CHAPTER 6

SESSION VII

APPLICATIONS AND TECHNOLOGICAL ASPECTS

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TOWARDS MORE INTELLIGENT SYSTEMS: A GENERAL TREND IN COMPUTERS

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ABSTRACT

In computer developments, there is a permanent trend towards more powerful systems for less money and there is no limit in view to this development yet. This increased power is transferred to the user not only in the form of cheaper computations, but much more so in the form of higher 'intelligence' of the application system. From a land information perspective, there has been a trend for computerized systems to help drafting maps, systems to maintain an overlay type of multi-purpose cadastre; and data base-oriented land information systems. Present research and development in computer science may contribute to an application-oriented language which permits one to install and work with an LIS without much formal computer training; and 'expert systems' which embody not only the facts but also the rules to deal with these facts and which may assist decision makers to evaluate complex situations.

ABREGE

Le dévelopement des ordinateurs et des programmes nous montre une tendence à long term: la puissance des machines permet d'évoluer à un niveau superieur d'"intelligence." Nous observous les mèmes phénomènes dans les systèmes pour traitement des données cadastrales et nous discernous: (1) des systèmes de dessin graphique; (2) des systèmes à couches multiples; et (3) des systèmes à base de données et nous prevoyons (4) des languages spécialisés pour les applications des systèmes d'information sur le territoire, et (5) des systèmes experts, qui contiennent pas seulement les faits mais oussi les règles comme elles sout utilisées par les spécialistes.

1. INTRODUCTION

In surveying, computers were first used for complicated calculations. Today, surveyors use computers increasingly to draw maps. This is a shift from the use of computer exclusively as powerful calculators to their use as more versatile, multipurpose machines for the treatment of all kinds of data, including, but not limited to long term storage of results and producing output as legible, hopefully pleasing, reports and maps.

This paper will discuss in very general terms how the computer can be used to produce maps. It will present basic concepts in graphical data processing and will link these to database management for geometric data and to the future expert systems of the so-called 'fifth generation' computers (Feigenbaum and McCorduck, 1983).

Using these concepts to classify present systems, three generations are proposed:

- 1st generation: purely graphical systems - electronic drafting
- 2nd generation: annotated, multilayered, storage-oriented systems
- 3rd generation: database-oriented, integrated systems which manage complex models of reality and provide different renderings.

Practical criteria are given to classify the different software packages, as they were developed over the last decade, into the above mentioned generations. The concepts associated with these generations will be detailed in order to understand their functionality and limitations.

This paper will not discuss the single packages as they are offered in the marketplace. Given the fast changes in the products, this would be a futile endeavor. It seems more important to make the underlying concepts of the three generations understood.

This basic text should enable the practitioner to assess systems in relation to his needs and then find the one most appropriate to his situation. It is not necessarily the most sophisticated one, a comparison between the needs and the system's capabilities is necessary to optimize a selection. To achieve such optimization, one should try to find out, by appropriate questions and tests, in which generation a system tends to fit. The ensuing functionality and limitations then become clear.

This paper is therefore not intended as a buyer's guide and will not touch on some practical topics very important to the buying surveyor, (e.g., prices, maintenance, service, ...), but will concentrate on concepts and functionality. The typical hardware considerations which dominate many discussions are excluded, the emphasis being put on software functionality.

In order to describe the different generations of interactive graphics system as used for map drawing, we need a knowledge of the fundamental principles relating maps to the real world (Annex A), of the metric/topological relations in maps (Annex B), and of data structure and consistency constraints (Annex C). Then the main text may focus on the three generations and on the concepts they are based upon in order to discuss their functionality as it is visible to the user.

A final section will show how the developments visible in these systems relate to a trend in the development of computer applications in general.

2. THE FIRST GENERATION: GRAPHIC EDITOR

Shortly after the computers were invented, they were used to produce graphical output, maps and other sorts of diagrams.

