Pavement Management Graphic Reporting System Using Existing IBM Hardware and SAS Software

BRUCE T. DIETRICH

The use of interactive computerized color graphics to communicate pavement information is becoming an important component of pavement management systems. Multipurpose geographic information systems have the capability of providing many of these graphic needs. However, many of these systems come with high price tags in terms of hardware, software, data communications, and training. In order to provide needed additional graphic reporting capabilities at a minimum cost, the Florida Department of Transportation is developing a pavement management graphic reporting system that uses existing IBM hardware and SAS software. The system is accessible from any of several hundred graphic terminals and personal computers around the state that are networked into the department's IBM 3090 mainframe computer. The system allows users to interactively create color-coded geographic maps of various pavement features on the state highway system. It is driven by menus and does not require extensive computer experience to operate. The base map was digitized from U.S. Geological Survey mylar quad sheets with state roadway section identifications added during the digitizing. Pavement feature data that are selected for display are accessed from various sources such as relational data base files, flat files, and SAS data sets.

The Florida Department of Transportation (FDOT) is developing a pavement management graphic reporting system (PMGRS) to enhance the communication of pavement information within the department. After evaluating different alternatives, it was decided to develop an in-house system using existing software and hardware resources. FDOT currently has an IBM™ 3090 mainframe with an extensive statewide communications network and has licensed the SAS software system since the early 1980s. SAS™ is a widely used end-user software system that provides fourth-generation programming language capabilities, as well as user interfaces, statistical and other data analysis procedures, graphics, and data base interfaces.

Although not providing all the multipurpose functions of some of the commercially available geographic information systems (GISs), the in-house PMGRS will provide the basic function needed of providing color coded geographic maps of pavement information. It will be available on FDOT's primary computer network, on which many of the commercial GISs will not run. If the need arises, the PMGRS is portable to other computer systems because the SAS software system will also operate on mini- and microcomputers.

Besides a greatly reduced cost and greater control over the system, the mainframe-based PMGRS has additional advantages. It will require less training time because it uses computer systems with which pavement management personnel are already familiar. Also, existing SAS programs and algorithms are easily integrated into the PMGRS system and the powerful data analysis and user interface tools of the SAS system become part of the PMGRS. The mainframe FDOT corporate data also reside on the same computer system as the reporting system, which makes data access and updating much more straightforward. These factors also allow for quicker implementation of the PMGRS.

Pavement Management Office, Florida Department of Transportation, MS-32, 605 Suwannee Street, Tallahassee, Fla. 32301.

SYSTEM DESCRIPTION

Purpose

Like most departments of transportation, FDOT has an extensive data base of pavement information. In order to use this information, engineers have traditionally used bulky computer printouts and manually maintained charts called "straight-line diagrams" (SLDs). The printouts indicate the data values by roadway identification number and mileposts, and the SLDs provide a physical representation of roadway, so that the mileposts can be related spatially to physical features such as intersections.

The major purpose of the mapping portion of the PMGRS is to improve this process by rapidly providing color-coded maps to represent both the data values and their physical location in a single graphic. This allows the engineer to concentrate on analyzing the information provided, rather than spending a great deal of time deciphering computer codes and flipping through printouts and SLDs.

Providing information in a more usable format, along with other elements of the FDOT's pavement management system (PMS), will allow for more efficient expenditure of pavement funds. Florida has approximately 35,000 lane-mi of pavement on the FDOT-maintained system and spends millions of dollars annually on pavement rehabilitation. If a graphic reporting system can make even a small improvement in the efficiency of how pavement funds are used, it will pay for itself many times over.

Map Selection Capabilities

The initial version of the PMGRS allows the generation of maps containing information on pavement condition, traffic, and truck volumes, and on the resurfacing work program. Additional types of information that can be displayed are being added. The maps are selected through a series of user-friendly menus. The user selects the type of geographic area, the type of pavement-related information, and the time period desired for display. The available area selections include statewide, district, county, urban area, and roadway. Lists of county and urban area codes are provided on the selection menus from which the user may select. Figure 1 shows a county selection screen.

