Recent Trends in Internet / Web GIS and Mobile GIS for Disaster Management

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Abstract

Geographical Information System (GIS) is a tool which now finds applications in almost all fields of engineering, science, geography, planning and decision making, importantly pertaining to Disaster Management and Natural Hazards like earthquake, floods, cyclones, avalanche, landslide, tsunami, drought, forest fire etc. As GIS technology is changing at a very fast rate, moving rapidly from mainframes to desktops and finally to palm top systems, coupled with advancement in broad band communication technology has provided a new dimension to GIS analyst. In this paper we want to present the framework of advances and future trends of Internet GIS which will be very significant for Natural Hazards and Disaster Management in terms of accuracy and speed of processing and communication using satellite data. This information can be utilized more effectively during planning and decision making. This Internet/ Web GIS model can be extended to Mobile GIS, where plenty of research is underway. We will provide the Architecture of Internet GIS (both client side and server side with their relative advantages and disadvantages), we provide the System architecture and System design of Internet GIS. We provide the strategies to develop the client interfaces. We conclude with how this Internet GIS can be efficiently transitioned to Mobile GIS and provides a case study of Disaster Management using these technologies.

Keywords: *Architecture of Internet/Web GIS, Internet/Web GIS, Mobile GIS, Disaster Management*

I. OVERVIEW OF ADVANCES IN GEOGRAPHICAL INFORMATION SYSTEMS

GIS technology is changing at very fast rate, and it has moved from mainframe computer to work station and from desktop based PC system to palm top systems. With the recent advancement in broadband and wireless communication technology along with Internet facilities, a new area in GIS known as Internet/Web GIS has now provided a new dimension to GIS analyst. A subsequent advance in wireless technology, another area of GIS development, is Mobile GIS, based on mobile computing and mobile Internet (Fangxiong and Zhiyong, 2003). It is not conventional GIS modified to operate on a smaller computer, but an extension of Web GIS to mobile Internet including wireless Internet / Intranet and mobile communication network.

II. INTERNET GIS

Internet is a collection of interconnected network of computing machines worldwide, Where networks operate using a standard set of addresses allowing millions of computers connectivity on a global scale. Internet based World Wide Web (WWW) has emerged as an alternative means of accessing, viewing, and distributed spatial information. In Internet GIS, results are achieved by integrating front end query capabilities supported through standard Internet and WWW interfaces, and protocols with the capabilities of a commercial DBMS (Database Management Systems) and GIS software residing in the background. User defined queries are translated into corresponding SQL commands, and passed to the back-end GIS database for handling. The resulting response is returned back through a gateway or bitmap format suitable for fast transmission and quick viewing across the Internet. Online Internet GIS can perform two major Internet GIS applications, i.e., client side and server side base on common gateway interfaces (CGI) or gateway scripts. In a client-side Internet GIS application, the client (Web browser) is enhanced to support GIS functionality while in a server-side GIS application a web browser is used only to generate server requests and display the results. Client-side GIS applications are implemented typically by enhancing the Web browser by a Java applet, Active X, or plug-in's. Some client side applications even require users to install a complete client application. In either case, client-side applications requires software of some kind (other than a browser) to be transferred to the user.

An example of a client side Internet GIS application is one that runs as a Java applet. The code for the applet is transferred to the Web browser as binary instructions that provide a graphical user interface (GUI) for the GIS application. Vector-based data is then transferred to the client enabling the complex GIS functions on the client. The architecture should not be confused with a similar server side GIS architecture that implements a Java applet to create a GUI for the GIS application. In this case, the applet is simply an interface for an image. The complex GIS calculations and data remain on the server. An example of a server-side Internet GIS application is one typical of the mapping applications found on the major Internet portals. In these applications, users send a request to a server (i.e. an address), and the server processes the request and sends the results back as an image embedded in an HTML page via standard HTTP. The response is a standard web page that a generic browser can view. In server side Internet GIS applications, all the complex and proprietary software, in addition to the spatial and tabular data remain on the server.

