Geographical Information System based Management Information System (GISMIS)

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ABSTRACT
Information technology tools are being used more frequently by transportation agencies all over the United States in an attempt to increase productivity. Especially, very large depository of documents such as, right of way (ROW) maps or plan files for each state road sections ever built and kept by these agencies constitute a major challenge in terms of their efficient processing and retrieval when needed. Thus, information technology based productivity tools appear to be natural solutions to efficiently deal with this kind of very large databases.

The solution proposed for the New Jersey Department of Transportation (NJDOT) is to digitize these documents, and keep them in a digital format, and then to develop a Geographical Information Systems (GIS) based Management Information System (GISMIS) application that ensures effective management and retrieval of requested documents from this very large scanned digital document database. This paper first describes the development efforts of GISMIS tool, and then presents overall application functionality from different perspectives of systems design and various GIS related aspects of the developed tool. Important issues such as integration of GeoMedia Professional with other software tools such as Modular GIS Environment (MGE), MS Access Databases, Visual Basic (VB), and a third party product Falcon/Document Management System (Falcon/DMS), and dynamic segmentation capability of the application are also discussed.
1. INTRODUCTION AND MOTIVATION

In the new era of Information Technology (IT), GIS-based IT solutions are becoming vital and almost indispensable for transportation agencies, because of their unmatched capability of storing, manipulating and displaying geographically referenced valuable information from various databases in a user-friendly manner. One of the most useful capabilities of GIS-based maps is their ability to present the selected information and characteristics in a location specific manner by making it very easy for the user to retrieve this information using his/her knowledge of the geographical characteristics of the area.

The main motivation behind the development of Geographical Information Systems (GIS) based Management Information System (GISMIS) application presented in this paper is to make use of these basic and powerful GIS capabilities by effectively integrating transportation related data sources for creating “accessible, reliable, useful and affordable” information presented in a simple yet innovative way to the end users. It is clear that the very large digital document database of right of way (ROW) maps and plan files generated for each state road sections ever built in New Jersey cannot be effectively maintained, managed and used on a day to day basis without an effective information technology tool similar to GISMIS just due to the huge size of these databases that contain documents from early 20th Century and the need to geographically reference these files to the current New Jersey road network. Moreover, it is important to give access to this database to large number of users with different needs and familiarity levels with these documents. Thus, GISMIS application is proposed and designed to produce an IT solution that can address these needs by:

- Bringing GIS-based New Jersey transportation network data into unified data management environment, which is capable of integrating various digital document databases in order to generate valuable and useful information for the end users.
- Employing visual and geographical analysis capabilities of GIS along with efficient implementation of various database operations such as automated data analysis, querying processing and presentation.
- Enabling a range of users with different requirements and capabilities to gain easy access to this very large digital document database of ROW maps and plan files in New Jersey,
- Integrating a powerful third party document management tool namely, Falcon/DMS, with various capabilities of GIS.

Major research contributions of this application can be summarized as follows:

- Main originality and usefulness of this application lie in the flexible dynamic segmentation capabilities implemented as part of our GIS tool, where the layers with representation levels and properties can be attached according to different information needs of the users. This capability did not exist as part of the standard MGE package. Thus, automatic processing of the link information for the creation of a new database that contains sub-divided link information, which can be a very time-consuming, and probably impossible task due to the very large size of GIS link databases. Thus, a function was developed by Rutgers researchers to automatically sub-divide all the links according to a specified length. Further details of this unique implementation are explained in section 3.3.
- Also, the enhanced network capabilities of the tool as displayed in figure 1, 2 and 3, integrated with the third party database management tool is another major novelty of this customized application that makes it unique among available document management tools. It is clear that the database management and visual representation is a trendy concept adopted by many researchers and developers currently, but the GISMIS application presented in this paper is unique due to its attempt to integrate various individual applications including, MGE, GeoMedia Professional, Falcon/DMS, standard database management tools such as MS Access and SQL and customized application
programs written in Visual Basic and MATLAB, to fulfill the overall functional requirements of a customized application. We thus believe that our tool represents a combined strength of all various capabilities of individual applications by efficiently integrating them.

