Multi-media GIS: Analysis and Visualization of Spatio-Temporal and Multimedia Geographic Information

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Abstract

The advancement of computer technology enables the integration of GIS and multimedia technologies, called multimedia GIS, that allows to incorporate not only spatio-temporal geographic information in image/vector format, but also multimedia geographic information in descriptive text, scanned ground photographs, graphics, digital sound and video. This paper presents the concept and components of a multimedia GIS, and the benefits of using multimedia GIS. Two case studies of multimedia GIS applications for the integration, analysis and visualization of the spatio-temporal GIS database and multimedia information are demonstrated.

I. INTRODUCTION

Geographic information system (GIS) technology has been employed for several decades as an analytical tool for the capture, storage, analysis and display of geographic features tied to a common geographic coordinate system (Burrough, 1986; Star and Estes, 1990; Clarke, 1995). Within the framework of GIS, data are logically divided into two categories: spatial (geometric) data and attribute (characteristics) 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. 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. 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. In a typical vector data model, attribute information is stored separately with the spatial data in alphanumeric format. Thus, links between the spatial data and attribute data are required and established by employing a relational database management system (RDBMS). This is done by arranging a unique identifier (ID) for each spatial feature to be recorded in the key fields of the appropriate database table(s) employed to store the attribute information. Consequently, attributes can be retrieved and associations developed based on the identifiers. By the links between spatial and attribute databases, spatial analyses such as search, overlay, and select can be performed. Today, using GIS, resource managers, planner, engineers and many others can use geographic data more efficiently to simulate the effects of management alternatives.

However, information integration, essentially conditioned by current GIS software capabilities has two major deficiencies. First, current GIS generally ignores data sets in other non-structured formats such as text describing a geographic region, graphics, ground photographs, environmental sound and video. Second, current GIS lacks of the ability to provide interactive tools for the analysis and visualization of spatio-temporal geographic information demonstrating environmental changes.

The recent development of Windows system, multimedia, hypermedia, and system standardization activities, such as Object Linking and Embedding (OLE), and Component Object Model (COM), has provided new insights and techniques to integrate information in multiple formats in a coherent GIS environment for the analysis and visualization of spatio-temporal and multimedia geographic information. The objective of this research is to develop integrated multimedia-GIS approach that (1) is interfaced with a GIS for the analysis and visualization of spatio-temporal geographic information; (2) permits the combination of GIS database with descriptive text, scanned ground photographs, digital video and sound; and (3) allows the user to access both spatial-temporal database and associated multimedia information via a personal computer.

This paper is organized as follows. The next section presents the concept of multimedia and current use of multimedia in spatial information systems. This is followed by the development of a multimedia GIS, and the demonstration of two case studies. The last two sections describe the benefits of multimedia GIS applications and conclusions on the development of the multimedia GIS.

II. CONCEPT OF MULTIMEDIA AND CURRENT USE OF MULTIMEDIA IN SPATIAL INFORMATION SYSTEMS

The term "multimedia" in the 1970s meant a sound track synchronized to one or more slide projectors and an

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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.

Multimedia technology requires the use of additional specialized hardware, software and programming techniques. The hardware elements include PC with multimedia capability, stereo speakers, and a high- resolution color monitor. The typical components of a PC with multimedia capability nowadays include Pentium processor with 2.4 GHz speed, 256 MB random access memory (RAM), 32x CD-ROM drive, and stereo sound card. Other peripherals may include a color scanner, an analog-to-digital digitizer for converting analog video and audio, a video camera/VCR, and a CD-writer. Software and specialized programming techniques, which are useful to develop creative multimedia products, include the Windows operating system and multimedia authoring tools such as Macromedia Director, and Microsoft Visual basic, to name just a few.

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; Shepperd, 1991). 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. Alternatively, users can search for textual information by entering keywords, and associated photographs and maps are then retrieved and displayed by the system. The Domesday project demonstrated that the integration of text, photographs and maps is highly effective for representing and conveying geographic information in very details to the public.

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. 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. Another similar product was the "Great Cities of Europe project", a multimedia database about European cities. The database included cartographic data, images, text, slides, video and sound, representing relevant urban planning information including the structure, developments, problems and planning policies (Polydorides, 1993).

