MULTIMEDIA GIS: ANALYSIS AND VISUALIZATION OF SPATIAL AND TEMPORAL GEOGRAPHIC INFORMATION

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ABSTRACT

This paper discussed the concepts and development of a multimedia geographic information system (GIS) for analyzing and visualizing both spatial and temporal geographic information in image/vector format as well as multimedia information in descriptive text, graphics, ground photographs and digital video clips. The multimedia GIS presents a new way to analyze and visualize geographic information in various formats for environmental change analysis.

1 INTRODUCTION

Geographic information system (GIS) technology has been employed as an analytical tool for the capture, storage, retrieval, analysis and display of geographic features tied to a common geographic coordinate system. Within the framework of GIS, data are logically divided into two categories: spatial (geometric) data and attribute (non-spatial) data. The range of spatial data types currently used in most GIS is largely dictated by the data models they implement, namely vector and raster (Burrough, 1986). In a vector data model, cartographic representations (i.e., points, lines and polygons) are used and the relationships among different features are maintained by spatial topology in a GIS. In the raster data model, a grid-cell or pixel representation is used. Remotely sensed data such as satellite imagery and scanned aerial photographs are typical examples of raster data. These conventional vector and raster representations of geographical features in GIS focus on database management, query and spatial analysis (Rhind 1990).

Attribute data, on the other hand, are the characteristics about the geographic features, and commonly they are stored in alphanumeric format. In both vector and raster data presentations, links are established between attribute information and spatial features. In the typical vector data model, the relational database management system (RDBMS) is most favorably incorporated for manipulation of feature attribute information. Links are established by arranging unique identifiers (or Ids) for each spatial feature (or IDs) to be recorded in the key fields of the appropriate database table(s) employed to store the attribute information. Data can be retrieved and associations developed based on the identifiers. By allowing links between spatial and attribute databases, a series of operations such as search, overlay, and select can be performed. Today, using GIS, land managers, planners, resource managers, engineers and many others can use geographic data more efficiently than ever before to simulate the effects of management alternatives.

However, information integration, essentially conditioned by current GIS software capabilities, has two major implications.

- First, current GIS generally ignores data sets in other non-structured formats such as text describing a geographic region, graphics, ground photographs, environmental sound, video, animation, etc.

- Second, current GIS lacks of the ability to process temporal geographic information demonstrating environmental changes.

In the last fifteen years, there has been increasing interest in utilizing multimedia information in a spatial information system or a GIS. For example, the Domesday project in BBC has been regarded as the pioneer to link text, ground photographs and maps in a spatial information system (Openshaw and Monnsey 1987; Rhind et al 1988). Developed in the 1980s, Domesday databases incorporated Ordance Survey topographic maps of the United Kingdom at scales of between 1:625,000 and 1:10,000, 250,000 place names, 54,000 photographs and 30 million words of text. The user is able to search for a map or map locations by entering a place name, or by panning across a seamless map of the United Kingdom. When an appropriate map is found, the user might then display ground photographs and text describing the area covered by the map. A research team at Massachusetts Institute Technology (MIT) conducted a collaborative planning system (CPS) for the metropolitan area of Washington D.C. relying upon maps, aerial photographs, ground photographs, video clips and sound (Shiffer and Wiggins 1993). The CPS displays maps such as GIS coverages, databases and images with various overlays linked to descriptive video images, sounds, bar graphs and text, and supports land use analysis and automobile traffic analysis. These projects have demonstrated that the integration of text, photographs, video and maps in a spatial information system is highly effective for representing and visualizing geographic information in very details. Shiffer (1993) claimed that multiple representations of a spatial problem enabled the investigator to make use of the information in different contexts thus offering the potential to generate alternative approaches to solve the problem.

The recent development of Windows system, multimedia, hypermedia, World Wide Web (WWW) and Internet technologies, and system standardization activities, such as Open GIS consortium, Open Doc and Windows functionalities (i.e., Object Linking and Embedding OLE 2.0), Component Object Model (COM), and Common Object Request Broker Architecture (CORBA), has provided new insights and techniques to integrate information in multiple formats in a coherent GIS environment, namely multimedia GIS, for the analysis and visualization of spatial and temporal geographical information.

