A VIDEODISC BASED TERRAIN MAP DISPLAY SYSTEM*

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ABSTRACT

An interactive map display system using videodisc technology has been developed to support applications requiring detailed terrain backgrounds. As a proof of concept, a data base consisting of three thousand color photographs of standard terrain maps was stored on a videodisc. Overlapping maps and multiple scales were included to allow user flexibility in defining an area of interest. Computer generated color graphics are mixed with the output from the videodisc to enable placement of symbology and other dynamic data on the terrain background. Geographic control is provided by a joystick/cursor and function buttons which enable discrete zooming and panning within the data base. Registration of the foreground and background data is controlled automatically by the host processor which is interfaced to both the videodisc and digital graphics generator.

KEYWORDS: Interactive Map Display, Cartography, Videodisc, Computer Graphics

INTRODUCTION

The use of computer graphics is exploding due to a recognition of its ability to present large masses of data in a summarized, easily comprehensible form. Most military and many civilian applications which would benefit from the use of computer graphics are built around data sets where the geographic location is a key record attribute. A common and useful display of this information is often a picture of a geographic area with symbols representing data items positioned against a map of the area. The map provides the context necessary to relate the data items to their "real world" locations.

The maps most typically employed are generated by digital graphics hardware from chains of X,Y coordinates. These chains are then connected to form a geographic feature such as a boundary or coastline. The granularity of the resulting picture can run anywhere from very stylized to extremely detailed depending on the requirements of the application, the budget of the project and the ingenuity of the designers. In references (1, 2), for instance, a levels-of-detail approach is described that bounds the number of map points displayed for any given scale of map without depriving the user of useful information. This design also provides

*This work was supported in part by the Rome Air Development Center, United States Air Force, under Contract No. F19628-81-0001.

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a capability to automatically bring in new features such as roads and rivers at a large scale where further contextual information is needed.

The use of digital data alone, however, has limitations which can be significant in some applications. Many types of detailed terrain information are either basically non-linear, such as vegetation or contour shading, or linear but very dense (e.g. 100 foot contour intervals). While these features theoretically could be handled as chains of points, a great deal of storage and processing resources would be required in an interactive environment to support them. In addition, the digital source material to create detailed terrain maps is not available for much of the world and would probably have to be laboriously generated off-line.

In contrast to digital maps, there is an abundance of paper maps for most areas in the world. These maps come in many scales and projections and have often been tailored to highlight different features. Alternative approaches to map display can be employed using stored images of these maps. Two classes of solutions can be identified depending on the manner of storage. Digitized images can be created by defining a grid on the maps (typically 512x512 or 1024x1024 for raster scan devices) and assigning an integer for the image intensity at each point in the grid. Due to the large amounts of data required to define each image this approach magnifies all of the computer storage and processing limitations of digital maps based on chains of points. It is, however, useful for signal processing applications such as semi-automated photointerpretation where the photograph or map itself is the data of interest. Exploitation of LANDSAT data is one such application.

Image storage can also be accomplished in an analog form. Photographic slides represent one storage medium which is currently used for several specialized systems. These systems, however, typically suffer from electromechanical problems, are usually not reliable and can distort the image. A more interesting approach is the use of video recording devices for image storage. This medium is compatible with raster scan based graphics systems and can be used to store black and white or color images. No direct digital processing need be employed to display the image; the information can go directly from the recording device to the monitor. Consequently, there is no processing overhead and the computer system digital storage resources are not required for the image.

This paper describes an implementation of a terrain map display system based on the optical videodisc as a storage medium for the terrain map images. The terrain map display system is actually a subsystem for a testbed used to experiment with techniques for presenting and interpreting tactical battlefield information. The terrain map display system, however, has much wider application and represents a well-defined, separable subset of that testbed.

MAP IMAGE STORAGE WITH AN OPTICAL VIDEODISC

The optical videodisc player is a commercially available system for playing video recordings. Several manufacturers now produce or will soon be producing such systems. The Disco Vision Associates system used in our testbed employs a reflective plastic disc as the recording medium (Figure 1). A laser in the player scans pits in the medium and demodulates the resulting signal to produce standard NTSC color video. Two separate sound tracks (unused in this application) as well as a digital frame number are also encoded with each video frame. The player has a stop action feature and the ability to automatically search for an individual frame (via the encoded digital frame number). These last two features enable the continuous output of an externally specified frame and are essential to the use of the videodisc in our terrain map display system. Another computer based application has focused more on the search and play capabilities of the videodisc (3).

