generally, it is necessary to write one subroutine for one symbol. Then these subroutines are put into computer in order to form a subroutine base, i.e. symbol library. Each subroutine in the library can be called with parameters specified by users when the plotting file is created.

In many cases, those methods mentioned above can be applied, but the representation of symbols is procedure-dependant. When the software package for drawing symbols is fixed, it has little possibility to produce new symbols, i.e. adding a new symbol means a new procedure for drawing this symbol is should to be designed and add to the package. In another words, this type of package is designed to be function-oriented. As known to us, a function-oriented package has difficulty in increasing its function as those functions contained in the package must be pre-designed and pre-made. That is one of the reason why " many of the more basic graphics package have fairly limited, ..., symbols and facilities for symbol creation and edition " <sup>(5)</sup>. A drawing software package designed in this way can only produce those symbol which are deter-

mined by this package designer. It means that such a package has limited number of symbols and users are unable to build new symbols and can do nothing but making choices from prepared types of symbols. Besides, when the package increases it may not run perfectly because of insufficient core memory. It seems that procedure-dependent representation of symbols is not a convenient method to build up symbol library. Limitation in terms of ..... symbol creation will restrict applicability of cartographic package <sup>(5)</sup>

However, most of positioning symbols on the map often come in intuitive simple and geometric form which leaves a room for us to conceive a method to describe a symbol in data and criterion instead of a procedure.

### 3. Representation of a symbol

From the process of producing a symbol of this kind, we can view that the production is involved in two aspects: One is the description of a symbol and the other is the operations on this description. If we separate the two aspects into isolated ones, the representation ( or description of a symbol ) will be independent of the operations and is not related to the procedure of producing a symbol. So the representation is procedure-independent. Description of a symbol is formed from a set of structured data and criterion. A program designed to realize the operations — producing a symbol, can draw not only prepared symbols but also impromptu symbols without being modified.

It is obvious that any symbol ( including its structure and shape ) of this kind totally rely on their descriptions: how to represent a symbol. As known to us, all plane graphs are not necessarily the symbols of this kind. A symbol often takes the form clearly understood and fairly easy made. It is constructed by repeating some simple shapes or arranging different shapes. Descriptions of a symbol contain both constant and variable because the symbol may be used to depict  $n$  indices which are filled different values from region to region.

A symbol of this kind is defined as follows:

$$S := s|s, s \cdot M$$

$$s := G$$

$$G := \{ p_j | R(p, p) \}$$

Where  $S$  is the description of a symbol,  $M$  is a geometric transformation,  $G$  is a graph which is determined by a set of coordinates and relation  $R$  which describes linking line between two points.  $R$  may be a straight line or a curve. A curve described by a function.

$G$  usually means a primitive graph to compose a symbol and it can not be subdivided. A primitive will vary in shape and number with index value represented by it.

Coordinates in  $G$  may come in parameter form based on either Descartes system or other systems.

We are going to show some examples how to describe a symbol classified in its shape and its number of primitive.

(1) index value represented by shape

There are 4 pairs of indices, each of which is depicted by an arc, radius and vary correspondingly with two values of a pair. The four arcs construct a pie-chart showed in Figure 1.

Center of the pie is a reference point. This symbol consists of 4 similar primitives — but have different radius and central angles.

Supposing

$$R = \left\{ \begin{array}{ll} 1 & \text{straight link} \\ (x(t), y(t), t_1, t_2) & \text{curve link} \end{array} \right.$$

Initial angle is supposed to be A. All values of indices are normalized as  $(V_{i1}, V_{i2}, i = 1, 2, 3, 4)$ .  $M_0$  is a constant transformation.

$$G_1: p_0(x_0 = 0, y_0 = 0)$$

$$p_1(x_1 = V_{11} \cdot \cos A, y_1 = V_{11} \cdot \sin A)$$

$$p_2(x_2 = V_{11} \cdot \cos(A + V_{12}), y_2 = V_{11} \cdot \sin(A + V_{12}))$$

$$R_1(p_0, p_1) = R_1(p_0, p_2) = 1$$

$$R_1(p_1, p_2) = (V_{11} \cdot \cos B, V_{11} \cdot \sin B, A, A + V_{12})$$

In general

$$G_i: (i = 1, 2, 3, 4)$$

$$p_0(x_0 = 0, y_0 = 0)$$

$$p_1(x_1 = V_{i1} \cdot \cos(A + \sum_{j=1}^{i-1} V_{ij}), y_1 = V_{i1} \cdot \sin(A + \sum_{j=1}^{i-1} V_{ij}))$$

$$p_2(x_2 = V_{i1} \cdot \cos(A + \sum_{j=1}^i V_{ij}), y_2 = V_{ij} \cdot \sin(A + \sum_{j=1}^i V_{ij}))$$

$$R_i(p_0, p_1) = R_i(p_0, p_2) = 1$$

$$R_i(p_1, p_2) = (V_{i1} \cdot \cos B, V_{i1} \cdot \sin B, A + \sum_{j=1}^{i-1} V_{ij}, A + \sum_{j=1}^i V_{ij})$$

This symbol  $S_0$  is constructed by the four primitives  $G_i$ .

$$S_0 = \{S_1, G_1 \cdot M_0\} = \{S_1, G_1\}$$

$$S_1 = \{S_2, G_2 \cdot M_0\} = \{S_2, G_2\}$$

.....

$$S_0 = \{G_1, G_2, G_3, G_4\}$$

(2) Index value represented by the number

In a map there are symbols representing value by the number of their primitives. The primitive has invariable shape but will repeatedly be arranged. The primitive may be a pictorial drawing or geometric shape, such as triangle, rectangle, circle, etc.

Figure 2 is such an example. There are 5 indices to show certain theme. This symbol consists of 10 by 10 small rectangles will demonstrate the percentage of each index. One small rectangle, which is a primitive, represents a percent.

$V_1, V_2, \dots, V_5$  are normalized values of these indices. The primitive is defined as Figure 2.

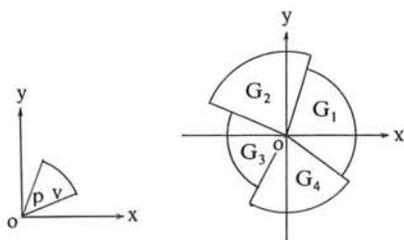


Figure 1

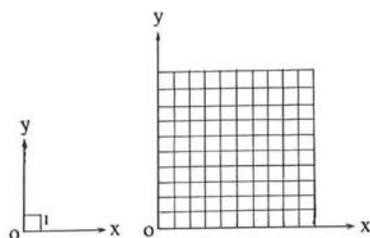


Figure 2

$G: p_0(x_0 = 0, y_0 = 0)$

$p_1(x_1 = 1, y_1 = 0)$

$p_2(x_2 = 1, y_2 = 1)$

$p_3(x_3 = 0, y_3 = 1)$

$R(p_0, p_1) = R(p_1, p_2) = R(p_2, p_3) = R(p_3, p_4) = 1$

Different colors filled in the primitive are supposed to show different indices

$S = \{S_1, S_2, \dots, S_5\}$

$S_1 = \{G, G \cdot M_1, G \cdot M_2, \dots, G \cdot M_{v_1-1}\}$

$S_2 = \{G \cdot M_{v_1}, G \cdot M_{v_1+1}, \dots, G \cdot M_{v_1+v_2-1}\}$

.....

$$M_i = \begin{cases} \text{constant transformation} & i=0 \\ T(\text{Mod}(i,10) \cdot 1, \lfloor i/10 \rfloor \cdot 1) & \text{others} \end{cases}$$

$\text{Mod}(x,y)$  is result of  $x$  modling  $y$ .  $\lfloor x \rfloor$  means integer part of  $x$ . Function  $T(x_0, y_0)$  means: translation of  $X$  and  $Y$  axes into  $x_0$  and  $y_0$  in the originals system.

#### 4. Drawing procedure

##### (1) Symbolism

As seen above, there are some expressions and variables in representation of a symbol, which means that an interpreter has to be included in the procedure. To simplify the jobs of the interpreter, we are going to develop symbolism based on the programming language in use but simpler than that of the language.

function: all common used mathematical function defined in the language.

digit: 0 1 2 3 ... 9

operation: + - × /

other: V ( ) . \$ !

constant: = c|c.c

variable: = vc  
 c: = cd | d  
 d: = { digit }  
 expression: the expression defined in the language.

The interpreter will translate those expression into codes, through which results will be computed. The techniques are referenced in textbooks <sup>(6)</sup>

Production of a symbol depends on an operation — drawing a line segment between two points, which is included in any computer system. In very simple way, a curve can be represented approximately by a series of short line segments obtained by discretizing its described function.

## (2) data structure

Description of a symbol includes primitive description, linking description and forming description, which are arranged in the following format:

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c ( integer ): symbol code
n ( integer ): the number of indices to be expressed
V1, V2, ..., Vn( variable ): variable will be appeared in the following expression and finally
replaced by values.
x(t), y(t), t1, t2, dt, k, f
x1, y1
...
...
xk, yk( primitive 1 )
x(t), y(t), t1, t2, dt, k, f
...
...
$ ( end of description of primitive 1 )
...
... ( primitive m )
...
$ $ ( end of all description of primitives )
Mb, Me( integer ): transformation code
a11, a12, ..., a31, a32, a33( transformation description )
Mb, Me
...
...
$ $ $ ( end of transformations )
l ( integer ): primitive number
b1, e1( integer )
...
... ( transformations used for primitive 1 )
bp, ej

```

\$\$\$ ( end of construction of primitive 1 )

...

...

m

$b_1, c_1$

...

... ( transformations used for primitive m )

\$\$\$ ( end of construction of primitive m )

!!! ( end )

$x(t), y(t), t_1, t_2,$  and  $a_{ij}$  are expressions;

$dt$  — increment in turning curve into segments;

$f$  — code for some pattern or color filled in enclosed polygon if  $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$  can enclose an area;

$a_{ij} (i, j = 1, 2, 3)$  : geometric transformations in matrix form.

### (3) Procedure of producing a symbol

For the reason of simplicity and clarity, we use functions to describe the procedure.

$\{Z\}$  — index set

$f(\{Z\})$  — expression

$c(\{Z\}, t)$  — a pair of expressions describing linking relation, i.e.  $(x(t), y(t))$

$xy(\{z\})$  — a pair of expressions showing the coordinates

$E(f(\{Z\}))$  — a procedure of computing expression  $f(\{Z\})$

$LK(c(\{Z\}, t), t_1(\{Z\}), t_2(\{Z\}), dt)$  — a procedure of descreting the curve described by  $c(\{Z\}, t)$  into a series of points every increment of  $dt$  from  $t_1(\{Z\})$  to  $t_2(\{Z\})$ . The result is a set of points.

$DRAW(G, LK)$  — a procedure of drawing either straight line segments or curve line according to  $LK$  between  $p_i$  and  $p_{i+1}$  in primitives.

Based on those descriptions and functions mentioned above, the production of a symbol of this kind can be expressed in the following way:

$\{V_i\}$  — value set of index

$desp\{Z_i\}$  — description of a symbol

@ — operation on the description

A symbol  $S_0$  of this kind is supposed locating and producing at the origin:

$$\begin{aligned} S_0 &= \{V_i\} @ desp\{Z_i\} \\ &\quad m \\ &= \{ \} \{ \} DRAW ( G_k \cdot M_i, L_k \cdot M_i ) \\ &\quad k = 1 M_i \in \{ M \}_k \end{aligned}$$

$\{M\}_k$  — transformation used for primitive  $k$ .

Different  $desp\{Z_i\}$  means different symbols but operation @ , drawing procedure, remain unchanging.

## 5. Summary

As pointed out in previous part, this method is available for not only those point symbols in topographic maps but also the diagrams in thematic maps. It is the most important in this method to separate description from operation. The description is dynamic and can not easily be modified. But the operation is static and procedure can meet different requirements for drawing symbols.

A function-based procedure formed simply collecting some functions limits its application, while an algebra-based operation designed for unified description instead of for some prepared symbols can complete all symbols described by the description and is not limited to certain symbols.

When applying this method to draw map symbols, it is essential to describe any of symbols in a formalized form. The representation of a symbol in this paper may not be exclusive one, however it really realizes a unified description of the symbols commonly used in maps.

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## **Session 19**

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### **Interactive and Educational Cartography**

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## Envisioning environments : map metaphors and multimedia databases in education and consumer mapping

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Interactive digital cartography (IDC) is the ability to create and modify maps in digital form in, more or less, real time. Significant advantages claimed over traditional maps have been : flexibility ( the ability to access and display a variety of related data, to control scale or alter other parameters of the map ); user control ( the ability for the user to decide which of the possible choices meet their specific needs ); and dynamic displays ( which can use techniques such as fluctuating colour levels, animated symbols and similar artifacts to extend the ability to convey information).

The most significant development , however, may be in IDC's ability to extend the types and quantities of data which can form part of a map, or alternatively how it enables the map to fit in to, and to function in support of, a much richer data environment. Such data environments are inextricably linked with three terms : multi-media, which currently battles against indiscriminate usage to sustain its credibility; hyper-media , with its implications of radical indexing alternatives ; and Geographic Information Systems.

This paper is in large part an attempt to investigate how IDC relates to these wider possibilities in an educational setting, and to some extent how this might affect our view on cartography. It does this from the particular perspective of general-purpose wayfinding maps : maps as devices for interpreting a general environment in a broad fashion. In this it builds, in terms of single sheets, on the long tradition of topographic mapping through national series at the 1:50,000 and 1:62,360 scales ; maps designed to present a broad perspective of an area within the confines of a single product. It concentrates on the use of multi-media systems in describing an area , i.e. systems which utilise a variety of data types, and inherently a variety of viewing strategies for knowledge representation.

## Interactive Digital Cartography

In its relatively brief history, interactive digital cartography has struggled to achieve its apparent potential for extending the functionality and enhancing the value of mapping products. This struggle has been conditioned for much of the time by hardware constraints which have either restricted the absolute ability to deliver mapping products in a truly interactive way, or have constrained their delivery to specific niche groups whose needs have often not mirrored those of wider groups of users ( for instance the military, spatial analysts and professional map makers ). Hardware constraints have been relaxed considerably in the last 3 years due to the enhanced performance of low cost systems. A range of IDC software has emerged that takes advantage of this change in the plateau level of mass desktop computing. This software can be divided into three categories.

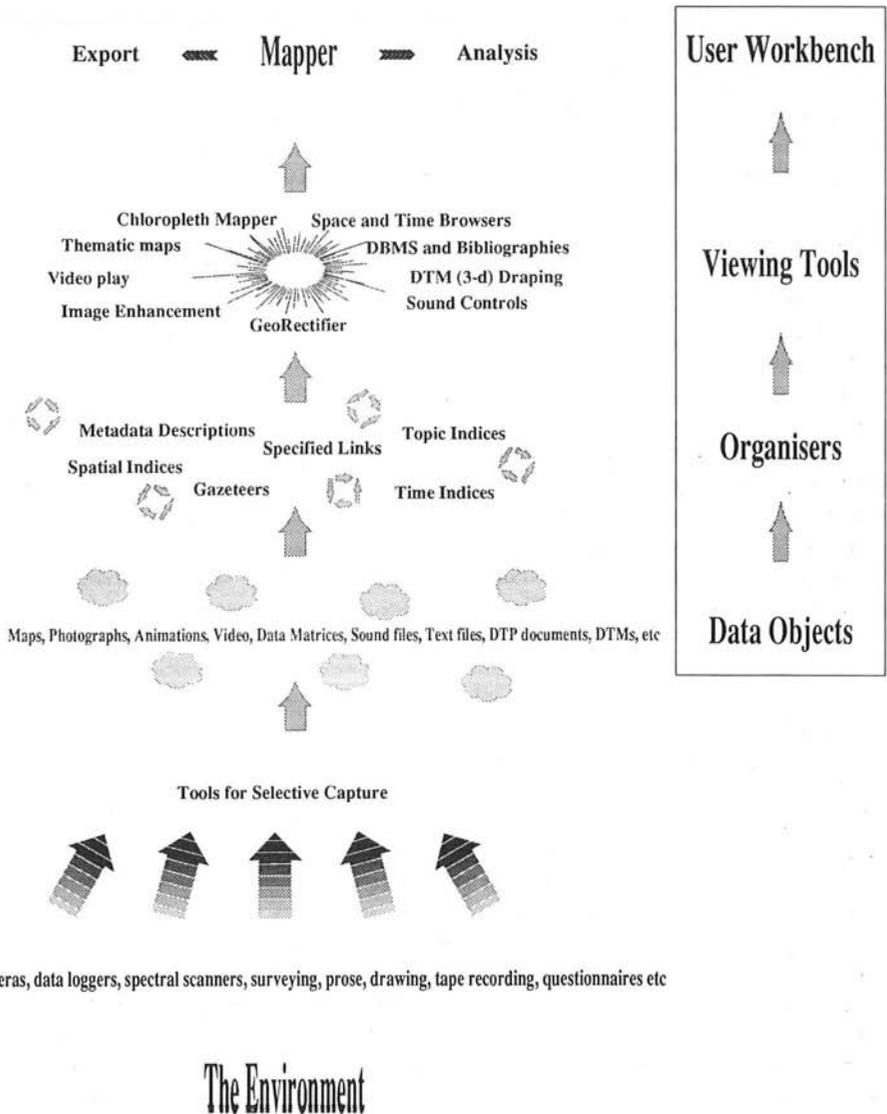
The first comprises interactive design tools for stable products. In this instance the user is fundamentally a map maker creating a map for use by a third party. The product may be a printed map, resulting from software such as Aldus Freehand<sup>1</sup> or Cart/o/Grafix<sup>2</sup>, or an animated digital presentation such as might result from the Macromind suite on the Macintosh<sup>3</sup>. The defining criterion is the lack of interaction between the product and the final user in anything but a page or reel turning mode.

The second category supports an exclusively cartographic data exploration process in which a variety of maps can be produced by the user for their own needs. The system designer defines a number of representational options, giving the user choice within this ambit. A number of products support this mode, sometimes related to data supplied by the vendor and sometimes with a more open interface (for instance Supermap<sup>4,5</sup>). The ability to support such exploratory mapping is central to many entry level 'GIS'.

The third category is by far the least developed, and uses cartographic representation as part of a much broader exploratory environment, as suggested by Figure 1. The essence is that it is designed to offer multiple representations of reality. The key to this is the combination of a wide range of data types, numerous data objects and structures, and alternative indexing and viewing tools. One can perceive this development either as a wider cartography or a broader data-base context in which some cartographic products are set, depending on your perspective. A tenet of this paper is that, from either view, the synergy between the data types can be used to produce something which is greater than the sum of its parts.

This paper is concerned with the development of such environments, and with the way in

**Figure 1 : Components of a Type 3 System for Multimedia Mapping**



Cameras, data loggers, spectral scanners, surveying, prose, drawing, tape recording, questionnaires etc

which designing for this environment differs from traditional cartography and GIS. It explores in more practical detail some of the issues raised in a previous paper<sup>6</sup>. Whereas class 1 and 2 IDC applications expand methods of delivering products in which, at least to date, traditional cartographic priorities and concerns are paramount, class 3 applications face a much wider challenge. Within such systems there will be room for traditional cartography, where the single map is the norm and the main problem is maximising the information content and communication efficiency for a given purpose within this single view<sup>7</sup>. However, the trademark of type 3 systems is the integration of maps and other forms and views of data. Consequently we can look to maps which are windows into alternative representations or designed to act as channels into a branching set of associated data.

The description of a wooded area on a map is a good example. On a 1:50,000 topographic map this is normally achieved by deciding on perhaps 3 or 4 classifications of wood types and applying these to areas we define as having tree cover. This provides an excellent overview of general pattern, but in other perspectives immediately raises issues of accuracy and selectivity, for instance in terms of extent of cover, spatial generalisation of stands and true homogeneity of species. Achieving appropriate accuracy of any spatial object is a well recognised problem in GIS<sup>8</sup>. Cartography may seek to deal with this for different users by employing variations in scale, generalisation and symbology, as well as considerable ( and often impractical ) amounts of additional effort. With type 3 systems we can enhance our knowledge content, reduce costs and avoid some of the error traps by linking together different views of 'woods'. In doing so we also create a less rigid and formalised view of the world. Table 1 suggests alternative representations for displaying middle-scale detail, and their relative strengths and weaknesses in representing woods. It is acknowledged that different media , both spatially and in terms of attributes, apply different filters and achieve different degrees of consistent coverage. In many ways, however, this underlines the value of their combination.

It is a tenet of level 3 systems that this juxtaposition and interdigitation of alternative representations offers a much better scope for portraying a static environment. It is also a tenet that temporal variations within the map's area of coverage can also be handled much more sympathetically. Type 3 systems augment our capacity for showing past states, animated processes or finer temporal resolution ( the visual impact of forest in winter or summer, in morning or afternoon, in sunshine or cloudy weather for instance). Table 2 uses the current key of the Department of Survey and Land Information 1:50,000 map series to indicate the augmentation possible simply by using visual data types or some form of modest temporal structure. It should be noted that options requiring considerable cost or unreasonable amounts of information ( for instance photographs of every bend in

**Table 1 : Benefits of Alternative Representations of Woodlands.**

	<i>Clear-Measurable Boundaries</i>	<i>Professional Design</i>	<i>Clear Patterns</i>	<i>Cheap to Create</i>	<i>Species Identification</i>	<i>Portrays Visual Impact</i>	<i>Species Interacting Visible</i>	<i>Solidity of Stand Apparent</i>	<i>Evidence of Associated Fauna</i>
Shaded Area Map	●	●	●		●	●	●		
Simple Symbology		●	●		●	●	●		
Satellite Images	●	●	●	●	●	●	●	●	
Air Photos	●		●	●	●	●	●	●	
Video			●	●	●	●	●	●	●
Sound				●					●
Text	●	●		●	●	●	●	●	●
DTM Drapes	✱		✱			✱			

**Key**

- Particular strength exhibited in this area
- Has capabilities in this area
- Limited strengths in this area
- Weak in this area
- ✱ Denotes impact of DTM when combined with other data types.

the road ) have been omitted, as have options for extending the traditional information base of the map, for instance with animated portrayals of population change over time. Having identified both the nature and peculiar strength of level 3 systems it seems clear that the current permissive technological shift which is relevant to Figure 1 is only the first of several ongoing adjustments which will liberate further options for envisioning environments. These adjustments particularly include those related to animated imagery (notably video), photo quality image rendition, networks to remote data and real-time position location. These technological changes are occurring concurrently, and are targeted

Table 2 : Augmentation of Existing 1:50,000 Features  
by Photography and Animation

Feature NZ 1:50,000 nzms260	Aspects of Portrayal by Photography and Animation						
	<i>Visual Impression</i>	<i>Attribute Information</i>	<i>Daily Change</i>	<i>Seasonal Change</i>	<i>Long term trends</i>	<i>Extremes of Conditions</i>	<i>Processes at Work</i>
Roads	*		*			*	*
Unsealed Tracks	*	*		*		*	
Tunnel							
Bridge	*		*			*	*
Footbridge	*						
Coastline	*	*	*		*	*	*
Sand and Mudflats	*	*	*		*		
Dam/Waterfall	*			*		*	*
Water Race	*						
Streams	*			*		*	
Contours	*						
Cliff	*						
Rock Outcrop	*						
Other Embankments/Cuttings	*						
Railway Features							
Forest	*	*		*		*	
Orchards	*			*			
Mangroves	*		*			*	
Burnt and Fallen Bush	*					*	
Buildings	*					*	
Church	*						
Lighthouses	*						*
Wrecks	*						
Power Lines							
Mines	*						

to move onto the high volume/low cost trajectory and so be significant for desk top and portable mapping in the future.

Their impact, however, may well be constrained by the more intractable, and in some cases less addressed, areas of design of interactive cartographic systems. Our

understanding of many issues in the high end, mensurative and analytical areas of GIS are still somewhat immature<sup>9</sup> and we should note that, for instance, that NCGIA initiatives 1,2,4,7,10,11,12 and 13 represent areas requiring research which have clear relevance for interactive wayfinding mapping systems. Impacts of type 3 systems may also be restricted by a conservative perspective on how mapping should evolve and how this evolution should relate to new options for describing the environment digitally. Problems in evolving an efficient and equitable market with regards copyright are also critical.

The next sections attempts to briefly review the progress to date on some proposed and completed systems with type 3 characteristics, This is followed by a discussion of the design requirements for a contemporary system. In order to focus discussion we address a single application with quite complex requirements, namely a system utilising multiple data types and representations to support students in university field and project work. The needs of this task can be seen to relate quite closely to those of many users of topographic and wayfinding maps at mid-range scales but are specifically targeted at supporting students in field projects, i.e. allowing them to identify data sources, to explore general hypotheses and to access analytical tools. This paper draws examples from an early prototype, *Havelock*<sup>10</sup>, which aims to provide support for second year student projects focussed on a study area of approximately 150 sq kms. It is currently a laboratory based system, with the intention to make the initiative portable.

The final section briefly discusses implementation issues.

## **Evolving Systems**

Even in 1993 there are surprisingly few operational type 3 systems that implement an effective interaction between cartographic and other knowledge representations. Some are reviewed here to indicate both progress in the field and the evolution of the available tool base.

In many ways the *Domesday* Project (1986) represented a first attempt to develop a product which integrated maps with many other forms of representation<sup>11</sup>, essentially all of those noted in Figure 1. This was achieved with some underlying sophistication but notable unfriendliness and limitations on the National disk of 'professional' data, where a range of simple choropleth and thematic mapping options was offered, and some interesting but disjoint 'simulated walks'. It achieved much greater integration on the Community disk. Here a tiled hierarchy of scanned topographic maps was the main navigating metaphor for accessing data about particular areas of the UK in both text and photographic form. The links between spatial referencing and actual images were crude (

being simply the link between an image and a tile in the mapping hierarchy ), and the material had little editorial control to ensure representative imagery was provided. Yet the system offered the chance to explore the United Kingdom in a way previously unavailable. In many ways, in spite of six years of rapid progress in computing, no initiative has really seized on the impetus of *Domesday*, and many of its features remain unmatched.

Its Achilles heel was undoubtedly the technology it utilised. Most of its effects were achieved by custom software, while access to sound and imagery relied upon a unique hybrid Laservision disk which delivered single analogue images translated into digital RGB form. The sound track was, in part, dedicated to digitised data. Its operating system, too, was limited, reflecting 8-bit computing at the time. In particular it pre-dated sophisticated windowing systems which are pre-requisites for the effective display and integration of data.

Quite rightly *Domesday* inspired a number of spin-off projects of similar scope in other nations in the late 1980s<sup>12,13,14</sup>. Most of these failed to come to fruition. One exception was the *Siuleq* project undertaken by Danish Radio<sup>15</sup>. This project aimed to create a multimedia data base of Greenland, and worked through more standard equipment to achieve its aims. Although native code was developed for the final product, the system was prototyped on a Macintosh with Hypercard and operates on a Macintosh using a subsidiary colour screen and laservision player. As a minimal resource the disk and player alone could be used to deliver information about Greenland, its people, places and culture. The project was modest compared to *Domesday*, both in scope and functionality. Its mapping interface was largely confined to relatively simple exploratory maps of Greenland designed for locating places and events.

Another line of development was the *Heritage New Zealand/Nga Ohaki Aotearoa* project proposed and prototyped in New Zealand<sup>16</sup>. In its development proposal it targeted specific shortcomings of *Domesday* and proposed to meet them by using a combination of standardised equipment, an advanced object-oriented windowing environment (Acorn's RISC-OS) and a combination of customised and off the shelf software<sup>13</sup>. In particular it sought to improve the links between map and non-map data, and most significantly to integrate all 'views' of data, in contrast to *Domesday's* two disks and two metaphors approach. Unlike *Siuleq*, but like *Domesday*, it chose a single integrated workspace in terms of available screens.

These initiatives were all large scale and offered the ability to recall a full range of data types. A final initiative which might be seen as in the same mould is the *GTV* from National Geographic<sup>17</sup>. This review of United States history, which one might expect to

have a strong geographic component, again utilises Macintosh and Laservision equipment. However, its use of spatial metaphors and indexing is very weak : the best example perhaps being the printed chart of US historical landmarks which accompanies the disks.

The problem with such systems has not been their inability to deliver different data types, but the lack of standard, low cost equipment on which to run them, the relative paucity of their functionality and the limited integration of data types. This has constrained the potential number of users, and thence the ability to assemble the large data sets involved. In contrast to these approaches a number of more modest but interesting developments have begun to emerge which offer only aspects of type 3 systems, but operate within purely digital environments and on standard systems. These are of three kinds : customised map information systems, of which *PC-Globe* is the best model, map information systems built on functional GIS foundations, and systems built using multimedia authoring tools.

The custom map information systems available are closed systems that address the need for general information on an area, and typically link only the less demanding types of data within a standard environment. They will allow, for instance, exploration of an area by zooming and panning, the display of selected spatial themes of an area, statistical tables and graphs for that area, and sometimes some explanatory text. Within its confines the interface is simple to use and fast, and some data exporting is allowed. It is cartographically very conservative. *PC-Globe* is the most widely known of such systems, and has been widely emulated.

Fully functional GIS offer a natural tool for building type 3 systems , since these GIS currently offer the widest options for customising new spatial views of data and new ways of spatial indexing, perhaps a damning impeachment of the state of the art. GIS have become attractive options with the recent trend for such systems to extend the number of data models they support and in particular to support and integrate imagery and grid models. While still generally expensive, full systems have been used to experiment with very flexible data bases , for instance in Antarctica<sup>18</sup> , and in the case of ESRI have spawned a product, *ArcView*, with primarily exploratory functions<sup>19</sup>, which are limited but subject to ongoing enhancement.

The major limitation of GIS for developing type 3 systems is their restricted ability in handling a full range of data types, especially in developing flexible links between data resources. GIS with well developed features are also costly. Multimedia authoring systems such as Hypercard<sup>20</sup> and Genesis<sup>21</sup>, address both of these problems, and are ubiquitous on some platforms. A number of modest but interesting multimedia type 3

systems have emerged from local projects. These include an Inuit experience in Western Canada<sup>22</sup>, a look at contemporary America<sup>23</sup> and a user-built information system for tourists<sup>24</sup>. The results from these initiatives, for the resources committed in development, are impressive, and interesting exploratory interfaces can be crafted in a very short time. The main limitations are generally slow graphics, no spatial analytical procedures and a lack of simple ways to implement necessary spatial recall and indexing functions<sup>25</sup>.

In summary one might observe that the projects based on laser vision have produced interesting results, but limited impact. While such custom systems may still have a function they seem likely to be increasingly linked to GIS engines to develop them on purely digital platforms. To date however these engines have failed to deliver the general flexibility of multimedia for handling various data types, although the MIPs system offers some hypermedia/multimedia links and other developments are in train<sup>26,27a,27b</sup>. Equally multimedia still lacks sufficiently powerful graphics facilities, and graphics/database links.

In terms of presenting data, *Domesday* set a series of challenges which have not yet been addressed in an integrated way. The systems developed to date show little innovative progress in advancing the effective use of mixed data types in mapping. However, a series of general purpose tools have emerged which allow experimentation in this area. It seems that the way forward lies in linking multimedia and GIS technology to create innovative cartographic and exploratory interfaces.

### **Design Issues for a Prototype**

Let us take the view that a wayfinding map is a formal structure for vicariously exploring the nature of an area. This can include navigation within an area, although this is not a focus of this discussion at present. Let us, for now, also sublimate the argument that a map is a polemic tool for promoting a view of the world.

It is generally agreed that a good map system should deliver as much information as is relevant and effective, and do so in a communicable way. Interactive maps extend this perspective by allowing the user to control parameters of the maps produced. It is accepted that within a particular format the benefits of free expression and access to a variety of data should be matched by the user's ability to operate the drafting tools and to appreciate the implications of a variety of outcomes.

For type 3 systems to be effective two further assumptions must be justified. The first is that the multiple representations of knowledge used do actually enhance user understanding, i.e. we must agree that seeing different versions of 'reality' (data types and

objects) and different visualisations of these versions (views) actually enhances comprehension rather than confuses it. The second is that access to these different representations can be made intuitively workable to the user.

This paper is unequivocal in supporting a growing user access to visualisation techniques and tools. The briefest consideration endorses the view that additional views of the same data objects, or thematically related data objects, potentially broaden the insight provided by a system. For instance, simply re-classing census data on the spatial distribution of income will yield new insights on where those on low income are located, but written commentary on the dynamics of rental housing in an area - or better still representative pictures of living-conditions of one zone as opposed to another -can only extend the user's appreciation of the situation on the ground. A radical might endorse the view further by arguing that maps are polemic devices : the extension of user views of the world simply makes this polemic more accessible to each and every user, and more open and honest. This applies whether one considers alternative representations linked to the standard topographic map and its uses, procedural mapping procedures<sup>24</sup> or innovative designs for tourist maps that have won recognition by use<sup>28,29</sup>,

The problem such a stance highlights is how to make such systems usable. One aspect of this is meeting the second concern above, i.e. ensuring user friendliness : an ostensibly usable system. A deeper aspect is attempting to support the user and guide them into wise use and interpretation of the information and viewing tools available<sup>30</sup>. Both concerns focus on the need to evolve a systematic design that integrates data objects, views, indexing schemes and user support. This last component can, in many ways, be seen as an enabling adjunct rather than a core component of mapping. It is, however, a key pre-requisite for type 3 systems. It can ensure the availability of guidance on using tools, on assessing views and on appreciating data quality. In the educational setting which *Havelock* is designed for it can also provide the appropriate learning ramp for users to make the transition from browser (simple exploration) to tool user (deeper analysis).

A class 3 system that addresses all of these issues must achieve three key goals. The first is to define a set of data to adequately describe the domain of concern. In this case we wish to describe a small area of some considerable complexity, and to provide the sophisticated range of data which a university education would require : statistics, terrain models, bibliographic references, remote and other images and climatic and geological data.

The second need is for the best mix of visualisation and manipulation tools, ones which allow browsing and latterly also the export of the findings into publications or for analysis.

The final need is for a suitable working context of interactive tools embedded in a consistent environment which is amenable to low and high skill users, i.e. a catholic and friendly user interface.

These issues are discussed in the following sub-sections, initially in general terms and then with reference to *Havelock*.

### *The Data Domain*

As with traditional cartography the definition of data for representation is an editorial task in which volume, cost, representability and availability are important concerns. The extension of the number of data types and simultaneous visualisations significantly increases the complexity of the editorial task and invites re-appraisal of the means of representation of different features in terms of costs and benefits. Determining the best balance requires ongoing research, and will inevitably be partly determined by the needs of specific contexts. It can be argued though that, *ceteribus paribus*, best results will be achieved by ensuring representative, accurate, compatible and varied representation of themes to be covered, i.e. utilising a range of data types embedded within data objects that are as compatible and cross referenced with each other as possible and amenable to a wide range of viewing tools.

In practical terms, the area for *Havelock* is small by map sheet standards, being some 12 by 13 kms (around 10% of a standard New Zealand 1:50,000 map sheet) but, as a harbour basin, is clearly focussed as a functional area. It is topographically diverse and, within New Zealand's relatively brief perspective, historically rich. It also has a significant bicultural dimension through its Maori presence. While in some areas, such as climatic data, information is limited to a few stations there is adequate land use and vegetation data and a wealth of historical imagery. There is also a seasonally diversified landscape and a dramatic set of visible and moving weather patterns, best exemplified by the passage of Southerly fronts across the harbour. A number of aerial photographs since the 1930s, and remotely sensed and digital orthophotos since the 1980s complement this resource, to which should be added over 300 scientific and popular references and a growing number of student projects in digital DTP form.

An appropriate starting point for designing the cartographic data domain is adopting the wisdom of experience by accepting that as a baseline the themes of the current 1:50,000 map should be included within the data. This foundation has been adapted and augmented by specialist map data on land resources from the New Zealand Land Resource Inventory and cadastre from the Digital Cadastral Data Base (by courtesy of the Departments of

Survey and Land Information, and Scientific and Industrial Research respectively). A layer of Maori nomenclature has also been added taken from Couch<sup>31</sup>. No historical maps are available in digital form, but all accessible remotely sensed imagery has been included.

Photographic images are a major augmentation, and pose a particular problem. Historically, the collection should be made representative for areas of the harbour and across time periods. This can, with some care, be achieved at a broad scale from what is clearly a pre-defined resource. Contemporary imagery is more problematic, in that it can be collected as required at very low cost.

'Accuracy' and 'Representativeness' with images are hard to define, but desirable goals, particularly with a potentially subjective medium and where universal coverage of material is almost certainly impossible. One strategy is to consider images as providing either a broad visual coverage of an area, a representative sample of exemplar features or the identification of specifically unique features. For *Havelock* four spatial levels of photographic capture were defined: *detail*, *site*, *locale* and *perspective*. The first is any individual item of human size or less, the second an object or area of up to house size, the third a small area of landscape such as a street or small lake, and the last a broad landscape view. In practical terms exhaustive coverage is only possible at the top level, which is in any case aimed at a general interpretation of the area. Here we might seek to include views that show all of the study area from a distance at which most locales would be broadly distinguishable. In the case in point a viewshed analysis was undertaken to see how many images would be needed to ensure no locale was hidden or more than 2 kms away. A solution with 72 photographs was achieved.

Small and/or numerous objects require a more selective coverage. In some cases

Objects	Number (est.)
Churches	7
Houses	950
Shopping Centres	5
Reserves	35
Monuments	12
Wrecks	10
Streams	120
Separate Stands of Wood	90
Jetties	16
Farm Animal Breeds	25
Wild Vertebrate Species	120

representative images can be used to illustrate similar occurrences of items. Others are by their nature unique. Table 3 gives estimates for necessary images to show specific items within the basin. Where universal coverage was impractical, as in most cases, the strategy was adopted of attempting to identify key or exemplar objects within each data theme and ensuring that images were available.

Representing change visually over time

involves identifying those aspects for which cyclic or extreme change mean separate representation by season or time of day is appropriate. These aspects naturally tend in a seasonal climate to be predominantly features of the natural environment. For shorter time scale change video can be employed, particularly time-lapse photography of Southerly and Easterly air streams entering the harbour. The time-lapse technique also has some merit for recording other short-term but dynamic visual changes ( use levels in shopping areas for instance ). Table 2 gives some insights into how representing temporal fluctuations might affect the total numbers of images required in the exercise.

#### *Avenues for Visualisation, Manipulation and Exporting.*

A good type 3 environment should also give access to appropriate raw data, appropriate processed information and appropriate tools for constructing alternative or enhanced views. We seek a balance between received wisdom ,and user-initiated questioning or exploration, so that users can influence the degree and kind of filtering of information, and move from specific theme to general trend and back to new focii as demanded.

Type 3 systems can offer a more effective exploratory data environment by three means. The first advance comes from better access to various traditional views of reality. The views may be better by being faster, more numerous , more varied or simply concentrated in one place. The second advance comes from the easy juxtaposition of these alternative views, and the ability to extract complementary information and note anomalies between them. The third, and most radical, advance comes from the implementation of new visualisations or views.

The issues raised here concentrate on i) what are the best set of traditional views of environmental data in this context? ii) what alternative views would be useful to develop? iii) which of these are practical in a current educational (low cost) environment? For parsimony we discuss these issues in reverse order.

i) Practical views. Views may be impractical because of an inability to deliver them interactively, because their properties are not general enough or well enough understood for them to be used, or because the resources required for their storage or display is too great. Many of the advances in scientific visualisation techniques, are not currently appropriate on the first grounds, and may never be for general use on the second. Some approaches for views, such as simulated photographic walks of every street in an area<sup>32</sup>, may run foul of the third, as may video data. The views discussed here are those achievable for *Havelock* using a target system as described in the penultimate section, which approximates to a current top-line desk top personal computer. Their links to

emerging work on Virtual Reality is discussed in the last section.

ii) Traditional Views. The range of traditional views is relatively straightforward, and ought to embrace ways of illustrating major map themes. Most of these views are static and involve interpretation of textual, diagrammatic, cartographic or image components. As defined here, all traditional views involve a basically 2-dimensional approach or less. The functionality of some options, for instance graph and charting procedures, is well understood and well supported by a number of independent and integrated software packages. In cartographic terms we might expect symbolic mapping of various selectable coverage themes and some forms of statistical mapping. The base line functionality of products such as *ArcView* might be taken as our intended limits here.

In selecting and navigating views one important aspect is user-familiarity. In this respect *Havelock* is able to use a generalised SPOT image as one key locational backdrop, because the harbour shore line is very distinctive and easy to navigate. However this is augmented, in spite of high storage costs, by scanned images of standard DOSLI 1:50,000 maps. This is because of the combination of excellent design, high information content and user familiarity with the product.

### iii) New views

Three niches exist for developing effective new views. Two come from embracing an additional dimension in display. The more traditional one of these is to utilise a third physical dimension to enable interpretation, i.e. to employ a digital terrain model to generate 3-d perspective views. *Havelock's* study area is very amenable to this, having explicit and dramatic relief. In such areas it is a very powerful option with a number of applications. For instance L'Esplattien and Bar have draped standard 1:50,000 maps over a DTM to enhance interpretation<sup>33</sup> and draping SPOT imagery or classifications over terrain models offers additional insights into what a remotely sensed image may mean. Draping small area census units, such as mesh blocks in New Zealand, can also show new insights. Real time draping and views of such drapes are not possible within currently affordable systems, but the concept can be made operational by defining a number of viewpoint locations from which pre-generated views can be recalled and, in the case of population data, interactively shaded for data and classification.

The second dimension to embrace is time. Visualising time as a third dimension has practicality in some areas, and using interactive features to explore temporal change through animation or other mapping means is eminently achievable. It is most simply done in a non-symbolic form through access to video clips, where the syntax for manipulation is usually driven through a VCR metaphor, so that motion can be suspended, resumed, fast

forwarded and so on. This same syntax can be applied to animating change, and indeed many pre-recorded symbolic sequences can already be recorded in system-specific 'film' mode. Interactively animating change, i.e. user control over a range of options, can be difficult within multimedia packages since their graphics control is often slow and primitive. The most obvious simple animations involve animated circles for displaying the change of settlements' population over time, or using colour shifts on line segments in a path or network to indicate movement over time.

A further aspect of the use of time is in browsing interfaces for images or text by location. An ideal interface for browsing a large collection of images would involve identification of images by certain attributes ( contents, time taken) and by location. A user may want also to know which candidate images were taken near a certain date. *Havelock* utilises a slide bar specifying the target date, with a further slider to define the permissible range around that target date. The location of images is displayed symbolically on a map, with colour and intensity dynamically varying to show each image's position within the target time band. The same technique is used for data with point distributions over time : with rapid movement of the slider bar it can , in effect, interactively animate changes in location or display migration or diffusion patterns.

The final area for basic extension is in combination of data objects and views. Some of these combinations , such as georeferenced overlay of two themes on a map, are mundane for a GIS but not for standard graphics packages. Others, such as drapes, are currently too time consuming for interactive use. Many possible combinations can be achieved by assembling and comparing individual views. Others can be achieved somewhat clumsily by utilising appropriate external tool modules. The potential for enhanced support for dynamic , spatially focussed comparison of views is considerable.

### *User Interface Design and Linkages*

The literature on GUIs is a dynamic one, which stresses the design of systems which are intuitive to use and consistent. This general literature has been notably lacking in specific developments of map metaphors, although this is now being redressed to some degree<sup>34</sup>. For practical purposes many of the most fundamental GUI design issues have been given substance and presence by specific WIMPs implementations and developers' guidelines from system vendors. For a type 3 system that wishes to work in such an environment the issues of general style are largely pre-determined by compatibility with this broader, established context. Available GUIs do differ, however, and the choice of specific context remains open. In a complex situation where different data types and visualisations are involved one important characteristic is the ability to support a very wide range of object-

specific options for actions without succumbing to excessive screen clutter. The WIMPs environments that have native support for object oriented pop-up menus and operate 3 button mice offer distinct advantages in supporting this both for type 3 systems, but also as the standard *modus operandi* for all other applications that may be called upon.

The key issues of interface design for type 3 systems relate to their complexity. One is a learning gradient issue : ensuring the user can be encouraged to explore the range of options available, be supported in developing new skills and avoid being overwhelmed by options that are too numerous or too advanced. Strategies for this include adaptive menu systems, use of alternative languages or vocabulary for certain kinds of user and 'gatekeeper' procedures to access certain functions.

The other significant issue is the well known one of navigation : ensuring the user knows their position in the data base<sup>35</sup>. This may involve knowing their recent exploration path, the criteria that selected a particular set of data, the spatial location of a particular view they are considering or potential links ( by topic or by visualisation technique ) for a particular data object on view.

Some of these issues can be quite easily handled within the scope of a stable data base for a small area. The question of spatial navigation for instance can be managed by a mandatory 'Where?' option on a button or menu for every data object displayed. This can recall a cameo map of the study area with location or extent of the current object marked. The question of linking views is more significant, and one which is of particular interest to users of type 3 systems. Each data object may have one or several possible viewing tools appropriate to it ( for instance a table of population numbers may link to text, spreadsheet, chart, map, 3-d overlay or other tools). The object may also refer to other related data objects with different viewing tools ( for instance photographs of the settlements or air photographs of the census districts involved ). Ensuring user knowledge of these links, both to visualisation techniques and related objects, is a major concern.

*Havelock's* goal of encouraging browsing and exploratory analysis, especially amongst lay users, requires an interface that is initially simple to use but supportive of growing demands from the user. The philosophy of the data set being 'open', in terms of linking to tools and to desktop publication software, also implies a means to assist the user in knowing of, and to some degree employing, these tools. It is a complex task, resembling more an integrated working environment, some of which is outside ones control, rather than a tightly defined action for which set 'tasks' can be enumerated as a basis for design<sup>36</sup>.

In *Havelock* the first criterion of design was for a supportive kernel which managed the

**Table 4 Top Level Menu Choices in Havelock**

Menu Item	Secondary Sub-Menus
Map Library	Vector Themes Map Builder RS Image Cameos
Purpose : browse available map material and export for cartographic purposes	
Census View	Simple stats (tables,charts,maps) ArcView
Purpose : access socio-economic data	
Remote Images	Browser Example Processed Images Drapes Launch Processor
Purpose : display images, examine specific outcomes, bridge to analysis	
Bibliography	Search View
Purpose : bibliographic support and eventually on-line access to past dissertations	
Images	Browser Searcher
Purpose : browse digitised photographs by major subsets, or interactive search in time and space. Includes some video footage of specific items accessed via cameo 'still'.	
Time Browser	Browse
Purpose : allow search by simple spatio-temporal key for non-textual resources	
DTMs	View DTMs Generate views for export
Purpose : Creation of custom views for use in projects	
Scans	Browse View
Purpose : access video images of large-scale areas or processes, typically views from vantage points and weather patterns. Some time-lapse material.	
Help	
Purpose : support and guidance for the kernel, its resources and associated tools.	

various browsing options to the user and provided ongoing support. This emphasised the need for a multitasking environment in which the support kernel could manage user guidance, user exploration and user tools. The kernel is in many ways the critical component in ensuring a usable and flexible system for prototyping, maintenance and development. In that specific tools and exploratory options can be plugged in and out of this core as needed.

Such a modular approach has clear value for prototyping, and has determined a design which at the top level is very conservative : entry is by a number of choices available from a simple pop-up menu. These choices are detailed in table 4. As can be seen, the choices offer a controlled set of combinations of data objects and visualisation techniques. All choices ( and support resources ) are (potentially) simultaneously available, so the user is able to control their sequencing and juxtaposition. There is in no real sense an exploratory hierarchy ( as structures *Domesday's* maps , GIST<sup>37</sup> and many hypercard stacks ). Indeed the essence of a type 3 system is the ability for simultaneous display of related information, i.e. to be simultaneously at various points in the structure. In *Havelock's* case too, most cartographic exploration is at one scale and is simplified by the limited study area. Consequently there is no real navigation problem in terms of positioning within a hierarchy. Some attempts have been made however to

ensure that links can be made between different views, and that most items can be placed in a specific time or space location. All items with a spatial or temporal coordinate have a 'where' button which displays both the textual description of a place and a map showing its location to within 50 meters.

Navigating data and viewing links is much more complex. The strategy being adopted for managing movements within the database has been to design the data domain as a series of data collections or objects and to link each group to a set of one or more viewing techniques. These techniques may simply involve launching a text file into a text editor window, or involve quite complex processing of data using parameters generated by the context of the user's request. For this purpose a number of subsidiary forms of each data types is recognised, generally corresponding to standard or proprietary formats.

However, links from objects to viewing techniques are much less demanding than ensuring cross reference of data on various criteria. Many of these latter can be met by more or less sophisticated schemes for textual search. More central to type 3 systems are links by location, especially where GIS techniques are not available. A particularly interesting and generic problem exists in creating a browser which allows the user to point at a map and assemble all the data objects with relevance for that location. The answer is simple for complete spatial data objects such as orthophotos and maps : a simple point in rectangle query can suffice. Text poses a problem in that often projects and reports relate to several disjoint areas and refer to them by pseudo-locational keys such as place names and addresses, so a link via a local gazetteer is needed. Photographs are the most demanding cases, since one is often interested in either photographs taken at a location ( which is easy to code as a point or a simple 3 dimensional statement of camera location and angle ) or views *of* that location. The latter involves either byzantine textual coding or searching a map of the viewshed revealed in the photograph.

This issue of the actual areas represented by a given data object is central to many links between data sources, and an important component of spatial metadata. Most schemes which attempt to define areas of coverage, such as the prototype Genius system<sup>38</sup> or the current draft FGDC metadata standard<sup>39</sup>, do so on a very simple rectangular area or named region basis. This is an inadequate substitute for describing the area of concern of data, and some effort is being put into defining a simple tag structure to link data objects with complex spatial extent , such as the viewshed of photographs, to a querying interface.

A final issue for the system interface is the link to external tools. One advantage of the systems chosen is file typing which allows simple links for exporting chosen resources to applications, whether extant at the time or not. All *Havelock's* resources are designed to

use standard file types which can be exported for final use within a DTP environment or similar, or to be loaded into tools for modification or analysis.

### **Practical Implementation Issues**

*Havelock* is a prototype exploratory system. Its brief and purpose have been explained, and general design issues outlined. This section describes its practical implementation in preparation for student use in 1993.

The key implementation issue has been to provide a combination of views on a number of themes, adequately cross-referenced, with appropriate speed of delivery and ease of use and within a practical budget, i.e. on standard equipment and using non-custom software. In 1992 no single platform offered the ability to meet all of these criteria, so a two tiered system was developed using ethernet and NFS mounts. The delivery system for users was to be a lab of Acorn A5000 workstations, a RISC based microcomputer with specifications around those of a well configured 80486 system with SVGA. This system has some excellent graphics and image processing tools, a flexible multimedia package and, most significantly an operating system which combines superior multitasking features with an operational similarity to Unix X-windows implementations, specifically Sun's Open Windows. This was important because *Havelock's* delivery to the user is partly by software native to the A50000, and partly by X window emulation from a host Sun.

This approach allows the utilisation of the unique benefits of both environments. Essentially the A5000s are cheap and familiar to the students, and come with very user-friendly software. Genesis<sup>21</sup> is able to implement a number of visualisations of the data itself, and has a very flexible set of commands for launching or linking to other applications that are required simultaneously. The A5000s have a proven track record for being accessible to the non-computer literate. Sun Sparcstations are both too expensive for general use, and too rich an environment for the uninitiated. However, they give access to *ArcView* as well as any enhanced interfaces to the data developed under *ArcInfo*. They also fulfil the role of spatial data editor, since many of the views delivered on the smaller system are derived from manipulations within *ArcInfo*.

Clearly the optimal configuration for delivery will change. In the short term however the differing characteristics of operating environments, and the tension between resource intensive visualisation techniques, such as 3-D draping, and a need for wide access to a system, encourage the view that this two tiered approach is practical in many institutions.

Table 5 shows the main classes of visualisation and how their implementation is shared between different environments in *Havelock*

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**Table 5 : System Roles in Havelock**

<b>Function</b>	<b>A5000</b>	<b>Sparc</b>
<i>Kernel</i>	Delivery and user support	Minimal support
<i>Map Library</i>	Display,map building,export tools	Preparation
<i>Census View</i>	Mapping small data sets, ArcView Display	ArcView Delivery and Editing
<i>Remote Images</i>	Editing browsing export and analysis	Editing
<i>Bibliography</i>	Display, export and editing	*****
<i>Images</i>	Display, export and editing	*****
<i>DTMs</i>	Display	Processing and editing
<i>Scans</i>	Display, Export and Editing	*****
<i>Help</i>	Delivery and user support	Minimal support
<i>Storage</i>	650 Mbyte local store	NFS partitions via ethernet