This paper thus discusses: (1) the concepts of a multimedia GIS; (2) the development of an operational multimedia GIS; and (3) the application of the multimedia GIS in environmental change analysis.

2 CONCEPTS OF A MULTIMEDIA GIS

The term “multimedia” in the 1970s meant a sound track synchronized to one or more slide projectors and an automatically advancing collection of slides (Olson 1997). Today, multimedia implies the use of a personal computer (PC) with information presented through the following media: 1) text (descriptive text, narrative and labels); 2) graphics (drawings, diagrams, charts, snapshots or photographs); 3) digital video (television-style material in digital format); 4) digital audio sound (music and oral narration); and 5) computer animation (changing maps, objects and images) (Bill 1994). Multimedia technology has been extensively utilized by commercial encyclopedia CD-ROMs such as Microsoft Encyclopedia CD-ROM to provide a multi-sensory learning environment and the opportunity to improve the understanding of a concept. Although the interactivity is not the essence of multimedia system, it is, however, the feature of a hypertext system. The essential feature of a hypertext system is the concept of hypertext (nodes or concepts) and hyperlinks (relationships) (Nielson 1990). In other word, hypertext represents a single concept or idea and is connected to other information by activating pre-defined hyperlinks. Interactive multimedia combines the ideas from both multimedia and hypertext system. It utilizes multimedia information in various formats and features interactivity and non-linear information retrieval (i.e., forward, backward, and cross-referencing).

Geographic information system is a computer-based information system for the capture, storage, retrieval, analysis and display of geographic information tied to a common geographic coordinate system. Therefore, it is a logic step forward to integrate multimedia technology with a GIS. The integration of multimedia and GIS, or multimedia GIS, will combine the strength from both technologies and provide more useful tools for the capture, storage, retrieve, analysis and display of spatial, temporal and multimedia geographic information.

3 THE DEVELOPMENT OF AN OPERATIONAL MULTIMEDIA GIS

The following sections utilize the Wisconsin Winnebago Upper Pool Lakes Sensitive Shoreline project as settings to explain the development of an operational multimedia GIS.

Located in the east central Wisconsin, Winnebago Upper Pool Lakes include Lake Poygan, Lake Winneconne, and Lake Butte des Morts. The objectives of Sensitive Shoreline project were: 1) to develop a GIS database showing the sizes and distribution of wetland habitat through the combination of digital image processing, GIS, global positioning system (GPS), and field survey; 2) to assess wetland dynamic change through the analysis of historical aerial photos and derived GIS database; and 3) to develop an interactive multimedia approach to access spatial and temporal data sets in image/vector as well as multimedia information in text, graphics, ground photographs, and digital video about the physical, chemical and biological characteristics of the wetland habitat.

Two primary sources of information were used in identifying the wetlands on the Winnebago Upper Pool Lakes and in constructing a GIS wetland database: black-and-white aerial photographs and information derived from field surveys. Black-and-white aerial photographs are primarily from the late 1930s through the early 1990s, ranging from 1:10,000 to 1:12,000 scales. Aerial photographs recorded in 1937, 1957, 1981 and 1992 respectively in the region were scanned and geographically registered using the ground control points (GCPs) obtained from a global positioning system (GPS) survey. Vegetation polygons were delineated on the digital images and attributes assigned based upon the information obtained from the field survey. Field survey was conducted in the summer (June-August) of 2000 when the identification of both upland and aquatic vegetation is easiest. Following initial, field reconnaissance survey along approximately 150 km shoreline of the Winnebago Upper Pool Lakes, forty-five (45) wetland sites were identified. Based upon their physical nature and locations of adjacent rivers or creeks, these wetland sites can be grouped into five distinct types of wetland habitats: offshore wetland complex, exposed and cattail-dominated marsh, protected and mixed macrophyte marsh, delta marsh, and small river mouth (non-delta) marsh. A vegetation classification scheme containing seven classes was created to develop a digital vegetation database for each site. As a result, a GIS spatial database in image/vector format was generated for all wetland sites, and ready for analyzing wetland habitats and studying wetland dynamic changes.