This architecture has several advantages because the application and data are centralized on a server. A comparison of the advantages and disadvantages of server side and client side GIS applications is given in

Table 1: Comparison of Server Side And Client Side

Technology	Advantages	Disadvantages
Server side Internet GIS	Simpler to develop	Primitive Graphical User Interface
	Easier to deploy	Lower graphics quality
	Easier to maintain	One-click functionality from a browser
	Adheres to Internet standards	
	Requires standard web browser	
	Low bandwidth required	
Client side Internet GIS	Vector data can be used	Difficult to develop
	Better image quality	Requires additional software
	Enhanced GUI	Longer download times
		No adherence to standards
		Platform / browser incompatibility

The Web is a stateless environment. A Web server receives a request from a client, processes the request, and sends a response with no knowledge about the client's state unless state maintenance is used. This is similar to a common software architecture known as pipe-filter architecture. Once the architecture of the system is selected, there are two additional architectural choices pertaining to state maintenance for a server-side application. One can choose a pipe-filter approach and accomplish state maintenance on the client-side, or could choose an object-oriented approach and accomplish state maintenance on the server side. Using a pipe-filter approach, state maintenance on the client side is accomplished by storing all state maintenance variables (extents, layers, command, input variables, etc.) on the client side. This is done by one of two methods, or the combination of both; the use of browser cookies, and/or the use of hidden input tags (or parameter tags) in the HTML page.

When a user sends a request to the server, all the state variables and command(s) are extracted from the HTTP request. The command is then executed on the server, a map is generated reflecting the users current state, the new map image is wrapped in HTML (including the current state variables), and the web page is returned to the client. State maintenance on the server side is accomplished by maintaining map and database objects on the server for the life of a user session. The state maintenance variables are directly accessed as properties of the objects that are maintained on the server. The only state variables required to be maintained on the client are those describe the interface (i.e. last command, active layer, etc.) A comparison of the advantages and disadvantages of server-side state maintenance is given in

Table 2. Advantages and Disadvantage of Server-Side State Maintenance

Advantage	Disadvantage
Easier to develop	Not highly scalable
Less server processing required	Requires implementation of session management
Allows for complex applications.	

A typical Internet system may consist of three distinct components: a server application, a client interface, and a data repository. The client layer consists of a personal computer running a Web browser. This layer provides the user interface and operates by generating requests to the application server via HTTP and displays the resulting HTML file in a Web browser. The middle layer is itself a receives requests from the client which are processed by the application server's Web makes requests to the data layer via TCP/IP and ODBC. The data layer is a data repository shape file format. The data repository is built and maintained through an off-line data shape files. Although an off-line process, data migration is an integral part of the system and is included in the overall system design. In this design, data in the repository and updated via migration process. The data repository is then accessed by the ESRI map application by means of an ODBC-TCP/IP connection. The map application processes data and generates HTML files which are in turn served to a client PC running a Web browser. In order to support the above system, there are several hardware configurations. The configurations are: single computer configuration, two-computer configuration, and multiple computer configurations. In the single computer configuration, the Web server, application server, and database server are installed on a single computer. In a two-computer configuration the Web server is installed on one machine, and the application server and database server are installed on a separate machine. In the multiple computer configurations, each component is installed on a separate computer. The ideal configuration for a particular deployment depends on the anticipated number of users visiting the site each delay, land number of maps served

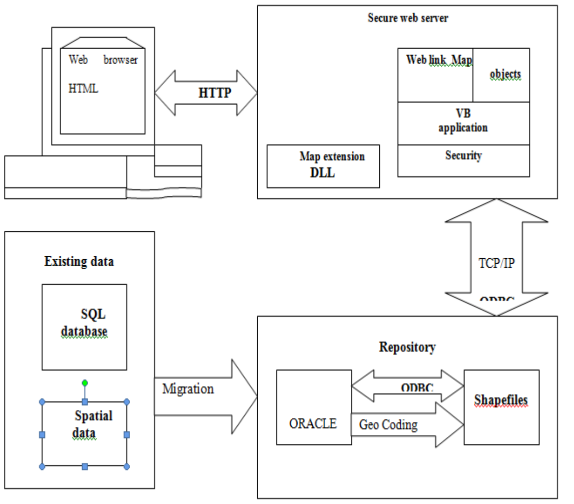


Fig.1 System Design Diagram

Configuration	Anticipated number of users
Single computer	100-1000
Two computer	1,000-1,500
Multiple computer	1,500 and more