N.B. : *Editing* refers to creation and amendment of resources by the system designer, not the user.

## Concluding Remarks

This paper has sought to identify a class of digital mapping application which lies on the intersection of multimedia and GIS, and to raise issues related to the implementation of such an application in a tertiary teaching context. Along the way it has raised a number of practical and design issues. Some of these are inevitably transient with technology. Others, such as the basic types of data we might collect, are more stable. The major area of change is likely to be in the areas of visualisation tools and user interface.

One means of focussing concern here may be to consider the relationship between Virtual Reality and class 3 systems. Superficially, virtual reality offers the means to create the environment so it can be more or less directly experienced ( subject to a few more years of progress in hardware). Yet virtual reality in fact offers two different visions. One is , literally, the creation of a virtual version of reality... at present grainy but with time predictably smoother, more complete and more subtle. In one respect this may seem the ideal exploration environment for a class 3 system. What it ignores is that the message of

complete reality is confusing : our maps and other artifacts for spatial display are at least as much attempts to overcome our constrained ability to manage this complexity as they are attempts to improve our ability to rove widely in search of information. Virtual Reality is not a surrogate for the art of creating wayfinding spatial data systems.

The other vision of Virtual Reality focuses on interfaces which involve the senses in greater communication with data, and on occasion enhanced means to modify the data to a particular purpose. In this respect VR may offer alternative ways to explore different knowledge representations, and particularly to navigate more intuitively through space on the way to these ends. Here virtual reality has common grounds with IDC, and also shares with it a common challenge. This challenge is to present the user with a range of knowledge representations and navigating interfaces that lets them explore reality. The agenda for this, in both cases, must include developing new visualisation tools, new means of combination and new user support and advice structures. In this endeavour many touchstones of cartography and visual design will retain their value, but will come to co-exist with new tools and new skills that must be enlisted to meet the challenge.

At the time of writing Havelock 0.75 was still to have its first exposure to student use. It is report further at the time of the spoken presentation of the paper.

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# Computer-assisted learning and the visualization of spatio-temporal data

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## Abstract

Cartographers are stimulated to develop new visualization methods while dealing with spatio-temporal data. They are encouraged to do so by GIS-users, who in turn are challenged by developments such as exploratory data analysis and scientific visualization. In this environment animated spatio-temporal maps play a key role. Since those maps are dynamic, the application of Computer Assisted Learning techniques seems to be the method to teach about the visualization of spatio-temporal data. This approach offers students the possibility to interact with maps. In the cartography curriculum of the Delft University of Technology Computer-Assisted Learning has already proved to be a valuable tool in teaching those aspects of cartography that are dominated by information technology. A tutorial called STMAPS is presented, which covers background information on spatio-temporal data, and deals with cartographic aspects of spatio-temporal maps. Theory, examples, questions and exercises make up the tutorial. It was developed in a PC-based Windows environment using an authoring tool.

## Introduction

Currently, one of the more interesting demands on cartography is the visualization of spatio-temporal data. Cartographers are being challenged by many disciplines, especially by those related to GIS. The advanced software, models, etc, used in this field nowadays frequently require the visualization of processes or developments through time. The need for spatio-temporal maps is even increased by some recent developments in GIS, following growing awareness of GIS-users of the possibilities offered by exploratory data analysis and scientific visualization.

These new developments put some pressure on the cartographic approach to the spatio-temporal map. To most cartographers, a map is an end product which communicates spatial information. They put all their knowledge and skills in the design to make sure the message reaches its users. With the introduction of GIS, maps have become a starting point of a spatial analysis, which often results, via several intermediate maps, in a final map presenting the outcome of the analysis. In general, this trend worried cartographers, since it appeared they would no longer play a key role in map making. However, with the complex cartographic functionality of

today's GIS packages cartographic skills are appreciated. With the introduction of scientific visualization and exploratory data analysis, things might change again. Maps do not only play a role in visual communication as they traditionally do, but also in what is called visual thinking [DiBiase et al, 1992]. In a spatial context, such as GIS, visual thinking is linked to exploratory data analysis. The combination of both processes results in an operation of prospecting and searching for spatial patterns, and while asking questions attempts are made to develop hypotheses based on the data. During this operation maps and other graphics are used to outline the researchers ideas. Because of the nature of the process of visual thinking, the maps used will require a different design approach when compared with 'traditional communicative maps'. These requirements could be confusing to cartographers, because while exploring data a researcher is not interested in a clear, and classified image, but wants all original data to be visually available. By looking at the visualized data, the researcher expects to discover pattern in the apparent chaos presented by the maps. It is likely that animated spatio-temporal maps have a function in this process.

These recent developments do not make the design of animated spatio-temporal map easier. Because, from the viewpoint of visual communication, it is not clear if existing cartographic grammar can be applied without adjustment [Kousoulakou & Kraak, 1992]. This problem is complicated by the fact that while discussing scientific visualisation researchers are not sure how to use motion effectively [Dorling, 1992]. In the literature the discussion in relation to spatio-temporal maps has only recently matured [see Campbell & Egbert, 1990 and Monmonier, 1990]. Dorling [1992] states in this context that questions such as 'How much does the user already know about the subject?', 'How difficult is the subject?' and 'How long can the audience's attention be held?...' will influence the design of animated (spatio-temporal) maps.

How to teach the topic of spatio-temporal maps? Since some are dynamic, the application of Computer Assisted Learning techniques seems to be a good approach to teach the visualization of spatio-temporal data, specially while it offers students the possibility to interact with maps. The origin of this approach can be found in the characteristics of the Delft cartography/GIS curriculum. Hard- and software are used as the main tools in teaching 'cartographic practice'. Computer-Assisted Learning already proved to be a valuable tool in teaching information technology-dominated aspects of cartography. The courseware discussed in this paper is a tutorial. It covers background information on spatio-temporal data, data structures and applications, and deals with cartographic aspects of spatio-temporal maps. It contains theory illustrated with examples, and to help the students, questions are asked and exercises given. The tutorial was developed in a PC-based Windows environment using an authoring tool.

### **Spatio-temporal maps**

The contents of the courseware's first section is mainly based on a literature survey and is summarized below. However, first it is necessary to clarify terminology used. Spatio-temporal maps are considered to be maps displaying processes with a spatial component changing over time. In this context other, confusing terms are found in the literature. This is due to the fact that the current theory is still under developed. Terms also used are animated or dynamic maps. These terms refer to maps with movement/action. Spatio-temporal maps can be of this type, but not necessarily so.

A map on a screen with blinking symbols to attract attention, should not be classified as a spatio-temporal map. DiBiase et al [1992] provide an interesting classification of animated maps, which also contains several spatio-temporal maps. In their paper they also stress the relation between animated maps and cartographic grammar.

To display spatio-temporal data cartographers can use traditional static as well as animated maps. In both situations the cartographer has several options available to deal with the temporal component. To explain the theory of spatio-temporal maps an illustration similar to figure 1 is used. In the tutorial it functions as the access to the topics explained, and it reflects the options available to the cartographer.

The scheme in Figure 1 shows a subdivision into three main spatio-temporal map types:

■ single static maps

The temporal component is transcribed graphically by means of the visual variables of the graphic sign system. Examples are maps in which variables such as value, orientation and size are applied.

■ series of maps

Here each single map represents a unique time slice. Visual variables are not necessarily utilized to depict the temporal component. Variations in time are shown via differences between the individual maps depicting subsequent time slices. It could be said that the temporal sequence is represented by a spatial sequence, which the user has to follow, in order to perceive the temporal variation. The number of maps is limited since it is difficult to follow long series.

■ animated maps

Here variations introduced by the temporal component are presented in a single map. Again, visual variables are not necessarily utilized. Variations in time are deduced from a spatial sequence but from the real movement on the map itself. According to DiBiase et al [1992] so called dynamic variables are applied to suggest movement. The animated spatio-temporal maps can be subdivided in two categories:

- time series

This type of animated maps display change in position or attribute seen from a fixed viewpoint. Examples are animations of the change in location of a country's population gravity point and the growth of a city's built-up area. This type is the animated version of a series of static maps.

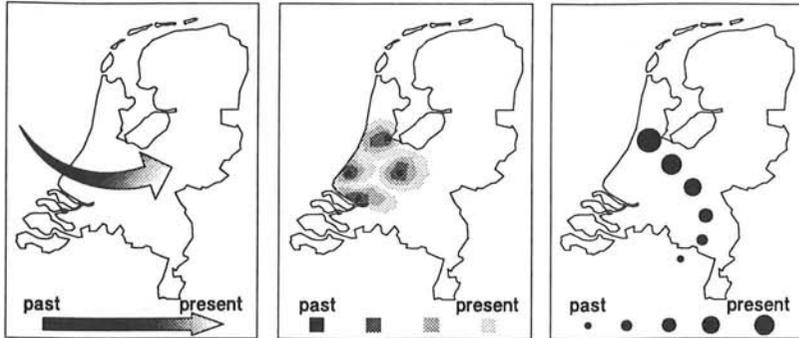
- fly-bys

An animated map composed of a sequence of views of a static (topographic or thematic) surface with a moving observer's viewpoint. Examples are those animations which simulate a flight over a landscape. This type can be seen as the animated equivalent of a static map in which arrows are used to indicate a path of movement.

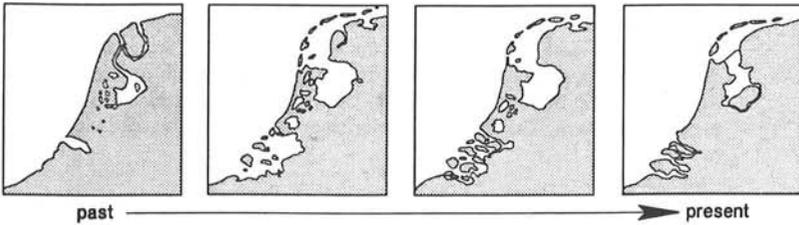
Linking this classification to traditional cartographic grammar, it can be said that for the locational component the graphic transcription is always done by utilizing the dimensions of the plane, and that for the non-locational component graphical variables are always used. From the above classification it can be seen that to display the temporal component three different options are available (see figure 2). The temporal component, therefore, is in general not regarded as an additional thematic component but rather as an additional dimension (in the spatial sense).

## CLASSIFICATION OF SPATIO-TEMPORAL MAPS

### a) single static map

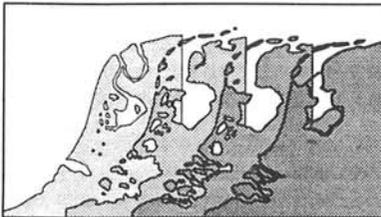


### b) series of single static maps



### c) animated maps

#### time series



#### fly-by's

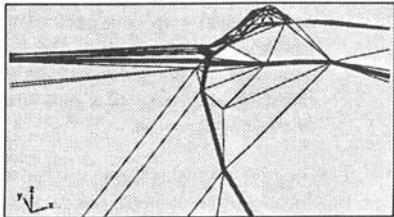


Figure 1. Spatio-temporal maps: a) single static maps; b) series of static maps; c) animated maps. The time scales displayed in a) and b) range from past to present as examples only. This could include the future as well.

The students are also informed that in relation to spatio-temporal maps topics of interest are not limited to visualization only [Langran, 1992]. They also include issues related to the data itself: storage and maintenance, database design, and a proper map-user interface. This last topic is treated in more detail, since research indicated [Kousoulakou & Kraak, 1992] the user appreciates animated spatio-temporal maps more, when he/she can interact with the map. The courseware stresses required functionality to present spatio-temporal maps. This includes options to stop, restart and browse forwards and backwards at, and offers the user flexible access to the spatio-temporal component of the data for visual communication as well as for thinking purposes. The Windows environment is a example of a suitable basic user interface. It allows the user to create multiple views on the data in windows, which can result in displays of temporal phenomena in both static and animated form. The courseware also indicates the challenge of multi-media. Animated maps combined with other graphics, texts, images, and sound offer interesting opportunities. However its effect on a visual communication environment is currently not fully understood, let alone the visual thinking environment.

		data-component			
		locational	non-locational	temporal	
spatio-temporal map display	static	single	plane	visual variable	visual variable
		series	plane	visual variable	spatial deduction
	animated	plane	visual variable	memory deduction	

Figure 2. Spatio-temporal maps and cartographic communication (adapted from Kousoulakou & Kraak, 1992).

## Computer Assisted Learning and the Delft curriculum

### Aspects of Computer Assisted Learning

Today computers are commonly used in educational programs. In their book Gold et al [1991] discuss a large variety of computer resources, linked to potential educational activities in which they can be applied in a geographic context. Resources include basic information processing tools, such as word processors, e-mail and multi-media. Educational activities can consist of slide shows presentations, the use of thematic mapping packages, as well as providing tutorials and demonstrators. In general all educational activities in which a computer is involved can be seen as Computer Assisted Learning (CAL). This paper concentrates on one aspect of CAL only: the tutorial. Recent advances in technology revived the interest in this type of CAL. In

disciplines dealing with spatial data this new interest is partly due to the extended possibilities to apply graphics. Graphics are not only an attractive, but also a versatile tool in communicating information on abstract or concrete concepts.

Tutorials are designed to help students master certain parts of the educational program. In a basic form they present material on a specific topic, and often the students have to answer questions, which result in feedback and directions how to continue. This approach allows the students to learn at their own pace, and sometimes at their preferred location. A disadvantage can be that this type of programs do not allow adjustment to the students' individual level of knowledge. How is CAL incorporated in the Delft curriculum, and what is the nature of the tutorial on spatio-temporal maps?

#### Delft cartography curriculum

At the Delft University of Technology the Faculty of Geodetic Engineering offers a four year educational program for geodetic engineers. Within the Faculty the Department of Geo-information is responsible for several courses in Cartography and GIS/LIS.

Each year of the educational program is split into four each eight weeks periods. In one such a period three or four courses are taught. This approach requires a strict time discipline, since all activities related to a specific course have to be finished within the eight week time period. Most courses, including the cartography courses, consist of lectures and practicals. In those courses all kinds of CAL techniques have been introduced to ensure diversification of teaching methods (see figure 3).

The basic view on cartography in Delft is based on a combination of the communicative and semiological schools of thought [Ormeling & Kraak, 1990]. Spatial information to be transferred is analyzed and represented according to the rules of the graphic sign system. In the framework of the educational program this view is incorporated in the world of GIS/LIS. In the curriculum this view is linked to developments in topographic and thematic mapping, with special attention to three-dimensional and spatio-temporal aspects.

#### CAL and the Delft curriculum

Figure 3 outlines the use of CAL in the Delft cartography curriculum according to a multiple classification given by Gold et al [1991]. In their original paper they described computer resources and indicated their educational use. Then they considered educational activities and indicated which computer resources can support these activities. The upper diagram lists the computer resources, and the lower diagram the educational activities. In each diagram the relative intensity of use by students is indicated. For a detailed discussion on each single resource or activity one should consult the chapter in Gold's book. In the upper diagram it can be seen that students use the computer heavily for general information processing tasks and GIS. The use of computer resources for computer managed learning and model building is moderate, while its use for e-mail and presentations is low. The lower diagram indicates which educational activities in the cartography curriculum are executed with the help of computers. The use of the computer as analyst is high. This includes

mapping, GIS (spatial analysis), remote sensing and exploratory data analysis. Teaching and editorial assistance by computer is moderate. Several tutorial programs are available, one on spatio-temporal maps which is discussed in the next section, and a tutorial on digital terrain models which also explains the Delaunay triangulation algorithm, and another deals with generalization. Low use can be seen where the computer functions as a study aid (software manuals / demonstrators like GIST), a tool (algorithm builder), adviser (library catalog / a program to keep track of study results), presenter (slide shows with results of mapping packages), personal assistant (to prepare presentations) and as editorial assistant (to write papers). Thick lines in both diagrams indicate links to the tutorial on spatio-temporal maps.

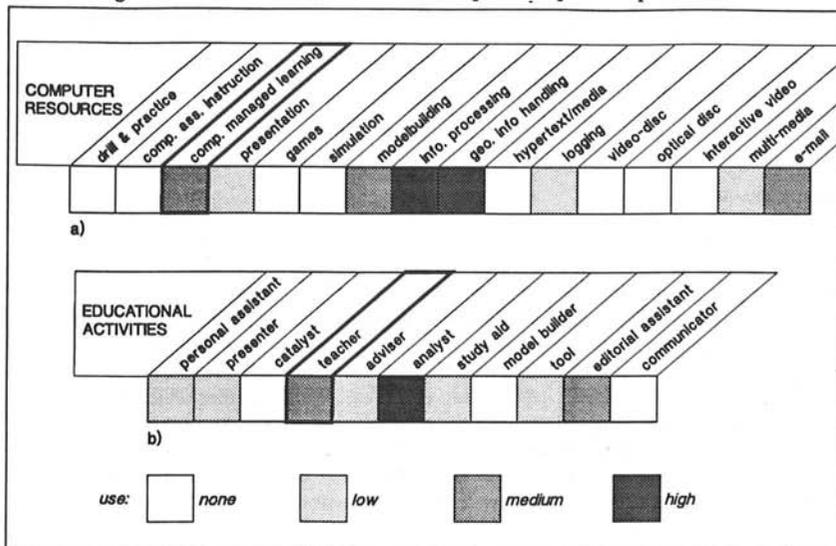


Figure 3. Computers and the Delft cartography curriculum: a) computer resources; b) uses of computer for educational activities (classification of resources and activities is based on Gold et al [1991]).

### STMAPS

The structure, the contents and the environment of the STMAPS (Spatio-Temporal MAPS) tutorial will be discussed using figure 4. This figure displays the screen which gives access to the main sections of STMAPS. Before this screen appears, a title screen and a user screen are shown. On the user screen student have to type their name, which results in the creation of several log-files which keep track of student's progress and results.

#### STMAP structure

Figure 4 displays six icons. Each of them, when activated, gives access to the corresponding section of the tutorial. When a student has finished a section the icon border is coloured, as can be seen with icon I. In the text highlighted key words give access to a glossary. Each screen has a help function which provides information

on its use, and gives access to an index. An example of an index application is a possibility to go back to a topic dealt with previously, in case a student needs some refreshing and clarification to understand the concept currently studied. To avoid that the only student activity is reading and moving through pages by pressing a mouse button, they are regularly asked to answer questions, and execute exercises. The questions are of the multiple choice type, and refer to the text and knowledge which should be available to the students, since they have progressed the educational program so far. To all questions there is always a response, which should stimulate the students to continue or help them to find the correct answer. The exercises are graphically-oriented, and include tasks with maps. Often the text is illustrated by demonstrations which give examples or explain algorithms used.

#### STMAPS contents

The first three sections (icons I, II, & III) represent topics which give the student background information to understand spatio-temporal maps and their use. The sections numbered IV, V & VI explain, based on this paper, the types of spatio-temporal maps which can be distinguished. The order of the sections presented in the figure by the icons is the preferred one when going through the tutorial, but another order may be selected. Section I discusses the characteristics of spatio-temporal data, and provides links to the basic cartographic theory. A conceptual model of time in cartography is given [Langran, 1992]. Section II treats the difficulties which occur when trying to include temporal data in a database or while designing a data structure to handle this type of data. Section III demonstrates the use of the spatio-temporal maps. Samples of application in GIS, multi-media and exploratory data analysis environment are given. Sections IV and V discuss the visualisation of temporal data in static maps. Examples are given, and typical tasks include design of the maps, based on data provided. These exercises are a graphical variant on the multiple choice questions. In design examples students have to indicate which visual variable, and which symbol they intend to use to display the data. Section VI represents the most challenging topic, the animated spatio-temporal maps. It contains several examples of animated time series as well as of fly-bys. It also covers animation in general, and provides links with cartographic theory. The most important aspect dealt with is the graphical user interface. Students have to answer questions in relation to the contents of maps in a static, and in an environment where interaction with the animated map is allowed. This to demonstrate the need to control the animation, if the user wants to answer questions or study a map which represents a specific moment in time.

#### STMAPS environment

STMAPS is being produced with an authoring tool called IconAuthor, which operates in the MS-WINDOWS environment [IconAuthor, 1991]. IconAuthor is a tool to create interactive multi-media applications that combine text, graphics, animation, full motion video and audio. It uses icons to represent a flowchart or structure of an application. The authoring tool allows the incorporation of graphics produced by other software, such as desk top mapping packages.

## 5.0 Conclusions

STMAPS is currently in the last phase of development. This year it will be tested and used in teaching cartography program at the Faculty of Geodetic Engineering. The advanced programming environment offered by Icon Author satisfy the specific needs of the tutorial on spatio-temporal maps. However, the development of tutorial is a very time consuming activity. A tutorial such as STMAPS is developed to create a diversification in the educational methods used.

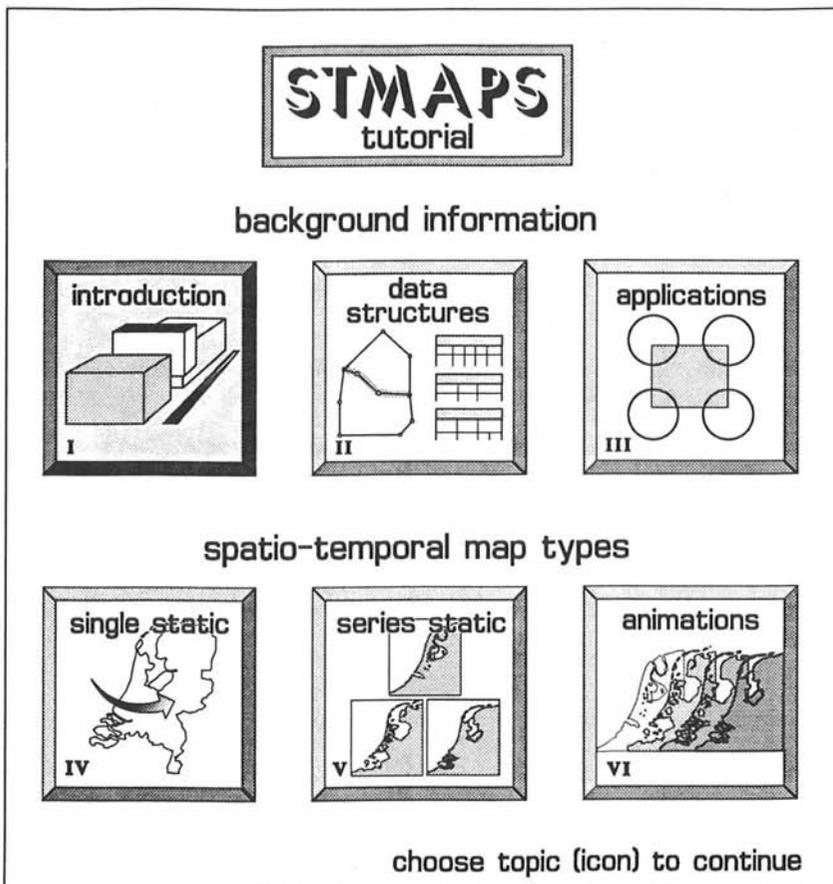


Figure 4. The access screen of STMAPS.

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# Representing the geographical space for visually handicapped students: a case study on map use

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## ABSTRACT

The paper presents the results of a research which the main purpose is to study the tactile graphic language in the process of getting spatial awareness and geographical knowledge. The relevance of maps and diagrams for the visually impaired student is discussed and the need of cartographic training is stressed. A set of exercises is suggested to introduce key concepts needed to understand maps. Finally, attention is called to the importance of applied research within Cartography, particularly regarding spatial data representations and maps in a multisensorial mode with the young user in mind.

## 1. INTRODUCTION

In Brazil, very little had been done to overcome the lack of cartographic products in tactual form directed to the visually impaired user. Tactile maps and graphics are hardly available. There are a few of them in school books made by dedicated teachers and professionals with limited knowledge, most times with no Cartography or Geography background. None of the current production methods used in many countries were tested in Brazilian institutions for the blind, where just conventional paper press and vacuum-forming copies are employed.

For the last three years, a research program dealing with tactile graphics in geographic education was carried out by a team coordinated by the author. This program has been developed at the Department of Geography, University of São Paulo/Brazil, with financial support from VITAE-LAMPADIA Foundation. The main purpose was to initiate in Brazil the field of Tactile Cartography.

The visual perception is the most important channel to acquire spatial information and to construct the concept of space. The sense of vision is also vital to learn Geography because we can see our world and images of it through the eye. Cartography has a relevant role in this process and it should provide suitable material for the visually impaired people. For this group of users, maps are even more necessary comparing to the sighted user. The blind person might need a map to go through a building without help. All types of cartographic materials should become available in the tactual form, including thematic and reference maps in different scales.

## 2. CARTOGRAPHY AND TACTILE MAPS: current issues

Maps and all spatial information products are becoming more relevant at the end of this century because all graphic representations are assuming a vital role in every day life, at school or work. Technological innovations are causing a great impact on Cartography in all levels. We are going through a decade of remarkable changes with new political, economical, cultural, environmental realities taking place in our world.

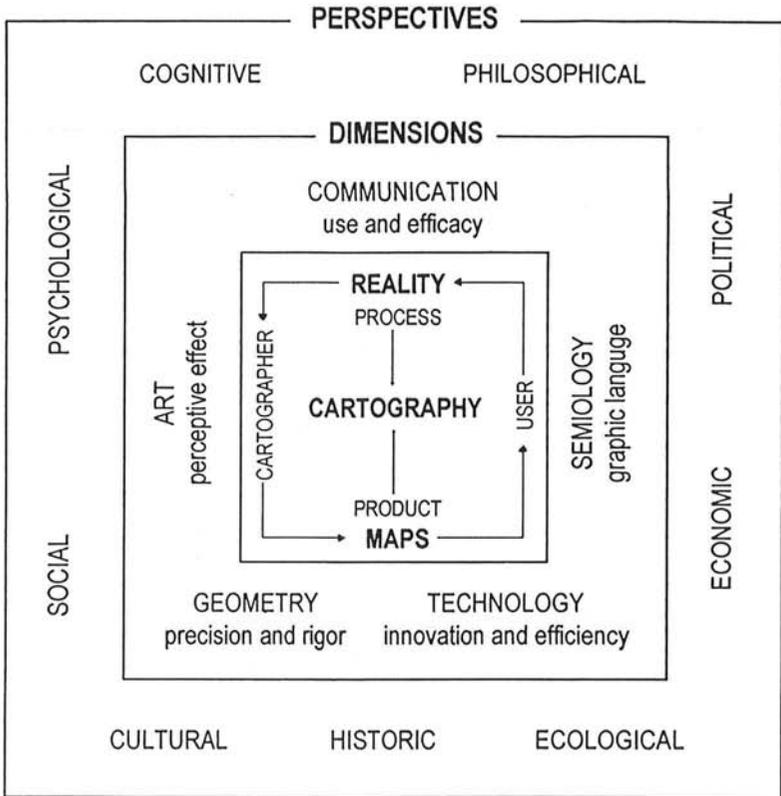
Taylor (1991) has raised many important points in an excellent analysis of this matter. This author calls attention to the urge of new concepts for Cartography, considering the social and cultural contexts, without the predominance of the technological paradigm. Harley (1989) made a fundamental analysis of the subject, causing considerable impact among cartographers.

Figure 1 is an attempt to emphasized perspectives and dimensions related to Cartography, which is viewed at the center as a communication system. It has to be accepted by cartographers and users that the discipline is changing constantly. It is very true that "cartographers are too often a group open to new technologies, but close to new concepts" (Rhind, 1991), this idea is particularly actual in Brazil.

It is time for cartographers to reconsider the discipline theoretical framework for the information era. First of all, producers and users have to be fully aware of the problems related to the cartographic language. Maps are graphic representations of reality, therefore they are abstractions showing parts of this reality. For this reason, omission is always present. Exaggeration, lack of precision, error, distortion, falsification and manipulation are potential problems to happen during the cartographic process. They can occur as a result of technical or financial restrains and ideological or political matters, not to mention the absence of proper cartographic training. Board (1991) and Monmonier (1991) discuss this subject extensively.

The best example of this situation can be found in the communication media. The largest newspapers in the city of São Paulo, Brazil, are publishing maps, graphics and images in many sections, as never before. New computer technologies recently introduced in the press production explain this graphic innovations. As a result, emerged a group of new map users and new map makers, lacking proper training and skills to deal with the language of maps.

FIGURE 1 - PERSPECTIVES AND DIMENSIONS IN CARTOGRAPHY



The visually impaired user and the tactile map maker are also a group with serious difficulties to overcome. In order to communicate geographic information and spatial data some of the problems to be avoided in conventional Cartography, become qualities and conditions to design good tactile maps. They need a much higher degree of generalization with omissions, exaggerations and distortions never imagined by the cartographer. Tactual Cartography should be based in different concepts, following other rules and using distinct techniques, both in map design and production.

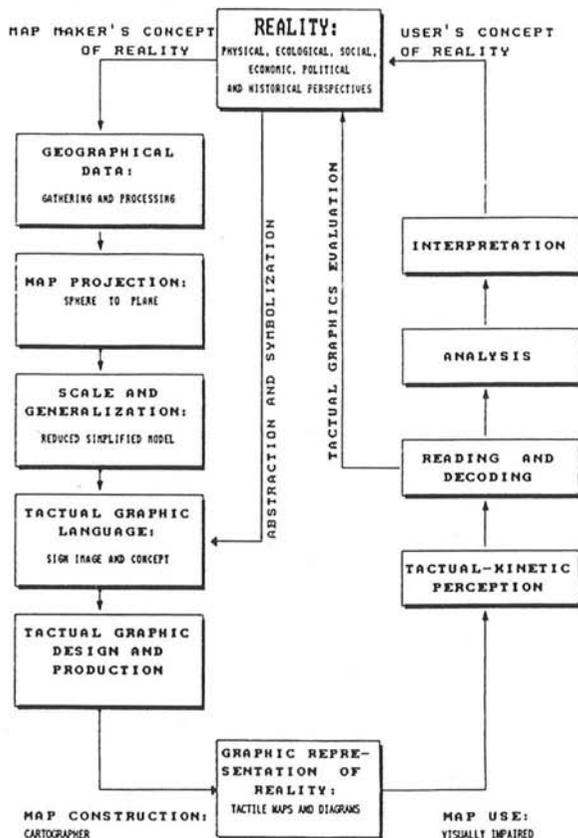
Many authors have contributed significantly to this field as editors of basic publications (e.g. Wiedel, 1972,1983; Schiff and Folke, 1982; Nicolai, 1984; Tatham & Dods, 1988; Ishido, 1989), doing relevant research or writing papers and books (e.g. James & Armstrong, 1976; Qingpu, 1988,1991; Keming, 1991; Kadmon, 1991; Coulson, 1991). The literature with an emphasis on tactile map design and applied issues will be presented in the following section.

### 3. TACTILE MAPS IN THE PROCESS OF CARTOGRAPHIC COMMUNICATION: the role of map design

Tactile maps are effective examples to stress the significance of the Cartographic Communication Process which has been widely studied by cartographers all over the world, for the past twenty years. The questions What, How and To Whom summarize the essence of this process that starts with the reality to be mapped by a cartographer. A few more questions might be added to the three basic ones: When and Where, Why and With which results.

Figure 2 shows the Tactual Graphic Communication Process as seen by the author (Vasconcellos, 1991). Some stages are essential to achieve communication effectiveness in the tactual format. For instance, when the user has vision problems, scale and generalization, design and production, reading and decoding need special attention.

FIGURE 2 - TACTUAL GRAPHIC COMMUNICATION PROCESS



The crucial point of the whole process is the tactual graphic language. This is the question "how". The signs have their concepts, represented by the geographical information, and their images, which apply the graphic variables. During the first phases, the research main goal was to translate the language of signs conventionally used on maps to a tactile format.

The starting point was the analysis of the visual variables in Figure 3, as proposed by the Graphic Semiology (Bertin, 1977) and applied in education by Gimeno (1980). Figure 4 presents the graphic variables using the third dimension, as a new set to be employed in tactile maps (Vasconcellos, 1991). Elevation (height) was added in the graphic variables set and it can be combined with all the other variables in multiple ways. Color is the only one that can not be used in the tactual graphic language, but different textures can be used in its place. In the same way as color, texture may be utilized with equal value for qualitative data or with different values to express order. It is important to analyze the nature of the data (quantitative, ordered and differential) to be able to select the correct variable.

FIGURE 3 - THE VISUAL GRAPHIC VARIABLES (after BERTIN, 1977)

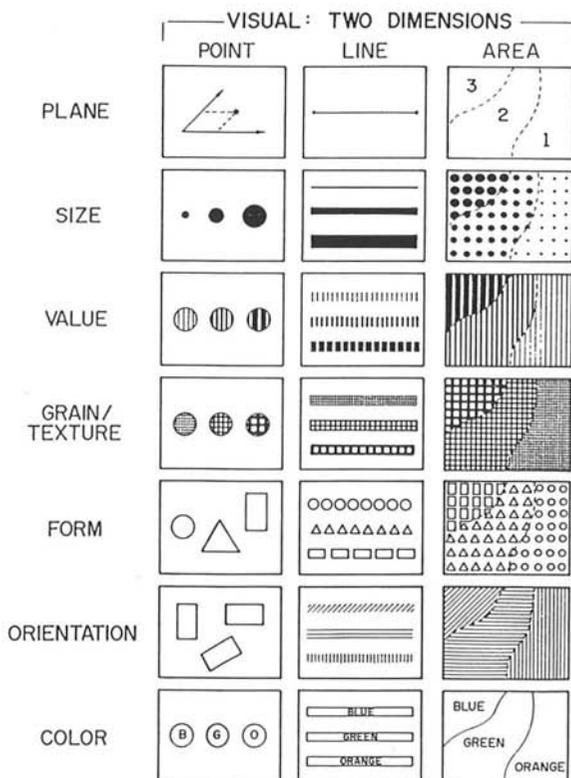
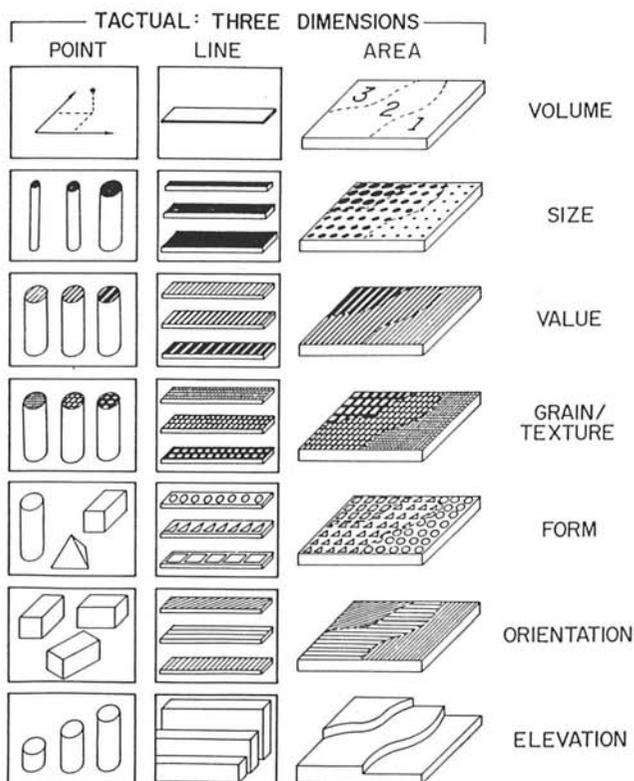


FIGURE 4 - THE TACTILE GRAPHIC VARIABLES



A catalog was constructed, based on these six tactual variables: height, size, value, texture, shape and orientation, with examples in points, lines and areas. Different materials and tools were tested to select the symbols to be used in the construction of maps, diagrams and drawings.

Tactile map design and use have been studied by a large number of authors. Just to mention some of them: Franks & Nolan, 1970; Nolan & Morris, 1971; Wiedel & Groves, 1972; Kidwell & Greer, 1973; James & Armstrong, 1976; Levi & Amick, 1982; Bentzen, 1982; Barth, 1987; Tatham, 1991; Edman, 1992. Several others have contributed greatly to the subject, although not cited in this paper: E.Berl , J.Gill, H.Vlaanderen, G.Jansson, G.Leonard. They all presented solutions to the design of maps for the visually impaired and have several publications on the topic.

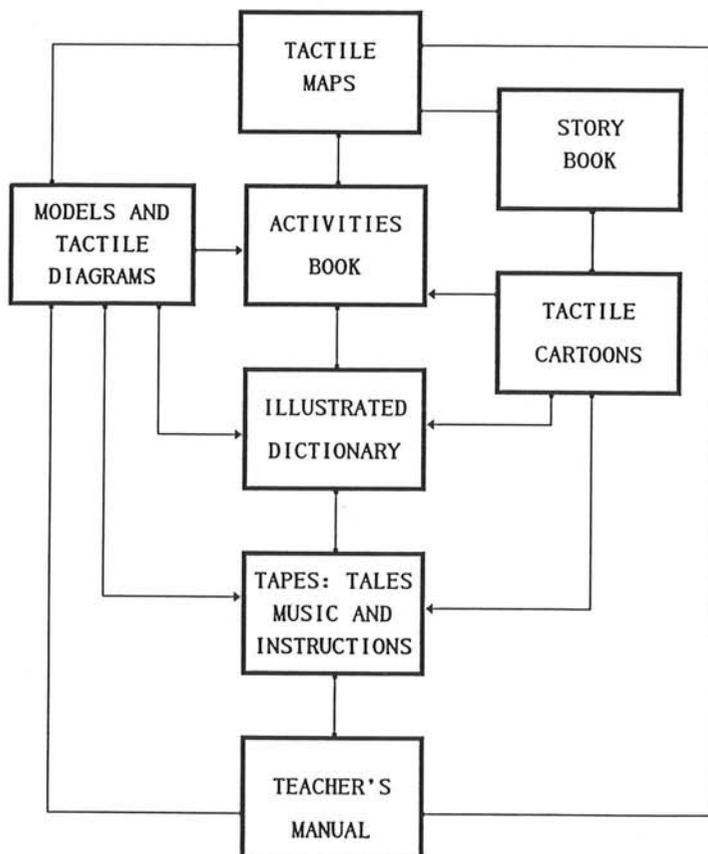
One might say that there are not such an expressive literature for map design and use in its visual format. Conventional Cartography are not so much worried about the user's needs and his perceptual limitations. Tactual Cartography can certainly bring light to cartographic education and to the utilization of maps and diagrams by the sighted user, mainly young children.

#### 4. TACTILE GRAPHICS IN GEOGRAPHY EDUCATION: relevance and efficacy evaluation

The research first results showed the high efficacy of the tactile graphic language and its importance involving space perception by children. Maps are always fundamental tools in the process to acquire geographical concepts and knowledge regarding the environment, mainly when visual impairment are present.

In the first phase (1990-92), the Brazilian Amazon Region was chosen as the reality to be studied. The program included several teaching tools and ideas: maps, models, tactile diagrams, activity books, games, illustrated dictionary, story book and teacher's manual. These materials, showed in Figure 5, were constructed and tested.

FIGURE 5 - TEACHING MATERIAL INTEGRATED VIEW



The methodology and the materials were tested with 50 visually impaired students and they were evaluated by 80 teachers. The tests showed that it is difficult to reach an agreement in the definition of guidelines, due to individual variations, preferences and levels of skill related to map reading and graphic language understanding. The subject is discussed by Hampson (1989), who arrived to similar conclusions.

Studies on developmental stages, mainly based on Piagetian theories (Gottesman, 1971,1975; Hatwell, 1985) can help to find answers, but more research is necessary with the visually impaired in mind. Authors as J.S.Bruner and L.S.Vygotsky must be read. Andrews (1991) has an excellent book, covering cognition and language in the case of sensory impairment, specifically related to Geography teaching. Other authors gave relevant contributions to geographic and cartographic education, although without mentioning the visually impaired (e.g. Petchenik, 1979; Boardman, 1983; Anderson, 1987; Castner, 1990, 1991; Gersmehl,1991; Gerber, 1992;).

After practical experience with the use of tactile maps and graphics in Geography lessons, it was possible to analyze problems and to suggest a few solutions, as the following:

- basic geographical concepts (proportion, scale, location, orientation) must be well understood before working with maps.

- the graphic language has to be introduced to the user prior to map reading through exercises with the graphic variables.

- it is advisable to create and use conventions as much as possible to facilitate graphic information reading. The map key is very important for the visually impaired, they are experts in decoding a legend. It should be used even for drawings.

- proper reduction and generalization are vital, also size is important because tactual perception is not global and the blind user must put together pieces of information to form the image.

- relief models help children to understand physical space. They are less abstract and should precede the introduction of maps.

- activities and geographic games can facilitate the whole process of learning Cartography and Geography.

- materials must be classified, considering levels of complexity, age and grade adequacy.

Experiences during the research first phase confirm that visual and tactual graphic language depends on training to be used properly, with all its potential. Sensory stimulation should start at home and at school, even before first grades. Children have to be well prepared to deal with maps and in the case of visually impaired students this is vital .

A training program directed to the visually impaired user was outlined for the second phase of our research, started at the end of 1992. Graphic materials, exercises and games are being constructed to introduce each of the basic concepts selected: point of view, proportion, scale, distance, location and orientation.

The program also includes the introduction of all tactile graphic variables showed in Figure 4, in the format of playing cards. Map key (symbolization) and grid use have to be practiced before the last stage of decoding and reading maps. This last exercise, called "full address", integrates all informations: it starts with the school map and it goes through several smaller scale maps (district, city, state, country, continent, earth, solar system) until it reaches the Universe. The proposed training program will be tested with sighted and visually impaired students, during the first semester of 1993.

## 5. FINAL REMARKS

At the end of 1992, a new research project was started with the State of São Paulo as the study area. It is centered in three main topics:

- \* tactile graphics design: analysis, construction and tests of different techniques and cartographic products.
- \* tactile graphics evaluation: definition of different levels of complexity, accordingly to prior spatial perception, geographic knowledge and experience in graphic language.
- \* tactile graphics use: training programs for teachers and visually impaired students.

The main purpose of this research is to study a tactual graphic language which will improve the teaching of Geography and Cartography to both blind and sighted children. Cartographic communication process and Graphic Semiology can bring relevant contributions to the field of Tactile Cartography. Therefore, the same methodology used for the Brazilian Amazon Project will be applied to study São Paulo, emphasizing an interdisciplinary approach directed to enhance the role of maps in education.

It is essential to take advantage of all senses to learn about the geographical space, using the right side of the brain and developing different skills. To reach this goal it is being planned a Center for Tactile Cartography and Multisensorial Teaching Resources at the University of São Paulo. If financial support is obtained, this center will develop and construct educational and cartographic products to the sensory impaired and the sighted user. It might be a way of getting people to enjoy more Geography and Cartography, to fully understand and use maps, in its visual or tactile form.

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# Teaching and learning map projections with a computerized tutor

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## Abstract

Map projections are an important part of the training and education in cartography. They are particularly suited for a treatment with the help of a computer because of their mathematical algorithmic nature and the great value of the visual representation of their characteristics.

This paper presents a computerized tutor for map projections based on the macro facilities and cartographic functions of the Arc/Info geographical information system software. It was developed at the Department of Geography of the University of Vienna, Austria. The whole system is menu driven and allows for user interaction by form menus. Its main function is to teach the various projections according to their characterizations as cylindrical, conic and azimuthal projections with their variations and pseudo forms. For every projection a description of its major characteristics and usage together with ellipses of distortion (Tissot's indicatrix) can be displayed. The user also gets a list of suggestions as to which projections should be used for certain applications and scales.

In addition a tutorial part of the system provides menus where the knowledge obtained by using this program can be checked by identifying specific projections according to their representation of parallels and other characteristics. The system is not only a useful tool for teaching classes but also provides a self-guided tour through the realm and applications of map projections.

## Introduction

Map projections play an important role in the education of cartographers, surveyors, geographers and all those who are involved in the processing, display and output of spatial data. The use of computers and suitable software has made it considerably easier to apply map projections for various tasks. Most of the geographical information systems (GIS) software provides an extensive set of projections and a user-friendly interface.

There exist already tutors for various disciplines like GIS (Raper & Green 1989, 1992; Maguire 1989; Hawke 1992), based on different implementation approaches. Cartographic

projection software has also been available for some time, e.g., the General Cartographic Transformation Package GCTP (Ellassal 1987) or Cartographic Projection Procedures for the UNIX Environment (Evenden 1991). GIS software, like Arc/Info, is widely used and readily available.

The widespread use of computers and mapping software not only in the mapping industry makes it necessary for the user to get acquainted to the various types of map projections, their characteristics and useful applications. Since an increasing number of people not educated in cartography may produce maps with available software packages it becomes an important task to provide them with a tool that helps them to acquire the knowledge necessary for the proper use of cartographic display techniques including the application of map projections.

The design considerations for the cartographic projection tutor are based on the following assumptions:

- The tutor should cover the most important projections used.
- It should make use of existing projection software.
- It should be easy to implement by using available software.

For that reasons it was decided to implement the tutor under workstation Arc/Info using the Arc Macro Language (AML) programming and graphical menu interface. The system was developed at the Department of Geography of the University of Vienna using Arc/Info version 6.1 on an IBM RS/6000 workstation.

## Map Projections

For the projection tutor it is important to choose a set of projections that are widely used and represent the main characteristics of the various projection classes. It is also required to introduce a classification scheme of map projections that is easy to represent and easy to understand by the student.

There are several ways to define such a classification (Maling 1973, Hoschek 1984, Snyder 1987). For this project we used a classification according to the surfaces onto which the Earth is projected (cylindrical, azimuthal, conic projections) and the projection characteristics of being equal-area, equidistant, or conformal, and those projections that are mainly or only used for world maps. The latter group is divided into projections that map poles to points and those that map them to lines.

Table 1 shows the projections used for the tutor assigned to their respective classes. Note that the gnomonic projection falls somewhat outside this classification, because it is neither conformal nor equal-area. For most

of these projections the spherical as well as the ellipsoidal forms are considered.

Table 1: Classification of map projections used for the projection tutor.

	<b>Equal-area</b>	<b>Equidistant</b>	<b>Conformal</b>
<b>Cylindrical</b>	Behrmann	Plate Carrée Cassini-Soldner	Mercator Transverse-Mercator Oblique-Mercator UTM
<b>Azimuthal</b>	Lambert	Postel	Stereographic <i>Gnomonic</i>
<b>Conic</b>	Albers Lambert	de l'Isle	Lambert

Table 2 lists the projections that are mainly used for world maps classified according to the representation of the poles. These projections usually are pseudo-forms of and/or combinations of the cylindrical, azimuthal or conic projections. Since these projections are almost exclusively used for world maps, only their spherical forms are considered.

Table 2: Classification of projections used for world maps.

<b>Pole as a point</b>	<b>Pole as a line</b>
Mollweide	Eckert IV
Sinusoidal	Eckert VI
Van der Grinten I	Robinson
Bonne	Winkel I
Hammer-Aitoff	
Briesemeister	

### **System Design and Implementation**

The system is designed around the Arc/Info AML programming and menu environment available on workstations. The current implementation gives the user the choice among three options:

- to choose a projection according to the classification into cylindrical, azimuthal and conic projections
- to choose a projection by its name
- to choose a projection according to its usage for the area of geographical application (world, hemisphere, continent, country) and type of maps used for (topographic maps, thematic maps, navigation maps)

Depending on the selection three representative areas of the world can be displayed using the respective projection:

- the whole world
- Europe
- the United States of America

The display contains not only the boundaries of the features presented but also a geographical grid to visualize the mapping characteristics of the projection.

An additional option provides the user with a display of ellipses of distortion (Tissot's indicatrix) to show the distortion characteristics of the projection. If required the user may display a menu showing a description of the main characteristics of the map projection displayed. This description comprises the:

- main characteristics,
- description,
- historical remarks,
- usage and application, and
- aliases

of the respective projection. Figure 1 shows an example of the description for the Bonne projection.

## **BONNE**

### **Characteristics**

pseudoconical, equal-area

### **Description**

The Bonne projection is an equal-area pseudoconical projection. The central meridian is a straight line, other meridians are complex curves. The parallels are concentric circular arcs, but the poles are points. The scale is true along the central meridian and along all parallels. There is no distortion along the central meridian and along the standard parallel.

### **History**

The principles of the Bonne projection were already developed in the 16th century, but it was considerably used by Rigobert Bonne (1727-1795), a French geographer, therefore its name. This projection has been used for large- and small-scale mapping. Many atlases of the 19th and 20th century utilize the Bonne projection, mainly for maps of continents.

### **Usage**

Mainly used for maps in atlases. Large-scale use of the Bonne projection for topographic mapping was introduced by France.

Figure 1: Help text for the Bonne projection

An extended feature of the system - not yet implemented - would be a training component, where the user is asked to identify map projections according to their characteristics or to suggest projections for certain applications or certain geographical areas.

### **Conclusions and Outlook**

Teaching and learning map projections can be supported by computerized tutorials and tutor programs. Thereby it becomes easier to show the different types of projections and their characteristic features. Changes are displayed immediately on the computer screen and modifications can easily be visualized.

The map projection tutor presented in this paper was developed at the University of Vienna to provide students of cartography and geography with a tool to practice their theoretical knowledge about map projections. It is also meant to support classroom teaching by interactively showing the effects of different projection methods, parameters or types.

The current version is implemented with a German user-interface. It is however easy to provide versions in other languages by simply translating the menus and help texts. The training component for the identification of projections according to their graphical representation is not yet realized. For future versions it might be worthwhile to use a multi-media approach including animated sequences, e.g., to show the mapping process from the sphere to a cylinder, cone or plane.

### **Acknowledgment**

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# Wherefore art thou cartographer? Your GIS needs You!

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## 1. Introduction

In the UK, a recent monograph (1), as part of an initiative by the Association for Geographic Education (AGI) Research and Training Committee, has identified and highlighted the concern of some cartographers and GIS specialists about the role of cartography in GIS and vice-versa. In the context of GIS, others (2; 3; 4) have also drawn attention to the need for cartographers and the GIS community to become more closely involved with each other.

With recent developments in computer hardware and software, maps can be designed, created and produced far more easily than in the past, and by virtually anyone. Maps are no longer the domain solely of the cartographer. Whilst considerable flexibility and opportunity is afforded for creative map output this can also lead to far too much freedom for a person with little or no cartographic knowledge and training. The end result may indeed be a colourful and aesthetically attractive map but it may not be an efficient or effective means of communication.

It is argued here that cartographic expertise has a vital role to play in the design of maps to communicate information output specifically from GIS and DIP systems. The objectives of the paper are: firstly, to highlight and emphasise the importance of including map design in GIS and DIP education, training, and use; secondly, to identify and highlight some of the possible reasons why map output from GIS and DIP systems tends to be poor, and to consider the need for guidance in map design to be included as an integral and interactive part of commercially available GIS and DIP software; and finally, as an example, to highlight the importance of map design using the visual variable colour.

This paper specifically focuses on the 'average users' of the desktop systems now available to teaching, education, and small commercial outfits who are likely to have little cartographic background or training, rather than the large specialised map producer (5). This is where cartographic expertise seems to be most needed in order to encourage new research, provide

guidance, and initiate cooperation between GIS specialists and cartographers. The paper also seeks to place emphasis on the importance of the visual end-product as a means for communicating spatial information.

## 2. The Revival of Graphics in Communication

Increasingly one is seeing a wide variety of colour graphics and images being used as the primary means to communicate information (both spatial and non-spatial) derived, displayed, and output by Geographical Information Systems (GIS) and Digital Image Processing Systems (DIPS). This includes images, graphs and charts, and also maps (6; 7; 8; 9). The graphics may take the form of both softcopy (CRT display) and hardcopy (printed and plotted), and are usually the major form of output from such systems.

The apparent revival in the use of graphical techniques of communication (10) has largely come about through the development of the 'right technology', both software and hardware e.g. computers, peripherals, graphics cards and displays, and graphics software, and the widespread adoption of this technology by many disciplines who had not used it previously.

A major contributor to the increasing use of maps, as a means of communicating information, has been Geographical Information System technology (11), remote sensing DIP, graphics software, and more recently integrated GIS and remote sensing systems. CAD software, with or without an attached database package, must also be added to this list as it is often used for designing, creating and outputting maps. AutoCad, for example, can now link to databases and import and display satellite imagery (12). Many commercially available GIS software packages are in fact designed and marketed primarily as mapping systems, particularly when they have limited spatial analysis functionality. Conversely, 'full-blown' spatial analysis information systems often become used solely for map production. In the near future, the developments in Multimedia GIS must also be taken into consideration as potential sources of maps (13; 14). Both softcopy and hardcopy maps from such systems are likely to become part of public information systems and will permit a user to design and create (even to customise) their own maps.

Maps can be created with the aid of such software systems by digitising or scanning and displaying single or composited layers of geographical or spatial data, stored in digital databases, by overlaying or draping vectors onto background images e.g. scanned aerial photographs, video, or satellite images, or by classifying (supervised or unsupervised) digital satellite images (e.g. Landsat or SPOT).

To facilitate the design and creation of these maps, both GIS and DIP systems usually provide a range of graphics tools for editing and annotation. These take several different forms. Firstly, they may be an integral internal or external graphics software package or module. In many DIPS, for example, the graphics tools are typically existing commercially available pixel- or vector-