The multimedia GIS for the sensitive shoreline project was based upon interactions between the following components: 1) a GIS application module developed using Microsoft Visual Basic and Environmental Systems Research Institute (ESRI) MapObjects software to manipulate spatial data such as geo-referenced images and ESRI Arcview shapefiles of vegetation patterns, 2) an interactive multimedia system created in a Visual Basic designed to manipulate multimedia information such as hypertext, hyperlinks, scanned ground photographs, and digital video; and 3) a graphical user interface through the Microsoft Windows NT operating system. All three components were developed in a coherent programming environment running on a Compaq computer with 233 MHz microprocessor, 64 megabytes (MB) random access memory (RAM), and Windows NT operating system.

4 THE APPLICATION OF THE MULTIMEDIA GIS IN ENVIRONMENTAL CHANGE ANALSYSIS

The multimedia GIS case study for the sensitive shoreline project provides many functions that allow the user to manipulate and display images and digital maps, retrieve attribute information from existing GIS database, and visualize graphics in pie, line or bar graphs, text information in PDF format, as well as digital video clips.

For example, the multimedia GIS provides the correspondent manipulation of the digital images of 1937, 1957, 1981, and 1992. The user can select "Aerial Photos" from the menu bar, then select a site name from wetland site list for the study area, the aerial photographs of 1937, 1957, 1981 and 1992 will be displayed in four separate map windows (Plate 1). By zooming and panning into one area in one of the four map windows, the other three will correspondingly display the same area with the same map scale. This provides the user an instant view showing where the wetland changes occurred over time.

Another example is the correspondent manipulation of the digital images of 1937 and 1992, and derived 1937 and 1992 GIS database for each site. The user can select "Digital Maps" from the menu bar, then select a site name from the wetland site list, the aerial photographs of 1937 and 1992 and corresponding GIS digital maps will be displayed in four separate map windows (Plate 2). In the same manner, by zooming and panning into one area in one of the four map windows, the other three will correspondingly display the same area with the same map scale. Furthermore, the user can select the "Label" icon, click on any polygon on a digital map, and the vegetation class assigned for that polygon will be displayed on the screen. The user is also able to retrieve the attribute information (i.e., area, perimeter, vegetation class) directly from the attribute table stored in the GIS database by first zooming into an area on the digital map, then selecting the "Identify" icon from the tool bar and clicking on any polygon. The selected polygon will then flash three times, and its attribute information will be displayed in an "Identify Results" window.

The multimedia GIS also provides the link of each wetland site to the ecological characteristics of two representative sites. When the digital images and maps of 1937 and 1992 for a site are displayed, the two representative sites will be automatically selected. The user is then able to select "Representative Sites" from the menu bar and then select one of the sites. The user will be directed to view a separate window showing a few buttons with the captions such as "Bathymetry", "Sedimentation", "Fish", "Vegetation", "Dissolved oxygen", and "Clarity", to name just a few. By clicking each button, the user can view line, pie or bar graphs highlighting the physical, chemical and biological characteristics of that representative site. In addition, the user can select "Ground Photos" from the menu, and then a site name. A color photograph for that site will be displayed in a picture window. Similarly, the user can select "Video" from the menu bar, and then a digital video clip to view a television-style movie recorded from the field. More than ten (10) video clips were included as part of the database for the Sensitive Shoreline project.

5 SUMMARY AND CONCLUSIONS

This paper presented an innovative method to integrate GIS and multimedia technologies. Specifically, the concepts of a multimedia GIS were discussed and an operational multimedia GIS for the Wisconsin Winnebago Upper Pool lakes Sensitive Shoreline project developed as a case study. This prototype multimedia GIS proved the efficiency for integrating, analyzing and presenting spatial, temporal and multimedia geographic information. From the user's perspective, a multimedia GIS can provide a multi-sensory learning environment with multiple data formats (spatial data in image/vector format, attribute data in alphanumeric format, and multimedia data in the form of text, graphics, photographs, and digital video). Practically, resource managers who are not familiar with GIS concepts or technology can easily access to the multiple databases within a spatial framework, and perform interactive database query and spatial data retrieval. As a result, the multimedia GIS makes possible truly interactive collaborations among resources managers, policy makers, researchers, stakeholders, and the general public in natural resources management and planning.