How Map Information is Displayed

Variable message titles provided on each map indicate the area and feature types and values selected for display. Because the standard IBM graphic terminals have the capability to display seven different colors, data values are represented by four or five colors with blue and white reserved for county boundaries and labels. Legends with color bars are provided at the bottom of each map to indicate the data ranges corresponding to each color.

For pavement condition information, red is used to indicate sections that are considered deficient and eligible for rehabilitation, with green representing sections in excellent condition. Pink and cyan (greenish-blue) are used to designate intermediate-condition pavements. This order of red, pink, cyan, and green is repeated for other information values so that the user can consistently relate the colors to an ordering of values. When five colors are needed, yellow is added as a middle-value range. Figure 2 shows an example of a county map that displays flexible pavement cracking ranges. (Cross-hatching patterns are substituted for colors in this example for clarity).

Annotations

Depending on the type of area selected for display, different text and symbol annotation to the map is provided to help explain the data and allow for more detailed selection. Because of the tremendous amount of information available regarding roadway sections, trade-offs must be made between displaying information needed in a readable size and not creating a cluttered graphic that is confusing or difficult to read.

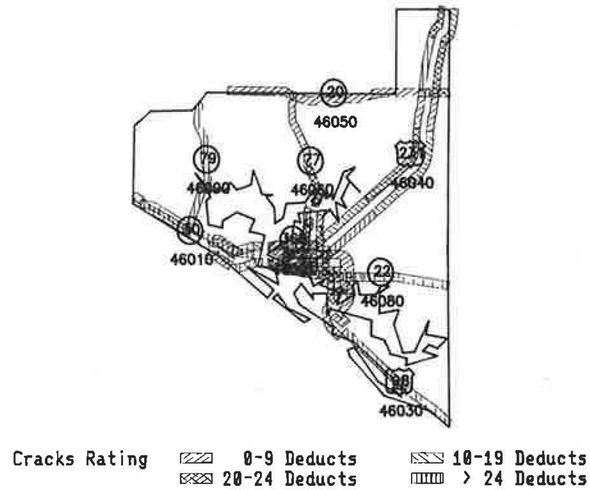

FIGURE 2 Flexible pavement cracking for Bay County, 1990.

At the district level, only county names and their FDOT code numbers are displayed as annotations on the map. At the county and urban area level, the county and section identification number for the roadway is displayed along with the road number and its jurisdictional symbol, such as an Interstate shield. At the roadway level, mileposts at information breaks are provided along with the road number.

These annotations are designed to provide enough information on one area map to allow a user to identify a next-lower-level area for a more detailed display. For instance, at the district map level, a county name (and number) of interest can be picked out for more detailed display at the county map level.

All the annotations are generated and placed by computer. In congested areas, some annotations fall on top of one another, which produces a screen that is difficult to read. To circumvent this problem, the annotations are processed through an algorithm to eliminate ones that would overlap.

Command ===>

ENTER FDOT COUNTY NUMBER: __ PRESS PF3 TO EXECUTE.

DIST	COUNTY	NO.	DIST	COUNTY	NO.	DIST	COUNTY	NO.	DIST	COUNTY	NO.
2	ALACHUA	26	5	FLAGLER	73	5	LAKE	11	7	PINELLAS	15
2	BAKER	27	3	FRANKLIN	49	1	LEE	12	1	POLK	16
3	BAY	46	3	GADSDEN	50	3	LEON	55	2	PUTNAM	76
2	BRADFORD	28	2	GILCHRIST	31	2	LEVY	34	2	ST. JOHNS	78
5	BREVARD	70	1	GLADES	05	3	LIBERTY	56	4	ST. LUCIE	94
5	BROWARD	86	3	GULF	51	2	MADISON	35	3	SANTA ROSA	58
3	CALHOUN	47	2	HAMILTON	32	1	MANATEE	13	1	SARASOTA	17
1	CHARLOTTE	01	1	HARDEE	06	5	MARION	36	5	SEMINOLE	77
5	CITRUS	02	1	HENDRY	07	4	MARTIN	89	5	SUMTER	18
2	CLAY	71	7	HERNANDO	08	6	MONROE	90	2	SUWANNEE	37
1	COLLIER	03	1	HIGHLANDS	09	2	NASSAU	74	2	TAYLOR	38
2	COLUMBIA	29	7	HILLSBOROUGH	10	3	OKALOOSA	57			
6	DADE	87	6	HOLMES	52	1	OKEECHOBEE	91	2	UNION	39
1	DESOTO	04	4	INDIAN RIVER	88	5	ORANGE	75	5	VOLUSIA	79
2	DIXIE	30	3	JACKSON	53	5	OSCEOLA	92	3	WAKULLA	59
2	DUVAL	72	3	JEFFERSON	54	4	PALM BEACH	93	3	WALTON	60
3	ESCAMBIA	48	2	LAFAYETTE	33	7	PASCO	14	3	WASHINGTON	61

