COMPUTER GRAPHICS AT THE UNITED STATES MILITARY ACADEMY

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ABSTRACT

The highly sophisticated Computer Graphics Laboratory (CGL) (Department of Geography and Computer Science) provides the United States Military Academy with a unique state-of-the-art environment for cadet and faculty participation in multilateral funded research projects. The Defense Nuclear Agency has asked the CGL to investigate the use of a plotter hard-copy device driven by an Apple II microcomputer to be used in conjunction with the Target Analysis and Planning System. The Defense Mapping Agency (DMA) and the Engineer Topographic Laboratories (ETL) are providing substantial economic and technical support to assist CGL personnel in identifying, demonstrating and testing military field applications of digital topographic data and digital data processing techniques. DMA has provided further funds for the purpose of comparing the information content of a low altitude multispectral scanner digital data tape to that of a conventional photograph. Work is being performed to assist in automating the terrain analysis procedure for ETL. Under the sponsorship of the US Army Institute for Research in Management Information and Computer Science and the Center for Tactical Computer Systems, the CGL is pursuing a program of applied research in the education of potential users of Ada, the recently accepted, DOD high-order language for embedded computer systems. In all cases cadet exposure to the research is maximized.

INTRODUCTION

The United States Military Academy has been involved in basic and applied research for many years. The Department of Geography and Computer Science (G&CS) has developed a research facility called the Computer Graphics Laboratory (CGL) with the mission of supporting cooperative research efforts with a number of Department of Defense and Department of the Army agencies. The CGL is a sophisticated installation consistent with its research activities, and an important adjunct to the educational program of West Point. Cadets, through courses of instruction, individual research projects and internships at various laboratories, have the opportunity to see and work with the latest technology.

Mapping, Charting and Geodesy (MC&G) serves as the unifying theme for the many disciplines in the Department. It was the recognition of this relationship which pointed the D/G&CS toward using the intellectual and technological resources available to enter into the broad field of computer graphics as applied to engineering and mapping.

For the past year two officers have been working full time on programs funded by the Defense Mapping Agency (DMA) and the United States Army Engineer Topographic Laboratories (ETL). The projects discussed in this paper are in the area of digital data exploitation and automated terrain analysis. A number of other projects are being done within the D/G&CS and will be explained in lesser detail.

FIELD EXPLOITATION OF DIGITAL TERRAIN DATA

This project has a number of objectives including experimenting with data base precision and formats, improving current capabilities to display terrain views and promoting the exchange of MC&G ideas among agencies, the Academy and other internal parties. One of the most important of the project objectives is to expose the technology of digital data exploitation to cadets and members of the military community.

Each summer the Department of Geography and Computer Science supports Cadet Field Training for Third Class cadets at Camp Buckner. In addition to supplying officers to conduct Land Navigation training, the Computer Graphics Laboratory provides computer support in the form of three-dimensional, computer-generated terrain views to include line perspective and oblique views. The algorithms for these programs were furnished by the ETL (Jancaitis 1975; Taylor 1979). Line-of-sight profiles and weapons placement plots are used to give the cadet a greater appreciation for the information on two-dimensional map sheets.

The simplest and most familiar of these graphics is the line-of-sight profile. The user may specify a particular data base to be used. Input prompts include coordinates of the endpoints of the line of sight, height above the ground at each endpoint, the number of samples to be taken between the endpoints and vertical exaggeration factor to enhance key terrain features. The result is a cross-sectional view of the terrain showing the endpoint coordinates and whether one is hidden or visible from the other. The actual ground distance is also given. This is a key feature since the distance may be as much as 20% greater than straight-line distance for hilly terrain. Although the cadets are familiar with hasty line-of-sight profiles, this rapid and accurate system introduces the possibility of applying line of sight (LOS) profiles by Signal personnel (LOS antennas), Artillery (positioning forward observers), Infantry and Armor (locating LOS weapons) and many others.

