1981

Draw-a-map: An Interactive graphical system using a relational data base

Ethel Comte

Rochester Institute of Technology
School of Computer Science and Technology

DRAW-A-MAP:
An Interactive Graphical System Using a Relational Data Base

A thesis submitted in partial fulfillment of the
Master of Science in Computer Science

Ethel C. Comte
May, 1981

Master of Science in Computer Science

Thesis Approval Form

This is to certify that _____ has submitted a thesis entitled:

Draw-A-NAR: An Interactive Graphical System Using a Natural Language Interface

to the faculty of the School of Computer Science and Technology in partial fulfillment of the requirements for the degree of Master of Science.

Approval: Name Illegible (thesis advisor) June 26, 1981 (date)

Name Illegible (committee member) 29 June 81 (date)

Name Illegible (committee member) 29 June 81 (date)

Table of Contents

Introduction

Recent developments in hardware technology have decreased the cost of storage and manipulation of data. As the cost/benefit ratio has improved, more work has been done in the areas of computer graphics and data base technology. This thesis demonstrates how these two areas can be made to complement to one another by using a data base to store data from a system which manipulates graphical and nongraphical data.

In brief, the focus of this thesis is an interactive graphics system, DRAW-A-MAP, which permits a user at a graphics terminal to draw a map on the screen, enter appropriate information about the map and its component parts, and store the map in a data base. At a later point in time, a user may request that the map be extracted from the data base and may make inquiries about the characteristics of the areas shown on the map.

Section 1 of this thesis discusses previous work in storing graphical data and explores the change from the storage of graphical data in data structures to the storage of such data in data bases. This discussion also features previous projects relating to map generation and the storage of data associated with the map.

Section 2 focuses on the data base aspect of the project. It discusses the demands imposed by computer graphics on data base technology, and the data base model that appropriate to computer graphics. It includes the features and conceptual schema of the data base for the DRAW-A-MAP system.

The graphical aspects of DRAW-A-MAP are considered in Section 3. This section involves a discussion of two techniques used to represent graphical data, their advantages and disadvantages, and the qualities a data structure must possess to represent graphical information. A discussion of the actual data structure used in DRAW-A-MAP follows.

The actual implementation of the DRAW-A-MAP system is the subject of Section 4. It includes the structural model of the system and discusses the user, the graphical and the data base interface.

The next section, Section 5, discusses enhancements that would make the system more "user friendly", more useful, and more efficient. It also describes how DRAW-A-MAP might be enhanced to become a production cartographic tool.

Section 6 concludes with an overview of the thesis.

The appendices follow: Appendix A contains the structural model of the system, Appendix B, a model of the data base design, and Appendix C ,source code.

1. Review of the Literature

Robin Williams [1] in a review of data structures used for computer graphics, states that the data structures for computer graphics must possess the following qualities:

> 1. The data must be ordered, particularly in the case of line drawings where a coordinate's position in the data structure implies a graphical meaning, i.e.,where and when the line will be drawn.
> 2. The data must be structured to allow the necessary searching and accessing of related data. For example, when a line on the screen is identified, the representation of the line in the data structure must be located with relative ease.
> 3. The data structure must be flexible enough to allow the updating procedure to be performed quickly.
> 4. The data structure must be able to handle the large amounts of data generated by computer graphics.

The following articles trace the efforts to achieve the above qualities in data structures.

1.1. Early Work in Data Structures Used in Graphics

In the first significant work done in computer graphics, Sutherland [2] in Sketchpad used a ring structure to contain graphical information. In his classic thesis, he demonstrated how screen images could be drawn and stored

---

[1] Robin Williams, "A Survey of Data Structures for Computer Graphics Systems," ACM Computing Surveys, 3 (March 1971), pp. 1-21.

[2] Ivan E. Sutherland, "Sketchpad: A Man-Machine Graphical Communication System," Proc. Spring Joint Computer Conference, (AFIPS Press, 1963), in Tutorial and Selected Readings in Interactive Computer Graphics, ed. Herbert Freeman, (New York: IEEE Computer Society, 1980) pp. 2-19.

interactively. He introduced the concept of instances, i.e,. one or more occurrences of a subpicture on a screen. This concept of subpictures is similar to the concept of graphical building blocks. Using a ring type data structure to support these instances, he related the concept of hierarchies in data structures to the graphical image itself.

Data structure flexibility is a very important aspect of handling graphic data efficiently. This flexibility was a result of the development of languages which had capabilities to manipulate and build list structures and to express data relations inherent in the data itself. The following discussion of L6, DSPL, APL and LEAP represent early attempts at creating this flexibility.

Early work involved the development of languages to support list type data structures. L6 [3] and DSPL [4] were low level languages developed to support data structures of the list type. These languages contained blocks (a sequential number of machine words) and fields (a sequential number of bits) and pointers (a word address). The user was

---

[3] K.C.Knowlton,"A Programming Description of L6", Comm. ACM, 9 (Aug.,1966), pp. 616-625. in Robin Williams, "A Survey of Data Structures for Computer Graphics Systems," ACM Computing Surveys, 3 (March 1971), ,p. 8.

[4] A. Van Dam and D. Evans, "Data Structures Programming System," Proc. IFIP Cong., 1 (Amstderdam:North Holland,1968), pp. 557-564. in Robin Williams, "A Survey of Data Structures for Computer Graphics Systems," ACM Computing Surveys, 3 (March 1971) ,p. 9.

able to create and name blocks and fields and could interconnect them with pointers to form structures. DSPL contained a paging facility to handle the large amounts of data with relative ease.

Higher level languages were also developed to support flexible data structures. Dodd [5] added six statements to PL/I creating APL (Associated Programming Language). The basic elements of APL were entities which were described by attributes. Related entities were then grouped into sets. References to entities were made through the entities themselves or through a set which owned the entity.

LEAP , a language developed to express data relations in associative structures, was developed in 1968 by Feldman and Rovner [6]. Leap itself was an extension of Algol with statements added to access the data by hash coding techniques. In LEAP, data associations were of the form

Attribute of Object is Value
or A(O) = V

[5] G.G.Dodd, "APL- a Language for Associative Data Handling in PL/I," Proc. AFIPS 1966 FJCC, 29 (New York:Spartan Books,1966), pp. 677-684. in Robin Williams, "A Survey of Data Structures for Computer Graphics Systems," ACM Computing Surveys, 3 (March 1971) ,p. 10.

[6] J.A.Feldman and P.D.Rovner, "An Algol-Based Associative Language," Comm. ACM, 12 (Aug. 1969), pp. 439-449. in Robin Williams, "A Survey of Data Structures for Computer Graphics Systems," ACM Computing Surveys, 3 (March 1971) ,p. 10-11.

an example of which is father (jack) = jim.

Data in Leap is stored on an A page, an O page, and a V page. Items (jack and jim) are treated as integers. Hash coding techniques were used to store the triple on a page of each type (A, O, V). The effect of this technique was that storage and retrieval of data was fast and did not require extensive pointer chasing.

The above languages and data structure techniques represent a few of many that were explored during the late sixties and early seventies. The late seventies saw an emergence of graphical systems built on techniques developed during the early periods. These systems handled graphical information drawn from traditional files.

1.2. Cartographic Systems

In 1977, an extensive cartographic system, the Crime Analysis and Research Package (CARP), was developed at the Geographic Information Systems Laboratory at the State University of Buffalo.[7] This system drew upon two files containing census and crime data. A third file contained such spatial information as geometric indices of census block groups, census tract boundaries, and centroids of statistical units. These three files, which were organized in

---

[7] Kurt E. Brassel, Jack J. Utano, Perry O. Hanson III, "The Buffalo Crime Mapping System: A Design Stretegy for the Display and Analysis of Refenerced Crime Data," Computer Graphics, 11 (Summer 1977), pp. 78-85.

indexed sequential and random access fashion, were used to generate maps on a graphic device. The generated maps revealed graphically how census data and crime data were related.

Williams [8] reports a similar project developed at the IBM Research Laboratory in San Jose which was used to allocate manpower in the San Jose police department so that each beat had an equal work load. A zone map which divided the area into small zones was used with data collected on housing, schools, traffic and police activities. The system generated a revised zone map which allocated police resources more equally.

Another project, the Domestic Information Display System [9], was built to generate choropleth maps which depicted socioeconomic characteristics of geometrically defined areas for the federal government. In this system the geometric entities (census tracts) were kept by their raster images. These rasters were colored depending on what characteristics that geometric area had. To improve response

---

[8] E.J.Cristiani,R.J.Evey,R.E.Goldman,P.E.Manty, "An Interactive System for Aiding Evaluation of Local Government Policies," IEEE Trans. on Systems, Man and Cybernetics, SMC-3 (March 1973), pp.141-146. in Robin Williams, "On the Application of Relational Data Structures in Computer Graphics," in Data Structures, Computer Graphics and Pattern Recognition, eds. A. Klinger, K.S. Fu, T.L.Knuii, (New York: Academic Press,1977), p.162.

[9] J. Dalton, J.Billingsley, J. Quann, P.Bracken, "Interactive Color Map Display of Domestic Infromation," NASA/Goddard Space Flight Center, Greenbelt, Md., Computer Graphics, 13 (August 1979), pp. 226-233.

time,data for this system was extracted from large data files resident on a main frame and transmitted to a minicomputer on which the graphics system ran.

1.3. Use of Relational Data Bases for Graphic Data

The year 1978 marked the appearance of graphical data stored in a data base. McIntosh [10] (in a project very similar to the DRAW-A-MAP system) used a relational data base to store a map generated by users on a graphical device. He stored the map in terms of nodes used to draw the map but did not provide the facility for nongraphical data to be stored with the map.

In another project Bonfatti and Tiberio [11] stored a map in a relational data base but its representation was quite different from that of McIntosh and DRAW-A-MAP. They used a bit map technique to store maps and nongraphical attributes in a data base. They subdivided the territory being studied into geographical cells. Attribute values were subdivided into classes and when a cell contained an attribute of a certain value, its bit was turned on. Therefore, for each class of attribute values there existed a bit map that indicated which geographical cells would be described

---

[10] J.F.McIntosh, "The Interactive Digitizing of Polygons and the Processing of Polygons in a Relational Database," Computer Graphics, 12 (Aug. 1978), pp. 60-63.

[11] Flavio Bonfatti and Paolo Tiberio, "Data Management for Thematic Map Generation," Computers and Graphics, 3 (1978), pp. 71-78.

by that attribute. Map generation consisted of cell by cell logical operations performed on the bit maps. Data from which the bit maps were generated was stored in a relational data base.

Additional work was done by Uno [12] in 1979 enhancing our notion of the data structure features desirable in graphical data base systems. He developed A-IDAS (Advanced Integrated Design Activity Support System), in which graphic data, geometric data and engineering data were stored in a relational data base. The building block approach was used in that he divided every geometric element into four geometric classes, i.e., vertex, edge, face and body. Each class consisted of several geometric application dependent categories or "legions", i.e., a point, an arc, a circle etc. which were stored in a relation. Another relation stored linking information which linked edges, vertices and faces. Various combinations of linkages and legions were used to generate a screen image of the item so described. The linkage relation also contained parameters which described line style, color, and other graphic symbols to be drawn with the object. Drawing routines were used to draw screen images directly from the data base. This system also provided a device independent graphic management facility thus making the graphic device independent of the data base.

---

[12] Sakae Uno, "A General Purpose Graphic System for Computer Aided Design," Computer Graphics, 13 (August 1979) pp. 25-32.

Weller and Williams [13] described a picture building system which allowed a user to interactively create and modify images. The system contained a graphics software package and a relational data base. The data base (XRM) was self describing,i.e.,it provided semantic (how the data is to be used) as well as the traditional syntactic (how the data is stored and accessed) support. This feature allowed the data base to be read by an interpreter which passed commands directly to the display file that generated the pictures on the screen. The data base/interpreter process provided for the operations of rotating, scaling, translating, coloring, setting intensity and line style, manipulating text, and creating transformations from the real world data space into the screen data space, to be done purely from data stored in the data base and not as traditionally done under program control. It also provided an efficient mechanism for correlation, i.e., the operation of identifying an item by pointing to its representation on the display terminal. This operation was performed using a correlation table that contained all the items on the screen with their locations in the data base.

In this thesis, DRAW-A-MAP defines a map as a collection of subareas and attributes specified by the user. Each

---

[13] Dan Weller and Robin Williams, "Graphical and Relational Data Base Support for Problem Solving," Computer Graphics, 10 (Summer 1976), in Tutorial and Selected Readings in Interactive Computer Graphics, ed. Herbert Freeman, (New York: IEEE Computer Society, 1980), pp. 193-199.

subarea is defined by the vertices that determine its graphical image, its name, and the attribute values which describe the characterisitics of the subarea. The data for each subarea is stored in a relational data base and may be retrieved on demand. For efficiency in drawing and manipulating the map, the data base also stores, for each subarea, a representative point in the subarea and the coordinates of its surrounding box. For each vertice of the subarea, the slope and y intercept of the line departing from that vertice is stored as well as the representation of that point in user-defined world coordinates.

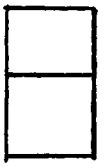
Building on the past and present techniques of storing graphical data, the next section will look at what must be considered in determining what storage techniques to use.

2. Data Base Considerations

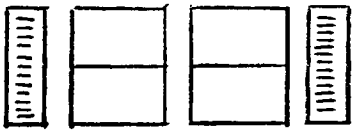
2.1. Data Base Design and the Structure of Graphical Images

In designing a data base management system to contain graphic data, the characteristics of graphic processes must be considered. By incorporating features in the data base design which support graphic processes, the resultant data base will enhance the execution of those graphic processes. The example of the screen image of a building will illustrate these processes as follows:

1. Graphics elements are defined as the basic building blocks of screen images. As such, they are primitives. An example might be a window in a building.

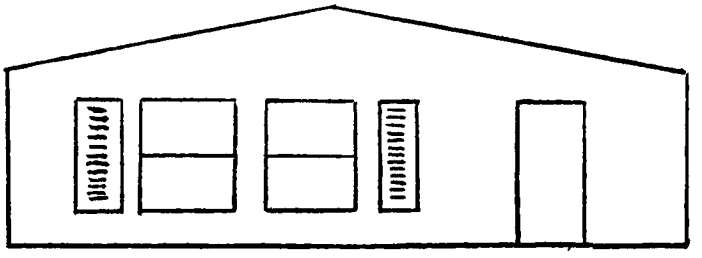


2. Primitives may be combined with other images to form entities (more complex graphical images). As such, primitives themselves remain distinctly defined but are part of an entity when the entity definition contains a 'call' to them. An example of an entity would be windows with shutters.



The entity would contain two references to the primitive describing windows as well as two references to a primitive describing shutters.

3. Graphical images are built by the process of grouping entities in a hierarchical manner. In the building example, a window with shutters might be part of the front of a house.



4. Graphic entities and primitives frequently have, associated with them, nongraphical data as well, i.e. the name of the manufacturer of the windows, their model number, their price and dimensions.

5. Graphical entities are subject to change in an interactive environment. In the building example, the dimensions of the windows or the window style might change completely, requiring that the primitive be changed.

A tabular implementation of the primitive/entity structure would be as shown in Figure 1. X and Y are relative coordinates that define the shape of the window in the coordinate space near the origin. The mode provides the name of the graphic operation to be performed in connection with its associated coordinate ,i.e., "move" means to make the coordinate the "current position" on the screen, while "draw" also means to make the coordinate the "current position" but in doing so, draw a line from the previous "current position" to the new "current position".

Table Window

X	Y	MODE
Ø	Ø	move
5	Ø	draw
5	1Ø	draw
Ø	1Ø	draw
Ø	Ø	draw
Ø	5	move
5	5	draw

Screen Representation

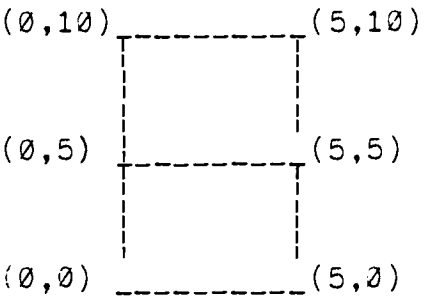


Figure 1

A composite screen image is generated through a table which contains a reference to primitive structures along with information regarding their placement on the screen. For example a table that would generate an image of two shutters beside two windows might appear as shown in Figure 2. This table is an entity which describes the instance of an image composed of two windows and two shutters. Scaling and translating factors control the placement of the windows and shutters on the screen, while the color and linestyle define graphical characteristics the lines are to have. The column "structure" actually contains references to primitive tables which give precise direction on how the respective images are to be drawn.

The facility for storing nongraphical information is shown in Figure 3. The table, window-shutter-info, contains

Table Window_with_shutters

Structure	Scalex	Scaley	Translatex	Translatey	Color	Linestyle
shutter	7	7	100	50	Green	Thick
window	10	10	150	50	Red	Thin
window	10	10	200	50	Red	Thin
shutter	7	7	250	50	Green	Thick

Figure 2

such nongraphical information as cost, manufacturer and dimensions. Note that the structure column contains a reference to another table, i.e., window. This is a reference to the window table which dictates the actual image generation of the window.

In selecting a data base management system to support the above structure, several additional requirements need to

Table Window-shutter-info

Structure	Cost	Manufacturer	Height	Width
window	30.00	Anderson	40	20
shutter	12.50	Ace	40	10

Figure 3

be considered. The first two imply the relaxation of certain assumptions at the primitive level, while the third applies to levels other than the primitive level. These are as follows:

1. In defining the primitives, the ordering of coordinates has specific meaning and, therefore, must be preserved. This, of course, may be avoided by having every line defined by both its beginning and ending coordinates, however this approach would require more storage and effort and is not necessary when ordering is preserved.

2. In defining primitives, duplicate records must be permitted because the same coordinates may be "visited" twice in an image.

3. Attributes of the data base must be permitted to contain the names of relations. As such, a hierarchy may be formed which permits entities to contain calls to primitives as well as calls to other entities.

2.2. Selecting the Data Base Model

A relational data base system seems to be the data base model most appropriate to computer graphics for the following reasons:

1. It has a simple structure, devoid of the fan and fan set structures (parent-child ordering constructs) found in hierarchical and network models. The absence of complex pointer schemes make the operations of data extraction and data integration relatively efficient. Consequently, the language

features,operators, and operands for accessing the data are simple,i.e. only one operator is needed for each of the basic functions: retrieve,insert, delete, and update.

2. The relational model provides for "symetric exploitation: the ability to access a relation by specifying known values for any combination of its attributes, seeking the (unknown) values for its other attributes. Symetric exploitation is possible because all information is presented in the same way".[14]

3. Relational data bases permit different logical views of the data which, in a complex system, would be useful to users with diverse interests.

4. For the nonsophisticated user, the relational model provides an easily understood data image, a table-- a structure with which most users are already familiar.

5. Relational data bases can support the graphics processes stated above. By permitting attributes whose domains contain relation names, hierarchies may be built.

6. Relational data bases offer the flexibility required by computer graphics. The following operations may be done with ease:

a. New relations may be added.
b. Additions may be made to existing relations.
c. Tuples within relations may be deleted.
d. Relations may be deleted.

---

[14] E.F. Codd, "A Relational Model of Data for Large Shared Data Banks," CACM, 13 (June 1970), in C.J. Date, An Introduction to Database Systems, (Reading,Mass.:Addison-Wesley,1977), p.448.

