# CAD: A VIABLE ALTERNATIVE FOR LIMITED CARTOGRAPHIC AND GIS APPLICATIONS

Robert C. Anderson
Lloyd D. Carmack, Jr.
Department of Geography and Computer Science
United States Military Academy
West Point, New York 10996

## BIOSKETCH

Major Robert Anderson and Captain Lloyd Carmack are Assistant Professors in the Department of Geography and Computer Science at the United States Military Academy, West Point, NY. Both graduated from West Point with BS degrees in 1974 and 1977, respectively. Major Anderson is an Intelligence Officer with MA degrees in International Relations from the University of Southern California and in Geography (Remote Sensing) from the University of Georgia. Captain Carmack is an Air Defense Officer with a MS degree in Geography (Computer-Assisted Cartography) from Rutgers University. Both are involved with research pertaining to military applications of GIS.

## ABSTRACT

The most popular GIS often require extensive investments of hardware, software and training, and may offer capabilities not needed by low end users. Consequently, those users with limited mapping requirements often cannot justify purchasing a GIS. PC-based CAD systems have a viable role in quickly and inexpensively performing limited mapping of layered spatial data, in lieu of GIS. This paper examines how low priced CAD packages can be used in the situations where layering of spatial data is more important than conducting manipulations on the data attributes. The user faces several problems when substituting a CAD package for a GIS. Issues investigated include constructing the data layers from various sources, maintaining registration, updating information and plotting output to a specific scale. CAD, with its inability for in-depth data analysis, in no way substitutes for GIS, but it can serve the low end user as a first step towards a GIS. CAD also has a role as an inexpensive educational tool capable of introducing students to the GIS attributes of inputting, layering, updating and outputting spatial data.

## INTRODUCTION

Geographic Information Systems (GIS) continue to be a hot topic and the cornerstone of an ever growing industry. The latest issue of any periodical associated with the field of geography is sure to include at least one article devoted to the subject. Estimates of worldwide revenues for the GIS market are expected to reach $464 million by 1991 (Lang, 1988). The move from theory to application has also resulted in a more focused definition of GIS to "a decision support system involving the integration of spatially referenced data in a problem solving environment" (Cowen, 1988). What sets GIS apart from other automated mapping systems are the processing capabilities related to the encoding, storage, analysis and display of spatial data (Berry, 1985).

As can be expected, the power of a full fledged GIS is often related to its price. Industry leaders such as ESRI, Intergraph, IBM, Synercom and ERDAS can provide complex, multi-user systems which might cost as much as $400,000 (Lang, 1988). While these systems are on the cutting edge of GIS technology, users having limited GIS or mapping requirements often cannot justify purchasing such a system.

Although not a GIS, Computer Aided Design (CAD) systems are recognized as serving a useful role in the GIS world. While most realize that CAD is limited in both terms of analysis methods and the volume of data that can be handled (Burrough, 1986), CAD is well suited to its role as a tool for cartographic applications due to the inherent electronic drafting and graphic overlay capabilities (Cowen, 1988). For the low end user or educator, CAD's capability to quickly layer spatial data, at relatively low cost, gives it a viable role in lieu of a full fledged GIS.

## BACKGROUND

The geography program at the United States Military Academy (USMA) includes courses in Remote Sensing, Photogrammetry, Surveying, Cartography and Computer-Assisted Cartography (CAC). New in the Spring of 1989 is a GIS course. The Department currently has several GIS packages used for research, such as PC ARC/INFO, VAX-based INFORMAP III and GRASS on a Sun workstation. These systems are too complicated and expensive to support teaching an undergraduate GIS course.

Our CAC course uses PC and mainframe mapping programs to introduce cadets to automated cartography. One block of the course requires cadets to produce a map using CAD as a drawing tool, instead of a canned mapping program. Once the cadets have completed this portion of the course, we then use CAD to build interest in the upcoming GIS course by introducing cadets to the GIS attributes of inputting, layering, updating and outputting of spatial data. We accomplish this with low cost (less than $400) CAD programs (DRAFIX and CADKEY) on IBM AT or Zenith Z248 machines. Our peripherals included Summagraphics digitizing tablets and hardcopy devices such as Alps 2000 printers and IBM and HP pen plotters.