based graphics software (e.g. Paint or CAD). An example is Dr.Halo. The DIP system R-Chips, from Reading University, uses the low-cost paint software Dr.Halo, which can be loaded as an overlay on a raw data or classified image. Alexander, the integrated GIS/DIP software from ITC (International Institute for Aero Space Survey and Earth Sciences) in the Netherlands, uses the Acorn software Paint and Draw. Images can be saved in the form of a Sprite and transferred (by dragging the Sprite icon) directly into the graphics software for editing and annotation. Secondly, other DIP systems include graphics software developed 'in-house' e.g. Erdas, Diad. In some cases special cartographic options are available to create specific types of map (15) Finally, another alternative is to offer a range of well-known image file formats e.g. TIFF to enable the user to output an image or layer to a file which can subsequently be exported/imported into the chosen graphics software. Similar graphics 'toolboxes' and options are also provided with commercially available GIS and integrated system software e.g. MIPS. The use of Postscript files, exported from a GIS to the Apple Macintosh software package Illustrator, can also provide access to map design tools lacking in the GIS (16).

All of the graphic options mentioned above allow the user to add text and frames, design and create symbols and orientation symbols, select and use colours and shading patterns, add keys or legends and outlines, and highlight areas, amongst other things. To a large extent realising the flexibility or power of these graphic design packages as mapping tools depends upon the quality and ease of use of the software, together with the imagination of the user. For example, if a classified satellite image is used as the source for vegetation information, graphics software can be used to add annotation such as text, a border, legend, grid, and orientation symbol to create a vegetation map. Colours or patterns, representing different vegetation types, can be selected from a default palette, or optionally created.

The choice of graphics software as the main map design toolbox in an electronic medium has largely come about because many are relatively low-cost, they are readily available, can easily be bundled with other software e.g. GIS and DIP, and are likely to be familiar and easy to use. Given this type of functionality there has been little point in developing new packages. They are also widely used as the basis for 'illustrative' cartography, particularly software for the Apple Macintosh (17). Uses include freehand drawn maps e.g. for dissertations, illustrative maps for journalistic cartography, and scientific mapping tasks required by many geography and geology departments. In recent years, marked improvements in the cartographic suitability of this software have been made (17).

### **3. The New Definitions of a Map**

Examining the many different examples of graphics and images that now come under the heading of a map (1; 18), it is clear that our perception and definition of 'what a map is' has changed over time. Developments in computer technology, new sources of spatial data and information, the ways in

which it is possible to design and create maps e.g. on-screen, the new and exciting possibilities associated with user freedom e.g. to create and use colours in the design and use of maps and images have all contributed to the development of many new types of maps e.g. maps for illustration, and maps using an image as a backdrop. The new technologies available offer an environment for experimentation, innovation, speed, and allow virtually anyone to design, create and produce a map.

A recent study (19) concluded that the current definition of maps should include aerial photographs, satellite images and map-like images displayed on a CRT. Factors that make these graphics more 'like a map' than 'not a map' are view orientation (oblique versus vertical), subject matter e.g. the earth's surface, familiarity of view, the recognition of spatial patterns and features, geographical reality, flat or plans, and scale. Images that undergo 'crafting', or contain map-like components e.g. a north arrow, grid and legend are considered map-like (19).

Graphics design software, coupled with GIS and DIP have therefore added a new dimension to mapping, referred to as small-format cartography (20). In effect the technologies have popularised the design and creation of maps, and this in turn has led to the evolution of many new types of maps which fall within the definitions given above. Furthermore, cartography is no longer seen as the domain solely of the cartographer; maps can be designed by the non-specialist.

#### **4. Poorly Designed Maps**

However, the opportunities available for virtually anyone to design and create a map have been found by many cartographers to lead to what are considered to be poor examples of maps (17). Moreover, they can be misleading and fall short of current standards (21). Closer examination of some of the examples of maps now frequently seen in, for example, student dissertations, journals and other publications, reveals that the output from GIS and DIP is not as good as it could or perhaps should be. Many examples leave a lot to be desired in terms of the quality of the map design. All too often, a 'pretty visual graphic', rather than an effective medium for communication is the end-result. While many examples, both 'on-screen' and printed hardcopy, are aesthetically very appealing and colourful, and in that sense attract attention (but in turn perhaps distract from the intended message), more often than not the output is not always the most effective or efficient means of communicating spatial information.

On the whole it would appear that too little attention and thought is being given to the end product as a 'map'; that is to considering the information the map is meant to convey and in fact does convey. This can be particularly important, especially if the 'end-user', who one can not assume has had exposure to education and training in cartography, results in being misinformed or even uninformed. In other words the map fails to communicate its message (22; 18).

## 5. Factors Contributing to Poor Map Design

What are some of the factors contributing to these poorly designed map products?

- The user of the software system: the designer of the map is primarily responsible for the map created - good or bad.
- The lack of cartographic background, knowledge, and training which includes both theoretical and practical knowledge and skills.

But, while lack of training is frequently cited (17) and is partly to blame, as others (1) observe that it would be naive to assume that the latter was the sole cause. Instead the quality of the map can be attributed to a combination of many hardware and software limitations and other constraints, as well as to the lack of training. These can severely limit what it is possible to achieve.

- The display and hardcopy technology available e.g. display monitors, printers, and plotters.
- The graphics software available and its graphic, and moreover its cartographic, design, and other capabilities, and/or limitations e.g. colour, patterns and tools. However, it must be remembered that few of the software packages were in fact intended for cartography, although many have been improved with user demand and application in mind.
- The 'power', flexibility, and ease of use of the graphics software, user-interface, and user familiarity.
- The 'new' environment (11) within which such maps are being designed and created differs significantly from that of the traditional map in terms of time and speed, user and display position, the capability to zoom and roam, screen size, user-interface, and the tools and Information Technology (IT) skills e.g. mouse and keyboard used.
- Prior familiarity with graphic design software can lead to bad practice when using the same software in GIS and DIP to produce maps.
- The lack of cartographic and perhaps graphic design guidelines e.g. help files and tutors which are specifically geared to the making of maps in an electronic medium.

These are some of the factors involved. But there are also a number of other, and perhaps more fundamental, reasons which have contributed, perpetuated, and still are contributing to the output of 'less than good' maps from GIS and DIP systems. These include:

- The significance placed upon the inclusion of cartographic education as a fundamental part of GIS and DIP degree programmes. Cartography is not always taught as a compulsory part of such programmes, or perhaps with sufficient emphasis.

- People entering GIS and DIP programmes often come from a wide range of different backgrounds, with different knowledge, capabilities and skills, frequently with little or no exposure to maps and cartography, traditional or otherwise, and even computing, to enable the user to make the most of the hardware and software for a cartographic application.

- The importance of the (carto)graphic as the end-product is often overlooked and undervalued as an important means of communicating information.

- The tendency for the aesthetic quality of the graphic end-product often seems to assume priority over the value of the graphic as a means of communication. In other words, as long as the system produces 'glossy', 'high-tech', and colourful output, this is considered acceptable. While aesthetics can be an important part of map design there are other considerations to be taken into account (18).

- Cartographic research, and subsequently guidance, in the form of 'map design' guidelines (23) for the correct use of, for example, text fonts, size, colour, composition, and order appropriate to map design in an electronic medium, has been quite limited (9).

- Relatively little attention appears to have been given to highlighting the differences between map design in a traditional, versus an electronic medium.

- The origins of the technology are still relatively young and have not been fully explored.

- Commercial GIS and DIP software developers (perhaps because of their inherent computer/technology backgrounds) have for the most part, until quite recently, paid relatively little attention to the importance of providing interactive facilities for the creation of 'good' maps as a desirable end-product from such systems.

- Cartographic research into map design in the electronic medium has been relatively limited and patchy, and little (except perhaps in the area of colour) has been put into operational practice.

If all these factors are taken together, then it is not surprising that many users of DIP and GIS systems produce poor quality map output; after all:

- Virtually anyone (within reason) can use the graphics software (in whatever form) to make a map.

- Users have very powerful graphics design software at their fingertips, with few appropriate, and often very poor, examples of their use for map making; software documentation seldom provides good examples of maps as illustrations.

- The freedom of access to design and create maps means that there is really no need to know anything about maps and/or cartography, or map design. This could also be said to be true of making maps using a traditional paper medium. But, the difference between them lies with the ease of use and appeal of using software, the endless opportunities for experimentation, and the fact that it does not require someone to be able to draw. It is also a matter of how the software is perceived. Part of the appeal of graphics software is that it is considered to be attractive and easy to use. This is probably more true of graphics software than computer-aided cartographic packages.

- The simplicity of the software user-interface all too often conceals far too much of the complexity and knowledge required for visual map applications. It is currently far too easy for the user to use such tools without the need to know anything about the potential applications. Instead users mimic an application with the software.

- The whole process of map design and production, because it is relatively easy to execute, given the available computer-based tools, tends to be perceived differently by the DIP/GIS user compared to the cartographer. Perhaps this results from a different attitude generated by the environment, the perception of what a map is, the tools of the software, the hardware, the lack of cartographic knowledge and training, or user philosophy. If you can use the software then potentially you can do anything with it. Unfortunately, the perception that maps are easy to design has been all too prevalent.

- The range of cartographic capabilities available, although dependent upon many factors, including the software and hardware, is ultimately left to the user to explore and to come to terms with. Many design packages unfortunately provide relatively few proper cartographic 'tools' - beyond what could be considered the very basics - although this has been steadily improving. Instead, the untrained user must make use of existing tools provided to 'create' the cartographics e.g. patterns, symbols, orientation symbols, and so on, for specialised applications.

The lack of cartographic constraints can be very beneficial in that it allows the user to make use of knowledge they already have, based upon imagination, innovation, and creativity, to design and create maps which best communicate the information to the end user. But, given the current lack of guidelines for the electronic medium it also forces users to rely, almost totally, upon their own knowledge base which can often be very subjective as it originates from personal likes and dislikes, feelings, and experience. Although it could be argued that there are some benefits to be gained

from this there are probably more disadvantages than advantages. The wealth of cartographic design principles arrived at over many years, as the result of extensive research, can not be ignored especially when they provide fundamental and well established basics for designing a map.

## 6. Colour as an Example

Colour has been studied in considerable depth by many researchers in art, psychology, science, graphic design, computer science and cartography (24; 25; 26; 27; 28; and 29). The problems associated with the use of colour as a communication variable in cartography are well documented (29). Colour is recognised as an important and difficult communication variable in map design (30). A considerable amount of colour research has therefore already been undertaken, albeit mostly from the perspective of the traditional paper map (29). As far as the communication of information via colour is concerned, research has revealed that colour perception is a complex function of human vision, training, prior knowledge, experience, association, the surface material (e.g. paper, surface illumination), social and cultural factors (31; 32; 33; 34). To date, by comparison, relatively little research has been conducted on the use of colour in map design an electronic medium.

In this paper, colour is used as one example of the importance of visual variables (the others being size, texture, shape, and value (23), which specifically highlights the problem of its use within an electronic medium for map design. Because of the opportunities for choice, the constraints imposed, and the limited guidelines available, the potential for colour misuse is quite considerable.

Colour is undoubtedly a very attractive variable to work with and one which surely belies its complexity as a means for communication. Large colour palettes, now provided with most graphics software, are very 'tempting' for the novice map designer. The chance to work with colour instead of black and white often has an overpowering influence on the user. This perhaps explains why it is often misused, resulting in images and graphics best described as 'kaleidoscopes' of colour. Faced with the choice of so many colours seems to instil in us a feeling that somehow colour offers a better result, quality, and value, and is more important. Users are often overwhelmed by the opportunity to use colour, and 'taken in' by the aesthetic qualities of colour creating a beautiful image rather than considering the significance of its use or misuse as a communication variable.

In the case of GIS and DIP systems with graphics software, the ease with which colours can be chosen and selected, and used, frequently means that someone with little knowledge of colour will have almost unlimited freedom of its use, which can often arbitrary. Choice of colours can be very difficult given all the possibilities. This is not helped by the use of large colour palettes, long lists of names e.g. sea green, lily white, salmon pink, brick red and in some cases triads of numbers on the scale 0-255 e.g. R (128), G(0), B

(128) (35). The end result is often a colourful and aesthetically attractive map but one which ignores established cartographic traditions (bearing in mind, of course, the limited number of studies and guidelines on the use of color in an electronic medium), and principles of communication. Without research and guidelines to help users, the continuing and rapid development of sophisticated software and hardware technology is perpetuating the creation of colourful maps and is not helping to alleviate the problems.

Perception of colour in an electronic medium is altogether different. At least three main areas require consideration: on-screen (softcopy), hardcopy, and the conversion between screen and paper hardcopy. Perception of colour maps displayed on a computer screen is important and the screen size, amount of screen flicker (28), the nature of the surround, the electron guns, and the facilities to adjust screen brightness and the level of background illumination (33), must all be taken into account. Hardcopy color output seldom matches the screen colour introducing even further problems. Translation between additive and subtractive colour systems is also complex. It is difficult to predict the combinations of inks for identical colour prints, and the colours produced when one ink is printed on top of another. Inks printed on different paper surfaces e.g. matte or smooth can also have an effect (34). Although it may be possible to create a satisfactory map on the display monitor, the corresponding paper product may be disappointingly poor. Further problems arise from the fact that there is a diversity of computer manufacturers for which there are no agreements about standards and compatibility, and no standards for the production of colours. Colours produced in images also vary depending on the make and model of the display screen and printer.

While a number of special colour guidelines have been established for the traditional paper map (29; 30) these do not really apply to the electronic medium of colour display monitors, printers and plotters. To help counter some of the problems arising with the use of colour in an electronic medium considerable work has been undertaken to study and develop various colour description systems e.g. CIE (Commission Internationale d'Eclairage), Munsell (30) RGB (Red, Green, Blue), NCS (Natural Colour System) (27), Tektronix HLS (Hue, Lightness, Saturation) (27; 34; 36), CCTHS (Colour Triangle with Hue and Saturation) (32), and the Hunt-Alvey Colour Appearance Model (34; 35).

Relatively little of the research to date has examined the interactive use of colour in the context of remote sensing, cartography and GIS. However, some (37; 38; 20) have considered the problems associated with colour selection on a microcomputer in the context of graphics software and cartography. Two approaches have been used, the development of colour charts, and the development of a knowledge-based system. This work has considered the problems of colour soft- and hardcopy, and colour calibration in relation to graphic design software for mapping (20). The development of a knowledge-based system, to aid in colour selection for cartography and DIP systems (38) and the use of colour charts in the context of soft- and

hardcopy from micro-computers (37) have also been explored. Perceptual colour spaces have been used for displaying remotely sensed imagery (39). Another approach was designed to provide a means for selecting colours, to help minimise the confusion between classes on classified imagery and for thematic maps (40; 41; 42). CANVAS was devised to assist the user to maximise the interpretability of the classified images. It was designed to be both interactive and operational as part of the DIP software.

## **7. The Need for Solutions**

The problems of designing maps in an electronic medium are many. These have been exacerbated by the rapid technological developments and widespread access to software which can be used to design, create and generate maps. These problems require research and solutions. More research into map design in an electronic medium is needed. Secondly, improvements in cartographic design facilities are needed in the future (17). Finally, education is needed to help raise awareness and to increase knowledge.

This will require new initiatives on behalf of the cartographic community to undertake new programmes of research (43). It will also require coordination with software and hardware developers. Education in the GIS and DIP curriculum should include compulsory treatment of cartography (both traditional and computer-assisted) with special emphasis being placed upon the treatment of map design and creation in an electronic medium. In the context of colour, for example, this might include consideration of the use of colour for on-screen interpretation, understanding human vision, the perception of colour, colour display and hardcopy devices, and the theory and practical use of colour description models.

## **8. Map Design Education**

Education is recognised as a major component of map design for the future (1). Whilst the development of operational online interactive approaches, designed to assist in aspects of map design for the user of a DIP and GIS system, are required e.g. similar to those developed and used for colour selection, new approaches to raising cartographic awareness and education are also required to provide the fundamental background knowledge and understanding of cartography in an electronic medium.

In the context of graphics software packages, some recent work by the author has involved the development of a map design resource package, and a self-paced, computer-aided teaching package, using Apple's Hypercard, for school-age pupils and undergraduate students. A range of both expensive and low-cost graphics software is widely available for nearly all computers providing an ideal environment to explore map design for different age groups.

Different levels of graphics software can be used to illustrate the cartographic capabilities of each package. Such software provides many opportunities to

explore and experiment with map design. These include the design and creation of symbols and patterns. With the aid of structured exercises it is possible to illustrate some of the key elements involved in map design, including a significant 'hands-on' practical component. Some of the benefits of using this software to teach elements of map design are the ease of use, they permit extensive experimentation, make use of IT, and can be used to overcome the fear of being unable to draw. Other advantages are that they can be used to illustrate the advantages and disadvantages of different software for cartography, and to enhance teaching.

As an introduction to map design the interactive Hypercard tutor can be used to introduce and support the resource package. It can be used to introduce the elements of map design and to provide a supporting framework.

## **9. Summary and Conclusions**

Communication via a visual medium is by no means trivial. In the case of map design in the electronic medium, knowledge about cartography, both old and new, and training in the use and application of such knowledge should necessarily be an integral part of both GIS and DIP courses and programmes. The significance of this requirement is that both GIS and DIP technologies are part of the new communication technology, namely Information Technology (IT), and they will find increasing use in the future. Maps form the main output from such systems, and are therefore the primary means of communicating spatial information to the end user.

However, a conflict currently exists between the freedom now available to access relatively sophisticated software and hardware technology, available to almost anyone, to enable them to communicate via the visual medium (hardcopy or softcopy), and the hidden complexity required to be able to communicate with that medium. This requires solution.

In the future more care needs to be taken to ensure that people who are trained to use GIS and DIP systems go a step beyond just being able to create, display and print out information in the visual form of a map. They must be made aware of the importance of communication via the map, they must be taught to think about the information they are trying to communicate, to consider the medium(s) and tools at their disposal, be aware of the past and present research, the complications involved, and the solutions. To do this they must have education, knowledge, understanding, training, practice, and experience. The freedom to be creative and innovative, whilst extremely valuable, must not be allowed to take precedence over a requirement for fundamental knowledge and an understanding of the principles and techniques developed through cartographic research. Beyond this, closer ties must also be established between cartographers, software and hardware specialists, and the GIS community to stimulate the required research resulting in the implementation of operational and interactive solutions.

The knowledge, experience, and practice of cartographers is vital in order to help overcome the current problems facing the design of soft- and hardcopy maps in an electronic medium. New initiatives from cartographers are therefore needed. Wherefore Art Thou Cartographer? Your GIS Needs You!

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## **Session 20**

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### **Map Based Information Systems V, Marketing Cartographic Data**

Chairman:

E. Siekierska, Canada Center for Mapping (Ottawa, CDN)



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## Cartographic treatment of topographical relief with "CAD" systems

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Cartographic depictions of topographical relief are, in principle, the result of three basic activities.

- a, The acquisition of three-dimensional data
- b, The processing of this data in accordance with certain geometric and graphic rules
- c, The fair drawing and, if necessary, the reproduction of the result

Computer-Aided-Design options—also called CAD systems—can be used to assist in these activities. These systems were primarily developed for engineering and architectural applications and the potential user can choose today from a wide range of high-quality commercial packages. With relatively little effort they can be tailored to be used for the editing and drawing of cartographic products of all kind. The examples presented in this paper deal with three-dimensional cartographic depictions of topographical relief. They were produced, together with in-house developed software, by use of "autoCAD", one of the more popular "CAD" systems.

In contrast to Engineers and Architects, who could apply CAD options to all stages of their design work, topographical cartographers, like many other users of CAD systems, were confined in their exploit of CAD assistance to the fair drawing stage only. To overcome this limitation special programming languages were developed for CAD packages, enabling the user to program the system, adding thereby additional analytical power to CAD. For autoCAD an implementation of the LISP language, called "autoLISP", has been embedded within the autoCAD package.

AutoLISP allows users and autoCAD developers to write macro programs and functions in this very powerful high level language, that is well suited for graphic (and cartographic) applications. It opens the way to a full integration of autoCAD drawing and editing options with not only the fair drawing stage, but also with the data acquisition stage and the computer assisted processing of the data into various forms of cartographic relief depictions. As explained further on, it is e.g. the introduction of a relatively simple autoLISP program which enables the cartographic exploitation of the three-dimensional options of autoCAD.

## THE ACQUISITION OF THREE-DIMENSIONAL DATA

The most convenient input of height data for the computer executed solution of cartographic and cartometric problems of three-dimensional character are matrices of height points, called "DTM", in the form of dense regular grids. They may originate from various sources - the most reliable being the direct survey of such point arrangements by either terrestrial or aerophotogrammetric surveying methods. Another widely used origin, although of reduced quality, are height contours of existing topographical maps. These can be used as input for a computer executed interpolation of a DTM. They can either be digitised with a digitizer, resulting directly in a sequential vector file of digital contours, or scanned with an optical scanner. The primary result of the scanning process is a raster file which must consequently be converted by software into a vector file. For both the digitising and the scanning method the problem of the missing third dimension must be solved. In the case of digitising the height of the contours is typed into the file during the digitising process. For the raster file of an optical scanner the problem is more difficult. For part of the illustrations of this article we used a DTM computed from topographical contours scanned by a scanner and converted by software into a "DXF" file as requested for the import of external files into autoCAD (see fig 1). Once inside autoCAD by command "dxfn", the scanned and converted contours become "entities" of an autoCAD drawing i.e. they can be edited by autoCAD commands. This signifies for our case that the missing elevations can be added to the contours. AutoCAD distinguishes between "line" entities which are just the connection of two points, and "pline" entities which are polygons, but are also treated by autoCAD as just one entity. Our raster to vector conversion program takes care to convert the rastered contours into "plines". To add an elevation to a contour inside autoCAD it is, therefore, enough to touch the contour line on the monitor screen with the cursor at just one point, to type the required elevation, and autoCAD automatically adds the third dimension to every point of the contour polygon. It is our experience, that this is a most convenient and fast way to turn a two-dimensional contour file into a three-dimensional one.

Once edited in autoCAD the contour drawing is exported, again as a "DXF" file, by the command "dxfout". As this file contains much more information than needed for a plain digital contour file this "DXF" file is processed by a program which extracts the sequential, now spatial, coordinates of the contours only. It is this extracted file, which consequently serves as input for a computer executed superimposition of a regular grid of points whose heights are derived from the heights of the digital contours. This is done by a program whose methodology was described in my article "Computer executed production of a regular grid of height points from digital contours" (see bibliography). Fig. 1 shows the methodological flowline of the creation process of a DTM from topographical contours with the assistance of an optical scanner, a raster to vector conversion program, autoCAD and appropriate, in-house developed, software.

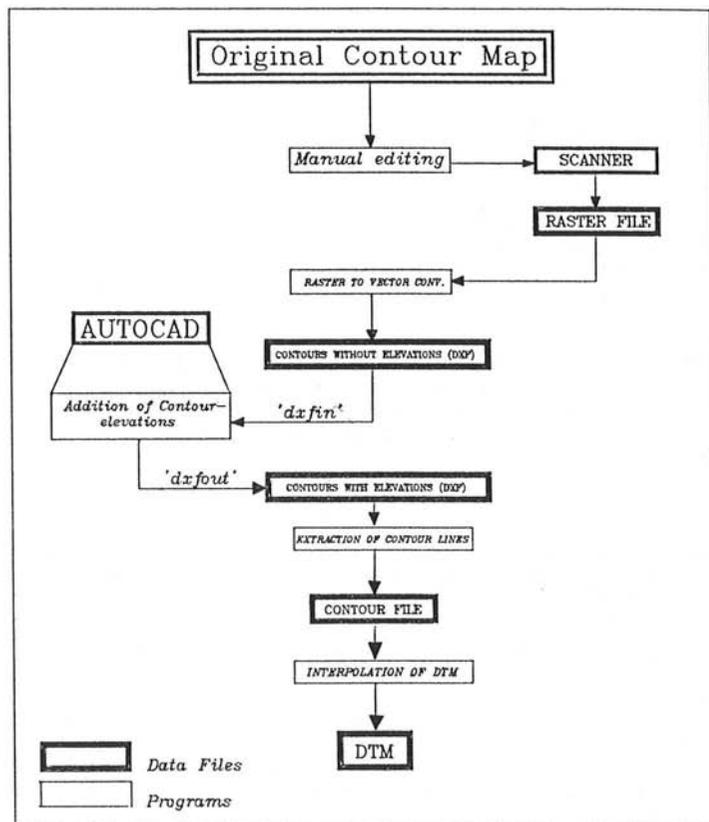


Fig.1

The creation of a DTM from existing topographical contours

After a DTM is created it can be imported into autoCAD using a relatively simple autoLISP program (named "DTMIN.LSP" -written in-house). The way the DTM is imported enables autoCAD to recognise it as a "3DMESH" or an arrangement of "3DFACES" and to treat it with autoCAD commands.

In order to discuss the various options for which a DTM can be used, either inside autoCAD or outside it, there follows a list of methods applied for the cartographic depictions of topographical relief. These can be divided into orthogonal and oblique presentations. They are:

#### Orthogonal Depictions

- a,Horizontal contours
- b,Hillshading
- c,Shadowed contours
- d,Oblique contours (Kitiro Tanaka method)
- e,Hachures

#### Oblique Depictions

- a,Perspective contours
- b,Perspective "fishnets" ("Blockdiagrams")
- c,Perspective hillshading

Oblique depictions have the visual advantage,that beside their direct three-dimensional impact,they enable to show arrays of profiles of the earth surface.If these are depicted in a criss-cross fashion they form what may be called a three-dimensional "fishnet" spread over the relief.

Once a DTM is imported into autoCAD,there is,in principle,no obstacle to program both the orthogonal and the oblique depiction methods in the autoLISP language and compute them inside autoCAD.For hillshading and perspective depictions this has,in fact,become superflous as they are in-built options of present day autoCAD.Any method not provided for can also be programmed outside autoCAD in any language and its resulting plot-file be converted into a DXF file for insertion into autoCAD for further graphic treatment,if desired.The little contour maps in the center of fig.2 and fig.3 were computed by an in-house developed contouring program using as input a suitable DTM.The program takes care to record on the resulting plotfiles the heights of the contours,although they are not needed for a two-dimensional drawing.To import this file into auto-cad it was converted by a conversion program (also in-house developed) into a DXF file.

As mentioned before,very powerful options of perspective depictions of three dimensional objects have been provided for in autoCAD (beginning from version 10).The perspective presentations of the contours surrounding the orthogonal contour maps in fig.2 were produced inside autoCAD.

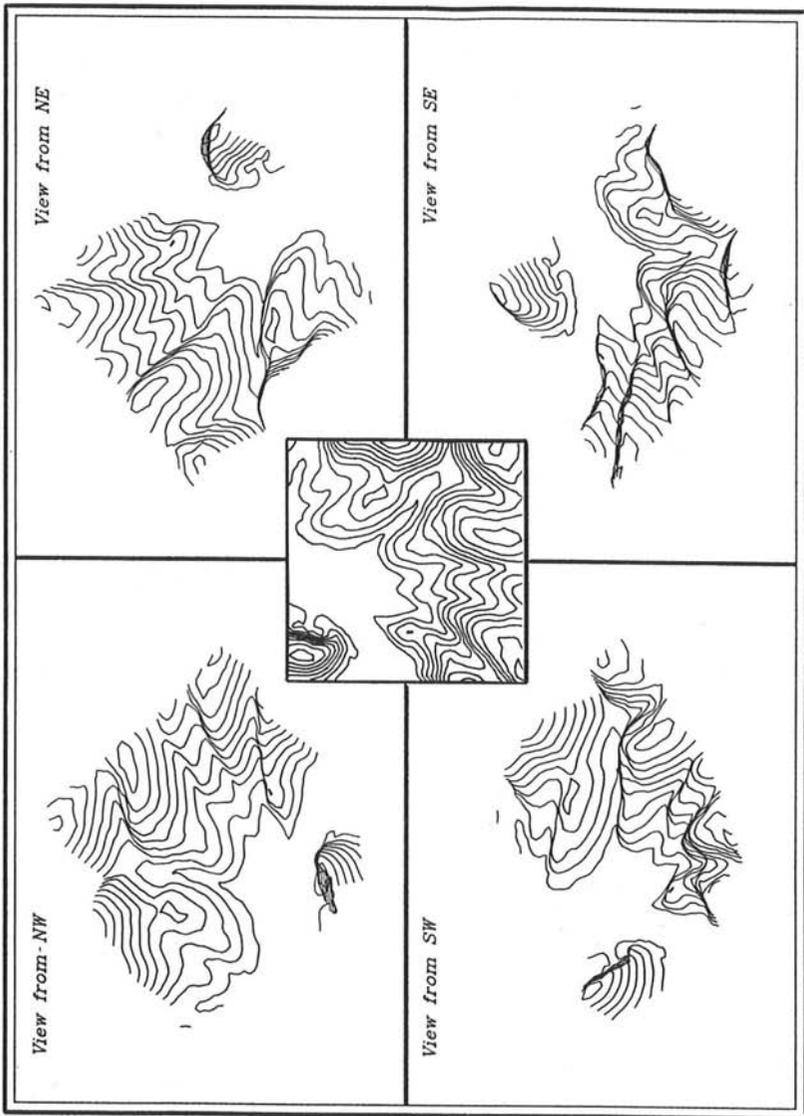


Fig. 2  
Perspective depictions of contours

Fig.3 shows axonometric "fishnets" from various viewing directions created by autoCAD using the command "vpoints". Contrary to the perspective contour depictions of fig.2, autoCAD did not draw in fig.3 the lines hidden from sight. The hidden parts of the contour lines in fig.3 were not recognised as such by autoCAD. It regarded the body presented by the contours as transparent.

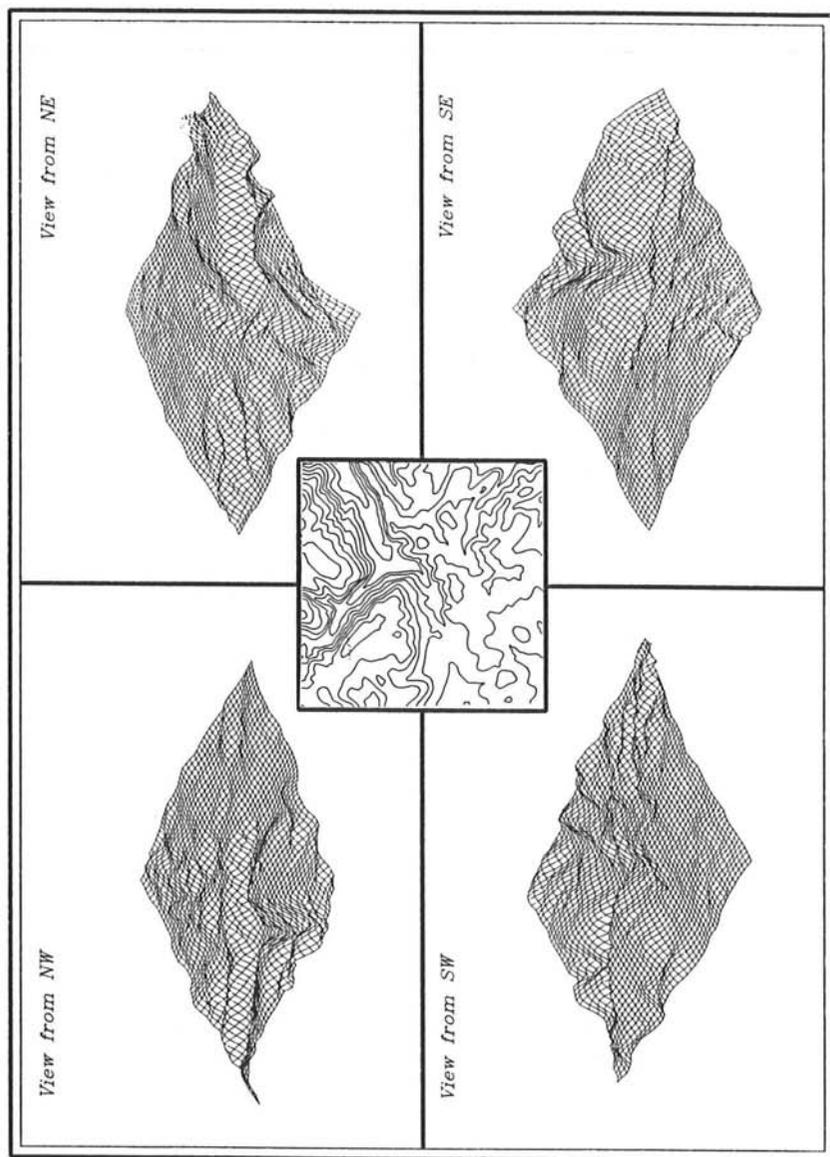


Fig.3  
Perspective depictions of "fishnets"

## HILLSHADING WITH autoCAD AND autoSHADE

Three dimensional bodies created in or imported into autoCAD can be depicted in the form of illuminated and shadowed images. This is done in conjunction with an additional software package named autoSHADE. Up to autoCAD version 11, this was a separate modul. In the latest version of autoCAD -version 12-it has become an integral part of autoCAD.

The methodology of autoCAD together with autoSHADE simulates the activity of a professional photographer. To produce a good photo the photographer illuminates his model with one or several projectors and chooses the best position for the camera and its inclination. He may "shoot" various light and camera combinations on one film. He then develops this film in his laboratory and makes positiv copies in various sizes, "cutouts" and "blowups". In the end he puts the image or images into frames or albums. This is exactly what autoCAD together with autoSHADE are doing. The "photography" is done in autoCAD. Using the command "lights" any number of light sources with either parallel light rays or rays emanating from one point, or both, can be placed in space in and/or around the model. Also the light intensity can be regulated. As the shading algorithm requires, that the body to be shaded consists of "3DFACES", i.e. an arrangement of closed area facets, only the "fishnet" depiction of a topographical surface can thus be shaded.

After the lights have been chosen the spatial coordinates of the camera and its angle of inclination are requested by the command "camera". When both the lights and the camera have been positioned, the command "scene" asks for the desired combination of lights and camera. This is the analogy to the individual snapshot of an entire film. The "Lights, the "Camera" and the "Scene" appear on the screen as icons. Finally the command "filmroll" stores the entire information on a file with the extension "FLM". The analogy is complete.

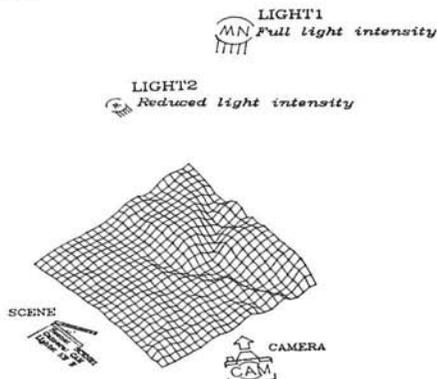


Fig.4

Fig.4 shows the screen image of a "fishnet" surrounded by the light and camera icons and the "scene" in the form of a "clapper".

Once the filmroll is ready it is inserted into autoSHADE. To mention again the earlier analogy, autoSHADE is the "laboratory" where the film is "developed". Except for the light positions all other parameters of the image can now be adjusted, including the position of the camera in space. This is very much like the choice of the developer, and the photographic paper and the inclination of the table of an optical rectifier in photogrammetry. The processed image can then be seen on the screen as a raster image and may be saved as a "TIFF", file. This can consequently be printed by an appropriate Laserprinter or Electrostatic printer. Version 12 of autoCAD has added the option to save the image also as a "Postscript" file.

In addition to the shadow depiction, autoSHADE can also "render" the image. This means, that for topographical relief there is the option to treat the surface with colours and textural properties such as vegetation, sand dunes, glaciers etc. This aspect of autoSHADE is beyond the scope of this paper but may open an interesting field for cartographic experimentation. Fig. 5 shows the same terrain as in fig. 3 and fig. 4 but in shaded fashion. As autoSHADE offers the option to activate an "obscuration" algorithm, hidden parts of the terrain are not shown.

*View from NE*



*View from SE*



*View from NW*



*View from SW*



## THE COMBINATION OF RASTER IMAGES WITH VECTOR DRAWINGS

The possibility to insert outside graphic images into autoCAD via a conversion into a DXF format opens the way for various interesting cartographic applications especially since the incorporation of autoSHADE into autoCAD ver. 12. As an example, hillshading can be combined with the same contours which served as the source for the interpolation of the DTM used as the 3Dmesh for oblique shading. Fig.6 presents a hillshading of the same relief as in fig.3,4 and 5.

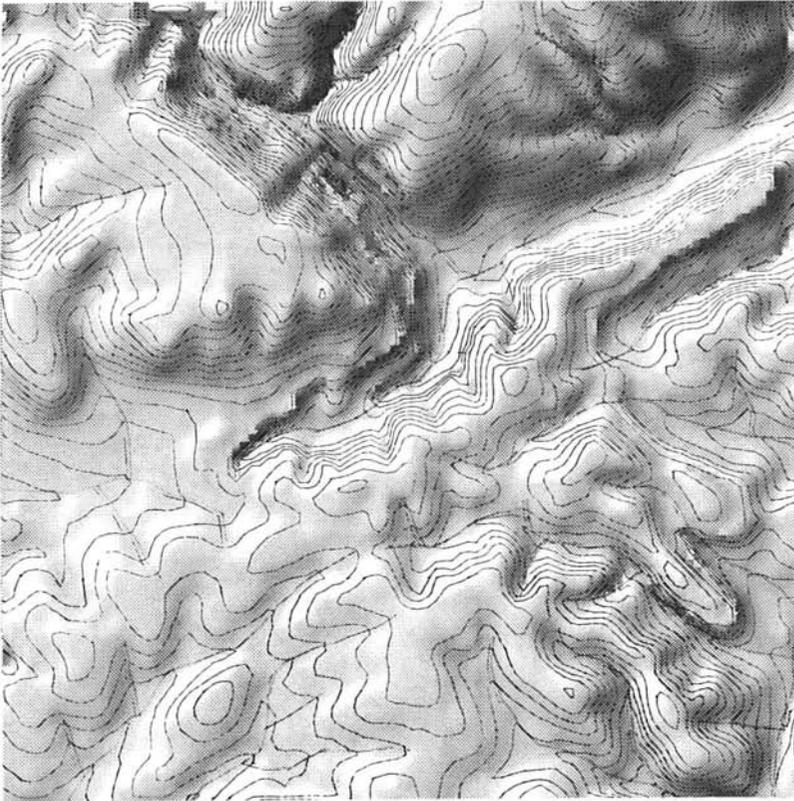


Fig.6  
Combination of hillshading with contours

## INTERACTIVE CARTOMETRIC OPERATIONS WITH autoCAD

The insertion of a DTM into autoCAD (with the autoLISP program DTMIN.LSP) covers the screen of the monitor with a regular grid of points in space. The cursor of autoCAD can be given the form of a "pickbox", a little square whose size can be determined by the user. Whenever the coordinates of any point on the screen are requested (by clicking on the "mouse"), autoCAD can be instructed to choose the coordinates of a point situated inside the pickbox. Depending on the density of the DTM and the size of "pickbox" there may be more than one point inside it. In this case autoCAD chooses the point nearest to the center of the box. Provided that the size of the pickbox is at least the size of one facet of the DTM, a x,y,z triplet of coordinates can be picked on any place on the screen. Fig.7 shows the crosshairs of the cursor with the pickbox on the background of the DTM grid.

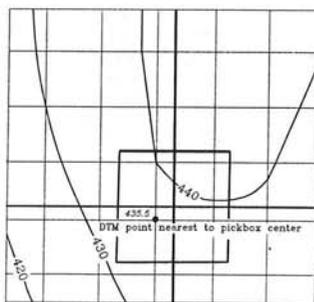


Fig.7

"Picking" heights on the monitor

AutoCAD works with "layers" like a cartographic draughtsman with transparent overlays. Assuming, that the DTM grid has been inserted on one layer and the contours of the same area on another layer-possibly in a different colour-, the two layers can be seen combined on the screen. The user is then able to travel with his cursor on the surface of the terrain as depicted on the screen. Hill up - hill down! This is the ideal situation for autoLISP to come into action. Cartometric endeavours of every kind can be programmed, enabling interactive computations such as intervisibility, volume computations, slope analysis, drawing of profiles etc.

In conclusion it can be said, that CAD systems have become an useful tool in the development of modern cartography. It is, however, important, that they should be applied by an efficient methodology, based on specific professional know-how and with the ability to develop, if needed, in-house software. In this case relatively low budgets are enough to enjoy the thrill and pleasure of highly sophisticated computer assistance.

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# Line simplification in three dimensions

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## Abstract:

Historically, one of the most researched operations in the automated generalization process has been line simplification. As a result, numerous algorithms have been developed in this area. These algorithms are designed to eliminate vertices determined not to be critical to the portrayal of the line at a specified scale. In general, the line is to be portrayed in two dimensional space; therefore, vertices can be eliminated without any regard to their elevation or Z-value. However, for certain applications it can be important to retain vertices because they contain important information about the elevation of the line. For these applications, a standard two-dimensional line simplification algorithm is insufficient.

It is the purpose of this paper to introduce an algorithm designed to identify points on a line that are critical to maintaining the elevation profile of that line. Elevation processing performed by this algorithm is currently working in a map production system. In this system, elevation processing is performed as an optional post process to line simplification. The map producer controls whether the algorithm will be performed and what input tolerance values to use. In this system two-dimensional line simplification is performed first. Then the original and simplified line serve as input to the algorithm which determines whether the elevation profile has been maintained to the degree specified by the input tolerance. The algorithm in turn selects additional critical points as needed. These points are critical because of their elevation value and will be used to shape the elevation profile of the simplified line.

## Introduction:

Line simplification algorithms are designed to reduce the number of points needed to portray the line and eliminate unwanted detail. They are used in map production systems where the data has been over collected or a change in scale is required. Algorithms such as the one defined by Douglas and Peucker<sup>1</sup> determine critical points on a line through distance measurements in two-dimensional (2-D) space. Critical points (xy-critical) are those points critical to portrayal of the line in 2-D. Figure 1a shows

a simple example of the Douglas-Peucker algorithm applied to a portion of a line. Points  $P_r$ ,  $P_s$ , and  $P_u$  are determined to be not critical to portrayal of the line in two dimensions. This is due to that fact that their perpendicular distances to the corresponding baselines do not exceed a distance tolerance. Points  $P_i$ ,  $P_t$ , and  $P_k$  are identified as critical points by the algorithm.

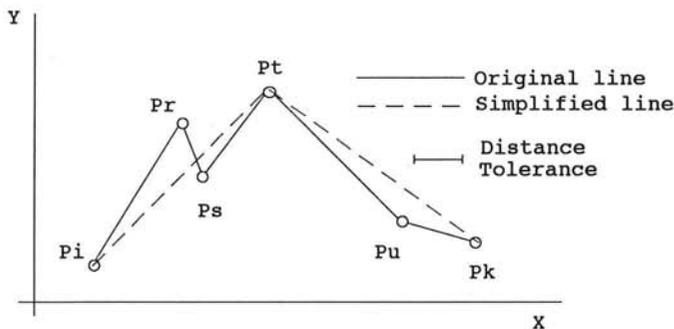


Figure 1a

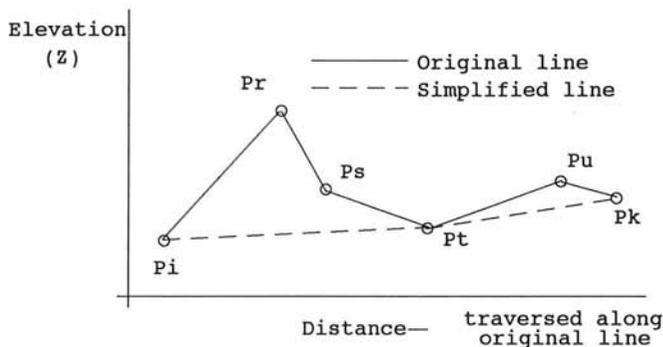


Figure 1b

Because algorithms like this do not consider the elevation (or Z-coordinate) value, points which define critical elevations are not explicitly retained. This results in a loss of elevation information which could be crucial to some process succeeding line simplification. For

example the simplification of geomorphic features could result in a loss of elevation values that would have been used later by a contour generation process.

Consider the line given in Figure 1a again. Figure 1b shows the elevation profile of the original and simplified line. Note that the elevation of the line versus the distance traversed along the original line in the xy-plane is plotted. The elevation profile of the simplified line shows the effects of retaining the Z-values of the xy-critical points only. It is clear that a lot of information about the elevation of this line, such as its maximum elevation, has been lost due to simplification. If it is important for the line simplification algorithm to maintain critical points based on elevation, then the simplified line produced by the above algorithm is insufficient. Additional processing should be done to ensure that points critical to the elevation profile of the line (Z-critical) are retained. An algorithm that selects Z-critical points and uses them to shape the elevation profile of the simplified line follows.

### Methodology

Consider the original and simplified line in Figure 1a with endpoints  $P_i$  and  $P_k$  and intermediate points  $P_r$ ,  $P_s$ ,  $P_t$ , and  $P_u$ . It is to be determined whether any of these intermediate points are critical to the elevation profile of the line. Let  $Z_r$ ,  $Z_s$ ,  $Z_t$ , and  $Z_u$  represent the elevation values of these points.

The algorithm starts by first drawing a baseline between the first and last points of the line in the plane of Figure 1b. This baseline shows the elevation profile of a simplified line if only the elevation values of the first and last points were retained. This baseline is of constant slope and its length in the xy plane is equal to that of the original line. This is shown in Figure 2.

All the intermediate points are projected to the baseline in the following manner. Let  $Z_r'$  represent the elevation of point  $P_r$  projected onto the baseline (see Figure 2). The formula for calculating  $Z_r'$  is given in Equation 1.  $Z_i$  and  $Z_k$  represents the elevation of the line

$$Z_r' = Z_i + \frac{d_{ir}}{d_{ik}} \times (Z_k - Z_i) \quad (1)$$

at points  $P_i$  and  $P_k$ . The values  $d_{ir}$  and  $d_{ik}$  represents the distance traversed along the original line from points  $P_i$  to  $P_r$  and  $P_i$  to  $P_k$  respectively. The Z-error that is introduced by not retaining point  $P_r$  is given by Equation 2

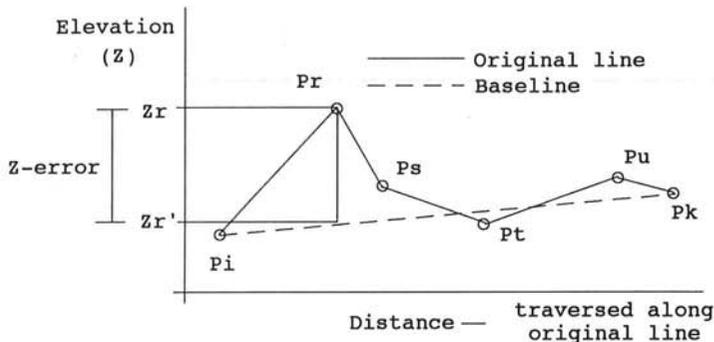


Figure 2

(See Figure 2). The Z-error is calculated in a similar

$$Z_{\text{error}} = |Z_r' - Z_r| \quad (2)$$

manner for all other intermediate points and the maximum Z-error value stored. At this point an elevation or Z-tolerance is introduced which is similar to the distance tolerance employed in the Douglas-Peucker algorithm. The Z-tolerance defines a threshold as to whether a point's elevation deviates from the current baseline more than an acceptable amount. If the maximum Z-error of the intermediate points does not exceed the Z-tolerance, then none of the intermediate points are critical (Z-critical) to the elevation profile. Otherwise, the point defining the maximum Z-error is retained. The algorithm is recursively applied to consecutive Z-critical points until no more points are specified to be retained. The effect of retaining point  $P_r$  in the algorithm is shown in Figure 3.

Two new baselines are generated: one between points  $P_i$  and  $P_r$ , the other between points  $P_r$  and  $P_k$ . Note there are no intermediate points between  $P_i$  and  $P_r$ . The Z-error is recalculated for points  $P_s$ ,  $P_t$ , and  $P_u$  with the new baseline defined by  $P_r$  and  $P_k$ . This is shown in Figure 3. If the maximum Z-error for these points does not exceed the Z-tolerance, no more Z-critical points are retained and the algorithm terminates. Otherwise, the algorithm continues by retaining the point corresponding to the maximum Z-error and recursively considering two new baselines. The algorithm terminates when all baselines have been considered and no more intermediate points with a Z-error that exceeds the Z-tolerance are found. As a result of performing this

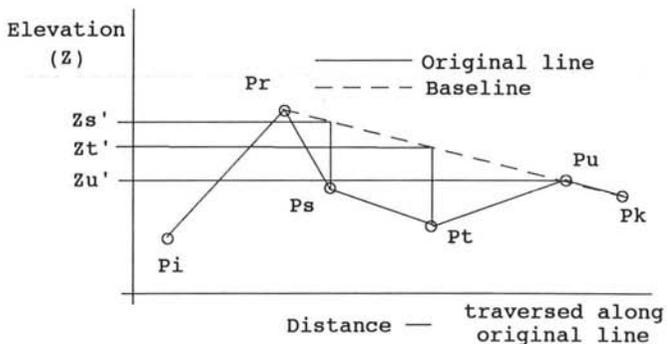


Figure 3

algorithm, a list of points critical to maintaining the elevation profile of the line is generated.

After the Z-critical points have been selected, they could be used as control points to the 2-D line simplification algorithm. In other words, they could be used to control in some manner the selection of xy-critical points. Or they could be used along with the xy-critical points generated by a 2-D line simplification algorithm to specify the simplified line. If this is done it is possible that more points will be retained than would have been retained by just performing a 2-D algorithm. Therefore, the simplified line could contain more detail than is desired for portrayal in two dimensions.

At this time a method will be introduced that maintains both the two dimensional and the elevation portrayal of the line to the degree specified. This can be done in the following manner. First 2-D line simplification is used to identify points critical to portrayal in two dimensions. These points will define the simplified line in 2-D. The above Z-retention algorithm is employed between each consecutive pairs of points on the simplified line to define Z-critical points. These points contain the Z-values that will be used to shape the elevation profile of the line. Points are inserted along a straight line on the 2-D simplified line that contain elevation values corresponding to the Z-critical points. In other words the Z-critical points are projected to the simplified line in the 2-D plane. To better understand this again, consider the line given in figure 1 again. Points  $P_i$ ,  $P_t$ , and  $P_k$  are identified to be retained for 2-D portrayal and  $P_r$  retained for elevation portrayal.  $P_r$  can be projected to the

simplified line in the 2-D plane so that the two dimensional portrayal of the simplified line has not changed. First a projection parameter  $t_r$  is calculated by computing the distance from  $P_i$  to  $P_r$  ( $d_{ir}$ ) and from  $P_i$  to  $P_k$  ( $d_{ik}$ ) along the simplified line and taking the ratio (see Equation 3). Using the projection parameter the new coordinates of  $P_r$

$$t_r = d_{ir} / d_{ik} \quad (3)$$

can be calculated. Equations 4, 5, and 6 are used to

$$X'_r = X_i + t_r \times (X_k - X_i) \quad (4)$$

$$Y'_r = Y_i + t_r \times (Y_k - Y_i) \quad (5)$$

$$Z'_r = Z_r \quad (6)$$

calculate these values. Note that the Z-coordinate value does not change. Note also that this projection preserves order. The sequence of points along the simplified line matches the sequence on the original line. This portion of the simplified line is now comprised of points  $P_i$ ,  $P_r'$ ,  $P_t$ , and  $P_k$  (See Figure 4a). The portrayal of simplified line in two-dimensional space has not been altered because of the Z-retention, but the elevation has (see Figure 4b).

It should be explained why the above method of performing the projection is recommended over the more straightforward perpendicular projection. Consider the line given in Figure 4a but where the elevation profile is such that  $Z_i > Z_r > Z_s > Z_t$ . If points  $P_i$  and  $P_t$  were retained

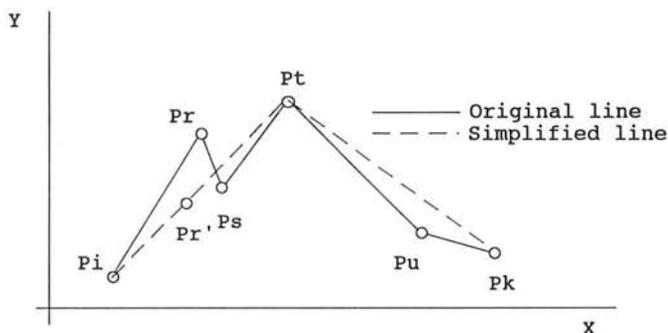


Figure 4a

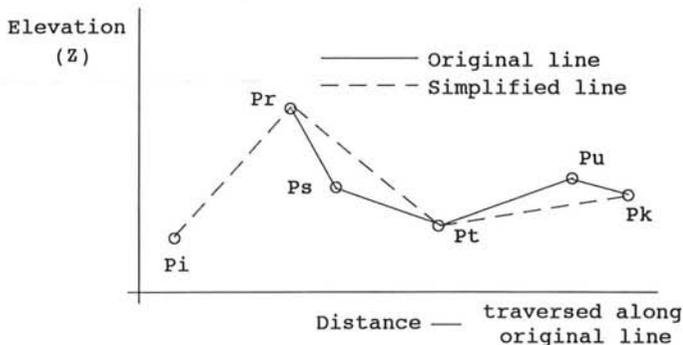


Figure 4b

by the 2-D algorithm and points  $P_R$  and  $P_S$  retained by the Z-retention algorithm then it is clear a perpendicular projection would produce a simplified line where the point ordering is  $P_i, P_S', P_R',$  and  $P_t$ . For this ordering the elevation profile has been modified to  $Z_i > Z_S < Z_R > Z_t$ . The elevation of the line no longer changes monotonically. The order preserving projection produces a line  $P_i, P_R'', P_S'',$  and  $P_t$  where the elevation profile has not been modified. The simplified line remains monotonic.

#### Conclusion:

Most line simplification algorithms are designed to keep points critical to maintaining the portrayal of the line in two dimensions. Therefore, points are deleted without any regard to their elevation or Z-value. This could be detrimental in a map production system where a process that follows line simplification is dependent on the elevation of the features. An algorithm to identify the Z-critical points on the line was presented. These points can be used as control points to a 2-D line simplification where the Z-critical points control in some manner the selection of xy-critical points. If it is desirable to not modify the simplified portrayal in two dimensions, the Z-retention algorithm can be executed as a post process to line simplification where the Z-critical points are projected to the 2-D simplified line in the manner described. This implementation has currently been employed in a map production system and also a commercial product where the Z-retention algorithm is optional.

It is clear that as line simplification becomes part of the generalization process in different automated map

production systems, factors other than just the xy-positions of the points on the lines become important. Therefore, the algorithms need to become flexible enough to consider these different factors when appropriate. The elevation of the line is just one additional factor which should be considered.

#### Acknowledgments

The support of personal from Intergraph Corporation is greatly appreciated. Special thanks to Frank Guza.

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<sup>1</sup> Douglas and Peucker, December 1973. "Algorithms for the Reduction of the Number of Points Required to Represent a Digitized Line or its Caricature." The Canadian Cartographer, Vol. 10 No 2.

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# Construction of basic information systems in Republic Slovenia

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## INTRODUCTION

Republic Slovenia lies on traffic, economic, and politically important crossroads in the central part of Europe and thus with the attainment of independence new conditions have been formed for its even more successful development. This area, which has in the past already been one of the European centers of flow of goods, services, capital, people, interests and information, is being shaped by appropriate policy of economy and of social nature into an area of open borders and even broader interregional cooperation. By changes on various fields of social life this tiny state is doing its best to join up-to date trends of European integration and to adapt to European standards. The economy development rate, market orientation and free enterprise have opened new possibilities for materialization of developmental strategies.

