Concepts and Principles of Web GIS

(Unit: II)

Semester: II

Paper Code: GIS 09
Name of Paper: Advanced Remote Sensing & GIS

PG Diploma in RS & GIS

Dr. SHYAMA PRASAD MUKHERJEE UNIVERSITY, RANCHI

1. Introduction:

GIS software has enabled users to view spatial data in its proper format. As a result, the interpretation of spatial data has become easy and increasingly simple to understand. Unfortunately, everyone does not have access to GIS, nor would he be able to spend the time necessary to use it efficiently. Web GIS becomes a cheap and easy way of disseminating geospatial data and processing tools. Many organizations are interested to distribute maps and processing tools without time and location restriction to users. Internet technology has made its way to many government organizations as well as numerous households. The ability to get information through Internet made spatial data providers to explore the Internet resources for disseminating spatial information. To provide a successful web GIS implementation it is required to consider the implementation as a process rather than a step. The implementation should also respect the available technology and the application requirements.

In this module we will learn about an overview of the current Web GIS technologies is presented. Available Internet GIS software is compared and how web GIS develop cycle which has been proposed as well as tested through publishing a geospatial information.

"Web GIS is a type of distributed information system, comprising at least a server and a client, where the server is a GISserver and the client is a web browser, desktop application, or mobile application. In its simplest form, web GIS can bedefined as any GIS that uses web technology to communicate between a server and a client, ESRI,2016". "The term WebGIS is being tossed around all over the place right now but thetrue meaning of the term may be very different than what you understand it to be. WebGIS explained In its simplest form, web GIS can be any GIS that uses web technology to communicate between a server and a client ,(SSP,2017".))

"The following are few key elements essential to web GIS (Mathelle,2009):

- ✓ The server has a URL so that clients can find it on the web.
- ✓ The client relies on HTTP specifications to send requests to the server.
- ✓ The server performs the requested GIS operations and sends responses to the client via HTTP.
- ✓ The format of the response sent to the client can be in many formats, such as HTML, binary image, XML (Extensible Markup Language), or JSON (JavaScript Object Notation"

In the document titled "A framework for deploying web GIS applications" (source: URL1) it has been pointed out that there are 5 essential elements in every web GIS app. These include:

- ✓ a web application
- ✓ digital base maps
- ✓ operational layers
- ✓ tasks and tools
- ✓ one or more geodatabase

2. Types of Web Maps:

A first classification of web maps has been made by Kraak. He distinguished static and dynamic web maps and further distinguished interactive and view only web maps. However, today in the light of an increased number of different web map types, this classification needs some revision. Today, there are additional possibilities regarding distributed data sources, collaborative maps, personalized maps, etc

a) Analytic Web Maps

These web maps offer GIS analysis, either with geodata provided, or with geodata uploaded by the map user. As already mentioned, the borderline between analytic web maps and web GIS is blurry. Often, parts of the analysis are carried out by a server-side GIS and the client displays the result of the analysis. As web clients gain more and more capabilities, this task sharing may gradually shift.

b) Animated Web Maps

Animated Maps show changes in the map over time by animating one of the graphical or temporal variables. Various data and multimedia formats and technologies allow the display of animated web maps: SVG, Adobe Flash, Java, Quicktime, etc., also with varying degrees of interaction. Examples for animated web maps are weather maps, maps displaying dynamic natural or other phenomena (such as water currents, wind patterns, traffic flow, trade flow, communication patterns, social studies projects, and for college life, etc.).

c) Collaborative Web Maps

Collaborative maps are still new, immature and complex to implement, but show a lot of potential. The method parallels the Wikipedia project where various people collaborate to create and improve maps on the web. Technically, an application allowing simultaneous editing across the web would have to ensure that geometric features being edited by one person are locked, so they can't be edited by other persons at the same time. Also, a minimal quality check would have to be made, before data goes public. Some collaborative map projects:

- ✓ Google Map Maker (Till March 31, 2017)—Google Maps
- ✓ OpenStreetMap
- ✓ WikiMapia
- ✓ meta:Maps - survey of Wikimedia map proposals on Wikipedia:Meta

d) Customised Web Maps

Web maps in this category are usually more complex web mapping systems that offer APIs for reuse in other people's web pages and products. Example for such a system with an API for reuse is the Open Layers Framework, Yahoo! Maps and Google Maps.

e) Distributed Web Maps

These are maps created from a distributed data source. The WMS protocol offers a standardised method to access maps on other servers. WMS servers can collect these different sources, reproject the map layers, if necessary, and send them back as a combined image containing all requested map layers. One server may offer a topographic base map, while other servers may offer thematic layers. Web maps in this category are usually more complex web mapping systems that offer APIs for reuse in other people's web pages and products. Example for such a system with an API for reuse is the Open Layers Framework, Yahoo! Maps and Google Maps.

e) Distributed Web Maps

These are maps created from a distributed data source. The WMS protocol offers a standardised method to access maps on other servers. WMS servers can collect these different sources, reproject the map layers, if necessary, and send them back as a combined image containing all requested map layers. One server may offer a topographic base map, while other servers may offer thematic layers.

f) Dynamically created Web Maps

These maps are created on demand each time the user reloads the webpages, often from dynamic data sources, such as databases. The webserver generates the map using a web map server or self written software. Some applications refer to depictions as hyper maps. One of the examples is- Bhoosampada by Indian Space Research Organizations.

g) Hyper Maps

Any approach offering the planar presentation of a portion of an n-dimensional orthogonal web map structure with the option to choose the axes for depiction from the dimensions.

h) Interactive Web Maps

Interactivity is one of the major advantages of screen based maps and web maps. It helps to compensate for the disadvantages of screen and web maps. Interactivity helps to explore maps, change map parameters, navigate and interact with the map, reveal additional information, link to other resources, and much more. Technically, it is achieved through the combination of events, scripting and DOM manipulations. See section on Client Side Technologies.

3.The web GIS advantage:

By utilizing the Internet to access information over the web without regard to how far apart the server and client might be from each other, web GIS introduces distinct advantages over traditional desktop GIS, including the following:

- ✓ It is borderless & have A global reach: Any web GIS applications can be presented to the world, and the world can access them from their computers or mobile devices. The global nature of web GIS is inherited from HTTP, which is broadly supported. Almost all organizations open their firewalls at certain network ports to allow HTTP requests and responses to go through their local network, thus increasing accessibility.

- ✓ ii. A large number of users: In general, a traditional desktop GIS is used by only one user at a time, while a web GIS can be used by dozens or hundreds of users simultaneously. Thus, web GIS requires much higher performance and scalability than desktop GIS.

- ✓ Better cross-platform capability: The majority of web GIS clients are web browsers: Internet Explorer, Mozilla Firefox, Apple Safari, Google Chrome, and so on. Because these web browsers largely comply with HTML and JavaScript standards, web GIS that relies on HTML clients will typically support different operating systems such as Microsoft Windows, Linux, and Apple Mac OS.

- ✓ Low cost as averaged by the number of users: The vast majority of Internet content is free of charge to end users, and this is true of web GIS. Generally, you do not need to buy software or pay to use web GIS. Organizations that need to provide GIS capabilities to many users can also minimize their costs through web GIS. Instead of buying and setting up desktop GIS for every user, an organization can set up just one web GIS, and this single system can be shared by many users: from home, at work, or in the field.

- ✓ Easy to use: Desktop GIS is intended for professional users with months of training and experience in GIS. Web GIS is intended for a broad audience, including public users who may know nothing about GIS. They expect web GIS to be as easy as using a regular website. Web GIS is commonly designed for simplicity, intuition, and convenience, making it typically much easier to use than desktop GIS.

- ✓ Unified updates: For desktop GIS to be updated to a new version, the update needs to be installed on every computer. For web GIS, one update works for all clients. This ease of maintenance makes web GIS a good fit for delivering Realtime information.