A first type of program packages allowed one to store, manipulate and draw maps and similar diagrams. The internal model of a map in this type of package is the map drawing. These packages treat the graphical elements (lines, symbols, etc.) as they appear on the final output as units and allow the user to manipulate these; he can erase lines, move them from one point to another, copy them from one place to another, rotate and scale parts of the drawing, etc. This is quite impressive and can speed up the production of maps. However, for the system, the drawing is a collection of graphical elements (lines, symbols, texts) without any meaning and without connection between them.

This may lead to results which are quite surprising and annoying to the user, but clearly understandable when one bears in mind what internal model is used.

Figure 1
Moving a line instead of an object

The user sees that the length of the west-east streets is too short and intends to make them longer by moving the eastern north-south road. To his surprise this results in Fig. 1b and it takes at least six tedious operations to make all the lines for the roads longer. What is missing in the computer's model is the topological information. The storage of unconnected lines is insufficient and the fact that the road lines are connected must be included in the internal model.

Similarly a move of a graphical element may result in a conflict of two elements at the same place - again the user has to spot the error and correct it (Fig. 2).

Figure 2
Conflict after move

Similarly an object may be moved without the explaining text coming along (Fig. 3).

Figure 3
Moving an object without accompaning text

These examples should make clear what is meant by 'unconnected' graphical elements.

These systems also treat graphical objects without meaning. There is no internal difference between a line representing a street center line and the borderlines of the drawing. This becomes obvious when some simple changes in the map presentation are required: since the system does not 'know' what the lines mean, we cannot simply eliminate all buildings or change the line style for all street center lines - the operator has to change each of them individually because only he can interprete the drawing and separate the borderlines of the drawing from the street lines.

Similarly a scale change is a change of the size of all objects (Fig. 4), including symbols and text - the result is often not the intended one.

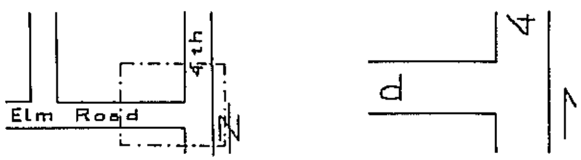

Figure 4
Graphical zoom cutting text off

All the mentioned errors can be changed by graphical editing but require manual, labor-intensive operations. The human operator is capable of doing them because he interprets the drawing and can add the information which is missing in the model the computer treats.

3. THE SECOND GENERATION: GRAPHICS WITH ATTACHED MEANING

It soon became obvious that users of spatial data management systems expected more from their systems than to be expensive and complicated copying machines which reproduce faithfully the once painfully digitized original (and provide only slight flexibility in updating the data).

System builders not only improved the methods to treat the graphical elements and added some topological ideas (e.g., polygons as a sequence of connected lines), but also allowed the user to attach additional data to the

graphical features of the map.

Graphic lines can now be annotated with properties the thing has in reality - typically for utility lines the material and diameter of the pipe, the age, etc.

This has proven useful as these data can be used for different representations on maps as well as for making lists of pipe qualities, etc. If the system features a user-friendly query language we may even get answers to questions such as, which one is the oldest pipe, how many pipes are of diameter "x", how long are the pipes of material "a" and older than "y" years.

Such systems were primarily built for keeping track of utility lines, updating pipe plans and at the same time allowing additional use. They were successful, because utility lines can be represented with a single graphical object (the black stretch of line) which stands for a real world object - and additional data can be attached to this graphical object.

Some systems even exploit the topological properties. Here again, the simple topological structure of utility networks (mainly trees) did help, when topological information was reconstructured from metric data.

Such systems typically do not fare well if we want to store information on objects which are not represented by simple graphics. For example, a lot is limited by its boundaries - which at the same time limit its adjoiner. There is no "natural" graphical object for the lot. An often used solution seems to be to add a point within the lot (a so called centroid) and attach all the lot data to this point. To logically connect this point to the boundary has proven difficult. Not all such systems can select just one lot with all its boundaries and nothing else, or can print a list of the coordinates of the corner points of a lot. Neither can some systems detect whether two lots overlap.

