PRACTICAL APPLICATIONS FOR DIGITAL CARTOGRAPHIC DATA BASES IN TACTICAL SURVEILLANCE AND STRIKE SYSTEMS

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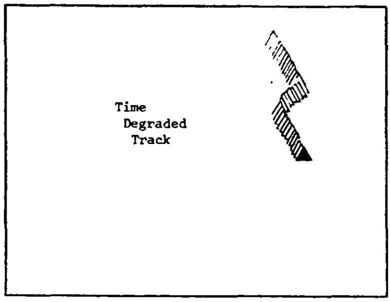
1.0. Introduction

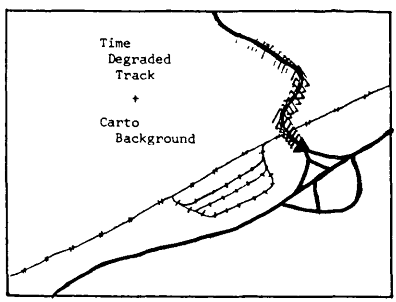
Digital cartographic data bases are becoming increasingly important in military applications for two reasons. First, radar surveillance and strike systems require cartographic data in order to place the otherwise cryptic radar-detected target symbols in a context that human operators can more easily understand. Figure 1-1 demonstrates the situation. Frame A shows a simple time-degraded target track. Notice how much more understandable the track becomes when projected against a cartographic background display in Frame B. This enhancement of symbolic radar reports is one benefit derived from tactical digital cartographic bases. In addition, accurately located cartographic features can help improve the radar's ability to find and track targets of interest.

The problems resulting from these applications will require solution by cartographic data base experts in the near future. To provide an indication of the direction solutions might take, this paper will present an overview of some applications of tactical digital cartographic data, including terrain shadowing calculations. The three types of data most used in tactical data bases are reviewed, along with their storage characteristics and current data sources. Due to space restrictions, this overview must of course be brief.

The problems described in this paper arose during work on two developmental surveillance and strike systems under research by the USAF.



A



B

Figure 1-1
Context Enhancement

2.0. Tactical Applications

The need for wide area reconnaissance in the near-real time frame of modern combat has developed out of the length of the borders that must be considered, especially in the European theater of operations, and the need for early warning of impending attack in order to expedite mobilization. As previously noted, the long range sensor reports by themselves are not sufficient to present the situation to a military analyst; they must be placed on a cartographic background to make sense tactically.

If a strike is to be called on the strength of sensor reports, the possible context of the target's movements must be examined closely. If the targets are moving into an area where the sensors will be unable to detect them, the strike must be postponed. Tracking a target accurately depends on locating it in four dimensions: x, y, z, and time. The sensors can provide accurate information on range, Doppler shift (target speed relative to the sensor), and time. This information must be correlated with the road network data in order to locate the target accurately. Thus, information about the target's location relative to bridges, rivers, railroads, and forests can be greatly helpful in planning future strikes.

By examining reports from one sensor in the context of the surrounding area, it is possible to "cue" other sensors to look at the target. This becomes increasingly important when targets have moved to areas where loss of contact is imminent due to foliage or terrain shadowing, which would not affect another sensor with different operating characteristics.

A further use for cartographic underlays involves accurate portrayal of the Ground Order of Battle (GOB), hostile anti-aircraft (AA) unit locations, and marshalling areas. This information is used to analyze and forestall hostile unit actions, and to locate safe penetration routes for strike aircraft.

In addition to actual combat applications, cartographic data is vital to realistic battlefield simulations. The prohibitively high cost of field tests has increased the importance of such simulations in recent years. Generating these simulations requires interactive access to lineal cartographic data in order to locate simulated targets realistically.

3.0. Terrain Shadowing

Terrain shadowing is the process of calculating the obstructions between a radar sensor platform and a target in order to determine if the target can be seen by the sensor. This will allow strikes to be scheduled for a time when the target is visible and will remain visible.

Shadow calculations attempt to answer one of two questions: "Given a platform position, what areas are shadowed?" and "Given a platform and a target, is the target shadowed?" Thus, terrain shadow calculations must consider the altitudes of both sensor platform and target, as well as the distance and bearing from sensor to target.

A terrain elevation model of the area being searched can be used to predict the shadows for a given platform position. For a simulation of a sensor, the terrain-model can be used to determine if the simulated target is shadowed. This terrain model is constructed from hypsographic data. The major problem with this approach is the lack of readily available data for most parts of the world.

4.0. Types of Tactical Cartographic Data

Tactical data bases use three types of cartographic data: lineal, areal, and hypsographic. These are understood in a specialized sense which probably lags behind the state of the art.

4.1. Lineal data

The term, lineal data, is used to describe those features of the earth that can be recorded as lines without losing any vital location information. These lines are actually strings of discrete cartesion coordinate points, usually recorded in terms of Lat.-Lon., x-y inches (from the lower left corner of the source material) or x-y meters (from some arbitrary position on the Earth's surface).

Lineal data is used to record features of particular tactical interest such as roads, railroads, airport and populated area outlines. Single point lineal features are used for landmarks, bridges, tunnels, and chart reference points.

In order to manipulate classes of features easily, each feature is described using a codified classification scheme, requiring about 12 bytes of encoded header information followed by 60 (or so) characters of descriptive text. The text usually contains a specific identification for the feature (such as "HUDSON RIVER", or "Route 365"). A type of single point feature called a "Graticule Point," provides the control for performing projection transformation, and registration. These are recorded in a pattern across the chart, combining the Lat-Lon or UTM grid coordinates with the Cartesian Coordinate x-y values of the digitizer.