The discs are produced by the videodisc manufacturer from film or videotape source material supplied by the user. Once a master disc is "cut" copies can be produced relatively inexpensively. The storage medium is written on only once, during its

Figure 1 Videodisc Player with Disc

manufacture, and as such is a read only memory. This limitation is minor in our application, however, since cartographic information is relatively stable over time.

A disc with encoded frame numbers has a 30 minute programming capability per side. At 30 frames per second of operation this translates to 54,000 individual frames of color video per side. This extremely high capacity can be exploited to allow the storage on a single disc of many relatively large scale maps for wide geographic areas.

The videodisc player is interfaced to a host processor via a parallel interface. The host software provides the user interface, supports the frame selection algorithm, and sends the chosen frame number to the videodisc player. For historical reasons our implementation employs a Motorola 6800 microprocessor in the host/videodisc interface. The microprocessor was used in an early proof of concept implementation employing a carousel projector and scan converter for image storage. In that system the microprocessor was used to handle a more complex set of control functions. With the videodisc a parallel interface directly connected to the host could be substituted.

HARDWARE CONFIGURATION

The hardware configuration of the video terrain system is shown in Figure 2. An Interdata 8/16 minicomputer acts as the host and controls the digital graphics system as well as the videodisc. User inputs to the system are received from a joystick and an alphanumeric terminal. Three function buttons on the terminal control the geography. Other function buttons along with keyboard commands are used by the host applications software to control the foreground graphics.

A nineteen inch color monitor is used to display the terrain maps and dynamic data. In order to mix the foreground and background video for

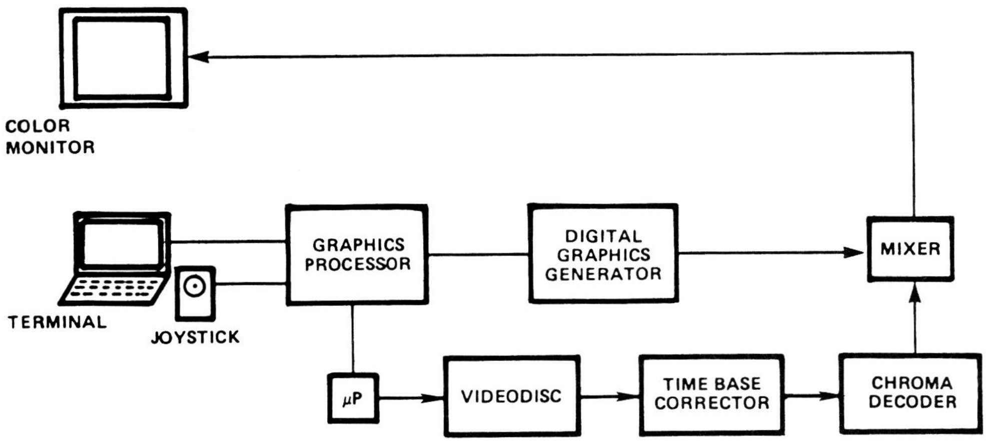

Figure 2 Hardware Configuration

output to the monitor a time base corrector is used to stabilize the videodisc output. In addition, a chroma decoder is required to convert the NTSC color video signal from the videodisc to RGB video signals compatible with the digital graphics output. Finally, a camera is used to supply color hardcopy products of the graphics screen in the form of 8x10 inch Polaroid photographs or Ektachrome transparencies. The user station is pictured in Figure 3.

Figure 3 User Station

Since the videodisc is essentially a rotating medium, its video output is subject to flutter and wow. The videodisc player internally corrects the synchronization sufficiently to drive a color monitor but not enough to enable direct video mixing with the digital graphics output. The time base corrector is employed to horizontally and vertically synchronize the two signals enough to produce a stable composite picture. Without this correction the foreground and background would move relative to one another.

TERRAIN MAP DATA BASE

Due to the nature of the medium, data must be presented exactly as it is stored. That is, if a picture of Germany with Frankfurt centered on the screen is required by the user then that picture must be pre-stored on the videodisc. To provide a flexible environment where the user can roam around or select specific areas of interest, many maps must be pre-stored on the system. Even so, any change in the terrain being displayed must be discrete in the sense that a different, pre-defined picture must be selected to accomplish the change.