The foregoing has specified the requirements that graphics places on data bases and has shown the advantages of a relational type data base. It must be noted that using a relational data base for the reasons given above and as suggested by Williams et. al. /** implies the relaxation of the assumptions of non-ordering and non-duplicity of tuples. Consequently, the operations of select, join and project are no longer available to the user. In DRAW-A-MAP these assumptions are relaxed only at the primitive level. At this level, relations are always used as a whole, i.e., each tuple is only meaningful as part of the entire relation. Likewise, the domains of the relation are meaningless standing alone. Therefore, at the primitive level the operations of select, join and project are not required and the appropriate assumptions may be relaxed. The next section describes how the DRAW-A-MAP data base is designed.

2.3. Data Base Design - DRAW-A-MAP

In the DRAW-A-MAP system, the graphical image of a map is drawn on a graphical device. This map, actually a polygon subdivided into subpolygons, is stored in the data base. In the creation of the map the user must indicate to the system what nongraphical types of information (attributes) will be

---

/** Robin Williams, "On the Application of Relational Data Structures in Computer Graphics", in Data Structures, COmputer Graphics and Pattern Recognition, eds. A KLinger, K.S. Fu, T.L.Knuii, (New York:Academic Press, 1977), pp. 153-165.

stored for each subarea of the map. Examples of attributes might be population,average income, median age, housing stock, crime activity indicators, etc. The map is then drawn on the screen, appropriate information pertaining to the specified attribute is entered and the map is stored in the data base.

The particular data base design used in the DRAW-A-MAP system is shown in Appendix B and Figures 4 thru 8.

The relation, "mpdir", shown in Figure 4, contains an entry for each map in the data base. This relation provides the name of the map (MPNAME), the author (AUTHOR), the name of the relation containing the attribute table (ATTRTBL), the number of attributes (NOATTR), and the number of subareas in the map (NOSUBA). It should be noted that two of the attributes contain relation names, i.e., the name of the map is used as a "call" to the relation containing the subarea data and the attribute table is a "call" to the

---

Relation mpdir

MPNAME	AUTHOR	ATTRTBL	NOATTR	NOSUBA
Monroe	Smith	Mon.atbl	3	10
Ontario	Jones	Ont.atbl	4	12

Figure 4

---

relation containing the attribute table.

The attribute table relation shown in Figure 5, contains the names of the user-defined attributes (ANAME) that will be stored for each subarea of the map. It also contains an attribute (ATYPE) which indicates the type of the attribute ('n' for numeric or 'c' for character). In the case of a numeric attribute low (ALOW) and high (AHIGH) values are stored to form a range of valid values.

The relation called by the map name, shown in Figure 6, contains information about the subareas of the map. This relation represents a graphic entity, as discussed above. As such it contains graphic information about the entity and references to relations containing primitives (SCOORD and WCOORD). The graphic information includes X and Y, coordinates of a point representing the subarea (used for filling the subarea); COLOR, the color of the subarea; BBXMIN,BBYMIN,BBXMAX,BBYMAX, minimum and maximum x and y

---

Relation Mon.atbl

ANAME	ATYPE	ALOW	AHIGH
population	n	1	32
area	n	1	100
income	n	0	50
party	c	(null)	(null)

Figure 5

Relation Monroe

SUBNAME	SCOORD	WCOORD	NNODES	X	Y	COLOR
Rochester Henrietta Brighton	Monro.s.2	Monro.w.2	4	230	365	green

(Relation Monroe -- continued)

BBXMIN	BBYMIN	BBXMAX	BBYMAX
220	315	280	385

(Relation Monroe -- continued)

POPULATION	AREA	INCOME	PARTY
25	10	20	dem

Figure 6

values which define the bounding box that surrounds the subarea; and NNODES, the number of vertices in the subarea. The subarea relation contains a reference (SCOORD) to the relation containing screen coordinates which define the subarea on the screen, as well as a reference (WCOORD) to the relation containing world coordinates. This relation also contains the attribute values for the attributes specified by the user (in this example AREA, INCOME and PARTY).

The relation containing screen coordinates (called from SCOORD), shown in Figure 7, also contains information about the line departing from this node to the next node (in the next tuple) in the relation. Because in DRAW-A-MAP this structure represents a closed polygon, no graphical operations need to be defined, i.e., the first node is assumed to have to operation of "move" while the remaining nodes have the operation of "draw". The slope and y intercept of each line are kept in the data base to avoid the necessity of continually recalculating them since they are very frequently used in polygon editing, unioning, and intersecting functions. Because storage in MRS is limited to integers, the slope is actually stored by its value multiplied by 10, although its true value is shown here. For convenience infinity is defined as 9999.

A second primitive defining the subarea is kept in the relation referenced from WCOORD and shown in Figure 8. This

---

Relation Monro.s.2

SCRX	SCRY	SCRSLOPE	SCRYINT
220	350	.9	136
256	385	-.6	545
280	370	999.9	9999
280	315	-.5	478

Figure 7

Relation Monro.w.2

WORLDX	WORLDY
20	30
26	37
30	34
30	23

Figure 8

relation contains the coordinates (WORLDX and WORLDY) which define the subarea in a user-defined (world) coordinate system. Such a system might be latitude and longitude readings, mileage markers, etc. This is useful because it preserves the integrity of a map when different graphical devices are used.

The following provides a review the features of this data base design which makes it useful for graphics.

1. A building block structure is used. The screen and world coordinate relations are primitives. These are referenced from an entity type structure which contains other information about the graphic image of this entity, as well as nongraphical information about the subarea.

2. The maintainance of a world coordinate system makes the image transportable to other graphical devices.

3. It is flexible. More maps may easily be added to the directory (relation mpdir) and subareas may be redefined by replacing these relations by new relations.

Retrieval of the map is an operation which may be done with ease and will be thoroughly explained in a later section. Basically it consists of one reference to the relation mpdir, one reference to obtain the attribute table and the subarea relation, and a reference to obtain the screen and world coordinate relations for each subarea. In DRAW-A-MAP, maps cannot be subdivided for retrieval from the data base, therefore all the references to the data base involve obtaining whole relations, a time saving mechanism.

The next section will present the graphical aspects of the DRAW-A-MAP system.

3. Graphic Considerations

3.1. Representation of Graphic Data

Two techniques appear to provide methods for storing graphical images in a file or a data base; the polygon technique used by McIntosh [15] and the bit map technique used by Bonfatti and Tiberio. [16] (The reader is referred to the discussion of these techniques in Section 1.) The method selected for an application depends upon the nature of the application. The needs of the application in terms of storage, data entry, manipulation of data, and the purpose of the system must be considered.

Storage requirements for the bit map technique depend upon the number of attribute classes that are maintained while those for the polygon technique depend upon the amount of fragmentation of the edges of the polygon. Data entry using the bit map technique is very tedious as data must be entered for each attribute class within each geographic cell of the map.

Manipulation of the map itself must be considered. The bit map representation allows cell by cell logical operations for determining unions and intersections of the map, a very simple process. On the other hand, the polygon technique involves fairly complex algorithms which are quite

---

[15] McIntosh, pp. 60-63.
[16] Bonfatti and Tiberio, pp. 71-78.

time consuming.

Finally, and most important, the purpose of the map must be considered. The bit map technique best represents nonaggregated collections of data and therefore would be quite useful for analyzing such data. The polygon technique is more appropriate for aggregated data, as typically found in sources like the census.

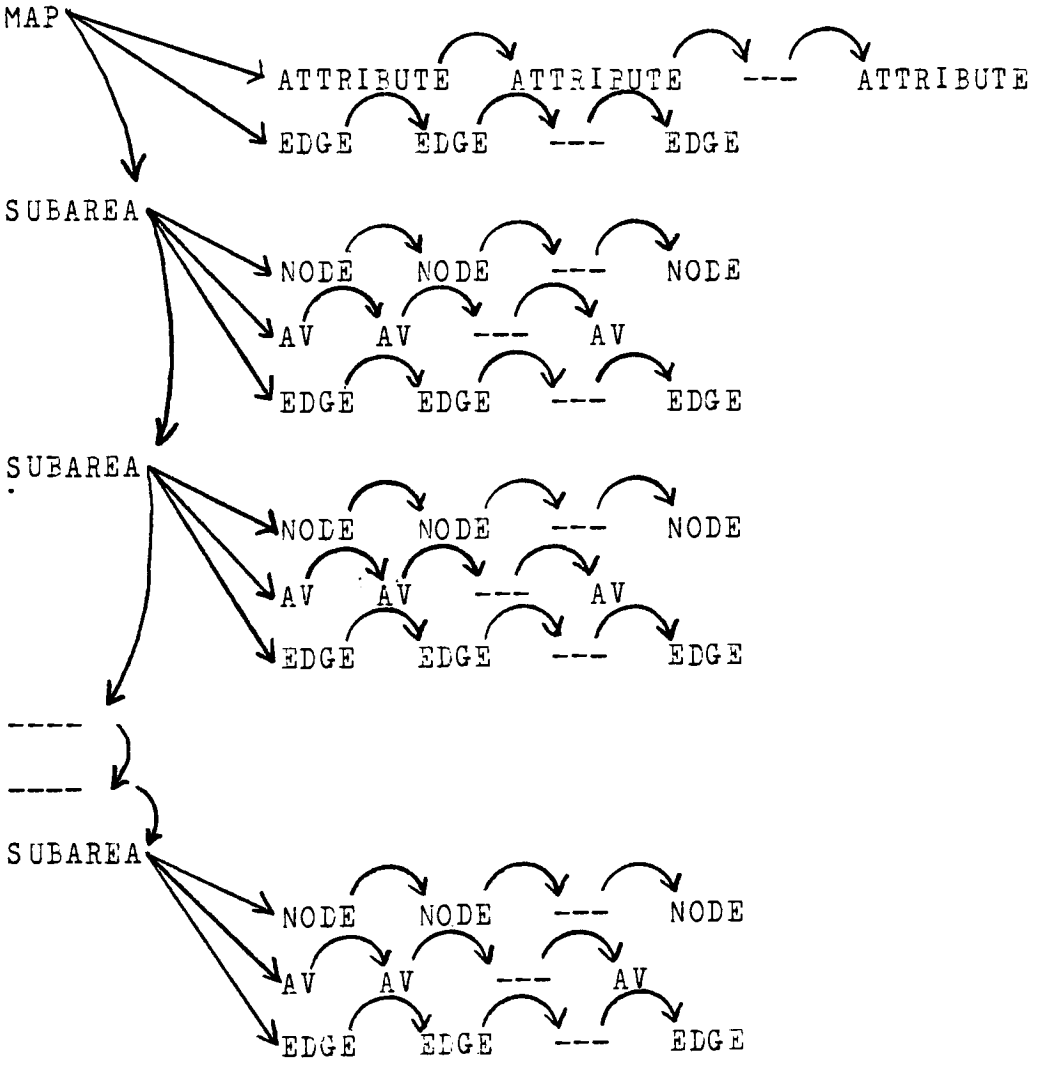
The polygon technique has been chosen to represent the data in the DRAW-A-MAP system because of the requirements of the system. In terms of storage, maps drawn with DRAW-A-MAP are not necessarily fragmented and the polygon technique is supported. Data entry is by subarea and under this technique is a simple process. Since the major focus of maps drawn by DRAW-A-MAP is to illustrate aggregated data,a static process, as opposed to analyzing data graphically, graphical manipulation operations are infrequent and the polygon technique is the one of choice.

3.2. Data Structures for Graphic Data

The data structure used in DRAW-A-MAP is designed to serve the dual purposes of efficient interface with the data base and ease in the execution of the algorithms necessary to perform polygon manipulating functions. The data structure of the DRAW-A-MAP system is shown in Figure 9 (its source code can be found in Appendix C.1). Note that the value of the attribute is shown in Figure 9 shortened to AV.

The arrows in the diagram represent pointers to structures.

The data structure consists of a singly linked list construct within a hierarchical structure. A singly linked list construct is used since concatenation of singly linked lists is easy, a process useful in combining attributes in



Organization of Structures in a DRAW-A-MAP
Figure 9

the case of map unions and in compiling a list of all the edges of a map for the process of subarea manipulation. The hierarchical aspect of the structure (maps contain a list of subareas and an attribute table, and subareas contain a list of attributes and a list of nodes, i.e., vertices) eliminates the need for a doubly linked list as the first node of a list may always be accessed directly from the level above.

Through pointers in the map structure, the program may access the attribute table (mattrtbl), the subarea list (msp), or the edge list (mpe) for the whole map. The map structure contains a pointer to the name of the map (mapname), a pointer to the author's name (author), a pointer to the name of the attribute table (mattrnm), the number of attributes for this map (mnoattr) and the number of subareas and nodes in this map (mtotsuba and mtotnode).

The attribute list contains information from the attribute relation (ANAME, ATYPE, ALOW, AHIGH) described in Section 2.3. as well as a pointer (atlnext) to the next entry in the list.

Each subarea structure contains the information described in Section 2.3 regarding subareas as well as pointers to the node list (spn), the edge list for that subarea (spe), the attribute list for that subarea (sattri) and the next subarea (snext).

The node structure contains the screen coordinates (NX and NY), slope (NSLOPE), and y intercept (NYINT) defined in Section 2.3. Since the world coordinates (WORLDX and WORLDY) are a function of the screen coordinates and since they are not used in the manipulation of data, they are also maintained in the node structure as nwx and nwy. Nnext is a pointer to the next node.

The attribute structure contains the actual values for the attributes named in the attribute table. Each subarea has its own list of attribute structures that contain the values which describe the subarea. The attribute structure contains a pointer to the attribute value (attribute) and a pointer to the next attribute structure (anext). As such this list and the attribute table list must be maintained in like order.

The major advantages to this structure is its extreme flexibility in data manipulation. Edges and attribute lists may be combined or split without the processes of allocating and freeing memory. The next section will describe the actual implementation of DRAW-A-MAP.

4. Implementation of DRAW-A-MAP

The implementation of the DRAW-A-MAP system is modular in nature, allowing changes to be made without worry of unwanted side effects. The modules which communicate with the graphical device and the data base reside on separate files for easy adaptation to new data bases or graphical devices.

4.1. Data Base Interface

The data base, MRS, and DRAW-A-MAP communicate through a set of modules designed for that purpose. Requests generated by these modules are printed on a file named frequest. Control is given to an executable file named mrscmds (shown in Appendix C.2) which calls MRS and directs it to read the file, frequest, for input. MRS then executes the request, places the results on the file,fmapres, and returns control to the DRAW-A-MAP system. Several versions of this file are shown. Which version is used depends upon how many (0,1,or 2) files have been requested.

This process is controlled by the following modules;

1) Readmap (Apendix C.3) receives the name of the map, searches for the map in the data base and reads it into the DRAW-A-MAP data structure.

2) Savemap (Appendix C.3) receives a pointer to the map and stores the map in the data base.

3) Deletemap (Appendix C.3) receives the name of a map and deletes it from the data base.

By limiting the purpose of these modules to that of communication with the data base, the system can easily be modified to operate with other data base management systems.

4.2. Graphical Device Interface

The DRAW-A-MAP system is implemented using the Tektronics graphical terminal.

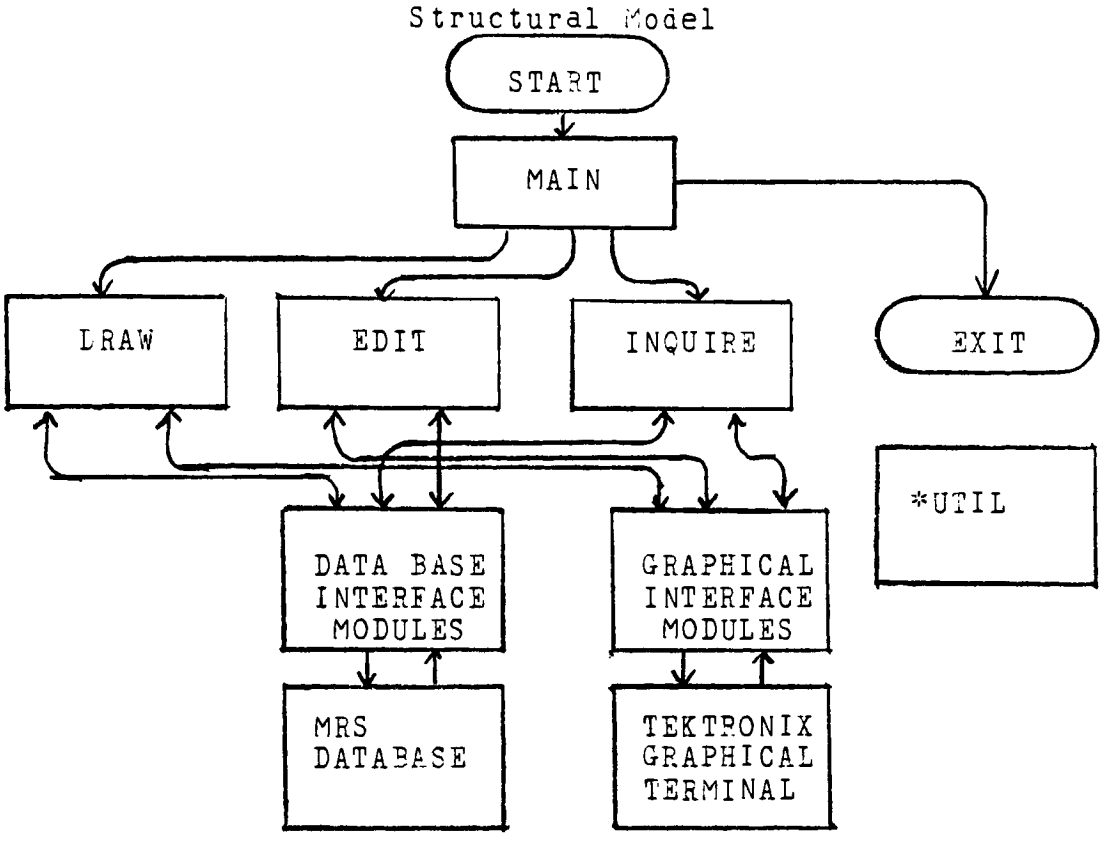
A set of modules (shown in Appendix C.4) contains the code necessary to communicate with the graphics device. This set contains modules to initialize the screen, to clear the screen, to clip a line against window boundaries using the Cohen-Sutherland clipping algorithm and draw it, to position the cursor on the screen, to read the cursor position, to read a character string from the keyboard, and to ring the bell.

4.3. Structure of DRAW-A-MAP

The structural model of the system is shown in Figure 10 and Appendix A. It consists of three primary modules; DRAW, EDIT and INQUIRE, which are controlled by a driver module (MAIN) and which communicate with the data base and graphical device via the modules described above.

4.3.1. Controlling Program

The driver program, MAIN (shown in Appendix C.5), controls the user's navigation through the system. Depending



* Called by DRAW, EDIT. INQUIRE as required
Figure 10

upon placement of the cursor by the user, control is transferred to the DRAW, EDIT or INQUIRY modules or the program is terminated.

4.3.2. Draw

The module DRAW (shown in Appendix C.6) allows the user to draw a map on the screen and enter it in the data base. The user is first prompted for the name of the map, followed by the attributes the map will have. To enhance drawing

accuracy the user may request that the boundary of a previously stored map be drawn on the screen. The user can then use these lines to draw the new map. In the drawing process itself, the user sets the cursor at a position where he wishes to have a node, and enters it by typing a period ('.'). A bell will ring indicating to the user that the system has received the node. To prevent splintering and overlaying of subareas along boundaries,a mechanism is in place to assure that nodes within a preset radius are assumed to be the same node. The system collects nodes until the user has closed the polygon by reentering the first node of the polygon. After the boundary polygon is entered and drawn, the polygon for each subarea is drawn. After entering each subarea, the user is prompted for the name of the subarea and the attribute values pertaining to that subarea.

