Implementation of A Coastal Decision Making System using Internet and Wireless Technologies

Xutong Niu[1], Tarig Ali[2], Ruijin Ma[1], Ahmed Elaksher[1], and Ron Li[1]
[1]Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University
[2]Center for Mapping, The Ohio State University
470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210-1275
Email: (niu.9, ali.50, ma.106, elaksher.1, li.282) @osu.edu
URL: http://shoreline.eng.ohio-state.edu/research/diggov/DigiGov.html

Abstract

This paper presents results of a coastal decision making system that utilizes the following tools: Internet, wireless technology, and Geographic Information Systems (GIS). The developed system consists of an on-site mobile spatial subsystem, a coastal structure permitting subsystem, and a web-based shoreline erosion awareness subsystem. The system is being tested and developed for applications in the Lake Erie, Ohio and will be adapted to the Tampa Bay, Florida area.

1. Introduction

This paper presents a novel technique for the integration of wireless technology, Internet-based GIS, and spatial data for coastal management and decision making. The system consists of three components: an on-site mobile spatial subsystem, a coastal structure permitting subsystem, and a shoreline erosion awareness subsystem. These components are used to perform the following functions: spatial data acquisition, real-time spatial database accessing, spatial database analysis, and on-site decision making. The developed system is being tested along the southern Lake Erie coastline where the coastal area is severely influenced by erosion (Li, et. al., 2002). Over much of the region, erosion rates have been less than one meter per year. However, local rates may exceed two meters per year (Highman, 1997).

2. System Architecture

The system architecture consists of three components: an on-site mobile spatial subsystem, a coastal structure permitting subsystem, and a shoreline erosion awareness subsystem (Figure 1). A portable GPS receiver is attached to a Pocket PC to collect GPS positioning data. The Pocket PC is also used for on-site analysis, evaluation, and decision making. The coastal structure permitting subsystem has been developed so that it can be installed on the agency personal computers to perform the evaluating and decision-making tasks in the office. Government agencies using this technique will be able to scientifically evaluate proposed coastal structures from several aspects with high quality geospatial information and analysis. The shoreline erosion awareness subsystem can be used to evaluate and update the shoreline database. Moreover, coastal residents will be able to access the Internet from their homes and browse the different modules in the subsystem to understand the current and future situations of shoreline erosion and impact.

3. System Components and Design

On the server side (illustrated on the left in Figure 2), ESRI® ArcSDE is used to manage the spatial database hosted on the server. On the client side, three subsystems are connected to the spatial database in different ways: the on-site mobile spatial subsystem, the shoreline erosion awareness subsystem, and the coastal structure permitting subsystem. Each component is described in detail in the following sections.

3.1. On-site Mobile Spatial Subsystem

A customized ArcIMS-based web page has been designed with Active Server Page (ASP) and VB Scripts. Through the ActiveX connector, it communicates with an ArcIMS image service that has been established on the server. A Personal Digital Assistant (PDA) is used as a mobile client. It connects to the server through the wireless Internet with a cell phone. The user can submit a request to the server through a designed web page. When the server receives a request, it will process the data and transfer the result back to the client. A portable GPS device is connected with the PDA to provide the geographic coordination information, which can be used to locate the user's position and update the database through the PDA. Equipment used include a Compaq® iPaq 3850 Pocket PC, a Pharos® Portable GPS device, and a Motorola® Star TAC 7860 cell phone.