In the early 90s, researchers proposed a new term called hypermap or hyperimage (Laurini and Milleret, 1990). Defined by Wallin (1990), a hypermap allowed multimedia information to be linked to the spatial objects such as roads and buildings, providing built-in hotspots inside map or aerial photographs displayed on the computer screen. When the user moved the cursor on the map or aerial photograph, the shape of the cursor would change if links to the descriptive text, photographs, digital video or audio sound were available. "The Covent Graden Hypermap" and "Explore the Grand Canyon" were examples of such products using the concept of hypermap (Parson, 1992; Jarol and Potts, 1995).

The Wisconsin Department of Transportation of the United States in the early 1970's collected roadway information by photographing the state's highways with 35 mm film. Using roadway photographs, the agency's traffic engineers created a spatial database linking accident data to crash sites, developed sign inventories and collected highway geometry (Hughes, 1996).

Other research linking multimedia to a spatial information system included those such as in water resources (Fonseca et al., 1994), in the geomorphological studies (Raper, 1991), in the development of GIS databases (Polydorides, 1993) and use of video and sound (Vining and Orland, 1989; Vleck, 1989; Cassetari and Parsons, 1993; Fonseca et al., 1993; McComb, 1994; Sullivan et al., 1995), and in the archaeological applications (Snow, 1997; Spikins, 1997).

Although current commercial GIS software such as ESRI's ArcView allow linking spatial features to ground pictures, hypertext documents, or even video clips, the use of the final product requires the user to have a copy of ArcView software installed in order to run the application program. Other than that, from the work undertaken in the development of the multimedia GIS application programs in two different programming environments: 1) ArcView; and 2) MapObjects, respectively, it has been found that the MapObjects application has several advantages over the ArcView application. For example, MapObjects, as a standard component software, provides more flexibility to work with raster/vector data and other data such as text, photograph, digital video and sound. Also, the MapObjects application is a standalone program which, along with all supporting system files, and data sets, can be stored on a CD-ROM and distributed to all interested users. With minimum requirements of hardware and software, the user is able to run the program in a user-friendly environment. By contrast, the ArcView application requires the end user to have a compatible ESRI ArcView software package. Finally, the integration of the MapObjects application with the interactive multimedia system is much easier to accomplish because the MapObjects application and the interactive multimedia system were developed in the same programming environment – Visual Basic.

III. DEVELOPMENT OF A MULTIMEDIA-GIS AND CASE STUDIES

Geographic information system has been recognized as a computer-based information system for the capture, storage, 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 could provide more useful tools for the analysis and display of spatial, temporal and multimedia geographic information (Figure 1). Therefore, a multimedia GIS can be defined as a computer-based information system for the storage, analysis and visualization of spatio-temporal and multimedia geographic information.

The integrated multimedia-GIS approach is 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 sets such as ESRI ARC/INFO coverages, ArcView shapefiles, and georeferenced remotely sensed data; 2) an interactive multimedia system created in a Visual Basic programming environment designed to manipulate multimedia information such as hypertext, hyperlinks, scanned photographs, digital video, sound and animation; and 3) a graphical user interface through the Microsoft Windows operating system. All three components are developed in a coherent programming environment – Microsoft Visual Basic.

Case study one: to link spatial features with multimedia information

The first case study demonstrated the linkage between spatial features with multimedia information. Figure 2 shows an integrated multimedia-GIS approach for the analysis and visualization of Everglades vegetation database that includes detailed digital vegetation maps and multimedia information highlighting the characteristics of flora and fauna of the Florida Everglades (Hu, 1999).

The multimedia GIS application presented above provides a unique way to represent geographic features in a spatial framework using a combination of spatial data in image/vector format; attribute data in alphanumeric format; and multimedia data in descriptive text, photograph, digital video, and sound formats. Consequently, the development of a GIS database for natural resource management does not need to be limited to the current data models (i.e., raster and vector data models), but also can incorporate multiple formats of information.