The literature has numerous references to the theoretical use of CAD as a mapping tool and increasingly as a surrogate (or at least a limited substitute) for GIS (Burrough, 1986; Moynihan, 1987; Cowen, 1988). However, the literature failed to prepare us for the problems encountered implementing CAD as a limited GIS. This article focuses on three areas: data capture, data processing and information output/display. We will share some of the issues necessary to consider when using a low cost CAD as a tool for certain mapping and limited graphic overlay applications.

## DISCUSSION

### Data Input

Because CAD packages are primarily electronic drafting tools, they may not be initially suited for the task of transferring spatial data from maps and air photographs to digital form. In fact, the inexpensive and relatively simple packages that we employ, use the digitizing tablet as a sophisticated pointing device. Although these packages are laden with commands to implement the many drawing capabilities they possess, they both lack built-in digitizing routines. Consequently, we had to supplement our CAD programs with stand alone digitizing software.

Although a wide range of hardware is available for data input, internal factors such as budget, ease of operation and limited training time available for our students, we limited our efforts at data capture to manual digitizing. A public domain digitizing program, DIGITIZE, developed by the Department, accomplishes basic digitizing operations. Additionally, the program converts coordinate files into the appropriate drawing interchange files which both CAD packages can import as drawing files (Loomer, 1987). While more elaborate CAD programs like AUTOCAD include digitizing routines, the higher price and increased difficulty of use may limit their application by the low-end user or educator. DIGITIZE may not accomplish the more elaborate functions of file editing and line smoothing that are found in a full fledged GIS or a more comprehensive CAD, but it does succeed in transforming the digitizing tablet into a data capture device. It is important, from the stand point of efficiency and error reduction, to digitize input once with a single digitizing program and then convert the files to the various formats required by the different CAD programs.

Other data input considerations associated with the use of CAD are related to both the actual digitizing process and to the manner in which CAD will be used to display and overlay the digital files. Two approaches may be used to exploit the graphic layering capability of CAD. The first approach would capture all the input data features onto a single layer, while the second method would digitize various data features onto individual layers. Experience has shown that more complex input is best reduced into layers prior to digitizing. Items can be moved from layer to layer within CAD; however, this can be a difficult and time consuming proposition if there are many features We think it is more efficient to separate features prior to digitizing, then merge them as required. It is important to include plenty of reference (or control) points as part of each layer's digitized file.

Data Processing

CAD is an effective graphics display tool because it can turn on or off different layers (of various geographical features) for selective editing and display. Even though CAD does not provide the analytical functions of a GIS, the layering capability can provide a graphics display similar in concept to the multiple layers of a GIS. Exploitation of the CAD layering capability depends on the operator's ability to develop the various layers.

A GIS would make use of techniques similar to INFORMAP's "Facetization" command which transforms arbitrary source documents into a fixed database (Synercom, 1988). This layering is fairly straight forward in CAD if multiple control points are included during the digitizing process. The process is only slightly more complex if the input sources vary in size, scale or coverage. With CAD, registration to a specific scale is established to a base layer (which may only contain the reference or control points) using editing functions such as "Scale" and "Rotation." Once registration is established, the layer can be turned off or left on and a new layer of information can be added to the drawing.

## Data Output

A problem that plagues anyone working with GIS and CAD is that of transferring the image on the monitor to paper without losing either resolution or information. We checked our output for geometric accuracy to determine the distortion one can expect from mapping with CAD. The digitizer sends coordinates of the input data to the CAD program which in turn displays the output to the monitor using screen coordinates. The scaling and rotation factors we applied to the layers we wanted to register and merge, were based on what we saw on the monitor. The final output, on paper or mylar, was set to either a 1:1 ratio or a multiple of the input (digitized) scale. It is not surprising that some error is introduced as the input coordinates are redefined several times before hardcopy output.

We used CAPTURE from the Desktop Digitizing Program (distributed by R-Wel, Inc. of Athens, GA) which calculates a least squares rectification from an affine solution if four or more control points are used. This program provides the residual error for each control point and the RMSExy (root mean square error) vector error for all points in the solution It also calculates the error in ground and map units and the overall scale (DDP, 1988).

