INTERACTIVE COMPUTER MAPPING*

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For two decades computer scientists have developed interactive systems and computer graphics researchers have followed suit very quickly. Systems which produce maps are somewhat more recent (Phillips and Geister, 1972; Deeker and Penny, 1972). This paper presents the results of some research on the Interactive Map of Urban Research, a system developed by the authors (Clement, 1973 b).

We may distinguish between four classes of interactive operations on maps:

1. Interactive maps can be useful for EDITING SPATIAL INFORMATION. In preparation for the production of a final hardcopy map and for the clean-up of digitized data sets. The operations would be performed on the pictorial elements such as boundary outlines, map symbols, place names and titles and would be typically line smoothing, data reduction, correction, name attachment, name placement and image composition.

2. With the addition of CONTENT INFORMATION to the spatial information, the data bank would be built up with the aid of interactive editing. Since there are

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often logical connections between content information, especially the topological information (i.e. in relationships between neighboring elements) certain control functions can be implemented to test the consistency of the data set.

3. An interactive map can also be a valuable tool for INVESTIGATING A LARGE SPATIAL DATA BASE. By displaying

data sets with varying symbolism, different classes, changing windows in a data set, etc., the user can get a very quick overview of the variables and their spatial distributions and plan his subsequent analysis or the graphic display of the data in a hardcopy accordingly.

4. With the incorporation of more computational power, together with structural relations between the spatial data and a more advanced query language the interactive map can become a powerful tool for DATA ANALYSIS. One can relate data sets and study the resulting spatial distributions immediatly on the display distribution. Also, route selection, network flow analysis, and spatial simulation become possible within the same system.

The INTURMAP System.

The INTURMAP system was developed to facilitate these four types of operations (Nake and Peucker, 1972; Clement, 1973a; Peucker,1973). The data and command structures are flexible enough to enable most of the possible applications, however, only a subset has been implemented:

- The editing of spatial data is performed through the deletion, creation and redefinition of graphic objects. One specific editing feature is the selective deletion of points along arbitrary lines. The system stores the operator's decisions and developes a strategy for "generalization" which can be used for subsequent generalisations (Clement, 1973a).

- Content information can be edited through the correction, redefinition and regrouping of adjectives. A specifically powerful feature is the definition of sets of objects which in turn can be treated as single objects.

- By displaying variables in map form, a quick overview can be achieved since maps can be produced in quick succession, combining two variables through statistical or graphical combinations, the user realizes very quickly in which direction a more sophisticated data analysis has to be pushed.

-There are only few statistical techniques which are not so complex that their application in an interactive environment would slow down the process to a point where interactive work would be possible. We have therefore restricted our development to combinations of pairs of variables through simple arithmetic operations and regression analysis with the mapping of the predicted values and their residuals.

The development was based on a series of objectives, usefulness, flexibility and extensibility, and machine independence. These objectives were approached through a series of developments: 1. Query language. 2. Interactive display. 3. Flexible data storage and retrieval. 4. The possibility of data editing and input.

1. Query language.

The query language has been designed to be be as easy and natural to use as possible. Thus the commands are sufficiently English-like that the expected action is fairly clear. Equally the system is fairly compromising with respect to errors in the user's interaction. Although it does not independently correct errors or guess the right answer, it indicates exactly where it had difficulties understanding.

The chief entities that are referenced by the query language are "geographical objects". A geographical object can represent anything that has a well defined locational description (boundaries, regions, points, etc.). It has associated with it content information (names, population, size, etc.) which is referred attribute-object pairs as keys in a hash table (Rovner and Feldman, 1968), and locational information, (i.e. point, line or region, boundary, etc.). Sets of geographical objects can be assembled directly

(CREATE WEST END_FROM CT001 CT002 CT003 CT004)

through a logical predicate that every object of the set must satisfy

(INCOME > 10,000 and (POPULATION/AREA) > 4.5)

or using a light pen to select objects displayed on the screen of the CRT. In addition, algebraic variables can be declared and manipulated with the same algebraic power as FORTRAN or PL/1.

The complete language is defined by means of a formal grammar. The production rules of this grammar are supplied to a parser-generator that produces parse-tables (Wales and Thomson, 1974). These are used to drive the parser to analyze input command. The advantage of this parser approach is that once the initial overhead has been assumed, the language can be extended very easily. Thus the query language constitutes a geographic programming language in its own right.

2. Interactive Display.

The display component of the system consists of two quite distinct parts. The part that the user deals with is called the Virtual Graphics System, and is not linked to a particular application such as mapping (Meads, 1972). It relieves an applications programme from being concerned with the details of the user interaction by letting the high level programme draw segmented images on a number of "virtual" screens that are potentially infinite in extent. The user determines the portion(s) of the image that he wants to look at. This is done by defining a number of "windows" of varying size into the "virtual" screen. This makes it possible to start with a general view of a large area and then gradually "zoom" in on a particular feature.

3. Data Storage and Retrieval.

The retrieval of statistical and locational information is handled separately, because of the different characteristics of these two sets of data. The three types of entities in the location data structure are points,boundary segments ("snakes" or curved lines with a start - head- and an end -tail) and lines (sequences of snakes). Geographical objects are assembled from these entities and combined with the statistical objects. In this way space is saved and and the property of spatial relationships (eg. adjacency) maintained in a flexible way.

The statistical values are stored in a table which is referenced by object-attribute pairs as keys to a hash function. When a command is given which requires some statistical data, space in core is acquired and the hash table is brought in.

4. Data Editing and Input.

The system allows for the transformation of data from one structure into the other. For the digitizing and editing of line data some previously developed programmes are used for the logical and geometrical improvement of the data (Douglas and Peucker, 1973).

Experience with the system

The system has shown to be highly flexible and extremely expandable. However, one has also to admit that the system had some serious faults. Some of these faults were brought about through the changes in the conditions around the development during the time of active work. Others were caused by misjudgment in the planning process.

One problem was that we had based the development on a graphics instrument which as of today has to be considered outdated for the purpose of cartographic design, but could not be replaced because of its high costs. The ADAGE graphics terminal allows very immediate interactive work but with roughly 6,000 vectors is too restrictive for cartographic work. The parser chosen (Wales and Thomson, 1974)) and the basic language (ALGOL-W) were highly unportable which caused some organizational problems when the research administration had to be moved from one university to another.

One serious organizational problem was our inability to attract users who would apply the system to real problems and suffer with us through some of the difficulties of a system in the development. Today we know that in order to get proper applications of such a system one actually has to pay users to work with the developers through the development stages and apply their practical knowledge for the improvement of the system.

There is no doubt that an interactive system can help very much the production and the usage of maps. There are in the meantime several attempts to develop such systems. With improvements in hardware ,especially interactive graphics, and in software, especially languages with more powerful data and command structure we can be confident that more interactive mapping systems will be developed and made available to interested users.

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