4.3.3. Edit

The module, EDIT, while not currently implemented, would allow the user to edit a map that he has just drawn or that has been previously stored in the data base. Editing operations would be of two major types: those affecting the graphical image and those affecting the attributes. Graphical editing would allow the user to manipulate the lines that appear on the screen. Thus he would be able to

1) Add a subarea by extending the boundary of the map.
2) Combine two subareas by deleting a line.

3) Split a subarea by adding a line to the map.

Care must be taken to assure that the necessary operations on attributes must be performed in order to maintain the validity of the attribute values associated with the subareas.

Also very useful for inquiry purposes would be a graphical operation which would allow the user to overlay one map with another, creating a union of the two maps. As a result of this operation, a user could inquire about the joint occurrence of attributes maintained on separate maps that describe the same geographical area.

A facility should be provided for users to edit attributes. Characteristics of subareas may change over time requiring the changing of attribute values therefore, the user may also wish to expand the capability of the map by deleting no longer useful attributes and adding new ones. Operations to handle these procedures would require changes in the attribute table as well as changes to the attribute values associated with each subarea.

4.3.4. Inquire

The module, INQUIRE, (Appendix C.7) is designed to allow the user to inquire about the data the map represents. The user has three ways to use this module.

1) He can request a tabular display of the data

associated with the map. This approach would provide data in tabular form for all subareas of the map but would not show the map on the screen.

2) He can request to see all the data for a particular subarea. The map would be selected by the user and displayed on the screen. The user would then select a subarea by placing the cursor on it and the information pertaining to that subarea would be displayed.

3) He can request information directly from the data base. The map selected by the user would be displayed. The user would type a request of the form appropriate to the data base management system used, and the results of the inquiry would be displayed on the screen. (not currently implemented)

4.3.5. Graphic Utilities

A set of graphic utility modules are found in UTIL. These modules,described below, are called from the DRAW, EDIT or INQUIRE modules and operate on graphic images on the screen.

The function, getslope, receives the endpoints of a line and returns its slope. The function, yintercept, calculates the y intercept of the line it receives and returns this value. These functions are shown in Appendix C.8.

The function, bound_box (Appendix C.9), determines whether two boxes defined by two sets of endpoints overlap. This function calls another function, bb (Appendix C.10), which takes a point, x and y, and a box, defined by two points, and returns an indicator based on where the point lies in relation to the box. The reader is referred to the

illustration in the comments section of both functions for more information about what indicators are returned.

The function, interoept (Appendix C.11), determines if and how two lines intercept each other. Intercept checks to assure that the bounding boxes of the lines for intersect before proceeding to find the intercept. For additional information on how the intercept function returns the information it has found, the reader is invited to read the comments at the beginning of the function. In the case of a single intersection not at an endpoint, intercept calls fintercept (Appendix C.12), a recursive procedure which examines smaller and smaller sections of the lines for intersection.

The function for determining whether a point is in a polygon is called inploy and is found in Appendix C.13. It receives a point and returns a pointer to the subarea of the map containing that point. Inpoly first assures that the point lies within the bounding box surrounding the polygon by using the function bb. It then checks all edges for intersection with the horizontal line which contains the point and is bound by the minimum and maximum x values of the surrounding box. After all intersections are calculated, whether the point lies inside or outside the polygon can be determined depending upon where it lies in relation to the intersection points.

The above describes DRAW-A-MAP, as it currently exists, a basic interactive graphical system for drawing maps. The next section will discuss how this system might be enhanced.

5. Enhancements

DRAW-A-MAP could be considerably expanded to create a production quality cartographic tool, to increase its efficiency in interfacing with the data base and to increase its "friendliness" to users.

As a production cartographic tool, a system such as DRAW-A-MAP, could contain:

1. Facilities to maintain line data, such as a river or a highway, point data, such as an historic site, and polygon within a polygon data, such as a lake within a subarea.

2. Facilities to develop specific graphic symbols with which to label the map.

3. A facility for including text data in the map to label the map, its subareas and its points of interest.

4. Facilities for filling subareas with a pattern expressing a meaning rather than a color.

5. Facilities to define free form lines, as would be found in a line defining a winding river or a complex polygon.

DRAW-A-MAP could be made more "user friendly". It could allow the user to enter maps traced from a real map on a bit pad. It could then allow the user to specify how large the map could be on the screen. Other screen operations, such as scroll, expand and contract, rotate, move, center and adjust size, could be added which would allow the user to operate on his drawing.

Drawing a map would be much easier for the user if he could erase lines and if he were allowed to draw the map first, using lines that could cross each other and then enter the subarea data. These features would require several complex polygon manipulation functions but would be useful.

Increased error prevention procedures could be implemented. Currently the system permits a map to contain areas that are undefined. It is also possible to have subareas defined outside of the boundary of the map as well as subareas which overlay or surround each other.

For more efficient operation the interface with the data base could be improved. The user and system could be able to detect and process error conditions returned from the data base. It could be possible to selectively retrieve or update maps that exist in the data base. It would also be useful to have a display/ interpreter (as described by Weller and Williams) [17] that reads directly from the data base and generates the map image on the graphical device.

The above enhancements, if implemented, would improve the quality and usefulness of the DRAW-A-MAP system.

---

[17] Weller and Williams, pp.193-199.

6. Conclusion

The DRAW-A-MAP system demonstrates how both graphical and nongraphical data may be stored in a relational data base. It provides an interactive system for drawing a map and suggests the many routes one might take in its enhancement.

Section 1 traced the development of techniques for storing graphical data. It began with the period during which languages were developed to handle list structures and data relations. It followed with descriptions of computer cartography applications and projects in which graphical data was stored in data bases.

Section 2 provided a discussion of the processes inherent in graphics and their ramifications for data base design. It specified what assumptions must be relaxed for a data management system to support graphical processes. It explained why the relational data base model is appropriate for computer graphics. The DRAW-A-MAP data base design was presented and explained.

The graphic considerations of DRAW-A-MAP were presented in Section 3. Both the bit map technique and the polygon technique (used in DRAW-A-MAP) for storing graphical data were explained. Their respective uses were discussed. The subject of data structures in computer graphics was presented. Those features a data structure must posess to

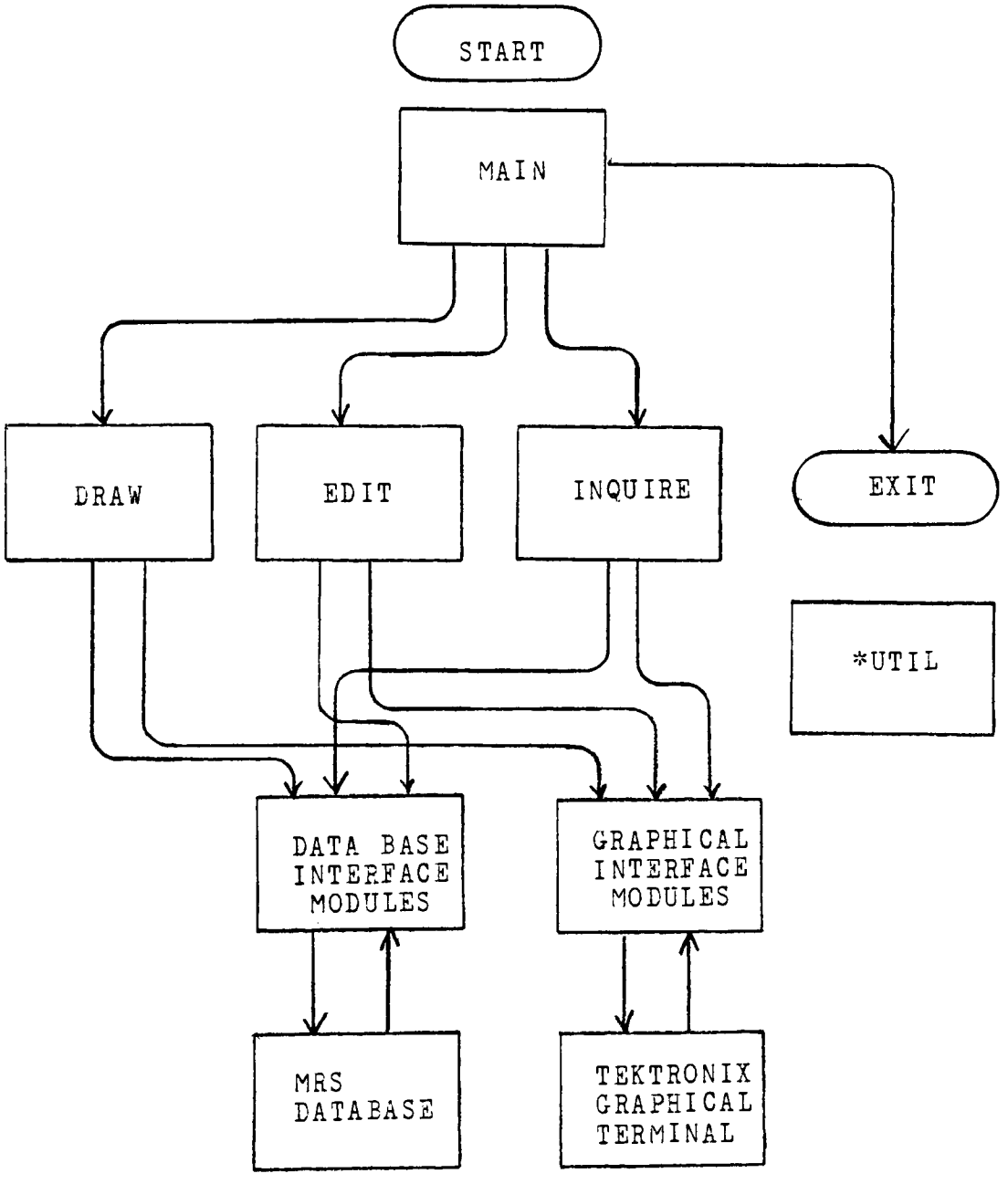
support computer graphics were discussed. The data structure used in DRAW-A-MAP was presented and explained.

The actual implementation of DRAW-A-MAP was the topic of Section 4. It was shown how DRAW-A-MAP was made portable between data base systems and graphical devices by the use of separate modules to execute the interface processes. The three primary modules of the system; DRAW, EDIT and INQUIRE were examined. The user's view and an inbternal view of the system were provided.

Section 5 concluded the description of DRAW-A-MAP with a discussion of the features one might add to convert the system to a production quality cartographic tool and how one might make the system more "user friendly".

Appendix A

Structural Model



* Called by DRAW, EDIT, INQUIRE as required

Appendix B

Data Base Design

Relation mpdir

MPNAME	AUTHOR	ATTRTBL	NOATTR	NOSUBA
Monroe	Smith	Mon.atbl	3	10
Ontario	Jones	Ont.atbl	4	12

Relation Mon.atbl

ANAME	ATYPE	ALOW	AHIGH
population	n	1	32
area	n	1	100
income	n	0	50
party	c	(null)	(null)

Relation Monroe

SUBNAME	SCOORD	WCOORD	NNODES	X	Y	COLOR
Rochester Henrietta Brighton	Monrc.s.2	Monrc.w.2	4	230	365	green

(Relation Monroe -- continued)

BBXMIN	BBYMIN	BBXMAX	BBYMAX
220	315	280	335

(Relation Monroe -- continued)

POPULATION	AREA	INCOME	PARTY
25	10	20	dem

Relation Monro.s.2

SCRX	SCRY	SCRSLOPE	SCRYINT
220	350	.9	136
256	335	-.6	545
280	370	999.9	9999
280	315	-.5	478

Relation Monro.w.2

WORLDX	WORLDY
20	30
26	37
30	34
30	23

Appendix C

C.1

Data Structure

(referred to as mpname.h or mpnamex.h(extern))

```
#define TIME    10
struct map {                    /* map data structure */
        char * mapname;         /* pointer to array containing map name */
        int mnoattr;            /* no. of attriutes */
        char * mattrnm;         /* name of attribute table */
        struct attbl * mattrtbl;        /* pointer to the attribute table */
        struct subarea * msp;   /* pointer to area containing subarea info */
        int mtotsuba;           /* no. of subareas in the map */
        struct edge * mpe;              /* pointer to beginning of edge array */
        char * author;                  /* name of person who entered map */
        int mtotnode; };        /* no. of nodes in this map */

struct subarea {                /* data structure coatining subarea info */
        char * subarname;       /* pointer to array containing subarea name */
        int stotnode;           /* no. of node in subarea */
        int sx,sy;              /* coordinate point in subarea */
        char * scolor;          /* pointer to color */
        char * scoord;          /* name of relation containing screen coordinateetes */
        char * wcoord;          /* name of relation containing world coordinates */
        int sbbminx,sbbminy,sbbmaxx,sbbmaxy;    /* bounding box description */
        struct node * spn;      /* pointer to beginning of node array */
        struct attri * sattri;  /* pointer to attribute values */
        struct subarea *snext;  /* pointer to next subarea */
        struct edge * spe;  };  /* pointer to list of edges */

struct node {                   /* data structure containing node info */
        int nx;                 /* x coordinate */
        int ny;                 /* y coordinate */
        long nyint;             /* y intercept of line */
        float nslope;           /* slope of line from this node to the next */
        int nwx;                /* world x coordinate */
        int nwy;                /* world y coordinate */
        struct node * nnext;    /* pointer to next node */
                };

struct edge {                   /* data structure containing edge info */
        int ebegx;              /* beginning x coord. */
```

```
        int ebegy;              /* beginning y coord. */
        int eendy;              /* ending x coord. */
        int eendx;              /* ending y coord. */
        long eyint;             /* y intercept of edge */
        float eslope;           /* slope of this edge */
        struct edge *enext;     /* pointer to next edge */
        };

struct attbl {
        char * aname;           /* pointer to attribute name */
        char atype;             /* indicates type of attriute, numeric or char */
        int alow;               /* lower limit of numeric variable */
        int ahigh;              /* upper limit of numeric variable */
        struct attbl * atlnext; /* pointer to next attribut in table */
        };

struct attri {
        char * attribute;       /* value of attribute */
        struct attri * anext;   /* pointer to next attribute value */
              };

struct map *mp, *mpx;           /* pointers to map structures */
struct subarea *sp, *spx;       /* pointers to subarea structures */
struct node *np, *npx;          /* pointers to node structures */
struct edge *ep, *epx;          /* pointers to edge structures */
struct attbl *atbp, *atbpx;     /* pointers to attribute table */
struct attri *ap, *apx;         /* pointers to attributes */

char * fname;                   /* function name */
int i,j,k;                      /* general purpose subscripts */
int xinter1,yinter1,xinter2,yinter2,    /* points of intersection */
xinter3,yinter3,xinter4,yinter4;
int temp;                               /* variable for saving values */
int xa1,ya1,xa2,ya2;                    /* points describing line or box a */
int xb1,yb1,xb2,yb2;                    /* points describing line or box b */
float m_a,m_b;                          /* slope of line a or b */
long b_a.b_b;                           /* y intercept of line a or b */
int lb,ub;                              /* upper and lower bounds */
char instring[17];                      /* string to receive input from screen */
char svstring[17];                      /* string to save input from screen */
char outstring[20];
int curx,cury;                          /* position of the cursor */
indent1 =           ;                   /* indentation */
indent2 =       ";                      /* indentation */
int scan;                               /* results of scanf */
int c;                          /* general character pointer */
float wwxm,wwxa,wwym,wwya;              /* relationships between screen and world */
int worldxl,worldxr,worldyb,worldyt;    /* coordinates descrining world */
int windxl = 1;
int windxr = 1023;
int windyb = 115;
int windyt = 779;               /* coordinates describing window on screen
            in which map will be drawn */
```

```
struct map *curmap [10]; /*array of pointers to maps in pgm. */
int nummap = 0;          /* subscript for curmap array */
char line [200];         /* array for characters received in input */

e1 = "scan error ";
e2 = "error in allocation of map area ";
e3 = "error in allocation of subarea area ";
e4 = "error in allocation of node area ";
e5 = "error in allocation of edge area ";
e6 = "error in allocation of attribute area ";
e7 = "error in allocation of attribute table name";
e8 = "error in allocation of attribute table area ";
e9 = "error in allocation of mapname";
e10 = "error in allocation of author name";
e11 = "error in allocation of screen coordinate relation name ";
e12 = "error in allocation of world coordinate relation name";
e13 = "error in allocation of subarea name";
e14 = "error in allocation of color area";
e15 = "error in allocation of attribute name";
e17 = "error in allocation of attribute value area";
```

C.2 Mrscmd, mrscmd1, mrscmd2

File - Mrscmd

```
cp frequest ./mapdb/frequest
cd mapdb
mrs <frequest
mrs <stop
rm frequest
cp fmapres ../fmapres
```

File - Mrscmd1

```
cp frequest freqx
cp frequest ./mapdb/frequest
cd mapdb
mrs <frequest
mrs <stop
rm frequest
```

File Mrscmd2

```
cp frequest ./mapdb/frequest
cd mapdb
mrs <frequest
mrs <stop
rm frequest
cp fmapres ../fmapres
cp fmap2res ../fmap2res
```