FIGURE 1 FDOT county number entry.

Replay Options

After a map is displayed and terminated, the user is given a menu of options that include replaying a previously created map, selecting another area, or selecting another feature for the same area. Other options include printing the data values for the last selection or exiting back to other menus.

During a session, all graphics developed during the session are kept in a temporary graphics catalog. From a replay window to this catalog, the user has the option to replay, plot, or save to a permanent catalog any of the previously created graphics. At the end of the computer session, the temporary file is automatically deleted.

From the replay window, the user also has the option to display up to four selected graphics on the same screen, or to replay a zoomed portion of a graphic. Figure 3 shows an example of four graphics on one screen.

Other Reporting Options

In addition to producing maps, the reporting system also has the capability of printing the data values that are displayed on the maps or producing other reports, graphs, and pavement analysis. The initial system can produce a performance history graph for a selected project location back to 1976. Adding performance forecasts and life cycle cost analysis capabilities to the system is planned. These tools could then be used in pavement rehabilitation alternatives analysis.

SYSTEM ISSUES

Considerations

As part of FDOT's overall pavement management implementation plan, the evaluation of reporting systems was an important element. A subcommittee was appointed to review the available options and to make a recommendation for implementation. The key items considered in this evaluation were capabilities, costs, implementation time, training requirements, and data processing requirements.

Capabilities

The production of color-coded maps of pavement information was the primary capability desired for the system. However,