Case study two: to manipulate spatio-temporal geographical information as well as multimedia information

Between 2000 and 2003, the author and two other investigators worked with the Wisconsin Department of Natural Resources (DNR) to construct a GIS database of wetland habitats and associated detailed vegetation maps for the Winnebago Upper Pool Lakes, including Lakes Butte des Morts, Winneconne,

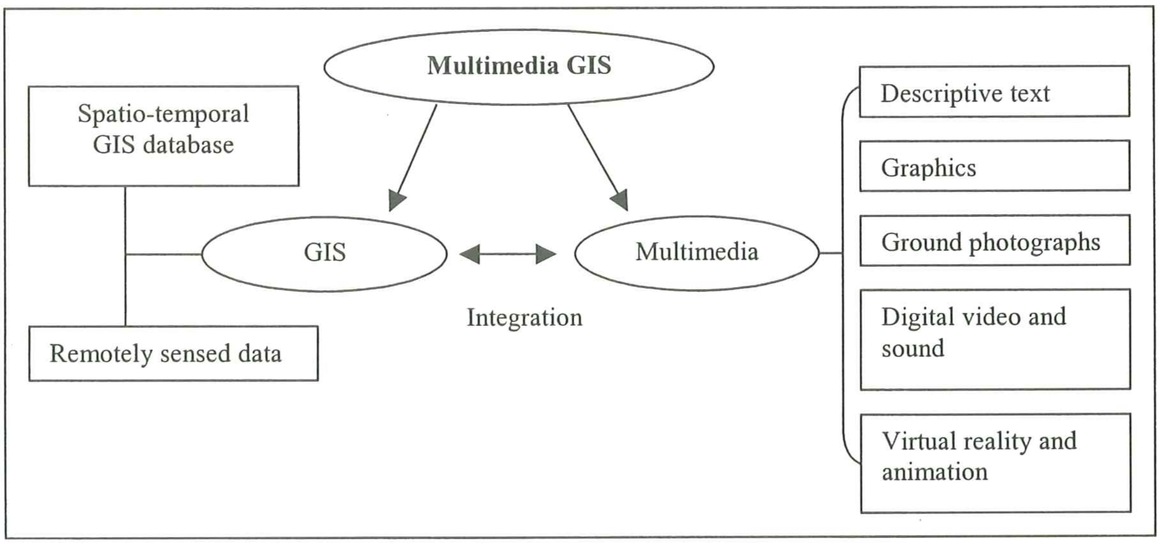

Figure 1. Concept of a multimedia GIS: integration of GIS and multimedia technologies