C.3 Readmap, Deletemap, Savemap

```
#define SQUOTE  '\047'
#define TIME    5
#include        <stdio.h>
#include        "mpnamex.h"
char * charp;
pinto = "into 'fmapres' ";
pinto2 = "into 'fmap2res' ";

int num1,num2,num3;             /* used only in scanf stmts. */
int num4,num5,num6,num7;
long num9;
long num10;
struct edge * node_edge(); /* func. that creates an edge list
                              for whole map */
char *encl();
int nattr;              /* counter for attributes */
int nsuba;              /* counter for subareas */
int nnodes;             /* counter for nodes */
int x,y;                /* temp. variables for x and y */
char name [50];         /* array to hold names */
char name2 [50];        /* second array to hold names */
char cname [12];        /* array for map name */
char scname [12];       /* array for screen coord names */
char wcname [12];       /* array for world coord relation name */
FILE *fopen(), *rp, *rp2, *wp;  /* pointers to files */

/*___readmap_____________________________________________________________*/
struct map * readmap (mpnm)     /* returns a pointer to a map , EOF or
                                   0 if error */
/* This function will read a map with up to five nongraphical
           attributes from a data base. It interfaces with MRS in the
           following manner.
                1. This program will print MRS commands on a file called
                      FREQUEST and close the file.
                2. It will give control to a file called mrscmd which
                   contains the following:
                      cp frequest ../frequest (moves the request file
                                               to the mapdb directory
                      cd  mapdb  (changes directories )
                      mrs <frequest;  ( calls MRS, using frequest)
                      from <stop;     (instructs MRS to stop)
                3. MRS executes the commands it has received and
                   returns the requested information on the file fmapres.
                4. File, fmapres, is moved to the program's directory.
                5. The program reads the file fmapres for its data.
        */
```

```
char *mpnm;                             /* name of map to be read */
{
        fnname = "readmap";
        printf ("Reading %s from the data base.\n\nSTANDBY",mpnm);

        /* This section requests information from the map directory. */
        /* open request file */
        wp = fopen ("frequest", "w");
        /* allocate a structure for the map */
        if ( mp = malloc ( sizeof (struct map))) == 0)
        {
                /* allocation error */
                printf("%s %s\n",fnname,e2);
                delay(TIME);
                return(0);
        }
        /* save a pointer to the map */
        curmap [nummap++] = mp;
        /* allocate room for the map name */
        if ((mp->mapname = malloc (strlen (mpnm) + 1)) == 0)
        {
                /* allocation error */
                printf("%s %s\n",fnname,e9);
                delay(TIME);
                return(0);
        }
        /* copy the map name in */
        strcpy(mp->mapname,mpnm);
        /* request information from map directory */
        fprintf(wp,"%s select author, attrtbl, noattr, nosuba from  ,pinto);
        fprintf(wp,"mpdir where mpname = '%s';\n",mpnm);
        fclose (wp);
        system ("mrscmd");

        /* The following section reads the information returned by MRS. */
        /* open the FMAPRES file */
        rp = fopen ("fmapres","r");
        /* gets headers */
        fgets (line,200,rp);
        fgets (line,200,rp);
        fgets (line,200,rp);
        /* read information from the map directory */
        if ( (scan = fscanf(rp,"%s %s %d %d",name2,name,&num1,&num2)) == EOF)
            || scan == 0)
        {
                /* scan error */
                printf ("%s %s\n",fnname,e1);
                delay(TIME);
                return(scan);
        }
        fclose(rp);
        /* gets the number of attributes */
        mp->mnoattr = num1;
```

```
/* gets the number of subareas */
mp->mtotsuba = num2;
/* allocate room for the name of the attribute table */
if ((mp->mattrnm = malloc(strlen (name) + 1)) == 0)
{
        /* allocation error */
        printf("%s %s\n",fnname,e7);
        delay(TIME);
        return(0);
}
/* copy it in */
strcpy(mp->mattrnm,name);
/* allocate room for name of author */
if ((mp->author = malloc(strlen (name2) + 1)) == 0)
{
        /* allocation error */
        printf("%s %s\n",fnname,e17);
        delay(TIME);
        return(0);
}
/* copy it in */
strcpy(mp->author,name2);


/* This section requests, receives and loads the attribute table
                and subarea information.  */
wp = fopen ("frequest", "w");
/* issues request for attribute table */
fprintf (wp,"%s select from %s;\n",pinto, mp->mattrnm);
/* requests all subarea information */
fprintf (wp,"%s select from %s;\n",pinto2,mp->mapname);
fclose (wp);
system ("mrscmd2");
rp = fopen ("fmapres", "r");
/* gets headers */
fgets (line,200,rp);
fgets (line,200,rp);
fgets (line,200,rp);

/* This section loads the attribute table. */
for (nattr = 0; nattr < mp->mnoattr; nattr++)
{
        /* allocate attribute table entry */
        if ((atbp = malloc (sizeof (struct attbl))) == 0)
                /* allocation error */
        {
                printf(" %s %s\n",fnname,e8);
                delay(TIME);
                return(0);
        }
        if (nattr == 0)
                /* put attribute table poiner in map structure */
                mp->mattrtbl = atbp;
```

```
        else
                /* tack this attribute table entry on list */
                atbpx->atlnext = atbp;
        /* save pointer for next link*/
        atbpx = atbp;
        /* read an attribute table entry */
        if (((scan = fscanf (rp, "%s %s %d %d", name,
        name2,&num1,&num2)) == 0)
            || (scan == 0))
        {
                /* scan error */
                printf ("%s %s\n",fnname,e1);
                delay TIME);
                return(0);
        }
        atbp->alow = num1;
        atbp->ahigh = num2;
        if (*name2 == 'N')
                atbp->atype = 'N';
        else
                atbp->atype = 'C';
        /* allocate room for name of attribute */
        if ((atbp->aname = malloc (strlen (name) +1)) == 0)
                /* allocation error */
        {
                printf ("%s %s',e15,fnname);
                delay(TIME);
                return(0);
        }
        /* copy it in */
        strcpy (atbp->aname,name);
}
fclose (rp);
/* end the attribute table list */
atbp->atlnext = NULL;


/* This section  loads all subarea information. */

rp2 = fopen ("fmap2res","r");
fgets (line,200,rp2);
fgets (line,200,rp2);
fgets (line,200,rp2);
/* initialize counter for all the nodes in this map */
mp->mtotnode = 0;

for (nsuba = 1; nsuba <= mp->mtotsuba; nsuba++ )
        /* loading subareas with map data */
{
        /* must allocate room for the subarea */
        if ((sp = malloc (sizeof (struct subarea))) == 0)
                /* allocation error */
        {
```

```
        printf ("%s %s \n",fnname,e3);
        delay(TIME);
        return(0);
}
if (nsuba == 1)
        /* load 1st subarea pointer into map structure */
        mp->msp = sp;
else
        /* tack on subarea list */
        spx->snext = sp;
/* save  pointer to subarea */
spx = sp;
                if ((scan = fscanf (rp2,"%s %s %s %d %d %d %s %d %d %d %d",name,scname,
                wcname,&num1,&num2,&num3,cname,&num4,&num5,&num6,&num7))
                    == EOF
                    || scan == 0)
                        /* reading subarea data */

                {
                        printf("%s %s\n",fnname,e1);
                        delay(TIME);
                        return(0);
                }
sp->sx = num2;
sp->sy = num3;
sp->sbbminx = num4;
sp->sbbminy = num5;
sp->sbbmaxx = num6;
sp->sbbmaxy = num7;
sp->stotnode = num1;
/* accumulates total nodes in map */
mp->mtotnode += sp->stotnode;
if (( sp->subarname = malloc (strlen(name) +1)) == 0)
        /* allocate room for subareaname */
{
        /* allocation error */
        printf ("%s %s\n",fnname,e13);
        delay(TIME);
        return(0);
}
/* copy it in */
strcpy(sp->subarname,name);
if (( sp->scclor = malloc (strlen(cname) +1)) == 0)
        /* allocate room for color name */
{
        /* allocation error */
        printf ("%s %s\n",fnname,e14);
        delay(TIME);
        return(0);
}
/* copy name in */
strcpy(sp->scolor,cname);
if (( sp->scoord = malloc (strlen(scname) +1)) == 0)
```

```
        /* allocate room for screen coordinate relation name */
{
        /* allocation error */
        printf ("%s %s\n",fnname,e11);
        delay(TIME);
        return(0);
}
/* copy it in */
strcpy(sp->scoord,scname);
if (( sp->wcoord = malloc (strlen(wcname) +1)) == 0)
        /* allocate room for world coordinate relation name */
{
        /* allocation error */
        printf ("%s %s\n",fnname,e12);
        delay(TIME);
        return(0);
}
/* copy it in */
strcpy(sp->wcoord,wcname);
if (nsuba == 1)
        /* no attributes for boundary area-- skip it */
{
        sp->sattri = NULL;
        continue;
}
for (atbp=mp->mattrtbl; atbp!=NULL; atbp=atbp->atlnext)
        /* get attribute values */
{
        if (ap = malloc (sizeof (struct attri))) == 0)
                /* allocate an attribute structure */
        {
                /* allocation error */
                printf ("%s %s",e6,fnname);
                delay(TIME);
                return(0);
        }
        /* read attribute value */
        if (atbp->atype == 'C')
                /* this attribute is character */
        {
                if (((scan = fscanf (rp2, "%s",name)) == EOF)
                    || scan == 0)
                {
                        /* scan error */
                        printf ("%s %s \n%",fnname,e1);
                        delay(TIME);
                        return(0);
                }
        }
        else
                /* this attribute is numeric */
        {
                if (((scan = fscanf (rp2, "%d",&temp)) == EOF)
```

```
                        || scan == 0)
                {
                        /* scan error */
                        printf ("%s %s \n%",fnname,e1);
                        delay(TIME);
                        return(0);
                }
                itoa (temp,name);
        }
        if (atbp == mp->mattrtbl)
                /* enter attribute address in subarea structure */
        {
                sp->sattri = ap;
        }
        else
        {
                /* tack it on the list of other attributes */
                apx->anext = ap;
        }
        if ((ap->attribute = malloc (strlen (name) +1)) == 0)
                /* allocate room for attribute itself */
        {
                /* allocation error */
                printf ("%s %s ",e17,fnname);
                delay(TIME);
                return(0);
        }
        /* copy it in */
        strcpy(ap->attribute,name);
        /* save pointer to most recently created structure */
        apx = ap;
    } /* end loop for attributes of this subarea */
    /* complete the list */
    ap->anext = NULL;
    /* save pointer to most recently created subarea structure */
} /* end loop for subareas */
/* complete subarea list */
sp->snext = NULL;
/* close FMAPRES */
fclose(rp2);


/* This section retrieves and loads screen and world coordinates */
for (sp= mp->msp; sp !=NULL; sp=sp->snext)
    /* for each subarea retrieve and load screen and world coordinartes */
{
    /* open FREQUEST */
    wp = fopen ("frequest","w");
    /* request screen coordinates */
    /* request world coordinates */
    fprintf (wp,"%s select from  %s;\n",pinto, sp->scoord);
    fprintf (wp,"%s select from  %s;\n",pinto2, sp->wcoord);
    fclose(wp);
```

```
system ("mrscmd2");
rp = fopen("fmapres","r");
rp2 = fopen ("fmap2res","r");
/* gets headers */
fgets (line,200,rp);
fgets (line,200,rp);
fgets (line,200,rp);
fgets (line,200,rp2);
fgets (line,200,rp2);
fgets (line,200,rp2);
for (nnodes = 1; nnodes <= sp->stotnode; nnodes++)
        /* load screen coordinates in node structure */
{
        /* allocate a node structure */
        if (( np = malloc (sizeof (struct node )) ) == 0)
        {
                /* allocation error */
                printf("%s %s\n",fnname,e4);
                delay(TIME);
                return(0);
        }
        /* read the coordinates */
        if ((scan = fscanf(rp," %d %d %ld %ld ",
        &x,&y,&num10,&num9)) == EOF
            || scan == 0)
        {
                /* scan error */
                printf ("%s %s \n",e1,fnname);
                delay(TIME);
                return(0);
        }
        if ((scan = fscanf(rp2,"%d %d  ",&num3,&num2)) == EOF
            || scan == 0)
        {
                /* scan error */
                printf ("%s %s \n",e1,fnname);
                delay(TIME);
                return(0);
        }
        if (nnodes == 1)
                /* enter node pointer into subarea structure */
                sp->spn = np;
        else
                /* tack new node structure on the node list */
                npx->nnext = np;
        np->nx = x;
        np->ny = y;
        np->nslope = num10 / 10;
        np->nyint = num9;
        np->nwx = num3;
        np->nwy = num2;
        npx = np;
}
```

```
            /* complete the node list */
            np->nnext = NULL;
            fclose (rp);
            fclose (rp2);
            /* collect edges for this subarea */
            sp->spe = node_edge (sp);
        } /* end for loop for subareas */
        /* collect all the edges for the map */
        mp->mpe = coll_edge(mp);
        printf ("\n%sMap %s available for use",indent2,mp->mapname);
        delay (TIME);
        return (mp);
}
```

```
/*___deletemap_____________________________________________________________*/

int deletemap(instring) /* function to delete map from the data base */
char *instring;         /* pointer to name of map to be deleted */

{

        fnname = "deletemap; ";
        printf ("Deleting %s from the data base.\n\nSTANDBY",instring);
        wp = fopen ("frequest", "w");
        /* requesting name of attribute table */
        fprintf (wp,"%s select attrtbl from mpdir",pinto);
        fprintf (wp," where mpname = %s;\n",encl(instring));
        /* requesting names of screen and world coordinate
                                        relations */
        fprintf (wp, "%s select scoord, wcoord from %s ;\n",pinto2, instring);
        fclose (wp);
        system ("mrscmd2");
        rp = fopen("fmapres", r");
        /* gets headers */
        fgets (line,200,rp);
        fgets (line,200,rp);
        fgets (line,200,rp);
        wp = fopen ("frequest", "w");
        if (scan = fscanf (rp,"%s",name) != 0)
        {
                /*getting name of attribute table and dropping it */
                fprintf (wp,"drop table %s;\n",name);
        }
        fclose (rp);
        rp = fopen ("fmap2res ,"r");
        fgets (line,200,rp);
        fgets (line,200,rp);
        fgets (line,200,rp);
        do
            /* reads and issues a drop command for attribute table relation,
                                    screen and world coordinate relations */
        {
                if (((scan = fscanf (rp, "%s",name)) == 0)
                        || scan == EOF)
                {
                        /* no more relations */
                        break;
                }
                else
                        fprintf (wp,"drop table %s;\n",name);
        }
        while (scan != EOF);
        /* deletes subarea relation */
        fprintf (wp, "drop table %s;\n ,instring);
        /* deletes tuple identifying the map from the map directory */
        fprintf (wp, "delete from mpdir where mpname = %s;\n",encl(instring));
        fclose (wp);
```

```
        system ("mrscmd1");
        fclose(rp);
        printf ("%s Map %s removed from the data base.\n",indent2,instring);
        delay (TIME);
}
```

```
/*___savemap__ ____________________________________________________________*/

savemap(mp)
/* This function writes the map pointed to by mp to the data base. */

struct map * mp;

{
        int tslope;     /* holds slope * 10 */
        char * encl();  /* function the encloses a string in single quotes */
        /* open FREQUEST */
        printf ("\n\nSaving map in data base");
        printf ("\n\nMap name: %s",mp->mapname);
        printf ("\n\n\n\n%sSTANDBY",indent2);
        wp = fopen ("frequest","w");
        /* put map entry into map directory */
        fprintf (wp,"insert into mpdir:[%s, ",encl(mp->mapname));
        fprintf (wp,"%s, ",encl(mp->author));
        fprintf (wp,"%s, %d, %d];\n",encl(mp->mattrnm),mp->mnoattr,mp->mtotsuba);
        /* creates attribute table */
        fprintf (wp,"create table %s(aname char(16) ,",mp->mattrnm);
        fprintf (wp,"atype char (1), alow numeric, ahigh numeric);\n");
        for (atbp = mp->mattrtbl; atbp != NULL; atbp = atbp->atlnext)
                /* filling attribute table */
        {
                fprintf (wp,"insert into %s:",mp->mattrnm);
                fprintf (wp,"[%s, ",encl(atbp->aname));
                enclc (atbp->atype);
                fprintf (wp,"%s, %d, %d];\n",outstring,atbp->alow,atbp->ahigh);
        }


        /* create subarea relation */
        fprintf (wp,"create table %s (subname char (12),scoord char (12),",
        mp->mapname);
        fprintf (wp," wcoord char (12), nnodes numeric, x numeric, y numeric,");
        fprintf (wp," color char (8), bbxmin numeric, bbymin numeric,");
        fprintf (wp," bbxmax numeric, bbymax numeric \n");
        for (atbp = mp->mattrtbl; atbp!= NULL;atbp=atbp->atlnext)
                /* gets names of attributes */
        {
                fprintf (wp, , %s',atbp->aname);
                if (atbp->atype == 'N')
                        fprintf (wp," numeric ");
                else
                        fprintf (wp, ' char(16) ");
        }
        fprintf (wp,");\n");


        for (sp=mp->msp; sp!=NULL;sp=sp->snext)
                /* write data for each subarea */
```

```
                fprintf (wp,"insert into %s: [%s, ",mp->mapname,encl(sp->subarname));
                fprintf (wp,"%s, ",encl(sp->scoord));
                fprintf (wp,"%s, ",encl(sp->wcoord));
                fprintf (wp,"%d, %d, %d, %s,",sp->stotnode,sp->sx,sp->sy,encl(sp->scolor));
                fprintf (wp," %d, %d, %d, %d",sp->sbbminx, sp->sbbminy,
                sp->sbbmaxx, sp->sbbmaxy);


                for (ap=sp->sattri,atbp=mp->mattrtbl;
                     ap!=NULL;
                     ap=ap->anext,atbp=atbp->atlnext)
                            /* get each attribute */
                {
                        if (atbp->atype == 'N')
                        {
                                temp = atoi (ap->attribute);
                                fprintf (wp,", %d", temp);
                        }
                        else
                                fprintf (wp,", %s ,encl(ap->attribute));
                }  /* end for */
                fprintf (wp,"];\n");
                /* create screen coordinate relation */
                fprintf (wp,"create table %s", sp->scoord);
                fprintf (wp,"( scrx numeric, scry numeric, ");
                fprintf (wp,"scrslope  numeric, scryint numeric );\n");
                /* create world coordinate relation */
                fprintf (wp,"create table %s", sp->wcoord);
                fprintf (wp," (worldx numeric, worldy numeric);\n");


                for (np= sp->spn; np!=NULL; np=np->nnext)
                        /* write out nodes */
                {
                        /* to screen relation */
                        fprintf (wp,"insert into %s: ",sp->scoord);
                        tslope = 10 * np->nslope;
                        fprintf (wp,"[%d, %d, %d, %ld];\n",np->nx,np->ny,
                        tslope, np->nyint);
                        /* to world relation */
                        fprintf (wp,"insert into %s: ",sp->wcoord);
                        fprintf (wp,"[%d, %d];\n", np->nwx, np->nwy);
                }
        }
        fclose (wp);
        system ("mrscmd1");
        printf ("\n%s%s saved in the data base ,indent2,mp->mapname);
        delay (TIME);
}
/*___encl_____________________________________________________________*/

char * encl(instring)
/* This function takes a string, encloses it in single quotes and
```

```
                returns it . */

char * instring;

{
        char encstring [50];
        encstring [0] = SQUOTE;
        for (i=1; *instring != '\0'; instring++)
                /* copy whole string */
                encstring [i++] = *instring;
        /* append final quote */
        encstring [i++] = SQUOTE;
        /* complete the string */
        encstring [i] = '\0';
        return (&encstring[0]);
}

/*___enclc_____________________________________________________________________*/

int enclc(ch)
/* This function takes a character, encloses it in single quotes and
                returns it . */

char ch;

{
        outstring [0] = SQUOTE;
        /* copy the character */
        outstring [1] = ch;
        /* append final quote */
        outstring [2] = SQUOTE;
        /* complete the string */
        outstring [3] = '\0';
        return;
}

/*___itoa______________________________________________________________________*/

itoa (n,s)
/* This function takes an integer and converts it to a string */
int n;          /* integer to be converted */
char s[];       /* string to be returned */

{
        int c,i,j;
        i=0;

        do { /* generate digits in reverse order */
                s[i++] = n % 10 + '0';  /* get next digit */
        }
        while ((n/=10) > 0);    /* delete it */
        /* complete the string */
        s[i] = '\0';
```

```
        for (i=Ø, j = strlen (s)-1; i < j; i++, j--)
                /* reverse string in place */
        {
                c = s[i];
                s[i] = s[j];
                s[j] = c;
        }
}
```