At the same time, a number of traditional techniques of graphical map drawing were computerized and integrated.

- Overlays: When map makers are faced with the problem that different users want to represent different data on the same base map, they often use overlays. Each piece of user data is put on a transparency and combinations of base map and overlays are made.

  A computer can handle a great deal more overlays than a draftsman would ever dare. It is not clear, however, whether an increase in the number of layers makes this primitive structuring method any more flexible and a user may be unable to organize data in a large number of layers without becoming confused.

- Flexible symbol selection: Instead of storing symbols as lines, they are stored as references into a symbol table. This allows more flexibility in the production of maps for different users, as the symbols can now be selected immediately before printing and can therefore be varied for different users.

- Joining of map sheets: Even if the basic organization of the stored data remains in map sheets, a computer-assisted method of joining two (or more) adjoining map sheets into one is often offered.

4. THIRD GENERATION: DATABASE MANAGEMENT SYSTEMS

The fundamental idea in database management systems is the separation of data storage and retrieval from the application of the stored data set. These programs are centralized and separated from the application (Fig. 5). Application programs use a number of standardized methods to retrieve and update the stored data (no application program is allowed to directly access the stored data).

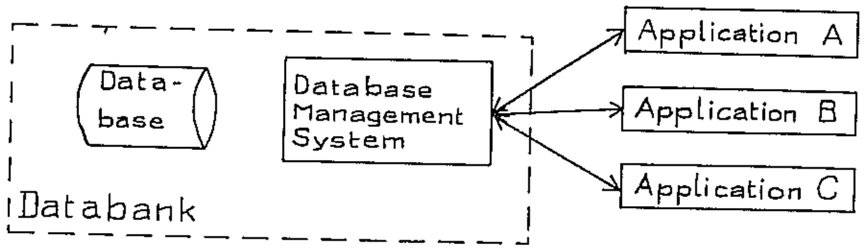

Figure 5
Database Management System

The central database management program contains a description of the data on the conceptual level and checks all updates against the state integrity constraints. Having one program set containing all the routines to access the physical data storage (disk) also makes the maintenance more economical and easier. For commercial applications, generalized database management systems have been developed; such program systems can easily be adapted to manage the data for many applications. Such systems are, alas, most likely not fast enough to treat geometric data.

Furthermore, database oriented systems concentrate the description of the data in one place. In consequence, changes to the data description due to changing requirements are easy to apply.

The primary advance in database oriented systems lies in the added possibilities of structuring data. The data structure can be modeled as closely as possible to render the real world situation. Non-geometric data can not only be attached to graphical data, but may exist in its own right and be structured as best suits the application. The more powerful data structuring tools also allow one to model the geometric situation better and to join topological information to metric.

The more truly modeling of the real world situation and the possibility of capturing more data open additional potential for new applications. The base data stored in the database can not only be used to create maps in varying scale and symbols for different users, but the data can also be used to direct

simulation programs. Most obvious examples are network flow calculations for electric utility nets, calculation of flow in sewer lines during heavy rain, etc. These are only possible if a meaningful model of the world - not only graphics - is stored.

This understanding of the situation is relatively new; it started in database theory and took a long time to be applied to graphical and geometrical problems. Because the high performance requirements in these areas seemed difficult to meet, reluctance to apply these concepts can be found among the designers of computer aided design systems. This is a limited point of view and should be replaced by more global considerations.

To gather geometrical data describing lots, names, utility lines, etc., is very expensive; to maintain such a data collection up-to-date requires a permanent effort. This can only be justified if many different users can use these data without new measurements. If a true multi-purpose cadastre emerges (NRC, 1980), which answers to many needs, then the cost of maintenance of the database can easily be covered. But this multi-user solution is only possible if the data collection is flexible enough to be used by different users. This is hardly possible in a conventional graphical system on paper (even with overlays) and is not much easier in a system of the first or second generation which imitates the conventional methods.