Undoubtedly, the great process of changes includes also all with space connected sciences, branches and activities. The need for accurate and rational methods of work and techniques demands accessible and maintained databases and information. The expansion of the LIS/GIS (land information systems / geographical information systems) concepts and technologies and numerous practical applications of the latter in Europe and the rest of the world have lately spurred also in Slovenia a readiness and need to seek possibilities for greater mutual connectivity of related branches. Thus new approaches are dealt with in science and research circles, state administration, local self-governing, sectors, economy and in other fields. First database pilot studies are being designed and proposals for standardization of input-output solutions are being prepared. In the present phase of development to achieve faster the set goals we lack above all knowledge and tools to be able to process the prepared data in a qualitative manner and to make best use of their versatility.

## SURVEYING GROUNDWORK

Surveying as a science and a branch is engaged in positioning of objects e.g. in defining accurate locations for natural and built up elements of the earth's surface and in presenting the latter in various forms and on various media. The surveying groundwork with source and basic data about space is the basis for a construction of information systems on other fields to be used in project-making, managing and decision-making. The state with a bit more than two million km<sup>2</sup> of surface and hardly 2 million inhabitants disposes of a comprehensive fund of

versatile surveying groundwork, mainly still run and maintained in classical forms. Thus whole Slovenia is systematically covered<sup>6</sup> with basic topographic maps on 1:5 000, in intensive areas e.g. on 1:10 000 in less intensive ones, with topographical maps on 1:250 000 and 1:50 000, and general maps on 1:250 000, 1:400 000, 1:750 000, 1:1 000 000, 1:1 500 000, and 1:2 000 000 scales. For individual more intensive areas also basic topographic maps on larger scales as 1:500, 1:1 000, and 1:2 500 are made. For the whole territory of Slovenia aerial survey in black-white technique in a 3 year cycle is carried out and contact prints on 1:17 500 scale are elaborated. In a digital form there are maintained: terrain data (digital relief model 100x100 m), territorial divisions of space (ROTE - Register of Territorial Units and EHIŠ - Evidence of House Numbers), and partly also points of geodetic network (for the time being above all the planimetric ones, the altimetric ones are in the phase of being constructed), and at present still in a very small extent land cadastral maps on 1:1 000, 1:2 000 and 1:2 500 scales. These are also the most important sources for data capture for conversion from classical to digital form, and for later use in adequate information systems. The period of elaboration of solely classical maps, charts, tables and lists of data has been throughout the world in the last decades in a phase of intensive technical restructuring. The development of hardware and software tools, concepts, technologies and new knowledge is thus felt in our environment too. Within the frame of the surveying service methodological and technological solutions to set up and maintain basic digital ownership (land cadastre and buildings cadastre), and topographic databases are in the phase of intensive preparation. These databases will be the groundwork for LISs - above all for parcel oriented information systems, various infrastructure information systems and information systems of the environment. From a broader aspect these surveying databases will be used for GISs - above all with subsystems of the topographic database.

## **NATIONAL TOPOGRAPHIC DATABASE**

The goal of activity within the topographic definitions of space is the set up and maintenance of a multipurpose national topographic database with subsystems<sup>4</sup>, which forms the precondition for a high quality connection of data and information of other carriers e.g. sectors (agriculturers, foresters, geologists, pedologists ...). The manager of the national topographic database will be the surveying service, which operates in an organized manner on the republic and the communal level (after the introduction of the new local self-governing on local and regional level). The database will be merged e.g. corporated and composed of topologically organized graphic and relational attributive database. According to available data, the creation of a unique topographic database can not be realized since worldwide problems of an automated generalization of data elements for the transition to an optional accuracy still remain to be solved. In addition to this also the cost component definitely favors the set up and maintenance of databases on lesser accuracy level. For this reason presumably three database levels will be defined, e.g. a local, regional, and national one. They will be presented by the following accuracy thresholds: 1:5 000 (e.g. 1:10 000) and larger, 1:25 000-1:50 000 and 1:250 000 and smaller. The system will enable the lowest possible topological level of data structures with the greatest possible adaptability for users.

The selectioning of topographic elements and their basic attributes to be included in the database will depend on the settled compromise among professionally argued

suggestions and limited possibilities of financial realization. The result will be an intermediate solution among ideal theoretically schemed subbases and foreseen possibilities of a practical realization of the construction and above all its later maintenance. The graphic data will mainly be captured by digitizing (graphic tables, scanner), the attributive ones will be obtained from data carriers.

All digitized databases will be object-oriented and structured on several levels as to the GIS tools demands, database management systems (DBMS - Data Base Management System) and user applications.

Subsystems to form the topographic database will presumably be the following:

- digital relief database with referral system
- vegetation digital database
- hydrography digital database
- infrastructure objects and devices digital database
- buildings digital database
- spatial units e.g. space territorial divisions digital database, and
- geographic names - toponyms digital database.

#### **Digital relief database with a referral system**

Digital relief database with a referral system is to contain<sup>2</sup>:

- contour lines for binding parts of a relief (e.g. index and intermediate contour lines ...), and
- braking lines for not binding parts of a relief (e.g. for sharp edges: terraces, ridges, gorges; for edges of variable pieces of land: rocks, walls, screes, depressions) as linear objects and
- altitude heights and some more important points on geomorphological forms (e.g. spot heights, concavities: Karst caves, funnel-shaped holes) and
- points of geodetic network (planimetric and altimetric ones) as point objects.

Among relief attributes there will be data of the source capture, scale and capture time, height above sea level contour lines e.g. points and other; among attributes of the points of geodetic networks there will be data on the kind of a point and the height above the sea level data.

#### **Vegetation digital database**

The vegetation digital database is to contain point objects such as single trees and areal objects such as woods (foliaceous trees, conifers, mixed), parks, cuts through the woods, surfaces in afforestation and fields, orchards, vineyards, hop fields, meadows and other land. Among others the attributes will define soil usage name, its code and kind.

#### **Hydrography digital database**

Hydrography digital database is to contain hydrographic objects, which are<sup>3</sup>:

- point (e.g. water springs, thermal springs, Karst swallow- halls)
- linear (e.g. coast, permanent rivers, rivers with not permanent water, canal, ditch, waterfall), and

- areal ( e.g.: lake, pond, moor).

Among the attributes there will be data on the type of a river, division segments and alike.

### **Infrastructure objects and devices digital database**

The infrastructure objects and devices digital database will define objects within<sup>1</sup>:

- energy infrastructure (electricity, gas, hot water, heat and product supply)
- communal infrastructure (waterworks, sewage system, public lightning, semaphorisation, public surfaces, waste disposals, exploitation of natural resources)
- traffic infrastructure (roads, railroads, cable-ways, air transport, water transport), and
- telecommunication infrastructure (post, radio and television).

The attributes of numerous objects, presented in a point, linear or areal manner will contain data about the manager e.g. maintainer of the object, code, name and kind of the object, heights ...

### **Buildings digital database**

Buildings digital database will contain areal objects such as dwelling buildings (dwelling houses, dwelling blocks, sky- scrapers, weekend cottages ...) and business buildings (also industrial objects, electric works, sport halls ...), farm buildings (hey-sheds, barns, corn-sheds ...) and other buildings. The attributes will be the kind of a building, its code ...

### **Spatial units digital database**

The spatial units digital database e.g. territorial divisions of space database will contain areal objects - territorial units like census circle, statistical circle, settlement, cadastral commune, local community, community, poll, register district and data on house numbers and streets. The attributes will define the code, the name of the object, coordinates of centroids, source data, date of formation and change ...

### **Geographic names digital database**

The geographic names - toponyms digital database will contain attributive records of names of places (settlements, cities ...), hidronyms (waters, lakes, seas ...), oronyms (mountains, valleys, passes ...) and horonyms (communes, communities, regions ...), coordinates of basic points of a name ...

For a detailed level of the topographic database an object catalog is in the final phase<sup>5</sup>. It is elaborated on the basis of basic topographic maps on 1:5 000 scales (e.g. 1:10 000 with the following definition of contents: group, name, definition, topology and models for data capture, storage, display and data exchange. The object catalogs for the contents of other two levels (the regional and the national one) are to be elaborated in the next phase.

## **CARTOGRAPHIC DATA BASE**

Cartographic data models are to proceed from the topographic database and will serve for analog maps elaboration. For the time being the official cartography is still not preparing methodological starting-points neither as derivation from topographic base nor as a direct construction from classic cartographic materials. The cartographic data models will contain (as to the scale of the presentation and the corresponding signs key) topographic objects to be presented by cartographic signs and obtained on the basis of cartographic generalization. The mathematical generalization of a cartographic data model can not provide an adequate elements presentation to be seen on screen or paper, therefore the cartographic generalization still has to be performed (simplification, magnification, shiftings, selection, grouping ... of these elements).

The contents of cartographic data models will be defined in signs catalogs for individual scales of maps and plans.

## **INTERNATIONAL DATABASE CONNECTIONS**

In addition to ensuring mutual connectivity of surveying and other information systems in Slovenia (agriculturers, foresters, planners, environmentalists ...) also connections with European environment has to be ensured like with CERCO for the official state cartography, with MEGRIN for information networks, with CORIN for environment and others, and take into consideration also their recommendations and adopted standards.

## **CONCLUSION**

Due to the fact that the set up and maintenance of surveying databases (cadastral and topographic ones) forms the greatest effort and expense (70-90% by some estimates) at the set up of LIS/GIS, the decisive element for further use is a good creation and standardization of chosen contents. Surveying data are the starting-point for all activities carriers and information, bound to location definitions in space. Till these basic data are not standardized and prepared in digital form so long individual users are forced to seek partial solutions to be able to use their data in their own information systems.

As far as solutions and results are concerned, the surveying branch is a bit behind the simultaneous and homogeneous development in others, on surveying dependent fields. We are aware of the fact that much professional and above all financial managerial effort has to be put into these tasks.

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## Traffic intensity maps.

H.F. Kern, H. Morhard (Karlsruhe and Stuttgart, D)

### 1. Present Situation

Every five years there is a traffic census in each country of the European Community. The last censuses took place in 1980, 1985 and 1990. At present preparations for the next census in 1995 are in progress. Due to the special situation in Germany - the traffic data of the former GDR are not comparable - a smaller extra census will be done in 1993 in which only some of the German states will participate.

The counting points are in those sections of federal, state- and districtroads where a highly constant traffic intensity can be expected. On several days from april to june 1990 the traffic in Baden-Württemberg, for example, was counted at about 5000 counting locations by 10 000 persons. The traffic participants have been divided into 10 different classes. The average daily traffic intensity of the traffic participants (cars and lorries) is the 24 hours annual mean calculated on the basis of the counting results.

The Bundesanstalt für Straßenwesen in Bergisch Gladbach collects and evaluates the data. The statistical preparation is provided by Ingenieurbüro Heusch-Boesefeld in Aachen. The results of the countrywide traffic censuses give insight, for instance, into the regional traffic structure and are important measures for the construction of new roads and for the extension of already existing ones as well as for matters of traffic security and traffic guidance.

The automatic counting equipment is also of great importance. It is installed at about 90 off-town road sections in Baden-Württemberg delivering data on a 24 hours per day all over the year basis. Besides there are project related countings in towns and communities.

All of these traffic data have to be presented cartographically in general as well as in detailed maps of varying scales.

### 2. Cartographic Presentation of Traffic Intensity

#### 2.1 Maps of Federal Authorities

Commissioned by the Ministry of Traffic the Bundesanstalt für Verkehr publishes among others the traffic intensity maps of motor highways. It depicts, in a scale of 1:750 000, the

automatic long term counting places and their average daily traffic intensity in the form of proportional bands. The map is generated by means of a plotter (fig. 1). For the year of 1990 the Ministry of Traffic has published a map depicting motor highways and federal roads as well and showing the "new" states for the first time. This map has been produced manually adopting a quite unconventional classification scheme (fig. 2).

## **2.2 Maps of the federal states**

In accordance with federative competences each federal state publishes its own traffic intensity maps after having gained the results from the central data procession. The road construction authorities are meant to design these maps following uniform principles, but in fact the published results are of a quite different quality and legibility.

The very detailed federal state maps, with scales between 1:100 000 and 1: 250 000 are mainly produced manually with conventional techniques (fig. 3).

Maps using computer aided cartography have been produced in Bavaria (fig. 4) and Hassia (fig. 5). The graphical design of the Hassian traffic intensity map for the year of 1990 has been fundamentally changed and its legibility has been improved using the GIS known in Germany as the ALK-GIAP from AED, Bonn.

## **3. Preparatory Work for Computer Aided Production of Traffic Intensity Maps in Baden-Württemberg**

### **3.1 Maps of the Automatic Traffic Counting**

With methods of computer aided cartography maps in the scale of 1:500 000 showing the results of the automatic traffic counting have been produced successfully in Baden-Württemberg between 1983 and 1991 (fig. 6; Kern, 1986; Kern, Morhard 1986; Kern, Morhard 1987). In 1992 the Landesamt für Straßenwesen Baden-Württemberg decided to return to a conventional manual production procedure, since the current revision and the introduction of a mostly interactive data processing solution appeared to be too expensive.

### **3.2 The Combination of the Traffic Data Bank with the Results of the Traffic Census**

It stood to reason to process the digital available traffic data by means of computer aided cartography because in Baden-Württemberg the traffic data bank already contained the latest geometrical data, road numbers, counting positions and a range of other information.

Among the main advantages of such a solution are a display screen presentation independent from the scale, the production of coloured preview plots, the combination with other statistical data as well as a digital map production with a constant quality of the map originals and, later on, simplified map revision possibilities.

In their final theses Schreiner (1986), Schulz (1989, fig. 7) and Erhart (1992, fig. 8) worked out solutions for a computer aided map production in cooperation with one of the authors.

## **4. Results**

### **4.1 Partial Automated Solutions**

The first computer aided maps have been plotted by means of a pen plotter or have been engraved on a flatbed plotter with a production time of up to 10 hours. Afterwards the engravings had to be provided with a match punching. As the engraved texts failed to meet the cartographical quality standards the lettering had to be done and to be mounted manually. That was followed by the photographic addition and screening of the final films (daylight films) and the production of a proof copy.

### **4.2 Desk Top Mapping**

A great progress resulted from the introduction of the Apple Macintosh (Hermann, Asche, Antunes 1991). The interactive positioning of texts, the optimization of thematical bands representing traffic intensity, the improved design of the legend and the usage of extensive font directories have eased the work considerably. By means of a laser writer, a colour electrostatic plotter or an inkjet plotter proof copies can be produced inexpensively and fast and interactive revisions can be done easily. The format limits for the exposure of films (formerly DIN A3) have been reduced by new equipment. For smaller presentation examples the programs Aldus FreeHand and PageMaker are valuable, for greater production purposes we rely on specialized PostScript programs that are useful to expose films with a very high resolution (fig. 8 and fig. 9).

### **4.3 Complete Digital Solution**

The next level to be reached in the computer aided cartographical production of traffic intensity maps will be the introduction of open systems and the continuing standardization of data formats. Workstations and networks in combination with large scale scanners and colour laser writers allow for the efficient treatment, control and production of offsetfilms.

## **5. Outlook**

Today, computer aided cartography can be used successfully to produce traffic intensity maps. While the quality of digital produced maps surpasses the manual achievable results already, the costs for the production of large format maps can not yet be determined with sufficient exactness. In the next years a cost reduction due to further improved performance and cheaper workstations seems to be possible. Multiple use and the combination with digital road maps, road guidance systems and travel- and transportinformationsystems (RDS) suggest further possibilities.

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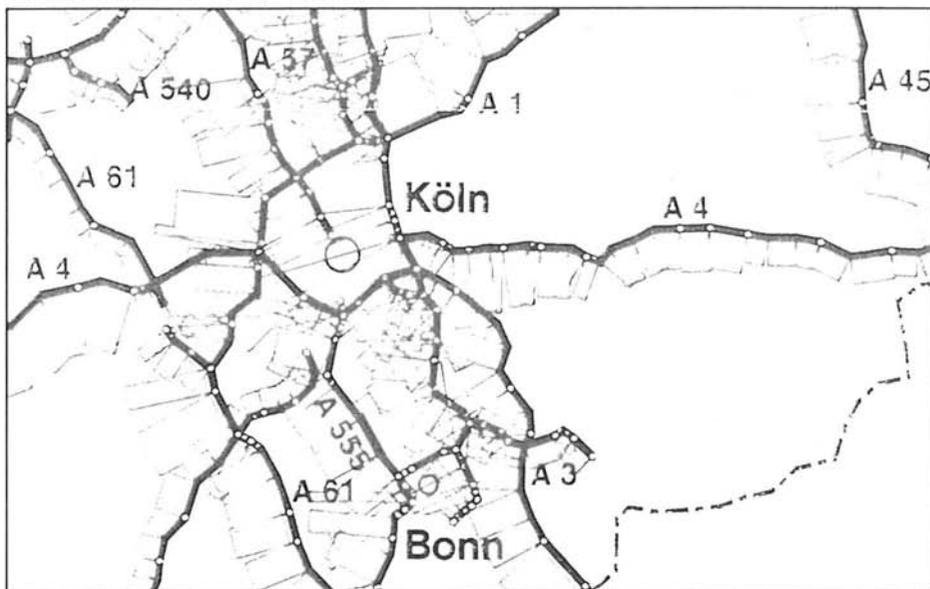


Fig. 1: Traffic intensities on federal motor highways 1991,1:750 000

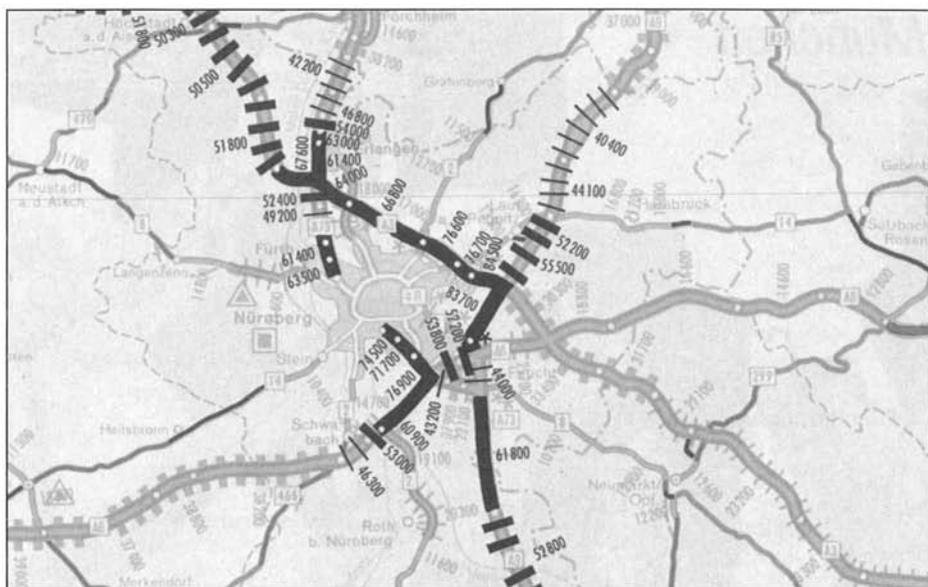


Fig. 2: Traffic intensities on federal motor highways and federal roads. Results of the traffic counting 1990, 1:750 000



Fig. 3: Rheinland-Pfalz, Traffic intensity map 1990, 1:200 000

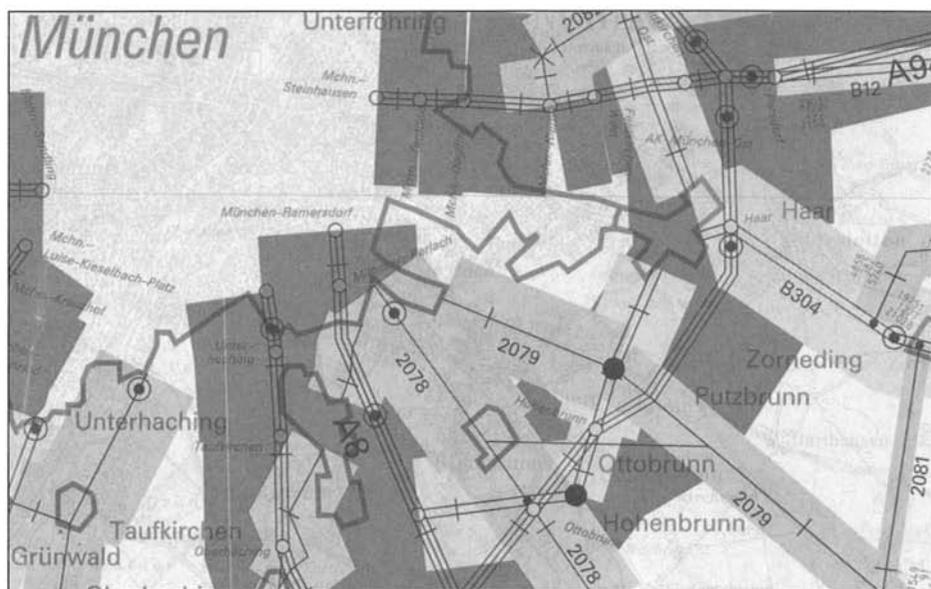


Fig. 4: Bavaria, Traffic intensity map 1990, 1:200 000

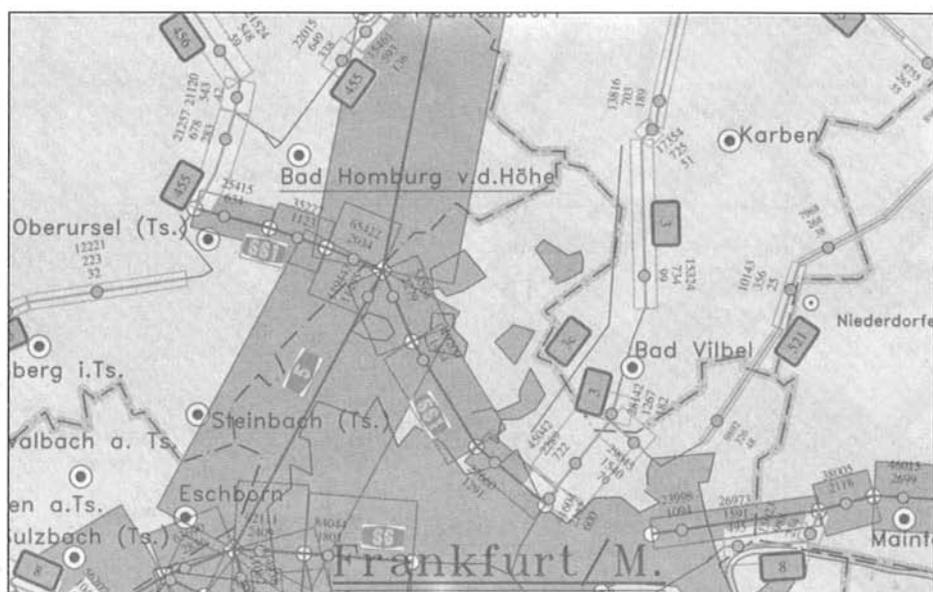


Fig. 5: Hattia, Traffic intensity map 1990, 1:100 000

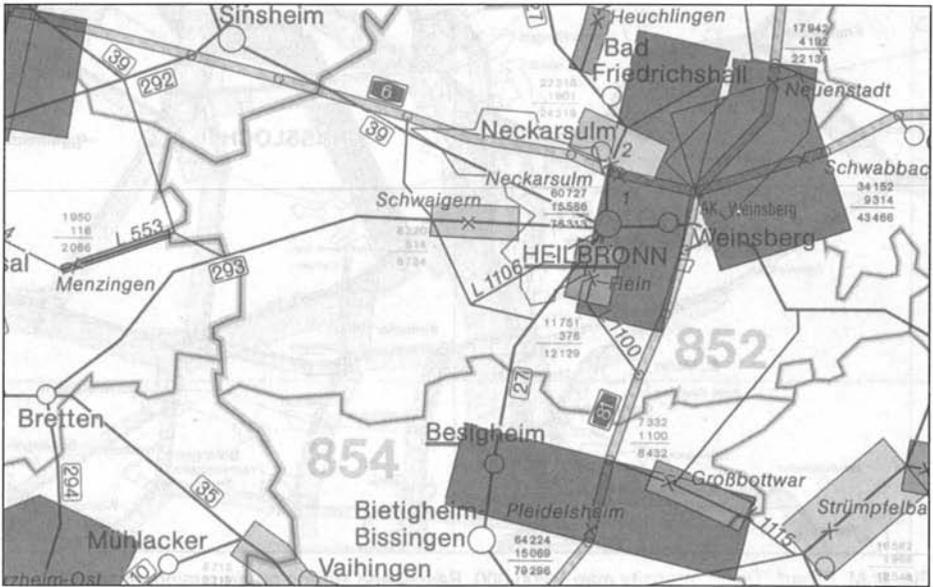


Fig. 6: Baden-Württemberg, Traffic intensity map 1989, 1:500 000

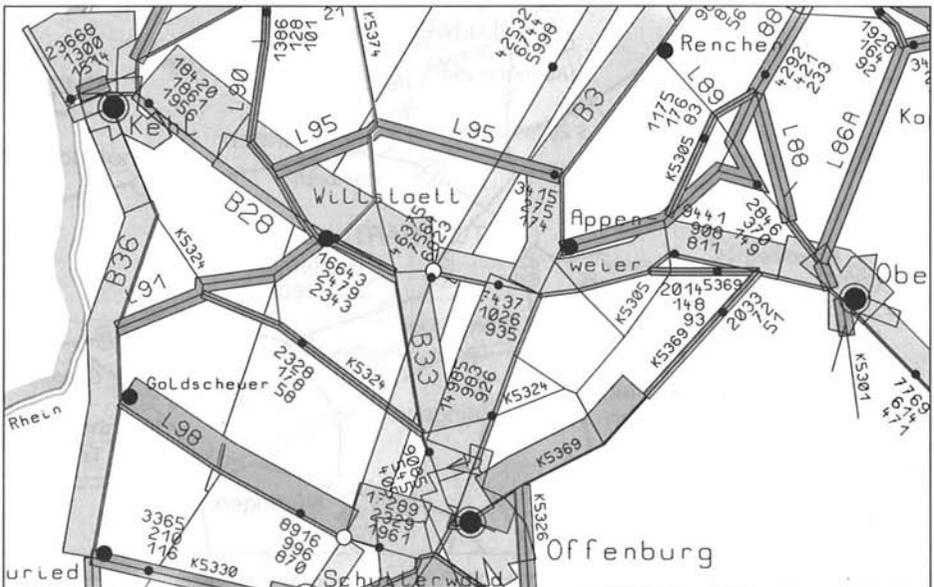


Fig. 7: U. Schulz, Traffic intensity map 1:200 000, engraving (including lettering)

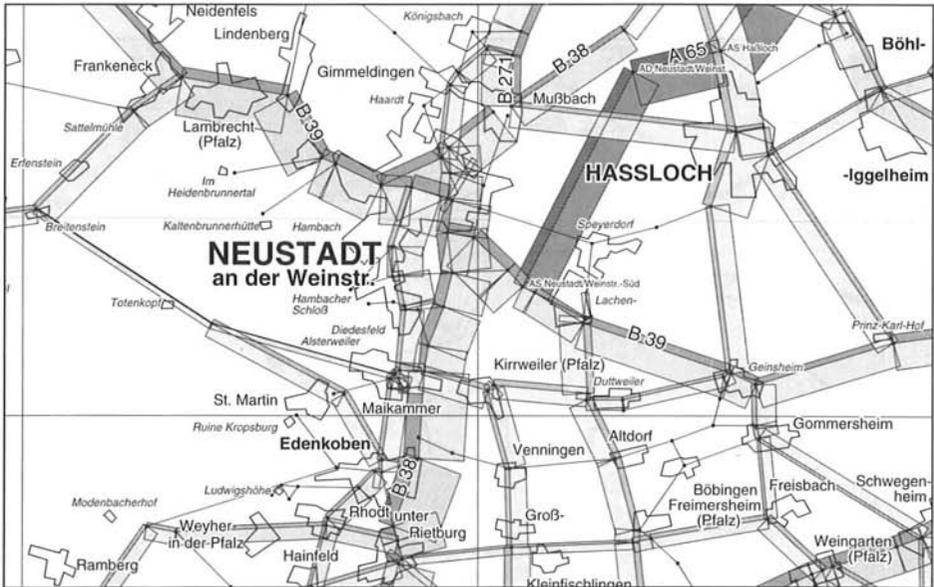


Fig. 8: M. Erhart, Traffic intensity map 1:200 000, Pascal and Mirage programming, exposition on Linotronic Laser Imagesetter



Fig. 9: H. F. Kern, Traffic intensity map 1:500 000, PostScript programming, exposition on Varityper 6000

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## Protection de la production cartographique

J.P. Grelot (Paris, F)

Parler de marketing des données cartographiques situe l'activité de production de cartes dans un marché. Ce marché est davantage celui de l'oeuvre intellectuelle que celui de la production industrielle. Il subit actuellement les transformations de l'ensemble du secteur de l'information et particulièrement des bases de données : nous nous y habitons pour les aspects techniques, alors même que l'environnement économique et juridique n'est pas assuré.

Une carte géographique est une oeuvre de création originale, dont la fabrication requiert un savoir-faire de sélection d'informations, de mesures géométriques, de représentation d'objets. Ces étapes de fabrication demandent des délais importants et la mise en oeuvre de moyens techniques lourds, se traduisant par un coût rapporté à l'unité de surface sensiblement plus élevé que dans les secteurs classiques de l'édition.

Les cartographes ont de tout temps été confrontés à la préservation de leur patrimoine. Ils ont jusqu'à présent, sur les produits imprimés, réussi à faire valoir leurs droits. Ils se trouvent aujourd'hui confrontés à la numérisation pirate de leurs fonds cartographiques pour créer des bases de données, et à la reproduction frauduleuse de ces bases. La preuve de la copie est d'autant plus difficile à apporter que seuls certains éléments peuvent avoir été reproduits, avec éventuellement des déformations, ou encore que le produit suspect résulte d'emprunts faits à plusieurs éditeurs.

Nous proposons tout d'abord de dresser un bilan des situations auxquelles sont confrontés les éditeurs en classant les diverses formes de copies. L'exposé présente ensuite l'état de la protection juridique en France à partir des dispositions législatives et de la jurisprudence, en incluant les notions présentes dans les projets de directives du Conseil des Communautés Européennes. Il expose les travaux menés au sein du Comité Français de Cartographie en association avec le Syndicat National de l'Édition, pouvant conduire à un code des usages, comme il en existe en matière d'illustration photographique.

### 1. Classification des situations de copie

Les divers types de copie seront classés selon la nature du document d'origine (carte graphique ou carte numérique) et du document produit (carte imprimée, fichier de visualisation, carte numérique).

### **1.1. Copies imprimées**

On dénommera copies imprimées les cartes éditées et imprimées à partir d'une carte existante, destinées à être diffusées gratuitement ou mises en vente. Les procédés de fabrication sont la copie par photogravure conventionnelle ou par scanner, ou le dessin : dans le premier cas, on obtient une copie servile facile à identifier ; dans le second cas, la carte peut être assez éloignée de l'oeuvre première. L'éditeur copié subit un préjudice économique du fait de la minoration de ses propres ventes, et éventuellement un préjudice moral selon l'aspect du produit dérivé (qualité de la reproduction et assimilation par le consommateur de l'oeuvre dérivée à la production générale de l'éditeur d'origine).

### **1.2. Copies de visualisation**

Les copies de visualisation sont des images numériques d'une carte existante, destinées à des applications de visualisation d'un fond de carte sur un écran informatique. Elles sont obtenues par reproduction par scanner et, à une modification près de couleurs, constituent des copies serviles. L'auteur (ou le tenant des droits) subit un préjudice économique. Le copieur fait acte de parasitisme.

### **1.3. Copies par vectorisation**

Le produit est un fichier ou une base de données d'objets plus ou moins structurés selon des modèles cartographiques vectoriels ; il est destiné à des applications informatiques, dont certaines conduisent à l'édition de cartes imprimées. Le procédé technique utilise un scanner-vectoriseur ou une saisie manuelle sur table à numériser et, de même qu'en cas de dessin conventionnel, le produit obtenu peut présenter des dissemblances quantitatives (nombre d'objets) et qualitatives (géométrie des objets, richesse de leurs caractéristiques descriptives) d'avec le produit d'origine. L'auteur de la carte d'origine subit un préjudice économique. Le copieur apporte une valeur ajoutée d'organisation des données qui n'était pas présente dans le document d'origine.

### **1.4. Copies de produits numériques**

Les copies de produits numériques sont des copies de fichiers ou de bases de données, ici cartographiques. Le procédé va de la copie simple à la transformation géométrique par des algorithmes et à la réorganisation des données. L'éditeur et le diffuseur subissent un préjudice.

## **2. Dispositions législatives**

La réglementation française sur le droit d'auteur a été récemment actualisée par la loi 92.597 du 1 juillet relative au code de la propriété intellectuelle.

Son article L.112-2 donne une liste non limitative des oeuvres de l'esprit auxquelles elle s'applique, citant notamment les cartes géographiques, les plans, croquis et ouvrages plastiques relatifs à la géographie et à la topographie.

La loi précise que le droit de propriété incorporelle comporte d'une part des attributs d'ordre intellectuel et moral (droit inaliénable et imprescriptible au respect du nom de l'auteur, de sa qualité et de son oeuvre), d'autre part des attributs d'ordre patrimonial, dont la transmission ne peut s'opérer que par contrat. Il s'agit ici du droit d'exploitation de l'oeuvre :

- "l'auteur a seul le droit de divulguer son oeuvre" (art. L.121-2) ;
- "l'auteur jouit, sa vie durant, du droit exclusif d'exploiter son oeuvre sous quelque forme que ce soit et d'en tirer un profit pécuniaire" (art. L.123-1) ;
- "le droit d'exploitation appartenant à l'auteur comprend le droit de représentation et le droit de reproduction" (art. L.122-1).

Il résulte de ces dispositions que tout auteur d'une oeuvre de l'esprit bénéficie du monopole d'exploitation de cette oeuvre, et qu'il peut en interdire toute reproduction par un tiers. L'article L.122-4 précise : "Toute représentation ou reproduction intégrale ou partielle faite sans le consentement de l'auteur (...) est illicite. Il en est de même pour la traduction, l'adaptation ou la transformation, l'arrangement ou la reproduction par un art ou un procédé quelconque".

Lorsque l'auteur cède la propriété matérielle de l'objet constituant son oeuvre, il conserve toutefois ses droits d'exploitation. L'acquéreur de l'objet peut l'utiliser librement pour un usage privé et non destiné à une utilisation collective. S'il veut reproduire l'objet pour le diffuser, il doit requérir l'autorisation de l'auteur qui peut lui céder totalement ou partiellement le droit de reproduction (art. L.131-4), contre paiement éventuel d'une rémunération (art. L.122-7). Les modalités de cession sont ainsi précisées (art. L.131-3) : "La transmission des droits de l'auteur est subordonnée à la condition que chacun des droits cédés fasse l'objet d'une mention distincte dans l'acte de cession et que le domaine d'exploitation des droits cédés soit délimité quant à son étendue et à sa destination, quant au lieu et quant à la durée".

La rémunération de l'auteur est comptée proportionnellement aux recettes provenant de la vente ou de l'exploitation, ou forfaitairement si "la contribution de l'auteur ne constitue pas un élément essentiel de la création intellectuelle de l'oeuvre", ou si "l'utilisation de l'oeuvre ne présente qu'un caractère accessoire par rapport à l'objet exploité".

Le Conseil des Communautés Européennes prépare deux directives, l'une sur le droit d'auteur, l'autre sur les bases de données. La directive 91/250/CEE sur la protection juridique des programmes d'ordinateurs a été adoptée le 14 mai 1991 : ceux-ci, ainsi que le matériel de conception préparatoire, sont protégés "en tant qu'oeuvres littéraires au sens de la convention de Berne pour la protection des oeuvres littéraires et artistiques".

La proposition de directive sur les bases de données a été publiée au Journal officiel des Communautés européennes le 23 juin 1992. La directive est destinée à protéger les bases de données électroniques par le biais de la législation sur le droit d'auteur d'une part, et d'un nouveau droit spécifique permettant d'empêcher l'"extraction déloyale" du contenu d'une base de données. Ce principe s'applique que la base de données proprement dite soit ou non protégée par le droit d'auteur, mais qui ne s'applique pas si le contenu de la base est lui-même protégé par le droit d'auteur. En voici quelques extraits, en commençant par trois des quarante attendus :

5. considérant que bien que le droit d'auteur constitue une forme appropriée de droits exclusifs des auteurs de bases de données et en particulier un moyen approprié de garantir la rémunération de l'auteur qui a créé une base de données, d'autres mesures additionnelles sont nécessaires afin d'empêcher l'extraction et la ré-utilisation déloyale du contenu d'une base de données en l'absence d'un régime harmonisé de la concurrence déloyale ou de jurisprudence en la matière.

6. considérant que la création de bases de données exige la mise en oeuvre de ressources humaines, techniques et financières considérables alors qu'il est possible de les copier à un coût très inférieur à celui qu'entraîne une conception autonome.

28. considérant qu'en plus de l'objectif d'assurer la protection du droit d'auteur en vertu de l'originalité du choix ou de la disposition du contenu de la base de données, la présente Directive a pour objectif de protéger les créateurs de bases de données contre l'appropriation des résultats obtenus de l'investissement financier et professionnel encouru par celui qui a recherché et rassemblé les données, en protégeant le contenu de la base de données contre certains actes même lorsque le contenu n'est pas protégeable par le droit d'auteur ou par d'autres droits.

#### Article 1 - Définitions

1.1. base de données : une collection d'oeuvres ou de matières disposées, stockées et accessibles par des moyens électroniques, y compris les éléments électroniques nécessaires au fonctionnement de la base de données tels que le thésaurus et les systèmes d'indexation et de consultation de la base ; le terme ne s'applique pas aux logiciels utilisés dans la création ou le fonctionnement de la base de données.

1.2. droit d'empêcher l'extraction déloyale : le droit du créateur d'une base de données d'interdire l'extraction et la réutilisation à des fins commerciales du contenu de la base.

1.3. partie non substantielle : les parties d'une base de données dont la reproduction, évaluée de façon quantitative et qualitative par rapport à la totalité de la base de données dont elles sont extraites, peut être considérée comme ne portant pas préjudice aux droits exclusifs du créateur de la base de données dans l'exploitation de son oeuvre.

1.4. modification non substantielle : tout ajout, suppression ou modification [relative] au choix ou à la disposition du contenu de la base de données qui s'avère nécessaire pour que la base continue à fonctionner de la façon prévue par le créateur.

#### Article 2 - Objet de la protection : Droit d'auteur et droit d'empêcher l'extraction déloyale du contenu de la base de données

2.1. Conformément aux dispositions de la présente Directive, les Etats membres protègent les bases de données par le droit d'auteur en tant que collections au sens de l'Article 2 § 5 de la convention de Berne pour la protection des oeuvres littéraires et artistiques (texte de l'acte de Paris 1971).

2.3. Une base de données est protégée par le droit d'auteur si elle est originale en ce sens qu'elle est une collection d'oeuvres ou de matières qui, par le choix ou la disposition des matières, constitue la création intellectuelle propre à son auteur. Aucun autre critère ne s'applique pour déterminer si elle peut bénéficier d'une protection.

2.5. Les Etats membres prévoient un droit pour le créateur d'une base de données d'interdire l'extraction ou la réutilisation non autorisées du contenu d'une base de données, en tout ou en partie, à des fins commerciales. Ce droit d'interdire l'extraction déloyale du contenu d'une base de données s'applique indépendamment de la protégeabilité de la base de données par le droit d'auteur. Ce droit ne s'applique pas au contenu d'une base de données composée d'oeuvres déjà protégées par un droit d'auteur ou un droit voisin.

### 3. La jurisprudence française

La reproduction pure et simple constitue une contrefaçon, sanctionnée par les articles 425 à 428 du Code Pénal.

Lorsqu'il n'y a pas reproduction pure et simple mais adaptation, c'est-à-dire reprise de l'idée de l'auteur sous la forme originale et caractéristique, il y a encore exploitation de cette oeuvre et le consentement de l'auteur reste nécessaire sous peine de contrefaçon. Le plagiat est quant à lui imitation frauduleuse de l'oeuvre d'autrui, mais le plagiiaire ne reproduit ni n'adapte : il reprend la substance d'une oeuvre en lui donnant un tour personnel.

C'est à l'auteur qu'incombe l'apport de la preuve. La contrefaçon s'apprécie selon les ressemblances et non selon les différences, et la jurisprudence récente détermine en premier lieu ce qui fait l'originalité de l'oeuvre initiale pour déterminer si la ressemblance d'ensemble des deux produits l'emporte sur les divergences ponctuelles.

L'arrêt de la Cour d'Appel de Paris du 7 janvier dans l'affaire Michelin contre Du May pour une carte de France au 1:1.000.000, retient comme critères d'originalité "le sectionnement des kilométrages, le choix des localités, curiosités et symboles, la sélection et la classification des routes, le tracé des forêts". Il conclut que les ressemblances d'ensemble l'emportent sur les quelques différences existant quant au choix des couleurs, à leurs nuances, à l'emplacement des cartouches. S'il n'y a pas eu en l'espèce copie servile ni concurrence déloyale, il y a bien eu atteinte aux droits d'auteur et préjudice économique.

Le jugement du Tribunal de Grande Instance de Paris du 27 avril 1989 dans l'affaire Arno Peters contre Antenne 2 considère que, si la projection Peters repose sur une formule mathématique, "le résultat obtenu n'en constitue pas moins une oeuvre originale de l'esprit dans la mesure où ne pouvant être utilisé comme une carte de géographie classique, il a pour but de privilégier les pays du tiers-monde et de favoriser leur prise en considération au sein des peuples de la planète". Le décor utilisé par Antenne 2, quoique monochrome et vierge de toute indication, présentait une totale ressemblance avec la carte de Peters quant à la projection, caractéristique essentielle, et en constitue une contrefaçon.

L'arrêt de la Cour d'Appel de Paris du 16 décembre 1988 dans l'affaire l'Astrolabe contre F.F.R.P. pour une carte générale des sentiers de grandes randonnées, établit comme critères d'originalité certaines caractéristiques d'ensemble (figuration des lacs et des cours d'eau, absence de figuration du relief et des limites départementales, position du cartouche de la Corse) et les symboles, continus ou hachurés, de représentation des sentiers.

#### 4. Projet de code des usages

Les cartographes ont un savoir-faire, enseigné dans des établissements reconnus par le ministère de l'Education Nationale et sanctionné par des diplômes. Dans leur activité professionnelle, ils appliquent des règles de l'art d'autant plus fortes que se greffent des impératifs d'actualité de l'information, de sécurité ou une activité économique des utilisateurs. A contrario, celui qui ne respecte pas ces règles peut :

- soit aller à l'encontre du marché en proposant des produits à faible prix, puisqu'il n'aura pas engagé les coûts correspondant à un processus normal de fabrication, et empêcher les professionnels de réunir les conditions économiques de création et de pérennité de produits ;
- soit proposer des produits de mauvaise qualité induisant, dans l'esprit des consommateurs, une image d'incapacité des produits cartographiques ou du secteur d'activité à répondre à leurs besoins.

Le Comité Français de Cartographie et le Syndicat National de l'Edition ont engagé une réflexion débouchant sur un projet de code des usages professionnels, qui s'appuie sur la législation sur le droit d'auteur et sur les principes découlant des règles de l'art. Il s'agit encore à ce stade d'un projet, dont le texte est repris ici en conclusion de cette communication, comme un exemple de dispositions qui peuvent être convenues entre professionnels pour assurer une meilleure protection de la production cartographique.

# CODE DE PRATIQUES LOYALES

## EN MATIERE D'EDITION CARTOGRAPHIQUE

(projet)

### INTRODUCTION

Le "Code de Pratiques Loyales en matière d'édition cartographique" est accepté par les signataires comme texte de référence destiné à promouvoir des règles de moralité élevées, en matière d'édition cartographique, par le moyen d'une autodiscipline, et ce sans préjuger les dispositions du droit national et international.

Une carte géographique est un produit rassemblant une grande quantité d'information par unité de surface traitée, dont la fabrication exige la mise en oeuvre de ressources humaines, techniques et financières importantes alors qu'il est possible de le copier à un coût très inférieur à celui qu'entraîne une conception autonome.

Les éditeurs cartographiques sont à des degrés variables victimes de copiage ou de piraterie. Ces actions ont des conséquences directe : outre le préjudice économique ou commercial direct et immédiat, la profession est victime de la mauvaise qualité de certains produits issus d'édition cartographique.

La profession a donc décidé de mettre en place un code de déontologie montrant son unité et sa volonté d'appliquer des règles strictes.

### 1 - CHAMP D'APPLICATION

Ce Code s'applique aux produits et aux personnes définis à l'article 4 ci-après dénommés produits cartographiques.

Le code sera accompagné d'une procédure de label qui sera définie à l'article 10.

### 2 - INTERPRETATION

Le Code sera appliqué dans son esprit et dans sa lettre.

### 3 - PRINCIPES DE BASE

Toute édition de cartographie sur tout support, et en particulier numérique, devra se conformer notamment et non limitativement aux textes et lois applicables en matière de propriété littéraire et artistique, en particulier à la loi 92-597 du 1 juillet 1992 relative au code de la propriété intellectuelle et à la Directive Européenne sur les bases de données.

#### 4 - DEFINITIONS

Carte géographique : image codifiée de la réalité géographique, représentant une sélection d'objets ou de caractéristiques, relevant de l'effort créateur de son auteur par les choix opérés, et destinée à être utilisée lorsque les relations spatiales ont une pertinence essentielle (Association Cartographique Internationale, 1992).

Produits cartographiques : cartes géographiques ; plans, croquis et ouvrages plastiques relatifs à la géographie ou à la topographie (cf. loi 92-597 du 1 juillet 1992 relative au code de la propriété intellectuelle, art. L. 112-2).

Base de données : collection d'oeuvres ou de matières disposées, stockées et accessibles par des moyens électroniques, y compris les éléments électroniques nécessaires au fonctionnement de la base de données telles que le thésaurus et les systèmes d'indexation et de consultation de la base (cf. proposition de directive du Conseil des Communautés européennes concernant la protection juridique des bases de données, juin 1992).

Produit cartographique numérique : fichier ou base de données cartographiques.

Copie : résultat d'une reproduction.

Produit cartographique dérivé : produit cartographique réalisé par généralisation, avec ou sans réduction d'échelle, d'après des produits cartographiques existants ; la généralisation cartographique est l'adaptation des données qualitatives et quantitatives, par allègement du nombre des détails et simplification caractérisée des formes des tracés, en vue de l'établissement d'un produit cartographique répondant à des conditions déterminées (cf. 'carte dérivée' et 'généralisation cartographique', in Glossaire de Cartographie, Comité Français de Cartographie).

Copie imprimée : copie d'un document original, obtenue par photogravure conventionnelle (copie servile), par scanner ou par dessin, éditée et imprimée pour être diffusée gratuitement ou mise en vente.

Copie de visualisation : image numérique scannée d'une carte originale, obtenue par reproduction par scanner et constituant une copie servile à une modification près des couleurs, destinée à des applications de visualisation d'un fond de carte sur un écran informatique.

Copie par vectorisation : fichier ou base de données d'objets plus ou moins structurés selon des modèles cartographiques vectoriels, obtenu par numérisation sélective d'une carte originale, destiné à des applications informatiques de calcul, de modélisation, de visualisation ou d'édition de cartes imprimées.

Copie de produit cartographique numérique : copie de fichier ou de base de données cartographique, allant de la copie simple à la transformation géométrique par des algorithmes.

Auteur cartographique : concepteur et réalisateur d'un produit cartographique ; le plus souvent, l'éditeur définit les caractéristiques précises du produit de création, dont il confie l'exécution à l'un de ses salariés ou à un tiers rémunéré forfaitairement pour cette tâche.

Editeur cartographique : personne morale ou physique à qui l'auteur d'un produit cartographique ou ses ayants-droit a cédé le droit de fabriquer ou de faire fabriquer en nombre des exemplaires du produit, à charge pour elle d'en assurer la publication et la diffusion (cf. loi 92-597 du 1 juillet 1992 relative au code de la propriété intellectuelle, art. L. 132-1).

## 5 - CREATION, REPRODUCTION, ADAPTATION

Création : réalisation de la conception de l'auteur ; en matière cartographique, elle s'apprécie notamment par le choix des objets représentés et par celui de leur représentation (symboles, couleurs, etc.), ainsi que par la disposition générale ou la mise en page découlant du système de projection, de l'échelle, ou encore des cartouches.

Reproduction : fixation matérielle d'une oeuvre par tous procédés qui permettent de la communiquer d'une manière indirecte, et notamment imprimerie, dessin, gravure, photographie, moulage et tout procédé des arts graphiques et plastiques, enregistrement mécanique, cinématographique ou magnétique (cf. loi 92-597 du 1 juillet 1992 relative au code de la propriété intellectuelle, art. L. 122-3), ou tout procédé connu ou à venir.

Adaptation : reproduction partielle ou totale d'une oeuvre incluant la transformation d'une partie de ses caractéristiques originales ; le produit cartographique ainsi adapté est éventuellement complété d'éléments additionnels.

## 6 - DROITS, OBLIGATIONS ET CONSEQUENCES DE LA DIVULGATION

Les produits cartographiques doivent porter la mention de leur auteur, sauf dispositions particulières convenues entre l'auteur et l'éditeur.

Toute reproduction intégrale ou partielle, et toute adaptation faite sans le consentement de l'auteur ou de ses ayants-droit est illicite (cf. loi 92-597 du 1 juillet 1992 relative au code de la propriété intellectuelle, art. L. 122-4). Ainsi, les produits cartographiques ne peuvent être communiqués pour reproduction ou représentation sans accord exprès de l'auteur.

L'auteur d'une adaptation jouit de la protection du code la propriété intellectuelle sans préjudice des droits de l'auteur de l'oeuvre originale.

L'éditeur devra demander l'autorisation d'utiliser et d'exploiter tout produit cartographique sur quelque support que ce soit et pour chaque domaine d'application.

En cas de copie et reproduction simple, l'éditeur devra obtenir l'autorisation de duplication et représentation de l'auteur et, si l'oeuvre est une compilation de documents, veillera à obtenir toutes les autorisations.

L'éditeur s'interdit toute copie, au sens de l'article 4 du présent Code, qui ne lui aurait pas été autorisée par l'auteur.

Les produits cartographiques sont communiqués, soit par l'auteur original du produit, soit par un distributeur garantissant qu'il détient l'autorisation d'utilisation des produits à cette fin. Ceux-ci garantissent donc qu'aucun obstacle ne s'oppose à cette communication.

En cas d'édition similaire ou mise à jour, l'éditeur devra outre l'autorisation de duplication, obtenir les droits d'adaptation s'appliquant pour une adaptation déterminée.

L'édition dérivée et nouvelle sera soumise aux mêmes dispositions et l'éditeur veillera à la sauvegarde des intérêts de l'auteur.

#### **7 - PAIEMENT DE DROITS POUR EXPLOITATION COMMERCIALE**

Toute exploitation commerciale de produits cartographiques dûment autorisée conformément à l'article 6 ci-dessus, est justiciable du règlement de droits pour chaque domaine d'application.

#### **8 - QUALITE DE L'EDITION CARTOGRAPHIQUE**

L'éditeur respectera les règles applicables à la profession d'éditeur cartographique.

Il prendra soin de respecter les droits des éditeurs ou auteurs dont il aura utilisé les produits.

Il mettra en oeuvre les moyens appropriés pour que le produit cartographique soit licite et fiable, c'est-à-dire conforme aux dispositions légales, exempt d'erreur, complet et non périmé pour le domaine d'application considéré.

#### **9 - FORMATION**

La profession cartographique mènera les actions de sensibilisation adéquates auprès des enseignants et des formateurs, afin que les enseignements de formation initiale ou continue, universitaire ou professionnelle, inclue des exposés sur la législation et la réglementation en matière d'édition cartographique.

#### **10 - LABEL [ce paragraphe est à rédiger]**

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#### **Remerciements**

Cette communication a bénéficié des travaux menés au sein du groupe de travail sur la protection de la production cartographique (Comité Français de Cartographie) et du groupe des éditeurs de livres pratiques (Syndicat National de l'Édition), et des contributions spécifiques de Isabelle Blin et Gilles Galindo, de la Manufacture Française des Pneumatiques Michelin. Qu'ils en soient ici remerciés.



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## **Session 21**

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### **Multi Media Displays and Hypermapping**

Chairman:

M.P. Peterson, Uni. of Nebraska at Omaha (Omaha, USA)

generalize, how to generalize, how much to generalize, and how to resolve symbol conflicts. Although there exist written principles and guidelines for traditional map generalization, there is considerable latitude for cartographers in the interpretation of these guidelines. A cartographer can easily take many factors into account simultaneously in deciding how to place a generalized feature on a map. In digital environment, however, this process needs to be decomposed into separate, interrelated steps performed in a logical order to achieve a satisfactory result.

Early research on digital generalization, as summarized by Buttenfield and McMaster (Buttenfield and McMaster, 1991'), was isolated focusing on development of generalization algorithms, particularly on line simplification and smoothing. Then in later 1970s through 1980s, research emphasis moved towards the determination of critical points on linear features and the evaluation of generalization algorithms. Only recently has the issue of an integrated generalization solution been brought to cartographers' attention. Several conceptual models have been suggested for digital map generalization. Among them, a more comprehensive model has been developed by McMaster and Shea (McMaster and Shea, 1992<sup>2</sup>). This model represents a significant steps in the transition from manual generalization to explicit and operations of digital generalization. The model addresses the need to consistently and simultaneously reduce data complexity, while preserving data accuracy, aesthetic quality, and a logical feature classification.

A digital cartographic generalization system is intended to replace time-consuming and operator-dependent manual map generalization. From system design point of view, such a system should contain the following major components:

1). An output definition base

The first component is the definition, either given or derived, of the desired output associated to map scale or map purpose change. The definition consists of map scale, map content, accuracy requirements, cartographic license, feature classification hierarchy, and symbolization specifications. It is used as an objective base to be satisfied at the end of generalization process.

2). An analyzing mechanism

In manual generalization, a cartographer visually analyses a map and determines:

- the characteristics of features (location, shape, size, orientation, spacing, etc.)
- the distribution density of features (clusters vs. sparseness)
- the distribution pattern of features (regular vs. irregular)
- the relationship among features (importance, priorities, and dependency)
- the impacts and consequence (if feature A is generalized, how features B, C, and D are affected)

A digital generalization system must simulate, to some extent, or mimic the cartographer's thought process. It needs to "observe" and "think" as a cartographer, but by using analytical tools. Statistical measurements are probably the most powerful analytical means for characterizing digital data. Point distribution analysis, cluster analysis, trend analysis, and similarity analysis are examples of common relevant statistical tools (Davis, 1973<sup>3</sup>). Other areas such as pattern recognition and raster overlay analysis may also be applicable for analyzing digital cartographic data.

### 3). Data transformation functionalities

The essential idea of digital map generalization is to reduce data complexity, but preserve the representative depiction of the data within a reduced map space. Data stored in a digital form can be simplified in many ways:

- eliminating feature classes
- decreasing the number of vertices in a line or a polygon
- reducing feature dimensions, for example from an area to a skeleton line or to a centroid point; from double lines to a single line
- smoothing curves
- combining clusters of features
- removing a number of features from a feature cluster

These data transformation processes, which are analogous to the cartographer's manual drawing, recalculate and create new geometric representations of the digital data. The major parts of the data transformation mechanism are a library of generalization operators and algorithms and an operational sequence setup. Proper employment of the algorithms and operators ensures accurate and consistent transformation of digital data from its master data source to a reduced map scale.

### 4). An adjustment mechanism

Data transformation must be supplemented by certain adjustments to achieve a cartographically acceptable result. The adjustment mechanism should consist of detecting symbol conflicts and violations of cartographic license and providing resolutions, as well as evaluating accuracy and refining the results. Comprehensive analysis should be performed horizontally (within a data layer, usually containing the same type of features) and vertically (across different data layers).

### 5). Visual evaluation tools

Because fully automated generalization systems do not yet exist, visual evaluation tools are necessary to assist cartographers during generalization. These tools include the capabilities of:

- dynamic display during processing
- on-line measuring templates
- multiple viewing on the screen
- local viewing of full symbolization
- displaying the result to scale

## II. Development of an Interactive Generalization System

As addressed above, a fully automated cartographic generalization system would require a well-defined knowledge base and implementation of the operational processes of analysis, data transformation, and adjustment. An interactive approach, or amplified intelligence approach as described by Weibel (Weibel, 1991<sup>4</sup>), is considerably more practical for most organizations. An interactive approach lets the computer do the algorithmic processing wherever possible, as in the cases of area aggregation and line smoothing, and leaves the decision-making to the user. This approach has been used in the development of a cartographic generalization system at Intergraph Corporation, named MGE (Modular GIS Environment) Map Generalizer.

The design of Map Generalizer allows the operator to select generalization operators and algorithms, to set up parameters, to choose geographic features, and to accept/reject the result based on visual perception. More importantly, it provides the user with a capability to store generalization steps, conditions, and parameters, which will become the guidelines for future processing and contribute to the establishment of a knowledge base for a future fully automated rule-based generalization system.

In contrast to the traditional scale-dependent database approach, MGE Map Generalizer aims at deriving maps at various smaller scales from a single, larger scale master database (Fig. 1). Since there is currently no commercially-available system to directly convert feature graphics of maps from one scale to another (while achieving a cartographically acceptable result), the Map Generalizer can save both time and labor and increase the value of existing databases. In other words, it permits customers to build and maintain databases which can produce multiple scale representations, without creating one database per scale. Consequently it reduces overall costs for data collection, revision, verification, and storage. Of course, this assumes that there is sufficient overlap in map content between maps of different scales