Output accuracy is a function of preciseness of the input control points. A DMA 1:25,000 topographic map served as the base map for the first test. We digitized map information at 1:25,000 scale, added additional layers of input data at the same scale and output the combined map at both 1:25,000 and 1:50,000 scales. This file had four control points: two were UTM grid line intersections and two were major road junctions. Our DIGITIZE software limited us to inputting the coordinates from the keyboard of only two control points (the grid line intersections). The coordinates for the two road junctions were read using a 1:25,000 grid coordinate scale (Table 1).

TABLE 1
Accuracy Assessment Using Grid Line Intersections and Road Junctions as Control Points

| Data Source | Ctl Pts | Output Scale | RMSExy (m) | % Scale Error |
|---|---|---|---|---|
| Map | | | | |
| 1:25,000 DMA Topo | 4 | 1:25,061 | 8.297 | - |
| 1:50,000 DMA Topo | 4 | 1:49,981 | 21.787 | - |
| CADKEY | | | | |
| 1:25,000 at 1:25,000 | 4 | 1:25,190 | 3.80 | 0 515 |
| 1:25.000 at 1:50,000 | 4 | 1:50,317 | 4.58 | 0.672 |
| DRAFIX | | | | |
| 1:25,000 at 1:25,000 | 4 | 1:25,079 | 3.963 | 0.0718 |
| 1:25,000 at 1:50,000 | 4 | 1:49,938 | 4.155 | 0.0860 |

The error in the map data is caused mostly by the inaccuracies of the road junction coordinates. The scale and RMSExy values are the average of three iterations of the DDP. Percent Scale Error was calculated by dividing the map scale by the difference of the map scale and the output CAD scale.

For the second test we used the same 1:25,000 scale base map and a 1:15,000 orienteering map as an additional source of information. The orienteering map was similar to an aerial photograph since it contained detailed map information and lacked a coordinate grid system (Table 2). We merged the map information of the two maps and printed/plotted output at the scales of 1:25,000 and 1:15,000.

TABLE 2
Accuracy Assessment Using Road Junctions as Control Points

| Data Source | Ctl Pts | Output Scale | RMSExy (m) | % Scale Error |
|---|---|---|---|---|
| MAP | | | | |
| 1:25,000 DMA Topo | 5 | 1:25,163 | 20.682 | - |
| 1:15,000 Orienteer | 5 | 1:15,308 | 25.686 | - |
| CADKEY | | | | |
| 1:15,000 at 1:15,000 | 5 | 1:15,514 | 24.634 | 1.346 |
| 1:15,000 at 1:25,000 | 5 | 1:25,925 | 26.653 | 1.025 |
| 1:25,000 at 1:25,000 | 5 | 1:25,421 | 19.758 | 3.028 |
| DRAFIX | | | | |
| 1:15,000 at 1:15,000 | 5 | 1:15,413 | 19.404 | 0.686 |
| 1:15,000 at 1:25,000 | 5 | 1:25,212 | 25.641 | 0.195 |
| 1:25,000 at 1:25,000 | 5 | 1:25,475 | 20.436 | 1.240 |

It is not surprising that the RMSExy error vector and Percent Scale Error increased when using five true "ground" control points, instead of grid line intersections. Other factors which affect the accuracy of the data captured include various hardware and operator errors indicative to the digitizing process (Cameron, 1982).

## APPLICATIONS

### Cartographic Applications

CAD has been used quite extensively as a mapping tool. Some of the primary applications have been in land planning and planimetric mapping, such as residential subdivisions and commercial areas (Cowen, 1988). CAD is well suited for generating smooth curves in cul-de-sacs, for providing labels, titles and legends and for high lighting features by shading and/or patterns. CAD loses no map information due to generalization when the scale is decreased and it maintains data fairly accurately.