Table 3: Number of Anticipated Daily use

i. Dual processor-500 MHz
ii. 512 Mb RAM
iii. Dual hard drive storage @ 13 GB each
iv. TI (or better) Internet connection

Similarly, the system is required to have the following software for system development and deployment A server-side Internet GIS application is composed of four distinct components: Web browser/client interface. Web application/server, GIS application/Map server, and a relational database management system. Although the components are integrated into a single system. Each component is distinct and should be considered separately.

Application	Software
Operating system	Window NT or higher
RDMS	Any SQL
Internet Browser	Internet Explorer or Netscape
Map/application	ESRI or any Internet map server
Geocoding engine	Arc view or any other compliant
Application development	Visual Basic. Map object
Client development	MS Visual Interdev

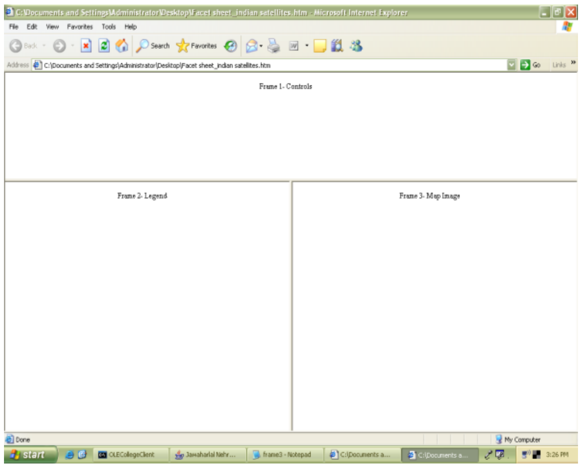
Table 4: Software requirement

Client Interface

The client interface for an Internet GIS application is typically a Web browser implementing HTML form elements or implementing a Java applet. The client component can consist of a series of static and dynamic HTML pages that may or may not be implemented using HTML frames. By using HTML frames, the following advantages can be obtained.

i. The entire interface need not be transmitted with every request
ii. Frames can be resized and scrolled individually
iii. Provides functionality similar to a standalone application,.

A Web application interface can be divided into number of functional are. It is an example of such an interface.



Here Frame 1 is a non-resizable, non-scrollable frame used to display a state HTML page consisting of the HTML form elements that compose the pull down menu. The images that compose the image link button bar, and the Java Script functions that process and submit users actins. Frame 2 is a resizable, scrollable frame used to display a dynamically generated HTML page consisting of the map's legend, image links that provide functionality to adjust the legend, and Java Script functions used to process and submit user actions. Frame 3, also a resizable, scrollable frame, is used to display a dynamically generated HTML page containing the map image, and Java script functions used to process and submit users' actins.

The GIS application/Map server may be designed and developed with appropriate software such as MS Visual Basic, ESRI Map Objects. The database design may be based on SQL or MS Access. The success of Internet GIS application depends upon the requirement of the project and software. Developing GIS applications for the Internet is a situation where the best solution depends on the application requirements. By carefully analyzing requirements and planning an Internet GIS application an software developed can greatly simplify the development process. The first step a developer must accomplish is to gain a thorough understanding of the application requirements. An understanding of the application requirements will allow the developer to make the right architectural choice for the application. Typically a server-side application is a good choice for developing an Internet GIS application because of advantages that include ease of development and standardization.

