STRATEGIES OF REAL-TIME CARTOGRAPHY

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I. Introduction

Machine oriented numerical cartography in recent years has seen interesting and exciting developments in numerical algorithms, data structure, interactive systems design, man-machine communication and hardware devices which have been utilized in analytical, display and production settings. These prodigious efforts, not unsurprisingly, have resulted in a number of new cartographic products which go far beyond the conventional definition of what constitutes a map. This paper provides a conceptual structure for these standard and new cartographic products by further developing the idea of real and virtual maps, and showing that many cartographic operations are really transformations between states and such maps. This notion of real and virtual maps fits neatly into the existing cartographic communication concepts which can be made much more powerful on an operational basis by interactive (Moellering, 1977) and real-time cartographic systems. The strategies of use of virtual and real map transformations are related to the kinds of cartographic tasks to be done with an emphasis on recent work by the author on dynamic spatiotemporal cartographic displays.

II. Interactive Cartographic Tasks

To date three broad classes of interactive cartographic systems have evolved which reflect the different goals and philosophies of those working in the field. The three classes may be defined as systems for cartographic production where the end product is a sheet map or generating information for sheet maps, systems for cartographic display which are usually thematic, and analytical systems designed to solve a specific and usually small class of cartographic problems. It should be noted that these classes are not always mutually exclusive. Examples of production systems are provided by Hufnagel (1979) who describes the Automated Cartography System, a large system developed by the U.S. Defense Mapping Agency, Hoinkes (1973) who describes a system in Switzerland used for producing air charts and thematic sheet maps. Sheperd (1976) who describes an interactive digitizing system for producing thematic maps, and Wittig (1978) who describes a system for manipulating and producing land use maps. In a similar vein Boyle (1976) and Reed (1979) describe the editing and processing requirements of such systems. Several examples of display oriented systems are provided by Phillips and Sibert (1979) who describe a system for extracting and displaying oil lease information, Turner and Moellering (1979) who describe ICMS a choropleth mapping system, Dalton, et al. (1979) who describe DIDS, a domestic information display system being developed by the U.S. federal government, Moellering (1978) who describes a system for dynamically manipulating and displaying three-dimensional cartographic objects, and Schneider (1979) who describes CDS, a traffic congestion display system. Finally, examples of analytical systems are provided by Tobler (1975) who describes WINDS, a program for analyzing geographical interactions, Christiani, et al. (1973) who describe GADS, a data analysis system to aid local governments, Osleeb and Moellering (1976) who describe TRANPLAN, a system for designing transit networks, and Bryant and Zobrist (1977) who describe IBIS, an image based information system. Together these systems are representative of the tremendous developments going on in numerical cartographic systems.

III. Cartographic Information Processing and Communication

The richness of the cartographic information processing and manipulation techniques suggests that Muehrcke's (1972) exposition of the cartographic processing system (Figure 1) is no longer adequate to describe the situation in view of the much wider ranges of cartographic products available. Nor is the elaboration of the cartographic communication process by Koláčný (1969) really adequate either because of the development of several cartographic products have signaled a need for a broader definition of the concept of the map. This situation was noted by Riffe (1970) when he recognized that map like images displayed on a CRT display were fundamentally different from what he called conventional sheet maps. Riffe saw that the transient nature of a cartographic CRT image was a different class of cartographic product and hence called these temporary maps. Since then many cartographic products such as numerical cartographic animations, holograms, and various computer data representations of cartographic information have been more fully developed. These products can contain much, all, or perhaps even more kinds of information than can be contained in a conventional map. A similar situation also holds between cognitive maps, a human mental map, and the physical sheet map (Board, 1978).

The solution to this problem is the concept of real and virtual maps proposed by the author in earlier papers (Moellering, 1976, 1977) and expanded here. After examining the situation very carefully it became clear that there are two attributes which differentiate a real (or conventional) map from other kinds of cartographic products which could be converted into a real map, Table 1. That is to ascertain whether the cartographic product is directly viewable as a cartographic image or whether it has a permanent tangible reality to it. As shown in the table some cartographic products lack only one of these attributes whereas most digitally stored data lack both. Any product which lacks one or both of these attributes is called a virtual map. However, in all cases a virtual map can be converted into a real map by some means. The definitions of the kinds of real and virtual maps are as follows:

Real map - is any cartographic product which has a directly viewable cartographic image and has a permanent tangible reality (hard copy). There is no differentiation as to whether that real map was produced by mechanical, electronic or manual means.

