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WITH A WORLDWIDE DATABASE(U) ARMY ENGINEER TOPOGRAPHIC
LABS FORT BELVOIR VA K KURTZ ET AL. 1985 ETL-R-077

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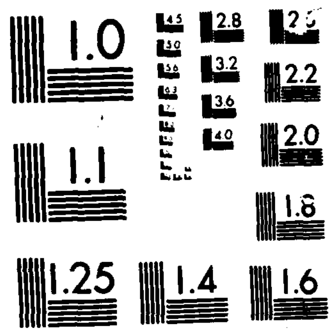

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ETL-R-077	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): GIS-Based Applications with a Worldwide DAtabase	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): K. Kurtz and T.E. Jorgensen	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Topographic Laboratories, Fort Belvoir, VA 22060-5546	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release;
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

software
terrain analysis
Digital Topographic Support System (DTSS)
geographic information system
map

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This presentation will deal with difficulties associated with developing GIS-based applications programs capable of being used worldwide, or for a significant portion of the world. Issues discussed will include data format requirements, on- and off-line storage requirements, coordinate and datum transformation problems, and the need to write software which can be easily used by an operator who may not be an expert in Geographic Information System (GIS) operation or in a particular discipline for which the software is based. Alternate solutions to the problems will be pre-sented, and trade-offs involved in the various solutions, with respect to the

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GIS-BASED APPLICATIONS WITH A WORLDWIDE DATABASE

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ABSTRACT

This presentation will deal with difficulties associated with developing GIS-based applications programs capable of being used worldwide, or for a significant portion of the world. Issues discussed will include data format requirements, on- and off-line storage requirements, coordinate and datum transformation problems, and the need to write software which can be easily used by an operator who may not be an expert in Geographic Information System (GIS) operation or in a particular discipline for which the software is based. Alternate solutions to the problems will be presented, and trade-offs involved in the various solutions, with respect to the issues mentioned above, will be discussed.

Keywords: Terrain analysis; DTSS (Digital Topographic Support System),

INTRODUCTION

The purpose of this paper is to present problems encountered and solutions considered in developing GIS-based software for worldwide application. This software is being developed to automate and expand upon terrain analysis processes currently carried out by hand using map-based products. The software we have been developing uses data in either gridded or vector format depending on the individual model, and in some cases, a combination of the two. The software will eventually become part of the Digital Topographic Support System (DTSS), an automated terrain analysis system to be fielded in the early 1990's. The DTSS will be used by terrain analysts with an understanding of the input and output requirements and purposes of the models being used but with a limited background in computers and geographic information systems. The software should produce outputs at whatever scale and projection and for whatever area the user desires. The software should not be limited to a single area of the world, or to a few special areas, but must be able to work on the wide variety of areas around the world where it is possible that it will be needed.

Through the use of an advanced GIS for this development, a degree of flexibility not possible using the current manual techniques can be achieved. Work can proceed independently of map scales and map boundaries, and products can be produced which can be readily converted to the scale, projection and coordinate system desired. Data from different sources and in different formats can be combined into a product of the format we desire. Products can be generated for whatever area is desired, subject to data availability, and not be limited by artificial map sheet boundaries. Unfortunately, the organization and discipline imposed by creating products for specific pre-defined mapsheets and scales is lost by this approach. Our problem is developing software which takes advantage of the opportunities of a GIS without making the software too cumbersome to use or the output products and information too complicated to manage.

THE APPLICATION

The software we are developing is designed for terrain analysis applications. Terrain analysis is the process of analyzing a geographic area to determine the effect of natural and manmade features on military operations. At the heart of terrain analysis is the collection of terrain information which is raw data in any form about a segment of terrain. When these data have been evaluated, analyzed, interpreted, and integrated, they become terrain intelligence.

This intelligence may be useless or even dangerous unless kept up-to-date and its production and revision must never end. This continuing activity is carried on through the four-step intelligence cycle: (1) collection planning, (2) data collection, (3) processing collected data into intelligence, (4) dissemination of the intelligence. Once the four steps are completed, the process begins again, to keep intelligence up-to-date. Collection planning is the process by which deficiencies in terrain data are identified, and methodologies to build, maintain, or improve the geographic data base are developed for the purpose of providing the best possible intelligence products at the time of request. Data collection is a gathering process of the kinds and coverages of data identified in the planning process. Collection activities can involve imagery (both photographic and nonphotographic), maps, and written material. The volume and diversity of the collected material involved requires a concentrated data management effort to store and catalog the data using photo and map indexes.

