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INTERACTIVE GRAPHICS: ANALYTICAL TOOL FOR GEOPROCESSING

by E. R. Hill

Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

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E. Richard Hill
Sr. Research Scientist
Battelle-Northwest
Richland, WA 99352

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ABSTRACT An innovative approach to geoprocessing has developed at Battelle's Pacific Northwest Laboratories. PTOLEMY, an interactive geoprocessing system, is implemented in FORTRAN and operates on a minicomputer. The system uses polygon overlap techniques for geographic retrieval and employs the concept of a separately maintained geographic base file.

Interactive graphics provides another dimension for interacting with a data base. Queries are formulated using pictures as well as conventional means. This combination of techniques permits access to information based upon geographic data or upon characteristics of other technical data in the data base. With the ability to selectively peruse either type of file while maintaining information relationships, the analyst sees immediate results. An interactive system, such as PTOLEMY, enables the analyst to make dynamic reformulations and refinements of queries to produce the required information as it is needed.

INTRODUCTION

Maps are commonly used items. People relate extremely well to them and to similar devices, such as the models on display at our national parks. People can easily and conveniently communicate geographic locations when they point to an area on a map. The concept of location is communicated without the necessity of knowing absolute coordinates.

PTOLEMY, an interactive graphics system developed at Battelle's Pacific Northwest Laboratories, functions in a similar way. Maps are displayed on the screen. A researcher who recognizes the map can formulate criteria for data retrieval by pointing at various areas on the screen with the light pen. The computer translates this action to coordinates for the data retrieval calculations, performs the retrieval, and displays the results.

The system is implemented in FORTRAN, and operates on a 48K byte minicomputer. The geographic retrieval capability uses FORTRAN subroutines transferred from the Des Moines geographic system software. The PTOLEMY file structures are enhanced versions of the structures developed at Des Moines. Improved data linkage and more effective map integration should result from the improved file structure.

The remaining sections of this paper describe the PTOLEMY system, its development, an example of its application, and conclusions.

Background to PTOLEMY Development

PTOLEMY has had the benefit of previous work in geoprocessing. The Des Moines Geoplanning Research Program produced several ideas and developments which has enhanced geoprocessing technology.[1] A major piece of work

was the geographic software system which was developed to construct, manage and retrieve geographic base data.[2] This system was interfaced with the Formatted File System. The combination was a sophisticated data management system which provided a full range of geographic retrieval capabilities in batch mode.

The geographic system used the polygon overlap technique developed in the Map Model System.[3] Several important concepts formed the basis of the geographic system.[4]

1. Physical independence of geographic data and other urban data.
2. Integration of data using cross reference indices.
3. Permitted the use of several identifiers for the same geographic entity.
4. Improved digitizing, editing and geographic file construction.
5. Emphasis on transferability.

The Des Moines geographic system technology was the basis for the design of the Fresno County planning information system. The geographic system software was transferred to the Fresno County environment. It is the basis for

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1. Des Moines Geoplanning Research Program, System Conceptualization, USAC-DM13-002, NTIS PB220582, April 1973.
2. Des Moines Geoplanning Research Program, Systems Design/Development, USAC-DMB-0003, June 1973.
3. Samuel Arms, Map/Model System, Technical Concepts and Program Descriptions, Columbia Region Association of Governments, Portland, OR, February 1968.
4. E. R. Hill, The Des Moines Geoplanning Research Project, presented at URISA Conference, Atlantic City, NJ, August 28-31, 1973.

the geographic retrieval and data linkage requirements of the system. The system operates in a highly responsive mode using terminals to communicate to the central computer. The county relies upon their system to access computerized maps and data files and to coordinate the data to answer vital questions concerning building permits and various other applications.

