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WEB GIS: IMPLEMENTATION ISSUES

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ABSTRACT: With the rapid expansion and development of Internet and WWW (World Wide Web or Web), Web GIS (Web Geographical Information System) is becoming ever more popular and as a result numerous sites have added GIS capability on their Web sites. In this paper, the reasons behind developing a Web GIS instead of a "traditional" GIS are first outlined. Then the current status of Web GIS is reviewed, and their implementation methodologies are explored as well. The underlying technologies for developing Web GIS, such as Web Server, Web browser, CGI (Common Gateway Interface), Java, ActiveX, are discussed, and some typical implementation tools from both commercial and public domain are given as well. Finally, the future development direction of Web GIS is predicted.

KEY WORDS: GIS, Web GIS, WWW, Internet, Data distribution

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1 INTRODUCTION

With the rapid expansion and development of Internet and WWW (World Wide Web or Web), Web GIS (Web Geographical Information System) is becoming ever more popular and as a result numerous sites have added GIS capability on their Web sites (BOSTON *et al.*, 1994; PUTZ, 1994; SHIFFER, 1995; SOVIK, 1997). Web GIS can be simply defined as "GIS on the Web".

1.1 Development of Web GIS

Keeping in mind the popularity and users interrtion towards Web, developers of GIS turn their interest towards Web GIS along with traditional GIS. For development and use of GIS applications, availability of spatial data in digital forms was the main problem of the last few decades. To overcome this hurdle many data development efforts have been made or have been completed to provide digital spatial data. After these developments, the data availability obstacle becomes a data access obstacle. Then, the following access-related problems arise.

- Spatial data locating in digital form.
- In-time access to required spatial data.
- Access to most recent version of spatial data sets.
- Data formats compatibility.
- Huge storage capacity requirements for data.
- Requirements for exchange of resources/fees (for data access).

Web GIS provides an opportunity to overcome many of these problems and provide many other facilities to technical and non-technical users. For users of spatial data, the Web allows visual interaction with spatial data. By using Web one can setup a Web Server that produces maps and generates charts from user data. These maps and charts can be updated in real time as new data is received. At the same time a user can interact with maps and charts and an other can update these maps and charts , so all users can view

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these updates at the same time. The spatial data is widely accessible from any location of the world by using Web technology. The data can be created from one location and modified from another location with new data e.g. one can collect new data from field and instantly update old data with new data. Some important capabilities of Web GIS are as follows: (TASC, 1996a)

- Image archive is linked to geographic locations.
- Streaming video linked to geographic locations/positions.
- Thematic maps can be dynamically configured by the user.
- Construction and work package information available.
- Show GIS data over satellite imagery for "real world" visual referencing.
- Generation of Custom Report on user-defined queries.
- Analysis of map-based data.
- On-line annotation through "post-it" notes.
- Electronic commerce.
- On-line data updates.
- Decision support.
- Real-time data access (for emergency management).

One of the interesting characteristics of the Web is that information is distributed. This characteristic provides help when software documentation is made available via the Web. Software documentation can be immediately updated after finding an error and users do not have to wait for the next version of the software for corrections. All the information is distributed all over the world among many sites/servers. So user can feel that he/she is accessing the information from one site (that is not true technically). Taking advantage of distributed system, GIS data and analysis tools can be resided in different machines on the Internet/Intranet. These GIS data and analysis tools (individual components or modules) would deliver to the user machine (client) on request to server. There are many other advantages of Web GIS including the following.

- Greater reach. No matter where the Web GIS server is located, user can reach it.
- Wider access. It is easy to simultaneously access the most up-to-date data from many different Web GIS servers located all around the world.
- Simple usage. User friendly Web browser enable users to access Web GIS servers all around the world.
- Platform independent. No matter what machine you use, as long as you have a Web browser and access to Internet, you can access and manipulate the geographical information from a Web GIS server.
- Users can interactively analyze coverage.
- Maps can be distributed in a manner that depends on cost.
- User can custom-build his/her own maps.
- Under lying databases (RDBMS, OODBMS) can be queried through a map interface.
- Information once distributed by hand can now be distributed to other employees or the public at large.

As the data is updated or as new features are added, your Web site continually shows your latest information/capabilities (Web as a dynamic).

