RAPID SIMULATION DATABASE BUILD USING HARDCOPY INPUT

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ABSTRACT

This paper describes the result of a research and development effort focused on developing technologies supporting rapid extraction of simulation databases. The specific goal of the project during this period of time was to significantly reduce the time required to extract features [roads, contours, streams, etc.] from graphic hardcopy sources [i.e, maps and charts]

This problem is significant to overall database construction cost and timelines. Currently, attempts are being made to use large maps scanners and commercial vectorization software to improve extraction efficiency. Unfortunately, the result of the use of only color or intensity to separate objects is that substantial interactive editing of the final product is necessary. This restricts the use of maps as an effective information source.

A new process was defined as a result of this task. It represents an integration of insights gained through the technologies of image processing, pattern recognition and neural network based learning. It represents two kinds of improvement: (1) A reduction in setup time [the operator need only identify typical objects, not define a complete color lookup table] and (2) reduction in interactive editing [by on the order of 90%] due to the higher quality of the output.

Examples are presented of images which illustrate the new process. They show the very significant capability which has resulted. In addition, possibilities for extension of the process to multi-spectral image data are defined.

BIOGRAPHIES

Edward Quinn is a Section Manager within the Cartographic Systems Department at Loral Defense Systems/Akron. His activities are focused on system design and implementation for database generation and database related products within the Simulation Division. He has written a number of technical papers, all on these topics. Ed holds a Masters Degree in Physics. In addition, Ed is an Adjunct Professor of Computer Science at Kent State University.

Gregory DeLozier is a Senior Scientific Analyst at Loral, specializing in scientific and technical applications of image processing, artificial intelligence and systems level applications of computer science. His current work is concerned with the use of integrated pattern recognition technology for cartographic database generation. He has written a number of technical papers in these fields. Greg holds a Masters Degree in Computer Science and is currently a Ph D. candidate. He is, in addition, an instructor at Kent State.

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INTRODUCTION

The rapid construction of databases is a long term goal which supports the objectives of all phases of simulation. The criticality of this technology is particularly important for applications such as mission rehearsal. The cost reductions which the technology implies are of increasing importance as well, due to the increasing proportion of total system costs which are associated with database construction.

For simulation based on the presentation of real-world terrain, a problem is that a great deal of the geographic knowledge of the world remains stored on hardcopy maps and charts. Paper maps represent an intellectual resource which has been refined by geographers over several hundred years as a carrier of information in a format which can be readily assimilated by human beings.

Although attempts to automate information extraction from paper maps are continuing, it is estimated that roughly 90% of the potential information which could usefully be extracted remains only in hardcopy form.

This difficulty is due to the very different methods which computers [and image generators] require that geographic data be stored. An illustration of this difference is the fact that the only use of map-like hardcopy graphics in a simulation environment is to convey the content of the simulation database to human beings.

This mismatch between the way that human beings have represented and interpret data and the very specialized formats required for real-time simulation is a fundamental problem which impedes advances in the use of simulation as a tool to refine designs, train equipment operation and aid the planning process, regardless of the application. Rapid database build is the technology which attempts to bridge this difference and resolve the problem in a cost effective way.

TECHNOLOGY BACKGROUND

1. Data Tablets

Initial efforts to extract information from paper maps were focused on efficient methods of using data tablets to manually delineate the geographic positions of objects, using a special cursor control device [a puck] to do so. For this task, the puck was augmented to include function keys and even miniature numeric keyboards. By this means the necessity of the operator of continually shifting their attention from the computer keyboard to the puck was minimized.

Other techniques, such as staged data extraction and efficient editing tools were also introduced. These allowed the complete data collection and attribution task to be achieved at an overall average rate of approximately one feature [lines, points or areas] per minute.

For specialized tasks, pucks which included image sensor arrays were also introduced. For high contrast [black/white] idealized sources, these reduced the necessity of the operator to precisely follow the line. These restrictions on the use of this technology prevented its widespread application.

2. Softcopy Digitization

Hardcopy image scanners became available, initially as a result of process color industry applications. These are capable of rapidly converting the hardcopy map to a digital image. The increasing power and display capability of the computer workstation, when coupled with the recent introduction of low cost desktop scanners, has given rise to increasing use of softcopy [or "heads-up"] digitizing. The capability to control all modes of the process [editing, data collection, merging, database management, etc.] directly from the workstation's graphic screen has made this mode of operation increasingly popular.