Overview of the PTOLEMY System

PTOLEMY is being developed as an interactive computer graphics program to manage geographic-related information. The function of the system is to retrieve information according to specifications supplied interactively by the researcher. The researcher enters commands using the keyboard and light pen. Maps are viewed on the display screen. Data listings are produced either on a line printer or on an electrostatic printer. Hardcopy of the maps viewed on the display screen can be produced either on an electrostatic printer or on a mechanical plotter.

The PTOLEMY system operates on a data base which contains a geographic base file and other special data files relating to the field of application. The geographic base file contains the cartographic data which supports the map display and manipulation capability. The cartographic data consists primarily of point and polygon descriptions of geographic entities. These data are linked to the special data in the application files.

Geographic Retrieval

PTOLEMY specializes in geographic data retrieval using the polygon overlap method. The researcher requests a map from the data base to be displayed on the display screen. Then he uses the light pen to draw a search

polygon around his area of interest. On command, PTOLEMY compares the search polygon with each of the entities displayed on the screen to produce a new map file. The new map file contains only geographic entities from the original map which overlapped the search polygon. The new map is displayed on the screen at a scale that fills the screen. In effect, PTOLEMY zooms in on the map data within the search polygon while maintaining all linkages to the data in the application files. This new map file is retained in the cartographic data base until specifically discarded by the researcher. If desired, the researcher may use this new map to zoom in again or he may choose to continue with another map in the data base. The researcher may zoom as many times as desired (within the limits of disk file storage space), or to any level of detail (within the limits of the data resolution).

The zooming process is also used to construct a new map from pieces of existing maps. Zooming is performed once for each piece of an old map that is desired. Instead of building a new map file for each zoom, the pieces are collected into one composite map.

When the new map meets the researcher's satisfaction, PTOLEMY will produce, on command, a data listing from the application files. The data linkages, which were maintained in the zooming process, are followed to retrieve the application data which corresponds to the new map.

Content Retrieval

PTOLEMY is also designed to produce maps as a result of content retrieval from the application data files. The researcher specifies the item (data field) of the application file and the desired value. PTOLEMY searches the application file for items with the specified value. When one is found, the linkage

is traced to the geographic base file. The corresponding geographic entities are extracted to a new map file and displayed on the screen.

ANALYTIC TOOL

PTOLEMY is a system designed to aid the researcher in the analysis of data. The system command language is sufficiently simple that the user can learn its operation in a few minutes. It is not necessary to learn a computer language.

The system is primarily intended to perform geographic data retrieval: given an area, retrieve data pertaining to it. Examples may help in understanding the use of this facility.

1. Determination of School Boundaries. The analyst would draw proposed school boundaries and retrieve school population data. Alteration of the boundary (search polygon) would change the school population until a proper number is obtained.
2. Evaluation of Proposed Transportation Corridor. The analyst would draw the proposed corridor and retrieve various data which would impact corridor selection. The data retrieved for several alternative corridors would provide information necessary for a decision. The content retrieval feature is especially useful. The problem in this case is to determine geographic patterns from known data values.
3. Plot the location of geothermal hot springs with temperatures between 180° F and 200° F.
4. Plot the locations of traffic speeding violations.

A by-product of the system is the capability to produce maps. Enlargements of any area of a map can be made. The same area can be selected from several maps to produce a composite. Examples may help illustrate this facility.

1. A street repair crew may need a detailed map showing street segment,

water lines, sewer lines, underground cables and easements for three blocks of Grand Avenue.

2. A hearing for the extension of a road would find helpful a detailed map showing existing street segments, property boundaries and easements.

PTOLEMY Commands

There are seven commands currently implemented in the PTOLEMY system. All commands are typed on the keyboard. The command appears in the screen as it is typed.

DISPLAY (filename) the content of a file on the screen

WINDOW (filename) allows the researcher to construct a polygon of his choice against the background of a map for geographic zooming or retrieval

COPY (filename) the portion of the currently displayed file enclosed by the window to a new (or latest) file

DELETE (filename) causes a file to discarded

LABEL causes data on the screen to be labeled with reference data from the file

LIMN (to draw) causes the information displayed on the screen to be output to a choice of a mechanical plotter or electrostatic printer

REPORT causes the system to search the data base and build a report for data displayed on the screen.