The structure of the spatial data, as well as the structure of a relational database is a critical factor that influences the performance of a GIS application. In an Internet environment performance is usually the most important factor, thus a developer should make performance the number one priority when designing the database. A de-normalized database will provide the best performance for an Internet GIS application.

III. MOBILE GIS

The development of versatile computer hardware and software along with the successful implementation of Wireless Application Protocol (WAP) in communication network is a new concept of work on the move. It is easy to see that the integration of geo spatial information and mobile Internet is inevitable. The integrated system is designed to work on mobile intelligent terminals and brings new dimension and at any time and at any place to access geo spatial and attribute information in GIS, which is known as Mobile GIS.

Traditionally, GIS mainly focused its attention on static spatial entity (also known as static GIS or SGIS), the analysis is correlated to position and its attribute, but it does not consider the moving nature of the world, i.e., it cannot record the change of a piece of land in terms of its change in the boundary of the field or the ownershi8p of a field. In 1988, Langram and Chrisman introduced the concept of Temporal GIS (TGIS) where the attention is focused on to a moving spatial object/entity. TSDGIS adds a new dimension in its analysis space i.e., position, attribute, and time. Interestingly, both SGIS and TGIS consider a spatial entity that has a geographical aspect such as a road, mountain top, building, but does not consider a non-geographic entity such as a car, desk or a book.

Mobile GIS is a kind of GIS where it considers a non-geographic moving object in geographic space. It identifies a relationship between moving object in geographic entity, or a moving object and another moving object. For example, by integrating GIS, GPS, wireless Internet to build a mobile GIS to monitor cars, the GIS analyst is interested in studying the moving car in geographic entity space, and the moving car is a non-geographic entity.

Mobile GIS is not a modified conventional GIS to operate on a smaller computer, but a system built using a fundamentally new paradigm. It extends unlimited information on the Internet and powerful service functions of GIS to mobile devices to provide mobile users practice and thousands of potential application.

The general architecture of a mobile GIS is an integrated system of mobile client, a server, a wireless network, a mobile client position recording system, such as a SGPS mobile client can be a moving car equipped with GPS that can send information regarding the geographic position to the server by SMS. Alternately, a PDA equipped with GPS can show a digital map, and communicate with the server through a wireless network having GSM. CDMA, CDPP, or GPRS that can support digital data transmission. Mobile GIS can be simply divided into two categories, depending upon the manner by which access to Mobile Internet is done. The one is based on Short Message Service (SMS)/Multimedia Message Service (MMS), while the other is based on Wireless Application Protocol (WAP).

SMS/MMS-based Mobile GIS can only be suitable for mobile phones with simple system functions, unfriendly graphical user interface (UUI), poor information presentation and restricted application field, because of the limitations of SMS/MMSD such as restricted carrying information, time lag, unfriendly interactive mode, and so on.

On the contrary, WAP is a bear independent international standard protocol that has been optimized for mobile devices with limited display and small keyboards of mobile handsets and low bandwidths of wireless networks; land permits applications and services to operate over all existing and foreseeable wireless networks such as GSM, CDMA, PHS, TDMA and WCDMA. The WAP specification encompasses a relatively simple land compact version of it possible to request to mobile service from a mobile terminal and return a map in the form of an embedded bitmap (e.g., WBMP).

Hence, WAP-based Mobile GIS has richer information presentation, friendlier GUI, more system functions, and more application files that the former. Moreover, it can work on la wide range of mobile devices with a WAP micro browser only, from Personal Digital Assistants (PDAs), mobile phones, and in-car computers to other small mobile devices. WAP-based Mobile GIS can be as mobile users (with a WAP mobile terminal only). It can perform almost the same functionality as of Internet GIS but in a mobile environment at any place and without the limitation of operating system and wired link. It is expected that because of the advantages of WAP, the WAP-based Mobile GIS will play a leading role immobile information services markets.