- ✓ Diverse applications: Unlike desktop GIS, which is limited to a certain number of GIS professionals, web GIS can be used by everyone in an enterprise as well as the public at large. This broad audience has diverse demands.

4.Major Elements Web GIS:

Development of the Web and expansion of the Internet provide two key capabilities that can greatly help geoscientists. First, the Web allows visual interaction with data. By setting up a Web Server, clients can produce maps. Since the maps and charts are published on the Internet, other clients can view these updates, helping to speed up the evaluation process. Second, because of the near ubiquitous nature of the Internet, the geospatial data can be widely accessible. Clients can work on it from almost any location. Both of these features altars the way geoscientists do their work in the very near future. The combination of easy access to data and visual presentation of it addresses some of the primary difficulties in performing geosciences evaluations (Gillavry, 2000). Web GIS is not without its faults. The primary problem is speed; GIS relies on extensive use of graphics. Connection speeds over the Internet can make heavy use of graphics intolerably slow for users. It will not match the complexity of dedicated GIS programs such as "ArcView & ArcInfo", or "MapInfo" in near future. On the other hand, Web GIS does not require the same resources as these programs. Powerful computers, extensive training, and expensive site licenses are not required for a site wide GIS solution (Strand, 1998).

4.1 Transferred Geo Data:

Except attribute data, a decisive question for using GIS in the Internet is the data format (vector or raster), which is used to transfer data to client. For data transmission to the client, map is converted in to no space raster or a suitable vector format. When raster data is transferred, a standard Web browser without extension can be used, since Web browser displays GIF and JPEG. That means the data on the server has to be converted to a raster format. The data volume due to the known image size and the original data on the server is safe as only an image is sent to the client. The disadvantage of using raster data is the lack of comfort of handling and regarding cartographic aspects, like font problem. Moving over an object with mouse cannot highlight single objects. In addition, a server contact is necessary per each request from the client. Because of low vector data volume, it transmits faster than raster. Vector data handled by a standard Web browser with extended functionality (e.g. using plug-ins). The user gets a more functionality with vector data. For example, single objects can be selected directly or highlighted. One more advantage of using vector data is the possibility of local processing; it is not necessary to contact the server per executed browser action. The amount of vector data sent over Web could be three to four times less than the amount of raster data needed for equivalent resolution resulting in faster response time and greater productivity (Nayak, 2000). Disadvantages of vector data are manufacturer dependence, as well as, changing data volume; the amount of data varies with the selected area. To avoid data redundancy in client side, dynamic generalization must be provided. Distributing vector data may also endanger copyright rules. The choice of transferring data form (vector or raster) varies with applications and the existing infrastructures. Software products, which offer optional transferring of vector or raster data, may provide advantages. They may allow a pre-selection with raster data, and afterwards, loading of the actual vector data with the possibility of subsequently local process (Leukert & Reinhardt, 2000). Different consortia are developing future standard formats for transferring data over the Internet. The Open GIS consortium, for example, presents Geography Markup Language (GML). GML shall enable the transport and storage of geographical information in eXtensible Markup Language (XML). Geographic information includes both properties and the geometry of geographic features (www.opengis.org). The W3C submits Scalable Vector Graphics (SVG), which is a language for describing two-dimensional vector and mixed vector/raster graphics in XML (www.w3.org).

4.2 Interactive Web Maps:

There are several technology levels to publish map data on the Web, ranging from sites that simply publish static Web maps to more sophisticated sites which support dynamic maps, interactively customized maps and multiple computer platforms and operating systems. In terms of Web GIS, the most challenging map is the interactive one. Within the Open GIS Consortium, a Special Interest Group (SIG) for WWW Mapping is working on issues of Web-based GIS publishing. This group has recently developed an essential model of interactive portrayal (Figure 1).