Two special commands have been implemented which are specific to one application. The commands provide information retrieval depending upon flow and temperature values in the data.

FLOW causes the flow data to be examined for specified values. The corresponding geographic entity is displayed on the screen.

TEMP causes the temperature data to be examined for specified values. The corresponding geographic entities are displayed on the screen.

The DISPLAY Command

A map is displayed on the screen by typing DISP and the name of the map file on the keyboard. PTOLEMY responds by locating the map file and displaying it on the screen. The map is always drawn to a scale such that it fills the screen.

The WINDOW Command

The researcher types WIND on the keyboard. The system responds by displaying a tracking cross in the center of the screen. Movement of the cross to the desired location is controlled by the light pen or from the keyboard.

Once the tracking cross is positioned, a signal from the keyboard records a polygon vertex at its location. After all points of the window have been recorded, control from the keyboard indicates that the window is complete.

The COPY Command

Typing COPY on the keyboard along with a file name causes information to be copied from one file to another. Information from the file being displayed is copied to the specified file. Only the portion of the file is copied which is enclosed by the current window definition.

The file specified by the command must be the newest file in the system or a new file to be added to the system. Creation of a new file is automatic and requires no special attention by the researcher.

Specification of a file name not in the system causes the file to be entered into the system and space allocated for it.

The DELETE Command

The command is used to discard a file which is no longer needed.

The LABEL Command

Reference information is available in the files to aid the researcher in recognizing features of the map. Typing the label command causes the features displayed on the screen to be labeled.

The LIMN Command

Typing LIMN (to draw or paint) on the keyboard causes a hard copy of the information displayed on the screen to be produced. The user has the option of using either a mechanical plotter or electrostatic printer.

The REPORT Command

Typing REPT on the keyboard causes a report to be produced on one of three devices. The user can select either the typewriter, an electrostatic printer or an impact line printer.

The report contains information from the data files for the features being displayed on the screen.

Application Example - Geothermal Resource Assessment

PTOLEMY is being used by Dr. Phillip N. Lamori at Battelle-Northwest to study data correlations for a geothermal resource assessment project.

Two geographic base files for geothermal hot springs have been loaded into the system. One file contains the geographic locations of geothermal hot springs. The second file contains outlines of the western United States which are used for orientation purposes for both the researcher and final map plots.

The geographic base file for geothermal hot springs was loaded by first digitizing the locations of the springs from maps. A coordinate conversion program was used to convert from digitizer coordinates to geodetic latitude and longitude. Four points of known coordinates in both coordinate systems were used as a basis for calculating geodetic coordinates.

The outline map for the western United States was loaded in the same way by digitizing a map and performing coordinate conversion. In this case, however, the points were used to define the outline of polygons which represent the outlines of the states.

Technical data was then collected for the hot spring and loaded into the technical data file. This data includes temperature, flow, and reference label from original diagrams, for each hot spring. A strict relationship between the technical data records and the ~~hot spring~~ cartographic records was developed and maintained. This relationship permits the geographic location in one file to be associated with the corresponding data in the technical data file.

With the data loaded into the system, let's visualize how the researcher makes use of it.

For example, let's assume the user wishes to produce a listing and map for a geothermal springs in south central Colorado. The technique employed will be to describe the area of interest using a background map as a guide. Then the area of interest will be matched with the geothermal spring file to extract only the springs in the desired area. This procedure causes a new file to be constructed automatically by the system. For orientation purposes the background map is added to the new file. The corresponding data is then extracted from the technical data file and listed.

The map of Colorado is displayed on the screen by typing "DISP COLO". The upper basin area will be described with the light pen. This is initiated by typing "WIND". The area is outlined by moving the tracking cross on the screen with the light pen and pressing the space bar to record the corners of the described area. The ESC key is pressed when the area is complete. The area of interest is now remembered by the system until a new area of interest is described.