The context of the Map Generalizer within the MGE map production system is depicted in Fig. 2. Map Generalizer is designed to enhance Intergraph's widely used map production systems. As computer-assisted cartography has evolved in the last fifteen years, commercial and public sector agencies have implemented numerous systems. The earlier systems had relatively low levels of "feature intelligence" (IGDS and MicroStation) but newer systems such as MGE include relational database capabilities. Cartographic databases offer enhanced data maintenance, revision, and analysis functions considered valuable by most producers. Regardless of the level of intelligence in the data sets, Intergraph's systems provide finishing and plotting for high-quality cartographic representations.

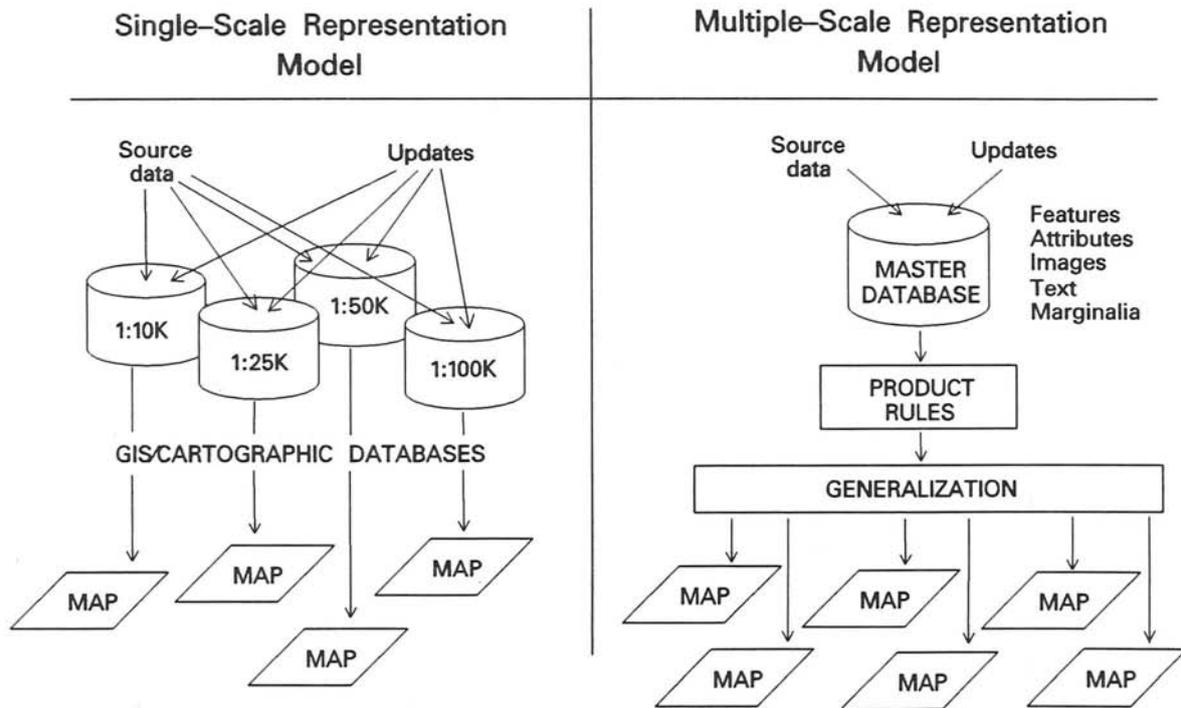


Fig. 1

# Computer-Assisted Map Production System

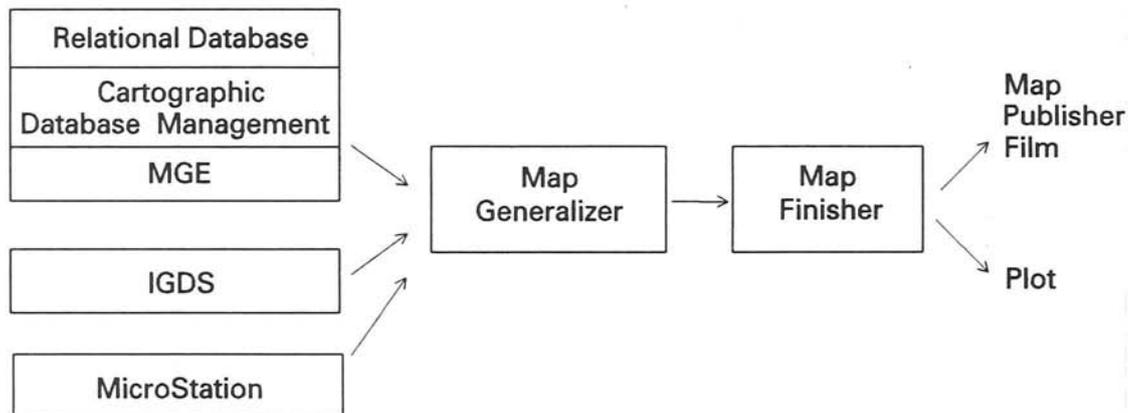


Fig. 2

## MGE Map Generalizer Operators

Digital data transformation in generalization is achieved by using algorithms that have been developed as generalization operators. The operators that have been and will be implemented in MGE Map Generalizer are grouped into the categories described below (Fig. 3).

### Feature Selection/Elimination

This process selectively retains or deletes features during a change in map scale or purpose. Features continue to represent the general characteristics of the mapped area at a smaller scale will be retained, while others that are less important will be eliminated. For example, buildings that appeared on 1:24,000 scale USGS topographic maps are generally eliminated for maps at 1:100,000 or smaller scales.

### Simplification

This process reduces the amount of coordinate data in a linear feature or an area boundary, while maintaining the characteristics of the feature or boundary. It identifies the critical points and removes unwanted detail, such as, small fluctuations in a shoreline, based on user-specified criteria.

### Typification/Refinement

This process reduces the complexity of a group of features by displaying fewer features while maintaining the representative pattern in their distribution. The overall visual impression of feature density and distribution should be preserved.

### Aggregation

After reducing scale, features may become so close together that they can not be represented individually. Aggregation generates areal features from point or areal features that are in close proximity to each other.

### Collapse

Collapse changes the dimension of a feature or reduces its areal extent. It may be applied to part of a feature or the entire feature, wherever the feature extent becomes smaller than a pre-set tolerance. For example, a double-line river may be collapsed to a single-line river if the width is below a threshold value at output map scale.

### Classification/Symbolization

This process groups features that share similar attributes into a new category and represents it by a new symbol if necessary.

### Exaggeration

This process enlarges (widens) and adds detail to the representation of a feature for the purpose of legibility or

# Map Generalization Operators

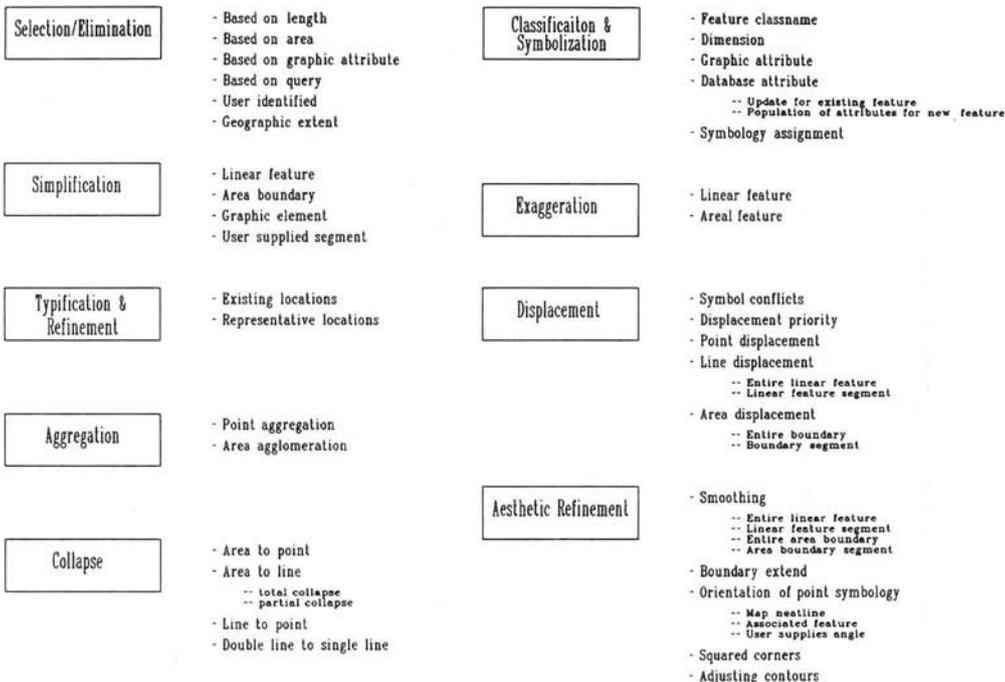


Fig. 3

emphasis. It enhances the visual impression and unique characteristics of a feature. For example, a small peninsula may be deleted based on size but its significance as a navigational point of reference may require it to be exaggerated and retained instead.

#### Displacement

Displacement repositions the geometry of less important features in order to avoid symbology conflicts with more important features. Feature permanence and accuracy requirements are usually among the major concerns when determining feature importance.

#### Aesthetic Refinement

This process alters or adjusts the geometry or symbology of a feature in order to improve its visual impression. Examples include the orientation of point symbols, the smoothness of lines, and the intersections of contours to roads.

### III. Initial Research on Operational Sequence

With all the definitions, tools, and operators available, the actual generalization will be performed according to a logical sequence of operations or workflow. In order to establish an optimum workflow for a particular generalization process, the following aspects may be taken into account:

#### \* Feature class-dependency

Each of the feature classes, including hydrography, vegetation, and transportation, has its special characteristics. Therefore, each could require a unique generalization workflow. This suggests that in the phase of data capture and data preparation, it would be helpful if different feature classes are separated. In fact, many existing digital databases have been created in this way already.

#### \* Feature dimension-dependency

Within each feature class, there usually are different dimensions of features (i.e. point, linear, and areal). Many generalization operators are developed such that each of them is for a particular feature dimension. For example, simplification is for linear features (including areal boundaries) and point aggregation is for points. Therefore, the workflow for a feature class can be sub-divided based on feature dimension.

#### \* Operational logic

It has been recognized (Robinson et al., 1984<sup>5</sup>) that cartographic generalization, even in manual process, should start with feature selection or elimination. Displacement and aesthetic refinement naturally follow most of the other operations. The intermediate steps vary with different cases. An iteration of operations is often necessary.

\* Minimizing spatial accuracy reduction

As a result of digital generalization, many data points are moved or displaced from their original positions. Part of the displacement can be minimized by, besides carefully choosing algorithms and parameters, executing generalization operations in certain order. Two operational sequences for areal feature generalization are, for example:

- \*\* Simplification, Aggregation, followed by Smoothing, or
- \*\* Aggregation, Simplification, followed by Smoothing.

Each of the above will result in a difference in the output. A sequence that produces less positional displacement is considered better (McMaster, 1986<sup>d</sup>).

\* Maximizing process efficiency

In cases where processing efficiency is important (as in the case of large data volumes or where the scale-change is drastic, the workflow should be customized in order to maximize throughput.

\* Minimizing the need for subsequent readjustment

Unnecessary repetitions of the same operation should be avoided. For example, to generalize a cluster of small areas, Aggregation followed by Smoothing may be better than Smoothing followed by Aggregation because the latter may require further smoothing of the aggregated boundaries.

Building a more general workflow will be based on many case-dependent workflows. The development and optimization of generalization workflows will involve a great amount of research and experimentations.

#### IV. Recommended Research

The availability of an interactive digital cartographic generalization system, such as MGE Map Generalizer, provides cartographers with an effective suite of tools for interactive digital cartographic generalization. While this is an important first step, future research should focus on the following areas:

Enhancement of user interface and software capabilities and flexibility to handle more complex workflows

Development and improvement of algorithms to generalize a wider variety of feature types and feature-to-feature relationships

Implementation of analytical tools for analyzing input data conditions and output map quality

Building capabilities for symbol conflict detection and resolutions

Providing more visual tools to assist cartographic judgement and decision-making

Exploring other applications of generalization, such as in GIS/LIS and natural resources management areas.

## V. Conclusions

Digital cartographic generalization has advanced to the stage where organizations should strongly consider multi-scale databases in stead of the more-traditional single scale approach. Digital cartographic generalization provides the opportunities of exploiting a single representation for cartographic products at a range of scales. In addition to improving data consistency and reliability across different scale products, digital cartographic generalization provides the opportunity for more effective, more consistent and more efficient cartographic visualization.

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# A comprehensive approach in cartographic animation

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**Abstract:** Animation is a useful visualization tool for presenting and investigating geographical data. In spite of this potential a comprehensive approach to the use of animation in cartography does not exist. This paper examines the visual and acoustic means of animation and how they can be applied in cartography. Additionally it develops a system of animation variables which can be used for the creation of complex cartographic animations.

## 1. Animation in Cartography

Animation is a useful form of presentation for cartography. It has the ability to show the spatial and temporal dimension of geographical data and also to show data in a variety of forms. Animation can be employed in cartography to present results of investigations, but -more important- animation can be used in scientific investigation process as a tool to visualize geographical data for purposeful exploration and the development of questions and hypothesis ( DiBiase et. al. 1992, Monmonier 1989 and 1991).

In spite of the potential of animation for cartography only a small amount of work has been done in this area. Most works are concerned with the realization of an animated map sequence for one special issue (Moellering 1976 and 1980, Rase 1974, Tobler 1970). Only the later works pick up a more common and extensive attempt at the cartographic application of animation (Campbell and Egbert 1990, Monmonier 1989 and 1991, Dibiase et. al. 1992). A comprehensive and systematic approach to the use of animation does not exist. This paper tries to develop a systematic and comprehensive approach for the application of animation in cartography. It presents the visual and acoustic means of animation and how it can be used in cartographic animation.

## 2. The visual animation variables

### *Definitions*

To realize the complete potential of animation for cartographic visualization the means of animation must be examined and described. A system of basic elements, similar to Bertin's graphic variables must be defined which may serve as the basis for the generation of complex cartographic animations. For this purpose we will have a look to the definition of animation.

Animation is a sequence of changing images. The changes can refer to all parameters which determine an image; however they must be in a logical context.

According to this definition the essential feature of animation is the change from one image to the next image. Therefore, the basic elements of animation,

the animation variables, have to be derived from the changes which can occur. The changes in a cartographic animation can be related to all parameters determining a map. Maps are graphical representations of a spatial data model. Consequently the changes can be referred to the data model as well as to the graphic model. Thus, two groups of animation variables are to distinguish: the *variables referring to the data model* and the *variables referring to the graphic model*. Additionally, a third group of variables has to be established: the *variables referring to the sequence*. These variables are not related to the individual maps but to the complete animation sequence.

## 2.1 Animation variables referring to the data model

The data model underlying a map is determined by the geographical objects and their attributes and by the data processing method, like classification or interpolation, which is used to transform the raw data into a processed form. Therefore, the variation of the data model in an animation may be related to the *data set* or to the *data processing method*.

### *Variables of the data set*

Variations in the data set cannot be made randomly. According to the definition of animation they must be in a logical context, e.g. the successive maps and changes must be connected by subject or by location. Considering this restriction following changes, which also may be called variables, can be defined:

#### *- a change in object's location.*

This type of animation can show the *varying position of an object* to present the movement of the object.

Additionally, location animation can depict the *same topic at different locations* to make clear spatial disparities and similarities.

#### *- a change in object's value.*

This type of animation depicts varying values of one object; thus it is suitable for presentation of time series data. For example the variation of rainfall in an area over a period of 10 years.

#### *- a change in object's type.*

Different data related to one subject are shown in this animation to make correlations visible. For example an animation for population may present number and density of population, ethnic composition, levels of education, income etc.

#### *- a change in number of objects.*

This means the *successive* presentation of map objects. In such an animation the user is led through the presented topic. A well defined succession may help the user to see and understand statistical or spatial relationships.

#### *- a change in combination of objects.*

Often a variety of objects or attributes have to be depicted to see all existing correlations. It is difficult to show such complex subjects in one single map and mostly they are more confusing than helpfully. In an animated map sequence the single objects and attributes can be combined in any possible way and the user may get a better impression about the correlations.

### *Variables of data processing*

Data processing is an essential step in map making process. The raw data will be classified and set into a geometrical reference system. Variations in data processing enables the user to get an extensive impression about the data presented in a map.

#### *- a change in classification.*

An animation with varying numbers of classes depict the data in different generalization. For example a map sequence with an increasing number of classes will at first show common trends and then give a more detailed distribution of the data.

#### *- a change in geometrical reference system.*

The change in geometrical reference system can be a simple *aggregation* of objects. An animation with aggregation is similar to the classification animation. It is a kind of generalization that gives the user an overview about spatial structure on various aggregation levels.

A change in geometrical reference system can also be a *transformation* from one reference system into another; for example the transformation of irregular point data into a regular grid or into isolines. An animation with transformation allows the presentation of the data in different ways and helps the user to get a better insight into the data.

## 2.2 Animation variables referring to the graphic model

The changes of the graphic model can be related to the changes in the data model but they also can be used independently.

Animation is a combination of graphic and cinematographic presentation forms. Therefore, the graphic models of an animation are composed by *graphic objects*, which carry the information and by a *camera* and a *light source* which determine the view point and the illumination of the scene. (In computer animation we do not have a real camera and light source, both are virtual objects only).

Accordingly, two groups of animation variables can be distinguished:

- the variables of the graphic objects and
- the variables of the cinematographic objects

### *Variables of the graphic objects*

The graphic objects in a cartographic animation are the elements of a map, the point, line and area symbols. The animation variables of these objects correspond with the colour-pattern variables; they are: changes in position, shape, size, direction, colour, texture and intensity.

The variables can be applied as follows:

- *a change in position* depicts movement, flows or diffusion of geographical objects.
- *a change in direction* or
- *a change in shape* can denote change in quality of an object.
- *a change in size* shows different quantities as growth of population or the difference between coal and oil resources of a country.

- a *change in colour hues* or
- a *change in texture* show varying qualities of a geographical object.
- a *change in intensity* may denote a change in quantity for example the altering population density.

#### **Variables of the cinematographic objects**

**Camera**, the most important one of the cinematographic objects, determines the way the user will see the graphical objects. It defines

- the perspective,
- the extension of presented area and
- how detailed the objects are shown to the viewer.

These parameters depend on the camera's position which defines the corresponding animation variables. They are: vertical position (zenith), horizontal position (azimuth), distance (height) and angle (inclination).

In cartographic animation the variables may be used in the following way:

- a *change in vertical position* or
- a *change in horizontal position* cause a change in the presented area; for example a 'fly-by' shows three dimensional objects from any desirable direction.
- a *change in distance*, a zoom, is equal to a change in scale. It presents geographic information in different degrees of generalization.
- a *change in angle* presents the graphic objects in different perspectives, for example a plane map is turning into a three-dimensional presentation.

**Light sources** are used in animation to create shadow effects for three dimensional objects and to highlight special objects.

### **2.3 Animation variables referring to the sequence**

Finally, animation variables can be defined that are related to an animation sequence as a whole. A sequence is a structured set of individual images or maps. The structure of a sequence is determined by the *order* of the single maps and by the *duration* of the maps and changes. Duration is to be divided in relative duration which describes the *rhythm*, the temporal relations between the maps and their changes, and in absolute duration which describes the playing *speed* of an animation. The animation variables referring to the sequence may be defined as order, rhythm and speed.

#### **- order**

The order of a sequence's maps cannot be altered in any cartographic animation. In temporal animations, which depict changes over time, the succession of individual maps is determined by the temporal data. In non-temporal animations however, the user may define the order that is useful for his purpose.

#### **- rhythm**

Rhythm defines the relative duration a map or a change will be presented. It is -like order- dependent on the data. In temporal animation rhythm is determined by the real duration of changes of geographical objects; in non-temporal animation it can be defined by the user.

- *speed*

The playing speed of an animation is independent of the data. It can always be varied for the user's purpose.

### 3. The acoustic animation variables

#### 3.1 Forms and functions of sound

In common animation the visual part is mostly combined with a sound-track. Sound is an important element in an animation to transmit the message. It supports and confirms the visual message of the animation.

Multimedia techniques offer the possibility for creating, combining and presenting pictures and sound on a computer. Therefore, the technical requirements for animation combined with sound are available.

The use of sound in cartography has not been considered seriously up to now. However, with the application of animation in cartography, cartographers are to think about sound and its potential for transmitting cartographic information (Krygier, 1991).

Sound has different forms: voice and music.

- *voice*

Voice can be part of the legend in a cartographic animation. Its role may be in the most simple form a pure vocal reproduction of the occurring graphical changes. In addition, voice may explain correlations between changing objects or it gives additional information not presented in the visual part of the animation.

- *music*

Music can be applied in a cartographic animation to make changes and their temporal patterns more apparent for the user. Music is -like animation- a sequential presentation form and therefore highly appropriate for reproducing changes. Zuckerkandl (1969) considers music even as the best communication form for presenting changes.

'To be sure, the eye shows us unaltered things that change their place. But the ear? Hearing a melody is the clear perception of a movement which is not attached to a mobile, of a change without anything changing. This change is enough, it is the thing itself. ... Compared with seeing and touching, hearing proves to be the faculty that gets to the essence; ... Instead of asking how we can perceive motion with the ear *too*, we find that the core of the process of motion... is *directly* perceptible *only* with the ear.'

Both sound forms are described by acoustic characteristics which may be defined as acoustic variables. They can be used for composing the sound-track of a cartographic animation.

#### 3.2 Acoustic variables

The acoustic variables are to distinguish in *variables referring to one sound* and in *variables referring to a sequence of sounds*. This differentiation is

similar to the differentiation of visual variables which are distinguished in variables related to one individual map and in variables related to a complete animation sequence.

#### *Variables referring to one sound*

##### *- pitch*

Pitch can be used to indicate the kind of change that takes place. A sequence of rising pitches may present increasing data values; a sequence of descending pitches on the other hand presents decreasing values.

##### *- Loudness*

Loudness is, like pitch, an ordinal variable. It may denote changes in the quantity of an object. Increasing loudness represents increasing data and decreasing loudness represents decreasing data. Additionally, loudness can be used to point to changes or to emphasize abrupt changes.

##### *- timbre*

Timbre describes the character of a sound, for example the bright sound of a flute or the warm sound of a cello. Timbre allows a qualitative differentiation. In animation it can denote changes in quality of an object or it may be used to represent more than one changes at the same time.

##### *- duration of sound*

The duration of a sound determines the time interval one sound is played. It indicates the duration of a change of geographical data.

#### *Variables referring to a sequence of sounds*

##### *- melody*

A melody is a defined sequence of pitches. It may denote a defined change within the animation and signify its temporal pattern whether it is a single, periodical or episodic event.

##### *- rhythm and speed*

The rhythm and speed of a sound sequence create the acoustic 'picture' of the change's dynamic. Rhythm and speed are determined by the duration of the individual sounds in the sequence. They can be compared with the visual variables 'rhythm' and 'speed' referring to the animation sequence.

##### *- spatial position of sounds*

New techniques in music equipment make possible to hear sounds in three dimensions. Spatial sound enables the listener to perceive direction and distance of a sound and with it, to perceive the spatial dimension of the changes in a cartographic animation.

#### **Conclusion:**

Animation is a useful visualization tool for cartography to present results of investigations and to visualize geographical data for purposeful exploration and the development of questions and hypothesis. If cartographers want to realize the complete potential of animation they have to examine the means of animation and their application in cartography. This paper presents the visual and acoustic means of animation and defines a system of animation variables which may serve as the basis for the creation of complex cartographic animations.

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## Ariadne's thread – structure in multimedia atlases

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### Atlases

An atlas is an intentional set of maps; it consists of a number of maps and other graphics brought together for some purpose. Usually this is more than just a reference purpose. As an intentional set of maps, atlases can be compared to rhetoric: the author or atlas editor wants to make some point, he wants to reach an objective, and in order to do so he presents the material in a given sequence. The comparison with films is relevant here: single shots get a meaning when combined into an edited sequence. Atlases are produced in order to answer specific questions, just as novels answer all-important questions such as "Will the heroine find true love; Will the hero conquer evil; Will they solve the mystery?" Comparable questions for atlases would be: "Are people here in control of their environment? Do all people have access to the nation's resources? Do people here have better chances than people elsewhere, and if so, at what price?"

In order to enable the readers to find the answers, atlases have to be structured, and they have to allow for comparisons. Atlas users want to compare different countries, they want to compare the patterns for various themes for the same area, or the development of a single theme for a specific area, they want to compare the same theme for different areas, in order to deduce whether some common patterns exist, and they want to compare the maps with various other models of reality, such as graphs, diagrams, textual descriptions, or satellite images. For the maps to enable these comparisons, they have to follow preset standards, regarding scale, degree of generalisation, symbolization, projections, or data quality. The other presentation formats (fotos, diagrams, satellite imagery) are bound to answer to comparable standards as well, but we have not found out about those yet.

In order to find our way in the geographical data presented in an atlas we have to structure them: we put the material in a given sequence and in a specific order of importance, an information hierarchy, for instance. There are two main types of use of paper atlases: a guided search, usually for reference or for educational purposes, and a browse mode. If we want to know the location of a specific city, we look for it in the atlas index, and then find it at the atlas page and cross-reference indicated. Or, as in *l'interAtlas*, educational material is presented in a strict sequence, that allows us to follow the argument and understand spatial processes. For guided search place names indexes, and topical indexes are available, next to index maps and the table of

contents. For browsing, no specific aids used to be available. Before we turn to multimedia atlases it is good to see how traditional paper atlases are structured.

### Structure in paper atlases

In order to analyse the structural aspects of paper atlases it seems best to identify the tools used for structuring. Here we can discern:

1. the **scale tool**: we use it when we render more important areas at larger scales than less important areas
2. the **geographic sequence tool**: we use it when we present areas deemed more important earlier in the sequence than less important areas
3. the **thematic/topical sequence tool**: we use it in order to suggest the existence of some causal relationships between various map themes
4. the **temporal sequence tool or time machine** which presents everything (such as a number of snapshots in time) in a historical or chronological sequence, allowing us to show the spatial development of a phenomenon
5. the **superposition or windowing tool**, which allows either for close ups (positioning) or for overviews (orientation)
6. the **colour coding tool**, which is used to show that all atlas pages with a similarly coloured map margins refer to the same area, or to the same theme.
7. the **graphical emphasis tool**, which is used within specific maps in order to indicate the hierarchy between the various information categories represented

Apart from these structuring tools, other tools are used as well in atlases, such as tools for atlas use. Here we can discern **reference mechanisms**, such as scale reference mechanisms, milieu reference mechanisms, relative or absolute positioning reference mechanisms, **simplification tools**, used for explaining or memorizing the complex images the maps show us, and **alternation tools**: by alternating various views on the same area (such as chorological and economic maps, or analytical and synoptic maps) and repeating this same combination for different areas we avoid being influenced too much by one specific standpoint of the map author; moreover, opposing these images generates extra information.

Of course, there are other important aspects of atlases, such as their points of view, which can be ideologically or phraseologically differentiated, the way in which maps, other graphic formats and texts are integrated in the atlas, or the **access mechanisms**, such as place names indexes, map sheet indexes and thesauri. As these aspects are present as well in digital atlases we will not discuss them here.

### Digital environment

We are still producing atlases now, as we were 400 years ago. However, one should realize that neither Ortelius or Mercator, neither Sanson or Arrowsmith had the kind of competition our cartographical products have now, from television, video and computer games. It is not sufficient to move the traditional atlas concept to an electronic environment. If we want our potential atlas users to be interested in electronic atlases, they will have to be interactive. The users should not run out of motivation too soon when using these atlases. Therefore, what we should envisage is to provide atlases that simulate a world in which we can move about, atlases that let

the users interact with the graphics on the screen and with the simulated world, for instance by adding their own data.

In paper atlases we are confronted with the mapmaker's perspective on the data, while in electronic atlases it is our own perspective (Armenakis). When we study these electronic atlases, they can be subdivided into different groups, such as the "view only" type (such as the electronic *Atlas of Arkansas*) which still is based upon the mapmaker's perspective; the "interactive" type, which has the user's view on the data selected by the mapmaker, and the "analytical" type of electronic atlases which provides a user's view on data selected by the user himself.

One of the most important drawbacks of maps is their isolating character: they present only a restricted selection of themes for a restricted part of the world at a specific time (Freitag 1988, p.76). This drawback has been turned, as we have seen, into a structuring tool for paper atlases. Because of the ease of scrolling, the geographic sequencing tool has lost its use in a digital environment. As we have the possibility to zoom in or out on our maps we lost the scale tool as well. The temporal sequence tool has been strengthened as we have options for animation in this new environment. The thematic sequence tool, the graphical emphasis tool and the alternation tool have been preserved, and the superposition tool has been strengthened, as we are able to ask for windows with enlargements or with overview maps at whatever location on the screen we want them.

New tools for structuring in the digital environment are the highlighting tool (which will either increase the contrast with the background constantly or temporarily, by blinking) and the layering tool, which allows us to construct a specific cartographic image layer for layer, in the specific sequence we want.

When we look at **access structures**, in principle the (geographic) sequence has been lost. When we still want the users to **follow a specific route** by presenting e.g. a default sequence, we will have to see to it that this route is interesting and that it is fun: we have to provide some sort of guided discovery process, with added value; it should be possible to apply knowledge of facts and theory gained during the journey, in order to gain comprehension, perception and practical skills. For guided navigation, search engines have to be built that enable users to locate places or other named objects, even with wildcards, or to locate all the settlements within a certain radius or buffer. When we want to go **browsing**, at the other hand, there are various modes available (McAleese 1989): distinct scanning, browsing, searching, exploring and wandering. Each of these has to be catered for.

Every interactive navigation system is a world in miniature, with well-trodden highways, open seas, for which visitors need both maps and means to travel (Hoffos 1992). The many maps that have been devised for video games are an example; but there are other, more serious types of education and entertainment now released on CD-ROM or CD-I or videodisc, that need maps as well. The Domesday project is an example of the latter, but the same goes for sword and sorcerer kind of video games, or flight simulator games, strategy games, sports games or detective games like Sherlock Holmes or Carmen Sandiego, and civilization games like SIMCity.

SIMcity is a civilization game, the kind of computer game played by adults on their

home PC. It shows a landscape which can be developed, i.e. where a city can be built, based on numbers of taxpaying citizens, a budget, employment, housing, infrastructure requirements, and a rating given to the player (in the form of a popularity poll for the city's mayor). One plays the game in a specific time frame, with monetary restraints, and a possible threat of natural disasters for which one has to be prepared. It is rather difficult to look at the larger framework, as one's work area is only a small part of a much larger region. This larger region is considered empty, and therefore a lack of interaction with the outside world emerges which we should avoid in our atlases. One may move throughout the area, but the player himself is not visible, only the cursor. The environment can be built in any location, and if a certain spot has been built already, it can even be bulldozed and developed again.

Carmen Sandiego is a detective game, also available for PC, with educational aspects meant for high school children. It has been at the top of PC games sales for almost three years in the US. It is about gathering clues to catch a thief, who moves about a lot, and during the information gathering process one learns also about foreign places. During the chase, one might go in the wrong direction, and have to retrace one's steps. This is possible, but only if the player has made notes himself. Though there is a map option (flight), this only shows possible destinations from the current abode, and not former haunts. This suggests the importance of being able to keep track of one's movements.

### Structure in multimedia atlases

As the newest development in electronic atlases, multimedia atlases provide a variety of analogue and digital forms of data (maps, graphics, animated films, video, graphs and diagrams, satellite images) that come together via common channels of communication (Laurini and Thompson 1992). Up till now these data formats have been mostly presented in a "view only" type of presentation, that is a presentation where the user cannot influence specific images, but there is no reason why this should not change to an interactive or even analytical mode. The *Geoscope Interactive Global Change Encyclopaedia* is a good example. Here, the user can make his own selection of the data to be presented, and he can influence the colours and class boundaries of the maps that are displayed by the system.

In cartographic applications multimedia is usually realised using a Hypercard information structuring model, in which sets of nodes are connected together by undifferentiated (associative) links. Such a set-up can be a bit open-ended, and it can be difficult, especially because of the various formats used together, to perceive it as a unity. What glues together the various chunks of information? What provides the spatial relationships between the various disparate images? The fact that it stems from the same package is not enough. It should be a similar style of execution, specific lettering, colour coding, a marginal reference, apart from the common network or web structure that links the image back to the origin of the journey.

There are other requirements as well: one has to be equipped with a sort of log, which has recorded all the actions one took; the system should maintain records of topics or sections whose last cards have been reached, flagging them to the user by highlighting the buttons on the section header card and the map (Raper 1992). From an interface users should discover where they are going and help them remember

how they got there. It is especially important for users to be able to distinguish between the several layers they have access to. One would want to retrace or undo a number of the most recent navigational steps, save one's place in the interface and return to it later, annotate files, keep user notes and comments on a note pad (Apple 1992).

Hoffos has stated the navigational requirements for multimedia packages (1992):

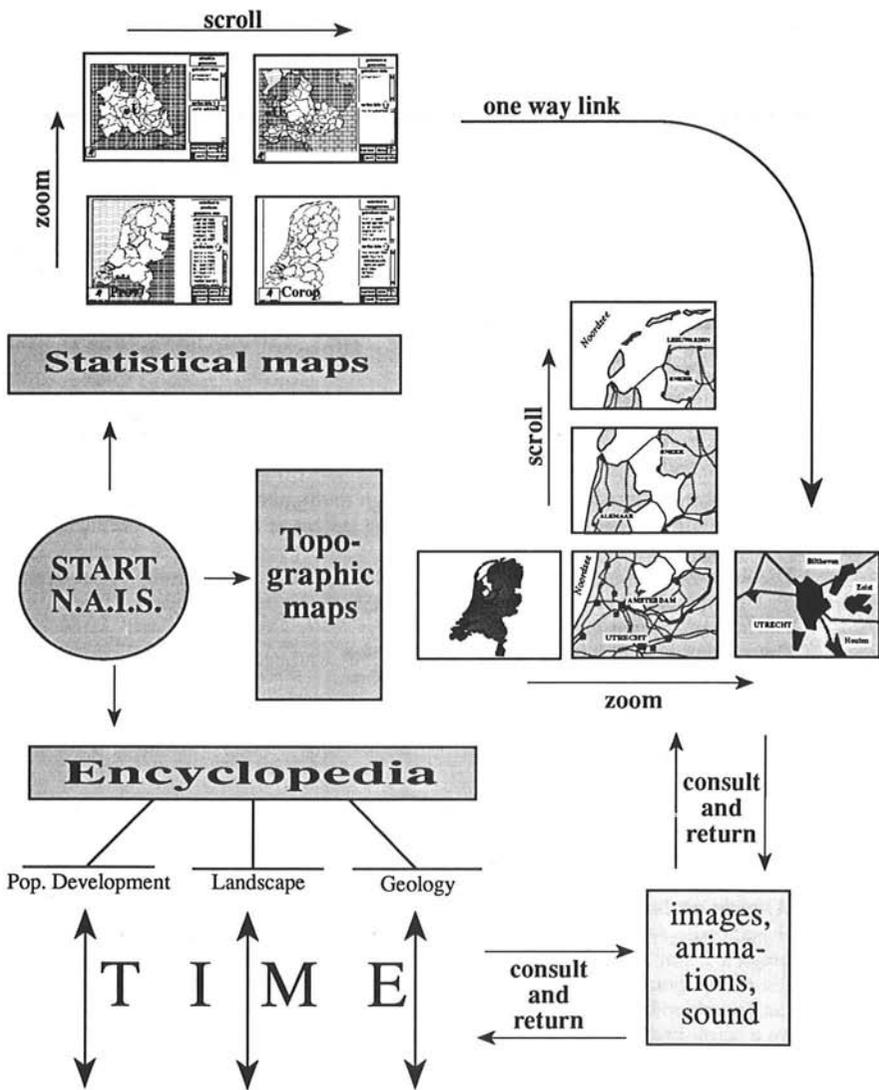
- Users should be able to develop a coherent mental image of the programme's structure, while still allowing them to move about easily within it.
- Users should never have to go further in to get further out
- Users should always be able to come and go by the same means
- The same routines should work consistently throughout the entire programme; the same action should produce the same results in a similar context
- It is useful to leave a metaphorical trail of pebbles along the path, so users can backtrack to the last interesting fork or cross-road and explore another route (Apple produced a 'recent' function for Hypercard, showing up to 40 previously accessed cards)
- Most users appreciate some form of map or gauge to indicate where they are in the programme, and how much remains to be explored (also available in Apple Hypercard).

Other important aspects for navigation through multi-media systems are:

- Users should be required to interact with the system at regular, non-predictable intervals,
- The multimedia systems should provide visual responses to every choice users make during interactive sessions
- The systems should have time-out functions
- The systems should have a screen-save function
- The users should have access to a dialogue box.

Moreover, users should be able to be trailblazers for other users, showing profitable routes through the system.

Multimedia atlases should therefore provide users with an overview of the route they took, the present position, showing both geographic position, the topic selected, and the position in the atlas. This presupposes a study of the potential and plausible routes a player or atlas user might select - in fact, it requires a study of map use. In Utrecht we have developed a prototype of an electronic multimedia atlas, NAIS (for Nationale Atlas Informatie Systeem, an acronym modeled on the Canadian example). From a starting point (see figure 1), it allows users to move in different ways: to topographic maps of the Netherlands, to statistical maps of the country and to an encyclopedical section, which contains maps and texts. The **topographic maps** have a scroll and a zoom function; they can also be linked to imagery and animation, but this link presupposes a return journey. The **statistical maps** allow one to scroll (from one province to the next) or zoom (from the country, subdivided into provinces or districts, to provinces, subdivided into municipalities); one is also allowed to go from a statistical map to a topographic map of the same area, but one is not allowed a return journey yet. This is sort of a drawback, as the comparison between statistical and topographic maps improves understanding of the statistical maps. The **encyclopedic part** contains texts and maps (on landscape, geology, demographic development,



LINKAGES MAP OF N.A.I.S. MULTIMEDIA ATLAS

etc.), structured in time; one is allowed to hop on from here to the imagery, but again, it is obligatory to move back to the encyclopedia afterwards. So landscape photographs showing moraines, and animations of the process of them being pushed up by glaciers, can be accessed both from topographic maps of areas where these moraines are located and from geological or landscape sections in the encyclopedic parts. But it is impossible to move from the topomap via these images to the encyclopedia - to do so, one has to make a detour via the start menu. Even when, in this case, because of the zoom and scroll functions a trail of pebbles to enable one to retrace one's steps is not so necessary, this example shows that at least a map of the atlas, which shows the potential links, is a must for its proper use.

In the start of this paper I referred to rhetoric; in this sense atlases could be regarded as having a narrative structure. This narrative structure seemed lost in the digital environment, but as far as Multimedia systems on CD-ROM or CD-I are concerned, this narrative is more within our grasp than ever, as the potential of sound and therefore of narrative is added to our other possibilities.

#### Scenario's

In the past some geography manuals have been produced, disguised as children's literature. The most famous is probably *The wonderful journey of Nils*, which describes the journey of a Swedish boy, who has been changed by magic into a Liliput-like creature, with a flock of wild geese from Southern Sweden to Lappland and back. By moving over the country in a seemingly random way, all the country's landscapes, the ways of life and the problems of its inhabitants were described. The book was commissioned by the Swedish educational authorities from the Noble-prize winning writer Selma Lagerlöff. Comparable books have been written for other european countries as well.

It would be perfectly feasible to change this children's story or the movie that has been made from it, into an adventure game: in order to accumulate a number of credits, players would have to move about and encounter problems in various parts of the country and solve them. These problems would vary with the geographical location and the topical layer selected. In order to move about, a certain capital would be available; it would be dipped into depending on the travel mode. In order to be as realistic as possible, the player should be represented as a sprite, a small image or character which can easily be manipulated on the screen during the course of a presentation (Brennan 1993). The alternative would be to provide a flight-simulator-like environment, but this would probably require too much memory space. If such a scenario could be linked to digital atlas files (such as the *PC Atlas of Sweden*), a most powerful and alluring educational tool for secondary schools could be created.

New electronic atlases should be planned by producing the scenarios first, before collecting the necessary data. The types of movements expected should then be ascertained, and subsequently the tools should be prepared to allow the users to move about, either for following specific route or in a browse mode, and to keep track of their movements. And if they have no thread or pebbles to find back their origin, at least they should have a map for their journey through the atlas.

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# Electronic mapping systems – a multimedia approach to spatial data use

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## ABSTRACT

Modern and cost-effective information technologies present a whole new world of opportunities for digital mapping and map use. Of particular importance to spatial data representation and exploration are computer-assisted methods collectively known as visualization which are primarily concerned with the multi-dimensional graphic representation and communication of spatial information. Associated with visualization is the concept of electronic mapping which uses interaction and multimedia techniques for the creation of multi-dimensional, fine-tuned electronic maps. Based on map graphics, electronic mapping systems provide cartographer and map user with fresh and intuitive options for the visualization, manipulation and evaluation of spatial data.

## 1.0 INTRODUCTION

Over the last three decades, the worldwide spread of modern information and communication technologies has led to a dramatic increase of generally available information. Immense amounts of data have become such an immanent feature of the Western world at least that the phrase "information era" seems an appropriate characterization of the situation. While the data explosion has undoubtedly contributed to a general democratization of information, ever larger volumes of data raise the problem of managing these data to extract the information required for specific tasks. Vast arrays of unexplored data, accumulating at an accelerating rate, are clear indications of the constantly widening gap between the availability of data and their appropriate use <sup>(12)</sup>. Causally related to the information revolution is the evolution of media to communicate the information. In this development, the electronic media have added audiovisual data like sound, video and animation to the classic data types of text, graphics and images. State-of-the-art information technologies provide a growing number of facilities to store and manage audiovisual data in digital form. Implemented on standard computer systems they are fast bringing this potential to the user enabling him to interact with all the different types of information, and to manipulate the

data in a variety of ways, and to mix them into interactive applications. Such combined interactive processing of data, graphics, video and sound is termed "multimedia" or "hypermedia".

Earth sciences, in particular, have witnessed an explosion of information, especially since earth observation satellites, operating from the early 1970s, have made available vast arrays of spatio-temporal data of our environment. Undoubtedly the enormous amounts of environmental data have greatly widened the cartographer's capacity to process and communicate these data cartographically – despite increasing data protection efforts. At the same time, advances in computing and computer technology provide the cartographer with a whole range of sophisticated hardware/software options for data selection, analysis and storage. Powerful graphics workstations now facilitate rapid graphic display of geographic data, construction of two- and three-dimensional map models, dynamic presentation of environmental change and spatial mobility, multimedia integration and spatio-temporal simulations. Growing concern for global and regional environmental problems calls for earth scientists to commit themselves to the task of employing the electronic tools at their hands for the effective and efficient management of the mass of geographical information.

## 2.0 SPATIAL DATA REPRESENTATION

As the enormous quantities of largely alphanumeric data long exceed our capacity to utilize them, it becomes necessary to develop some kind of understanding of the quality and usefulness of this information <sup>(12)</sup>. Transforming data to graphic form can help to accomplish this. In fact, the last two decades have seen a constant growth of two- and three-dimensional graphics and images being employed to represent qualitative and quantitative information. At the same time, graphics have developed from mere illustrations into an independent means of communication. Modern computing and information technologies have substantially fostered the creation and propagation of information graphics. Today, the visual presentation of information is already dominating our perception habits. Films and videoclips of virtual environments, animated satellite weather graphics and electronic traffic information maps on German state-controlled TV, electronic railway timetables of the Swiss and German state railways, electronic books, the interactive multimedia newspaper of Basle (Switzerland) are current examples to illustrate the trend.

### 2.1 VISUALIZATION

The graphics revolution has clearly multiplied the demand for effective computer-assisted methods of graphic data presentation and analysis. Collectively known as "visualization", these methods aim to "make visible" information by employing visual tools of computer graphics. The purpose of visualization is to represent general or specific characteristics of spatial data sets for communication or subsequent analysis by symbolization. Visualization requires the use of interactive graphics systems. Hardware and software components of these electronic mapping systems provide a variety of choices for visual data presentation ranging from the single graphic to animation and multimedia as well as for interactive exploration of the multidimensional data.

Apart from its technological component visualization is not a completely new concept of communicating information. Visual presentation of data is common in statistics and the earth sciences since the nineteenth century. The scholarly works of BERTIN <sup>(2,3)</sup> and TUFTE <sup>(19,20)</sup> have amply

demonstrated the unique power of visualization to disclose and understand complex data relationships. In the context of recent US-American investigations into supercomputing the central role of visualization for effective digital data use has once again been emphasized <sup>(10)</sup>.

## **2.2 VISUALIZATION IN CARTOGRAPHY**

Maps are well established and familiar tools to visualize geographic information. As graphic abstractions of the three-dimensional reality, maps employ symbols to represent and communicate spatial data. With reference to the concept of modelling, the fundamental process of cartographic information processing, the transformation of spatial data into two- and three-dimensional graphic models, is described as cartographic modelling. Successful modelling of geographic information is a decisive factor in creating useful maps that facilitate effective visual communication, spatial data navigation and application-oriented data use. Due to their unique property to visualize spatial information by graphic abstraction, maps are considered an ideal instrument to organize, analyse, and communicate the vast amounts of geographic data in a way that cannot be matched by any other product.

While the cartographer has largely been restricted to conventional two-dimensional map graphics in the past, modern computer graphics systems offer sophisticated and versatile tools for the development of complex three-dimensional graphic models. Workstation-based techniques of multimedia data handling provide new and cost-effective means of allowing the cartographer to experiment with the graphic representation of complete sets of geographic data.

## **3.0 ELECTRONIC MAPPING SYSTEMS**

### **3.1 ELECTRONIC MAPPING**

Geographic information systems (GIS), developed for the management of large sets of geographic data, provide the cartographer with powerful and efficient tools of data storage, evaluation and analysis. Most GIS support some kind of graphic display of evaluation results but lack powerful functions to visualize spatial data complying with the principles of cartographic modelling. This insufficiency has turned out to be a major impediment to meet the cartographer's as well as the map user's requirements of map graphics, as a majority of them are not prepared to give up the professionally modelled map as the principal instrument to represent and access complex spatial information. Within the context of the current controversy on the status of GIS in cartography, case studies have investigated the cartographic shortcomings of GIS. <sup>(11)</sup> In the ongoing debate the argument is gaining ground that GIS – like multimedia – is a digital technique of spatial data management which can be made use of in the visualization process. By combining GIS features of data storage and analysis with visualization, the cartographer is able to model novel, electronic maps that fully exploit the potential of computer technology. In this context, the term "electronic map" is used to characterize digital maps designed for the use on graphics workstations or electronic mapping systems, i.e. primarily for softcopy display on high-quality monitors and not for hard copy output.

In contrast to GIS, visualization is central to electronic mapping, and the map graphic is the essential part of an electronic mapping system. Its data structures and their cartographic representation can, however, be manipulated interactively through "active" map elements, so-

called hot symbols, and navigation buttons, annotated with graphics, images and text supplements. Electronic maps support the interactive integration of time-based data, allowing dynamic visualization of spatio-temporal information, of animation and sound as well as systems guidance by so-called agents. By employing state-of-the-art technology for the symbolization of geographic information, electronic mapping systems help to bring the cartographic visualization process better into line with the map user's contemporary perception habits.

Resulting from changing data communication and perception patterns, the map user is heavily relying on multidimensional, multimedia data presentations. This signals a trend away from abstract graphics like the conventional topographic map towards dynamic rather than static, two-dimensional rather than three-dimensional map models, and images rather than graphics to visualize spatial data. The closer their visual similarity to the user's three-dimensional environment, the more effective they exploit his ability to recognize spatial patterns thus facilitating natural, intuitive cognition of data structures. Visualization is therefore of fundamental importance for easy and effective access and use of spatial data for subsequent data analysis, processing or decision making. Commercial electronic mapping applications that exploit this potential are regional and national atlases (e.g. Arkansas, Sweden), urban and regional informations systems (e.g. GeoFinder town and county guide of Los Angeles), tourist information systems (e.g. the Grisons system installed at the Swiss motorway resthouse "Heidiland") and an increasing number of map-based educational systems (e.g. the Planetscapes system containing Landsat and Voyager images).