If the objects manipulated by the system (graphical lines) are different from the categories managers are interested in, the users have to learn to translate their requirements in terms of the objects handled by the system. This makes it difficult for managers to predict which tasks can be carried out by the system and which can not. Very similar tasks - in terms of the user's model - may be very different in terms of the system's model. Such unpredictable behaviour - from the managers point of view - is frustrating and limits the use of the system. Even tasks which could be carried out are not done for lack of understanding. Similarly, large differences between the user's model (real world objects) and the system's objects (lines drawn) result in problems for the operators: they are constantly forced to translate their objectives into the realm of the system's actions. This makes their task harder, more error prone, and slower and also requires more extensive training.

5. LONGER TERM TREND

The development in mapping systems is quite typical of the development of computer applications in general. An understanding of this trend can help us to foresee the immediate future.

- Increased use of computers to other ends than calculations (number crunching). Computers can also profitably be used for long term storage and retrieval of data; they allow one to structure the data according to different points of view and to retrieve them in a different context.

- Trend to use interactive, direct communication between user and computer and restrict 'batch' processing to special cases. Graphical output can improve the man-machine communication considerably.

- A trend away from treating a very limited share (drafting) of a complex application area towards an integrated approach (multi-purpose cadastre). The intermediate step to use a computer system to simulate traditional technical solutions (drafting and overlay) is very common and helps the user to understand the system operation. This intermediate step seems less successful in drafting applications, as graphics treated by the machine and the interpretation by the human operator are semantically so closely coupled but may be differently modeled. A desire for adding more information, however, destroys the simple metaphor of the drawing and makes the system complicated to use.

- Most important is the trend to use more realistic models in the computer. More and more knowledge about the real world situation is embodied into the computer programs, and the programs can consider an increasing number of aspects and rules.

  The extreme frontier are systems which store arbitrary facts and logical deduction rules and then are able to make reasonable conclusions on their own; such systems expose a (nearly) intelligent behavior and this area of research is thus called 'artificial intelligence'. Much research has been done in this area in the past and we are now slowly beginning to see the practical fruits of these efforts (Feigenbaum and McCorduck, 1983).

  For commercial applications, '<u>fourth generation</u>' languages appear on the market which contain some knowledge about their field of application and allow one to instruct computers to produce desired results almost without programming and with very little training (for an application to mapping see (Frank, 1982).

'Expert systems' (also called 'decision support systems' or 'knowledge bases') become feasible; such systems contain not only a description of real world situations, but also the rules used by experts in the field to deal with them. Such systems support human experts by making use of advice of other experts available to them, helping them to follow complex administrative or technical procedures, and keeping track of complex situations and permitting one to explore 'what...if...' questions. It seems obvious that such ideas can profitably be applied in the area of zoning, environment and resource management.

6. CONCLUSION

Different stages in the development of spatial data management systems as needed for a multi-purpose cadastre have been identified and the problems associated with each of them explained. It becomes apparent that systems develop along a line, first, to incorporate ever increasing amounts of data about the world and, second, to include rules about how to use these data. Such systems appear to behave more 'intelligently' and become easier to use and produce more useful results. Database oriented systems as they are built now are just an intermediate step. They allow one to capture the complex reality more adequately and are more flexible in using the stored data. The next generation of systems will incorporate expert knowledge about the mapping

profession. They will be easy to adapt to changing requirements and they should be easy to use with little training.

In spite of this development, the cartographer today must decide if he wants to use today's systems. There will always be better systems just around the corner. Decisions today should be based on a clear understanding the range of applications and the limitations of present systems. Only if the requirements and the system's ability match closely, profitable operation may be expected.

ANNEX A: MAPS AND REALITY

Maps usually describe an external, real world situation in its past, present or future form as we perceive it. Maps seldom describe unreal, imaginative worlds as the maps that go with Tolkien's <u>The Lord of the Rings</u> or Stevenson's <u>Treasure Island</u> (Post, 1979). Here we assume the existence of an objective description of the exterior world - without this assumption a meaningful discussion of multipurpose maps is not possible. Maps are a special class of data collections and they describe special aspects of the world.