The line perspective view is another way to bridge the gap between the map and the actual terrain. The perspective view may be used to show cadets that in times of limited visibility or hours of darkness, it becomes important to determine what the terrain looks like from the information on the map. By selecting the observer's location, height above the ground and azimuth of interest, the computer is able to generate a view of the terrain depicting what would be seen if the observer were actually there looking in that direction. It is an invaluable training tool relating the three-dimensional terrain (ground) to the two-dimensional map. The perspective view is also important in gaining an understanding of slope. While the contour map gives indications of where steep and gradual slopes occur, the perspective shows the angles as one would see them on the ground.

The above principles are applied again when the cadet is taught to construct a hasty prospective view from contour lines and key terrain features. The oblique view is generated by placing a number of cross-sectional views from the LOS profile side by side. Like the perspective view the actual "role of the terrain" can be seen from this view. The observer is assumed to be at a distance of infinity from the terrain and an angle of 30 degrees from the horizon. The user can input the size (length by width) of the terrain to be used and the viewing azimuth. Unlike the perspective view, actual horizontal distances are easily measured from the oblique view creating a kind of relief map to which the cadet can easily relate. By increasing the vertical exaggeration option, key terrain features are enhanced as in the other views. The cadet can readily determine where terrain will mask the view of an observer or prevent engagement by a LOS weapon.

All soldiers are concerned with selection of positions for direct fire weapons. The weapon's placement plot shows the coverage for a particular weapon giving characteristics such as left and right limits, range and height above the ground. The user selects the location and size of the area of interest and the contour interval to be used. A contour map of the area is drawn and a location is selected for the weapon. The coverage diagram is computed and drawn as an overlay.

These programs have been beneficial to the Land Navigation instruction. A survey completed this summer indicates the majority of cadets were able to better understand the information on their standard map sheets after having been exposed to the graphic displays.

While this training has been conducted for the past three years, this year for the first time the graphics displays were generated directly from the computer instead of using a "canned" presentation from tape. The link was made using standard tactical FM radios over a distance of approximately 8 miles and was tested at a 2400 baud rate. Additional communications equipment would permit the test system to operate at 9600 baud. The plan for next year is to expand the program to use a microcomputer to generate the map products in the field as needed by the soldier. The communications link would allow access to large data bases stored on the host computer.

AUTOMATED TERRAIN ANALYSIS

The CGL, in support of funded research for the Defense Mapping Agency and the Engineer Topographic Laboratories, has been investigating the problems concerned with implementing an automated terrain analysis system. The overall research efforts are designed, first, to address the possibility of multispectral digital data replacing the photograph, and, second, to discuss the problems in identifying and classifying that terrain which may be of concern to the military commander.

The purpose of this section is to describe the apparatus and classification system at the CGL, discuss the results of some preliminary tests and relate these results to conclusions drawn by other research personnel.

Classification System.

Landsat scenes are displayed on the CGL's DeAnza VC 5000 color image processing system which is driven by a VAX-11/780. Initially a complete Landsat scene (approximately 185 km on each side) is displayed on the screen. The viewing of the complete scene is made possible by selecting every 7th row and column of the digital data purchased from EROS.

Should the analyst desire to display every Landsat pixel he may do so by moving a cursor to the selected area and having the scene redrawn. The DeAnza has the capability to display 480 by 512 pixels.

The operator may utilize the DeAnza's hardware zoom (8X magnification) feature to examine a scene more closely. When the scene has been studied and the analyst is ready to gather training samples he has two options, record them individually or in rectangular groups.

Gathering training samples from small fields such as isolated swamps, roads, etc., necessitates being able to look at and record the brightness values of individual pixels. A specific area in the scene is selected and the DeAnza's 8X zoom capability enabled. The analyst then moves a cursor inside the now large image pixel and instructs the computer to record the Landsat brightness values in all four bands. The only requirement here is that the programmer ensure that his system housekeeping is sufficiently precise to allow the recording of the brightness values from the proper pixel (after selecting, zooming, scrolling and densifying).

When the areas of concern are large, it is beneficial to use a variable size box cursor and record all values inside the box.

