

AN INTEGRATED PC BASED GIS FOR INSTRUCTION AND RESEARCH

Brian Rasche and David J. Cowen
Department of Geography and
Social and Behavioral Sciences Lab
University of South Carolina
Columbia, SC 29208

ABSTRACT

This paper describes the development of a totally PC based GIS system. The system utilizes the IBM enhanced graphics adaptor and a graphics kernel system. It expands on the original Map Analysis Package (MAP) by adding significant capabilities to input and display map layers. The system has been successfully utilized in several research projects and serves as the focal point for a graduate class in Geographical Information Systems.

INTRODUCTION

The Map Analysis Package (MAP) is probably the most widely used grid cell based geographical information system in existence (Tomlin Dissertation, 1983). For several years, the original mainframe FORTRAN code has been available for a nominal fee from the Yale University School of Forestry and Environmental Studies. Versions of the original algorithms now can be found in other Geographical Information Systems, such as The Map Overlay and Statistical System (MOSS). The simple English Language syntax and the powerful map algebraic approach, combine to create a versatile and comprehensive system for handling grid cell data bases. Furthermore, the system is quite well documented in the user manual and supplemental instructional materials, as well as in several research papers that describe its concepts and applications. The evolution of personal computers has provided an exciting framework for the creation of a self contained environment for MAP. The dual purpose of this paper is to describe a design strategy for such a PC based system, and to examine one resultant system that has emerged.

PC MAP ACTIVITIES

PMAP

One approach to the development of a PC version of MAP has been detailed in the work of Berry and Reed. These efforts have focused on the conversion of the original FORTRAN code into PASCAL and subsequently have resulted in the creation of PMAP. PMAP now includes several enhancements and modifications of the original version of MAP. Further, also is well documented and supports some interesting printer graphics. (Berry and Reed, 1986)

FORTRAN

Another approach to the development of a PC version of MAP has focused on the transfer of the original FORTRAN code into a desk top environment. Working at Harvard with the assistance of a grant from IBM, Tomlin completed the original work in this area. (Tomlin, 1986) The availability of this original source code, coupled with the emergence of powerful PC FORTRAN compilers and graphic kernel systems, have provided the impetus for the development of an enhanced PC version of MAP. This development has progressed through a cooperative effort at the University of South Carolina, the State University of New York at Buffalo (Marble, et al. 1987), Harvard and Penn State University.

DEVELOPMENT STRATEGY

The basic philosophy behind this cooperative PC development was to build upon the structure of MAP by improving the data input options, the user interface and the display capabilities (Fig. 1). The goal was to provide an integrated system that could handle any type of data input and greatly improve the options for displaying the output. The system was designed to be used on IBM-PC or compatible machines, with enhanced graphics adaptors (EGA), and support of a variety of graphic output devices through a graphics kernel system. Therefore, this hardware and software configuration should function in a widely available and affordable environment which supports acceptable graphic resolution and offers considerable output flexibility.

Operating Environment

The major enhancements to the original map operating environment consist of on-line assistance and a partitioned screen layout. The on-line assistance provides a list of extensive <EXPLAIN> options. Documentation for each of the 59 commands can be obtained through a simple <EXPLAIN> function that generates a screen of text describing the operation of the command and the proper syntax, including mandatory and optional modifiers (Fig. 2). The user interface divides the enhanced graphics adapter screen into three separate areas, a display window, a command line and a legend area. While this design enables the user to conduct all operations on a single monitor, a display window is left exclusively for graphics output. This environment has proven to be extremely friendly and responsive, thereby practically eliminating the need for external documentation.

Input Systems.

In order to be an integrated GIS, a system must be capable of handling any type of geographical data. Although MAP is strictly a grid cell based system, it is possible to convert any type of geographical features into a raster data structure. Points can be represented as individual cells, lines as contiguous groups of cells and areas as clusters of the same values. Continuous surfaces are matrices of numbers. The original version of MAP provided for the input of points <POINT>, linear features <TRACE> and gridded files <GRID>. While these options ultimately enable one to present any layer of geographical information, they required considerable preprocessing and manual encoding. MAP's major limitations related to the handling of geographical coordinate systems and the generation of gridded files directly from a polygon data structure.