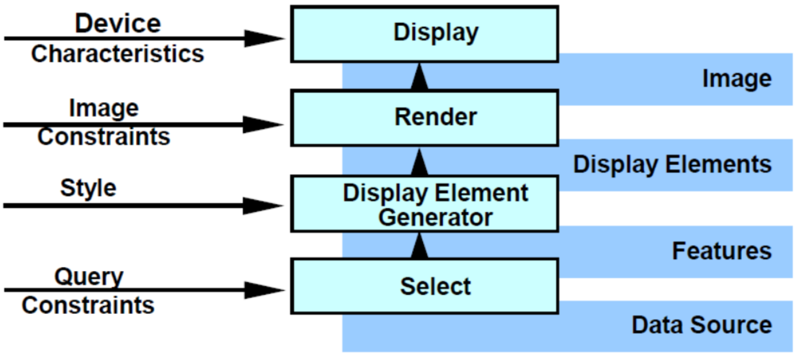

Figure 1: Open GIS model of portrayal workflow (Doyle, 1999)

This model is a very useful tool to analyze and compare different architectures for Internet Map Servers and other Internet based GIS applications. Moreover, it is more precise than the common expression, which often leads to misunderstandings. The interactive portrayal model has four tiers:

- ✓ The Selection process retrieves data from a geospatial data source according to query constraints such as a search area or thematic selections
- ✓ The Display Element Generator process turns the selected geospatial data into a sequence of display elements. It attaches styles such as symbols, line styles, fill styles to spatial features, generates annotation from alphanumeric attributes, sorts the display elements in a certain order and does other graphical processing

- ✓ The Render takes the display elements and generates a rendered map. Examples of rendered maps are In-memory display lists, GIF-files or postscript files
- ✓ The Display process makes the rendered map visible to the user on a suitable display device Between these four tiers, there are three different types of data:
- ✓ Features and coverage's (e.g. raster data) retrieved from the Selection process
- ✓ Display elements generated form the Display Element Generator
- ✓ Images produced by the Render

The next capability for interactive Web maps is to allow users to add new themes to the map from a catalog of available data sources. This can be accomplished by specifying the entire theme, or by querying the spatial or attribute data and returning all those features that satisfy the query criteria (Strand, 1998). When maps are comprised of multiple themes, each theme being displayed as a graphical layer in the map image, the displayed map can become too complex to be of value, unless users are allowed to select which themes are displayed.

4.3 Internet Map Servers:

Internet Map Server (IMS) applications allow GIS database custodians to easily make their spatial data accessible through a web browser interface to end-users. High-speed corporate intranets make an ideal network for distributing data in this manner, given the fact that bandwidth requirements can be high. Making data available to the entire world is certainly feasible and any organization that has a public website can certainly add an IMS without opening up too many additional security holes. For a working IMS, software requires two components to function. A geospatial data processing engine that runs on the server side as a service, Servlet or Common Gateway Interface (CGI) application, and processes the raw spatial data into a map and a standard web server that manages the incoming requests and replies with the proper map data back to the client side browser or application window. The end product is either a JPEG or GIF image or vector, which is transmitted back to the client browser or a stream of data that is interpreted by a plug-in to the client browser. IMS that transmit back an image have a limited capability that does not extend much beyond pan, zoom, and basic vector attribute query. The feature streaming IMS requires a downloadable plug-in, but allows for advanced buffer, query, labeling and sub setting operations to be performed. Some IMS sites offer both a plug-in and a simple HTML version, which is nice for plug-in weary surfers. An overview of the eight most commonly used Internet Map Servers is provided in Table 1.