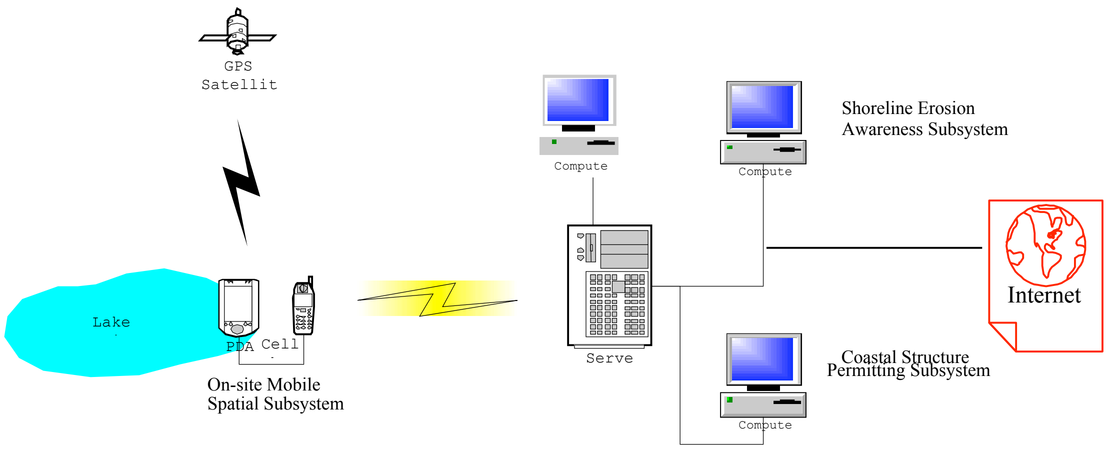

Figure 1. System Architecture

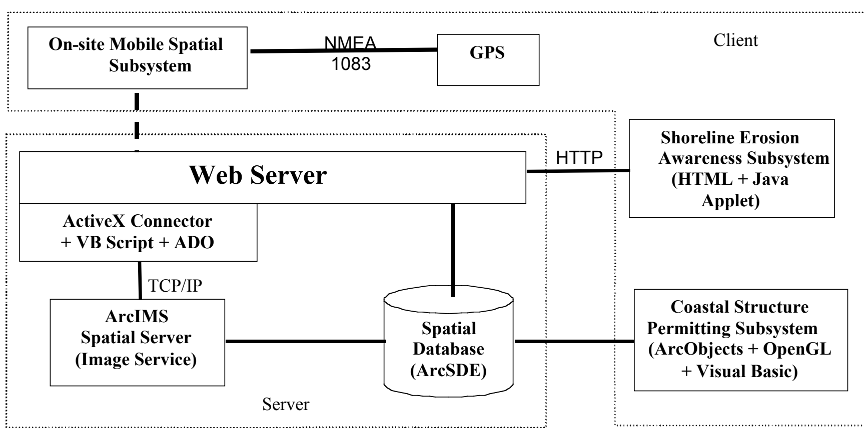

Figure 2. System Design Diagram

3.2. Coastal Structure Permitting Subsystem

The coastal structure permitting subsystem simulates the decision-making process in a GIS environment for granting building permits on coastline properties. The purpose of such a subsystem is to help Ohio Department of Natural Resources (ODNR) decision makers quickly and efficiently access all relevant data and evaluate the potential impact of new structures. It also allows local residents to access their own and/or their neighbors' building plans in addition to providing an effective educational tool for the community to learn about environmental concerns. The subsystem incorporates a geospatial data set relevant to ODNR's permitting approval process and includes instantaneous and tide-coordinated shorelines, aerial/IKONOS-derived orthophotos, a coastal terrain model (CTM), a water surface model (WSM), parcel and construction design maps, as well as USGS DOQ, DLG, and aerial/IKONOS/USGSderived DEM. These data are combined with the agency application process to provide a complete analysis tool for ODNR managers. The subsystem can be connected to the on-site mobile spatial subsystem through a wireless Internet connection.

3.3. Shoreline Erosion Awareness Subsystem

In the shoreline erosion awareness subsystem, observations of shoreline and bluff positions are generated using satellite imagery and aerial photographs. Periodic comparison of these features provides a basis for determining short- and long-term erosion rates. The purpose of this subsystem is to predict shoreline changes due to erosion processes. This subsystem provides fundamental information for examining environmental changes and supporting coordination between coastal management and land-use decision making. The information can be used to identify coastal areas at high risk of erosion in the present and in the future, precisely identify areas in need of protection, and identify efficient and inefficient shoreline protection measures.

The subsystem has been designed with a GIS application and client-side interface components. The client-side interface for an Internet GIS application is typically a web browser implementing the elements of HTML form, a Java applet, or both. In our web-based shoreline erosion awareness application, we have employed Microsoft Front Page to design the subsystem interface with embedded Java Applets. The resulting client component consists of a series of HTML pages with frames. Major advantages of the subsystem are that the entire interface does not have to be transmitted for every request, and that it provides functions in the same manner as stand-alone desktop applications.