Virtual map - type I - has a directly viewable cartographic image but only a transient reality as has a CRT map image. This is what Riffe called a temporary map. Given the direction of current scientific work, electrocognitive displays may be possible.

Virtual map - type II - has a permanent tangible reality, but cannot be directly viewed as a cartographic image. These are all hard copy media, but in all cases these products must be further processed to be made viewable. It is interesting to note that the film animation adds a temporal dimension to the cartographic information.

Virtual map - type III - has neither of the characteristics of the earlier classes, but can be converted into a real map as readily as the other two classes of virtual maps. Computer based information in this form is usually very easily manipulated.

As can be seen, this classification of real and virtual maps is more efficient than earlier schemes since it explicitly takes into account the two most important attributes of cartographic products. The classification is therefore exhaustive and all cartographic products can be classified with this scheme.

Transformations between classes of real and virtual maps define most of the important operations in cartography and therefore merits examination in more detail. Here a transformation between two cartographic states can be symbolized as $t(S_1 \rightarrow S_2)$, a transformation from state 1 to state 2 of cartographic information. Figure 2 shows the possible states and transformations between them. For example, in order to generate a CRT map image cartographic information must be transformed from virtual map type III to type I, $t(V_{III} \rightarrow V_I)$ while normal coordinate digitizing of cartographic data is $t(R \rightarrow V_{III})$ with the additional transformation for interactive digitizing of $t(V_{III} \rightarrow V_I)$ and $t(V_I \rightarrow V_{III}$ $t(V_I \rightarrow V_{III})$. The task of reading a map and creating a cognitive map as defined by Board (1978) and Robinson and Petchenik (1976, p. 20) is $t(R \rightarrow V_I)$.

It is now feasible to expand Muehrke's diagram for an interactive real-time cartographic system and to specify the real and virtual and transformations which it contains, as shown in Figure 3. The real-time interactive system permits very quick transformations between the data, CRT image and mental image. This process is very efficient because of the fact that these transformations are taking place between virtual map states where the cartographic information is very manipulable. It should now be clear why real-time interactive systems in general are so much more powerful and efficient. Only when the CRT map image is designed, processed, or analyzed, depending on the goals of the particular system, is that map converted to a real state, usually a more laborious process. All cartographic processing systems involve at least one or two transformations as do many geographic systems which have a mapping component. In fact many of the more elaborate cartographic systems, such as those mentioned above, have many tens of these transformations imbedded in them which are related to the cartographic processing tasks discussed by Brassel (1978) and Baxter (1976).

IV. Real-Time Cartographic Strategies Using Real and Virtual Maps

One can now look at these basic classes of systems discussed at the outset and assess the importance of the above transformations. The production oriented system must have very efficient $t(R \rightarrow V_{III})$ and $t(V_{III} \rightarrow R)$ which encompasses the digitizing and digital production. Also of importance are the $t(V_{III} \rightarrow V_I)$ and $t(V_I \rightarrow V_{III})$ which are involved in interactive editing. With a display oriented system the most important transformations are $t(V_{III} \rightarrow V_I)$ and $t(V_I \rightarrow V_{III})$ which are crucial to the interactive and real-time display capability of the system which is usually carried out on high performance color display equipment. The analytically oriented systems in many cases are not as critically dependent on the efficiency of these transformations, although the $t(V_{III} \rightarrow V_I)$ and $t(V_I \rightarrow V_{III})$ are important in order to produce reasonable interactivity.

If one has access to a highly interactive real-time system with very efficient $t(V_{III} \rightarrow V_I)$ and $t(V_I \rightarrow V_{III})$ which will manipulate the cartographic information as a solid three dimensional object, then several important additional dynamic display capabilities can be developed which incorporate an additional temporal aspect to the display as shown by Moellering (1978). It is then possible to take a static cartographic surface, displaying it in three dimensions, and dynamically "explore" it. This strategy is particularly useful for examining complex surfaces. The cartographer then has the ability to dynamically zoom in on particular areas of the surface in order to examine them more closely and at the same time move the viewing window around on the surface in real time. The higher the complexity of a surface, the more useful is this approach. If one has cartographic data which is temporally sequenced, then it is possible with such a system to create a dynamic spatiotemporal display of that data, which might be something such as the population growth of the U.S. Such a display would foster better understanding of the dynamics of such growth. If such dynamics can be associated with a particular spatial process, then such a display can be used as an analytical tool as well. In some cases the notions of dynamic spatiotemporal display and analysis can be combined with surface exploration to form a very powerful strategy. Further details of the creation of these dynamic displays are discussed in Moellering (1980).