3. Spectral/Intensity Extraction

Given the widespread availability of image scanners, it is natural to attempt to directly use the image as the information source for extraction [i.e, without human interaction]. In viewing a hardcopy map, it [at first glance] seems obvious that the use of discrete rather than variable colors, standardized symbology and stable scaling would make a color based automated extraction process relatively simple. Indeed, a number of commercial ventures are based on exactly this approach. Such a process is illustrated [at the top level] in Figure 1.

Unfortunately, complications exist which prevent the complete realization of the objective of a highly automated approach. These include such factors as the use of halftones [in which discrete color combinations are used to represent intermediate colors] and the physical size of the scanning aperture [which mixes colors over a wide range at the boundaries of objects]. As a result, the color map image is presented to the computer as a series of pixels with color values ranging over a wide scale. No convenient process is available to convert the digital image to a form more nearly representing that which is perceived by the human eye.

A consequence of this limitation is that errors are incurred in extracting separate 1 bit image layers for each object type. This results in the requirement for substantial manual intervention and editing operations. Only approximately a 2:1 improvement is achieved in efficiency [over puck based digitization]. Given scanner and software acquisition costs, as well as the cost of editing itself, this prevents the widespread use of this process for converting color map information to an intelligent vector database.

IMPROVED PROCESS

Our organization has explored this problem in detail for both maps and multi-spectral imagery for several years. This focus is due to the importance of this technology to efficient, rapid extraction of information for mission rehearsal, planning and other simulation applications.

In April, 1993 a new initiative began which examined the issue from the perspective of an integrated approach. It was observed that a number of attempts had been made in the past which attempted to solve the color extraction problem. Each had examined the problem from the perspective of the potential gain to be realized from the use of a single element of technology.

An example of this is the use of statistically based extraction, which attempts to derive optimal feature class boundaries in color space. A variety of algorithms [K-Means, Isodata, for example] are available for such feature class partitioning. However, as mentioned previously, the use of halftones on maps and a finite scanner aperture size significantly degrades the result of any color extraction process. The colors presented to the computational process are not completely unique.

Hence a technique which is based only on color is guaranteed to result in errors.

Before beginning the process of researching an integrated approach, the following objectives were established:

1. The new process would easily interface with current methods [color based extraction], without materially affecting overall process flow. This would ensure a relatively easy transition to new methods.

2. Operator interface/training would simplify the process rather than increasing its complexity. In essence, it is required that the operator be concerned with identification functions rather than functions based on setting up a data structure.

3. The development process would be such that prototypes could be easily constructed, strung together, and revised [or expanded] to handle additional classes of problems [such as multi-spectral image extraction].

The above objectives were achieved as follows:

1. Process Interfacing: The new process accepts the same 24 bit color raster input file currently being used for feature extraction. The output is a series of 1

bit/pixel images which indicate the presence or absence of the desired object. These files are directly processed by commercial vectorizers, just as current outputs are.

2. Operator Interfacing: The use of a neural network to interactively develop classification parameters was chosen. Rather than directly setup the process pipeline, the operator identifies examples of object types. The network then setups the pipeline with the proper parameters, after it has "learned" them. This identification process is simpler than the process of attempting to setup a color look up table.

3. Development Environment: Use of the Oberon Object Oriented Development Environment [1] was chosen to allow rapid prototyping within an environment that could support an efficient visual user interface.

In addition, Oberon allows process insertion and modification to be accomplished interactively without long recompilation sequences. Recompilation of even procedures that are thousands of lines of code consumes only seconds of time and can be performed without recompiling unaffected portions of the code body.

An additional assumed requirement of the developed process was that, in order to maximize the probability of success, a multi-stage classification approach would be used. As finally implemented, the process uses mixtures of trained networks and conventional pattern recognition and/or image processing algorithms to solve specific components of the problem.

The basic principle of our process relies on a coarse to fine classification. The advantage of this approach is that for simple initial decisions, only a subset of the total possible parameter space need be used, leading to rapid decisions as well as easy learning and training evaluation. As the process continues, the tests become more refined and selective. Consequently, the use of specific image measurements is injected in order to clearly differentiate between closely related possibilities. By minimizing the range of possibilities at each stage and restricting parametric inputs to only those of significance, processing time may be constrained to be within acceptable limits and the complexity of the process at each stage is constrained as well.