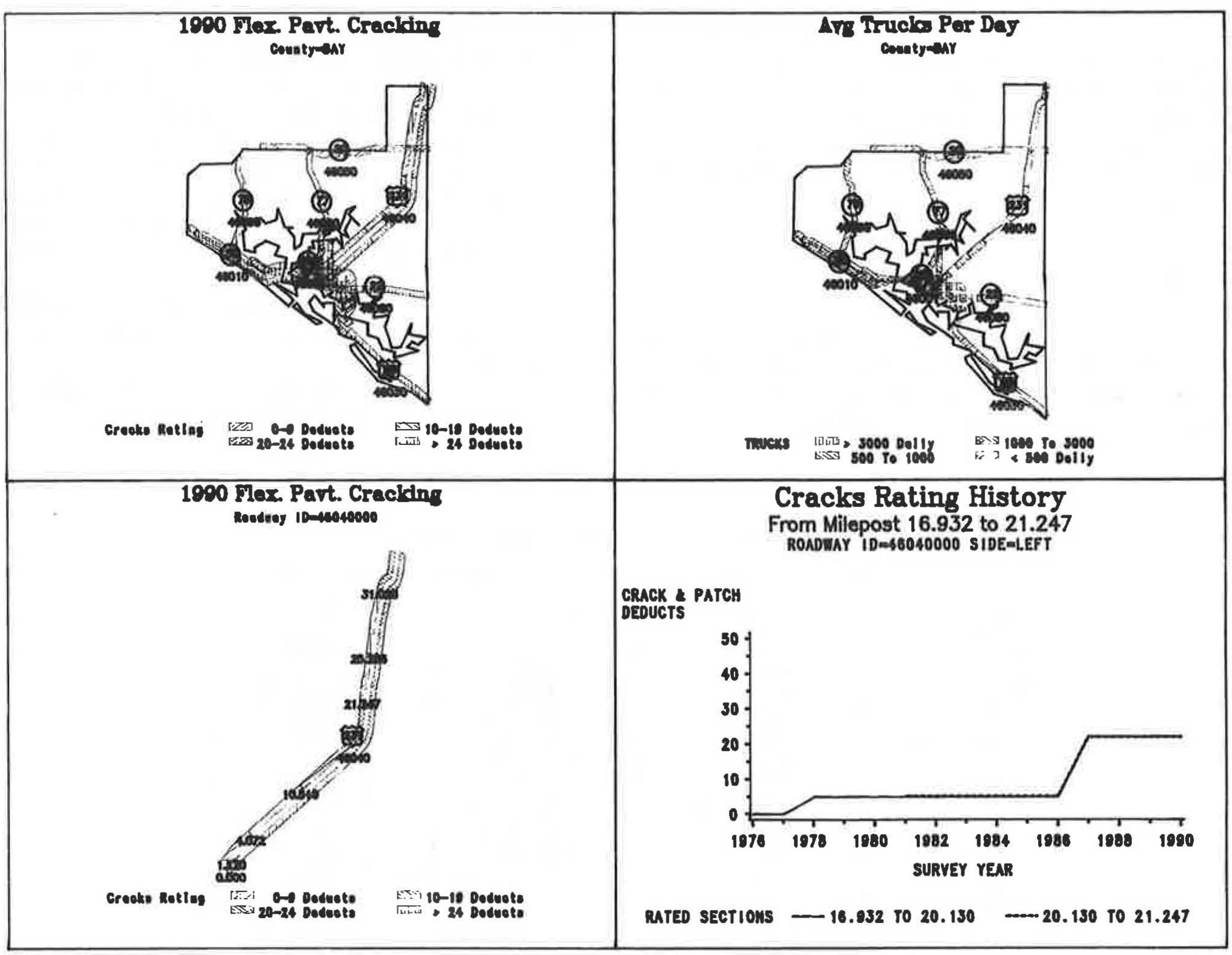

FIGURE 3 Single screen with four graphics.

the ability to produce reports and forecasts and to perform analysis in a user-friendly environment were also important. The color maps make an attractive display, but unless this information is turned into a cost-effective product, it accomplishes little.

Many of the capabilities available through multipurpose GISs were not considered necessary, or, in many cases, even applicable to a PMS. Because of other considerations, updating the FDOT's roadway data base directly through a GIS is not practical at this time. Therefore, to interactively click on and edit a data base file, a primary feature of a GIS, is not needed. Because only pavement-related data are being displayed and analyzed, capabilities to analyze area-type data such as land uses or property boundaries are also not needed. FDOT already has extensive computer-aided drafting and design (CADD) equipment. This equipment was used for digitizing and identifying the roadway base map, so the digitizing features of a GIS were also not a requirement.

There are some features of a multipurpose GIS that would be useful for pavement management reporting but are not currently available in the SAS-based system. These are the ability to turn different information levels on and off without leaving the basic map display and to click on sections of a road and display its attribute values. Another feature that is only partially available with SAS is the ability to window in for a closer view of a selected area, and to dynamically move along a roadway at the closer view.

Fortunately for the evaluation subcommittee, FDOT's Planning Office had recently completed an evaluation of commercial GISs for use in reporting transportation planning information. In support of this effort, the Planning Office was also in the process of digitizing the state's road system with CADD equipment for use by a GIS system. The commercial GIS selected by the Planning Office appeared to have the capability of producing the maps desired, and, with other software packages and data processing, could produce reports for pavement management.

In evaluating the commercial GIS for use by pavement management, a number of drawbacks were noted. These included high costs and the time and effort to implement it for pavement management. It was decided to also investigate the possibility of using existing SAS software on the IBM mainframe with in-house programming development as an alternative to the commercial GIS.

Costs

One of the biggest drawbacks to the commercial GIS for pavement management use was the cost to make it available to engineers throughout the department.