C.4 Iomod

```
#define ALPHAENTER      31      /* ascii char. for alpha mode */
#define GHAPHENTER      29      /* ascii char. for graph mode */
#define GINENTER        26      /* ascii char. for graphic input mode */
#define CHANGED          5      /* flag indicating a change in mode */
#define SAME             6      /* flag indicating no change of mode */
#define ESCAPE          27      /* ascii escape character */
#define ERASESCREEN     12      /* ascii form feed character */
#define BELL             7      /* ascii char to ring bell */
#define SETDARKLINE     29      /* ascii char to set next line as invisible */

#define GINMODE         -1      /* flag indicating the terminal is in GINMODE */
#define ALPHAMODE       -2      /* flag indicating the terminal is in ALPHAMODE */
#define GRAPHMODE       -3      /* flag indicating the terminal is in GRAPHMODE */

#include        <stdio.h>
#include        "mpnamex.h"

int xlow,xhigh,ylow,yhigh;      /*used to input numeric values */
static int current_mode = ALPHAMODE;    /* current mode */
int low_x_last = 0,                     /* last low x plotted */
low_y_last = 0,                 /* last low y plotted */
high_x_last = 0,                        /* last high x plotted */
high_y_last = 0,                        /* last high y plotted */
last_x = 0,                             /* last x plotted */
last_y = 0;                             /* last y plotted */
```

```
/*___initt_____________________________________________________________*/

int initt()
/* This procedure initializes the screen. */

{
        clearscreen();
        cursorhome();
        anmode();
}

/*___file_to_screen____________________________________________________*/
int file_to_screen(flname,lineno)
int lineno;             /* the lineno on which it is to be written */
char *flname;           /* the file to be used */
/* This function takes what is in a file
        and writes it on the terminal. */

{
        FILE *fp, *fopen();
        int i;  /* result of fgets */
        char *sfgets;           /* result of fgets */

        /* open file */
        fp = fopen (flname, "r");
        /* clear the screen */
        clearscreen();
        for (i=0; i< lineno; i++)
                /* space down to first print line */
                printf ("\n");
        while ((sfgets = fgets (line,80,fp)) != NULL)
                /* copy lines out as they are read from the file */
                printf ("%s%s",indent2,line);
        fclose(fp);
        return;
}
/*___placecursor_______________________________________________________*/

int placecursor(x,y)
/* This function places a cursor at the
        specified x,y coordinate position. */
int x,y;

{
        if (check_mode (GRAPHMODE) == SAME)
                putchar (SETDARKLINE);
        plot_val (x,y);
        plot_val (x,y);
        anmode();
}
/*___clearscreen_______________________________________________________*/

int clearscreen()
```

```
/* This function clears the terminal. */

{
        putchar (ESCAPE);
        putchar (ERASESCREEN);
        cursorhome();
        sleep (3);
}

/*___readcursor_____________________________________________________________*/

int readcursor()
/* This function gets the cursor position
        and places it in curx and cury. */

{
        fnname = "readcursor;";
        check_mode (GINMODE);           /* turn on crosshairs */
        c = getchar();                  /* read first character */
        /* read high and low order x and y */
        xhigh = getchar();
        xlow = getchar ();
        yhigh = getchar();
        ylow = getchar();
        c = getchar ();         /* get the 'ret' */
        curx = ((xhigh & 0037) << 5) | (xlow & 0037) ;
        cury = ((yhigh & 0037) << 5) | (ylow & 0037);
        check_mode (ALPHAMODE);
        return(0);
```

```
/*___readstring_____________________________________________________________*/

int readstring(instring)
/* This function reads a string from the terminal and
        places it in the string instring */
char *instring;

{
        int nc;         /* number of characters read */
        anmode();
        nc = 16;
        i=0;
        while (( --nc > 0) && ((c = getchar()) != '\n'))
                /* read a character and load into instring until end
                                        of string is reached or instring is full */
        {
                instring[i++] = c;
        }
        /* terminate string */
        instring[i] = '\0';
        return(i);
}

/*___drawline_______________________________________________________________*/

int drawline (x1,y1,x2,y2)      /* draws a line from point 1 to point 2 */
int x1,y1,x2,y2;                /* coordinates */

{
        moveabs (x1,y1);
        drawabs (x2,y2);
}

/*___moveabs________________________________________________________________*/

int moveabs (x,y)       /* This function moves the cursor to the given point. */

int x,y;                /* The point */

{
        if (check_mode (GRAPHMODE) == SAME)
                putchar (SETDARKLINE);
        plot_val (x,y);
}

/*___drawabs________________________________________________________________*/

int drawabs (x,y)       /* THis function draws a line from the cursor position
                        to the given point. */
int x,y;                /* the point */

{
        if (check_mode (GRAPHMODE) == CHANGED)
```

```
                plot_val (last_x, last_y);
        plot_val (x,y);
}

/*___cursorhome_____________________________________________________________*/


cursorhome()
/* returns cursor to upper left corner of screen */

{
        int x=0, y=779;
        if (check_mode (GRAPHMODE) == SAME)
                putchar (SETDARKLINE);
        plot_val (x,y);
        check_mode (ALPHAMODE);
        return;
}

/*___bell___________________________________________________________________*/

bell()
/* sounds the bell */

{
        putchar (BELL);
        return;
}

/*___delay__________________________________________________________________*/
delay (time)
/* This function causes a delay so the user has a chance to read the
                screen. */
int time;
{
        sleep (time);
}
/*___check_mode_____________________________________________________________*/

static int check_mode (mode)
/* This function checks the mode the terminal is in and resets it
        if necessary. */

int mode;       /* Desired mode */

{
        if (current_mode != mode)
        {
                putchar (ESCAPE);
                switch (mode)
                {
                case ALPHAMODE:
                        putchar (ALPHAENTER);
```

```
                        break;
                case GRAPHMODE:
                        putchar (GRAPHENTER);
                        break;
                case GINMODE:
                        putchar (GINENTER);
                        break;
                }
                current_mode = mode;
                return (CHANGED);
        }
        else
                return(SAME);
}
```

```
/*___plot_val_____________________________________________________________*/

static plot_val (x,y)
/* This function sends x and y values to the terminal to move
        the cursor to a new position. It will leave a dark line or a visible
        line depending on what was set before the routine was called.
        Note that the x and y values are broken up into high and low 5 bits
        with a code put on each value to tell the terminal which value
        is being sent. */
int x,y;                /* point to be plotted */
{
        if (x == last_x)
                /* x value is the same as the last */
        {
                xlow = low_x_last;
                xhigh = high_x_lsat;
        }
        else
        {
                xlow = (x & 0037) | 0100;
                xhigh = ((x >> 5) & 0037) | 0040;
        }
        if (y == last_y)
        {
                ylow = low_y_last;
                yhigh = high_y_last;
        }
        else
        {
                ylow = (y & 0037) | 0140;
                yhigh = (( y >> 5) & 0037) | 0040;
        }
        /* put out characters */
        putchar (yhigh);
        putchar (ylow);
        putchar (xhigh);
        putchar (xlow);
        /* save current values */
        high_x_last = xhigh;
        low_x_last = xlow;
        high_y_last = yhigh;
        low_y_last = ylow;
        /* save current point */
        last_x = x;
        last_y = y;
}
/*___showline_____________________________________________________________*/

int showline(x1,y1,x2,y2)
/* This function controls the drawing of a line after having
        clipped it. */

int x1,y1,x2,y2;        /* endpoints of the line */
```

```
{
        if (clip (&x1,&y1,&x2,&y2) == 0)
                /* line is visible */
                drawline (x1,y1,x2,y2);
}

/*___clip_____________________________________________________________________*/

int clip(x1,y1,x2,y2)
/* This function will clip the lines sent to drawline to restrict
           them to the window in which they are to be written. */

int *x1, *y1, *x2, *y2;          /* These are pointers to endpoints
                                    of a line. */
{
        int c,x,y;
        int c1,c2;
        c1 = code (*x1,*y1);
        c2 = code (*x2,*y2);
        while ((c1 > 0) || (c2 > 0))
                /* line is not entirely on screen */
        {
                if ( c1 & c2 ) != 0)
                        /* line is entirely off screen */
                        return(-1);
                c = c1;
                if (c == 0)
                        c = c2;
                if (c & 0001)
                        /* crosses left edge */
                {
                        x = windxl;
                        y = *y1 + (*y2 - *y1) * (windxl - *x1) / (*x2 - *x1);
                }
                if (c & 0002)
                        /* crosses right edge */
                {
                        x = windxr;
                        y = *y1 + (*y2 - *y1) * (windxr - *x1) / (*x2 - *x1);
                }
                if (c & 0004)
                        /* crosses bottom edge */
                {
                        x = *x1 + ( *x2 - *x1) * (windyb - *y1) / (*y2 - *y1);
                        y = windyb;
                }
                if (c & 0010)
                        /* crosses top edge */
                {
                        x = *x1 + (*x2 - *x1) * (windyt - *y1) / (*y2 - *y1);
                        y = windyt;
                }
                if (c == c1)
```

```
                {
                        *x1 = x;
                        *y1 = y;
                        c1 = code (*x1, *y1);
                }
                else
                {
                        *x2 = x;
                        *y2 = y;
                        c2 = code (*x2,*y2);
                }
        }       /* end while loop */
        return(0);
}
```

```
/*___code_____________________________________________________________*/

int code (x,y)
/* This function returns an integer c which denotes how the
           point falls in relation to the screen.

        ┌──────────┬──────────┬──────────┐
        │   1001   │   1000   │   1010   │
        ├──────────┼──────────┼──────────┤
        │   0001   │   0000   │   0010   │
        │          │  screen  │          │
        ├──────────┼──────────┼──────────┤
        │   0101   │   0100   │   0110   │
        └──────────┴──────────┴──────────┘

*/
{
        c =0;
        if (x < windxl)
                c = c+1;
        else if (x > windxr)
                c = c + 2;
        if (y < windyb)
                c = c + 4;
        else if ( y > windyt)
                c = c + 8;
        return(c);
}
/*___skiplines________________________________________________________*/

skiplines(x)
int x;          /* no. of lines to skip */
/* This function skips x number of lines. */
{
        int i;
        anmode ();
        for (i=0; i<x; i++)
                printf ("\n");
}
/*__anmode____________________________________________________________*/
int anmode()
/* This function puts the terminal in alpha/numeric mode. */

{
        check_mode (ALPHAMODE);
}
/*___finish___________________________________________________________*/
```

```
int finish ()
/* This function resets the terminal. */

{
        clearscreen ();
        cursorhome();
        anmode();
}
/*___outline_____________________________________________________________*/
int outline ()
/* This function outlines the section of the screen on which
        the map will be drawn */

{
        check_mode(GRAPHMODE);
        drawline (windxl,windyb,windxr,windyb);
        drawline (windxr,windyb,windxr,windyt);
        drawline (windxr,windyt,windxl,windyt);
        drawline (windxl,windyt,windxl,windyb);
}
```

C.5 Main

```
#include        <stdio.h>
#include        "rpname.h"
main()
{
        int b;          /* result of bounding box test */
        int stopflag;   /* flag telling us to exit the program */
        int draw(), edit(), inq(), delete();    /* functions */

        stopflag = 0;
        /* initializes the screen */
        initt();
        /* puts up the intro screen */
        file_to_screen("intro1",0);
        /* getting the carriage return (cr) */
        readstring (instring);
        do
            {
                /* puts up selection screen */
                file_to_screen ("intro2",5);
                readcursor();
                if (((b = bb (curx,cury,0,437,1023,900)) == 0) || ( b == 9))
                {
                        draw();
                }
                else if (((b = bb (curx,cury,0,356,1023,436)) == 0) || (b == 9))
                {
                        delete();
                }
                else if (((b = bb (curx,cury,0,267,1023,355)) == 0) || (b == 9))
                {
                        edit();
                }
                else if (((b = bb (curx,cury,0,174,1023,266)) == 0) || (b == 9))
                {
                        inquire();
                }
                else
                {
                        stopflag = 1;
                        clearscreen();
                        printf ("\n\n\n%sDRAW-A-MAP completed",indent2);
                        delay(5);
                        /* reset terminal */
                        finish();
                }
        }
        while ( stopflag == 0);
        return;
```

```
}
/*___delete_____________________________________________________________________*/

delete()

{
        fnname = "delete; ";

        clearscreen();
        printf ("DELETE\n");
        printf ("\nWhat map do you wish to remove from the data base? ");          readstring(instring);
        /* delete the specified map from the data base */
        deletemap(instring);
        return;
}
/*___edit_______________________________________________________________________*/

edit()

{
        fnname = "edit;  ;

        clearscreen();
        printf ("\n\n%sEdit module entered. ",indent2);
        printf ("\n%s%sNot currently implemented.\n\n",indent2,indent2);
        printf ("%s%s%sReturning to main program--",indent2,indent2,indent2);
        delay(10);
}
```