The general case of data collection reflects the fact that physical objects in the world are perceived by the observer with his sensors (eyes and ears to name the most important ones). The perception of reality is not objective, but regulated by the subject's experience, expectations, task, etc. He creates from this perception his own conceptual model. This purely mental conceptual model is not directly visible. In order to communicate it to other human beings, the observer must use some observable physical phenomena (sound, drawings on paper, etc.) to express its content. The rules of representation are conventions between the parties involved; they define how the mental concepts are transformed into observable and interpretable patterns and communicated. The receiver must understand these rules in order to interprete the message sent and create his own mental, conceptual model. It is inevitable that the conceptual model in the receiver's mind is different from the sender's. Standardization of encoding and education are the two most important methods to keep these differences small enough so that they do not interfere with the goal for which the information is needed (Frank, 1983).

Communication of mental concepts or ideas is not only possible between two persons in a face to face situation, but may be transported in time and/or space to distant receivers. Different machines may be used to transform the encoded ideas (then usually called data). The most versatile ones are computers, but printing and copying machines, etc., must also be considered. Only human beings can interprete the data and form a mental model. Computers are strictly limited to processing the data they are fed - they will never understand (as humans do) what the data mean in real world terms. However, the rules (the programs) computers employ may enable them to perform sophisticated operations on the data, but only on the data, not on the ideas implicated. If we use terms such as "the computer knows" we mean that there are programmed rules which embody certain aspects of a human being's understanding of a situation and allow the computer to imitate reasonable behavior in treating the data.

Maps are - from this point of view - nothing more than graphical notations of mainly spatial concepts about the real world. For the following discussion these specific properties are of a less importance than their general properties in terms of a medium to communicate ideas.

ANNEX B: TOPOLOGICAL AND METRIC RELATIONS IN MAPS

Topology is, to express it in a nonmathematical way, what is left from geometry if you make your drawings on a balloon. Topology (exactly graph theory) is a branch of mathematics dealing with two types of objects, namely, points (called nodes) and lines (called edges) and one type of basic relation between them (called incidence).

Topological data can be seen as opposed to metric data. To analyze topological relations, the exact location of the nodes and the form of the edges are of no importance; only the fact that two points are connected by a line is relevant. In topology the two Figures 6a and 6b are equivalent.

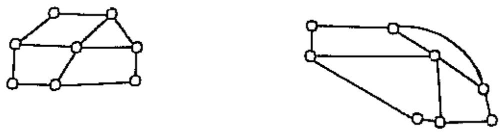

Figure 6
Two topologically equivalent figures

The metric (in the original sense of measurable, not in the sense of using the metric measuring units) data describe measurable properties, or more precisely, distances between points; the metric information in Figures 5a and 5b are therefore very different.

Metric and topological data together are represented in a map. For example, to register the extension of a plot of land, it is not sufficient (but necessary) to record the relative positions of the corner points - these are the metric properties - but we also have to join the topological information on which points the boundary lines run between.

Topology also includes reasoning about adjoining properties and the like. Cartographers have always represented topological and metric information together in their maps, and are used to dealing with them in combinations.

When computers were mainly used for the computation of metric data, dealing with topological relations continued in the traditional graphical way. If today computers are used to support this part of the cartographer's work, too, they must be capable of dealing in a natural way with metric and topological data.

Since it is possible to produce a complete map drawing using metric information alone, a look at the final product will not reveal if a system treats topology or not. In the operations, however, differences in ease of use are noticeable.

ANNEX C: DATA STRUCTURES AND CONSISTENCY CONSTRAINTS

To manage large data collections, especially if they contain spatial information, has been proven difficult and time consuming (Cranford, 1978). A multitude of small errors and discrepancies tend to creep in undetected

during update operations, and subsequent problems in processing the data lead to their detection and ultimate correction. (This can be seen as an application of the third law of thermodynamics, applied to data collections.)

For example, it is obvious that a subdivision plat must look something like Fig. 7a. For many reasons, Fig. 7b cannot depict such a plat.