The hardware required by the commercial GIS included minicomputers in each district and intelligent workstations or a powerful personal computer for each user. There was also the possibility that a separate communications network might be needed to transmit data from the main data bases to each district minicomputer. Each minicomputer hardware and operating system was estimated to cost $60,000 and the workstations from $7,500 to $10,000 each, depending on the capabilities provided.

In contrast, the in-house system could make use of the existing IBM mainframe and communications network and over 160 existing IBM graphic terminals. In addition, approximately 500 existing personal computers that are networked to the IBM mainframe have graphic display capabilities. If needed, additional IBM graphic terminals currently cost $1,650 per terminal.

The GIS and related software had an estimated cost of $72,000 for each minicomputer and $17,500 for each workstation. In addition to the purchased software, extensive in-house software development would be required to transfer and maintain data from the IBM data base to the minicomputers and to develop menus, displays, and reports on the GIS workstations.

As mentioned previously, the SAS software system was already licensed by the FDOT for other purposes, so no additional purchased software cost was required for the PMGRS. The SAS products used by the PMGRS are base SAS, SAS/AF™, SAS/GRAPH™, and SAS/DB2™. The renewal licensing fees for these products for the FDOT's IBM 3090 model 400E mainframe computer will be $22,450 in 1991. A first-year license for a similar mainframe system would be $51,200. Licensing fees will vary by the size and type of the computer system, and include technical support from the SAS Institute. Training is available at additional cost. In-house software development of the PMGRS required approximately ¾ of a man-year by a professional engineer in the Pavement Management Office and ¼ of a man-year by an engineer in the Engineering Systems Section. Additional short-term technical support was provided by numerous individuals in the Information Systems Office.

A major cost and time constraint in implementing a geographic referencing system is the production of a digitized map with intelligence to it. The term "intelligence" refers to a map's ability to relate its x, y coordinates to external data referencing systems. As mentioned previously, this effort was already underway to support the GIS for planning purposes. Two additional design personnel were assigned to accelerate this process.

The digitized base map will be maintained by planning as roadway sections come on and off the state highway system. This base map will provide the same geographical data source both for the Planning Office's commercial GIS for planning information and for the SAS-based PMGRS for pavement management reporting. The availability of graphic reporting by both systems should make the identification of data base errors much easier. Through the reporting and correcting of these errors, much more reliable data should result.

Implementation time was also a major consideration. Because of funding constraints, it is uncertain when sufficient hardware will be available for pavement engineers in the districts to have ready access to a multipurpose GIS. Also, considerable software development and training for users and systems operators would be required for the multipurpose GIS.

Development of a prototype SAS PMGRS was begun in October 1989 and was demonstrated in December 1989. Full implementation of the system depended primarily on completion of the digitizing and editing of the base map, because the hardware and data bases were already in place. While the base map was being completed, additional fine tuning and enhancement of the prototype PMGRS was carried out. Initial, field (beta) testing of the PMGRS was begun in September 1990 with full implementation announced in December

1990. At that point, 97 percent of the digitized sections had passed the required quality control editing criteria.

Initial response from users on the PMGRS has been positive. Most requests from users have been to add additional feature information to the system. Other requests have been to add additional detail to the maps, such as displaying the entire road network when displaying project locations. Additional plotting capabilities have been requested, such as plotting to scale on an existing county map, or transferring a graphic map output file to a CADD system. Several other offices have expressed interest in adapting the SAS mapping technique to applications within their areas of responsibility.

The amount of training to develop, use, and maintain the reporting system was also considered. The hardware and operating system used by the Planning Office's GIS is the same as that used by the department's CADD system, so there is considerable experience with it available. However, IBM equipment is much more widely available in the department, and has been in use longer, particularly by pavement engineers, many of whom are not directly involved with the use of CADD equipment.

The software for the Planning Office's GIS is new to the Department, along with its database and report writing software. SAS has been in use by the department since the early 1980s and several engineers in the Pavement Management Office have had extensive experience with its use. Numerous programs to extract pavement data from the data bases, process this data, and produce reports and graphics have already been written. Many of these were easily incorporated into the PMGRS. A well-organized SAS users group is also active within the department to share techniques and applications from other offices and help train new users.

