INTERACTIVE CARTOGRAPHY

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INTRODUCTION

In the last two decades great strides have been made in the application of machinery, especially computing machinery, to assist with cartographic tasks. The large bulk of this past work has been carried out with batch-oriented cartographic systems. A good review of the state of the art is presented by Peucker (1972a, 1972b), and Taylor (1972). Although batch production techniques still receive the bulk of the attention in computer-assisted cartography as evidenced by Gutsell (1973), Csati (1974) and the British Cartographic Society (1974) and probably will remain so for the final production of sheet maps, one can detect active recognition that in many ways interactive techniques can enhance many of the tasks in a computer-assisted cartographic system. These trends have been reviewed from differing points of view by Edson (1974), Boyle (1975), and Moellering (1975). These developments are also having an effect on the philosophy of thematic cartography as discussed by Morrison (1974). One would expect that such an impact will be even more keenly felt as time progresses.

CURRENT DEVELOPMENTS

To date the application of interactive techniques to cartography is still in its initial phases; however the fundamental feasibility of the approach has been proven at the laboratory stage. The fundamental advantage of interactive techniques is that one can establish man-machine communication, where there are tasks that one performs much better than the other. Machines are far better and faster at numerical data handling tasks and computation than a person; on the other hand, a person can rather easily perform certain kinds of logical operations that can be very difficult to replicate with computer algorithms. Hence, man-machine interaction allows the combining of the advantages of the person and the machine into a capability which is far more powerful than either approach alone.

Although the application of interactive techniques to cartographic problems is still in its early stages of development, a number of already existing uses can be distinguished. Of immediate interest to large governmental mapping agencies is sheet map production. Perhaps the most productive area to date has been in the use of interactive techniques for map digitizing and editing. One of the leading workers in this area is Boyle (1973, 1974a) who has produced an efficient interactive digitizing system which has effective editing capabilities, while Rhind (1974) details work proceeding at the Experimental Cartography Unit in London. Interactive thematic cartographic systems have also been developed, examples of which have been produced by

Youngmann (1972), Peucker (1973), and Hessdorfer (1975). In both cases the systems relate to "macro area" systems displaying large areas.

In contrast to the above examples, where the map or map display is the final output product, one can examine the status of several geographic information systems, experimental or prototype in which the emphasis is on solving specific problems in addition to producing a cartographic output. Examples which may be cited are by Phillips and Geister (1973) who developed a water quality display and analysis system for the U.S. Environmental Protection Agency, Christiani (1973) who has developed an interesting urban information system, and Schneider (1974) who reviews developments in transit route planning.

REAL AND VIRTUAL MAPS

If one is to analyze and discuss these developments in an orderly fashion, it is useful to distinguish between two possible types of cartographic products generated by these systems; real and virtual maps. A real map is one which has a tangible reality about itself and can be recognized as a map by direct observation. Perhaps the clearest and certainly the most widely used example is that of the ordinary sheet map. There are also several other kinds of real maps, produced by a wide variety of plotting devices on paper or film sheets, both general and thematic, which look very much like conventional sheet maps. There are however, several additional types of cartographic products which are fairly different from conventional cartographic products, the microfilm plot from a Computer Output Microfilm device as discussed by Broome (1974), as well as the Computer Animated Film (Tobler, 1970), (Moellering,1973), which can be viewed directly from the film.

In contrast, the virtual map is one which when displayed to the viewer looks like a real map, but has no physical reality in the form seen by the viewer. Perhaps the clearest example and certainly the most widely used kind of virtual map is the one which appears on the face of a CRT screen. The image qua image does not have a physical reality of its own, but may exist in some other nonimaging numerical or information state in some type of electro-mechanical storage device, computer or otherwise. The particular advantage here is that the image is of a transient nature and generally fairly easy to alter or edit as is necessary. It is also possible to store a virtual image in analog form on video tape. When viewing the spatio-temporal dynamics of a Computer Animated Film, the image is of a virtual type which simulates motion or change. The animation is not in the film itself, but an illusion of animation is created by the sequential display of the films. Although an individual frame may be considered a real map, the animated sequence is of a virtual nature. It is also possible to store virtual maps in an optical format. For example, it is possible to store Fourier transforms of maps (Wingert, 1973) or holograms of cartographic images as described by Youngmann (1974), either of which are not directly viewable, but can only be seen when converted into the proper display format for viewing.