At the end of the process, a most probable classification has been assigned to the pixel being tested. The appropriate location is marked in the corresponding feature separate layer [one layer for each type, such as road, contour, etc.]. For cases where a strong degree of ambiguity still exists, two locations may be marked.

This redundancy is also a capability of the process that is not available with conventional approaches. It significantly reduces the possibility of gaps and holes in the output [which must be filled, either interactively or automatically]. As a result, image postprocessing to correct such deficiencies [prior to vectorization] are significantly reduced and simplified.

As with other elements within the processing pipeline, this kind of
processing is also adjusted to be sensitive to feature type.

PROCESS ILLUSTRATION

In order to demonstrate this procedure, a simple example will be used. This example concerns the extraction of contour information from a map. Such a process would be required in order to derive a terrain surface for simulation [with additional processing of the contours for actual generation of the surface].

Figure 2 shows the original map. It is a standard color map scanned using a conventional 300 DPI color desktop scanner. The output file being viewed may be formatted as a 24 bit TIFF file, or in variety of other formats for viewing.

When viewing the image, the operator can identify on the large screen area devoted to the map a number of examples of each kind of feature [Figure 3]. A maximum of eight object types can be simultaneously trained. After initial samples [and counter examples] have been collected, the pipeline solution to classification can be generated.

The operator can then probe the solution by using the cursor to designate the center of a small square region and then examine the solution [several of these are present in figure 4]. If in error, the samples are immediately corrected [relabeled]. After a suitable number have been examined, the process cab be reiterated if necessary.

Experience has shown that a maximum of three passes of the solution/correction cycle is necessary. The process has been tested by both persons familiar with the algorithms involved and with relatively unfamiliar personnel, with similar results.

A single bit image showing the result of classification is shown in Figure 5. The result of the new process results in very stable line work and little noise. This significantly reduces the interactive cleanup work which would otherwise be necessary before attempting vectorization.

Two additional stages of processing are shown in Figures 6 and 7. In Figure 6, the contours have been vectorized and labeled. This process involved a small amount of interactive time to review the data [always desirable during data collection] and then attribute it. This time was much less, however, than would have been required with the color based data.

Figure 7 shows the resultant terrain surface in a perspective view. The contours were converted to a Triangulated Irregular Network ["TIN"] and then a terrain matrix constructed.

FUTURE WORK

At this point, the process is nearing the point where it may be used as an operational capability. It has been demonstrated to work with DMA Arc Digitized Raster Graphic [ADRG] images, images from large format scanners, and desktop scanners of a variety of qualities. Although work could still be performed to enhance the user interface and further reduce processing time, the advantages of the process are readily available at the current stage of development.

The success of the technique is also encouraging our group to apply it to multi-spectral imagery. The problems of map data collection bear much more resemblance to image processing than we had first imagined when the project was initiated.

A similar success with imagery would significantly enhance data collection for areas where current hardcopy map data of the proper scale is not available. It appears to us that by tuning the spatial descriptors to reflect the scale of objects which must be extracted, the outline of the current process can be largely kept intact. Here, as with the map data extraction process, the goal would not be to solve all possible classes of feature extraction problems at once. Instead, it would be to significantly enhance and simplify current methods.

It is our belief that the availability of this approach would be of great value to the problem of extracting databases for simulation and other applications.