There are a number of application system modules of the FDOT's PMS that reside on the IBM mainframe in the form of application programs and data bases. The pavement condition survey, work program administration, and current-year traffic characteristics systems are presently accessed by the PMGRS. Other application systems that could potentially be integrated into the PMGRS are the integrated contracts and estimating system, construction quality reporting, roadway characteristics inventory, deflection data, skid hazard reporting, accident reporting, maintenance management, and traffic characteristics history and forecasts.

Because of their complexity, tieing these application systems together within one computer system is a difficult task. Adding additional operating systems and distributed processing to the picture, as would be required with the commercial GIS, makes this process all the more difficult. The SAS system provides good software tools for accessing data in a variety of forms. This capability makes reporting and correlating data from multiple systems much easier than with conventional programming languages.

Currently, a major difficulty in accessing these application systems at FDOT is that many of them use an IMS hierarchical data base. This data base system was developed by IBM in the early 1970s. Extracting data from multiple layers within the hierarchical data structures can be difficult, particularly when a large amount of interactive data updating is taking place. FDOT is getting around this problem by copying extracts of the IMS data over to IBM's new DB2 relational data base system. This data base is much easier to extract data from because of its relational qualities and not having as much contention with data update transactions. The PMGRS uses data from these DB2 extracts, rather than going directly against the IMS data bases.

METHODOLOGY

Map Development

A key element to the PMGRS is the digitized and identified (or tagged) roadway system base map. This map was produced over an 18-month period through a major effort by the department. U.S. Geological Survey (USGS) 7.5-min, 1:24,000-scale original mylar quadrangle sheets were used as the base medium for digitizing. Florida encompasses 1,038 of these sheets, which were purchased from the USGS at a cost of $65,000. Original mylars were used to avoid changes in size that can occur with paper maps because of humidity variations.

Before digitizing, Florida roadway section identification numbers and begin and ending points were manually annotated on paper copies of the quad sheets. This information was obtained from SLD records maintained by the Planning Office. Many nonstate system roads down to the major collector level were also annotated. A team of three to four engineers was used to digitize the quad sheets, with a similar number providing annotations, accuracy, and graphic quality control checks. Approximately 2 man-years of effort was required for the annotation process and an additional 2 man-years for the digitizing and editing. This effort was spread over an 18-month period, with other mapping projects interspersed during this period. Programming and systems support was also provided by the engineering systems data processing group for specialized graphic user commands, tagging, file processing, and translation and systems support.

Referencing Systems

Geographic information in Florida is referenced by the FDOT to its state plane coordinate system. Roadway pavement information is stored by roadway identification number, roadway side, and milepost. An effective graphic reporting system must accurately tie these two referencing systems together.

Because of the shape of Florida, the state is divided into three zones for its state plane coordinate mapping system. This allows for more accurate projections of the earth's curved surface to the two-dimensional map surfaces. As each quad sheet was digitized, its corners were tied down to the state plane coordinate system for its zone.

The digitized coordinates were then translated by computer programs to latitude and longitude values on the basis of the projection method used for each zone. The latitude and longitude values are then used by the SAS mapping procedures to easily produce a map on graphic computer terminals.

However, to indicate pavement information on the map, a relation between the roadway map coordinates and the roadway information referencing system must be made. This relation was defined during the digitizing process by identifying or tagging each roadway graphically to its FDOT roadway identification number. The digitized points for each roadway are stored sequentially from the roadway beginning point in one or more graphic line string elements. Several line strings are often needed when a roadway section crosses several quad sheets that are digitized separately. A graphic user command was written by the engineering systems group to place the tags in the graphic elements. They also wrote C programming language routines to sequentially connect multiple-line strings for the same roadway section and to convert the tagged-line string graphical elements into sequential files of latitudes and longitudes by roadway. Error checks were also built into these programs to detect and flag various digitizing errors.