2. BACKGROUND

It is important to first review various types of GIS-based IT solutions proposed for transportation related problems. Recently several researchers attempted to harness the power of GIS by incorporating it with various database applications. We can classify these recent research projects under three major categories

2.1 Planning Applications and GIS

From the standpoint of transportation agencies, there is an increasing demand for planning systems employing GIS. Dixon et al. (1) used GIS for the analysis of transportation needs in rural areas, and for the identification of potential implementation constraints early in the planning process. Distance traveled, acceleration, fuel consumption, engine performance and air pollutant emissions on a second-by-second basis are collected using this integrated GPS-GIS tool.

A new framework for the integration, analysis and visualization of urban traffic data within GIS was proposed in Claramunt et al. (2). This framework emphasizes the proactive interaction between a spatio-temporal database and various visualization levels along with the concept of dynamic phenomena of urban traffic data.

Finally, Choi et al. (3) presented an integrated transit-oriented travel demand-modeling procedure using GIS. The main goal of this work was to develop procedures and an algorithm to automatically generate both link and line data for transit demand modeling from the conventional street network data using spatial analysis and dynamic segmentation. The system architecture was presented with transit building algorithm fully incorporated into GIS analysis and database operations. In this specific application, GIS database resides on top of the street network, which includes route data for dynamic segmentation, and stop data for GIS analysis and transit data modeling.

2.2 Operational Applications and GIS

Several researchers developed integrated tools for improving the effectiveness of real-time transportation operations. These tools addressed various operational problems including, real-time incident management, logistics and transit operations.

Wide-Area Incident Management Support System (WAIMSS) developed at the Virginia Tech Center for Transportation Research by Ozbay et al. (4) employed blackboard architecture to support incident management operations by providing facilities for spatial and temporal data analysis, and mechanism for interaction between different responding agencies. WAIMSS had several functions including, Database Management, Knowledge Processing/Inferencing, Graphical and Procedural Programming, and User Interface. Software and tools chosen for the system to accomplish these functions were Arc/Info, Nexpert-Object, C and Open Interface Elements respectively.

Wide-area Incident Management System on the Internet (WIMSI) tool also developed by Ozbay et al. (5) presented a conceptual architecture of the Web-based decision support system developed for incident management. Symantec Café Java development package was used to develop the WIMSI prototype based on this proposed conceptual architecture. This prototype used ArcView
Internet Map Server for GIS function implementation. System architecture of the prototype as well as the implementation and development efforts were also described in this paper.

Smith et al. (6) presented an ArcView-based GIS system employed for the support of real-time analysis and data management needs of transit operations. This tool employed GPS/GIS/Internet Platform to manage utilities along highways used by Texas Department of Transportation (TxDOT) is discussed by Quiroga et al. (7). The management of utility data takes into consideration both utility and roadway network characteristics. The platform used spatial and geographic database models to represent utility facilities located within a highway ROW map.

In another recent paper, Mendoza et al. (8) discussed the GIS-based accident data management system for Mexican Federal Roads by the Mexican Institute of Transportation (IMT). The information management system for the portion of the Federal Road Network (FRN) within the state of Oaxaca was developed by integrating into ArcView a series of data such as state, including cartographic representation, classification and naming of the roads, traffic volume and composition, and information on accidents.

Ziliaskopoulas et al. (9) also provided very useful insights to the development of an Internet-based GIS that brings together spatio-temporal data, and various transportation planning and management models in a single efficient framework to be used by a range of transportation professionals of different backgrounds such as planners, engineers and operational staff. Visual Interactive System for Transportation Algorithms (VISTA) was introduced as a general client/server implementation framework. According to this framework implemented in Java programming language, the client is machine-independent, and user interface can be used on multiple platforms and across the Internet. As GIS runs on the user’s computer, it remotely submits requests to the server for execution.

2.3 Conceptual Developments for GIS

Few researchers tried to propose new conceptual approaches for the development of innovative GIS applications that are specifically tailored for handling transportation databases.