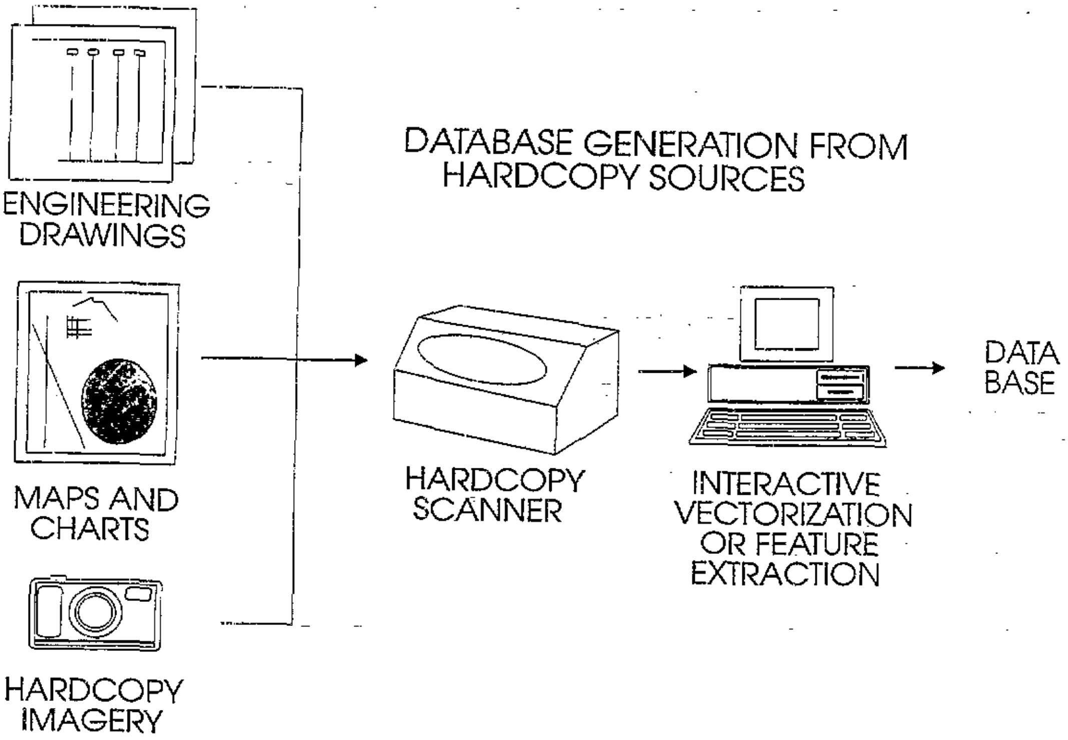

Figure 1 Hardcopy Processing Sequence

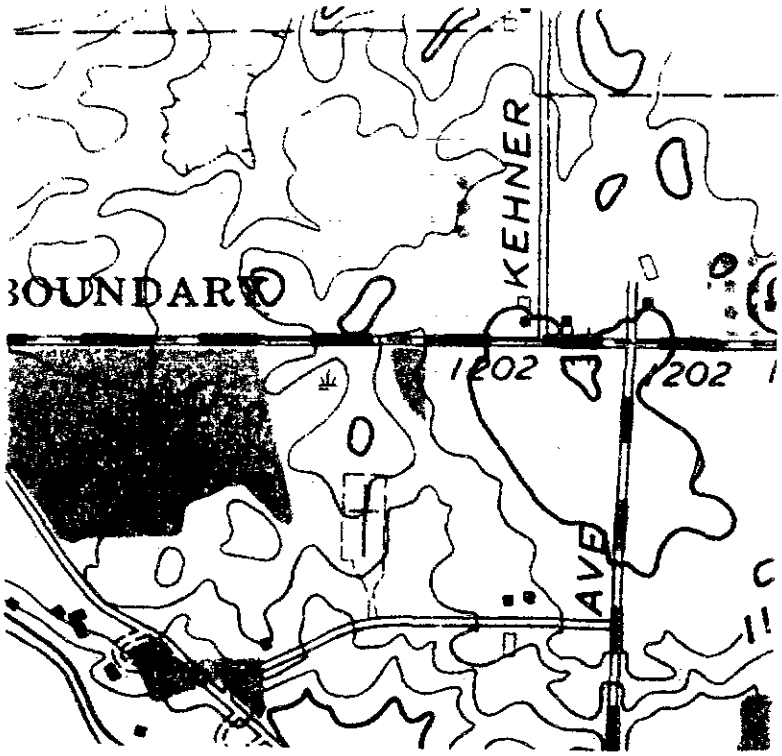

Figure 2 Original Color Map