4. Experimental Results

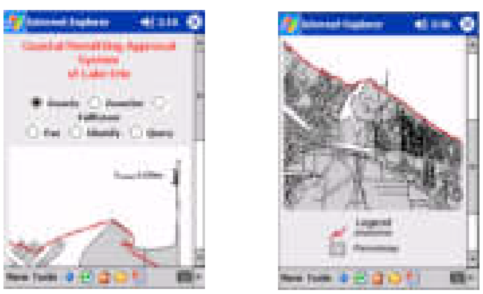

Figure 3. Interface of the Mobile Spatial Subsystem

Figure 3 shows the mobile spatial subsystem implemented with ArcIMS, ActiveX objects, and VB scripts. It provides simple map browsing functions (such as zoom in, zoom out, and pan) and query functions including identify and query. The data used in the subsystem include parcel maps in Erie County, Ohio, a digital T-Sheet shoreline, and a coastal structure information table. The coastal structure information table stores information related to coastal structures, including parcel number, application number, center location of the parcel, size and materials of the structures, and so on. These data are saved in a Windows 2000 server in the GIS and Mapping Laboratory at The Ohio State University. The experiment was carried out along the Lake Erie shore in Sandusky, Ohio, in early July 2002. The GPS signal was first received for the spatial coordinates of the parcel in the field, which were found to be (370654, 4583966) in the UTM coordinate system. The PDA was connected to the server through a wireless network and the coordinates input into the query interface and submitted to the server with a request for parcel and structure information. The server located the parcel containing the given coordinate and transferred a parcel map, along with information about the coastal structure, to the PDA. Several parcels had been previously surveyed in order to test the subsystem. Real-time database updating was tested at the same time.

Figure 4 gives a snapshot from the coastal structure permitting subsystem. The applicant submits an application for a stone revetment to protect the parcel property, which was in danger of eroding. This parcel is located in Erie County, Ohio. The applicant also provided a design map to ODNR. Presented as a paper map, the design was digitized and a 3D, CAD-based structure model was extracted. It can be seen that there has been erosion by displaying the historic, current and future shorelines, as well as the structure, in a 3D scene.

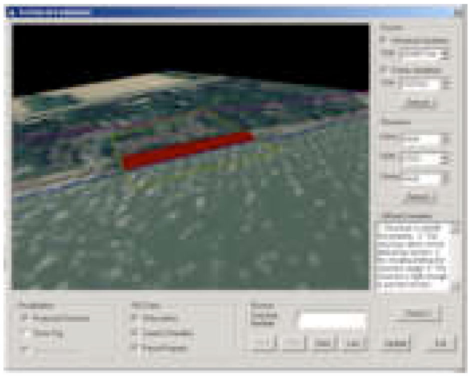

Figure 4. Permitting Subsystem

The subsystem performed the following predefined analysis. First, by comparing the structure spatial extension with the parcel boundary, the structure was seen to be within the applicant's property limits. Second, by comparing the position of the structure to the severe shoreline erosion area, the proposed structure was seen to be stable, i.e., that it would not be flanked by erosion. Third, by comparing the historical mean high water level (MHW), the structure was seen to be sufficiently higher than the water level, and thus would not contribute to erosion. Fourth, by comparing the structure's position with shoaling distribution, the structure was not seen to be limited in performance by shoaling. In consequence, the subsystem completed determined through its assessment that the structure would be stable and its purpose could be fulfilled. However, at this time additional manual inspection is still required.

Figure 5. Scenario for a Potentially Eroded Parcel

The erosion awareness subsystem was tested in a study area along the southern Lake Erie coast that extended for 11Kms from Sandusky to Vermilion, Ohio. Linear regression has been used to predict future shorelines (2015, 2025, and 2050) using transects that have been constructed perpendicular to the 1990 shoreline. The correspondences between shorelines acquired at different times were established accordingly. The purpose was to overlay the future shorelines with property parcel data obtained from Erie County. This enables coastal residents to see different future erosion scenarios (Figure 5). The subsystem also provides coastal residents with a 3D visualization of the coastal terrain model and the water surface, an animation of bluff erosion, a panoramic view of the test area, and a simulated fly-through of the test area.

5. Conclusions

This paper demonstrates an integrated system to combine Internet-based GIS, wireless technology, and spatial data for coastal decision making. The system consists of three components: an on-site mobile spatial subsystem, a shoreline erosion awareness subsystem, and a coastal structure permitting subsystem. This research was supported by the Digital Government Program of NSF, Grant No. 91494.

References

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