An iconic model, which employs a new methodology to facilitate spatial intersect queries from geographic shapes without the use of topological relationships was proposed by Sutton et al. (10). GIS can be a map linked to a data (a relational model), or data stored as mathematically tractable model (an object of iconic model). The proposed “dynamic location” method stores geometry as an object within a single database field in contrast to dynamic segmentation, which takes the first approach above. The paper presented advantages of dynamic location technique as a graphical model for spatial intersect in a linear referencing environment.

GIS requires an efficient data sharing and manipulation capabilities that require a common schema or data model flexible enough to handle needs of diverse users. As an attempt to improve GIS applications for transportation domain in this direction, an enterprise GIS-Transportation (GIS-T) data model, which defines relations among transportation data elements such as transportation features and their attributes, cartographic objects, linear referencing systems (LRS) objects, logical transportation network elements, was proposed by Dueker et al. (11). Approaches for new dynamic tracking or moving object class in GIS-T were also discussed in the same paper.

3. GISMIS SYSTEM OVERVIEW

From the brief review of recent work in the area of GIS for transportation applications, it is clear that GISMIS presents a unique solution for a unique problem that requires management, maintenance and access of large document databases that have to be arranged in such a way that the user can retrieve the required documents for specific geographic location.

Development of a custom application similar to GISMIS enables the creation of a unified platform for integrating several software tools and controls to provide capabilities that can respond to
all of the potential users’ needs. GISMIS design is in fact based on the unique needs of NJDOT professionals for utilizing several tools and databases in a single application. The key to the system is the effective access to data stored in several databases via GIS Mapping Window with full range of analysis capabilities offered by GeoMedia Professional. More importantly, the databases that contain ROW maps and plan files generated for each state road sections in New Jersey are currently managed and maintained using a third party product called Falcon/DMS. One of the most important tasks of GISMIS is the integration of GIS side of the application with this document viewing and management tool.

Figure 4 shows the basic logic of our application. When the user clicks the link on any highway shown on the GIS map, our application using the queries embedded in the VB program retrieves the link information from the GIS database including, mile post start, mile post end and route number, and then writes it on an ASCII file that is then accessed by Falcon. Once Falcon reads this information, it launches a special query to identify corresponding digital files from a released document vault, where each scanned document was added, and then indexed in the Web Server. A list of these file names are then shown in a different window to the end user who can go ahead and review each digitized ROW map or plan file by simply clicking on a name in that list.

3.1 Application Architecture
GISMIS application and its proposed functions were designed to help potential users access various databases through the desired GIS functionality. GeoMedia Professional is used as a software-development environment, and as the main desktop and a viewing and analysis tool. GeoMedia Professional which enabled us to integrate GIS data from different sources and in different formats into a single unified workspace environment presented in the form of a base map also allowed us to create customized queries on spatial and attribute data from various sources.

Originally GeoMedia Professional was going to be used as the only GIS platform to develop a customized application package in conjunction with the third party product. Due to new requirements of NJDOT for accessing ROW maps in a more efficient way, and to remedy inconsistencies that existed between the ROW maps and the existing NJDOT GIS map, dynamic segmentation was needed to narrow down the number of ROW maps identified by the search process. This was only possible if the links originally coded into NJDOT network were automatically modified to reflect the milepost information of ROW maps. In general, ROW maps cover distances much smaller that the original link lengths in the GIS database used by NJDOT. Dynamic segmentation technique was used to modify the active links as to reflect smaller lengths covered by ROW maps. Dynamic segmentation feature is not available in GeoMedia Professional; thus, it was decided to change the work plan to employ MGE and MicroStation, along with GeoMedia Professional, and modify the original NJDOT GIS map using dynamic segmentation feature available as part of these new tools.