V. Summary and Conclusions

It can be seen that the concept of real and virtual maps is very useful for classifying a diverse range of cartographic products. By examining transformations between various states of these real and virtual maps, one can gain a greater insight into the manipulation of such information in interactive and real-time cartographic processing systems. It is clear that by capitalizing on virtual map transformations one can look past current systems to the potential of more powerful and flexible interactive real-time cartographic systems.These can deal with more complex cartographic objects which include the manipulation of aspects of spatiotemporal dynamics.

VI. References

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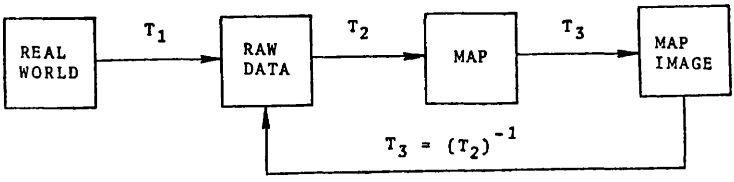

Figure 1. The Cartographic Process (after Muehrcke)

PERMANENT TANGIBLE REALITY	DIRECTLY VIEWABLE AS A CARTOGRAPHIC IMAGE: YES	DIRECTLY VIEWABLE AS A CARTOGRAPHIC IMAGE: NO
YES	<u>REAL MAP</u> Conventional Sheet Map Globe Orthophoto Map Machine Drawn Map Computer Output Microfilm Block Diagram Plastic Relief Model	<u>VIRTUAL MAP-TYPE II</u> Traditional Field Data Gazeteer Anaglyph Film Animation Hologram(stored) Fourier Transform(stored) Laser Disk Data
NO	<u>VIRTUAL MAP-TYPE I</u> CRT Map Image a) refresh b) storage tube c) plasma panel Cognitive Map (two-dimensional image)	<u>VIRTUAL MAP-TYPE III</u> Digital Memory(data) Magnetic Disk or Tape(data) Video Animation Digital Terrain Model Cognitive Map (relational geographic information)

Table 1. Classes of Real and Virtual Maps

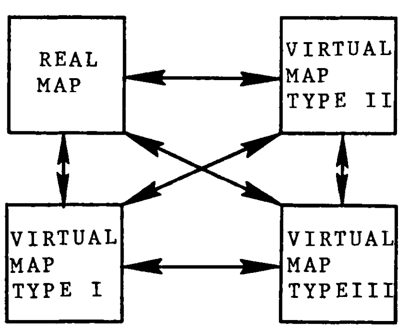

Figure 2. Transformations Between Real and Virtual Maps

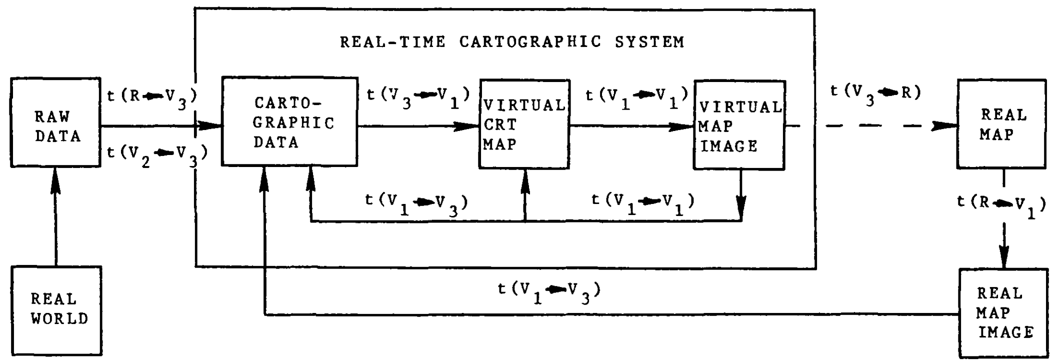

Figure 3. Expanded Cartographic Process for Real-Time Cartographic System Using the Concept of Real and Virtual Maps