Additional processing and error checking programs were written by the Pavement Management Office, in SAS, to process the sequential files of latitudes and longitudes. These programs first checked the overall direction of the digitized roadway against the direction listed in the mainframe data base and flagged those that differed. The begin and end mileposts for each section were also extracted from the data base. Starting with the beginning milepost obtained from the data base, a milepost was calculated for each digitized point using a trigonometric formula for the distance between points defined by latitudes and longitudes. These computed mileposts were then stored in a SAS data file for use by the PMGRS. The computed end milepost for each roadway was also compared to the end milepost from the data base to further identify digitizing, tagging, or data base errors.

Modular Design

A modular design was used for the PMGRS programs for more efficient testing, documentation, and modification of the system. The mapping modules can be broken down into three basic categories: data extraction, map processing, and map display. Many different types (or features) of data are available about FDOT roadways, each with different data base locations, descriptions, and value ranges. Locating these data and displaying them in a meaningful manner require separate modules for input and output of each feature. However, because each feature of data is tied to the same roadway and milepost referencing system and uses the same base map, the same map processing modules can be used for all features.

Data Extraction Techniques

As mentioned earlier, each feature requires a separate module to extract it from its data base location and to put it in a format for map processing. In addition to the many different features that can be displayed, there are also different types of geographic areas to select for display. Rather than create another set of submodules for each area type within each data extraction module, macro variables were used to customize the extraction modules. Macro variables are variables that can be assigned values through the user-interface menus and screens, and then substituted as code in designated places within other programs or modules. By using SELECT and CRITERIA macro variables, the same programming code can be used to select any type of area. For example, the macro code WHERE &SELECT = &CRITERIA can be used to create the statements WHERE COUNTY = '46' or WHERE DISTRICT = '3' by assigning different values to the macro variables.

An IBM mainframe relational data base and Structured Query Language (SQL) statements are used by the PMGRS to extract data that frequently change, such as the work program and roadway characteristics. These extracts are fairly efficient. For data that do not change frequently, such as the pavement condition survey, a SAS data set is used for even more efficiency.

Some types of information that are to be displayed require the merging of two or more data types. In order to merge or join two different data files requires a common key in both files. The FDOT stores its mileposts to the thousandths of a mile, which makes it difficult to merge different files using the milepost as a key. For example, a project's limits may be recorded only a few thousandths of a mile different from the condition survey limits so the logic to match the correct sections can get complicated when dealing with thousands of records. An SAS macro program developed by the Pavement Management Office to solve this problem has been incorporated into the PMGRS. The program searches all data files to be merged and stores, by roadway, all milepost breaks that are in either file. These breaks are then processed against the original data files to create new records in each file, so that each file has common milepost breaks for each roadway. The files can then be merged by roadway and milepost with an exact match of limits.

Map Processing and Dynamic Segmentation

After the roadway feature information has been extracted and placed in a standard generic format, it is passed to the map-processing modules. The generic format consists of feature records or observations that contain the roadway ID, roadway side, beginning milepost, ending milepost, and up to six feature values that pertain to that section. Each feature observation is assigned a unit number and is then processed against the base map file. Using an index or pointer file, each roadway ID is located in the map file, and the map observations containing the coordinates of the digitized line are sequentially searched to locate the feature begin and end milepost points. Because the digitized map points will often not fall exactly on the feature breaks, an interpolation routine is used to create new points at the feature limits. This process of locating varying length feature sections at run time is called dynamic segmentation.

The SAS mapping procedure that is used by the PMGRS is designed to indicate color-coded response values by unit areas rather than by lines such as roadways. In order to get around this problem, the line segment created for each feature observation is passed to another module that converts the line into a unit area. This is done by creating two points for each line point and offsetting them. The direction of offset is determined by the roadway side value; the amount of offset is determined as a percentage of the range of coordinate values to be displayed. SAS's statistical procedures are useful in quickly determining the range. Each unit area that is created is assigned the same unit number as its corresponding feature observation.

Annotation

As described before, annotations are added to the map depending on the type of area being displayed. The type of area is stored as a macro variable and used to determine the type of annotations needed. The only feature-dependent annotation that is used is the work program. In this case, the work program item number is indicated rather than the roadway ID. SAS statistical procedures are again used to determine the coordinates at which to place the annotations. A search algorithm locates and eliminates overlapping annotations.