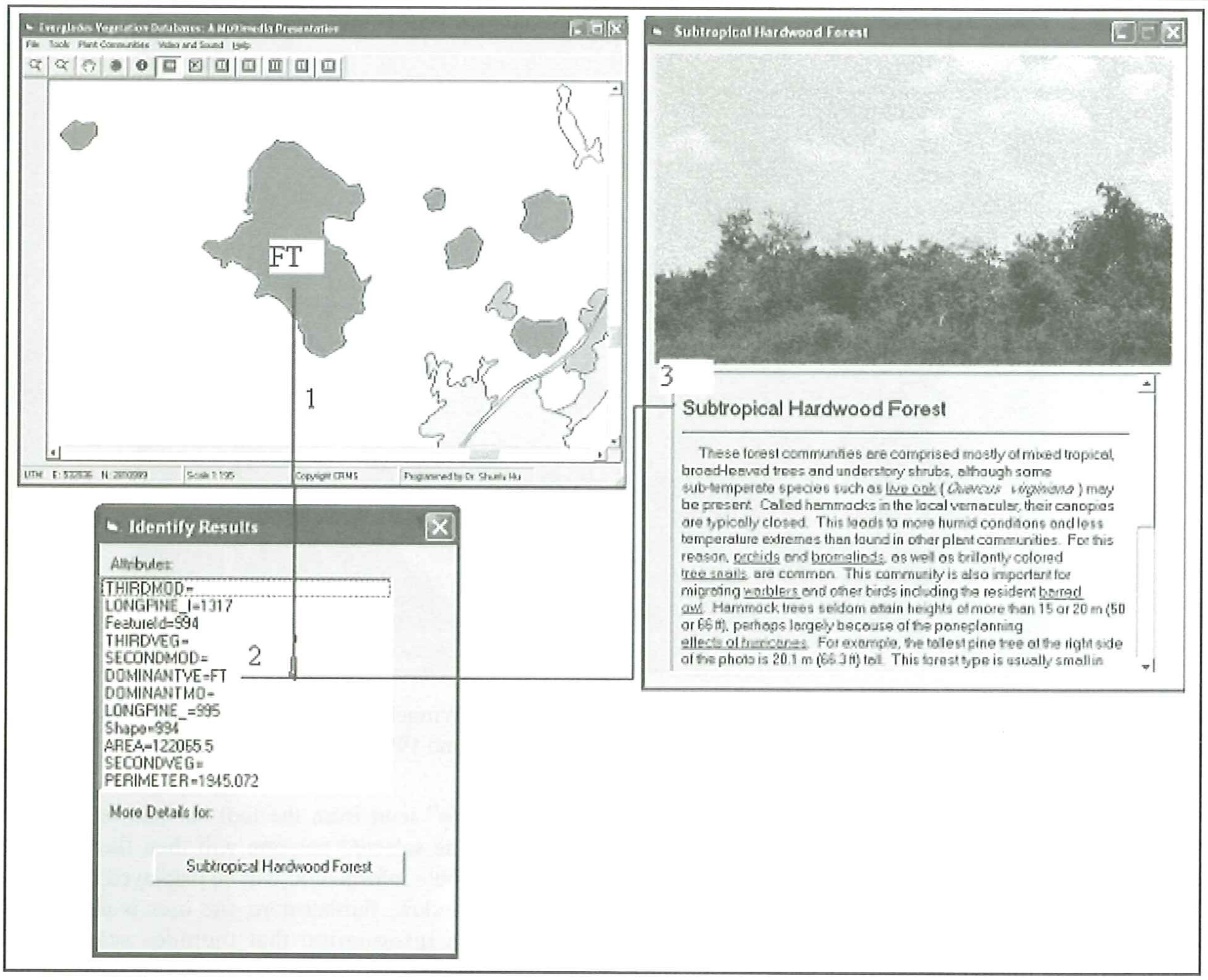

Figure 2. A multimedia GIS application for Everglades vegetation project: 1) map showing a polygon of Subtropical Hardwood Forest (FT); 2) attribute information from a GIS database; 3) multimedia information (text, ground photographs, hypertext, hyperlinks) of the FT.

and Poygan (Hu et al., 2003). Thirty-nine (39) wetland sites were identified along approximately 150 km shoreline of the Winnebago Upper Pool Lakes. Historical black-and-white aerial photographs, which are primarily from the late 1930s through the early 1990s, and range from 1:20,000 to 1:40,000 scales, were collected, scanned and geographically registered. As a result, a detailed spatio-temporal GIS database was generated for each site, that contains four geocoded digital images of 1937, 1950, 1971 and 1992 and two digital vegetation maps developed from the geocoded 1937 and 1992 digital images. In addition, multimedia information in descriptive text, graphics, scanned ground photographs, and digital video was generated to highlight the physical, chemical and biological characteristics of the wetland habitat in the region.

In order to provide the resource manager and the general public with the means to easily access to the spatio-temporal GIS database as well as the multimedia information, the author developed an integrated multimedia-GIS computer program for the project. The program provides the correspondent manipulation of the digital images of 1937, 1950, 1971, and 1992 for each site (see Figure 3). 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, 1950, 1971 and 1992 will be displayed in four separate map windows. 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.

The program also offers the correspondent manipulation of the geocoded digital images of 1937 and 1992, and derived digital maps of 1937 and 1992 for each site (see Figure 4). 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. 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