Figure 7
A consistent and an inconsistent subdivision

Such knowledge must somehow be built into a program to make it impossible to enter data which are in violation of these rules. It is much easier and cheaper to prevent errors than to make labor-intensive corrections.

This problem is ubiquitous in all large data collections. The addition of so-called plausibility tests during data entry in order to catch as many of the errors as possible is common practice in data processing. The same methods must be applied to collections of spatial data.

A stringent analysis of these problems in database theory has shown that data processing generally relies on certain properties to help in the data set. If these properties are violated (as in Fig. 7b), processing of the data is not possible and processing errors and incorrect output result. It is therefore necessary to define the set of rules which must be fulfilled by the data; these rules are called 'data consistency constraints' (or 'data integrity rules').

Such rules do not necessarily capture all restrictions which are imposed on the data from the real world situation, but only a minimal set, needed for orderly processing. Programs can be made to treat fewer real world concepts in the data (first generation graphics editors which treat lines) and need therefore fewer integrity constraints. In consequence, such programs can not detect many gross errors in the data.

If we want to catch as many errors as possible during data entry and create useful, 'error free' data sets, the relations between different data parts must be analyzed and constraints formulated.

The database concept brought the idea of a conceptual schema which describes exactly the different data to be entered in the data set and the corresponding relations and constraints - all independent of the application programs. This independent formulation is the first step towards a guarantee that all programs, which may change the data, are bound by the same constraints formulated.

Unfortunately, the formulation of integrity constraints for geometric data is quite complicated and not much research has been done in this area (Burton, 1979; Cox et al., 1980; Frank, 1983). However, it is feasible and some early attempts, most notably by the Bureau of Census (Corbett and

Fransworth, 1973), have shown that this is the only way to achieve usable, 'error-free' data sets without unacceptable high expenditures for error correction.

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A DATA BASE MODEL FOR A LAND MASS INFORMATION SYSTEM

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ABSTRACT

The role of data base structure is only now being appreciated in using land related information. The organisation and structure of data determine the ultimate potential of the data for use by a variety of applications. This paper develops a data base perspective on the use of land information by identifying information types and their encoding within a data base environment. This paper draws on the experience of a georeferencing pilot project, conducted at the University of Guelph, for building a comprehensive data base for land mass data. A number of specific concepts, which span both the data base technology and land related information systems which emerged from the pilot study, are discussed.

ABREGE

Le rôle des bases données n'est évaluée que pour l'utilisation de l'information cadastrale. L'organisation et la structure des données déterminent leurs possibilités ultimes aux fins de diverses applications. Le présent article se penche sur l'utilisation de l'information cadastrale par rapport aux bases de données en définissant les différents genres d'information et leur type de codage au sein d'une base de données. Le présent article se fonde sur un projet pilote de méthode de référence à des données géographiques mené par l'Université de Guelph et visant à mettre sur pied une base de données complètes sur les terres. Nombre de concepts précis tirés du projet pilote, qui portent tant sur la technologie des bases de données que sur les systèmes d'information du territoire, font également l'objet de l'article.

INTRODUCTION

The interest in automated land information systems can be traced back to the initial developments in automated cartography in the late 60s and early 70s. At that time, the primary motivation was to facilitate the production of map graphics using computer assisted methods. The results achieved are attested to by the use of computer graphics in 1972 to produce the line work for sheets of the 1:50,000 NTS series produced by the Surveys and Mapping Branch of Energy, Mines and Resources in Ottawa. Essentially, the process involved an emulation of manual methods used in cartography, specifically the tracing (with digital encoding) of line work which subsequently was used under computer control to direct the movement of a stylus (pen), scribe tool, or photospot projector in the production of faired drawings.

The actual storage and management of land related data initially took the form of a feature code and a subcode associated with each encoded topographic feature. The spatial component of each feature was embedded in the set of co-ordinates which could be displayed to provide the graphic representation required for mapping. These initial developments in automated cartography were in turn supplemented by turn-key systems provided

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