It is interesting to note that it is possible to view current trends in computer-assisted cartography as exploring conversion methods between real and virtual maps. Current work in digitizing reflects efforts in efficiently converting a real map into a form which can be displayed as a virtual map, which then can be more easily manipulated in this form, and finally used to produce a real map product. Researchers have also come to realize that virtual maps are more easily edited and updated, especially in view of recent developments in computer technology. It is clear on a conceptual level that interactive techniques provide an efficient means for manipulating virtual maps. (Consider the problems of batch digitizing before interactive digitizing was developed.) Upon completion of manipulating the virtual map, it is a relatively straightforward step to produce a real map for the user.

It can be said that interactive computer techniques are still under active development. The body of literature pertaining to interactive computer techniques had been scattered widely, but a recent book by Newman and Sproul (1973), annual meetings on computer graphics and interactive techniques (Lucido, 1975) and a journal named Computers and Graphics, (Schiffman, 1975) have all helped to put communication and exchanges of ideas in this area on a more systematic basis. Further proposed developments for interactive cartographic systems have been voiced by McLelland and Moritz (1974), Edson (1974), and by Hoinkes (1974). These three papers represent proposed developments for large governmental agencies interested in proven technology before being willing to invest the millions of dollars into production systems for sheet maps. At the research level in cartography and computer graphics, it is clear that the pace of new developments will continue. It is reasonable to presume that these large governmental agencies will proceed with experimental and prototype systems in order to be able to test current techniques and also adapt the newest techniques before committing to production cartographic systems.

IMPACT ON GEOGRAPHICAL INFORMATION SYSTEMS

If one is to discuss the application of interactive techniques in cartography one must also include in the discussion a consideration of Geographic Information Systems (GIS) which in many cases produce a cartographic output. Initially, perhaps it would be helpful to define two basic orientations of a GIS, the first being an institutional system and the second being a research oriented system. An institutional GIS is one which is usually managed by a governmental agency and generally contains a reasonably large data base. In many cases the purpose of the system is seen as providing data to other agencies in that governmental unit such that these offices can intelligently solve their analytical problems. Some individuals even regard a GIS as a data utility. Because of their size such systems are usually batch oriented. Examples of such a system are Minnesota Land Management Information System, Natural Resources Information System, and Canadian Geographical Information System, (Tomlinson, 1972). A research-oriented GIS is much more specific in terms of the problems to be analyzed and hopefully solved. Phillips (1973), Peuker (1973), Boyle (1974), and Osleeb, Moellering and Cromley (1975) are examples. In most cases such research-oriented systems are interactive. It is also common for such systems to incorporate a substantial amount of display of virtual maps with CRT devices. Many have the capacity to produce real maps as well.

Although almost every GIS has the ability to do some geographical data handling, only a limited number have the ability to perform more extensive types of analytical operations. It is contended here that the usefulness of such research-oriented systems can be considerably enhanced by adding more analytical power to them.

Figure I shows two distinct components of such a system. The first is a cartographic display capability, essential to an interactive GIS. These techniques are fairly well developed as shown by Boyle and Peucker. The second facet of the system is that of spatial analysis. This implies the application of analytical techniques developed principally in geography, but also including analytical techniques developed in other areas, to the solving of specific problems which the system has been designed to examine. In some circles this capability has been called formal modeling, but the scope of this type of analytical approach is really much broader. As an example, many of the kinds of analytical techniques of concern here were discussed at a NATO Advanced Study Institute held at Nottingham in 1973 (Davis and McCullagh, 1975). It is interesting to note that there is at least one example in geography where an analytically oriented GIS has been designed and built with a very extensive analytical capability, but lacks an interactive capability. The system is named NØRMAP and has been developed by Nordbeck and Rystedt (1973). It is clear that NØRMAP would be much more convenient to the user if it were to incorporate an interactive cartographic display capability.