After gathering the training samples the analyst computes the mean, variance and smallest and largest values in all four bands. He may also choose to have the scatter diagrams of any two bands drawn on the screen at any one time or to draw the histogram of his training sample in each band. At this time the analyst has the option of rejecting the training samples and repeating the collection procedure.

Once the training samples have been gathered and accepted the system will search for all similar terrain. An interesting feature is the ability of the operator to have the system classify just within a movable, variable size box cursor. This provides the opportunity to select features to be "compared" against the training sample, allows for flexibility and versatility, and greatly shortens the classification time. Computer time is not being wasted applying the decision algorithm to displayed pixels for which the analyst has no interest. All pixels which are considered to be of the same class as the training sample are displayed in a distinctive color.

The modularized system will permit the easy installation of any classification algorithm. Although a probabilistic decision strategy has been used extensively, the parallelepiped rule is presently being utilized because of its simplicity and speed. A necessary step when using a probabilistic decision rule is to establish a threshold value. When identifying one type of terrain from the whole scene the selection of the threshold value becomes an experimental exercise with the analyst slowly iterating toward the parallelepiped decision rule (Thompson 1982b).

Experimental Design.

By using maps, CIR photography, and personally gathered ground truth data, landcover overlays at scales of 1:250,000, 1:50,000 and 1:25,000 were prepared of a region in the vicinity of West Point, New York.

The purpose of the experiment was to study whether, after selecting proper training samples of several classes, could the automated terrain analysis system, using Landsat data and a spectral classifier, identify/classify all similar terrain? The classes tested were urban, impervious, non-forest vegetation, water and swamps. The system was evaluated both in total area and site location and was compared to the landcover classifications at all three scales.

Table 1 shows the number of plotted locations at each scale found within the ground truth area. Naturally when making a map at a scale of 1:250,000 fewer distinct terrain features will be plotted by the cartographer than would be plotted at 1:25,000. It was hoped that the Landsat classification would show a pronounced greater similarity to one particular classification scale.

The area covered by each class was measured at the three scales and compared to the area located from using the Landsat data (number of pixels times the area of each pixel).

The number and site of each feature was compared by making an overlay of the screen after each classification.

Experimental Results.

Repeated tests encompassing myriad conditions led to the same conclusion--Landsat data does not allow for accurate discrimination of the above classes in the type of terrain found in the Hudson Highlands.

The Landsat automated system found 26 water bodies (certainly the easiest feature to locate) which corresponded in number to the 1:250,000 classification. However, the area varied so widely the entire operation was suspect. The other features varied tremendously in number, area and location (errors of location were the result of varying classification errors, not planimetrically mislocating the item) (Thompson 1982b).

The results of this test, although disappointing, are compatible with what one might expect from this rugged, dense, mountainous region composed of small lakes, small swamps, underbrush, rock, tall grass, etc.

"An automated terrain analysis system based on Landsat data as presently configured is not possible in terrain of this type and probably not possible anywhere" (Thompson 1982b). Schreier, et al. (1982) point out that "Relatively few computer-assisted land classification methods based on multispectral Landsat data have become operational...." The primary reason offered by them was because of the "...complexity of the spectral data and the limited ground resolution of the Landsat multispectral scanner" (Schreier et al. 1982). Vogel (1977) stated that Landsat data is inadequate for classifying most of the basic terrain elements. This statement came at the conclusion of a meticulous study in which Landsat data was examined to see if it could meet the needs of a large number of cartographic, mapping and terrain requirements. Out of over 300 subcategories the requirements for only 2 could be met by Landsat data. Gordon (1980) concluded after an experiment in Ohio "...that substantial errors are associated with use of Landsat data for land cover and change analysis," and Sharp (1979) suggested "...that too much is being expected from the Landsat demonstration projects."

High Resolution Data.

Tests have been conducted at the CGL using low-altitude, high-resolution multispectral digital data collected by Daedalus Enterprises Incorporated over an area in southeast Kansas. Pixel size is approximately 12 feet on the ground with data being gathered in 5 bands (blue, green, red, infrared and thermal infrared). At the same time that the 5-band multispectral digital data was being gathered, overlapping color infrared and color photographs were taken. This data provides an excellent base on which to build an evaluation of an automated terrain analysis system.