Project. The vast majority of GIS data bases and existing maps can be linked to the Earth's surface by latitude and longitude, Universal Transverse Mercator (UTM) or State Plane Coordinates. A major enhancement to the MAP system incorporated the ability to convert easily between these systems. The FORTRAN subroutines necessary to accomplish this objective were extracted from the General Coordinate Transformation Program (GCTP) which are based on Snyder's Map Projections Used by the USGS. (Snyder, 1984) The command <PROJECT> reads a DOS ASCII file and outputs another file in a user specified measurement units. This routine eliminates much of the need to preprocess existing digital files before entering MAP, and allows the integration of a wide range of data bases. For example, data from digital line graphs, digital terrain models, Census polygons and digitized points all can be converted to UTM coordinate points and then input as separate layers.

PLPMAP. In order to benefit from the projection options, it is important to be able to read the resultant files and convert them into a common grid structure. The origin, cell size, and overall dimensions must be identical for each map and should be treated as user defined parameters. The existing MAP structure adequately handled points and gridded (matrix) data bases, however, it did not allow for true polygon input. The desire to accommodate all existing structures involved the inclusion of a general purpose point, line and polygon processor, <PLPMAP>. This routine reads any file output from <PROJECT> as either state plane or UTM coordinates and

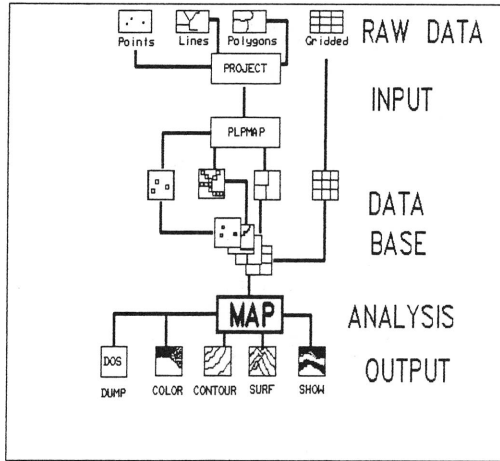


Figure 1. Flowchart of Integrated PC MAP System.

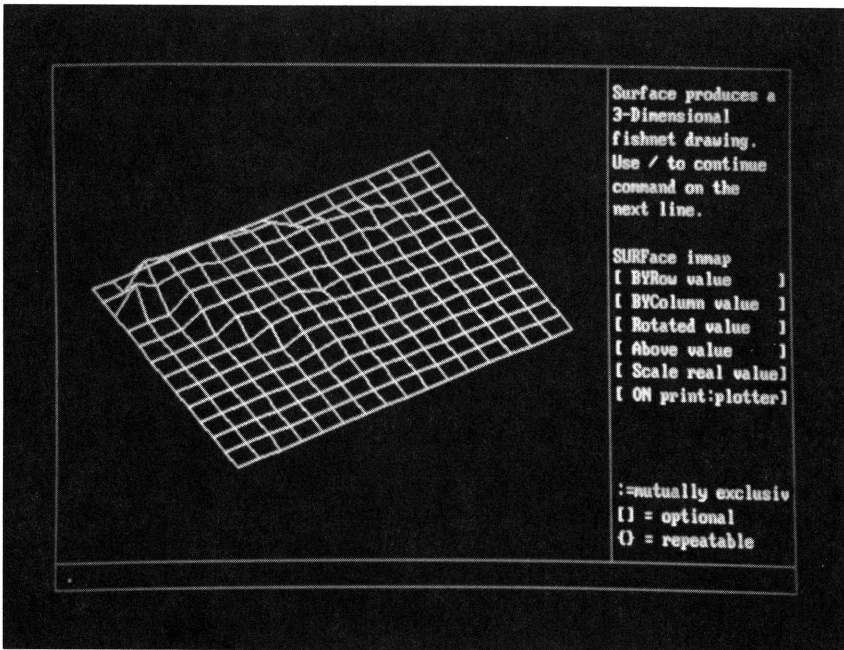


Figure 2. SURFACE map and EXPLAIN command on EGA monitor.