Table 1: Selected Internet Map Servers

Internet Map Server	Transferred Geo data	Platform of IMS	Browser Extension	Data Interface
ArcView IMS 1.0a (ESRI)	Raster	UNIX, WIN 9X, NT	Html, Applet	Shapefiles, Coverage's, SDE Layer, …
MapObjects IMS 2.0 (ESRI)	Raster	WIN 9X, NT	Html, Applet	Shapefiles, Coverage's, SDE Layer, …
Arc IMS 3.1 (ESRI)	Raster, Vector, (Internal ESRI formats)	WIN 98,NT	Html, Applet	Shapefiles, Coverage's, SDE Layer, …
MapXtreme NT Ver 2.0 (MapInfo)	Raster	WIN NT	Html, Applet	MapInfo format map, Shapefiles, SDE Layer, Raster format
MapXtreme Java Ver 2.0 (MapInfo)	Raster, Vector	WIN NT, UNIX, …	Applet	
MapGuide 4.0 (AutoDesk)	Raster, Vector	WIN NT	Plug-in, ActiveX, Applet	DWG, DXF, DGN, Shapefiles, Coverage's, MapInfo...
GeoMedia Web Map / Enterprise 3.0 (Intergraph)	Raster, Vector	WIN NT	Plug-in, ActiveX	MGE, Shapefiles, Coverage's, MapInfo, Oracle, Access, …
Map Server 3.5 (Minnesota DNR)	Raster, Vector	WIN 9X, NT WIN 2K	Html, Applet	Shapefiles, SDE Layer, Raster format

In the Internet Map Servers product suite contains: IMS as out of the-box but customizable and expandable tool or IMS as development environment. When deciding for IMS, one should pay attention to the offered data interface to use existing geodata without problems.

5. Web GIS Architectures:

In performing the GIS analysis tasks, Web GIS is similar to the client/server typical three-tier architecture. The geoprocessing is breaking down into server-side and client-side tasks. A client typically is a Web browser. The server-side consists of a Web Server, Web GIS software and Database (Figure 2) (Helali, 2001).

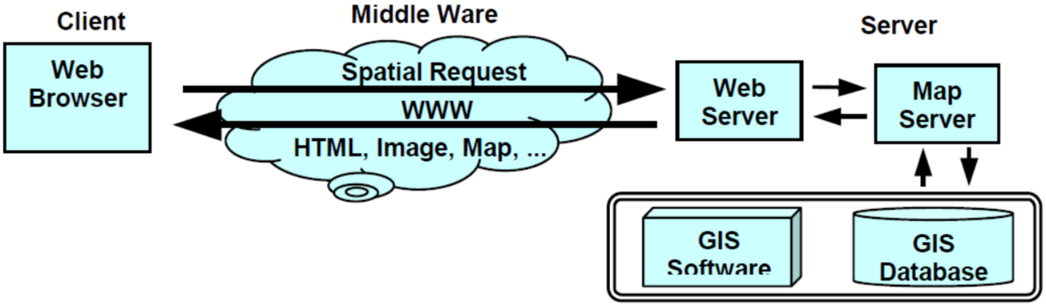

Figure 2: How a typical Web GIS model works

This model of network widely exists within enterprises, in which some computers act as servers and others act as clients. Sever simply have the proprietary GIS running, and add a client interface at the client side and a middleware at the server side to communicate between the client and the proprietary GIS software. Recent development in object-oriented programming make it possible to produce software components, and send them to the client before running it in the client machine, such as Java classes, ActiveX components and plug-ins. This comes out to the thick client GIS. The thick-client architecture let the client machine do the most processing works locally. Both thin and thick-client systems have some advantages and drawbacks, but they are not the best solution in terms of taking advantage of network resources.

5.1 Thin Client Architecture (Server-Side Applications):

The thin client architecture is used in typical architecture. In a thin-client system, the clients only have user interfaces to communicate with the server and display the results. All the processing is done on the server actually as shown in Figure 2. The server computers usually have more power than the client, and manage the centralized resources. Besides, the main functionality is on the Server side in thin architecture there is also the possibility for utility programs at the server side to be linked to the server software. Figure 3 shows schematic communication between Web browser, Web Server and GIS server. On the Web Server side, there are some possibilities to realize the GIS connection to the World Wide Web; CGI, Web Server Application Programming Interface (API), Active Server Pages (ASP), Java Server Pages (JSP) and Java- Servlet. The descriptions of the five possibilities mentioned above are in Helali, (2001).