It was revealed that a spectral classifier alone could not accurately classify the terrain, even with high resolution data, because seemingly homogeneous features were often statistically nonhomogeneous (Thompson 1982a). The automated terrain analysis system of the future will have to employ "smart software" which will make contextual, tonal and textual decisions in conjunction with a straightforward spectral separation.

The Future.

Despite difficulties and set backs the future will demand digital data. "Three fundamental driving forces underlie a shift at DMA towards a reliance on digital data bases for mapping, charting and geodesy operations. These are the need for product flexibility, the need for responsiveness, and the need to reduce production costs" (Williams 1980).

Leighty (1979) after discussing our current problems said, "We should expect that highly automated systems for information extraction from aerial imagery will be a part of our production capabilities in the future...."

Improvements may be expected through better resolution, improved hardware, contextual, tonal and texture analyses, more sophisticated modeling, multitemporal data, greater use of the electromagnetic spectrum, more detailed definition of the parameters involved, and countless other innovative approaches.

TABLE 1. Number of plotted terrain features at three scales in the ground truth area.

Feature	1:250,000	1:50,000	1:25,000
Water Body	23	60	68
Swamp	0	22	47
Impervious	5	19	56
Urban	5	10	21
Vegetation (non-forest)	15	23	28

OTHER PROJECTS

Environmental Early Warning System (EWS).

The United States Army Construction Engineering Research Laboratory (CERL 1980) in Champaign, Illinois, developed the prototype of a computer program designed to allow "...decision makers and environmental specialists to rapidly determine whether proposed mission changes can be expected to result in unacceptable environmental impacts at affected installations." Although not an Environmental Impact Assessment or Statement, the program defines a series of analyses and graphical displays (Environmental Early Warning System) which "...provide preliminary notification of certain potentially serious environment-related problems at very early stages of project planning." In essence, it is a system designed to respond to "what if" questions, that is, questions which ask "what if this battalion, school or activity were moved from installation X to installation Y?"

CERL recognized that the line printer graphical output of its prototype lacked detail and sophistication. Computer Graphics Laboratory personnel were asked to make EWS operational on the Department's VAX-11/780 minicomputer and integrate the system with a modern graphical analysis package so better quality display graphics could be produced. Two modules of Odyssey (Polyps and Prism) were purchased and made operational. While recognizing that current problems prevent the purchase of further Odyssey modules, it is the intention of the CGL, using other graphics display systems or different techniques, to amplify and embellish the graphical output of EWS. Currently work is being done to determine the suitability of low-cost raster based plotters (Tektronix 4612, ACT-1 Color,...) as output devices. Concurrently, the problems involved with changing the display from raster to vector output are being investigated.

Army Housing Management System.

A second project accomplished for CERL provided an opportunity for considerable cadet participation. The overall mission was to gather information and make recommendations to expedite the eventual implementation of the Army Housing Management System (HOMES). The formidable task of HOMES is to allow for the automated management of the very extensive real property family holdings of the United States Army. The housing functions were divided into thirteen categories with the cadets enrolled in EF 383, Management Information Systems, being instructed to conduct a systems analysis of the planning, programming, and budgeting and the finance and accounting functions. In addition to the benefits of having the cadets learn firsthand the challenge encountered in performing a systems analysis, a complete documentation of these two functions was achieved. The student initiated identification and step by step documentation of the interrelated functions facilitated recommendations for automating the system. Specific recommendations are not presented here but, in general, they concerned item definition, suggested design of an integrated data base and suggestions as to which functions could be automated. In a follow-on effort, cadets enrolled in EF 483, Data Base Management Systems, were involved in a course project which produced a detailed definition/description of the specific data items identified in the systems analysis. In a related effort another cadet, in an individual study project identified and extracted data items from the Standard Army Multi-Command Management Information Systems (STAMMIS) for use in HOMES. Specific missions included writing a COBOL program to extract data items from STAMMIS and the transfer of data from the VAX-11/780 to the AM-100 computer.

Ada Technology.