subsequently converts them into either points, lines or filled polygons. The input files must be in SAS/GRAPH format (SAS Institute, 1981) and polygons must be closed loops, with embedded islands identified by a missing value code. The algorithm uses a centroid assignment procedure for converting polygons to specific grid cells. Presently, the SAS/GRAPH format is used by many organizations. Its straight forward structure can be developed from any topologically structured format. (Cowen et al, 1985) Gridded files, such as DTMS, can be handled with the existing <GRID> command.

In practice, the combination of <PROJECT> and <PLPMAP> have greatly expanded the input capabilities of MAP. In conjunction with a PC based arc node digitizing system, that includes an affine transformation, these procedures enable one to go easily, and directly from a digitizing tablet to a MAP dataset. Other special purpose formatting routines have been created to transfer any existing gridded data base, such as ERDAS or SURFACE II (Samson, 1975), into MAP.

Display Considerations

In order to create a more complete GIS, it was also necessary to improve the output display functions of MAP. In the original version, MAP was designed to generate character based line printer output using a <DISPLAY> command. The PC environment provides the additional capability of quickly generating color displays on a graphics monitor. Although Tomlin incorporated an interesting three dimensional perspective graphic display routine <SHOW> into the PC FORTRAN version (Fig. 3), there still remained the need to add other mapping options and direct the output to hardcopy devices.

COLOR. The major approach implemented for this aspect of the system involved the development of a general purpose <COLOR> procedure that incorporated a linkage to a graphics kernel system, GSS CGI, that supports several different display adaptors, and both raster and vector plotting devices (Graphics Software Systems, 1986). The syntax for the command is stated simply as: <COLOR> mapname on (PRINTER or PLOTTER). The output will be routed to whichever device has been included in the configuration of the system. The <COLOR> procedure can display sixteen colors simultaneously on the enhanced graphics adaptor (Fig. 4). By incorporating a choice of three different palettes, the user may select a color scheme that is best suited to the particular data. For example, <PALETTE1> produces a variety of distinct hues, <PALETTE2> presents colors appropriate for continuous data, such as elevation; and <PALETTE3> generates color progressions of gray, blue, and red to yellow. The vector plotter option was designed to minimize pen changes while also optimizing the pen movements (Fig. 5). It is a surprisingly efficient output mode for raster data, with the plotting speed varying inversely with the homogeneity of the map.

The raster printer output mode of <COLOR> utilizes a series of patterns available with CGI. In order to utilize these patterns, a simple look-up table that assigns map values to pattern numbers was created. The first seven map values were assigned increasing gray scale density patterns, while the values eight through fifteen were assigned to various geometrical designs (Figs. 6 & 7). The <COLOR> command provides a versatile, attractive and easy to use procedure for generating an infinite variety of maps. Through the normal MAP overlay and renumbering steps, any number of maps can be combined and features assigned different colors and symbols. It cannot be over-emphasized that the final output map, whether presented on the monitor or as hardcopy from the plotter or printer, can portray an unlimited variety of information.

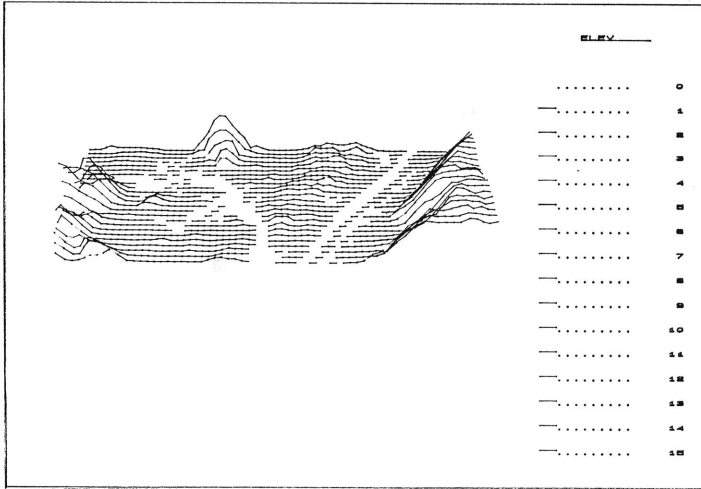


Figure 3. Example of output from SHOW command on vector plotter.