A certain amount of overlap between maps is desirable to enable effective work in the neighborhood of an object. While requirements may vary depending on the specific task, experimentation has indicated that a 50% overlap in both the North/South and East/West directions is sufficient for most applications. This amount of overlap allows objects near the corners or centers of an edge to be positioned at the screen center by selecting another map (Figure 4). To cover a given area with 50% overlap requires

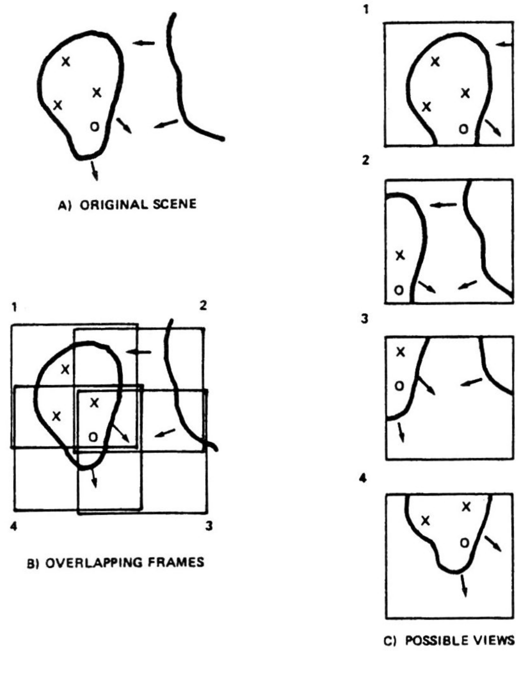

Figure 4 Frame Overlap Scheme

four times as many frames as a non-overlapping set of maps. Consequently, the storage capacity of the system is effectively reduced by a factor of four.

In most applications the ability to move from wide areas to smaller areas is necessary. The user, for instance, may want to work for a time in a small area, move out to a larger area to get re-oriented and then zoom down into another area. This capability is provided by storing maps at multiple scales on the videodisc. Again, the movements are discrete in that they are accomplished by selecting different pre-stored maps.

The 3000 map data base developed for our testbed system covers a 550 mile by 750 mile region in central Europe that includes East and West Germany and parts of Denmark, Czechoslovakia and Poland. Using the same format all of Europe could be stored on one side of a videodisc platter. Five different scales can be selected including one map of all of Europe down to maps covering 55 mile by 45 mile areas. The distribution of maps is given in Table 1.

The map data base was created by photographing paper maps and having a videodisc cut from the resulting film-strip. The paper maps were taken from several different map series published by the Defense Mapping Agency. The most detailed maps were taken from the TPC (Tactical Pilotage Chart) series which are at a 1:500,000 scale. The actual scale of the map being displayed, however, depends on the size of the area of the paper map that is photographed and the size of the CRT screen. On our system's nineteen inch screen, each major image occupies an area with a seventeen inch diagonal. The largest map scale on our terrain map display system is therefore, approximately 1:280,000.* This particular scale, however, is not a system limitation and larger scale maps could be produced from the TPC maps or more detailed terrain maps. If a 1:50,000 series of maps were employed as the source material, for example, a 6 mile by 5 mile area could be presented on the screen at an effective scale of 1:28,000.

Table 1

Distribution of Maps in Testbed Data Base

Level	Number of Maps	Nominal Scale on 19" Monitor
1	1	1:10,100,000
2	2	1:3,000,000
3	26	1:1,000,000
4	600	1:500,000
5	2202	1:250,000

In general, the number of maps required to cover a given area is related to the square of the scale. Consequently, the size of the most detailed scale to be presented influences the size of the coverable area more strongly than the number of scales present in the data base. For instance, it takes sixteen times as many maps to cover a given area at a 1:500,000 scale as it does with a 1:2,000,000 scale, but to include the smaller scale series requires only a 1/16 increase (i.e., 6%) in the number of frames.

In certain applications, notably route planning, maps oriented with North at an angle may also be useful. Maps at many angles would have to be provided since the direction of travel would not be fixed. The impact on the overall system coverage would depend on the granularity of the angle desired. For 90° (i.e. North, South, East or West would be "up" on the screen) the multiplying factor is 4, for 10° the factor is 36. In any case, the 54,000 frame capacity of a single videodisc provides reasonable room for most uses.

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*The effective scale can be derived as follows:

effective scale = scale of paper map

$$\times \frac{\text{diagonal of CRT screen}}{\text{diagonal of photographic mask}}$$

$$= \frac{1}{500{,}000} \times \frac{17 \text{ inches}}{9.5 \text{ inches}} = \frac{1}{280{,}000}$$

DISPLAY OF DYNAMIC INFORMATION

The capability to display dynamic information on top of the terrain maps is a requirement for our tactical battlefield display system as well as for most other envisioned applications requiring map data. This dynamic information can take the form of symbols, points, lines, curves, etc. that represent some physical or defined item. A building, radio antenna, flight plan, mass of troops or weather front are just a few of the possibilities. A digital color computer graphics system is used to display dynamic information in our testbed system. The video output from the digital graphics generator is mixed with the video signal from the videodisc to produce an overlayed picture (Figure 5).