C.5 Draw

```
#define TIME            5
#define US              '\137'  /* underscore character */
#define MAXNODES        50
#define NEAR            50
#include        <stdio.h>
#include        "mpnamex.h
/* functions used in entering the map */

int getmpname(),draw(),savemap(), gattrtbl(), drawmap(),
drawpoly(), getworldc(), getsubbox(),
getsubname(), getcolor(), swcoord(),
build(), getattrib(), isnum();

long yintercept();

float getslope();

struct subarea *drawsuba(), *drawprev(), *drawboundary();

char * itoa ();

struct edge *node_edge(), *coll_edge();

int startx, starty;             /* coord. values used in entering
        subarea nodes */
/* temporary storage for all nodes */
int nnodesx [MAXNODES];
int nnodesy [MAXNODES];
int ncount;             /* counter for nnodesx and nnodesy */
int nnodes;                     /* counter for nodes */
ret = "'ret'";
per = "'.'";
/*___draw_____________________________________________________________*/

int draw()      /* function controling the drawing of a map */

{
        fnname = "draw; ";
        clearscreen();
        printf("You are now ready to draw the map.\n");
        /* allocate map structure */
        if ((mp = malloc (sizeof (struct map))) == 0)
                /* allocation error */
        {
                printf ("%s%s ,e2,fnname);
                delay (TIME);
                return(0);
        }
```

```
        /* save map pointer in curmap */
        curmap [nummap++] = mp;
        /* initialize counters */
        mp->mtotsuba = 0;
        mp->mtotnode = 0;
        /* get the author's name */
        if (getauthor(mp) == 0)
                /* error occurred */
                return(0);
        /* get the map name */
        if (getmpname(mp) == 0)
                /* error occurred */
                return(0);
        /* get the attribute table */
        if (gattrtbl(mp) == 0)
                /* error occurred */
                return(0);
        /* draw the map */
        if (drawmap(mp) == 0)
                /* error occurred */
                return(0);
        clearscreen();
        printf ("\n%s Do you wish to save this map? ",indent1);
        readstring(instring);
        if (* instring == 'y')
                savemap(mp);
        return(1);
}

/*___getmpname_____________________________________________________________*/

int getmpname(mp)
/* gets the name of the map and puts it in the map structure */

struct map *mp;

{
        fnname = "getmpname; ";
        printf("\n\n%sPlease enter the name of the map you are creating. ",
        indent2);
        readstring(instring);
        /* allocates area for map name */
        if ((mp->mapname = malloc(strlen(instring) +1)) == 0)
                /* allocation error */
        {
                printf ("%s %s",e9,fnname);
                delay (TIME);
                return(0);
        }
        /* copies name of map it allocated area */
        strcpy(mp->mapname,instring);
        return(1);
}
```

```
/*___getauthor_____________________________________________________________*/

getauthor(mp)
/* This function enters the name of the author into the
                map. */

struct map *mp;

{
        printf("\n\n%sPlease enter your name. ",indent2);
        if (readstring (instring) == 0)
                /* no name entered */
        {
                mp->author = "none";
                return(1);
        }
        /* allocates area for author name */
        if ( mp->author = malloc(strlen(instring) +1)) == 0)
                /* allocation error */
        {
                printf ("%s %s",e10,fnname);
                delay (TIME);
                return(0);
        }
        /* copies name of author it allocated area */
        strcpy(mp->author,instring);
        return(1);
}
```

```
/*___gattrtbl_____________________________________________________________*/

int gattrtbl(mp)
/* This function prompts for the attributes, their types and
        their ranges if numeric. It stores the items in the attribute
        table */

struct map *mp;

{
        fnname = "gattrtbl; ";
        clearscreen();
        printf("\n\n%sEnter the attributes this map will have, each ",indent2);
        printf ("attribute followed by a %s. Each map must have at least ",ret);
        printf ("one attribute. When the list is complete ");
        printf ("enter another %s.\n\n%s",ret,indent2);
        /* set attribute count to zero */
        mp->mnoattr = 0;
        readstring (instring);
        while (*instring != '\0')
        {
                printf ("%s",indent2);
                /* count the attributes */
                mp->mnoattr++;
                /* allocate attribute table structure */
                if ((atbp = malloc(sizeof (struct attbl))) == 0)
                        /* allocation error */
                {
                        printf ("%s %s",e8,fnname);
                        delay (TIME);
                        return(0);
                }
                if (mp->mnoattr == 1)
                        /* enter beginning of attr. table in map */
                        mp->mattrtbl = atbp;
                else
                        /* link this one to the previous one */
                        atbpx->atlnext = atbp;
                /* allocate room for storage of attibute name */
                if ((atbp->aname = malloc (strlen (instring) + 1)) == 0)
                        /* allocation error */
                {
                        printf("%s%s",e15,fnname);
                        delay (TIME);
                        return(0);
                }
                strcpy (atbp->aname,instring);
                /* read the next attribute */
                readstring(instring);
                /* save pointer to current attribute */
                atbpx = atbp;
        }
        /* attribute table list is completed */
```

```
atbp->atlnext = NULL;
clearscreen();
printf ("\n\nEnter the following information for");
printf (" the specified attributes.\n\n");
atbp = mp->mattrtbl;
while (atbp != NULL)
        /* for each attribute entered, get its characteristics */
{
        /* prints attribute name */
        printf ("%s%s",indent2,atbp->aname);
        /* prints attribute type */
        printf ("\n%sData type ('n' for numeric or 'c' for character): ",indent1);
        readstring(instring);
        if (*instring == 'n')
                /* this attribute is numeric */
        {
                atbp->atype = 'N';
                /* get range */
                printf ("\n%sEnter lowest integer value permitted: ",indent1);
                readstring(instring);
                atbp->alow = atoi (instring);
                printf("\n%sEnter highest integer value permitted: ",indent1);
                readstring(instring);
                atbp->ahigh = atoi (instring);
        }
        else
                /* this attribute is a character type */
        {
                atbp->atype = 'C';
                atbp->alow = 0;
                atbp->ahigh = 0;
        }

        /* skip 3 lines */
        skiplines (3);
        atbp = atbp->atlnext;
}
if ( mp->mattrnm = malloc(10)) == 0)
{
        printf ("%s %s\n",e7,fnname);
        delay (TIME);
        return (0);
}
/* create a name for the attribute table */
build (mp->mattrnm,'a',mp->mapname,0);
return(1);
```

```
/*___drawmap_____________________________________________________________________*/

int drawmap(mp)
/* This function controls the actual drawing of the map. */
struct map *mp;

{
        fnname = "drawmap; ";
        clearscreen();
        skiplines(5);
        printf ("%sDo you wish to draw a new map",indent2);
        printf (" using a previously drawn map? ");
        /* skip 2 lines */
        skiplines(2);
        printf ("%sRespond with 'yes' or 'no'.  ",indent2);
        readstring(instring);
        if (*instring == 'y')
                /* first subarea of the map will be the boundary of a previously
                                drawn and stored map */
        {
                mp->msp = drawprev();
                if (getworldc() == 0)
                        /* get world coordinates, if error return 0 */
                        return(0);
                /* get new world coordinates */
                windtoworld(mp->msp->spn);
        }
        else
        {
                if (getworldc() == 0)
                        /* get world coordinates, if error return 0 */
                        return(0);
                /* first subarea will represent boundary */
                mp->msp = drawboundary (mp);
        }
        /* prepare to get subareas */
        spx = mp->msp;
        file_to_screen("draw2",2);
        /* read the 'ret' */
        readstring (instring);
        do
            /* draw and load the subareas */
        {
                /* get next subarea */
                spx->snext = drawsuba(mp);
                placecursor (0,88);
                printf("%sDo you have more subareas to enter? ",indent2);
                readstring(instring);
                if (*instring == 'y')
                {
                        spx = spx->snext;
                }
                clearscreen();
```

```
        }
        while (*instring == 'y');
        /* collect the edges of the map */
        /* subareas are complete */
        mp->mpe = coll_edge (mp);
        return(1);
}
```

```
/*___drawprev_____________________________________________________________*/

struct subarea * drawprev ()
/* draws previous map boundary and returns a pointer to the boundary
        subarea */

{
        clearscreen();
        printf("\n\n%sEnter the name of the map to be ",indent2);
        printf ("used in drawing this one. ");
        readstring(instring);
        /* get the map here */
        readmap(instring);
        clearscreen ();
        outline();
        /* draw the boundary for this map */
        drawpoly(mp->msp->spn);
        /* disconnect rest of previous map */
        mp->msp->spn->snext = NULL;
        for (ncount=0,np=mp->msp->spn; np!=NULL; np=np->nnext,ncount++)
                /* load nodes into array for checking later */
        {
                nnodesx[ncount] = np->nx;
                nnodesy[ncount] = np->ny;
        }
        return(mp->msp);
}
/*___drawpoly_____________________________________________________________*/

int drawpoly(np)
/* This function draws the polygon represented by the node list. */

struct node *np;

{
        int xfirst,yfirst,xprev,yprev;
        for (i=0; np != NULL; i++, np=np->nnext)
                /* drawing each line represented in the node structure */
        {
                if (i== 0)
                {
                        xfirst = np->nx;
                        yfirst = np->ny;
                }
                else
                        showline (xprev,yprev,np->nx,np->ny);
                xprev = np->nx;
                yprev = np->ny;
        }
        drawline (xprev,yprev.xfirst,yfirst);
        return (1);
```

```
/*___getworldc_____________________________________________________________*/

int getworldc()
/* This function gets the ranges of the world coordinates
        and controls the screen to world transformation. */

{
        fnname =  getworldc; ";
        clearscreen();
        outline();
        /* These coordinates are used to establish the relationship
                            to the world coordinate system. */
        placecursor (0,88);
        printf ("%sPlease enter the world coordinates ",indent2);
        printf ("of the lower left \n");
        printf ("corner of the rectangle. (separated by commas)  %s", indent2);
        /* read these coordinates */
        do
            {
                if ((scan = scanf ("%d,%d",&worldxl, &worldyb)) == EOF)
                {
                        /* scan error */
                        printf ("%s %s", e1, fnname);
                        delay (TIME);
                        return(0);
                }
        }
        while (scan == 0);
        printf ("\n%sPlease enter the world coordinates ",indent2);
        printf ("of the upper right \n");
        printf ("corner of the rectangle. (separated by commas)  %s", indent2);
        do
            {
                if ((scan = scanf ("%d,%d",&worldxr, &worldyt)) == EOF)
                {
                        /* scan error */
                        printf ("%s %s", e1, fnname);
                        delay (TIME);
                        return(0);
                }
        }
        while (scan == 0);
        /* get the 'ret' */
        readstring(instring);
        /* set screen to world relationships */
        setwwrel();
        return(1);
}
/*___setwwrel_____________________________________________________________*/

int setwwrel()
/* This function sets the relationship between the screen
        coordinates and the given world coordinates. */
```

```
{
        /* holds differences between world and window values */
        float worlddiff, winddiff;
        worlddiff = worldxr - worldxl;
        winddiff = windxr - windxl;
        wwxm = worlddiff / winddiff;
        wwxa = worldxl - windxl * wwxm;
        worlddiff = worldyt - worldyb;
        winddiff = windyt - windyb;
        wwym = worlddiff / winddiff;
        wwya = worldyb - windyb * wwym;
        return;
}

/*___windtoworld_____________________________________________________*/

windtoworld(np)
/* This function maps screen coordinates to world coordinates. */

struct node *np;        /* pointer to a node */

{
        np->nwx = (wwxm * np->nx) + wwxa + .5;
        np->nwy = (wwym * np->ny) + wwya + .5;
        return;
}
```

```
/*___drawboundary_____________________________________________________*/

struct subarea * drawboundary(mp)
struct map *mp;
/* This function controls the drawing of the boundary by the user. */


{
        char found;     /* flag to indicate that a match has been found */
        fnname = "drawboundary; ";
        file_to_screen("draw1",0);
        /* read the 'ret' */
        readstring(instring);
        clearscreen();
        outline();
        readcursor();
        bell();
        ncount = 0;
        nnodesx[ncount] = startx = curx;
        nnodesy[ncount++] = starty = cury;
        /* counter for nodes */
        nnodes = 0;
        do
            /* This loop controls the entry of nodes of a polygon
                and continues until the polygon is closed. For each
                point that is entered, a list of previous nodes are checked.
                If any node is within NEAR distance the nodes are considered
                to be equal. This prevents splintering and overlaying of
                adjacent polygons.                                      */
        {
                /* initialize flag */
                found = 'N';
                for (j=0;j < ncount; j++)
                {
                        /* search for near nodes */
                        if ((curx > nnodesx[j] - NEAR)  &&
                            (curx < nnodesx [j] + NEAR) &&
                            (cury > nnodesy [j] - NEAR) &&
                            (cury < nnodesy [j] + NEAR))
                                /* if a new node or a node within NEAR of it is in
                                        the node list the node is made to equal that node
                                        otherwise it is added to the list */
                        {
                                curx = nnodesx[j];
                                cury = nnodesy[j];
                                found = 'Y';
                                break;
                        } /* end for loop */
                }
                if ( found == 'N')
                        /* node was not found */
                        /* add new node to lists */
                {
```

```
                nnodesx[ncount] = curx;
                nnodesy[ncount] = cury;
                ncount++;
        }
        /* allocate a node for this point */
        if ((np=malloc (sizeof(struct node))) == 0)
        {
                /* allocation error */
                printf ("%s%s",e4,fnname);
                delay (TIME);
                return(0);
        }
        np->nx = curx;
        np->ny = cury;
        /* make transformation to world coordinates */
        windtoworld(np);
        /* increment node counter */
        nnodes ++;
        if (nnodes == 1)
        {
                /* get a subarea for it  */
                if ((sp=malloc(sizeof(struct subarea))) == 0)
                {
                        /* allocation error */
                        printf ("%s%s",e3,fnname);
                        delay (TIME);
                        return(0);
                }
                /* enter first node addr. in subarea */
                sp->spn = np;
        }
        else
                /* tack node on the end of the node list */
        {
                npx->nnext = np;
                /* calculate slope */
                npx->nslope = getslope(npx->nx, npx->ny, curx,cury);
                /* calculate y intercept */
                npx->nyint = yintercept(npx->nx,npx->ny,npx->nslope);
                /* get world coordinates */
                windtoworld(np);
                /* draw the line to it */
                showline (npx->nx,npx->ny,curx,cury);
        }
        /* get next node */
        readcursor();
        /* ring the bell */
        bell();
        /* save last address */
        npx = np;
}
/* do the above until the starting position is reached */
while (((curx > startx - NEAR) && (curx < startx + NEAR)
```

```
    && (cury > starty - NEAR) && (cury < starty + NEAR)) == 0);
/* complete the list */
np->nnext = NULL;
/* complete the polygon */
bell();
showline(np->nx, np->ny, startx,starty);
/* calculate the slope */
np->nslope = getslope(np->nx,np->ny,startx,starty);
/* calculate y intercept */
np->nyint = yintercept (np->nx,np->ny,np->nslope);
/* get world coordinates */
windtoworld(sp->spn);
sp->scolor = "none";
sp->snext = NULL;

sp->subarname = "bound";
sp->stotnode = nnodes;
getbox(sp);
sp->sx = NULL;
sp->sy = NULL;
swcoord(mp,sp);
sp->spe = node_edge(sp);
sp->sattri = NULL;
/* accumulate total nodes in map */
mp->mtotnode += nnodes;
/* accumulate total subareas */
mp->mtotsuba ++;
clearscreen();
return(sp);
```

```
/*___drawsuba_____________________________________________________________*/

struct subarea * drawsuba(mp)
struct map *mp;
/* This function controls the drawing of the subareas by the user. */


{
        char found;             /* flag to indicate that a node match has been found */
        fnname = "drawsuba; ";
        clearscreen();
        outline();
        for (sp = mp->msp; sp != NULL; sp = sp->snext)
                drawpoly (sp->spn);
        anmode();
        readcursor();
        bell();
        found = 'N';
        for (j=0;j < ncount; j++)
                /* search for near nodes */
                if ((curx > nnodesx[j] - NEAR)  &&
                    (curx < nnodesx [j] + NEAR) &&
                    (cury > nnodesy [j] - NEAR) &&
                    (cury < nnodesy [j] + NEAR))
                        /* if a new node or a node within NEAR of it is in
                                the node list the node is made to equal that node
                                otherwise it is added to the list */
                {
                        curx = nnodesx[j];
                        cury = nnodesy[j];
                        found = 'Y';
                        break;
                }
        if (found == 'N')
                /* node was not found add it to the list */
        {
                nnodesx [ncount] = curx;
                nnodesy [ncount] = cury;
                ncount++;
        }
        startx = curx;
        starty = cury;
        nnodes=0;
        do
            /* This loop controls the entry of nodes of a polygon
                and continues until the polygon is closed. For each
                point that is entered, a list of previous nodes are checked.
                If any node is within NEAR distance the nodes are considered
                to be equal. This prevents splintering and overlaying of
                adjacent polygons.                                      */
        {
                found = 'N';
                for (j=0;j < ncount; j++)
```

```
        /* search for near nodes */
        if ((curx > nnodesx[j] - NEAR)  &&
            (curx < nnodesx [j] + NEAR) &&
            (cury > nnodesy [j] - NEAR) &&
            (cury < nnodesy [j] + NEAR))
                /* if a new node or a node within NEAR of it is in
                        the node list the node is made to equal that node
                        otherwise it is added to the list */
        {
                curx = nnodesx[j];
                cury = nnodesy[j];
                found = 'Y';
                break;
        }
if (found == 'N')
        /* node was not found add it to the list */
{
        nnodesx [ncount] = curx;
        nnodesy [ncount] = cury;
        ncount++;
}
/* allocate a node structure */

if ((np=malloc (sizeof(struct node))) == 0)
        /* allocation error */
{
        printf ("%s%s",e4,fnname);
        delay (TIME);
        return(0);
}
np->nx = curx;
np->ny = cury;
/* calculate world coordinates */
windtoworld(np);
/* increment node counter */
nnodes ++;
if (nnodes == 1)
{
        /* allocate subarea space */
        if ((sp=malloc(sizeof(struct subarea))) == 0)
                /* allocation error */
        {
                printf ("%s%s",e3,fnname);
                delay (TIME);
                return(0);
        }
        /* enter node list in subarea */
        sp->spn = np;
}
else
{
        /* tack node on the end of the node list */
        npx->nnext = np;
```

```
                /* calculate slope */
                npx->nslope = getslope (npx->nx,npx->ny,curx,cury);
                /* calculate y intercept */
                npx->nyint = yintercept(npx->nx,npx->ny,npx->nslope);
                /* get world coordinates */
                windtoworld(np);
                /* draw the line to it */
                showline (npx->nx,npx->ny,curx,cury);
        }
        /* get next node */
        readcursor();
        /* ring the bell */
        bell();
        /* save last address */
        npx = np;
}
while (((curx > startx - NEAR) && (curx < startx + NEAR)
    && (cury > starty - NEAR) && (cury < starty + NEAR)) == 0);
/* do the above until the starting position is reached */
/* close the polygon */
showline(np->nx,np->ny,startx,starty);
bell );
/* get the last slope */
np->nslope = getslope(np->nx,np->ny,startx,starty);
/* get the last yintercept */
np->nyint = yintercept(np->nx,np->ny,np->nslope);
/* indicate the end of the list */
np->nnext = NULL;
/* temporarily end th subarea list */
sp->snext = NULL;
if (getsubname(sp) == 0)
        /* error occurred */
        return(0);
/* save total number of nodes */
sp->stotnodes = nnodes;
/* get bounding box parameters */
getbox(sp);
/* color the polygon and save the color */
getcolor(sp);
/* create names for the screen and world coordinate relations */
swcoord(mp,sp);
/* create list of edges for use in manipulating the whole map */
sp->spe = node_edge(sp);
/* accumulate total nodes for map */
mp->mtotnodes += nnodes;
/* accumulate subarea total for map */
mp->mtotsuba++;
clearscreen();
/* get the attributes for this subarea and store them */
if (getattrib(sp,mp)== 0)
        /* error occurred */
        return(0);
return(sp);
```

```
/*___getbox_____________________________________________________________________*/

int getbox(sp)
/* Determines the parameters of the box that surrounds this subarea */

struct subarea * sp;

{
        npx = sp->spn;
        /* set minimum and maximum to be the first node */
        sp->sbbminx = npx->nx;
        sp->sbbminy = npx->ny;
        sp->sbbmaxx = npx->nx;
        sp->sbbmaxy = npx->ny;
        npx = npx->nnext;
        for (;npx!=NULL; npx = npx->nnext)
                /* check all other nodes */
        {
                if (npx->nx < sp->sbbminx)
                        sp->sbbminx = npx->nx;
                else if (npx->nx > sp->sbbmaxx)
                        sp->sbbmaxx = npx->nx;
                if (npx->ny < sp->sbbminy)
                        sp->sbbminy = npx->ny;
                else if (npx->ny > sp->sbbmaxy)
                        sp->sbbmaxy = npx->ny;
        }
        return(1);
}
/*___getsubname_________________________________________________________________*/

int getsubname(sp)
/* gets the name of the map and puts it in the map structure */

struct subarea * sp;

{
        fnname =  getsubname; ";
        placecursor (0,88);
        printf("%sPlease enter the name of the subarea you are creating. ",
        indent2);
        readstring(instring);
        /* allocate room for the subarea name */
        if ((sp->subarname = malloc (strlen(instring) +1)) == 0)
                /* allocation error */
        {
                printf ("%s %s\n",e13,fnname);
                return(0);
        }
        /* transfer name */
        strcpy(sp->subarname,instring);
        return(1);
```

```
/*___getcolor_____________________________________________________________*/

getcolor(sp)
/* This function prompts for the color of the subarea,enters it in
        the subarea structure and colors the subarea. */

struct subarea *sp;

{
        printf ("%sPlease enter color.(Ø=black, 1=blue, 2=green or  4=red)  ",indent2);
        readstring(instring);
        /* save color in subarea structure */
        if (*instring == 'Ø')
                sp->scolor = "black";
        else if (*instring == '1')
                sp->scolor = "blue";
        else if (*instring = '2')
                sp->scolor = "green";
        else if (*instring = '4')
                sp->scolor = "red";
        else
                sp->scolor = "white";
        printf("%sPlace cursor in the subarea and enter %s.  ,indent2,per);
        readcursor();
        /* save a representative point in the subarea */
        sp->sx = curx;
        sp->sy = cury;
}
```

```
/*___swccord_____________________________________________________________*/

int swcoord (mp,sp)
/* Sets up names fcr wcrld and screen relations. */

struct map *mp;
struct subarea *sp;

{
        static int subno;       /* counter of subareas */
        fnname = "swcoord; ";
        /* allocate room for screen and world coordinate names and copy
                the names to those places */
        if ((sp->scoord = malloc (10)) == 0)
                /* allccation error */
        {
                printf("%s%s\n",e11,fnname);
                delay (TIME);
                return(0);
        }
        /* create a name for the screen relation */
        build (sp->scoord, 's',mp->mapname,subno);
        if ((sp->wcoord = malloc(10)) == 0)
        {
                printf ("%s%s\n",e12,fnname);
                delay (TIME);
                return(0);
        }
        /* create a name for the world relation  */
        build(sp->wcoord, 'w',mp->mapname,subno);
        /* increment for next subarea */
        subno++;
        return(0);
}

/*__build_____________________________________________________________*/
int build(dest,type,mname,subno)
/* This function builds names for the world, screen and attribute relations. */
char dest[];
char type;      /* world or screen */
int subno;      /* counter for label */
char mname[];   /* name of map */

{
        char ssubno [2];        /* counter in a string */
        j=i=0;
        /* get first 5 letters from the map name */
        while ((i<5) && (mname[i] != '\0'))
        {
                dest[j++] = mname[i++];
        }
        /* insert a _ */
        dest[j++] = US;
```

```
        /* insert a 'w','s' or 'a' */
        dest[j++] = type;
        /* insert a _ */
        dest[j++] = US;
        /* change subno to alpha */
        itoa (subno,ssubno);
        for (i=0;ssubno[i] != '\0';)
        {
                /* add subno to name */
                dest[j++] = ssubno[i++];
        }
        dest[j] = '\0';
        return;
}
```

```
/*___getattrib_____________________________________________________________*/

int getattrib(sp,mp)
/* Gets the attributes for subarea and stores in sattribute structure */
struct subarea *sp;
struct map *mp;

{
        int anum,first;
        fnname = "getattrib: ";
        clearscreen();
        printf("\n%sEnter attribute values followed by a %s",indent2,ret);
        first = 1;
        for (atbp=mp->mattrtbl;atbp!= NULL;atbp= atbp->atlnext)
                /* get a value for each attribute in the table */
        {
                printf ("\n%s%s",indent2,atbp->aname);
                if (atbp->atype == 'N')
                        printf (" (numeric) ");
                else
                        printf (" (character) ");
                readstring(instring);
                /* allocate an attribute structure for it */
                if ((ap= malloc (sizeof (struct attri))) == 0)
                        /* allocation error */
                {
                        printf ("%s%s\n",e17,fnname);
                        delay (TIME);
                        return(0);
                }
                if (first == 1)
                {
                        /* connect this attribute structure to the subarea */
                        first = 0;
                        sp->sattri = ap;
                }
                else
                        /* tack it on to end of attribute list */
                        apx->anext = ap;
                /* allocate room for the attribute value */
                if ((ap->attribute = malloc (strlen (instring) +1)) == 0)
                        /* allocation error */
                {
                        printf ("%s%s\n",e6,fnname);
                        delay (TIME);
                        return(0);
                }
                if (atbp->atype == 'N')
                        /* the attribute is numeric, you need to check its bounds */
                {
                        if (isnum(instring) == 0)
                                /* user did not enter numeric data */
                        {
```

```
                        printf ("\nExpecting numeric attribute--skipping");
                        ap->attribute = "0";
                        apx = ap;
                        continue;
                }
                /* change it to numeric */
                anum = atoi (instring);
                if ((anum < atbp->alow) || (anum > atbp->ahigh))
                        /* it is out of range */
                {
                        printf ("\nOut of range-- skipping");
                        ap->attribute = "0";
                        apx = ap;
                        continue;
                }
        }
        /* copy attribute into attribute structure */
        if ((ap->attribute = malloc (strlen (instring) +1)) == 0)
                /* allocation error */
        {
                printf ("%s%s\n",e6,fnname);
                delay (TIME);
                return(0);
        }
        strcpy(ap->attribute,instring);
        /* save pointer to last attribute */
        apx = ap;
    }
    /* attribute list is completed */
    ap->anext = NULL;
    return(1);
}
/*___isnum_____________________________________________________________________*/

int isnum(instring)
/* This function determines if instring contains a number. */
char *instring;

{
    for (;*instring!='\0';instring++)
        /* checking each character */
        if ((*instring < '0') ||  (*instring > '9'))
                /* found non numeric character */
                return(0);
    return(1);
}
```

```
/*___node_edge_____________________________________________________________*/

struct edge * node_edge(sp)     /* returns pointer to a edge list */
/* returns 0 if error */
struct subarea * sp;                    /* sp is pointer to a subarea */

{
        struct edge *sepx;              /* pointer to an edge */
        fnname = "node_edge; ";
        for (np=sp->spn;np!=NULL;)
        {
                /* allocate edge structure */
                if ((ep = malloc ( sizeof (struct edge))) == 0)
                {
                        printf ("%s %s\n",e5,fnname);
                        return(0);
                }
                if (np == sp->spn)
                        /* save beginning of edge list */
                {
                        sepx = ep;
                }
                else
                        /* link to the list */
                        epx->enext = ep;
                /* save edge pointer for next link */
                epx = ep;
                ep->ebegx = np->nx;
                ep->ebegy = np -> ny;
                ep->eslope = np->nslope;
                ep->eyint = np->nyint;
                if (np->nnext == NULL)
                {
                        np = np->nnext;
                        ep->eendx = sp->spn->nx;
                        ep->eendy = sp->spn->ny;
                        ep->enext = NULL;
                }
                else
                {
                        np = np->nnext;
                        ep->eendx = np->nx;
                        ep->eendy = np->ny;
                }
        }
        return(sepx);
}

/*___coll_edge_____________________________________________________________*/

struct edge * coll_edge(mp)             /* collects all edges for a map,
                                           places them in a list and returns a
                                           pointer to the edge list */
```

```
struct map * mp;                        /* pointer to a map */

{
        struct edge *sepx, *epx1;       /* pointer to an edge */
        fnname = "coll_edge;  ";
        i=0;
        clearscreen();
        for (sp= mp->msp; sp!= NULL; sp=sp->snext)
        {
                for (ep= sp->spe; ep!= NULL; ep=ep->enext)
                {
                        if ((epx = malloc ( sizeof (struct edge ))) == 0)
                        {
                                printf ("%s %s\n",e5,fnname);
                                return(0);
                        }
                        if (i++ == 0)
                                /* first edge */
                                /* save beginning edge list pointer */
                                sepx = epx;
                        else
                                /* link it to the previous one */
                                epx1->enext = epx;
                        /* save pointer for linking */
                        epx1 = epx;
                        epx->ebegx = ep->ebegx;
                        epx->ebegy = ep->ebegy;
                        epx->eendx = ep->eendx;
                        epx->eendy = ep->eendy;
                        epx->eslope = ep->eslope;
                        epx->eyint = ep->eyint;
                }
        }
        /* comlpete the list */
        epx->enext = NULL;
        return(sepx);
}
```