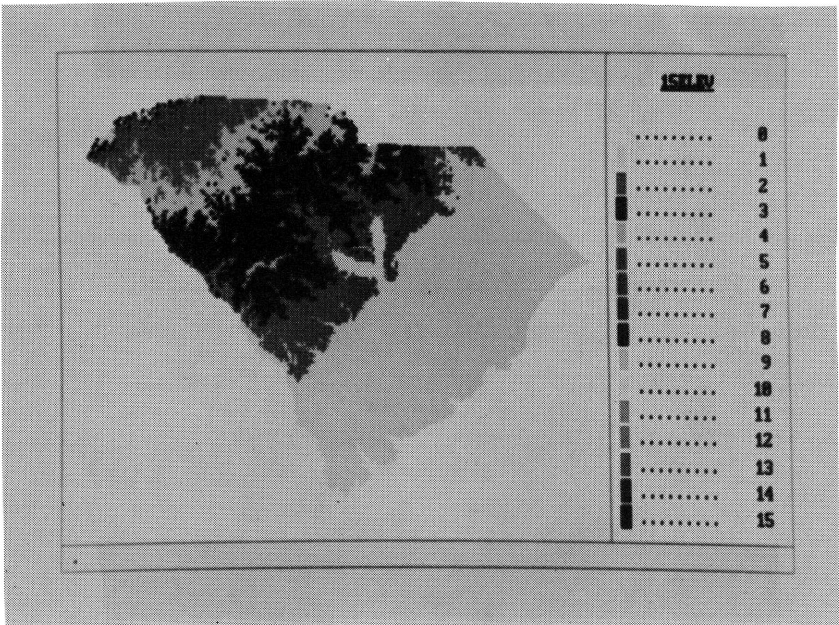


Figure 4. Elevation map of South Carolina displayed on EGA monitor with COLOR command.

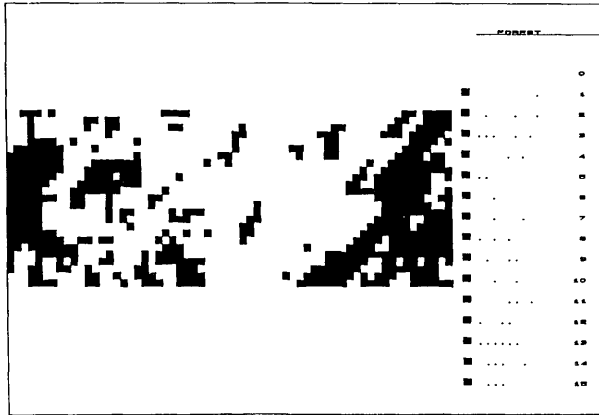


Figure 5. Single value vector plot created with COLOR command on plotter.

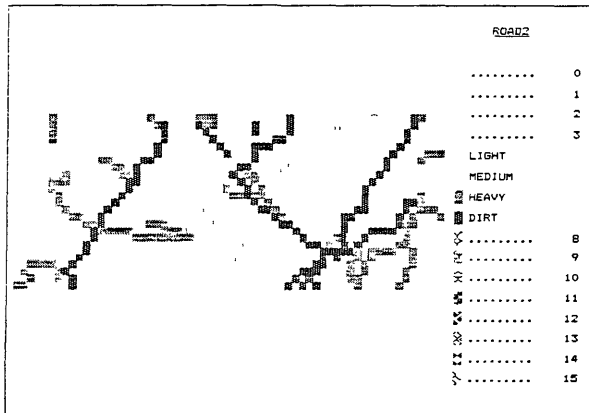


Figure 6. Dot matrix printer map generated by COLOR command. Note labels for values 4 through 8.