Geographic control is accomplished with a joystick and three function buttons: zoom-in, zoom-out and translate. The joystick is used to position a cursor which is used by the host processor to compute a latitude/longitude. This position along with a data base describing the center and extent of all terrain maps on the videodisc is used by the host processor to select a new map. If a zoom function is involved, the map at the next smaller (or larger) scale whose center is nearest to the cursor position is selected. For a translate function, maps of the same scale are searched against. The host can then cause the videodisc to display the new map and can appropriately adjust the position and scale of the dynamic data via the digital graphics generator. While the responsiveness of the system is somewhat dependent on the amount of digital graphics being displayed, most geographic transformations require one to two seconds to perform.

Overlaying of the digital graphics and terrain maps is accomplished by a simple combination of the pictures without the use of any reference points internal to these pictures. Consequently, care must be taken to ensure that the host processor correctly maintains the registration of the images. Three important factors for the registration are 1) the distortions introduced when photographing paper maps, 2) the accuracy of the data base describing the terrain maps and 3) ensuring that the projection function used for the foreground data is identical or sufficiently close to the projection function of the terrain maps. Fortunately, maximum position differences between the foreground and background pictures are percentages of the screen size so if a more accurate fix on an object is desired a larger scale map can be used.

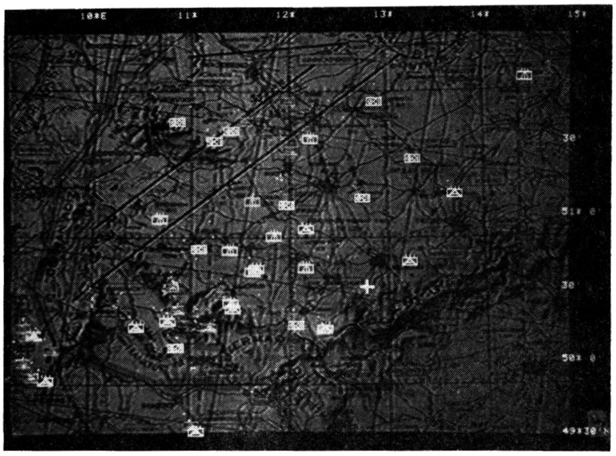

Figure 5 Overlayed Picture

To accomplish the foreground/background mixing a video switch was developed in-house. The switch outputs background (map) video unless one of the foreground RGB signals is present. In the latter case, the switch outputs the RGB foreground signals. Initial experiments at mixing the signals simply averaged the signals. With that approach, the black digital graphics background halved the intensity of the terrain maps and a colored foreground symbol acquired colors from the map. A red symbol against a blue map, for instance, appeared purple. The switching approach was used to avoid the washout problems described above and to highlight the digital graphics.

CONCLUSIONS AND EXTENSIONS

Based on our experimentation, the videodisc appears to fill a useful gap between applications that require only simple, stylized maps and those that require very detailed digital data bases containing terrain data. The use of image data rather than digital data bases frees up computer storage and processing resources that can be applied elsewhere. In addition, the use of familiar maps and the resulting increase in user acceptance can be an important factor in automating existing manual applications. While DMA maps were used for our experiments any paper map or photographic material can be recorded on a disc including a standard world atlas, road maps, serial photographs, and Landsat data.

The high capacity of the videodisc, 54,000 frames, makes it an ideal storage medium for terrain maps since there is room for many types of maps at several scales with the built-in overlap necessary for user flexibility. The potential for increased future capacities as well as digital videodiscs can only increase the utility of videodisc technology. The storage of images, however, does not support automated techniques employing map data such as position estimation for ground objects following a road network, automatic route planning, or computing terrain shielding. For these types of applications a detailed digital data base and large amount of processing power would still be required.

The use of existing paper maps for source material is not without its limitations. These maps are a compromise between all of the features that the end user might need and the amount of clutter produced by each of them (4). The use of feature overlays is one approach to providing the user with control over the map content in support of different applications. In a separate effort at the MITRE Corporation a Video Frame Store is being developed to explore this approach. The frame store will enable feature overlays for the same geographic area to be brought in from the videodisc or host computer and combined into a composite map. Color transformation capabilities will be included to allow certain features to be highlighted and pixel interpolation algorithms will be available for subimage expansions. The video frame store will eliminate the requirements for a time base corrector since it acts as a frame buffer. More importantly, it will provide significant additional flexibility to dynamically tailoring maps to specific applications and will enable more continuous zooming and panning movements on the screen.

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