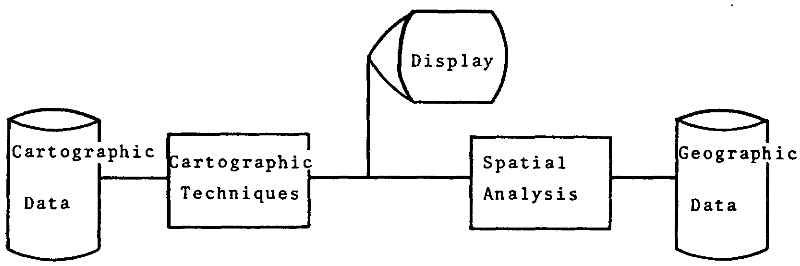

Figure 1. Schematic Layout of Analytical Geographic Information System

An alternative way to view the situation is shown in Figure 2. Here there are three fields represented, cartography, geography, and computer graphics. Although research is active in each of these fields individually, it is not uncommon to have a research task incorporate two of the three fields. For example, in intersection A the traditional approach in geographical analysis is to apply modeling and/or analytical techniques to geographical data, using cartographic techniques to produce intermediate working maps and also produce a final map of the results of the analysis. The bond between geography and cartography has always been very close. Many batch-oriented GIS fall into this intersection. Intersection B, incorporating techniques of cartography and computer graphics, especially interactive techniques, has resulted in systems which generate cartographic output and have no analytical power per se, although they may have some data handling capability. It is possible that such a system should be considered as belonging to a separate class of Cartographic Information System (CIS) rather than some subset of a GIS. Intersection C, which includes geographic techniques and computer graphics, has been little used because invariably the geographic output at some time is cartographic. In passing one could note that some computer graphic people have fallen into the trap of examining geographic problems while ignoring cartographic concepts; this has inevitably led to trouble. Finally, intersection D is where the real power of such an analytical system really lies. Here one finds systems which incorporate a cartographic display, computer graphic techniques and geographical analysis usually with virtual maps. These systems are a combination of analysis and display integrated with man-machine interaction. The amalgamation of all these approaches will result

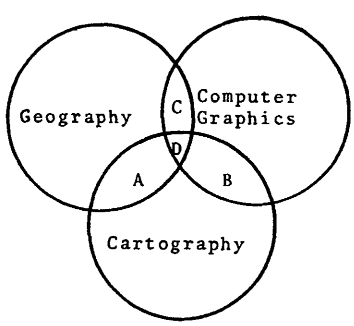

Figure 2. The relationship between Cartography, Geography and Computer Graphics

in very powerful systems indeed. For the immediate future it is suspected that this sort of system design will be primarily relegated to research-oriented systems focused on specific problems or on a small class of problems.

NEED FOR FURTHER WORK

It is clear that work to investigate the full integration of these techniques as envisioned in intersection D of Figure 2 is still very much in progress. One can envision many more systems of this kind being designed and built before standardized approaches are clearly defined.

However there are several tasks which require more research in order to accomplish the above goal. The first of these is to conduct more research in cartography on symbol displays for virtual maps along the lines of Wong and Yacoumelos (1973). The large bulk of research along these lines to data has been conducted in the examination of static symbols for real maps. Although some of these notions can be transferred to virtual maps, more explicit research in cartographic symbol perception should be carried out relative to virtual maps, particularly dynamic symbol displays. Noncartographic works like Huggins and Entwisle (1974) are helpful, but more explicit cartographic examinations are necessary.

A second area of research work requiring fuller definition in the cartographic domain is that of ergonomics, human factors, relating to interactive aspects of the types of displays mentioned above. This entire set of notions has hardly been touched as it relates to cartography. Again, one can utilize suggestions from research carried out in other fields as by Foley and Wallace (1974). However these concepts should be examined in an explicit cartographic setting.

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