Under the sponsorship of the U.S. Army Institute for Research in Management Information and Computer Science

(AIRMICS) and the Center for Tactical Computer Systems (CENTACS), the Department is pursuing a program of applied research in the education of potential users of Ada, the recently accepted, DOD high-order language for embedded computer systems. The research effort has involved the development of an elective level, one-semester course entitled "Ada Concepts and Programming" which was taught to a select group of ten computer science concentrators. Ada/Ed, an Ada translator developed at New York University for CENTACS, which runs on the VAX-11/780, was used in support of the course to provide "live", hands-on programming capability. Three of the cadets enrolled in the course continued in the second semester with a team research project to investigate transition methods which can be used for new Ada programmers. Ada has been taught as a regularly offered elective course since the Second Semester, Academic Year 1981-82. The CGL is continuing to participate in Ada related projects, to include the Ada Training and Education Committee of the DOD Ada Joint Projects Office, a CENTACS evaluation of proposals to redesign two existing military embedded computer systems in Ada and the Air Force Ada Programming Support Environment (APSE) Design Evaluation.

Target Analysis and Planning System (TAPS).

The CGL has been asked by the Defense Nuclear Agency to develop a driver for a plotter hard-copy device driven by an Apple II microcomputer in support of TAPS. The project was completed in June of this year. In July a module was written which provided a flexible world-wide capability to transfer between Universal Transverse Mercator (UTM) grid coordinates to Cartesian coordinates referenced to an operator determined origin. This module will enable the TAPS program to be used world-wide instead of being confined to Europe as it has been for the past three years. The module takes into consideration the curvature of the earth and changes constants used to convert between UTM and Cartesian coordinates to accommodate the user's particular spheroid.

CONCLUSION

One can easily see that the volume of work done by the CGL is more than two researchers can accomplish alone. Much of the work is done by cadets through summer intern assignments or special topics courses offered under the supervision of the research officers. Other projects are accomplished through the volunteer efforts of full-time faculty members. The mission of the CGL remains clearly to expose the cadets to the current technology. The reward to the agencies who support the CGL is the energy and enthusiasm the cadets and faculty supply in meeting the challenge of this new technology.

REFERENCES

Gordon, S. 1980, "Utilizing LANDSAT Imagery to Monitor Land-Use Change: A Case Study in Ohio", Remote Sensing of Environment, Vol. 9, No. 3, pp. 189-196

Jancaitis, J.R. 1975, "Modeling and Contouring Irregular Surfaces Subject to Constraints," Final Technical Report, No. ETL-CL-74-19 for U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, on contract DAAK02-72-C-0256

Leighty, R. D. 1979, "Research for Information Extraction from Aerial Imagery", Proceedings Remote Sensing Symposium, pp. 251-261, Reston, VA

Schreier, H., L.C. Goodfellow, and L.M. Lavkulich 1982, "The Use of Digital Multi-Date Landsat Imagery in Terrain Classification", Photogrammetric Engineering and Remote Sensing, Vol. 48, No. 1, pp. 111-119

Sharp, J. 1979, "Demonstrating the Value of Landsat Data: A Case for Lowered Expectations", Photogrammetric Engineering and Remote Sensing, Vol. 45, No. 11, pp. 1487-1493

Taylor, C.C. 1979, "Computer Generation of Shaded Relief Images for Cartographic Applications", unpublished technical report, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA

Thompson, L.G. 1982a, "A Statictical View of Automated Classification", Paper submitted for publication, Photogrammetric Engineering and Remote Sensing

________. 1982b, "Automated Terrain Analysis", Paper presented at the Eighth International Symposium of Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, IN

United States Army Construction Engineering Research Laboratory, CERL Environmental Division 1980, "The Early Warning System, A Preliminary Example"

Vogel, T. 1977, "An Analysis of Landsat System for Cartographic and Terrain Information", Engineer Topographic Laboratories, Report Number 9

Williams, O. 1980, "Outlook on Future Mapping, Charting and Geodesy Systems", Photogrammetric Engineering and Remote Sensing, Vol. 46, No. 4, pp. 487- 490