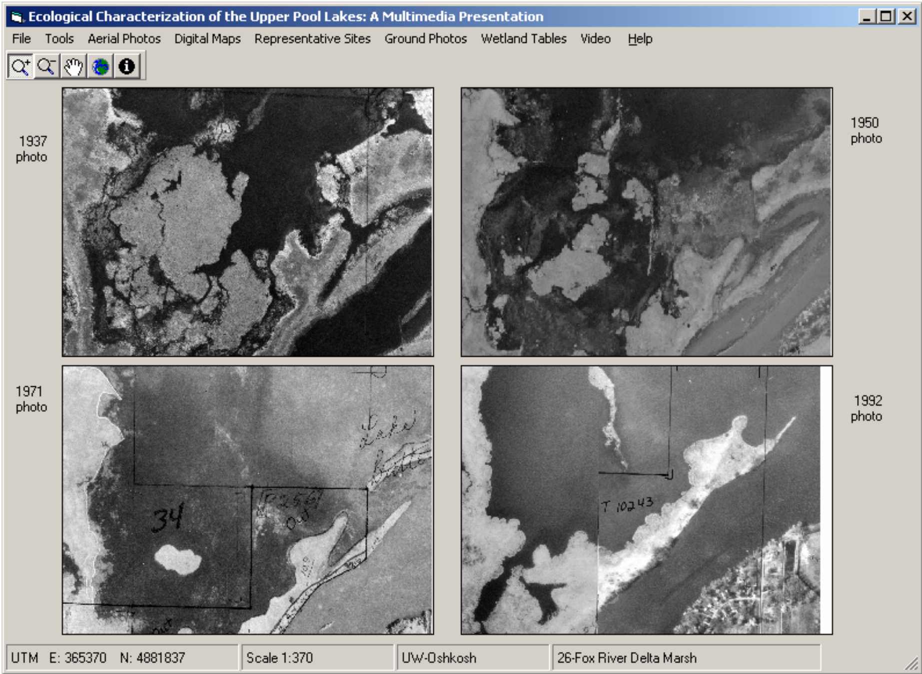

Plate 1. Graphical user interface for the Winnebago Pool Lakes Sensitive Shoreline project multimedia GIS database. Geo-referenced images of 1937, 1950, 1971 and 1992 for Fox River Delta Marsh are displayed in four separate map windows.

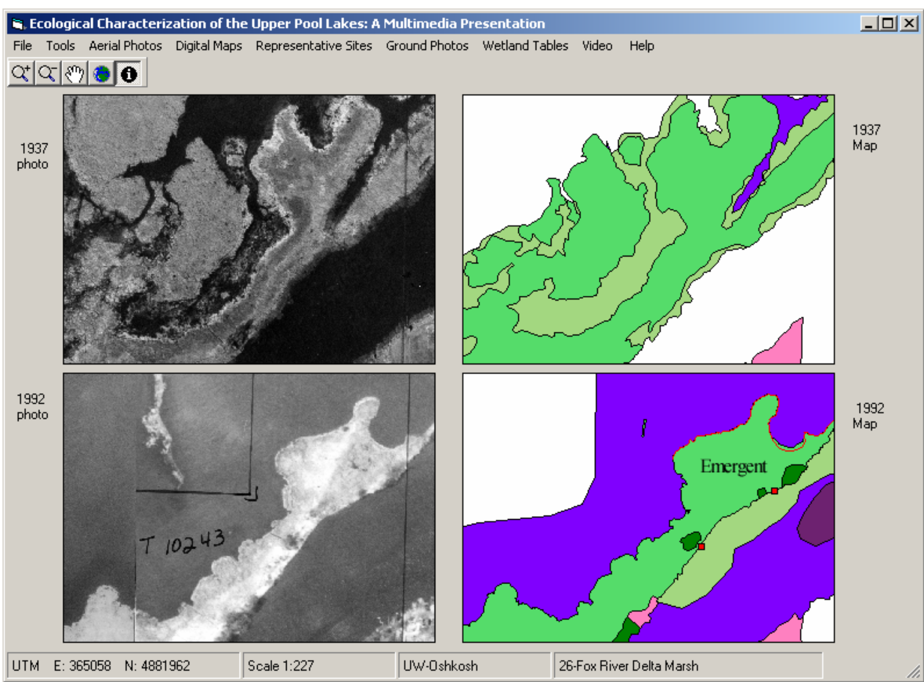

Plate 2. Geo-referenced images of 1937 and 1992 for Fox River Delta Marsh and their corresponding digital maps are displayed in four separate map windows.

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