In our application, MGE is used as the primary GIS platform. MGE is an environment highlighting the complete spectrum of spatial information capture, processing and management. MGE Basic Nucleus (MGNUC) is the platform and prerequisite front-end setup application for MGE. In our application, MGE and its applications are based on MicroStation, and it combines MicroStation graphics for mapping, and MS Access for database applications. MGE has a structure that allows the user to access common utilities including, software tools, graphic data and the database system in an efficient workflow. MGE Basic Administrator (MGAD) enables the developer to define the structure of the database. MGE Segment Manager (MGSM) data server provides the capabilities to display and to analyze data stored in distributed attribute tables in GeoMedia Professional. Open Database Connectivity (ODBC) integrates all the tools used in the application by creating interface to MS Access Databases and the MGSM project file. Due to its full compliance with ODBC standards, the system is supported
by the application-programming interface (API) for database access, and thus Standard Querying Language (SQL) can be used as its database access language.

GISMIS is seamlessly connected with Falcon/DMS, which is a general document management solution for the MicroStation CAD community. Falcon/DMS presents a comprehensive and flexible solution to provide advances in network technology. Falcon/DMS manages documents within the traditional client/server architecture by making fast and reliable transfer of data available to more users. Another product that was already installed, but partly used in the project was Falcon/SVP. Falcon/SVP includes tools for configuring and managing web-based Falcon implementation. Requiring only a Web browser, Falcon/SVP provides users with ‘view only’ access to documents by allowing them to enter criteria on a search form that, upon submission, produces a result of matching database records. The search results form is configured to pull key information from each document's record residing in the Web Server, and allows user to view the corresponding scanned documents through Falcon/DMS tool on a client machine (12).

GISMIS is developed inside a VB programming structure, because of VB’s ability to incorporate add-in technologies providing our application with a high performance and a scalable application. VB allows the co-existence of MGE and GeoMedia Professional in a single application. Software functionality and interfaces among VB, MGE, GeoMedia Professional, Falcon products and data files are shown in Figure 2. While VB controls the whole application, MGE ensures the integration of data files with GIS user interface application namely GeoMedia Professional, which displays the map to the users.

GISMIS application design integrating the whole application in data level and command level, and current application architecture are presented in Figures 3 and 4 respectively. As shown in Figure 4, any client running MS Operating System and GeoMedia Professional can use GISMIS application with full access to the document files and functionality of our application. Due to security reasons, outside users cannot be given access to the Web Server at NJDOT, thus the access is only limited to users within NJDOT.

3.2 Application Interface and Tool Functionality

Prior to the tool development, the project team sought out the information about the objects, properties and methods available in GeoMedia Professional. The customized button which is named and created as GeoMedia Command Wizard, and which visually stands for the GeoMedia Command itself initiates the complete process. GeoMedia Command encapsulates the programming code written in VB 5.0, and fires the complete application. As soon as the command is activated and map is displayed as in Figure 5, the application is ready for the user to select a link, and retrieve the associated information from the connected databases for that selected link.

The directory of the digital documents including ROW maps and plan files for the selected link is created by query, and resulting information is stored on an ASCII File, which bridges GIS and Falcon products. The FalconGeo custom module then processes this information read from the ASCII File, and presents a list of documents stored related to these mileposts as shown in Figure 6. Falcon/DMS then accomplishes the task of displaying the related documents similar to the one shown in Figure 7 stored in the Web Server associated with the link of interest.

The main focus of integration was to ensure the efficiency of the overall IT solution by effectively controlling the desired level of information in a reliable and affordable manner. User is provided by the capabilities of connecting to various databases, choosing his/her own level of detail, displaying it on a detailed highway map of New Jersey, manipulating data, and saving all the connections in a GeoWorkspace (.gws) file for his/her future work. User has the freedom to change and save legend properties in .gws file, and to control the display of the map window and map objects such as feature classes, images, query results and thematic displays.

GISMIS allows spatial querying and analysis capability to the users for selecting individual highways by simply clicking on the focus of interest on the map window with several interactive
tools. Features on the map (e.g., road segments, highways, and local roads) can be turned on or off. Standard functions such as pan and zoom capabilities allow navigation through the map. The user can also query the desired information through the query window. The extent of the map zooms directly to the selected set of information.