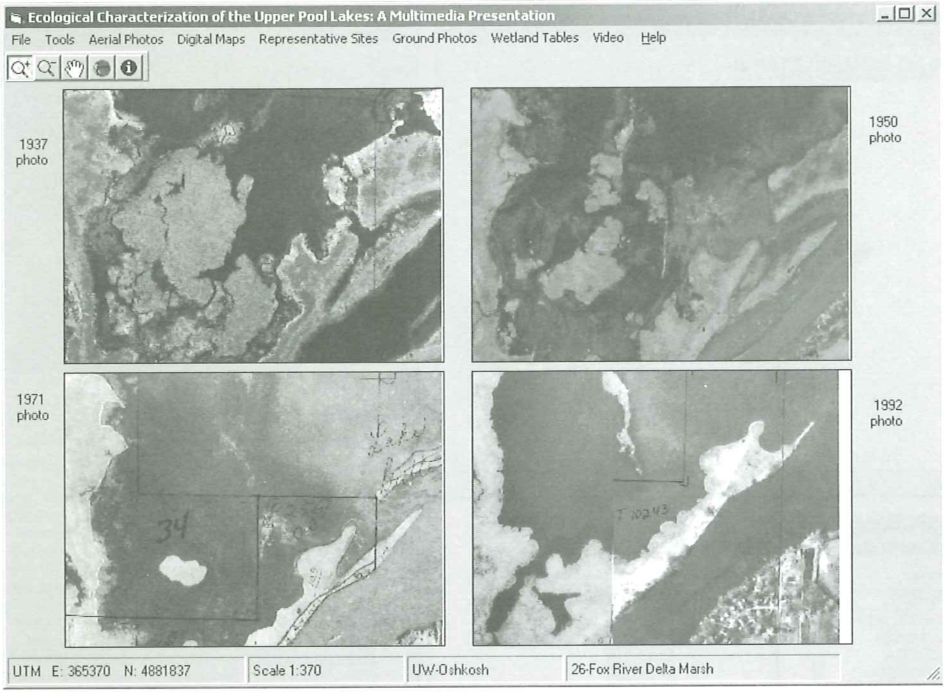

Figure 3. Graphical user interface for the wetland mapping project of the Winnebago Upper Pool Lakes. Displayed in four separate map windows are geo-referenced aerial images of 1937, 1950, 1971 and 1992 for the Fox River Delta Marsh site.

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. Furthermore, the user is able to retrieve multimedia information that includes scanned ground photographs and descriptive text about the characteristics of the vegetation plant communities, and graphics highlighting

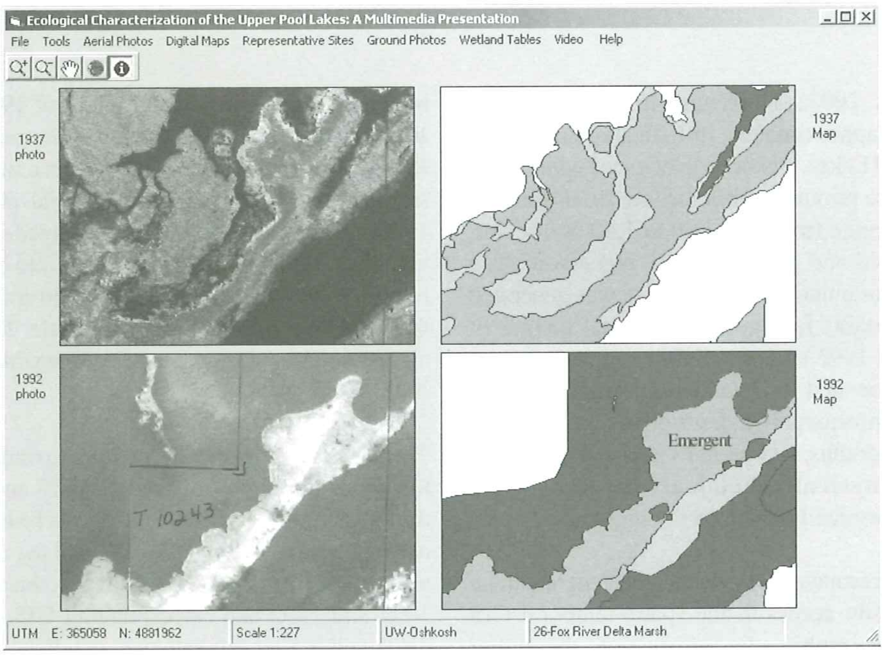

Figure 4. Geo-referenced images of 1937 and 1992 for the Fox River Delta Marsh and their corresponding digital vegetation maps.

the physical, chemical and biological characteristics (e.g., temperature, bathymetry", "sedimentation", "fish", "dissolved oxygen", and "water clarity" of representative wetland sites (Figures 5 and 6). In addition, 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.

IV. BENEFITS OF MULTIMEDIA GIS

The integration of multimedia in GIS is a promising field in the future development of GIS. Multimedia GIS provides several benefits. First, from the user's perspective, the 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). The integration of text, photographs, video and sound in a GIS is highly effective for representing and visualizing geographic information at different level of detail. 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.