C.7 Inquire

```
#define TIME    5
#include        <stdio.h>
#include        "mpnamex.h"
iret = "'ret'";
done = "'done'";
struct map *ckcurmp();  /* function to check if map is in core */
/*___inquire_____________________________________________________________*/

int inquire()
/* This function controls the map inquiry process. */

{
        char distype;           /*display type */
        clearscreen();
        anmode();
        printf ("INQUIRY\n");
        printf ("\nWhat type display do you want? (t=table or d= drawing of map) ");
        readstring (instring);
        if (*instring == 't')
                distype = 't';
        else
                distype = 'm';
        printf ("\nWhat map are you requesting? ");
        readstring (instring);
        skiplines (3);
        if ((mpx = ckcurmp (instring)) == 0)
                /* user is requesting a different map than the one
                                we have in storage. */
                mp = readmap (instring);
        else
                mp = mpx;
        if (distype == 't')
        {
                printmap (mp);
                return;
        }
        /* user wants a drawing */
        do
        {
        put_on_screen(mp);
        placecursor (0,90);
        printf ("\nSelect a subarea for inquiry ");
        printf ("by placing the cursor in that subarea.\n ");
        readcursor ();
        /* identify subarea */
        sp = inpoly (curx,cury,mp);
        if (sp ==  0)
```

```
                /* error -this is not a subarea */
                placecursor(0,120);
                printf ("Please position the cursor in a valid subarea\n");
                delay (5);
        }
        else
        {
        placecursor(970,760);
        printf ("\n%s Name:  %s", indent2,sp->subarname);
        prtatt (mp,sp);
        }
        placecursor (0,60);
        printf ("\nPress %s to continue",iret);
        printf (" or terminate inquiry by typing %s. ",done);
        temp = readstring (instring);
        }
        while (temp == 0);
}
/*___put_on_screen_____________________________________________________________*/

put_on_screen(mp)
struct map *mp;         /* pointer to a map */

{
        clearscreen();
        /* draw interior */
        for (sp= mp->msp; sp != NULL; sp= sp->snext)
        {
                /* outline the subarea */
                drawpoly (sp->spn);
        }
}
```

```
/*___printmap_____________________________________________________________*/
int printmap(mp)                /* prints the map as in storage */
struct map * mp;                /* pointer to a map struct */

{
        fnname = "printmap; ";
        clearscreen();
        printf("Map name = %s\n", mp->mapname);
        printf("Author = %s\n", mp->author);
        prtatbl(mp);
        printf("No. of subareas = %d\n", mp->mtotsuba);
        printf("No. of nodes in map structure = %d\n",mp->mtotnode);
        printf ("Map edges\n");
        prtedg(mp->mpe);
        printf ("\nPress %s to cntinue.",iret);
        /* get the ret */
        readstring (instring);
        clearscreen();
        for (sp=mp->msp; sp != NULL; sp=sp->snext)
        {
                prtsub(sp);
                prtatt(mp,sp);
                printf ("\nPress %s to continue.",iret);
                /* get the ret */
                readstring (instring);
                clearscreen();
        }
}
/*___prtatbl______________________________________________________________*/
prtatbl(mp)
struct map *mp;
{
        printf ("\nAttribute table-- %s  %d attributes\n",mp->mattrnm,mp->mnoattr);
        printf ("%sNAME    TYPE    LOW    HIGH\n",indent1);
        for (atbp = mp->mattrtbl; atbp != NULL; atbp = atbp->atlnext)
        {
                printf ("%s%-12s%3c%8d%7d\n",indent2,atbp->aname,atbp->atype,
                atbp->alow, atbp->ahigh);
        }
}
/*___prtsub_______________________________________________________________*/
prtsub(sp)
struct subarea *sp;
{
        printf ("\n\nSubarea %s %d nodes\n",sp->subarname,sp->stotnode);
        printf ("%sx=%d y=%d color=%s\n",indent2,sp->sx,sp->sy,sp->scolor);
        printf ("%sScreen coord. relation name = %s\n",indent2,sp->scoord);
        printf ("%sWorld coord. relation name = %s\n",indent2,sp->wcoord);
        printf ("%sBound by ",indent2);
        printf ("%s %d,%d   %d,%d\n",indent2,sp->sbbminx,sp->sbbminy,sp->sbbmaxx,
        sp->sbbmaxy);
        printf("%sX     Y       SLOPE     YINTERCEPT",indent2);
        printf("     WORLD X   WORLD Y\n");
```

```
        for (np= sp->spn; np!=NULL; np= np->nnext)
        {
                prtnode(np);
        }
        printf ("Subarea edges\n");
        prtedg(sp->spe);
}
/*___prtnode_____________________________________________________________________*/

prtnode(np)
struct node *np;
{
        printf("%6d%5d%12.2f%11ld%12d%10d\n",np->nx,np->ny,np->nslope,
        np->nyint,np->nwx,np->nwy);
}
/*____prtatt_____________________________________________________________________*/
prtatt(mp,sp)
struct subarea *sp;
struct map *mp;
{
        printf ("\nAttributes\n");
        if (sp->sattri == NULL)
                printf ("%sNone\n",indent2);
        else
        {
                for (ap=sp->sattri,atbp=mp->mattrtbl; ap!= NULL; ap= ap->anext,atbp=atbp->atlnext)
                {
                        printf ("%s%s (%c)  %s\n ,indent2,atbp->aname,atbp->atype,ap->attribute);
                }
        }
}
/*____prtedg_____________________________________________________________________*/
prtedg(ep)
struct edge *ep;
{
        printf("%sBEG  X   Y    END  X   Y      SLOPE  YINTERCEPT\n",indent2);
        for (; ep!= NULL; ep = ep->enext)
        {
                printf("%11d%4d%10d%4d%11.1f%8ld\n",ep->ebegx,ep->ebegy,
                ep->eendx,ep->eendy,ep->eslope,ep->eyint);
        }
}
/*___ckcurmp_____________________________________________________________________*/
struct map * ckcurmp (instring)
        /* This function checks to see whether the requested map
        is in core. If it is , the function returns a pointer
        to it, else it returns a zero. */
char *instring;         /* name of map */

{
        for (i=0; i < nummap; i++)
        {
                mpx = curmap [i];
```

```
                if (strcmp (mpx->mapname, instring) == 0)
                /* found the map */
                        return (mpx);
        }
        /* map not found */
        return(0);
}
```

C.8 Getslope, yintercept

```
/*___getslope_____________________________________________________________*/

float getslope(x1,y1,x2,y2)      /* returns the slope of a line */
int x1,y1,x2,y2;                 /* end points of the line */

{
        float ret;       /* value returned */
        float xdiff,ydiff;       /* variables conaining x and y differences */

        if (x1 == x2)
                ret = 999.9;
        else
        {
                ydiff = y1 - y2;
                xdiff = x1 - x2;
                ret = ydiff / xdiff;
        }
        return (ret);
}
/*___yintercept___________________________________________________________*/

long yintercept (x,y,m) /* a function that calculates the y intercept
                when given an x, y, and the slope of the line */
int x,y;
float m;

{
        float temp;              /* temporary variable */
        long ret;
        long ceil,floor;
        if (m == 0.0)
        {
                ret = y;
                return (ret);
        }
        if (m >= 999.0)
        {
                ret = 9999;
                return (ret);
        }

        ceil = 9999 - y;
        floor = y - 9999;
        temp = m * x;
        if ( temp < floor) || (temp > ceil))
                return (9999);
        ret = y - temp;
        if (ret > 9999)
```

```
                ret = 9999;
        return (ret);
}
```

C.9 Bound_box

```
#include <stdio.h>
#include        "mpnamex.h"

/*___bound_box_____________________________________________________________*/

int bound_box (b1x1,b1y1,b1x2,b1y2,b2x1,b2y1,b2x2,b2y2)
/* This function returns a 1 if the boxes
                        described by (b1x1,b1y1,b1x2,b1y2) and
                        (b2x1,b2y1,b2x2,b2y2) overlap, 2 if they overlap
                        on boundaries only, else it
                        returns a 0. */

int b1x1,b1y1,b1x2,b1y2,b2x1,b2y1,b2x2,b2y2;    /* box boundaries */
{
        int p1,p2,p3,p4;                                /* vertices of the box 1 */

        /*
                p1-------------p2
                |              |
                |              |
                |              |
                |              |
                |              |
                p4-------------p3

        */
        int xmin,xmax,ymin,ymax;                        /* min. and max. x and y values */

        if  (b1x1 < b1x2)
        {
                xmin = b1x1;
                xmax = b1x2;
        }
        else
        {
                xmin = b1x2;
                xmax = b1x1;
        }
        if (b1y1 < b1y2)
        {
                ymin = b1y1;
                ymax = b1y2;
        }
        else
        {
                ymin = b1y2;
                ymax = b1y1;
```

```
        }

        /* If any vertice of box 1 lies in box 2, they overlap. */
        if (
        (( p1 = bb (xmin,ymax,b2x1,b2y1,b2x2,b2y2)) == 0) ||
            (( p2 = bb (xmax,ymax,b2x1,b2y1,b2x2,b2y2)) == 0) ||
            (( p3 = bb (xmax,ymin,b2x1,b2y1,b2x2,b2y2)) == 0) ||
            (( p4 = bb (xmin,ymin,b2x1,b2y1,b2x2,b2y2)) == 0)
            )
                return (1);
        if ( (p1 == 9) || (p2 == 9) || (p3 == 9) || (p4 == 9))
                /* point is on the boundary of the box */
                return(2);
        if ((p1 == 1) || (p1 == 2) || (p1 == 8))
            &&
            ((p3 == 4) || (p3 == 5) || (p3 == 6)))
                return(1);
        else
                return(0);
}
```