Map Display

After the unit areas and annotations are created, they are passed through an SAS projection procedure that converts the latitude and longitude coordinates to screen coordinates for display.

At this point, the generic map processing modules are exited and the customized feature display module takes over. The feature type is also stored as a macro variable to facilitate branching to the appropriate feature display module. The titles, footnotes, and legends are customized in the feature display module and the feature value ranges for each display color are assigned. The SAS mapping procedure then automatically creates the legend boxes and determines the colors for each unit area on the basis of its feature values.

After the map is displayed, it is saved in a temporary graphics catalog. The user is then given a menu option to replay any of the graphics that have been created during the computer session. The replay window also allows the graphics to be copied into a permanent catalog. If the terminal has a plotter attached to it, a hard copy plot can be obtained. Multiple graphic displays on one screen or closer view zooms can be selected by the user. These are created by use of the SAS/GRAPH template facility. When the session is terminated, the temporary graphics catalog is deleted.

PERFORMANCE

Performance or the response time the user experiences is an important factor in the usefulness of any computer system. At the present time, the performance of the PMGRS is considered to be fair to good. The digitized base map consists of approximately 200,000 points on 3,800 roadway sections. Only part of these sections are on the state-maintained system, so the actual working file for the PMGRS has been reduced down to approximately 1,000 sections and 90,000 points. A line density reduction procedure in the SAS software also allows the use of fewer points as the area being displayed gets larger.

Performance can vary significantly depending on the mainframe computer operating system settings. Central Processing Unit (CPU) time utilization on the FDOT's IBM 3090 is typically running at 65 to 70 percent of capacity, but some performance limitations have been experienced because of disk access. A recent change in system temporary working file allocations caused response time to double when the SAS temporary files were written to disk rather than using virtual memory. The temporary file allocations within the programs were changed to avoid this problem.

The PMGRS maps can require from 10 to 100 sec of CPU time to generate, depending on the geographical area and feature selected. The actual clock time to generate a map varies 1 to 5 min, with most maps taking from 1 to 3 min. Once generated, a map can be replayed from a graphics catalog in a few seconds, with a few seconds' additional delay in remote locations ascribed to communications line transmission.

As CPU capacity on the mainframe is inevitably used up, response time will probably increase and other alternatives may be needed.

FUTURE DIRECTIONS

The first enhancement to the PMGRS will involve the conversion from SAS Version 5.18 to SAS Version 6.06, which has recently been released. The new version should provide some performance improvements and significant improvements in the user interface capabilities. Screens with user selection lists that can be clicked on with a mouse will be available, along with more screen control capabilities. These improvements will make the inclusion of additional roadway features and additional user options easier. SAS Version 6.06 will also operate on micro- and minicomputers similar to the way it does on the mainframe. This capability will allow the eventual partial distribution of processing of the PMGRS to microcomputers without changing the basic user interfaces. If CPU and response times become critical on the mainframe, using microcomputers for some of the map processing, with the mainframe acting as a file server, may become necessary.

Because the FDOT has adopted the roadway ID and milepost as its primary roadway data referencing system, other roadway features can be added to the PMGRS just by creating the data extraction and display modules. Also, because the map processing code is fairly compact, other offices not necessarily involved with pavements could develop their own menus and extraction and display modules, while using the same processing code and base map.

As commercial GISs become more refined and hardware becomes more available, FDOT may want to reconsider them for pavement management purposes. However, the SAS Institute is also developing additional mapping capabilities that are similar to the capabilities of a multipurpose GIS. This may be a more attractive route to follow.

CONCLUSION

FDOT's PMGRS is providing roadway information to pavement engineers in an easy-to-use format and in a cost-effective manner. Pavement management is much more than just a picture of what exists today. The PMGRS provides data analysis and reporting capabilities in addition to its graphic features. Providing these same features with a multipurpose GIS may be a complex, expensive, and time-consuming undertaking. IBM hardware and SAS software are already available in many agencies and their capabilities should not be overlooked.

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