4.2. Areal data

Areal data differs from lineal data only in the meaning of the lines, which represent the borders around features (such as swamps, lakes, and forests) rather than the features themselves. This difference presents some very difficult problems for data processing, however, since what is stored in the computer is not the feature of interest, but its outline. Although some techniques for symbolizing areal data using "Area Fill" have been developed, no work has yet been done towards developing techniques for making tactical use of this data. Figure 4-1 presents an example of symbolized areal data in order to illustrate the following discussion.

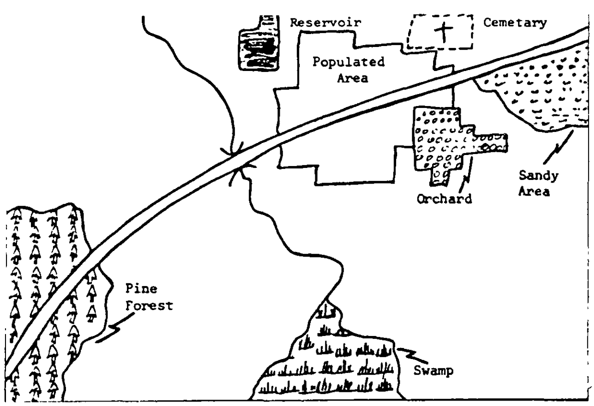


Figure 4-1
Areal Data Examples

The lack of such techniques creates several problems, which will require solutions in the near future. For example, there is a great need to be able to determine if tactical MTI (Moving Target Indicator) radars can "see" through foliated areas. Since no information is recorded inside the borders of the area, the terrain shadowing techniques described in the next section cannot be used. Instead, analysts must make a large number of assumptions about the contents of the area, including the average height of the foliage, the ratio of deciduous to coniferous trees, and the percentage of the area actually foliated.

Another difficult problem in working with areal features is deciding whether the feature is closed or not, and on which side of the line the feature exists. When the map segment under consideration contains only a portion of an areal feature, it is impossible to determine on which side of the boundary the feature lies without examining the entire feature.

4.3. Hypsographic data

Hypsographic data is useful for tactical systems in two ways: providing an elevation coordinate to improve tracking accuracy on lineal road coordinates, and provide data for terrain shadowing calculations.

The primary problem with hypsographic data is that it is largely unavailable and when obtained, in a form that is inconvienent to work with.

5.0. Data Characteristics

There is no difference between the data characteristics of areal and lineal data; both are recorded as strings of coordinate values with an attached header record describing the type of feature. The primary consideration when processing lineal data is to preserve the network continuity to allow for automated route following from node to node. Areal data, in contrast, describes not a network but a boundary. (The only areal data used so far, was the boundaries of highly populated areas, which provided a context for reports shown on the wide area display.)

The storage space needed for lineal data has little relationship to the area being covered; instead, it depends mainly on the density of features of interest and the granularity of the data. Carefully adjusting the granularity for the most accuracy with the least number of data points will permit a reasonably small area (40 km x 60 km) to be stored at an accuracy of 15-20 meters using around one million bytes for x, y, and z coordinates. Attempting accuracies of 10 meters or less can increase the amount of data dramatically. The controlling factor for accuracy in data culling is the straightness of the network segments. Very straight segments (even long ones) can be stored with only two points, while curved segments may require thousands of points to represent the same distance.

In contrast to lineal and areal data, hypsographic data is recorded as a matrix of elevations, with each elevation's position in the matrix corresponding to its position in the real world.

The storage space needed for matrix data is directly proportional to the spacing within the matrix and the size of the area it represents. Storage may vary from several thousand bytes for a small area (40 km x 60 km) with wide spacing (about one elevation value every 500 meters), to tens of millions of bytes for a large area (120 km x 240 km) with a narrow spacing (one elevation value every 30 meters).

6.0. Data Sources

Although cartographic data bases have been evolving along with computer assisted cartographic techniques, most of the research has been in support of map sheet production. In order to create a tactical cartographic data base, it is necessary to first collect the digitized data from existing charts, and then to transform this collected data into some form that will support the requirement for rapid access. Experience has shown that such diverse distributors of source materials as the USGS, DMA and New York State Department of Transportation Map Information Unit must be used in order to complete the collection process. This same experience has shown that the chart collection, digitization, transformation, and data base creation processes can require excessive expenditure of manpower and time. The problem of maintainability is compounded by the scattered sources, and overly complicated collection process.

7.0. Recommendations

The best approach to the problem of integrating cartographic data would be to maintain a single data base that could provide any of the various types of data required. This seems impossible at present, because the diverse formats used to record different data types are incompatible. Failing the development of a general purpose data base, the rule should be: "Let the form fit the function."

The requirements for accuracy, accessability and maintainability dictate that data bases for display contain more types of features, but not necessarily to a very accurate level, while tracking data bases require only one or two types of data, but must be more accurately recorded. The display requirement might easily be met by using actual images of the appropriate maps, while the tracking could be done with data recorded from aerial photos, using state-of-the-art orthophoto digitizers. Thus, the great amount of detail required for display, and the accuracy of location required for tracking could be easily provided.

8.0. Summary

Digital cartographic data bases are of increasing importance to tactical advanced sensor exploitation. The requirements for improvements in accuracy, accessibility, maintainability, and flexibility of digital cartographic data bases have been changing so quickly that they have outstripped the state of the art. Major advancements in all these areas are required in the near future.