3.3 Dynamic Segmentation
One of the major problems with standard linear maps similar to the one provided by NJDOT for document management applications, standard highway links are most of the time too long, and the information, in this case number of documents, associated with each standard link can be beyond the needs of the user. Most of the time user is interested in a smaller portion of these links, but without using an additional GIS capability namely “Dynamic Segmentation”, it is not possible to subdivide these standard links into smaller links that will enable the user to better focus to his/her area of interest. GISMIS enhances the management of this information over a standard linear GIS network by taking advantage of this Dynamic Segmentation capability of MGE toolbox. An MGE tool, MGSM, accomplishes dynamic segmentation by eliminating manual operations required to break linear networks into smaller segments. Dynamic segmentation has the capability of displaying and analyzing any portion of a linear feature without modifying the base map. MGSM facilitates creating, validating and maintaining control network segmentation integrating map coordinates with LRS, where the spatial characteristics of a feature is described using positions along a linear network (13).

However, for performing dynamic segmentation process as required in this application, a new database was created by sub-dividing each link in equal length, which is specified as 0.5 mile by NJDOT. Unfortunately, MGE does not have an automated function readily available for the creation of this new database. However, automatic processing of the link information for the creation of a new database that contains sub-divided link information is a very important requirement to eliminate the manual manipulations that can be excessively time-consuming, and probably impossible to achieve due to the very large size of the New Jersey link database. Current NJ highway database includes 943 links, and for accomplishing dynamic segmentation 10491 sub-links in total had to be created using a MATLAB code written by Rutgers researchers by automatically sub-dividing all the links according to a specified length. MATLAB code developed as part of this project creates a new database that contains appropriate information for each sub-link. MATLAB code complies with the specifications of the database component of the main application. It also provides the flexibility to enhance the application by allowing NJDOT to modify the lengths of sub-links for their future needs, and thus creates different types of network solutions without making any changes to the rest of the application.

4. CONCLUSIONS AND FUTURE WORK
Without effective IT tools for analysis management and maintenance of available data, it is difficult to take advantage of the abundance of information that is available within an organization. It is important that organizations take advantage of recent advancements in data management, maintenance and the analysis of information by adopting customized tools such as GISMIS.

GISMIS is a powerful and highly useful application that allows end users to search and display their search results through a user-friendly GIS-based Graphical User Interface (GUI) that takes full advantage of the GIS capabilities for pinpointing otherwise difficult to locate documents, which reside in very large databases. Moreover, it is fully integrated with powerful document management tool Falcon/DMS, and adds to its capabilities by creating an added value to an already existing product. One of the most important improvements for future is the implementation of
GISMIS as an Internet-based application using a new product from the same Intergraph product family used in this project namely, GeoMedia WebMap, which will enable the research team to incorporate internet-based capabilities using already acquired familiarity and expertise. This web-based application would drastically increase the possibility of access to these important databases by users outside the DOT. However, a web-based application that enables access to critical documents cannot become operational unless many other important issues regarding security and control of access are adequately addressed.
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FIGURE 1 Overall Framework of GISMIS

PROCESS
Information is written in an output (ASCII flat) file, each time a link is clicked. Data are overwritten each time, thus preparing ASCII files for the last link clicked on.

OUTPUT
ASCII Files contain the directory structures of scanned documents

Falcon
Information about directory structures are retrieved from ASCII Files for Falcon Application processing

Mile Post Start
Mile Post End
Route Number
Information for a specific link
FIGURE 2 Interfaces between different software tools for the integration of a single application
FIGURE 3 GISMIS Application Design

GISMIS APPLICATION INTERFACE

GeoMedia Professional

MGE

Falcon/DMS

INFO

Web Server

VB

INFO

Web Server

FIGURE 3 GISMIS Application Design
Web Server at NJDOT
- Falcon/SVP Web Module
- Html Template Files
- Released Document Vault for storing the scanned engineering document
- Microsoft Access
- MicroStation
- MGE

Client Machines at NJDOT
- GeoMedia Professional
- MS Windows 95/98/NT/2000

FIGURE 4 Current Application Architecture
FIGURE 5 Initialization of Application
FIGURE 6 User Interface that presents list of documents stored in Falcon/DMS related to the mileposts of the selected link
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