Processing collected data can be described as the integration of the available data into concise written summaries and versatile thematic overlays that contain a collection or derivative of information not readily available before. The classical collection of overlays consist of surface configuration, vegetation, obstacles, hydrography, transporation, and soils. The map is a large contributor to the overlay content and the battlefield intelligence process is keyed to particular map sheets. The overlays use the established coordinate systems, scales, and neatlines of the map sheet to which they are keyed. Special purpose maps can be synthesized by combining or extracting the data from one or more of the thematic overlays and applying some algorithm to produce a terrain analysis product that contains the information required to answer a specific problem, such as a cross-country movement map. The process should be an iterative process by which a disseminated product can be further modified to incorporate additional information or specific user annotations.

The Digital Terrain Analysis System (DTAS) was developed at the U. S. Army Engineer Topographic Laboratories (ETL) to investigate the feasibility of automating the synthesis portion of the data processing step of the four part cycle previously described. The system uses prototype digital terrain analysis data sets developed at the Defense Mapping Agency's Aeronautical and Hydrographic/Topographic Centers. Each Center produced data sets with roughly the same content as the information found on the classic set of overlays. Both versions contained elevation data in gridded format. One version stored the feature data in vector form, the other stored them as gridded data. The prototype data bases provided us with an excellent starting point in our research but they were of limited extent, disjoint, and did not contain many of the specific physical attributes that can be found worldwide.

Software has been developed on the DTAS to process and display this data and incorporate algorithms necessary to create special purpose maps such as for cross-country movement. The DTAS software can be divided into three categories. The intervisibility category includes models which calculate and display electronic or optical line-of-sight. These models can be run to show visibility between points or to show a visible region for a given point or points. The models in this category use gridded elevation data which can be augmented with vegetation data, and perform somewhat complex geometric calculations. The GIS is used mainly for storing the final products. The overlay category includes those models which select areas or features based on some attribute and perform boolean operations on the overlays of areas with given attributes. These models usually involve simple selection criteria for the areas or features or may use a simple algorithm to calculate some value for all areas resulting from the boolean overlay, thus producing a new overlay. An example of this type of model is the cross-country movement model which combines soil, slope, and vegetation overlays to produce a vehicle speed overlay for a given vehicle under given conditions. The models in this category make extensive use of the GIS capabilities to store and access data and to overlay polygons. Finally, there is software which simply searches the data base for information, such as maximum elevation in an area, or performs simple calculations. Except where needed to access the data base, these models do not require advanced GIS capabilities. The current DTAS software is not completely suitable for a worldwide data base, and does not make best use of the capabilities available. Our current efforts focus on improving this software.

OVERCOMING LIMITATIONS

The traditional methods of storing geographic data by mapsheet at a given scale and projection are to a large extent imposed by the media used and are no longer required when data is stored digitally. As paper maps will be with us for the foreseeable future it is important for us to retain the capability to accept data and produce output consistent with these paper maps, but it is not necessary to organize data storage around the mapsheet framework. While it is not necessary to divide the data by mapsheet, the breaking down of data into files for management storage is necessary, but this breakdown need not be made visible to the user, who should only need to specify the area and type of data or product needed.

The scale can be chosen when the output product is generated, and this product can be for a specific mapsheet, for a part of a mapsheet, or for an area overlapping several mapsheets. The scale, projection, and coordinate system can be chosen to meet the needs of the user. One advantage of this approach is the flexibility it provides, that is to say the output format for a product is virtually unlimited. The user need only specify the area and type of product needed, and not have to determine what combination of some predefined standard products or areas will fulfill the need. Another advantage is that the time to create a product can be reduced considerably by only dealing with the area of interest, and not processing unnecessary information.

IMPLEMENTATION ISSUES

Designing the data base storage for a system using our applications software will be a task requiring a great deal of planning. The data base files, both elevation and geographic attributes, will have to be broken up for efficient use and storage. At the same time, requiring the user to specify the files where the data will be found for each run of a program would result in software more difficult to use than we feel is appropriate for the intended user. Current software uses hardcoding of file names or user specification of file names to a large extent, though this is currently under revision. The system will require data management tools for use with the software which will automatically direct the software to the correct data. It will also require a data structure to a large extent consistent for all parts of the world so that the software can recognize the location of data within the files. The capability may also be required to combine data for adjacent areas into a single file before processing when output products cover areas whose data are contained in more than a single file. Though these capabilities could be written into each program, the more likely approach is one in which a single software package performs the data location and retrieval tasks for all the software.