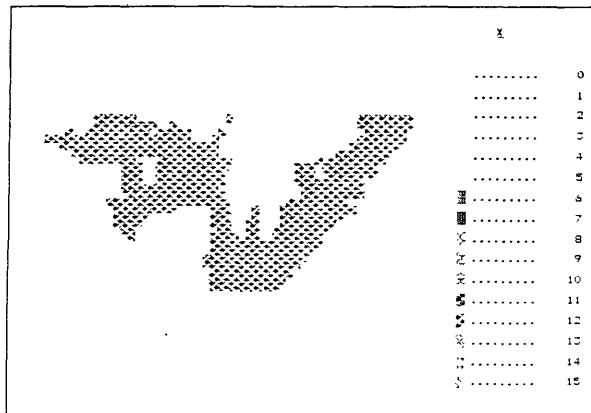


Figure 7. Single value COLOR printer map using only pattern.

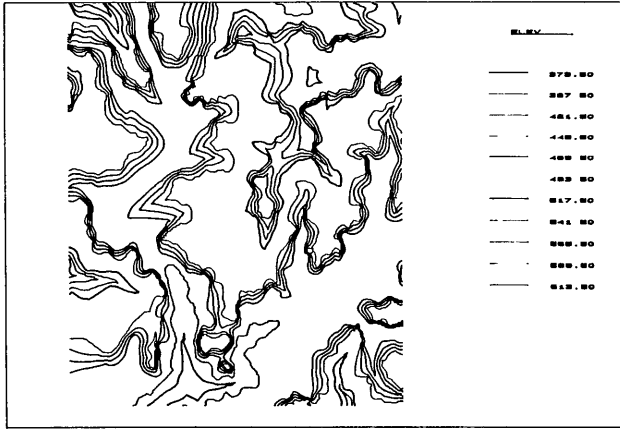


Figure 8. CONTOUR of elevation on vector plotter. Original data 218 x 180 for a 7.5 minute quadrangle.

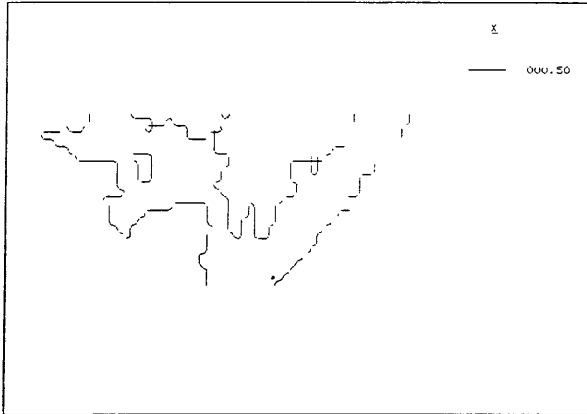


Figure 9. CONTOUR of single value on printer.

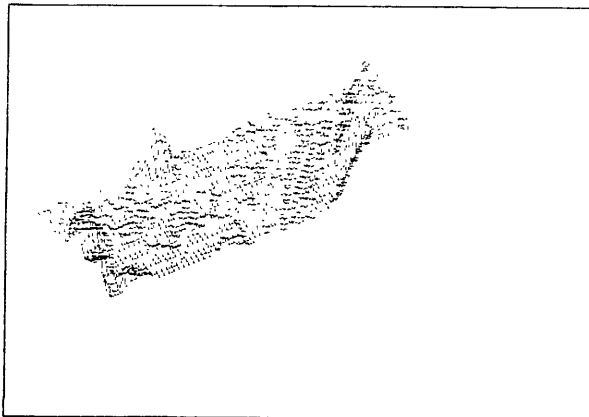


Figure 10. SURFACE map of elevation on printer.