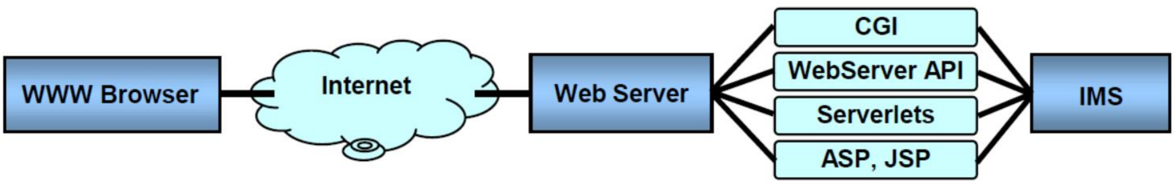

Figure 3: Server-Side Applications

The user on the client side does not need any knowledge about the linkage of the IMS at the server side, but the system administrator or application developers should be familiar with these techniques. This Architecture used in ESRI ArcView IMS, MapObjects IMS and MapInfo MapXtreme systems.

Major advantages of this model driven form Data Base centralization and are:

- ✓ Central control
- ✓ Easy for data eminence/updating
- ✓ Keep the latest version
- ✓ Generally cheaper
- ✓ Integration possibilities
- ✓ Regarding some cartographic aspects such as font

And disadvantage are:

- ✓ Not responsive to local needs: users have different invokes
- ✓ No local accountability: accountability need application in client side
- ✓ Large data volume (size of the database)
- ✓ Response time slow: users use a browser and it take long time to download new HTML frame
- ✓ Less interactive: in client side there is limited application and browsers abilities
- ✓ Vector data does not appear in client side: browsers without additional plug-in can not read vector files

5.2 Thick Client Architecture (Client-Side Applications)

In general, a Web browser can handle HTML documents, and embedded raster images in the standard formats. To deal with other data formats like vector data, video clips or music files, the browser's functionality has to be extended. Using exactly the same client sever communication in Thin Client architecture, vector files format could not be used. To overcome this problem most browser applications, offer a mechanism that allows third tier programs to work together with the browser as a Plug-in. The user interface functionality has progressed from simple document fetching to more interactive applications. This progress is as follows: HTML, CGI, using HTML forms and CGI, Java script to increase user interface capabilities, Java applets to provide client-side functionality. Currently user interface capabilities combined with remote invocations (Figure 4) (Byong-Lyol, 1998).

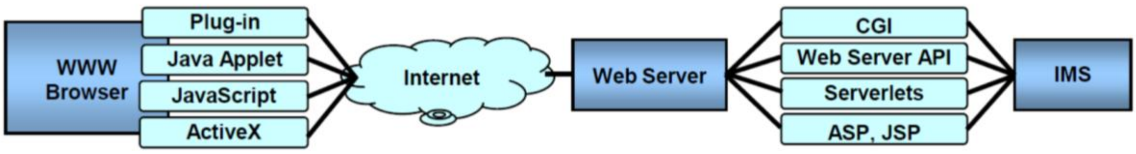

Figure 4: Client-Side Applications

Major advantages of this model are:

- ✓ Document/graphics standards are not required
- ✓ Vector data can be used
- ✓ Image quality not restricted to GIF and JPEG
- ✓ Modern interface is possible; it is not restricted to single-click Operations

And disadvantages to Client-Side GIS

- ✓ Nonconformance cans limits
- ✓ User base
- ✓ Users require to obtain additional software
- ✓ Platform/browser are incompatible

5.3 Medium Client Architecture:

For avoiding vector data in client side and reducing problems of previous architectures, Medium Client is suggested. With using extensions in both client and server side, clients may have more functionally than Thin client architecture. In Figure 5 these four components in interactive map are pictured as services, each with interfaces, which can be invoked by clients of that service.