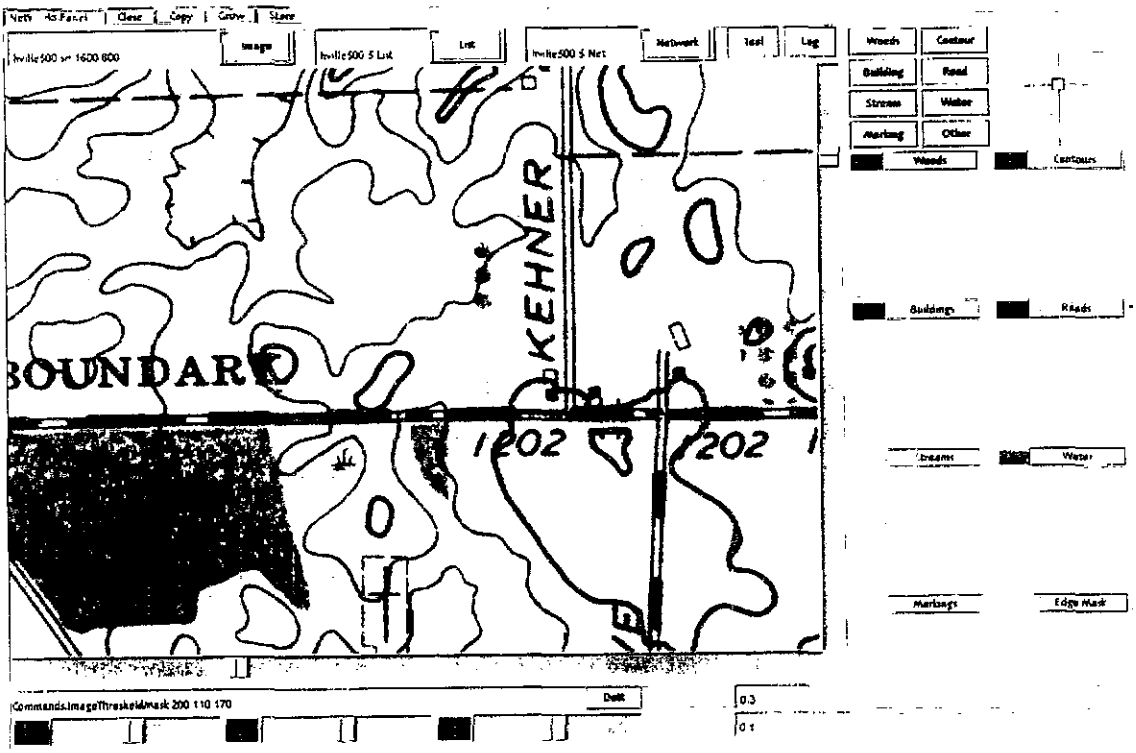

Figure 3 Color Map Interactive Screen

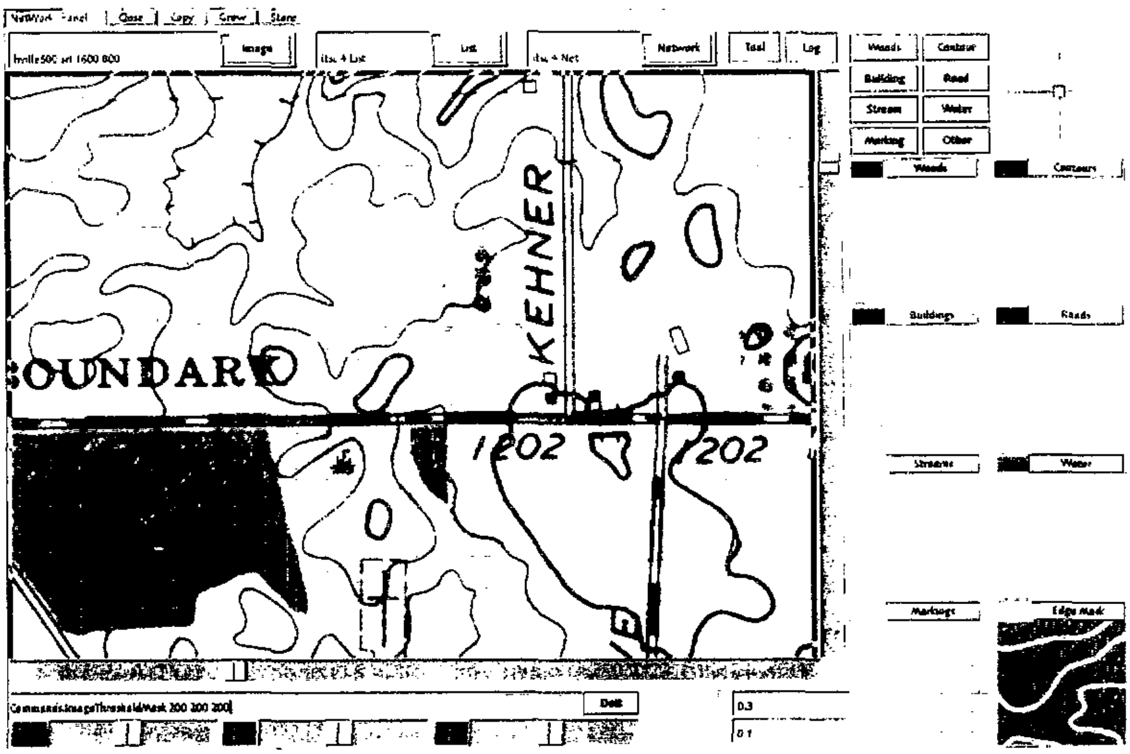

Figure 4 Trial Classification for Map Output