### 3.2 SYSTEM COMPONENTS

Like Desktop Mapping, electronic mapping employs modern graphics systems which, over the last decade, have established themselves as flexible, efficient mapping tools in computer-assisted cartography<sup>(1, 8)</sup>. Frequently based on microcomputers, they offer easy operation, high-level processing and a great potential for cartographic visualization at an economic price/performance ratio.

Electronic mapping requires an electronic mapping system at the heart of which is a high-interaction graphics computer supplemented by optical data storage facilities (CD-ROM, videodisc). Performance features of standard hardware/software make it possible to configure interactive cartographic workstations from off-the-shelf products for individual mapping applications and evaluation purposes. A new breed of dedicated low cost graphics systems (personal digital assistants, PDAs) is currently being introduced into the market. As systems manufacturers have indicated that the systems will also be used to visualize spatial data, the cartographer should explore the cartographic potential of these platforms. Systems of special interest are pen-operated handheld computers or "penbooks" for which city maps and graphics-based travel guides are being developed.

To make full and effective use of electronic mapping systems, the design of the man-machine dialogue, commonly termed "user interface", is of key importance to both map maker and map user. Major attention has been directed towards solving this problem in connection with the development of microcomputers for non-professional use. One truly revolutionary concept was the use of graphic symbols or "icons" to visualize familiar objects (e.g. of an office environment) which could be selected and manipulated directly on screen by means of an electronic pointer tool, the so-called mouse. In keeping with the thinking and feeling of the non-professional computer

user, in particular, this so-called object technique facilitates intuitive operation, enabling him to take an active role in computing without in-depth knowledge of data processing.

#### 4.0 APPLICATION POTENTIAL OF ELECTRONIC MAPPING

##### 4.1 SELECTED CASE STUDIES

To study the problems related with the design, development and use of electronic mapping systems, selected aspects of electronic mapping have been investigated for various applications in cooperation with potential systems users. In keeping with users' systems requirements, all applications are using standard hardware/software components of computer graphics: *Apple Macintosh* and *IBM* microcomputers and commercial *AutoCAD*, *cart/o/info*, *MacroMedia Director* and *SuperCard* software.

A first case study investigated the application potential of two- and three-dimensional *AutoCAD* (11.0) data for the development of interactive perspective maps<sup>(7)</sup>. Axonometric data of the town centre of the German spa Bad Urach have been visualized in an electronic three-dimensional town plan in which the user is able to determine his position and line of vision. The system has been developed on an *IBM PC/AutoCAD* basis. Commercial presentations of a similar application, a simulated walk through a (virtual) town, indicate that hardware manufacturers consider dynamic three-dimensional visualization of spatial data a key application to demonstrate the potential of high-performance graphic computers (Silicon Graphics).

A second application is the transformation of an existing *Freehand* (2.02) town plan of the Omani capital Muscat/Masqat (SE Arabia) into an urban electronic mapping system. Integrated into the system are additional thematic and topographic maps, a street and object index, historic town views, images, video and sound. Special attention is paid to provide the user with easy-to-understand ways to interact with all the information presented. The user is able to place all information selected interactively in a number of windows on the screen map. If required, he can print his individual town plan on an inkjet plotter integrated into the system. The ongoing project is developed on an *Apple Macintosh* microcomputer/*MacroMedia Director* authoring software system.

In a feasibility study for the Brandenburg environmental agency (LUA), a third application evaluated the effective use of existing GIS data for electronic mapping purposes<sup>(13)</sup>. On an *Apple Macintosh* hardware/*cart/o/info* software platform a prototype of an electronic map-based information system has been developed for environmental planning. Active map elements facilitate access to latent information in the electronic map data base (e.g. topographic and thematic maps, graphics, images and existing GIS data). Different layers of spatial information can be accessed at a time and mixed interactively (e.g. topographic base, areal photos, satellite imagery). The prototype supports free selection of three available map scales (1: 150,000, 1: 50,000, 1: 10,000 scale) for exploration and analysis. All selected data can be placed in a number of windows on the screen map and hardcopied if required. The system provides the regional planner with an easy-to-use framework, allowing him to evaluate environmental data in a variety of ways and to produce high-quality environmental planning maps tailored to project-specific requirements. Based on the prototype, a network oriented electronic mapping systems of a county in the German free state of Saxony (Mittweida) is currently under development geared to

centralized spatial data base management but decentralized geographic information use via ISDN telecommunications network.

Parallel to the Brandenburg prototype a fourth case study investigated the integration of GIS and multimedia data into an electronic atlas of environmental change <sup>(18)</sup>. The application visualizes environmental change in the Swiss canton of Lucerne by communities from 1900-1990, allowing the user to select different states of change. Selected active map elements linked with latent information can be activated to display additional graphics and images, a hot link to spreadsheet software (Excel) facilitates individual access to the complete data sets for further evaluation. The project has also been developed on an Apple Macintosh hardware/cart/o/info software system. A similar commercial application has recently been presented on an IBM PC hardware/ SPANS multimedia software system.

A fifth and final case study is evaluating the application potential of the Apple Macintosh based SuperCard software system as a platform for an electronic introduction to map reading. The electronic map introduction is developed from an existing conventional introduction for a Berlin school atlas. The application starts with a brief video sequence that introduces the topics covered by the system. Easy-to-use navigation buttons and icons allow the user to pause at any point and to select specific information which he can then work on interactively. This multimedia application is aimed to communicate the principles of cartographic data processing and symbolization to young map users in a multidimensional, yet easy-to understand way.

#### 4.2 ASPECTS OF SPATIAL DATA USE

By integrating the abilities of the computer, electronic mapping provides the user with effective tools to interact with the multidimensional information presented in electronic maps. In contrast to desktop mapping which is aimed at the production of digital maps intended for hardcopy output and conventional data use, on-screen interaction and interactive data exploration are the key concepts of electronic mapping. Spatial data use in electronic maps is based on the concept of links between the data visualized on the map and additional spatial information which otherwise could not have been integrated into the map by conventional methods because of modelling problems. To access the information stored in an electronic map, electronic mapping systems provide navigational tools of which navigation buttons and active map elements, and to some extent still, the menu bar are the most important. While buttons allow the user to navigate through the database, active map elements facilitate access to latent spatial information hidden in the screen map until activated and displayed in one or several windows on screen. Electronic mapping systems allow the user to summarize his single- or multi-dimensional evaluation of the data including annotations in user-defined map form. If required, all electronic mapping data displayed on screen can be printed on a variety of hardcopy units.

This concept of interactive spatial data use stimulates the map user's motivation to explore the evaluation potential of electronic mapping system allowing him to acquire more and more specific information. Electronic mapping systems enables the map user to become actively involved not only in spatial data evaluation but also in the visualization of geographic information as they encourage him to experiment with "measurements, categories, symbolization schemes, scales, scopes, generalizations, azimuths, elevations, times or time periods, and juxtapositions" <sup>(9)</sup>.

Electronic mapping systems provide a flexible and effective environment for the creation and evaluation of multi-dimensional, fine-tuned maps geared to serve specific data evaluation requirements. By providing cartographer and map user alike with fresh and intuitive options for the visualization, manipulation and use of geographic data, electronic mapping is shifting emphasis from maps for spatial data presentation to maps for interactive spatial data exploration.

## 5.0 CONCLUSION

Although it is commonplace to the cartographer that there are many possible maps of the same set of spatial data, cartographic modelling, whether digital or conventional, has been concentrating on the single optimal map graphic. As a consequence, the map user had to be content with whatever map was available to him. Modern and cost-effective information technologies now present a whole world of new opportunities for computer-assisted mapping and map use. Closely associated with interactive computer technology, visualization is widening the focus by presenting new challenges to cartographic modelling, necessitating a reconsideration of the process of cartographic data processing. Contributing to a greater variety of map products, visualization is removing the cartographer's century-old restriction to single map solutions by promoting multiple-perspective treatment of spatial data. As a result, the conventional two-dimensional map graphic has ceased to be the only or ultimate product of cartographic modelling. Adding novel forms of spatial data presentation to the map graphic, electronic mapping is playing a major role in this ongoing development. By fully exploiting the potential of visualization, electronic mapping provides powerful, interactive, and multi-dimensional graphic means of explaining, exploring, and communicating geographic information in a changing field of spatial data handling.

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# Grading of the map functions in navigation system

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## Abstract

One of the main purposes of map functions is to facilitate navigation. For navigation, the main questions to be answered are "Where am I?", "Where is my destination?", and "How do I get there?". But before trying to answer these questions, one must first answer, "Where should I go?", and after, "Where was I?". The map is an effective instrument to answer these questions. But effectiveness varies with the quality of the map and the means by which necessary information is obtained. In navigation systems, maps are utilized in a dynamic process and some of the information processing steps which are normally carried out by the human brain are replaced by an information processing machine. Sometimes, information is given by voice instruction.

A framework using the map action schema adapted from the map communication schema in a dynamic process is proposed and map functions in the existing assortment of navigation systems in Japan are examined and classified according to their performance.

## 1. INTRODUCTION

### 1.1. Navigation

Studies about car navigation systems from the cartographic point of view, including those written from the GIS approach, are still modest, [French, Robert L. 1987],[Lichtner, Werner 1987], [Mark, David M. 1987], [Mark, David M. 1989],[Petchenik, B. 1989],[Gould, Michael D. 1989],[Hsu, Po-Siu 1990], [Lee, Jay 1990],[White, M. 1991], since the systems are still mostly in the experimental stage. They focus on improving the ability of the systems (as one of the Vehicle Driving Information Systems) rather than on the cartographic objects themselves and have produced little concrete data on map use. Nevertheless, one of the main purposes of map functions is to facilitate navigation. The term, "navigation", includes not only car navigation but also any type of human navigation. For navigation, the main questions are, "Where am I?", "Where is my destination?", and "How do I get there?". But before trying to answer these questions, one must first answer, "Where should I go?", and after, "Where was I?". The map is an effective instrument to answer these questions. But effectiveness varies with the quality of the map and the means by which necessary information is obtained. In navigation systems, maps are utilized in a dynamic process and some of the information processing steps which are normally carried out by the human brain are replaced by an information processing machine. In the most extreme case, the system transforms the map information into an instruction needed for the next action, in the form of a visual or an oral representation. In such circumstances, the map is not a static instrument. Step by step, the user extracts neces-

sary information and/or receives necessary instructions.

### 1.2. Map Communication

The map communication schema [Ratajski, L. 1978] is useful to understand the interaction between the user and the map, because it describes the relationship between the four major elements of map communication, geographic reality, information, map and user. But in navigation systems, there exist two additional major elements. One is the information processing machine and the other is the dynamic interactive process environment. What will be the new map communication schema when these two elements are included?

### 1.3. Japanese Experience

In recent years, several types of digital map systems for navigation have been developed and launched into the market in Japan, from the simple background map for location plotting to the multimedia display, including hyper mapping. How efficient are they, from the point of view of human interface design for navigation purposes? Different map functions in the several existing systems in Japan are examined and classified, in order of the capacities of each system.

## 2. MAP ACTION SCHEMA FOR NAVIGATION

### 2.1. Mapping Theory

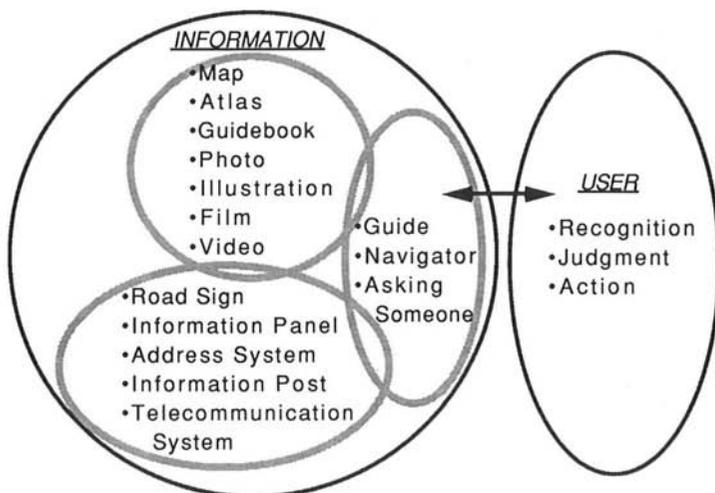
The need for navigation systems is not so clear because people can walk or drive a car without a navigation system! But for cartography, they bring us a new situation of map use, because they are utilized under interactive and dynamic conditions, including subject change, scale change, map rotation, path-finding, notation of additional information, and give instructions for the next action in real-time. This is realized because the map is digitized and some of the tasks normally executed by the user are replaced by the system. The new situation of map use demands not only the traditional internal development of cartography, but also the development of basic theory in close relation to ergonomics, psychology, cognitive science, linguistics, semiotics, and even ethnology. This will help to stimulate the building of more comprehensive mapping theory.

### 2.2. Elements of Navigation

#### 2.2.1. Man and Spatial Information

The main components of navigation are the user, the information and the information processing machine. Among the traditional methods of way-finding, asking someone his or her way is the most popular one, followed by the utilization of on-site information, such as road signs, street name plates and/or the use of published materials (e.g., maps, atlases, guidebooks,...). If news about traffic congestion or weather is needed, radios, televisions, portable telephones and on-site transmission systems (e.g., beacon system) are useful. The user receives this information and determines his next action (Figure 1).

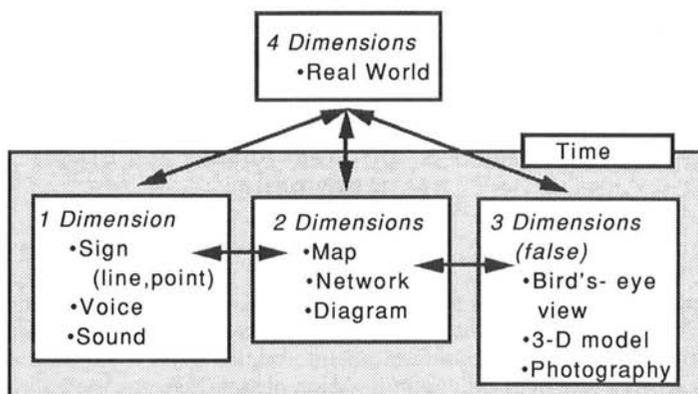
The relationship between the user and published materials is relatively independent of the surroundings compared to that which exists between the user and on-site information because the latter one is dependent upon the social environment or the information infra-structure of the society.



**Figure 1. User and Spatial Information**

### 2.2.2. Transformation Between Different Dimensions

In a dynamic process, spatial information has to be transformed into linear form [Morita, Takashi 1978]. A typical example of such a situation is as mentioned above when someone asks another person to show them the way to his or her destination using a map. Directions may be given, not only verbally, but also by indicating the route on the map with one's finger, and finally by showing the proper direction with one's hand. There, the information is provided visually and/or orally in a dynamic process. Information is converted between different dimensions in relation to time development (Figure 2). With two or three dimensional



**Figure 2. Transformation Between Different Dimensions**

information, people can recognize their location and its environment, but if people want to know "how do I get there?" and "what should I do next?", such information is not directly available. People have to interpret given information into instructions leading to the next action on their own. It is more direct to receive linear one dimensional information (e.g., sign, voice, sound). The superimposition of one dimensional information onto the background of two or three dimensional information is also efficient.

### 2.2.3. Different Phases and Stages of the Navigation

The map is a form of representation of spatially-referenced information, any and all forms of which people need if they are useful for navigation. What kind of information is necessary and when? The principal questions asked by the user regarding navigation can be classified into two phases and three stages (Figure 3). At the very beginning of the trip, we pose the questions "Where should I go?", "How do I get there?", and "Where am I?". This is the *Planning* phase and *Pre-Trip* stage. In the *Action* phase and *On-Trip* stage, the questions are, "Where am I?", and "What to do next and when?". During the *After-Trip* stage, we think about, "Where was I?", "What was my course?", and "What did I do at that time?". The last question, answered by making a notation, if necessary, is asked for the purpose of facilitating one's next journey.

Stages \ Phases	<i>Pre-Trip</i>	<i>On-Trip</i>	<i>After-Trip</i>
<i>Planning</i>	<ul style="list-style-type: none"> <li>•Where to go?</li> <li>•How to go?</li> <li>•Where am I?</li> </ul>	<ul style="list-style-type: none"> <li>•Where to go next?</li> </ul>	-
<i>Action</i>	-	<ul style="list-style-type: none"> <li>•Where am I?</li> <li>•What to do next?</li> </ul>	<ul style="list-style-type: none"> <li>•Where was I?</li> <li>•What was my course?</li> <li>•What did I do?</li> </ul>

**Figure 3. Different Phases and Stages in Navigation**

### 2.2.4. Map Action Schema

Maps play a primordial role in dealing with these questions, but how do they function? For this problem, the communication theory is useful since the map is treated there as a vehicle to communicate information to user. The map communication schema describes the communication process between the addresser and recipient using maps in different phases. But this schema lacks the notion of real-time interactive action between the spatial information and the user.

The principal actions are: 1.) The problem to solve has to be discriminated among

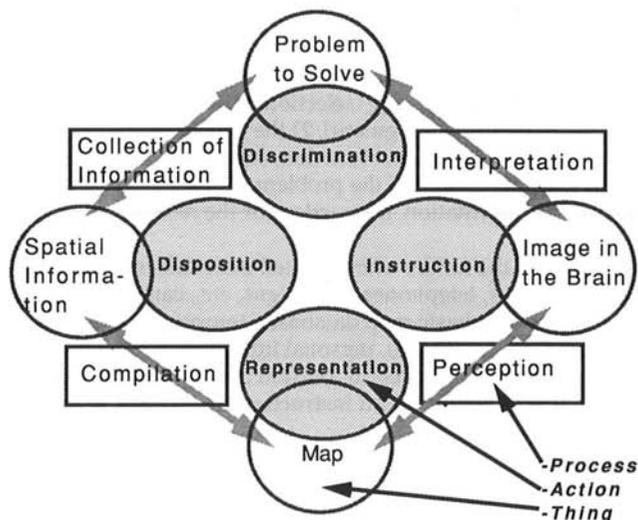


Figure 4. Map Action

other problems, 2.) The spatial information has to be organized as it is immediately in disposition and available for the next step of usage, 3.) The map has to be represented. Otherwise, it is not perceived, and finally 4.) The brain conceives of the instruction to lead to the next action. The schema adopted is shown in Figure 4.

#### 2.2.5. Customized Function

One of the advantages of navigation systems is that they help the user determine his or her next action. A simple electronic atlas can not provide such information because there is no human interface for navigation. Under general and primitive conditions, the human brain processes all available information to make a decision. But if some of the human brain's functions are replaced by a machine, as in the case of optimal route selection, for example, navigation becomes more free. Furthermore, if one's sense of selection can be input and customized, the navigation will become ever more comfortable (Figure 5).

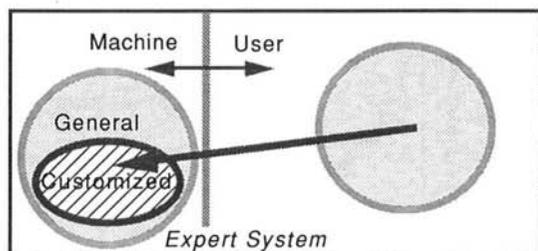


Figure 5. Customized Function

2.2.6. Classification Framework

Figure 6 is a framework to classify the different functions which are aligned by 1) the different phases of the journey (selection of the destination, route planning, location on the field, real-time judgment), 2) the degree of commitment to the interactive system (no system, general function, customized function), and by 3) the different actions (discrimination of the problem, disposition of the information, representation of the information, instruction for the next action).

With this framework, the nature of traditional materials, such as atlases, guidebook, radio and TV news, telephones, road signs, etc., can be discussed as well as the new functions, such as basic map databases, temporal information (e.g., traffic congestion, weather conditions), personal information (e.g., memo), route simulation and recommendations, present location determination, general instructions for the next action, personalized instructions (e.g., route selection) and automated navigation.

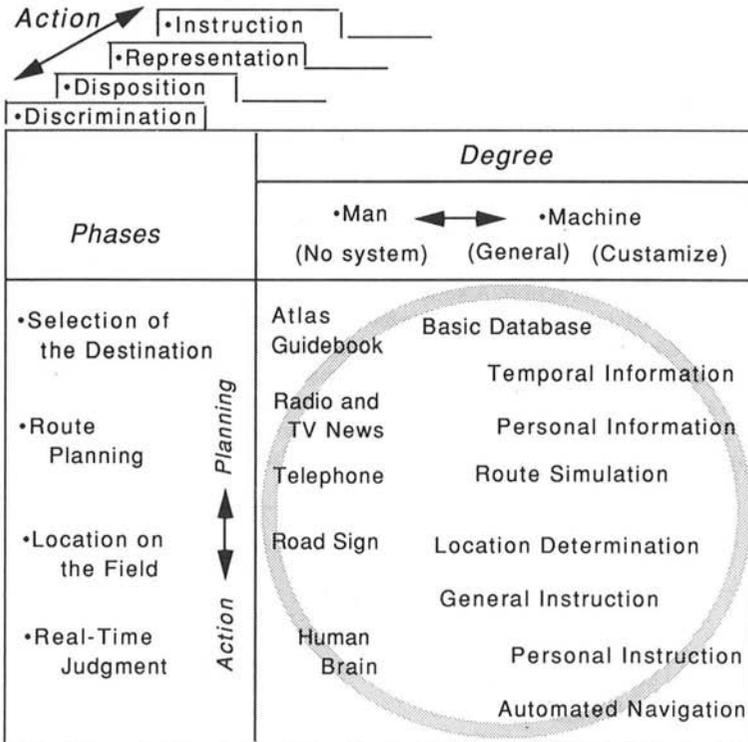


Figure 6. Classification Framework

### 3. OBSERVATION AND CLASSIFICATION

#### 3.1. Actual Situation in Japan

By 1992, more than two hundred thousands units of car navigation systems had been released in the Japanese market. Over the last decade, the principal development has been done by automobile companies, but from the beginning of the '90s, consumer electronics companies also used GPS, mainly as a location sensor, in products targeted mainly at after-market systems. Those systems<sup>1</sup> are autonomous and independent of the physical infrastructure. Nevertheless some initiatives have appeared since 1986, including RACS: Road Automobile Communication System by the Ministry of Construction (1986, Beacon Post); AMTICS: Advanced Mobile Traffic Information and Communication System by the Police Agency (1987, Sign Post) and finally, since 1991, VICS: Vehicle Information and Communication System (RACS and AMTICS are reorganized and studies beacon post system and information transmission system by using the Frequency Modulation) by the Ministry of Construction, the Police Agency, and the Ministry of Post and Telecommunication. On the other hand, road network data was built by DRMA: the Japan Digital Road Map Association founded by the Ministry of Construction in 1988, and movements to standardize data exchange began 1990, CD-CRAFT: CD and CRT applied format by the four companies<sup>2</sup>; and Naviken: CD format for navigation by the Navigation System Researchers' Association in Japan<sup>3</sup>.

#### 3.2. Action and Different Functions of System

What is the performance level of these existing navigation systems? To have a general view, the basic function related map use of these systems are classified as an inventory of principal functions following the above-mentioned "map action schema".

##### 3.2.1. Discrimination

This function allows the user to discriminate between applicable and inapplicable information in the database and in the infra-structure. Related functions are: •menu display (base menu, pull down menu, selectable pictography) •retrieval (subject list, name list) •outside information receiving (traffic condition, weather news).

##### 3.2.2. Disposition

This function mainly concerns setting up a useful data set by connecting location information (thematic information) with background information. Related functions are: •setting appropriate map •scale change (up/down) •map matching •adjusting actual location •satellite (GPS) position condition •getting de-

1. 1981:•Honda Electro-Gyrocator •Nissan Drive Guide, 1987:•Toyota Electro-Multivision, 1989:•Nissan Multi-AV Navigation System, 1990:•Honda Navigation System •Matsuda Car Communication System •Mitsubishi Multi-Communication System •Pioneer Satellite Cruising System •Toyota G-map, 1992:•Clarion Map Narration System •Kenwood GPS Navigation System •Maspro GPS Car Navigator •Sony Digital Map Navi System •Toshiba Portable Navigation System, 1993:•Pioneer Marine GPS Viewer

2. Toyota, Nissan, Sumitomo, and Nippondenso

3. about 40 member companies

tailed spot information •getting traffic information •optimal route guidance (automatic, customized) •point registration (home, destination, crossing points)  
•marking (point of interest).

### 3.2.3. Representation

With this function, information in disposition can be represented not only visually but also verbally. Related functions are: showing-•distance •overall direction •center of map •scale information •atlas number,page,x-y, and •symbol selection of present location (arrow, radius) •map rotation •page change •map scroll •delete detailed map when driving •transitory course (line) •reach from the nearest intersection •special detailed map for intersections •recommended route guidance •day/night display switching.

### 3.2.4. Instruction

Currently there are few instruction functions on the market. Those available are:  
•showing direction to take •showing through point •blinking sign •alarm sound  
•guide narration.

## 3.3. Grading of the Map Functions

Using the above-mentioned basic function inventory and the classification framework, different stages of map functions may be graded as follows. Before proceeding, it is worth noting that although these functions are treated separately here, in reality, they are often combined together in navigation products on the market.

### 3.3.1. Traditional Road Atlas

This is a stage which precedes navigation systems. Everything has to be done by human intelligence. It begins from the discrimination of "What kind of road atlas and other related materials are necessary?".

### 3.3.2. Paper Map with Location Detector

This is a combination of an independent location receptor and a paper map. The location detector (mostly GPS) provides the position on the field. The user determines the position using a paper map. At this point, there is no appropriate human interface which connects the location and the map.

### 3.3.3. Paper Map with Location Indicator

In this stage, the map gains intelligence. The location detector determines a position on the field, then the system searches for the corresponding page of the paper atlas and the user sets the appropriate page on the system. The system displays the position by indicating the x and y coordinates on the grid scale frame. By this stage, the location point is connected to a corresponding point on the map.

### 3.3.4. Bit-Map Background Map

The location detector determines a position on the field and the system displays the corresponding page of the bit-map background map. The present position is indicated by a symbol on the map, and the symbol follows the movement of the position. If the symbol leaves the screen, the next page will appear in the proper

position. In better systems, the present position is located in the center of the screen and the map scrolls. In this stage, present location is indicated automatically on the digital map.

### 3.3.5. Vector Road Network Map

The location detector determines a position on the field and indicates this position on the center of the screen. The user chooses the appropriate map scale, then the system displays the corresponding map, which scrolls following the given position. The location corresponds to the road by using the map matching function. If a least distance simulation function is included, the best route is recommended. By this stage, the map function is more than simple background information.

### 3.3.6. Vector Map Superimposed on a Bit-Map Background Map

This map system has the same functions as the Vector Road Network Map. However, the user's perception of the map is more enhanced because in the background there is a map replete with real images, which are represented by either false 3-D shading or photo imagery. This superimposed map is not only intelligent, but is also more realistic and attractive to the user than a simple Vector map.

### 3.3.7. Hyper Mapping

With this function, information is processed like it is when a Macintosh Hyper Card is used. Different information is connected by using a button on the screen. The button's function may be activated by a touch sensor or cursor. Then, a map or related information (e.g., photo, illustration, text) will pop up and one can continue to pull down increasingly detailed maps to find what one is looking for as long as buttons still exist on the screen.

### 3.3.8. Multimedia Mapping

With multimedia mapping functions, one dimensional information is given in relation to the 2-D or 3-D map. These functions are indispensable when a real-time instruction is needed. Such functions include narration, warning sounds, blinking and arrow signs, which are interpreted as map information and serve to build human interface. Information, such as, "The next intersection is approaching" and "Turn to right" are provided.

### 3.3.9. Customized Mapping

Generally, people make a plan before starting something. They collect information, decide their destination and then select each step along the way. If each step can be input into the system beforehand and if instructions can be given, based on this information, then route guidance can be customized. If the system can receive current information, such as traffic and weather conditions, the instruction can become more efficient. With customized mapping, personal route guidance is included as a map system.

## 4. CONCLUSION

The Map-Action Schema was proposed and different map functions for navi-

gation were graded in order of the degree to which their functions instruct the user. The multimedia with customized mapping function has the highest level of performance, as it provides the user with appropriate direct instructions for their next action in the form of one dimensional information.

This instruction function will be the next issue to study and the experimental approach will be indispensable.

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## **Poster Session**

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**Maps for Knowledge, Action and Development**



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# Concepts, definitions and theory in the modern cartography

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## Introduction

This article deals with the development of **cartographic concepts**, their **definitions** and the **need for a new theoretical basis** in research and development in cartography of today. The modern cartography is based on highly automated techniques: computers and their peripherals, advanced software packages, remote sensing as well as automatic interpretation and visualization of satellite images, electronic publishing utilizing all modern tools of graphic designers and graphic techniques - and last but not least - the digital data and knowledge bases and their management systems as well as the information systems utilizing all mentioned techniques. We have to accept the fact that the modern cartography in the modern GIS-world requires **a completely new basis both for the practical production and for the theory and concept definition.**

Such concepts like map, digital map, digital landscape model, cartographic presentation, visualization, cartographic information system, geographic information system, cartographic data base, geographic data base, are often used but many times incorrectly. Many attempts to define e.g. concepts like "map" or "cartography" or the role of the modern cartographer have failed because of the lack of correct knowledge about terminology, concepts and theory of the fields of science like computer science, information processing, image processing or mathematics and logic. There is a great need for modernizing the cartographic education as well as improving the theoretical discussion and interaction between researchers in different fields. In modern cartography we need: cartographers as data collectors and managers as well as cartographic designers and perhaps sometimes draftsmen, geographers and planners of various sectors as information users and analyzers, adp-experts as data base and knowledge engineers as well as equipment and e.g. data transportation specialists,

mathematicians and statisticians as developers of methods. Traditional basis has to be broadened by the knowledge of information systems in general.

Modern cartography comes very close to GIS - but cartography is not only GIS and GIS is not only cartography. Starting from the **definition of information system** the definition of the **cartographic information system** as well as the **geographic information system** can be derived. In this article these concepts are discussed and an **information system oriented approach to the modern cartography** is introduced.

#### Geographical information system - GIS

Geographical information system is a concept which is very often poorly understood and used. It should be dealt in two pieces: "information system" and "geographical information". An information system can be defined as in /5/: "A computer-based system with the defining characteristic that it provides information to users in one or more organizations." In a more wider meaning it can be broadened "to include all computer-based systems, or further broadened to include many non-computer-based systems".

To land information applications the term information system has also been adopted as e.g. in /3/: "An information system may be formally defined as a combination of human and technical resources, together with a set of organizing procedures, that produces information in support of some managerial requirement."

"Information" and "data" are terms which have also to be defined. Data are only coded representation having no meaning, it becomes information when a person has access to it /4/.

In geoinformatics we can use the terms "geodata" and "geoinformation" or "geographical information" analogically. The prefix geo- adds to the term information an extra meaning of being defined by coordinates or by some other reference to the site.

In /8/ geographical data is described as follows:

"Geographical data describes objects from the real world in terms of:

- the object's position with respect to a known coordinate system,
- the object's physical attributes associated with the geographic position,
- the spatial relationship of the object with surrounding geographic features (topology)."

The same author gives the definition of geographic information system as follows:

"A geographic information system is an information system that is designed to work with data referenced by spatial or geographic coordinates."

Aronoff /1/ gives also quite a broad definition of geographic information system. He says that "Geographic information systems are computer-based systems that are used to store and manipulate geographical information." There are no limitations about the functions or application area of a GIS.

Thus we can call GIS's **all information systems which in a way or another process geographical information**. This is the definition which has been generally accepted in Finland.

Examples of geographical information systems are: a GIS for land use planning, a GIS for road design, environmental monitoring system, electronic chart and navigation systems, tourist guide system and last but not least a cartographic design and map production system.

#### Cartographic information system - CIS

Cartographic information system is an information system the goal of which is to produce maps, either printed, plotted or maps viewed on the screen. A cartographic information system can be an individual information system or then it can be a subsystem of a GIS for some other application. A GIS includes typically several subparts like data management and analysis as well as the basic cartographic input and output functions. A complete cartographic information system provides possibilities for map data input and output. It can give possibilities for map design and data analysis. Depending on the application the form and the selection of functions of the cartographic information system varies very much. In some cases the most important cartographic part of the system is the screen map interface.

A map design and production system is a complete cartographic information system and as such a specialized type of a GIS. E.g. in a mass media map -application the system produces only maps on screen having only some few functions of a cartographic information system.

Clarke /2/ says that "almost every geography program in the country offers at least some form of computer cartography". We can broaden and generalize this a little and say that **all geographic information systems include some kind of a cartographic subsystem**. From that point of view cartography gets a great challenge in the world of increasing amount of geographical information systems.

#### Digital map

There has been attempts to define "a digital map" based on the traditional definitions of a map. It seems to be most frustrating. It would be better to make the definition based on the new object itself.

Cartographic information system produces maps. Those maps are produced by using digital map data. The digital map data is stored in files or in the map data base. From the digital map data various different map outputs can be produced. Outputs can be printed or plotted "hardmaps" on paper or then "softmaps" /6/ viewed on the screen. However, neither the graphical output nor the digital data in the data base are "digital maps" as such. Digital data requires always some way of either visualization or other perceptualization and, on the other hand, an output requires always the background digital data in order to be a "digital map".

In defining the term "digital map" we have to include in the definition both the digital map data and the visualization. In addition to visualized data we sometimes need maps which are presented in some other than visually perceivable form, e.g. tactual maps are sometimes required. We can give an informal definition as follows: "**A digital map is the digital map data together with the perceptualization of that data.**"

A digital map is traditionally 2-dimensional or 2+1 -dimensioned. The third dimension can be either height of the object or then e.g. time. If time is one dimension then the map can be dynamic moving according to the time.

We can ask then where is the limit between the map and a landscape picture or a 3-d CAD-model. At least we can say that a map should be **measurable**, so a map needs coordinates, a projection and a defined precision. A map **data content must be described**, so it needs a legend and defined symbology. A 3-d map on the screen is very similar to globe. If globe is concerned as a map, as it is in the ICA definition of cartography: "The art, science and technology of making maps, together with their study as scientific documents and works of art. In this context maps may be regarded as including all types of maps, plans, charts and sections, three-dimensional models and globes representing the earth or any celestial body at any scale."/7/, also a digital 3-D -model should be accepted as one of the cartographic presentations. But - where is the limit between a dynamic model and a virtual reality?

Traditional hardmaps on paper are of course also required. The role of them, however, changes. Hardmaps are no more data stores but they are made for visualization. New map types will be created and a new need for cartographic map design and visualization theory is growing.

### Cartographers role

Cartographer is no more only a map designer or a data collector. He or she must be familiar with information systems, hardware, software, applications, data input and output. The cartographer is the one who must be able to design a new cartographic information system, as well as to develop the utilization of the system. One of the most important task of the modern cartographer is to design new digital map products and their computer assisted production processes. This is a point which mostly reflects the traditional role of the cartographer.

Clarke /2/ considers the new fields of cartography as disadvantages. He says that "the cartographer of the nineteen nineties **must** be a data base expert, a user-interface designer, a software-engineer, retain a sense of map esthetics, and still produce maps". I see this not as a disadvantage but a very good advantage for cartography. Without these new tasks and challenges the profession of cartographers would have already died.

Among cartographers there will be different groups of specialists: cartographic information system users, cartographic information system developers and cartographic information system engineers.

"**CIS-user**" is a person whose role is the most similar to the traditional role of a cartographer. CIS-users are cartographers who are able to utilize cartographic information systems, they know data input and output procedures and are able to design e.g. a new digitizing procedure for a new map type. A user is able e.g. to select the right output media for the purpose in question. He knows map editing and he has an overall idea about the software structure of a cartographic information system. A user is able to learn himself a new cartographic software.

"**CIS-developer**" is a user and application oriented person who is able to act as a project leader in an information system establishment project. He is not a programmer nor a data base expert but he must be able to manage the information system project from the beginning to the end. He must have a good general view on the system market, he must manage the cost/benefit point of view and he must be able to communicate with both the becoming users and the adp-experts. Systems design is one of the most important topics in the education. System developer must have enough information about e.g. raster and vector -solutions, terrain models, spatial data structures and algorithms as well as hardware architecture.

"**CIS-software engineer**" is a person who works as a software consultant. A software consultant either develops software products for clients or builds applications by using some ready made modules and combining them by own programming. A CIS-consultants speciality is software engineering together with cartography. Compared to systems design software engineering also includes the implementation of the system, the programming work. As in all of these three roles of a cartographer, also in CIS-software engineers role the profound familiarity with cartography and mapping is most important.

Most cartographers will be "CIS-users", some of them will specialize themselves to "CIS-developers" and only few cartographers will become "CIS-engineers".

#### Information systems oriented approach to modern cartography

When we discuss the new concept of digital map and its various forms we see the fact that digital maps as well as cartographic information systems depend strongly on the application field in which they are utilized. Maps on the screen differ much from printed maps and the cartographic visualization techniques in a navigation system is

greatly different to the one used in land use planning. We see that it is not possible e.g. to define a general guide about the symbology or colours of "a softmap" on the screen. On the other hand it is impossible to define the best possible software package for a CIS - it depends completely on which functions are desired and how much one is willing to invest.

Digital map design is no more only designing of one graphical product but it is more designing of the entire system, the production process, data collection, map output, software, hardware, conversions and, of course, the final graphical outputs on the screen and on the paper. Cartographic production design seems to get many features of information system design.

The modern cartographer must include many new topics in his studies. New fields which have to be included in the curriculum of cartography are:

-for CIS-users

- general computer science and information processing
- computer aided cartography
- hardware and software architecture
- data base management and spatial data structures in general
- digital terrain and elevation models
- introduction to programming
- introduction to information systems
- project management

-for CIS-developers

- spatial data structures and algorithms
- computer architecture in detail, peripherals
- design and implementation of a CIS/GIS
- digital image processing

-for CIS-software engineers

- data base management systems
- computer graphics
- software engineering.

It is very much recommended that CIS-engineering students also take courses in:

- human computer interaction
- knowledge engineering
- computer networks
- object-oriented approach to programming and systems design.

## GIS - a new challenge to cartography

As already mentioned in the previous chapters all geographic information systems utilize in some way maps and they can be said to include some type of a cartographic information subsystem.

On the other hand the applications of geographic information systems are continuously increasing. If geographic information systems were previously a field of geographers and surveyors, they are now a tool for almost everyone, both in professional and personal life.

These facts show a very inspiring future for cartography and cartographers. The only demand is that cartographers are able to take the challenge. This means that the education of cartographers must ensure strong enough abilities for both information systems design and cartographic theory. Cartography has always been a mixture of technical and aesthetic skills, in today's cartography this polarization must also be accepted.

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## Topological selections in broad sense

W. Hehai (Wuhan, RC)

### ABSTRACT

Spatial analyses can be considered as co - processing of related geo-features using the topological relationships among them. From the point of view of geometry the topological selections can be categorized as follows:

1. Topological selections based on the point features;
2. Topological selections based on the line features;
3. Topological selections based on the area features.

The basic peculiarity of topological selections lies in where the object attributes does not serve as the selection criteria, instead the relationships between at least two object categories have to be used. Topological selections provide "new" information derived from the original geo-data. Therefore, the topological selections belong to the intelligent information retrieval.

Topological selections can be carried out by two main subprocedures:

1. Forming the first (base) object set;
2. Searching the second (related) object set which should have topological adjacent/incident/inclusive relations with the first (base) one.

Topological selections in broad sense lie in that for determining the base point/line/area feature elements there are very diverse approaches can be chosen: ① by selections of the given feature classes; ② by identification of the individual objects; ③ by entering the known object keys; ④ by digitizing an arbitrary point/line/area (point in polygon). For area based topological selections the base areas can in turn be determined by following methods again: A. naming polygon numbers; B. identification of polygons by cursor; C. Defining a line (traveling through a series of polygons which can be reformed) by selections, by entering the known keys, by random digitization, by mathematical calculation (e.g. circle, ellipse, star line etc.), and so on.

## KEYWORDS:

Spatial analyses; Topological selections; Complex object; GIS.

## 1. INTRODUCTION

Spatial analyses are critical important for GIS. Thereby GISs differ from the computer assisted cartography. Spatial analyses are based on the topological selections and can be considered essentially as co-processing of some kinds of related geo-features according to the topological relationships among them. From the point of view of geometry topological selections can be categorized as follows:

- (1) Topological selections based on the point features;
- (2) Topological selections based on the line features;
- (3) Topological selections based on the area features.

From the point of view of inclusive relationship, there are two other kinds of selections which appear as the particular forms of topological selections, namely:

- (4) Horizontal inclusive selection - selections by irregular polygons. They can be realized either by selecting some geo-features within a given administrative unit or by a selection within a randomly digitized polygon.
- (5) Vertical inclusive selection - selections of complex objects by subordination relationships in hierarchy.

The basic peculiarity of topological selections lies in where the object attributes does not serve as the selection criteria, instead, the relationships between at least two object categories have to be used. Topological selections provide "new" information derived from the original geo-data. therefore, the topological selections would have the intelligent behaviours.

## 2. IMPLEMENTATION PROCEDURES

Topological selections can be carried out by two main subprocedures:  
Forming the first (base) object set;

Searching the second (related) object set which should have topological adjacent/incident/inclusive relations with the first (base) one.

### (1) FORMING THE FIRST (BASE) OBJECT SET

Topological selections in broad sense lie in that for determining the base point/line/area feature elements very diverse approaches can be chosen:

- A. By selections of the given feature classes;
- B. By identification of the individual objects;
- C. By entering the known object keys;
- D. By digitizing an arbitrary point/line/area (e. g. appointing a point in a polygon).

For area based topological selections the base (kernel) area can in turn be determined by following methods:

A. Forming the base (kernel) area through aggregating the neighbour area needed:

- a. Using the known polygon numbers;
- b. Identifying the polygon numbers by cursor.

B. Forming the base (kernel) areas along the selected line features (railways, rivers, administrative boundaries, etc.) which can be anew formed by selections, by entering the known object keys, by randomly digitized lines, by calculating some mathematical lines (e. g. circles, ellipses, star periphery, etc.)

For selecting the geo-features by administrative unit or by randomly digitized polygon all the approaches for determining the base (kernel) object set mentioned above can be also used.

For selecting the geo-features by vertical hierarchy, it is necessary to indicate the feature category codes which specify what geo-features should be selected and the depth level in hierarchy which specifies what feature details must be obtained.

## (2) SEARCHING THE SECOND (RELATED) OBJECT SET

Besides forming the base features for each topological selection for searching the second (related) object set it is also necessary to indicate the feature class codes of those geo - objects which will be topologically adjacent or incident to the base features mentioned above.

The conception "related" can be understood as co-location, neighbourhood, proximity, adjacence etc. Therefore, it is necessary to indicate tolerance representing the degree of interrelationships.

For point set based topological selections the radius of proximity and the feature codes need to be entered. The former represents the related circle-form buffer region around the selected center point object. The later indicate what kinds of geo-features should be selected within the buffer region.

Similarly, for line set based topological selections the width of linear buffer (corridor) and the feature codes need to be entered.

For area set based topological selections only the feature codes are to be entered. They indicate what kinds of geo-features should be selected within all adjacent regions.

### 3. SYSTEM WHGDB

All types of topological selections mentioned above are implemented in the integrated Cartographic Database System "WHGDB" (General Cartographic Database WTUSM, Department Cartography) in which all the peripheral graphic devices (digitizer, display unit and plotter etc.) are coupled with CPU and managed under the self developed software system WHGDB. Therefore, it is practically a cartographic workstation.

The ability of graphical information retrieval is one of the fundamental functions of cartographic database management system. Here the retrieval functions can be divided generally into two main categories: traditional retrievals and topological ones.

Traditional retrieval means that those retrievals taken out by the attributes inherently belonging to the objects themselves, e. g. object class codes, location coordinates, geonames, etc.. Here there are the four sub-categories:

- A. Retrieval by feature class layers;
- B. Windowing;
- C. Retrieval by irregular polygons;
- D. Retrieval by geo-names.

The peculiarity of the traditional retrievals consists in the simple reproducing the original geo-information stored in the database without providing any derived information.