By carefully sizing numbers and labels, the cartographer may choose, for example, to "lose" labels containing square footage but keep house numbers visible on a map of an entire housing subdivision. A separate layer, of a smaller area at a larger scale, may contain lot dimensions and other information not needed at smaller scales. In our West Point phone books, we have several pages of maps detailing the family housing areas. Last year one of our cadets developed such a database. He produced an electronic map of the housing areas, any portion of which could be zoomed in on for detailed information, as well as separate layers containing the various housing areas at larger scales (Albert, 1987). These separate layers could easily be updated and output for future phone book editions.

GIS Applications

Inexpensive CAD compares favorably with GIS systems in several areas. These include cost (hardware, software and operator training), layering of data, updating/adding layers, data display (in vector format) and data output. CAD can be used to overlay layers which enables an operator to visually (manually) identify areas that are common, while this is done by automatically in a GIS. However, CAD cannot manipulate or conduct extensive analysis of attributes on a layer or among layers.

As an example, let us choose to overlay soils, vegetation and road data. We task the GIS to display locations where specific soil types intersect with particular vegetation types and then overlay the roads. The resultant map contains only the areas where the polygonal data are common, with the road data included for reference. This can also be accomplished with CAD. We first assign patterns for our polygonal data to ensure adequate visibility of layers, once they are activated, so data is not masked (a problem using only colors). Or we could put each type of soil and each type of vegetation on individual layers and activate the layers with the particular attributes as necessary. Some minimal analysis of layered data is possible in CAD, but it is easy to see this quickly becomes a labor intensive effort for limited results. Newer and more expensive CAD programs link layers to a database. This only allows the user to tag items on layers with their attributes, not perform manipulations on the layers. As layers are moved, merged and scaled, their attributes follow along; attribute values are not changed or modified in the new layers.

## CONCLUSION

Low cost CAD is a high powered drawing tool with many cartographic applications, especially in the field of planimetric mapping. CAD cannot substitute for a GIS, but it can serve the low end user whose requirements are more concerned for layering of spatial data, not for the manipulation of data attributes found on the layers. It is also viable as an introductory tool to GIS in an educational environment, exposing students to the concepts of inputting, layering, updating and outputting spatial data. We realize that by opting for a more expensive CAD package, the operator may experience fewer problems in the data input and layering manipulations. In any case, the use of CAD in a GIS role is not feasible for data manipulation, but limited mostly to constructing, updating, displaying and outputting layered spatial data.

NOTE: Commercial products are described to support the discussion. Their mention does not represent an endorsement by the US Military Academy or the Department of the Army.

## REFERENCES

Albert, D.S., 1988, Final Report On Independent Study Into CAD. Unpublished Research Paper, Department of Geography and Computer Science, West Point, New York.

Berry, J.K., 1985, Computer-Assisted Map Analysis: Fundamental Techniques. Computer Graphics 1985 Conference, #SIS-85-1, National Computer Graphics Association, Fairfax, Virginia, 18pp.

Burrough, P.A., 1986, Principles of Geographical Information Systems for Land Resources Assessment. Oxford University Press, Oxford.

Cameron, E.A., 1984, Manual Digitizing Systems, Basic Readings In Geographic Information Systems, (ed. Marble et al). SPAD Systems, LTD, Williamsville, New York, pp. 3-11 - 3-18.

Center for Remote Sensing and Mapping Science, 1988. Desktop Digitizing Package Reference Manual, Department of Geography, University of Georgia, Athens, Georgia.

Cowen, D.J., 1988, GIS Versus CAD Versus DBMS: What Are the Differences?, Photogrammetric Engineering and Remote Sensing. Vol. 54, pp. 1551-1554.

Lang, L., 1988, The Movers and Shakers of GIS. Professional Surveyor, Vol. 8, pp. 4-9

Loomer, S.A., 1987, DIGITIZE, Digitizing Tablet Support Program, Computer Graphics Laboratory, Department of Geography and Computer Science, West Point, New York

Moynihan, R., 1987, Micro-Based CAD Systems in Surveying and Mapping Education. Technical Papers, 1987 ASPRS-ACSM Annual Convention, Vol. 4, pp. 133-139.

Synercom Technology, Inc., 1988, INFORMAP III Systems Reference Manual, Version 1.2, Houston, Texas.