The geothermal spring map is now displayed on the screen by typing "DISP GTHS". The system will build a new file of springs in the area of interest (TST1) by typing "COPY TST1" on the keyboard. As soon as the new file has been built it is displayed on the screen, along with the prompting phrase "COMMAND:".

To add the state outline to the new file, the outline must first be displayed by typing "DISP COLO". Then a window of the entire state outline is made by typing "WIND" and outlining the area of interest. As before, the tracking cross is moved using the light pen and the space bar on the keyboard is pressed when a corner of the area is reached. When the window is complete, the state outline is added to the previously constructed file by typing "COPY

TST1" on the keyboard. When the operation is complete, the file TST1 is displayed on the screen along with the prompting phrase "COMMAND:". This time, the display includes the outline for Colorado as well as the hot springs.

A data listing for the springs on the display screen is obtained by simply typing "REPT".

Costs

Awareness of the cost of data processing systems is important to the planning and development of capability for problem solving in a production environment. The following information data reflects the costs associated with the development and operation of PTOLEMY. The data are presented as a guide to those interested in similar capability. It should be noted that changes in individual requirements and specifications can alter costs significantly. Therefore the data presented should be used for guidelines only.

The software consists of approximately 2000 FORTRAN statements, including FORTRAN subroutines which were developed as part of the geographic system software by the Des Moines Geoplanning Research Program. Estimated cost of software development is $20,000.

PTOLEMY operates on a DEC PDP 11/35 minicomputer with a Vector General video display.

PDP 11/35	48K bytes memory	$24K
2	2.4M byte disk drives	12K
Vector General Video Display		60K
		$96K

The cost of developing the data base is significant. Assuming that accurate maps and application data are readily available, collection costs will range from one to two dollars per geographic entity.

For example, construction of a computer map for 1000 geothermal hot springs, loading the application data (temperature, flow, etc.) and building linkages between the data would cost in the range of $1000 - $2000.

As a second example consider the construction of a census block map and a parcel map for a city. Suppose that there are 1200 census blocks and 24,000 parcels. Costs for building the data base would range from $25,200 to $50,400. (1 * (1200 + 24,000) and 2 * (1200 + 24,000))

Operating costs for the system depends on the charge-out rates for the machine and the researcher.

Conclusions

PTOLEMY is an effective tool for the researcher. The ability to peruse a data base and study graphical results is invaluable. Responses to queries are rapid enough that the researcher does not become distracted and impatient. Hard copy of final results provides a permanent record for reference and presentations.

A good use of the system appears to be a situation similar to literature searching. The researcher has a feel for the information he needs and the system provides the details. The researcher can visually verify the results immediately and can fine tune his query, if necessary, to satisfy the requirements. The search for a transit route to maximize potential riders is a good example. The route can be changed a block at a time, if necessary until the conditions are solified.

Memory size of the machine is restrictive. Memory is used for program, display files for the video screen and data storage. The concurrent use of memory for geometric calculations and data display taxes available memory. The current version of PTOLEMY limits the size of polygons for overlap calculations to a maximum of 25 vertices. This could be restrictive in some applications. Data display and calculations need not be concurrent. Calculation speed would be increased if this condition were eliminated because the free memory would be used to reduce overlay requirements.

Disk storage would be restrictive for large data bases. The two disk drive systems will handle a 10,000 polygon geographic base file with supporting data files.

PTOLEMY would be useful to application with large data bases if the environment were modified. The system should work in concert with a system on a larger data base handling machine. The large system would manage the data base. PTOLEMY would operate in an intelligent terminal environment with a high speed data link to the large machine. Portions of the data base would be extracted for transmission over the data link to PTOLEMY. The researcher would use the system in the same manner as outlined in this paper. The arrangement would provide access to very large data bases while still retaining the capability to use PTOLEMY as an analytical planning tool.