```

.....
*   Header   Window   Keys   Point based   Line based   Area based   *
*                                     Topsel       Topsel       Topsel       *
*     1       2       3       4       5       6       *
*   All   Geo-name   Polygon   Complex object   *****   Return   *
*     7       8       9       10       11       1111   *
.....

```

Fig. 1 Main types of map database retrievals

Topological selections appear as the higher level of cartographical selections. All diverse variants of topological selections are illustrated in Fig. 2

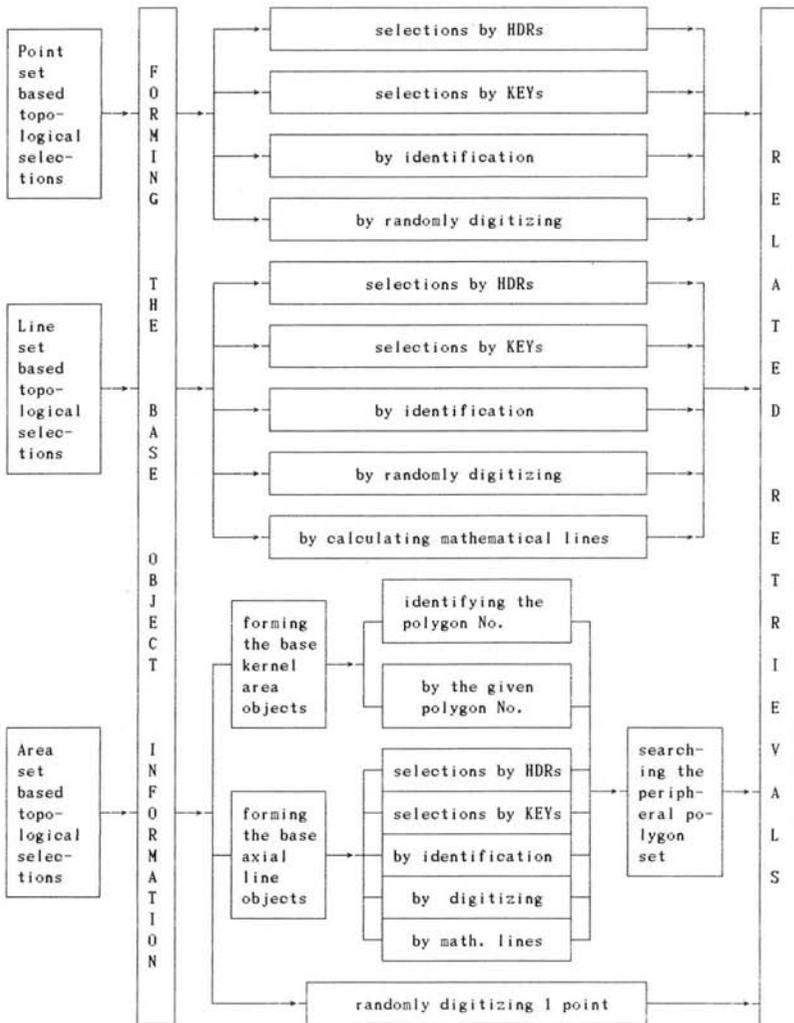


Fig. 2 MODEL OF TOPOLOGICAL RETRIEVALS

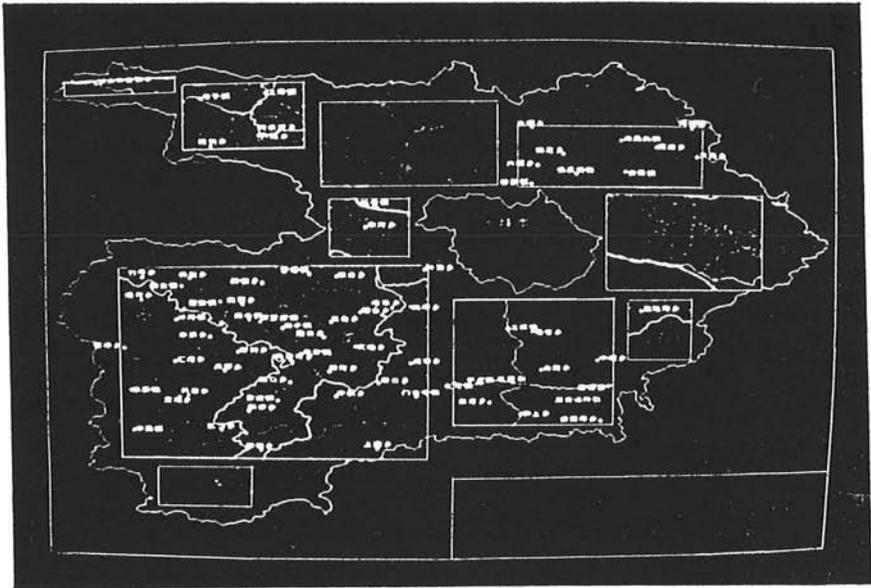


Fig. 3 Boolean combination of selections by window and by HDRs (layers).

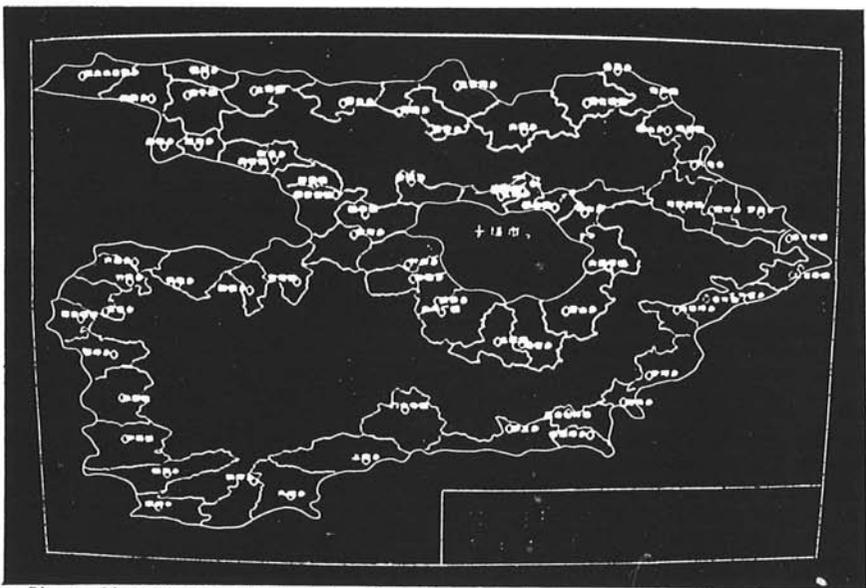


Fig. 4 Line object based topological selection-selecting the administrative units along higher level boundaries, and displaying the geo-features within these units.

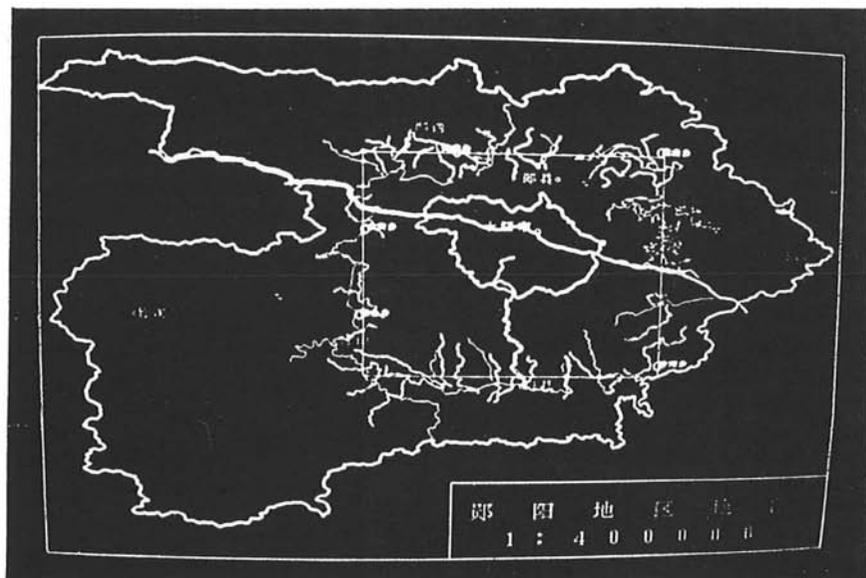


Fig. 5 Line object based topological selection-selecting the topographic features along randomly digitized lines.

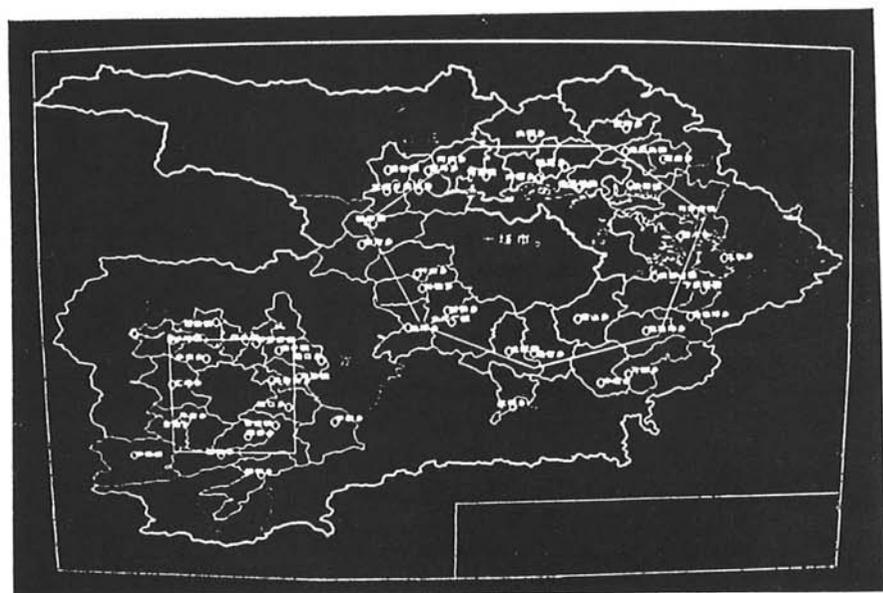


Fig. 6 Line object based topological selection - selecting the administrative units along randomly digitized lines and displaying geo-features within these units.

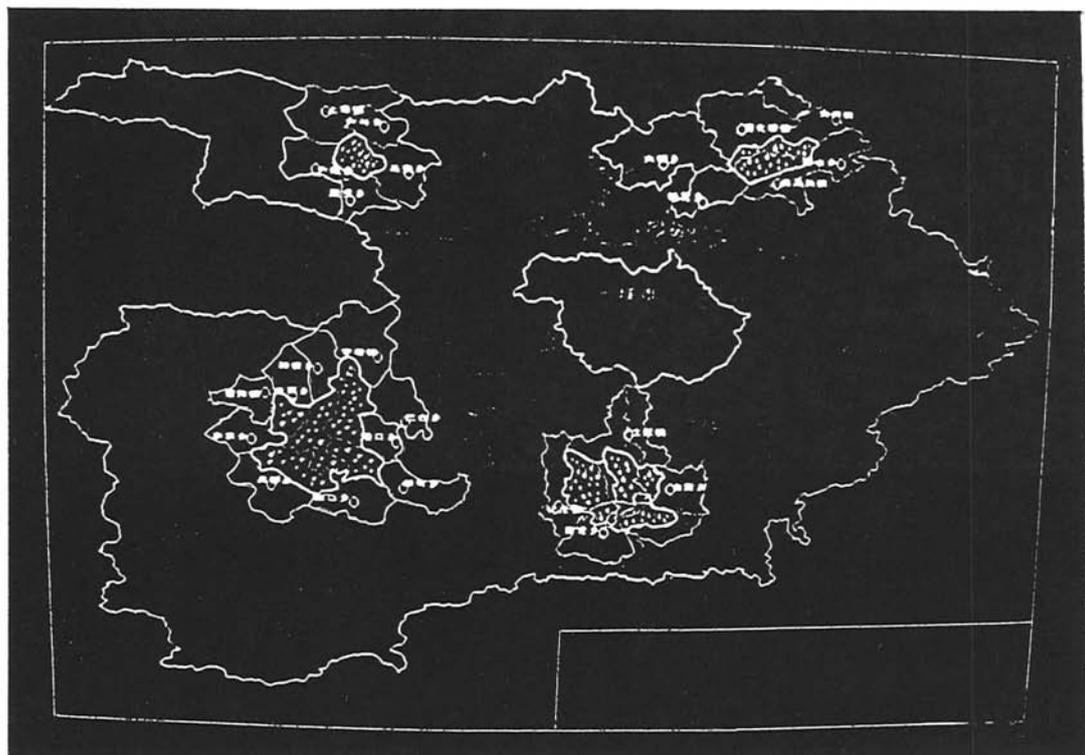


Fig. 7 Area object based topological selection - selecting all adjacent administrative units around the kernel area and displaying the geo-features within these units.

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# Knowledge representation approach to cartographic conceptual model formalisation

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## ABSTRACT

The development of a rigorous scientific discipline for cartography is a lofty ideal aspired to by many cartographers. Having evolved, with characteristics taken from an artistic viewpoint, mathematic cartography and the communication paradigm, theoretical cartography is now at a stage which we might describe as the "New Cartography". Cognition, communication, visualisation and formalism are principal aspects of the new direction of cartography, as has been pointed out by D.R.F. Taylor, but how to formalize the theoretical system is still a formidable (and an arduous) task.

Thirty years research has proved that a formalistic cartographic theorem can not be described by simple formulae as in mathematic cartography - because "...each graphic problem is unique and it's solution cannot be predetermined by rigid formulae" [Burden]. Neither can it be described entirely by a non-operational specification like the communication paradigm because "not all such research proved to be useful to the design of better cartographic products" [Taylor]. Further, the cognitive processes involved in the understanding of digital maps should not be entirely based on those used with paper maps. New concepts and new ideas are needed to construct the new cartography.

Knowledge engineering, a branch of artificial intelligence arising in the 1970s, has shown some new concepts for formalism in problem solving because of it's capability for knowledge representation. We named such a concept as 'Non-rigorous Formalism'. A well built knowledge based system is a non-rigorous formalistic system which is suited to optimally organising domain knowledge to solve special problems, although it is not as exact as mathematic formulae. Such a system can be used as a tool to formalise cartographic theorem and further to develop an expert system to solve practical problems. The new cartography, therefore, must consist of both formalistic specification and operational system support, especially in the digital mapping and GIS era.

In this paper, such a system consideration, called "the knowledge based system approach" is introduced. The main idea being that knowledge representation in the artificial intelligence area be used as a methodology to formalise cartographic concepts and processes. The relevant concepts, definitions, and system structure are presented.

## 1. INTRODUCTION

As an old discipline, cartography is undergoing a period of rapid change caused by the information revolution. Never before in the history of cartographic innovations has the discipline experienced such drastic technological advances in data capture, data manipulation, data visualisation and product generation. The contents of maps are managed and output by map databases and GIS; map styles are changed by electronic maps [Taylor 1990], map making processes are altered by expert systems and automated mapping systems[Muller 1990, Zhang 1990], and map representing forms are expanded by multi media techniques. Today cartographers are no longer limited to produce one type of product. A map consisting of symbols on a sheet of paper is only one of many options that cartographers have at their disposal.

However, the conceptual and theoretical development of cartography as a discipline is not sufficient for producing these new maps, because the cognitive processes involved in the

understanding of maps are still based on those used with paper maps. So old cartographical theorem not only lags behind cartographical technology, but even resists the advance of cartographic discipline itself. "Unfortunately, the advent of new technologies such as computer aided mapping, land information and geographic information systems (before the theoretical understanding of cartography was completed) decreased the interest and amount of research in theoretical cartography. As a result of that, there is no widely accepted 'cartographic theory' yet that can be used as the basis for the cartographic process" [Remirez 1990]. Thus, there is a need to re\_examine and redefine the nature of this discipline.

Focussing on cartographic generalisation, this re\_examination seems to be more important than ever. Because of the lack of a theoretical basis, cartographic generalisation has always been based on individual skills and experience. Unfortunately, until now, most cartographic generation systems (even knowledge based systems for generalisation) have been aimed at simulating human cartographers' behaviour instead of searching new concepts. To implement a cartographic generalisation system successfully, new concepts of cartography and cartographic generalisation must be established first, as "the information in the system must be illuminated by ideas and concepts." [Waters 1989]

Cartographic generalisation is a complex procedure which contains not only principles but also operations especially in digital environment. To represent this in a formalised way, the communication paradigm might be too abstract that can hardly touch the specific operations, while the pure mathematic method might be too rigid that can scarcely adapt the dynamic process. So some new methods are needed.

Knowledge engineering, a branch of artificial intelligence arising in the 1970s, has shown some new concepts for formalism in problem solving because of its capability for knowledge representation. The knowledge contained in a knowledge base generally is domain knowledge and experts special heuristic knowledge, so we named such a concept of formalisation as 'Non-rigorous Formalism'. A well built knowledge based system is a non-rigorous formalistic system which is suited to optimally organising the domain knowledge to solve special problems although it is not as exact as a mathematic formulae. The most important point here in this paper is that the purpose of using knowledge-based systems is for formalizing some conceptual models instead of only for implementing a system.

In this paper, such a system consideration, called "the knowledge based system approach" is introduced. First, an analysis of cartographic generalisation is given and a new conceptual model is provided. Next, some formalisation styles and a formal represent frame are discussed. Finally, a implement structure is shown.

## **2. A NEW CONCEPT MODEL FOR CARTOGRAPHICAL GENERALISATION**

Cartographic generalisation is one of the most intellectually and technically aspects of the mapping process. In a digital environment, the procedure of cartographic generalisation is quite different from the manual one. A multitude of generalisation models have been developed during the 1970s and 1980s. Lech Ratajski [Ratajski 1967], Joel Morrison [Morrison 1974], Nikerson and Freeman [Nikerson and Freeman 1986], Brassel and Weibel [Brassel and Weibel 1988], and McMaster and Shea [McMaster and Shea 1989] established their models for generalisation respectively. Here, the last two models need to be mentioned.

### **2.1 BRASSEL AND WEIBEL MODEL**

The model developed by Brassel and Weibel [Brassel and Weibel 1988], consists of five

processes of generalisation in a digital environment, including structure recognition, process recognition, process modelling, process execution, and data display (Fig.1).

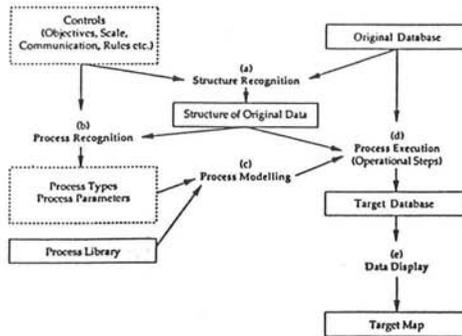


Fig. 1 Brassel and Weibel model (1988)

Structure recognition is for identifying specific cartographic objects, the spatial relations and measures of importance. Process recognition identifies the exact generalisation operators to be invoked and involves both data modification and parameter selection. Process recognition determines what is to be done with the original database, what kind of conflicts have to be resolved, and which types of objects and structures are to be carried in the target database. Process modelling compiles rules and procedures from the process library. Process execution does the actual generalisation. It is at this stage where the rules, procedures and algorithms applied to the original database in order to create the generalised output. Data display is the last process.

Brassel developed the function-and-object concept, [Brassel 1985] where generalisation functions such as smoothing, simplifying etc, may be applied to an individual object or combined objects or features. Brassel gave categories of objects, including point, line, composite, area, and volume features, and provided an extensive list of operators divided into point, line, area, volume, and 'text' operators.

## 2.2 MCMASTER AND SHEA MODEL

A concept model provided by McMaster and Shea [McMaster and Shea 1988; Shea and McMaster 1989] identifies three considerations for comprehensive generalisation, including: (1) why we generalise; (2) when we generalise; and (3) how we generalise [Fig.2]. In expanding on the nature of why we generalise, three distinct types of intrinsic objectives were addressed: philosophical objectives, application objectives, and computational objectives. Fundamental principles of the development of the model is the establishment of six philosophical principles of generalisation, including: (1) reducing complexity; (2) maintaining spatial accuracy; (3) maintaining attribute accuracy; (4) maintaining aesthetic quality; (5) maintaining a logical hierarchy; and (6) consistently applying generalisation rules.

McMaster and Monmonier also developed a formal set of generalisation operators [McMaster

1989b; McMaster and Monmonier 1989]. The actual generalisation processes include classification and symbolisation. Before the objects or attributes are manipulated by the generalisation operators, decisions are made for what to be retained or eliminated. After selection, there is a series of binary decisions to do raster and vector based generalisation.

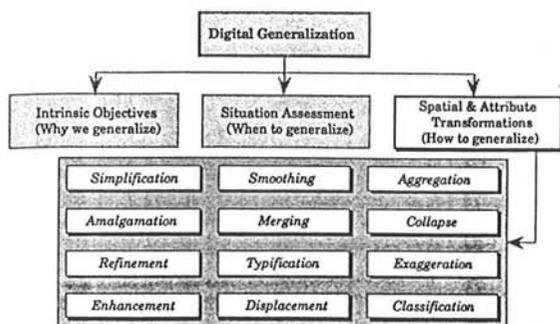


Fig.2 McMaster and Shea model (1989)

### 2.3. AN ANALYSIS OF GENERALISATION PROCESS

As we have known, generalisation in digital environment is different from generalisation manually. But how to define and isolate the processes of generalisation in digital environment, is still the most important and difficult work for cartographers. Thus far, work in this area has focused on the development of individual computer algorithms for the various aspects of automated generalisation process. Most efforts to automate the generalisation process would seem to assume that its components (or operators) are discrete and relatively unrelated, and that a complete generalisation procedure is no more than the sum of its parts, which are applied one after the other (Gail Langran 1991). The models provided by Brassel and McMaster might be the typical ones (although McMaster has considered some correlation between the operators and has done some work for it). To accomplish a generalisation process the only things need to do are checking the conditions when to generalise, determine what operators should be used, organising the sequence of the operators, and finally getting the result from the execution of rules and operators.

Actually, the processes of generalisation are not so simple. While one feature is being processed, other features may be affected; When one conflict is resolved, some new conflicts may occur; After several operators have been applied, some of them have to be reapplied in the new situations; Finally, there is no the best result can be found, what we can get are only such things that we feel satisfied. So, cartographic generalisation is a dynamic procedure in which there is no a predetermined sequence of operators, because in various of situations, an operator need to be executed only when some operators are executing or after some operators have been done. and there is also no 'best' result because we are not able to try all alternatives in a dynamic situation.

## 2.4. SOME IMPORTANT FEATURES IN GENERALISATION PROCESS

According to the analysis of the process of generalisation in digital environment, six very important features which were lack in thus far research are summarised: concurrentness, asynchronourism, dynamic scheduling, recursiveness, and satisfaction.

### [1] CONCURRENTNESS

generalisation requirements usually happened concurrently instead of sequentially. The process of generalisation is generally the performance of two or more generalisation operators within a specified interval or at the same instant of time. We call this as the concurrentness of the process of generalisation. There are two kinds of concurrences:

#### (a) interrelated concurrence

If process A definitely happens with process B, then we can say A and B are interrelated concurrent.

For example in Fig.3, when the river is processed, the bridge and the road across with the river must be processed at the same time.

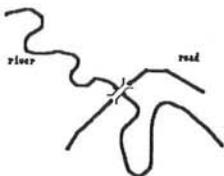


Fig. 3 interrelated concurrence

#### (b) triggered concurrence

If process A happens because process B happens and process B affected process A, then we can say A and B are triggered concurrent

For instance in Fig.4, when the road and the railway are generalised, the lakes must be displaced.



Fig.4 triggered concurrence

## [2] ASYNCHRONOURISM

The generalisation processes occur without a regular or predictable time relationship to a specified event or operator. they may happen at any time during the execution of generalisation program.

## [3] DYNAMIC SCHEDULING

The sequences and scheduling of generalisation operators change with the different demands that made on the running system and dynamic data rather than being fixed or predetermined in conventional applications.

## [4] RECURSIVENESS

Generally, the process of generalisation is neither a define sequences of operators nor a simple repeat loop. it is such a process that inherently repetitive. The result of each repetition is usually dependent upon the result of the previous repetition.

For instance in Fig.5, the selection of streets affects the generalisation of built-in area; the generalisation of built-in area will also affect street selection.

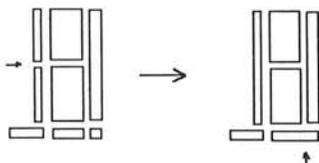


Fig. 5 recursive process in streets and built-up area

## [5] SATISFACTION AND INTERACTION

Cartographic generalisation is a creative procedure both in manual situation and in digital environment. The generalisation process is subjective, interactive, idiosyncratic and comprehensive in its perception and execution. There is neither a 'good result' standard nor a possibility to try all alternatives. What we can get after generalisation is only the result which satisfies the requirement from users. So the interactive capability plays a very important role in an automated digital generalisation system.

## [6] PURPOSE-ORIENTATION AND USER CONTROL

Despite there are plenty knowledge rules and generalisation operators can be applied in a generalisation system, the user's control, such as map purpose, scale etc, has a vital role during generalisation. Different maps should be and can be generalised based on different purposes and different styles. A pretty result of such research is provided by W.A.Macmaness [Macmaness 1991].

## A NEW CONCEPTUAL MODEL FOR GENERALISATION

In evaluating previous research, there has been focused on the generalisation models which include generalisation operators. As McMaster pointed out, for most part, researchers have ignored the interrelationships between these operators. Some researchers studied the interrelationships of operators [McMaster 1989b; Li and Kubik 1993], but the result is still in the stage where there is only a static view of generalisation process. based on the static view the generalisation process is no more than a sequence of operators regardless they are organised in a knowledge rule base or in an object-oriented method. What they have done, we might say in McMaster's terms, are why and when we generalise, and what to generalise instead of how to generalise although McMaster said that was 'How' [McMaster 1989; McMaster 1991].

Fig.6 presents an initial attempt at the development of a conceptual model which is based on a dynamic view and embodies all traits described above. Similarly, the first step in the generalisation process is that of *selection*, which is considered by many researchers as preprocessing step to the actual operations of generalisation, and here which is embedded in the *user's control* process. The basic controls from users are parameters such as purpose, style, scale etc and select database to exchange data to temporary map database.

As soon as map data gets into the temporary database the main loop of generalisation starts running. The system measures many different features to determine generalisation conditions. According to the measured data and data in the temporary map database as well as generalisation conditions the inference engine dynamically organises the schedules of operations which come from appropriate knowledge sources, executes specified operators. The reasoning system should resolve different level conflicts recursively and concurrently. So the blackboard control structure might be essential in this conceptual model. Users can control the execution while the temporary map is displaying on the screen so that they can find the satisfied results.

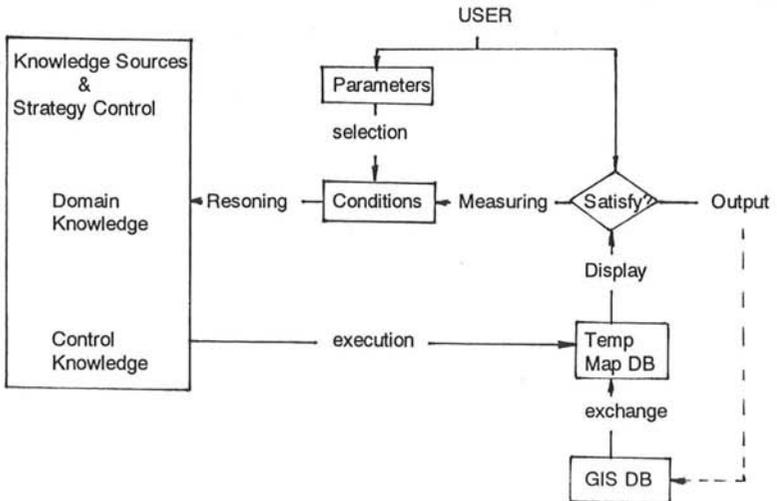


Fig. 6 Zhang, Kubik and Brooke Model (1992)

### 3. THE FORMALISATION OF THE GENERALISATION MODEL

#### 3.1 STYLES OF FORMALISM

Formalism, as a word, is well known, but in each situation it has a slightly different meaning. According to philosophical perspective, there are two main different styles of formalism: one is essentially **the foundationalist** corresponding to Platonist and one is essentially **the Axiomatic** corresponding to Aristotelian.

Platonism, briefly speaking, is a philosophy which suggests that what we see (that is, our empirical knowledge) is but a pale reflection of ideal entities which exist "in reality". It can be seen to be concerned with ideal knowledge and how such knowledge is reflected in our vision of the world [Leith 1990]. So the essence of foundationalism is that there is a solid foundation upon which knowledge of a discipline or knowledge of the world can be built. Mathematics has been such discipline for a long time, and Noam Chomsky's theory of syntax, which has been widely used in theoretical as well as practical computer science, is a modern day example.

Aristotelian is a philosophy which believes that the world is essentially what we see in front of us, and that we can build a picture of reality from this empirical, common sense information. Aristotle emphasised that knowledge is something which can, and indeed must, always be developed from knowledge which is already stated. To Aristotle, science was basically a method of collecting facts and axioms about the operation of the world, and from these basic blocks of knowledge and rules a science could be developed. The axiomatic formalism relies upon a given body of known "facts" (axioms) and a set of reasoning rules to work upon these facts to provide conclusions. A typical example is Euclid geometry. The use of the programming language PROLOG is an implementation of this axiomatising procedure.

Both the foundationalist and the axiomatic can be used as a framework to formalise knowledge. In this paper, for formalising the conceptual model of generalisation, only the axiomatic style is discussed. The foundationalist will be discussed in another paper later.

#### 3.2 KADS STYLE FORMAL LANGUAGE

KADS (the Knowledge Acquisition and Design Structuring) is a European research project which started from 1982 and is still under development [Weilinga, Schreiber & Breuker 1992]. KADS is centred around a so-called model of expertise which describes the problem-solving expertise of the system to be modelled, independent of a possible implementation. The style of knowledge representation in KADS is typical axiomatic. So we use KADS style formal language to describe the generalisation model. It is necessary to say that the description here is only KADS style instead of KADS formal language itself.

KADS divides the development process of knowledge-based system into different models, within which knowledge is represented by four layers to stress the different types of expertise. The four types layers are: domain-layer, inference-layer, task-layer and strategy-layer. Table 1 shows the four layers and how they interact. We will describe the layers with examples.

##### 3.2.1 THE DOMAIN LAYER

The domain layer describes all knowledge of the application domain in the form of concepts, structures and relations. This is supposed to represent declarative knowledge about the domain of application: facts and rules that are true in the domain, represented independently from how this knowledge is going to be used.

Level	Relation	Objects	Organisation
Domain	Describes	Concepts, Relations, structure	Axiomatic Structure
Inference	Applies	Meta-classes Knowledge sources	Inference structure
Task	Control	Goals,tasks	Task structure
Strategy		Plans, meta-rules, repairs, impasses	Process Structure

Table 1 the four layers in KADS(Breuker & Wielinga 1989)

Formally, a concept consists of a declaration  $\mathcal{L}$  which defines a language, and a set of axioms  $A$  expressed in the language:

$$\text{concept} = (\mathcal{L}, A)$$

The syntax is as follows:

```

concept    concept-name
  declaration
    constants
    variables
    functions
    predicates
    procedures
  axioms
end-concept

```

For example, the following is a concept for generalisation model:

```

concept    line-feature-1
  declaration
    constants
      nation-road, state-road : road;
      state-boundary, county-boundary : boundary;
    variables
      x : obj;
    functions
      width (obj);
      length (obj);
    predicates
      is-line(obj);
      is-road(obj);
    procedures
      measure-width(obj);
  axioms
    is-road(nation-road);
    is-road(state-road);
    if is-road(x) and measure-width(x) and width(x) < 20m

```

```
then is-line(x);  
end-concept
```

According to the domain-layer specification we can illustrate a hierarchy concept tree for all geographical elements for generalisation.

### 3.2.2. THE INFERENCE LAYER

The inference layer describes the problem-solving capabilities of a system in terms of knowledge-sources and meta-classes. Meta-classes declare roles and states in the problem-solving process. Knowledge-sources are functional description of inferences that operate on meta-classes. The combination of meta-classes and knowledge-sources forms a domain-independent and data dependency diagram: the inference structure.

For describing the generalisation model, we can define some meta-classes and knowledge-sources as inference structure:

```
meta-classes:  
  available-phase;  
  available-action;  
  current-phase;  
  current-action;  
  .  
  .  
knowledge-sources:  
  select-next-phase;  
  select-current-action;  
  specify-phase;  
  specify-action-adaptation;  
  .  
  .
```

### 3.2.3 THE TASK LAYER

The purpose of the task layer is to force control over the inference steps specified at the inference layer. the inference layer specifies which possible steps can be taken but it does not specify in which order these steps should be executed. This is the concern of the task layer. The following is an example:

```
task:          evaluate-phase  
goal:         test the environment information, change the phase status if necessary  
trigger:      state-transform, conflict-3  
task-structure:  
  WHILE not-empty(current-phase) DO  
    IF  changed(environment-data) and  
        not-empty(available-phase)  
    THEN  
      select-next-phase(available-phase) and  
      specify-phase-adaptation  
end-task
```

### 3.2.4 THE STRATEGY LAYER

the task layer represents the result of applying a single control strategy with no flexibility in problem solving. The strategy layer is a dynamic planner that could reconstruct the task layers. This layer is strongly dependent on the application problems.

#### **4. THE CONSIDERATION FOR IMPLEMENTATION**

This paper is showing part of the research of MAPGEN, a project undertaken by the Queensland University of Technology, granted by Australian Research Council. The purpose of MAPGEN is to develop a near operational computer software system which can actually produce maps automatically at various scales from one or more digital sources by using an Object-Oriented Database approach utilising knowledge base techniques [Kubik and Brooke 1991]. MAPGEN does not propose providing either a pure Object-Oriented Database or a completed Knowledge base; it emphasises Object-Oriented spatial organisation with some Object-Oriented facilities and Formalised digital cartographic concepts guided by knowledge-based procedures.

MAPGEN is a stand alone software system, but it is able to import data from other existing commercial GIS systems (such as ARC/INFO). The main function of MAPGEN is to generalise data either automatically or interactively (or a combination of them), finally outputting generalised data back to GIS.

To implement this system, we selected ARC/INFO, GENAMAP and MAPINFO as basic GIS data sources; SMALLTALK, C++, guru and WINDOWS as software development tools. The system structure of MAPGEN is a blackboard system which provides a three levels blackboard data structure, an Object-Oriented knowledge source frame and a dynamic scheduled scheduler mechanism.

The domain layer which represents all concepts is encoded by using Object-Oriented languages C++ and SMALLTALK so that it is easy to express hierarchical relationships. The inference layer is implemented in C++ and guru rule sets. The task layer is programmed as a special call from different knowledge sources. The strategy layer is embedded into the dynamic scheduler of the blackboard.

#### **5. FURTHER WORK**

MAPGEN is an ongoing project which is partially implemented. We will give more implementation details in further paper.

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# How to acquire reliable rules and knowledge for map design expert systems (mades) ?

K. Grosser (Leipzig, D)

## The Background

Nearly 11 years ago a study was finished dealing with the cartographic representation of population changes by colours [GROSSER 1983]. The study aimed both at the improvement of techniques of empirical investigation of map use and at results for cartographic practice. Today we have to consider that theoretical and empirical work in cartographic communication, map use, and map reading had a rather weak influence on the practice of cartography. Research and development in thematic cartography were dominated more and more by the introduction of computer systems for thematic mapping. Soon it seemed to be very easy for everybody to make thematic maps. But in the late eighties cartographers became aware of the danger that in spite of powerful mapping packages things can go wrong. Cartographic software could be misused because of the lack of cartographic knowledge with the software users. So they started to develop cartographic expert systems (ES) [BUDAPEST 1989, DVORKINA/DVORKIN 1990]. WANG 1992, p.8 gives a list of ES for symbol design.

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\* To stress the difference from the more general term Cartographic Expert Systems (CES) - encompassing for instance ES for cartographic generalization, name placement and other activities - the ES under discussion in this paper are termed MADES.

## The situation in cartography

Expert knowledge is defined as a combination of theoretical understanding of the problem and a collection of heuristic problem-solving rules [Luger and Stubblefield 1989; cited by WANG 1992, p.13]. The same authors say [see WANG, p.7] that this knowledge is not often found in textbooks, but comes from experience and judgement of humans working in the domain.

The special situation in cartography may be characterized as follows: Thousands of old and modern maps and atlases are available. I claim that they contain cartographic knowledge in a frozen form. Theories of graphic variables and of methods of cartographic representation (map types) do exist in textbooks and single articles. Moreover are there the above mentioned studies on map perception.

Nevertheless we have to consider that some unsolved problems have been left. For instance the question couldn't be answered sufficiently even by experts in cartographic design, when to use range graded symbols, and when graduated symbols. The answers can only be found by further empirical investigation.

This paper tries to show how an approach to research in map perception and map use can help to find a "cartographic way" of knowledge acquisition for ES. Because the author refers frequently to his own study [GROSSER 1983] it is reviewed relatively detailed.

## Review of the study on colour design of maps on population changes

The hypothesis of the study was derived from a broad analysis of maps on population changes and cartographic literature. The analysis yielded that in 6 of 7 maps warm colours (red, orange, partly yellow) were used to represent the increase of population, and cold colours (blue, partly green) show the decrease of population (in the study termed Principle B). The genesis of this principle of colour use was influenced by the colour scales in maps on temperature.

The opposite principle of colour use (cold colours for increase, warm colours for decrease; termed Principle A) can be justified by the warning function of warm colours (esp. of red). It was found in 15% of the analysed material.

The application of one of the principles depends on the purpose of the map. The need for stress the decrease of population in large towns (by warning colours) has arisen only in the last decades. Obviously in considerations of cartographic design we have to take into account also historical conditions.

In the hypothesis of the study was supposed that the results of the analysis of literature and maps must be reflected by the results of the empirical study, i.e. that they would reflect more or less the ratio of 6:1.

The psychological tests were performed with two colour versions of a map on population development (showing the types suggested by WEBB 1963, modified by WEBER 1969) in the scale 1 : 200 000. The first map was a printed one (designed according to Principle A). The alternative version (B) included the same line elements, but the areas of symbols and choropleths were hand-coloured. It was a substantial part of the technique of the study to use real maps, only differing in that element which was to investigate.

The sample of the tests included 60 persons, mostly employed at the Institute of Geography and Geoecology Leipzig. The efficiency of the alternative principles of design - i.e. of the colour attributes of the maps - were compared by the indicators mistakes, spent time, performance. A statistical analysis of the data of the test did not fully confirm the hypothesis. A few too similar hues and not well enough selected values arisen single problems on the elementary stage of perception. Therefore the reasons for the appeared mistakes were analysed very carefully - as far as they could be detected in the test sheets. In this way mistakes caused by the used colour principles could be separated from those ones caused by the weakness in details of colour choice or by chance.

The most striking evidence of the advantages of the B-version (warm colours for increase) was provided by the task "reading the map without the legend" (see Fig.A and Fig.B). This task was arranged after the task "reading with the legend" during the session, because it was supposed that map reading is not only a process of communication but a process of learning, or learning is part of communication, respectively. Furthermore the "reading the map without the legend" made obvious that it is very difficult for map users to recognize quickly the principles which have been the base of the cartographic design of the used map. This result led to the recommendation that the design principles of a map should be explained in the legend, similar to the following example

warm colours (red, orange, yellow)	= increase
cold colours (blue, green)	= decrease
strong colours	= strong change
light colours	= weak change

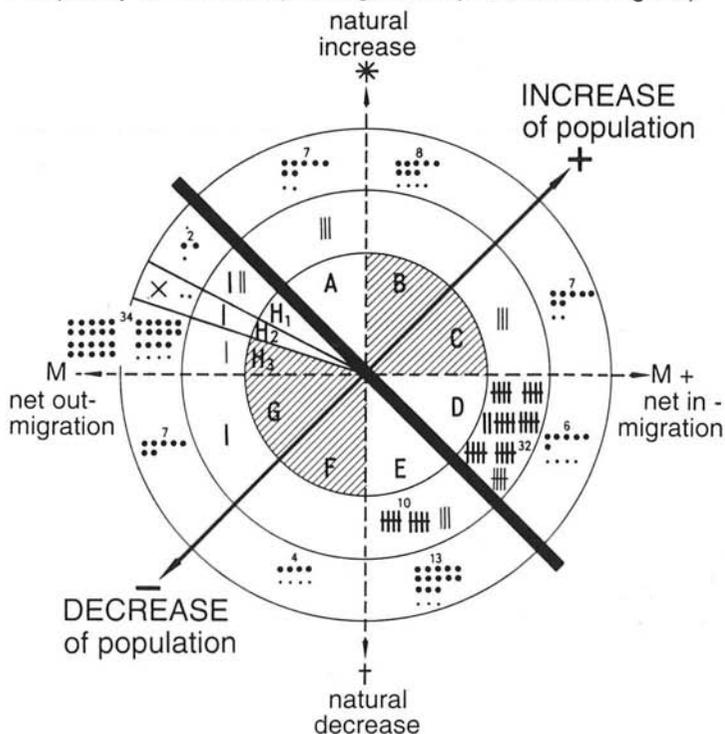
In addition to the test the 60 people of the sample were asked which colour version they favour (see the table).

	version A (cold colours for increase) favoured	version B (warm colours for increase) favoured
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cartographers (according to the analysis of maps and literature)	15 %	85 %
persons educated in geography	21 %	71 %
persons without any knowledge on the depicted subject	44 %	48 %
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(complement to 100% - no version favoured)



Figure B **Version B - warm colours for increase**  
 Frequency of mistakes (reading the map without the legend)



- | severe mistake (wrong tendency of pop. change reported) 45 x
- mistake (wrong intensity of pop. change reported) 88 x
- | severe mistake, corrected afterwards 17 x
- mistake, corrected afterwards 29 x
- × mistakes not counted because of the similarity of the colours of neighbouring types

**description of colours**

increase			decrease		
type	verbal description	ITC colour code	type	verbal description	ITC colour code
A	orange, light	310	E	blueish violet, light	012
B	red, strong	660	F	redish blue, strong	046
C	crimson, strong	062	G	blue, strong	016
D	redish violet, light	021	H <sub>3</sub>	blueish green, strong	306
			H <sub>2</sub>	blueish green	304
			H <sub>1</sub>	green, light	302

The evaluation of cartographic design closely correlates with the users' former experience and their knowledge of conventions. The advantages of the version B can't be explained by processes of elementary perception as it is done in some texts of cartographic theory. Consequently we have to prove traditional cartographic knowledge very critically before we put it into the knowledge base of an ES.

Suming up the results of the study it was justified to formulate rules for cartographic representation of population changes by colours. If we only have to show the total change (without the natural and migrational components) we should use a

scale of blue for decrease  
scale of red for increase

both becoming the lighter the nearer to stagnation. Stagnation however should not be represented by another colour than white or a very light grey (derived from the analysis of maps and literature).

When we have to represent WEBB's types of population changes the following colour scheme can be recommended (see also Fig.B)

increase	decrease
A redish orange, light	E blue, light
B redish orange, strong	F blue, strong
C crimson, strong	G green, strong
D crimson, light	H green, light

#### Transferring the approach

The approach of the reviewed study can be summarized as follows

1. analysis of the design of numerous maps,
2. analysis of textbooks and articles on map design,  
(derivation of the hypothesis for 3. from 1. and 2.)
3. empirical research on the reponses of users to different  
(alternative) versions of maps.

It will be discussed below, why the author considers a similar approach to the acquisition of knowledge for MADES as possible and useful.

1. Naturally the experts themselves are considered as a main source of knowledge acquisition for ES. In cartography however it is relatively easy to analyse the results of experts' work - the maps. Analysing maps we can find how they are designed, and that's what we want to support by a MADES. There is another point of view: Every expert in map design represents a special map style (in terms of aesthetics). If we want to find conventions or general rules the sample of experts must be big enough. Therefore it seems to be helpful to complete the knowledge acquired immediately from the experts by the analysis of maps. The map analysis however has to be done by an expert because within a great number of maps exist also bad solutions made by non-experts.

With respect to the knowledge representation in a MADES it should be thought over if to show the MADES user selected examples of well designed maps of the same type or theme he wants to produce, and help him to modify this prototype according to his need. This is a very common way in the practice of map design. On the other hand some explanations referring to examples of falsely or badly designed maps could prevent him from making severe mistakes.

2. Although the cited experts in expert systems [WANG, p.7] express their doubt to find enough useful knowledge in textbooks, the theoretical knowledge must come from there. WANG's ESSYD (Expert System for Cartographic Symbol Design) provides the evidence that Bertin's graphic semiology - in spite of some insufficiencies detected by him [WANG, p.14] - provides a good theoretical framework, especially for the selection of adequate graphic variables.

Regarding the methods of cartographic representation (map types) which are another essential part of cartographic knowledge we can refer to several textbooks. Looking at the diversity of the approaches and systems in this field we can expect that MADES will vary especially in this part of the knowledge base. The main schools of thought of thematic cartography will be reflected by the rules for selection and application of the representation methods [GROSSER 1991, p.14].

3. Empirical studies on map perception and map use are considered as a third group of knowledge sources. The author sees two ways to use these sources for MADES:

a) Existing studies should be analysed by experts to derive rules of relevance for cartographic practice or ES, respectively. In many cases the results of empirical studies may be too general or too theoretical, like the statement "the differences of sizes of symbols are underestimated". Nevertheless such an analysis will provide those points where new investigation must start, what leads to the second way.

b) Unsufficiently solved problems of map design should be investigated by empirical techniques because we can't put unreliable rules and knowledge into MADES. It is not necessary to wait for the results of a comprehensive analysis proposed under a). Many cartographers are aware of certain communication gaps between map makers and map users. So - from the author's point of view - some of the unsolved problems of map design are listed below. In general empirical research can be a mean to prove the reliability of cartographic knowledge from all sources, before using it in a knowledge base.

#### Some unsufficiently solved problems of map design (and map use)

- How to handle the contradiction of wide ranged data and the limited area in the map with respect to the underestimation of differences of symbol sizes ?
- When to use range graded symbols; in which cases are graduated symbols the better solution ?
- Which (dis)advantages have got circle symbols compared with square symbols ?
- Can we use colour scales, empirically proved for mapping population changes, outside the general subject population ?
- Which differences do exist with the perception of choropleths and symbol maps depicting the same data and the same classes ?

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## The electronic maps system conception

A. Martynenko (Moscow, CIS)

The electronic maps system (EMS) is a set of cartographic models that is gathered by the common ordered and checked with the scales, reference system, projection, contents and symbols. Cartographic models are formed as rasters and vectors by software and hardware on optical disk using the extant maps, space photos and other terrain data.

EMS is designed for displaying the significantly large terrains and small areas, any movements (phenomena) that could take place there, and also for analytical problems solution in GIS, control systems and navigation.

The principle EMS advantage is the chance to transfer real time cartographic information on any dynamical areas that is necessary and enough in the sense completeness and accuracy for problems solution by a lot of users (customers). EMS supports the quick (in seconds) map reproduction of various scales. You can get the required high accuracy large scale image with more detailed contents in any point of the small scale map.

The electronic maps mathematical base matching, where the electronic maps consist in the system, is reached by using the common scale row that gives you chance to get the required detailed and high accuracy cartographic image and projection that supports the continuous (without break) mapping of any areas on the earth with minimum errors and accepted reference systems. Connection between the electronic maps that have different projections and reference systems is carried out using the corresponding transformation algorithms or universal conformal projection equations.

EMS development includes scientific design and production (revising).

The scientific electronic maps design consists in the project and their requirements development, different mathematical base variants, contents and load, symbols simulation, and it also consists in the electronic maps models acquiring with the engineering-psychological value.

The electronic maps production (revising) is carried out by the initial cartographic documents scanning, computer processing, optical disk generating and recording.

The cartographic models system block-hierarchical design method is offered for electronic maps contents design. The sense of this method consists of the simultaneous logically correct multilevel set of the whole scale row models with different contents and load that are logic dependence between the objects and events (phenomena) that take place on the surface of the earth and their images. They also can be defined by using of the unified algorithms of the cartographic generalization. This method is based on the scale cartographic models system dividing into separate blocks, having the different generalization levels, and on the presenting of every element in their content (the level's content) as several data detalisation sublevels. Its advantage lies in

the dividing of the complex cartographic image design into the step-by-step operations of the less complex cartographic images (models) design. The base cartographic information that is necessary and enough for the cartographic models design on the other levels, is formed on the lower level.

Electronic maps contents and symbols design is an interconnect process. The list of the objects and cartographic image elements, their classification are the basis for the structure, quantity and symbols type definition. On the other hand the picture, symbol's and inscriptions' colour and dimensions influence significantly on the contents design. So during the contents and symbols design their optimum relationship is being chosen taking into account technical capabilities of image instruments (displays).

EMS conception is developed on the basis of the objective (of the integrated performance criterion) and particular criteria of the optimum mathematical base, contents and load, electronic maps symbols library. The cartographic information value criterion is advised to be used as a EMS performance estimate measure.

As an objective we shall regard an integrated performance criterion of the cartographic image system  $E$  that is created on the base of the particular criteria of optimum of contents and load and of cartographic image appearance.

As a particular criterion of the optimum  $E_j$  we take a certain meaning of indices, according to them it is created estimation of possible versions of the cartographic image taking into account their utilization and selection of the best one. For the complete solution of the problem it is expedient to determine two such particular criteria: the criterion of optimum content and load of cartographic image  $E_1$ , criterion of graphic and colour optimum  $E_2$ .

The main demand of the criterion  $E_1$  is that one: the cartographic image has to contain information about the basis elements of terrain, which is necessary and sufficient for the effective solution of the problem. These elements must be reflected on the screens in a definite correlation. The load of linear and digital symbols, inscriptions of geographical names must ensure their steady perception and making out in real conditions.

It is expedient to use time and quantity of errors in the work of customers as the indices for comparative estimation of cartographic image versions.

The comparison of the results of estimation of the work effectiveness of the customers depending on load category of cartographic image permits to expose utmost value of the load for symbols and inscriptions of geographical names.

The basis demand of the criterion  $E_2$  is that cartographic symbols and inscriptions of geographical names must show visually the main object of content and to dismember the elements of cartographic image, to provide quick and exact study and estimation of terrain.

It is necessary to raise obviousness of the relief image, to decrease dismemberment of tinting of its basic forms and to mark out the main mountain ridges, passageways and passes.

The dimensions of symbols (in angular value) must not exceed the minimum permissible ones, which proved the best vision and making out of symbols on the screens, as necessary condition to read them with due regard for physiological opportunities of an eye (keenness of eyesight, contrasting apprehensibility and impellent reaction). It is necessary to shorten the quantity of prints and their gradations for inscriptions of geographical names and explanatory inscriptions.

The colour appearance must provide steady colour discrimination of the symbols and colour rendition, which is co-ordinated with accepted colour appearance must provide not only optimum perception of cartographic image, which is projected on screens but its reliable distinction by design and colour with the situation (contrast), and also the best reading under the optimum lighting technological descriptions of screens and permissible levels of their outside exposure.

As the indices for estimation of the versions of graphic and colour appearance it may be minimum (threshold) dimensions of the hatched symbols and prints, their colour descriptions (coordinates of chromaticity, coefficient of transmission). It should be taken in account the influence of colour of the area symbols, and also the change of colour descriptions in the spots of crossing or superposition of the symbols.

The effectiveness of the customers's work is closely connected with functional condition of the human organism: negative condition (tiredness, monotony, stress) leads to the drop of effectiveness of labour or even to its disruption. Minimum psychophysiological expenditures are gained only under conditions of optimum graphic and colour appearance of cartographic models. In this case highly effective human capacity for work is well preserved for a long time.

Generalized criterion of effectiveness that reflects all the aims in common can be presented as multiform function:

$$E = E(E_1, E_2, \dots, E_n)$$

The expression of the particular criterion of effectiveness that shows degree of achievement of projected aims may be defined in this way:

$$E_i = \sum_{i=1}^n \alpha_i \sum_{j=1}^{m_i} \beta_{ij} g_{ij},$$

where  $n$  - number of groups of particular criterions;  
 $\alpha_i$  - weight class coefficient that takes into account the importance of  $i$  - particular criterion;  
 $m_i$  - number of indices in every group of particular criterions;  
 $\beta_{ij}$  - weight class coefficient that takes into account the importance of  $j$  - index in  $i$  - group;  
 $g_{ij}$  - criterion by the  $j$  - index of  $i$  - group.

As a measure of criterion of EM effectiveness it can be used the value of received cartographic information.

The value of cartographic information  $I_i$  received from EM will be bigger the higher will be drive and reliability of solving the problems with its application. That is why the criterion of value of cartographic information received by the solution of the problem can be defined by this expression:

$$V_j = \eta(u_j) I_i(K_i, N_i, I_i, u_j),$$

where  $\eta(u_j)$  - coefficient of value of received cartographic information that defines its influence on the drive and reliability of solving the problems;  
 $K_i$  - number of elements;  
 $N_i$  - number of objects;  
 $I_i$  - number of indications and parameters that define EM objects.

This criterion permits to state quantitatively the effectiveness that cartographic information received by SEM can bring by the best way of its usage. Maximization of the criterion in the area of possible solutions of the problems helps to find the best one.

The notion of value of cartographic information is polyhedral one.

The value of cartographic information depends not only on the degree of accordance to the projected aims (objective or function  $E$  that has a special purpose) but by the possibility to receive it and to give a meaning to it (to use it) during available time.

If all the components of SEM are defined the problem comes to searching for such meanings of variable quantity that maximized the meaning of the objective or the function that has a special purpose. Its equivalent is the generalized criterion of  $E$  effectiveness and it satisfies the considered conditions.

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## World, map, children

T. Matsuzawa (Tokyo, J)

( Part 1 )

The first thing that I have to tell you here is that, although the name of our organization is " The Expression Laboratory " when directly translated, we're neither a government nor a private research organization that specializes creating maps or doing any technical drawings. We are a small publishing company, which mostly spends its time writing and editing text for books and publications that often include maps. Therefore, we won't pretend to be an expert in creating maps.

However, we did produce a book called " The 21st Century World Atlas For Children, and for that we were invited to present our opinion at this 18th ICC'93 Conference.

The following pages describe the circumstances of how we came about producing this book in the changing geopolitical world situation. Please bear with its lack of proper organization.

( Part 2 )

The fast-paced changes in world atlases that have been brought about by rapid changes in the world geopolitics have been reported repeatedly by various media as you all know. As a result, we have been receiving sympathetic words from those who normally wouldn't show much interest in what we do.

Up until recently, we have often dealt with changes of the world in some degree like what size font we should use to display the name of a new country, or how much alternation we should make to borders according to the scale of that particular map. However, the recent fall of the U.S.S.R. could not be dealt with by simply redrawing or adding borders. It entailed much more.

What we are faced with is changing the way we show the world which we have been so accustomed to for so many years.

Even before the U. S. S. R. fell apart, we all have experienced the difficulties in showing such a large mass of land on a map.

Now, the U. S. S. R. is gone, and much of it has been inherited by a new Russia, and though it is still a vast piece of land that is difficult to deal with, the fact that almost half of the newly formed republics are now parts of Asia is also a very serious matter.

It has made us Japanese rethink the meaning of being, geographically and ethnically, Asian. And it also made us realize that the world we have recognized for such a long time can change.

In the end, the fall of the U. S. S. R. has made us reconsider how we look at the world on a world map.

The fall of the U. S. S. R. became the trigger for fast moving media such as TV, newspapers, and magazines to start reporting all sorts of changes in the world. This also includes the environmental changes which we actually see in the form of unusual weather.

The fact that should be recognized is that all those changes in the world are a great opportunity, as well as a source of major headaches, for those who create maps or publication which have maps in them.

This is because, people who had interest in world politics or geography, but had almost no interest in maps, have become readers of maps to find out and understand about the changing world. This seems a totally natural thing to happen. However, it was a major happening in the Japanese publishing business.

( Part 3 )

At this time, two different types of the people who read maps in Japan should be pointed out. The first category of people is those who regularly use the maps issued by the Geographical Survey Institute. At the individual level, they are the mountaineers and hikers who need maps, and at the same time are very interested in maps themselves. This group of people possess the knowledge and the ability to read maps correctly, and seldom make mistakes reading them.

The second category of people mainly use the road maps. Japan being an island nation, we can not travel to another country by a car. However, there are a large number of automobiles being used for transporting goods and people despite the narrow streets so common to Japanese towns. For the reason that maps are an essential tool when traveling unknown roads, there are many such road maps published in Japan. Certain people open maps not because they are interested in maps themselves but, because they are interested in the roads that are shown in these maps.

There is another category of people who reads maps that can not be left out. That is the students who are studying in the mandatory education system. Studying geography using maps is a part of Japanese mandatory education. As a result, all students own a map and a students' map book is distributed for free.

When considering maps or map books as a commercial publication, we normally try to satisfy both the first and the second category of people wants more of a topographic map which is extremely accurate and contains a lot of data, and the second category of people wants something that is easy to carry and use, and more like a tourist guidebook.

Often we receive complaints concerning "inaccuracy" and "lack of information." What we can see from these complaints are; crudity of a map (inaccuracy) voiced by the first category of people, and difficulty of understanding (lack of information) voiced by the second category of people.

The first category of people does not feel that they need a world atlas in Japanese and therefore, to them the release of the latest edition of The Times Atlas was more important than any new edition of a Japanese atlas.

( Part 4 )

As mentioned at the end of Part 2, those who started show interest in maps as the world began to change include many of the people from the second category. That is because those who had no interest in maps, because these maps lacked ease of use, and those who only use road maps are, basically, the same people.

Moreover, in Japan, this ease of use in maps is being furthered recently with the use of visuals to convey information.

3D maps are created using computers and computer generated maps using the data from various satellites which used be considered as supplemental information. These are considered to be forms of maps now.



Seeing that we just realized the origin of maps is much older than that of written language.

( Part 6 )

At this point it is totally natural that we became more interested in the history of maps.

When trying to explain the potential of maps, or fun of maps, starting with their history along with the history of the world and its progress is a quite natural way to proceed. However, this approach is not so common in Japan but, it probably is the most effective method.

At the same time we would like let the next generation of children see the possibilities of a medium, maps. Maps are not only an excellent tool to teach people about the world but, they are an excellent tool to teach many different forms of expression. Because we are into the last decade of this century and the world is changing so fast, we want to impart knowledge of the world as we know it to the next generation.

This is why we proposed and created "The 21st Century World Atlas For Children." In creating this book we did not take the approach where geographic information was used to supplement the information of current world events.

In fact what we wanted to do was to show the current maps along with the maps from the past, and to show to our children the possibilities of expression that the people before us have achieved.

In the end we include things we found interesting and wanted to know more about, and in doing so there was one thing that we realized. It is that there is no more appreciate medium than maps for children when teaching them about discovery, imitating, repetition, and collecting information which the history of maps is all about.

( Part 7 )

In creating this book, there were many and diverse ideas that we could not fit in it. Also because it was created entirely by Japanese staff, there may have been some parts of the contents that are not clearly explained.

However, so far, the response from our readers are good, and they, including their parents, seem to be enjoying the book. For this we are extremely pleased.

At this time we would like to present a comment we received from a 11 year old reader, and start thinking about our next theme in producing an atlas.

" This book is so much fun, I can't believe it's an atlas.