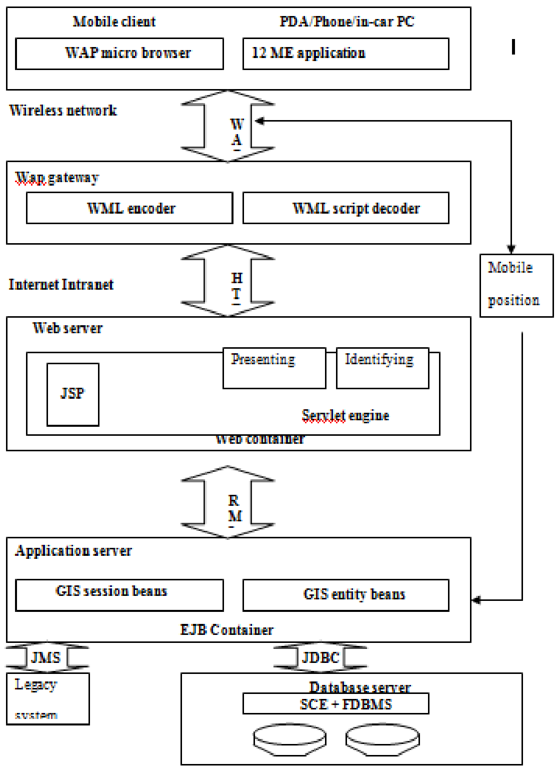


Figure 2: A Distributed Architecture of WAP-Based Mobile GIS

WAP-based Mobile GIS is a "thin client" distributes system via mobile Internet. It is an open, extendable, stable and cross-platform distributed system, because of the increasing application demand and the diversity of mobile terminals.

Currently, popular system architecture solutions for distributed systems are all based on distributed object technologies. There are three mainstream industry standards. Microsoft's windows Distributed Network Architecture (Windows DNA/. NET Architecture. Object Management Group's Common Object Request Broker Architecture (CORBA), Sun's Java 2 Enterprise Edition (J2EE) Architecture. A system based on Windows DNA/. NET running, including developing platforms and operating system. It cannot cross operating system platform especially, which is the fatal weakness of Windows DNA/. NET Architecture. CORBA is too huge and complicated, and its technologies and standards are updated relatively slowly.

J2EE is a specification and standard created by Sun and her industry partners. J2EE provides support for the technologies such as Enterprise Java Beans (EJB), Java Servlets API developing a multi-tier distributed system which can be rapidly developed and deployed, and can enhance the portability, security, load balancing, and extensibility for a distributed system. The advantages of building distributed GIS based on J2EE are

(i) Cross-platform, (ii) multitier separating for performing complicated tasks (iii) component reusing, and (iv) module developing.

Figure2 illustrates a J2EE-based distributed architecture, which is composed of four logic tiers from the client side to the server side: Presentation tier, WAP service tier, application tier and data service tier.

A. *Presentation Tier:*

Presentation tier is a carrier of the client of WAP-based Mobile GIS, and is mainly responsible for implementing the presentation logic of GIS data. Generally, the client without local storage data is a WAP micro browser need not perform any GIS and is analogous to a standard Web browser. The WAP microbrewer need not perform any GIS business logic nor it directly connects to a back-end database server or stores any state information, thus it is a really thin client. The client also may be a J2ME (Java 2 Micro Edition) application.

WAP Service Tier

WAP service tier includes a WAP Proxy (often referred to a WAP Gateway) and a Web Server. The WAP Gateway is required to handle the protocol of networking between the client and the Web Server. As depicted in fig. The WAP Gateway consists of WML encoders and WML Script decoders. The WAP Gateway can optimize the communication process and may offer mobile service enhancements, such as location, privacy, land presence-based services. The WAP Gateway communicates with the client (WAP microbrewer) using the WAP protocols and it communicates with the Web Server using the standard Internet protocols such as HTTP/HTTPS. Once the WAP Gateway receives WAP requests from client, it translates the request to HTTP request, and then sends them to the Web Server, Once the WAP Gateway receives LHTTP responses (Web contents) from the Web Server, it translates the Web contents to compact encoded binary formats for reducing the size and number of packets traveling over the wireless network to the client for displaying and /or processing.