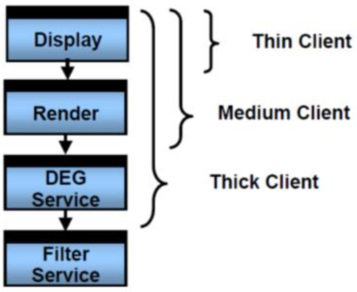

Figure 5: Medium Client position in Open GIS point of view

In other words, if a user's computer contains just the display service, then that user would be said to be using a thin client. If the user's computer additionally contained a render service, then that user would be said to be using a medium client. And finally, if the user's computer also contained the display element generator service that would indicate the user is using a thick client. After some consideration, it was decided that while this distinction may be somewhat helpful in describing web mapping, the terms “thick client” and “thin client” were already encumbered by very imprecise definitions used in marketing literature and were therefore not suitable for continued use in some cases (Doyle, 1999)

5.4 Distributed Architecture

Recent developments in information technology have resulted in a number of distributed object architectures that provide the framework required for building distributed applications. The framework also supports a large number of servers and applications running concurrently. Many of such frameworks provide natural mechanism for interoperability (Kafatos, 1999). For example, Distributed Component Object Model architecture in windows platform and Java Remote Method Invocation (RMI) in Java Virtual Machine (JVM) are the most popular protocols that are used in different cases. These architectures may be applied to GIS to improve the traditional client/server GIS model and develop scalable distributed GIS model. Some attempts have been made in the academic area (Zhang, 1998). The general idea of the distributed GIS service model is that a client program, in either an Internet browser or an independent application, should be able to access the resources distributed in the entire network. The resources here refer to both geodata and geoprocessing components available in the network. The client and the server in this context do not refer to a specific machine. Any machine, when it requests the remote resources during the processing, is a client, and any machine that provides such resources is a server. In a specific program, a client may connect to several servers if needed and a specific machine may be the client at one time and the server at another time. An ideal distributed GIS service model should be a "geodata anywhere, geoprocessing anywhere" model, which means the geodata and geoprocessing tools could be distributed with the largest flexibility virtually anywhere in the network. The geodata and geoprocessing components do not have to be in the same site, but they should be able to cooperate or integrate whenever they are needed to finish a specific task (Yuan, 2000).

Web GIS development processes faces new challenges such as technology innovations, voluminous data transfer rate, and non-specialist users. The following observations have been made:

Web GIS development is more than buying GIS software and hardware. In order to succeed, the implementation phase must be considered as a process rather than a step. The process starts with requirement analysis ending in web GIS use and maintenance.

• Requirement analysis will expose the needed functions, and consequently the web GIS architecture. Medium client architecture has been developed for the case study as it optimizes the projects requirements.

• As the data transfer rate is high from server to client, Internet band must be selected high; moreover, the amount of data dictates a high processor computer.

Reference

Alesheikh AA & Helali H (2001) Distributing National Geospatial Information. Proceedings of Digital Earth 2001, Fredericton, NB, Canada

Asbury S (2000) GIS Industry Outlook: The Birth of a New Millennium. GeoWorld, December 1999, Vol. 12, No. 12

Byong-Lyol L, Young-Chan K, Jin-I Y (1998) Web interface for GIS in Agriculture. By The Asian Federation for Information Technology in Agriculture

Doyle A (1999), Web Map Server Interface Specification. OpenGIS Project Document 99-077r1 URL: http://www.opengis.org

Kafatos E, et al (1999) Earth Observing Data Systems in the Internet Era. Photogrammetric Engineering & Remote Sensing, May 1999, Vol. 65, No. 5, pp540-548

Ladstätter P (2001) GIS on the Internet: Applications, Technologies and Trends. Munich URL:

http://geoinfo.cslm.hu/eugises/papers_pdf/Bos.pdf

Leukert K, Reinhardt W (2000) GIS-Internet Architecture. International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B4, Amsterdam 2000.

Nayak, S (2000) GIS Data Dissemination: A New Approach through WEB Technology.

Rolta India Ltd URL: http://gisdevelopment.net/application/internetgis/web.htm.

Peng (1997), An Assessment of the Development of Internet GIS. ESRI, http://www.esri.com

Strand EJ (1998) What's the Right Way to Web Map Data. Synergetics Inc., URL: http://www.geoplace.com/gw/1998/1298/1298nab.asp

Yuan S (2000) Development of A Distributed Geoprocessing Service Model, MSc thesis, Department Geomatics Engineering, Calgary, Alberta, Canad