The combination of a complete range of map inputs, unlimited overlay capabilities, available through ADDING, CROSSING, COVERING etc., and the RENUMBERING features of MAP, provides a truly universal approach to GIS manipulation and analysis. Furthermore, the limit of sixteen values on the EGA has not posed any serious constraints to the creative and aesthetic processes. The vector plot mode is limited to six pens. However, since the procedure calls the pens in sequential order, it is possible to pause and reload the pen carriage with six different pens. The user need only remember that any map is a matrix of numbers and that the <COLOR> command does not care how those numbers were created.

Contour. Another major enhancement to the display features of MAP was the inclusion of a <CONTOUR> option. <CONTOUR> threads contour lines between cells according to the intervals and ranges selected. As with the <COLOR> option, the display can be directed to the monitor, plotter or printer (Fig. 8). However, the routine was designed to function on raster output devices. While the screen and printer output are quite efficient, the vector plotter option is slowed down by frequent pen up and pen down movements, as well as pen changes. Further, the <CONTOUR> command provides a method of generating an outline map of original polygon or linear data bases (Fig. 9).

Surface. The third enhancement to the display features of MAP was the inclusion of a three dimensional display. <SURFACE> is a versatile, efficient routine that provides options for rotation, vertical scaling, altitude viewing and sampling of the matrix (Fig. 10). As with any three dimensional type of display, considerable experimentation with <SURFACE> is necessary in order to create a meaningful and aesthetically pleasing graphic.

Dump. The final addition to MAP consists of a utility for the export or transfer of individual maps from the data base to other systems. The <DUMP> command generates an ASCII DOS file in a row and column format that is handled easily by ERDAS and other image oriented systems, such as paint program. In practice this procedure has proven very useful for the creation of files that are "uploaded" to the mainframe version of MAP.

EVALUATION

The development of this system evolved over a nine month period. Since its completion, the system has been tested in several demonstration cases and several research efforts. One research project involved the analysis of various approaches for the extraction of stream locations and drainage basin boundaries from digital terrain data. The system provided a convenient and efficient environment for experimenting with different combinations of contours, aspect, slope, profile and stream operations (Fig. 8). Compared to the mainframe, the PC version of MAP saved the researcher hours of time. Furthermore, it produced much more usable and flexible output.

The other project involved the integration of several data layers in Pickens County, South Carolina. These layers consisted of Census County Divisions, Census tracts, USGS land use and land cover, a digital terrain model, water and sewer lines, water districts, industrial plants and major water discharge sites. The Census tracts and Census County Divisions were digital polygon files, and land use and land cover and DTM were gridded files, while all the other layers were digitized using a PC based system (Fig. 11). The entire data base was converted to 200 meter cells in UTM coordinates. Presently, this data base of 273 rows and 214 columns is being used county by planners to evaluate future industrial sites. They are learning how to use the system and are excited about their seminal experience with access to GIS capabilities.

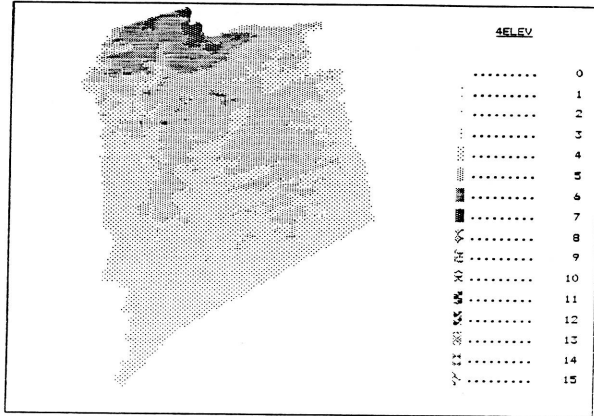


Figure 11. COLOR map on printer of 200 meter elevation data for Pickens County, S.C.
 Map is 273 rows by 214 columns.

FUTURE DEVELOPMENTS

Any GIS is an evolutionary system. By developing the graphics routines with a graphics kernel system, it will be possible to incorporate a variety of graphic devices, such as the laser printers and thermal plotters, as new drivers become available. It would also be feasible to move directly between MAP and a paint program for editing and color change. From a software viewpoint it would be desirable to functionally integrate the PC digitizing procedures into the same user interface.

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