The Web Server includes a Web container and Web protocols support, security support, and so on. Web caching mechanism for Glossarial Information. The web Container is GIS system based on Java often uses Java Applets and /or Servlets to extend the dynamically displaying functionality for the web browser.

The client devices of WAP-based Mobile GIS have several types (e.g., PDA and WAP phone) whose displaying the presenting capabilities are different. Sop the has to be a mechanism at the server side, that is, the Web Server may determine the type of the client device and generate corresponding presentation logic for the client. Fortunately, the Servlet Engine can solve the problem effectively. The Servlet Engine may provide two kinds of according to the type of the client devise for the client; the other is identifying the Servlet which is responsible for determining the type of the client device (through ID of the client device accessing mobile networks) and then notify the presenting Servlet.

B. *Application Tier:*

Application tier is the core of the J2EE architecture. It corresponds to GIS Application Servers that communicate with the Web Server in WAP service tier through Remote Method Invocation (RMI). An EJB container at an Application server is the runtime environment of EJB components including GHIS Session Beans and GIS Entity Beans, and controls these components to be performed and transferred. At the same time, the container also provides these components with all required services for distributed computing environments. Thus, these EJB components could more efficiently execute in the Application Server. The EJB components can use JDBC (Java Database Connection) technology to access to database servers, and use JMS (Java Message Service) technology to connect to back-end legacy systems. The Application Server has a special Locating Entity Bean to communicate the Mobile Position Center (MPC), a Server providing geographic location information, with Mobile Location Protocol (MLP). The mobile position technologies for real-time capturing the location information of mobile users generally are GPS, Cell Of Origin (COO), Time of Arrival (TOA), Angle Of Arrival (AOA), Enhanced Observed Time Difference (E-OTD) , and so on.

C. *Data Service Tier:*

Date service tier corresponds to Database Servers that are used to mandate and store geospatial and attribute data of the whole system. Object oriented database management system (OODBMS) is the most desired database server for a GIS system, but OODBMS is immature and very costly at preset, and hence it is not popular and commonly used (Gong, 2001). At present, the mainstream solution is that large object-relation database systems such as DB2, Oracle, Sybase, SQL Server, and so on are used to manage and store GIOS data, at the same time, spatial data engine (SDE) also can be developed to build the communication between data service tier and application tier. SDE is an open standards-based middleware such as ArcSDE, Spatial Ware and Oracle Spatial.

At present, low bandwidths are still the main bottleneck of all mobile applications (Wei.et al, 2003). So researches on the organization of geospatial data at the fat server side an on the presentation of geospatial information at the thin client side should be done farther. Fortunately, the mobile network is towards the development of 3G. In 3G age, when the mobile terminal moves at the same speed as vehicle, the transmission speed is 144 kbps, transmission speed is 384 kbps, when the mobile terminal is in the room, the transmission information wireless transmission. Therefore, it is not hard to understand that WAP-based Mobile GIS will have better development and application perspectives and considerable business value.

D. *Overview of Disaster Management through Internet GIS and Mobile GIS:*

Disasters are events that cause misfortune, damages, and adverse effects on property and environment of human beings. Disaster is defined as an abnormal condition of the environment which can exert a serious and damaging effect on human, animal and plant life beyond a certain critical level of tolerance (Barrett and Curtis, 1982). However, it is difficult to define the critical level of tolerance since it involves considerable knowledge on various aspects including economic conditions and human psychology. Some of the disasters that occur world wide on a regular basis are earthquake, floods, cyclones, avalanche, landslide, tsunami, drought, forest fire etc. Internet / Mobile GIS helps in disaster preparedness by providing repetitive and synoptic up to date information on the locally available resources and by facilitating the forecast of the event in time so that alternative arrangement could be provided. Disaster prevention measures can be improved through this technology in these ways (i) mapping the disaster prone areas (ii) predicting / forecasting of impending disasters, and (iii) monitoring the phenomena to predict their onset and progress.

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