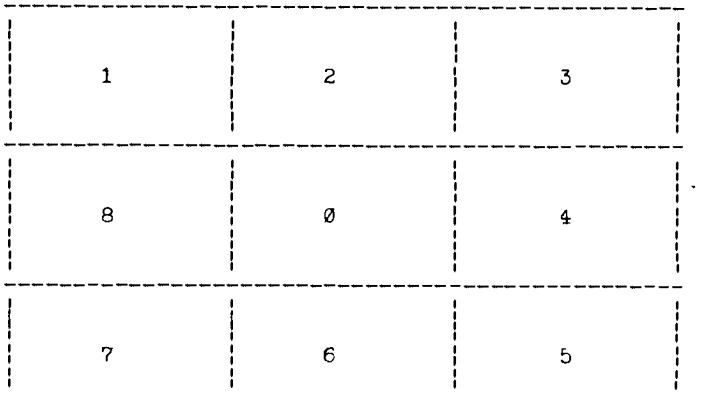
```
/*___bb_____________________________________________________________________*/

int bb (x,y,x1,y1,x2,y2)
/* function which tells us if a point is contained in a box */

int x,y;      /* coordinates to be tested */
int x1,y1,x2,y2;  /* boundaries of the box */

{
        int xmin,xmax,ymin,ymax;    /* min. and max. of x1,x2 and y1,y2 */
        if (x1 <=  x2)
        {
                xmin = x1;
                xmax = x2;
        }
        else
        {
                xmin = x2;
                xmax = x1;
        };
        if (y1 <= y2)
        {
                ymin = y1;
                ymax = y2;
        }
        else
        {
                ymin = y2;
                ymax = y1;
        };

        /* Note: This function returns zero if the point is in the box,
                   a 9 if the point is on the border of the box,
                   otherwise it returns an integer,describing the relation of the point
                   to the box.
```



```
                |               |               |
                ------------------------------------------------

        */

        if (((x == xmin) || (x == xmax)) &&
            ((y <= ymax) && (y >= ymin))) ||
            ((y == ymin) || (y == ymax)) &&
            ((x <= xmax) && (x >= xmin))))
                /* boundary condition */
                return(9);

        if (x < xmin )
                /* it must be in 1, 7, or 8 */
        {
                if (y < ymin)
                        return (7);
                else if (y > ymax)
                        return(1);
                else return (8);
        }
        else if (x > xmax)
                /* it must be in 3, 4, or 5 */
        {
                if (y < ymin )
                        return (5);
                else if (y > ymax)
                        /* it must be in 2, 6, or 8 */
                        return (3);
                else return(4);
        }
        else
        {
                if (y > ymax)
                        return(2);
                else if (y < ymin)
                        return (6);
                else return (0);
        }
}
```

```
/*___intercept_____________________________________________________________*/

int intercept(xa1,ya1,xa2,ya2,m_a,b_a,xb1,yb1,xb2,yb2,m_b,b_b)
/* This function determines the intercept of 2 lines,
        a and b. It returns the following;
                Ø - If the lines intersect at one point.
                        xinter1 and yinter1 are set to reflect the intersection.
                                        |
                                        |
                                ---------------
                                        |
                                        |

                1 - If the lines are identical.
                                ---------
                                ---------

                2 - If the intersection is a line with left endpoints
                        identical. Xinter1 and yinter1 are set to reflect the
                        intersection.
                                -------
                                -----------
                                1     2   3


                3 - If the intersection is a line with right endpoints
                        identical. Xinter1 and yinter1 are set to reflect the
                        intersection.
                                    -------
                                -----------
                                3   2     1

                4 - If the intersection is a line which is entirely contained
                        in the first line. Xinter(1,2,3,and 4) and yinter
                        (1,2,3 and 4) are set as follows.
                                    -------
                                ------------------
                                1    2     3     4

                5 - If the intersection is a line which  is not entirely
                        contained in the first line. Xinter (1,2,3, and 4) and
                        yinter(1,2,3, and 4) are set as follows.
                                -------------
                                    --------------
                                1    2      3     4

                6 - If the intersection is at one of the endpoints only.
                        Xinter1 and yinter1 are set.


                -1 - No intersection.

                -2 - Error.
```

```
*/

int xa1,ya1,xa2,ya2,xb1,yb1,xb2,yb2;     /* points */
long b_a,b_b;                            /* y intercepts */
float m_a,m_b;                                   /* slopes */
{
        int ret;                /* value to be returned */
        int std_form();         /* function which puts lines in standard form */
        int bound_box();        /* function which checks to see in two boxes
                                           or lines overlap */
        int fintercept();       /* recursive function which finds actual intersection */
        int lb,ub;              /* upper and lower bounds */
        int b;                  /* holds results of bound_box */

        /* initialize variables that hold intercept points */
        xinter1 = 999;
        xinter2 = 999;
        xinter3 = 999;
        xinter4 = 999;
        yinter1 = 999;
        yinter2 = 999;
        yinter3 = 999;
        yinter4 = 999;
        /* if either line is almost vertical assuma it is vertical */
        if (b_a == 9999)
                m_a = 999.9;
        if (b_b == 9999)
                m_b = 999.9;
        if (std_form(&xa1,&ya1,&xa2,&ya2,&m_a,&b_a,&xb1,&yb1,&xb2,&yb2,&m_b,&b_b) != 0)
                return(-2);
        if ( b = bound_box (xa1,ya1,xa2,ya2,xb1,yb1,xb2,yb2)) == 0)
                /* bounding boxes do not overlap */
                return(-1);
        if ((m_a == m_b ) && m_a == 999.9))
                /* both lines are vertical */
        {
                yinter1 = ya1;
                xinter1 = xa1;
                xinter2 = xa1;
                xinter3 = xa1;
                xinter4 = xa1;
                if (ya1 == yb1)
                        /* lowest points intersect */
                {
                        if (ya2 == yb2)
                                return(1);
                        if (ya2 < yb2)
                        {
                                yinter2 = ya2;
                                yinter3 = yb2;
                                return(2);
                        }
                        else
```

```
                {
                        yinter2 = yb2;
                        yinter3 = ya2;
                        return(2);
                }
        }
        else if (ya2 == yb2)
                /* upper points intersect */
        {
                yinter2 = yb1;
                yinter3 = yb2;
                return(3);
        }
        else if (ya2 == yb1)
        {
                yinter1 = yb1;
                return(6);
        }
        else
        {
                yinter2 = yb1;
                if (ya2 < yb2)
                {
                        yinter4 = yb2;
                        yinter3 = ya2;
                        return(5);
                }
                else
                {
                        yinter4 = ya2;
                        yinter3 = yb2;
                        return(4);
                }
        }
}
if (m_a == 999.9)
        /* only a is vertical */
{
        xinter1 = xa1;
        if ((xa1 == xb1) && (ya1 == yb1))
        {
                yinter1 = ya1;
                return(6);
        }
        if ((xa2 == xb1) && (ya2 == yb1))
        {
                yinter1 = ya2;
                return(6);
        }
        if ((xa2 == xb1) && (ya2 == yb1))
        {
                yinter1 = yb1;
                return(6);
```

```
        }
        if ((xa1 == xb2) && (ya1 == yb2))
        {
                yinter1 = yb2;
                return(6);
        }
        yinter1 = m_b * xa1 + b_b;
        return(0);
}
else if (m_b == 999.9)
        /* only b is vertical */
{
        xinter1 = xb1;
        if ((xa2 == xb1) && (ya2 == yb1))
        {
                yinter1 = yb1;
                return(6);
        }
        if ((xa2 == xb2) && (ya2 == yb2))
        {
                yinter1 = yb2;
                return(6);
        }
        if ((xa1 == xb1) && (ya1 == yb1))
        {
                yinter1 = yb1;
                return(6);
        }
        if ((xa1 == xb2) && (ya1 == yb2))
        {
                yinter1 = yb2;
                return(6);
        }
        yinter1 = m_a * xb1 + b_a;
        return(0);
}
if ((xa1 == xb1) &&
    (ya1 == yb1))
        /* left endpoints are the same */
{
        if (( xa2 == xb2) &&
            (ya2 == yb2))
                /* left and right endpoints are the same */
                return (1);
        else if (m_a == m_b)
                /* left endpoints and slopes are the same */
        {
                xinter1 = xa1;
                yinter1 = ya1;
                if (xa2 < xb2)
                {
                        xinter2 = xa2;
                        yinter2 = ya2;
```

```
                        xinter3 = xb2;
                        yinter3 = yb2;
                }
                else
                {
                        xinter2 = xb2;
                        yinter2 = yb2;
                        xinter3 = xa2;
                        yinter3 = ya2;
                }
                return(2);
        }
}
else if (( xa2 == xb2) &&
    (ya2 == yb2) &&
    (m_a == m_b) )
        /* right endpoints and slopes are the same */
{
        xinter1 = xa1;
        yinter1 = ya1;
        xinter2 = xb1;
        yinter2 = yb1;
        xinter3 = xb2;
        yinter3 = yb2;
        return(3);
}
if ((m_a == m_b) &&
    (b_a == b_b))
        /* slopes and y intercepts are identical */
{
        xinter1 = xa1;
        yinter1 = ya1;
        xinter2 = xb1;
        yinter2 = yb1;
        if (xa2 < xb2)
        {
                xinter3 = xa2;
                yinter3 = ya2;
                xinter4 = xb2;
                yinter4 = yb2;
                return(5);
        }
        else
        {
                xinter3 = xb2;
                yinter3 = yb2;
                xinter4 = xa2;
                yinter4 = ya2;
                return(4);
        }
}
if ((xa1 == xb1) &&
    (ya1 == yb1))
```

```
                /* endpoints are identical */
        {
                xinter1 = xa1;
                yinter1 = ya1;
                return(6);
        }
        else if ((xa2 == xb2) && (ya2 == yb2))
        {
                xinter1 = xa2;
                yinter1 = ya2;
                return(6);
        }
        else if ((xa2 == xb1) && (ya2 == yb1))
        {
                xinter1 = xa2;
                yinter1 = ya2;
                return(6);
        }
        lb = xb1;
        if (xb2 < xa2)
                ub = xb2;
        else
                ub = xa2;
        ret = fintercept (lb,ub,m_a,m_b,b_a,b_b);
        return(ret);
}
```

```
/*___fintercept_____________________________________________________________*/

int fintercept(lb,ub,m_a,m_b,b_a,b_b)
/* returns a zero and sets xinter1 and yinter1 when the intercept
          is found */

int lb,ub;      /* upper and lowers bounds in x direction */
float m_a,m_b;  /* slope of line a and b */
long b_a,b_b;   /* yintercept of lines a and b */

{
        int lb_y_a,lb_y_b,ub_y_a,ub_y_b;        /* y values of lines a and b at
                                                   upper and lower bounds */
        int f;                  /* result of fintercept */
        int wid, hwid;          /* distance between ub and lb */
        int diff_lb,diff_ub; /* distance between y values at upper and
                        lower bounds */
        lb_y_a = m_a * lb + b_a;
        lb_y_b = m_b * lb + b_b;
        if (lb_y_a == lb_y_b)
        {
                xinter1 = lb;
                yinter1 = lb_y_a;
                return(0);
        }
        ub_y_a = m_a * ub + b_a;
        ub_y_b = m_b * ub + b_b;
        if (ub_y_a == ub_y_b)
        {
                xinter1 = ub;
                yinter1 = ub_y_a;
                return (0);
        }
        if (((lb_y_a > lb_y_b) &&
            (ub_y_a > ub_y_b)) ||
            ((lb_y_a < lb_y_b) &&
            (ub_y_a < ub_y_b)))
                return(-1);
        /* due to rounding error the intercept was missed */

        diff_lb = lb_y_a - lb_y_b;
        diff_ub = ub_y_a - ub_y_b;
        if (diff_lb < 0) diff_lb *= -1;
        /* take absolute value of diff_lb and diff_ub */
        if (diff_ub < 0) diff_ub *= -1;
        wid = ub-lb;
        hwid = wid / 2;
        if (hwid == 0)
                hwid = 1;
        if (diff_lb < diff_ub)
        {
                if ( wid > 2)
                {
```

```
                ub = ub - hwid;
                lb = lb +1;
        }
        else if ( wid == 2)
        {
                lb = lb +1;
                ub = lb;
        }
        else
                ub = lb;
        if ((f = fintercept (lb,ub,m_a,m_b,b_a,b_b)) == -1)
        {
                xinter1 = lb;
                yinter1 = lb_y_a;
                return(0);
        }
        else
                return(f);
}
else if (diff_lb > diff_ub)
{
        if ( wid > 2)
        {
                lb = lb + hwid;
                ub = ub-1;
        }
        else if (wid == 2)
        {
                ub = ub - 1;
                lb = ub;
        }
        else
                lb = ub;
        if ((f = fintercept (lb,ub,m_a,m_b,b_a,b_b)) == -1)
        {
                xinter1 = ub;
                yinter1 = ub_y_a;
                return(0);
        }
        else
                return(f);
}
else
{
        ub = ub - hwid;
        lb = ub;
        if ((f = fintercept (lb,ub,m_a,m_b,b_a,b_b)) == -1)
        {
                xinter1 = ub;
                yinter1 = ub_y_a;
                return(0);
        }
        else
```

```
        return(f);
    }
}
```

```
/*___std_form_____________________________________________________________*/

int std_form(xa1,ya1,xa2,ya2,m_a,y_a,xb1,yb1,xb2,yb2,m_b,y_b)
/* puts boxes or lines in standard form */
int *xa1, *ya1, *xa2, *ya2, *xb1, *yb1, *xb2, *yb2;
long *y_a, *y_b;
float *m_a, *m_b;
/* points, slopes and yintercepts */

{
        int switchit(); /* function to switch variables */
        if ( *xa1 > *xa2)
        {
                switchit(xa1,xa2);
                switchit(ya1,ya2);
        }
        else if ((*xa1 == *xa2) && (*ya1 > *ya2))
                switchit (ya1,ya2);
        if (*xb1 > *xb2)
        {
                switchit(xb1,xb2);
                switchit(yb1,yb2);
        }
        else if ((*xb1 == *xb2) && (*yb1 > *yb2))
                switchit (yb1,yb2);
        if ((*xa1 > *xb1 ) ||
            ((*m_a ==999.9) && (*m_b == 999.9) && (*ya1 > *yb1)))
                /* a will be closest to y axis or if both vertical
                                        will be closest to x axis */
        {
                switchit(xa1,xb1);
                switchit(ya1,yb1);
                switchit(xa2,xb2);
                switchit(ya2,yb2);
                fswitchit(m_a,m_b);
                lswitchit(y_a,y_b);
        }
        return(0);
}

/*___switchit_____________________________________________________________*/

int switchit(var1,var2)         /* switches these two variables */
int *var1 ,*var2;               /* pointers to variables to be switchited */

{
        int temp;
        temp = *var1;
        *var1 = *var2;
        *var2 = temp;
        return(0);
}
/*___fswitchit____________________________________________________________*/
```

```
int fswitchit(var1,var2)                /* switches these two variables */
float *var1 ,*var2;                 /* pointers to variables to be switchited */

{
        float temp;
        temp = *var1;
        *var1 = *var2;
        *var2 = temp;
        return(0);
}
/*___lswitchit_____________________________________________________________*/

int lswitchit(var1,var2)                /* switches these two variables */
long *var1 ,*var2;                  /* pointers to variables to be switchited */

{
        long temp;
        temp = *var1;
        *var1 = *var2;
        *var2 = temp;
        return(0);
}
```

```
/*___inpoly_____________________________________________________________________**/

struct subarea * inpoly (x,y,mp)
/* This function returns a 0 if the given point (x,y) is not in
          any subarea of the map, otherwise it returns a pointer to
        the subarea it is in. */

int x,y;                          /* points given */
struct map * mp;                  /* pointer to map */

{
        int nsuba;                /* counter for subareas */
        sp = mp->msp;
        for (sp = mp->msp->snext; sp!= NULL; sp = sp->snext)
        {
                if (ckedge (x,y,sp) == 0)
                        return(sp);
        }
        return(0);
}

/*___ckedge_____________________________________________________________________*/
int ckedge(x,y,sp)        /* returns 0 if in this subarea else returns -1 */
/* After checking that the point is within the bounding box, this function
           checks each edge for intersection with the vertical line that
           passes through the point (x,y). In the event of intersections
           the x values are saved in the array,savex. This array is then
           scanned to determine whether the point is actually inside or
           outside the polygon. */

int x,y;                  /* points given */
struct subarea *sp;       /* pointer to a subarea */

{
        int savex[10];    /* area to save x values that cross y */
        int ctr;          /* counter of points on vertical lines */
        int b;            /* holds results of bb test */
        static int cnt;           /* subscript for savex */
        long yinterc;             /* y intercept of scan line */
        /* checking that the point is contained in the bounding box */
        cnt = 0;
        if ((( b = bb(x,y,sp->sbbminx,sp->sbbminy,sp->sbbmaxx,sp->sbbmaxy)) > 0)
            && (b < 9))
                return(-1);
        yinterc = y;
        for (ep = sp->spe; ep!= NULL; ep= ep->enext)
        {
                temp =  intercept (sp->sbbminx,y,sp->sbbmaxx,y,0.,yinterc,
                ep->ebegx,ep->ebegy,ep->eendx,ep->eendy,
                ep->eslope,ep->eyint);
                if (temp == 0)
                {
                        savex[cnt++] = xinter1;
```

```
                }
                else if (temp == 1)
                        /* lines are identical__ the point is in the polygon */
                        return(0);
                else if (( temp == 2) || (temp == 3))
                {
                        savex[cnt++] = xinter1;
                        savex[cnt++] = xinter2;
                }
                else if (temp == 4)
                {
                        savex[cnt++] = xinter2;
                        savex[cnt++] = xinter3;
                }
                else if (temp == 5)
                {
                        /* error__ bounding box exceeded */
                        return(-1);
                }
                else if (temp == 6)
                        /* intersection is at an endpoint of the bounding box line */
                {
                        savex[cnt++] = xinter1;
                }
        }
        ctr = 0;
        for (j=0; j<cnt; j++)
        {
                /* count points that are left of x */

                if (x < savex[j])
                        ctr++;
                }
        if (ctr % 2 == 0)
                /* counter was even, point is not in */
                {
                return(-1);
                }
        else
                /* counter,odd, point is in */
                {
                return(0);
                }
}
/*___getslope__ ____________________________________________________________*/

float getslope(x1,y1,x2.y2)     /* returns the slope of a line */
int x1,y1,x2,y2;                /* end points of the line */

{
        float ret;      /* value returned */
        float xdiff,ydiff;      /* variables conaining x and y differences */
```

```
        if (x1 == x2)
                ret = 999.9;
        else
        {
                ydiff = y1 - y2;
                xdiff = x1 - x2;
                ret = ydiff / xdiff;
        }
        return (ret);
}
/*___yintercept_____________________________________________________________*/

long yintercept (x,y,m) /* a function that calculates the y intercept
                when given an x, y, and the slope of the line */
int x,y;
float m;

{
        float temp;             /* temporary variable */
        long ret;
        long ceil,floor;
        if (m == 0.0)
        {
                ret = y;
                return (ret);
        }
        if (m >= 999.0)
        {
                ret = 9999;
                return (ret);
        }

        ceil = 9999 - y;
        floor = y - 9999;
        temp = m * x;
        if ( temp < floor) || (temp > ceil))
                return (9999);
        ret = y - temp;
        if (ret > 9999)
                ret = 9999;
        return (ret);
}
```

C.14 Intro1,intro2,draw1,draw2

File Intro1

DRAW-A-MAP

You have entered the DRAW-A-MAP system. The purpose of this system is to use an interactive graphics terminal to draw a map and then to store the map with its graphical and nongraphical data in a relational data base.

As you use this system you will be prompted to enter data or make decisions. Unless otherwise instructed, the answers to the prompts must be typed on the keyboard followed by a 'ret' (i.e., the return key). Where you are required to select an option from a list, place the cursor, using the wheels with arrows, on the option you want and then type a period ('.').

The cursor in this system is a square. When it is flashing, the system is indicating to you that you must respond.

Now type 'ret' to begin.

File Intro2

Select the operation you wish to perform by placing the cursor on that operation.

1. Draw a map.

2. Delete a map that has been stored in the data base.

3. Edit a map that has been stored in the data base.

4. Make an inquiry of a map.

5. Exit this program.

File Draw1

You are now ready to draw the boundarys of the map. Place the cursor at a vertice and enter a '.'. Move the cursor to the next vertice and enter '.' again. A bell will ring to indicate to you that the system has recorded the vertice. Continue to enter vertices around the boundary. The boundary will be considered to be closed when the first vertice is reentered. At the closure of the boundary, two bells will ring.

Now type 'ret' to continue.

File Draw2

You are now ready to draw the subareas of the map. Place the cursor at a vertice and enter a '.'. Move the cursor to the next vertice and enter '.' again. A bell will ring to indicate to you that the system has recorded the vertice. Continue to enter vertices around the subarea. The subarea will be considered to be closed when the first vertice is reentered. At the closure of the subarea, two bells will ring.

Now type 'ret' to continue.

Selected Bibliography

Bonfatti, Flavio and Tiberio, Paolo, "Data Management for Thematic Map Generation." Computers and Graphics, 3 (1978): pp. 71-78.

Brassel,Kurt E., Utano, Jack J., Hanson, Perry Ø.,III, "The Buffalo Crime Mapping System: A Design Strategy for the Display and Analysis of Referenced Crime Data." Computer Graphics, 11 (Summer 1977): pp. 78-85.

Codd, E.F., "A Relational Model of Data for Large Shared Data Banks." CACM, 13 (June 1970): in Date, C.J., An Introduction to Database Systems. Reading,Mass.:Addison-Wesley,1977.

Cristiani,E.J., Evey,R.J., Goldman,R.E., Manty,P.E., "An Interactive System for Aiding Evaluation of Local Government Policies." IEEE Trans. on Systems, Man and Cybernetics. SMC-3 (March 1973): pp.141-146. in Williams, Robin, "On the Application of Relaticnal Data Structures in Computer Graphics." in Data Structures, Computer Graphics and Pattern Recognition. eds. Klinger,A., Fu, K.S., Knuii,T.L., New York: Academic Press,1977.

Dalton,J., Billingsley,J., Quann, J., Bracken, P., "Interactive Color Map Display of Domestic Infromation." NASA/Goddard Space Flight Center, Greenbelt, Md., Computer Graphics, 13 (August 1979), pp. 226-233.

Date,C.J., An Introduction to Database Systems, Reading,Mass.: Addison-Wesley, 1977.

Dodd, G.G., "APL- a Language for Associative Data Handling in PL/I." Proc. AFIPS 1966 FJCC, 29 New York:Spartan Books,1966. in Williams, Robin "A Survey of Data Structures for Computer Graphics Systems." ACM Computing Surveys, 3 (March 1971) :p. 10.

Feldman,J.A. and Rovner,P.D., "An Algol-Based Associative Language." Comm. ACM, 12 (Aug. 1969): pp. 439-449. in Williams, Robin, "A Survey of Data Structures for Computer Graphics Systems." ACM Computing Surveys, 3 (March 1971) :p. 10-11.

Freeman,Herbert, Tutorial and Selected Readings in Interactive Computer Graphics. New York: IEEE Computer Society, 1980.

Forrest, A.R., "Recent Work on Geometric Algorithms", in Brodlie, K.W., Mathematical Methods in Computer Graphics and Design, New York: Academic Press, 1980.

Giloi, Wolfgang K., Interactive Computer Graphics, Data Structures, Algorithms and Languages, Englewood Cliffs, N.J., : Prentice-Hall, 1978.

Klinger,A., Fu,K.S., Kunii,T.L., ed. Data Structures, Computer Graphics and Pattern Recognition, New York: Academic Press, 1977.

Knowlton, K. C.,"A Programming Description of L6". Comm. ACM, 9 (Aug.,1966): pp. 616-625. in Williams, Robin, "A Survey of Data Structures for Computer Graphics Systems." ACM Computing Surveys, 3 (March 1971): p. 8.

McIntosh, J.F., "The Interactive Digitizing of Polygons and the Processing of Polygons in a Relational Database." Computer Graphics, 12 (Aug. 1978): pp. 60-63.

Martin, James, Design of Man-Computer Dialogues, Englewood Cliffs,N.J.: Prentice-Hall,Inc., 1973.

Newman,William M., van Dam, Andries, "Recent Efforts Towards Graphics Standardization." Computing Surveys, 10 (Dec. 1978): pp. 365-380.

Shamos, M.I., "Computational Geometry", A dissertation presented to the faculty of Yale University, May,1978.

Sutherland, Ivan E. "Sketchpad: A Man-Machine Graphical Communication System." Proc. Spring Joint Computer Conference, AFIPS Press, 1963. in Tutorial and Selected Readings in Interactive Computer Graphics. ed. Freeman, Herbert New York: IEEE Computer Society, 1980.

Uno, Sakae, "A General Purpose Graphic System for Computer Aided Design." Computer Graphics, 13 (August 1979): pp. 25-32.

Van Dam, A. and Evans, D., "Data Structures Programming System." Proc. IFIP Cong., 1 Amstderdam:North

Holland,1968. in Williams, Robin, "A Survey of Data Structures for Computer Graphics Systems." ACM Computing Surveys, 3 (March 1971): ,p. 9.

Wengorf, J.W.. "A Simply Extended and Modified Batch Environment Graphical System.", CACM, 21 (Nov. 1978): pp. 897-904.

Weller, Dan and Williams, Robin, "Graphical and Relational Data Base Support for Problem Solving." Computer Graphics, 10 (Summer 1976): in Tutorial and Selected Readings in Interactive Computer Graphics, Freemen,Herbert, New York: IEEE Computer Society, 1980.

Williams, Robin, "A Survey of Data Structures for Computer Graphics Systems.", ACM Computing Surveys, 3 (March 1971): pp.1,15.

_____, Giddings, G.M., Little, W.D., Moorhead, W.G., Weller,D.L., "Data Structures in Computer Graphics", Proceedings of Workshop on Data Bases for Interactive Design University of Waterlco, (Sept. 1975) in Data Structures, Computer Graphics and Pattern Recognition. eds. Klinger,A., Fu, K.S., Knuii,T.L., New York: Academic Press,1977.

_____, "On the Application of Relational Data Structures in Computer Graphics." in Data Structures, Computer Graphics and Pattern Recognition. eds. Klinger,A., Fu, K.S., Knuii,T.L., New York: Academic Press,1977.