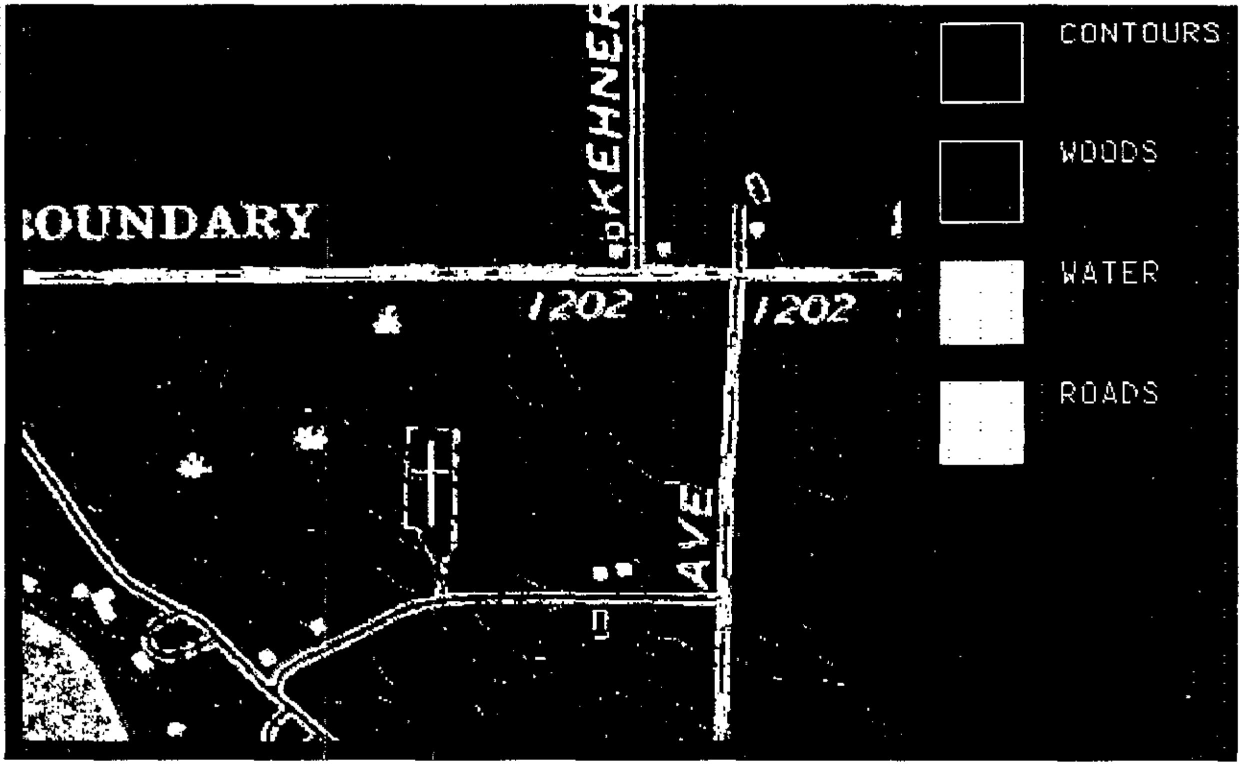

Figure 5 Classified Map Output

Figure 6 Map Vectors for Contour Layer

Figure 7 Perspective View Using Map Contours