Second, the correspondent manipulation of spatio-temporal GIS database as well as multimedia information in a multimedia GIS allows the user to analyze and visualize the dynamic changes interactively.

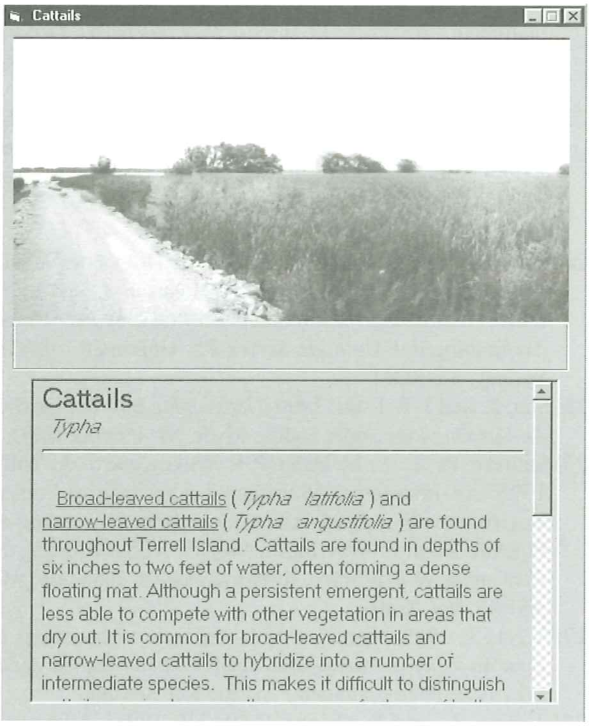

Figure 5. An interactive multimedia system to display a panoramic view of a plant community (e.g., cattails) and descriptive text about its characteristics. The user is able to retrieve more information (e.g., photographs and text) about individual plant species by clicking on an underlined hypertext.

Finally, the ability of linking digital map features with ground photographs, descriptive text and digital video clips can improve understanding in a great deal about natural environment.

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.

V. CONCLUSIONS

The advancement of computer technology enables the integration of GIS and multimedia technologies, called multimedia GIS, that allows to incorporate not only spatio-temporal geographic information in image/vector format but also multimedia geographic information in descriptive text, scanned ground photographs, graphics, digital sound and video. This paper makes contribution in the development of such a multimedia GIS for the analysis and visualization of the spatio-temporal GIS database and multimedia information. In the two case studies of the development of multimedia GIS, the author concludes that multimedia GIS proves to be a more efficient tool in integrating, analyzing and visualizing spatio-temporal and multimedia geographic information. It is anticipated that the multimedia GIS technology described in this paper can be successfully applied in other areas such as tourist management, urban planning, environmental planning, and education.

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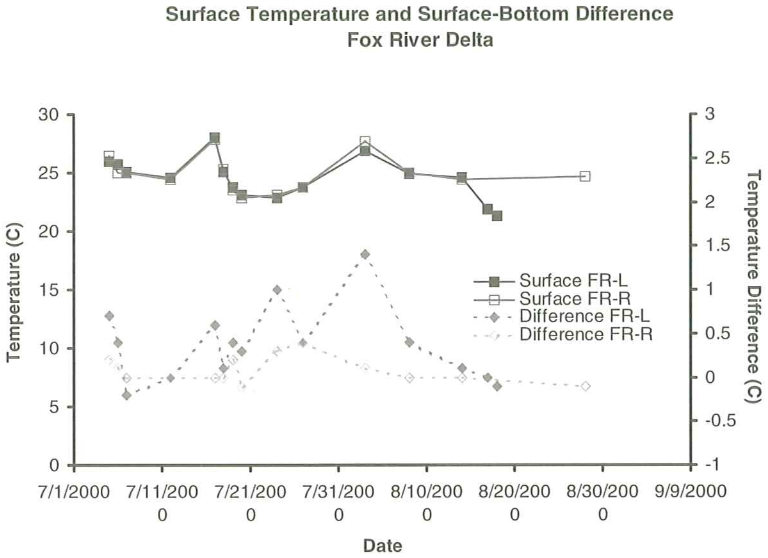

Figure 6. A line graph showing physical characteristics (e.g., temperature) of a wetland site.

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