An automated terrain analysis system designed to operate worldwide will require a means of loading the data when the system is placed in the area in which it is to operate. For efficient functioning of the software, the internal storage of attribute data would be in a format required by the GIS. This is not likely to be the same format as that in which the data is provided, and so, a conversion would have to take place at load time. Preliminary estimates of the amount of data required are in the several hundred megabyte range, meaning on-line storage would require more than a single device. The loader would be required to allocate files to disk in a logical manner and in a way which best suits the software functions. It would also have to supply information to the data management tool to enable it to access the correct files when required by the applications software. The data loading tool and data management tools would have to be very closely interconnected.

As our applications software uses both gridded and vector data, the data loading tool would be required to handle both. The use of appropriate files would be decided by the applications software, and the relationship of gridded and vector data would have little if any effect on the design of the data loading and data management tools. These tools would probably handle the two types of data independently with the applications software dealing with the relationships. This software would require access to a grid-to-polygon and polygon-to-grid capability which would probably be part of the GIS.

The transition of digital topographic data from established roots in simulation applications to targeting and intelligence functions has driven the data production process to push the limits of the capabilities of the collection methods and equipment employed. Targeting and intelligence functions require data which more precisely describes the area of interest, unlike simulation applications which require data representative of an area's characteristics. As the usage of digital topographic data expands, we can expect to see user requirements push toward more accurate data bases, with higher resolution, increased content, and expanding coverage. In combination with the DTAS development, ETL undertook an extensive effort to identify, consolidate, and unify the Army's requirements for digital topographic data. The effort culminated in a statement of requirements to DMA which described the data content, resolution, and accuracy that is collectively required by the Army. These requirements have had an impact on the direction of software development required to support the application.

Our application involves the capture of data from a variety of sources to supplement or refine existing digital topographic data, and includes a requirement for producing hardcopy products capable of being overlayed and registered to base maps. This combination of digital topographic data and large scale maps drives our software design to include considerations of datum, spheroid, and projection transformations to ensure proper registration between the data base and the maps used as an input source and/or an output base. Our approach involves the identification of the necessary transformation capabilities, a survey of existing software and data available to satisfy the requirements, and the purchase, modification, or generation of a consolidated utility package to accomplish the transformation tasks.

DMA has provided us with x, y, and z shift constants between a number of datums and the World Geodetic System (WGS). There is existing software on the DTAS that utilizes these published shifts, but only for a limited number of datums. We plan to expand the DTAS capabilities to include additional datums, and include the provisions to supplement and modify this software as new information is available. The spheroids under consideration include those identified in "Grids and Grid References" (TM 5-241-1), Appendix D. The parameters of these spheroids are readily available and have been incorporated in a number of software packages.

The possibility exists to hardcode the datum and spheroid selection based on the users input of a military grid or latitude/longitude location. This eases the users input burden but establishes a software maintenance headache as the boundaries of the preferred scheme for map production changes. Our approach is to provide the user with the probable parameters and allow him to overide with another value if desired.

Our initial attempt to identify required projections was a shopping list approach. There are projection construction parameters that may be left off map margin information that are required to correctly capture data or create registered overlays. For example, we cannot assume our operators to know the location of the standard parallels or the central meridan. Our current approach is to identify those projection transformations (forward and inverse) that are readily available, realizing that this may not be sufficient. We hope to add other capabilities, when feasible.

CONCLUSIONS

We are now investigating the efforts at the United States Geological Survey toward providing software assistance to the projection identification process. This method requires an input of a limited number of registration points and a decision tree solution to identify the projection at hand.

Our development has not yet focused on the idea of product content varied according to the specific product request. The information contained in a product at one scale may result in too much clutter if included in one produced at larger scale. The software could include capability to simplify the presentation of information according to the proposed scale and nature of the product. Considerable work remains to be done in this area, and will probably continue as users of the software provide feedback from their experience in its use.

There also exists some growth considerations for the software to go one step beyond the generation of complexed products to include route and network analysis and selection. We feel the current generation of geographic information systems coupled with artificial intelligence could provide this capability. Such work will probably proceed incrementally as we discover what intelligence tasks are best suited for automation.

The prospect of developing software which can be used worldwide presents several challenges to the system and software design process. We feel we have begun to identify some of these considerations and have made progress toward their solution. We are not attempting to speed up the process of building a global database for terrain analysis, but we do want to ensure the flexibility and functionality of the software required to do the job as the data becomes available.

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