In order to discuss implementation issues of Web GIS, it is necessary to review some background of the WWW's functionality. So the next section is about Web basics and development of Web GIS. Then Web GIS is divided into three categories and their implementations are explored separately. Finally, the future development direction for Web GIS is discussed.

2 WWW BASICS

WWW stands for World Wide Web (also commonly called as Web). WWW, started by T. Berners-Lee at CERN (the European Laboratory for Particle Physics) in 1989, is a distributed hypermedia information system built on the Internet (COMER, 1997). WWW has a numerous network-connected information servers, normally called as Web servers, which have a huge amount of Web documents linked

in a large hypermedia structure. Web documents, written in HTML (HyperText Markup Language), can contain many types of information such as text, graphics, image, sound, and so on. In addition to local links, Web documents can also have external links given in the form of a URL (Uniform Resource Locator).

Web users can browse the Web documents located at a Web server via a Web browser. At the time of this writing the popular browsers are those available at little or no cost such as Mosaic from the National Center for Supercomputing Applications, HotJava from Sun Microsystems Corporation, Netscape Navigator from Netscape Communications Corporation, and Internet Explorer from Microsoft Corporation

The reason that different Web browsers and Web servers can communicate with each other without any problem is that they speak the same language HTTP (HyperText Transfer Protocol).

In addition to provide static documents, Web servers provide dynamic documents as well. There are many ways to build dynamic documents, among which CGI (Common Gateway Interface) is the most popular one. The CGI standard specifies how a Web server interacts with an application program that generates dynamic documents. The application program is called as CGI programs, which can be written in Perl, C, C++ and so on.

3 IMPLEMENTATION ISSUES OF WEB GIS

In order to analyze the implementation issues of Web GIS, it would be beneficial to separate Web GIS into three broad categories according to the time at which the geographic documents are generated (COMER, 1997):

- Static Web GIS. A geographical document from a static Web GIS is stored as a file and its contents is determined (and fixed) by its author when it is created. As a result, each request for a static map document results in exactly the same response.
- Dynamic Web GIS. A geographical document from a dynamic Web GIS is not stored as a file, but created by a dynamic Web GIS whenever a browser requests the document. Because a fresh geographical document is created for each request, the response of a dynamic Web GIS varies from one request to another.
- Active Web GIS. A geographical document from an active Web GIS is not fully specified by the server, but a computer program that can run on the browser's local machine, can interact with the user and change the display continuously, and can use the geographical data at the server. When a browser requests an (active) map document from an active Web GIS server, the server returns a copy of the program and then the browser runs it locally. Thus with an active Web GIS, we can directly input, output, update, query, and analyze the geographical data at the server.

In the next three sections, the implementation issues for the above three types of Web GIS shall be discussed in detail.

4 STATIC WEB GIS

As WWW is a distributed hypermedia information system, we can simply link geographical map documents together. The author of a static map document determines the contents at the time the map document is written. Because the contents do not change, each request for a static map document results in exactly the same response. As a result, we have a static Web GIS (Fig. 1). Strictly speaking, this should not be called as GIS at all for it lacks the ability to analyze geographical data. In fact, numerous Web sites supports this type of Web GIS. For example, many Web sites provide maps for their locations.

The main advantages of a static Web GIS are listed below:

- Simplicity. It can be relatively simply created by someone who does not know how to write computer program.
- Reliability. As long as the links have been created and verified thoroughly, it remains valid.
- Performance. Since a browser can usually

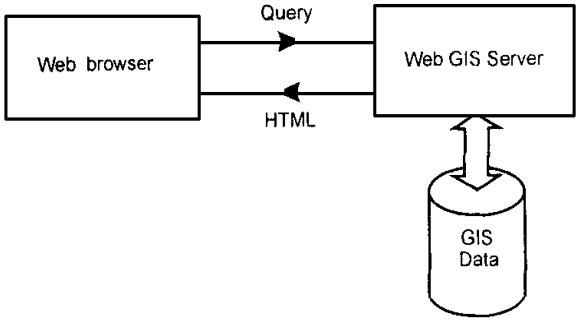

Fig. 1 Static Web GIS

place a copy of a static map document in a cache on a local hard disk, it can display the map rapidly.

The chief disadvantage of a static Web GIS is inflexibility. Whenever information changes, man has to edit a file. This is a time-consuming process. Furthermore, it is difficult to provide information dynamically to its users.

5 DYNAMIC WEB GIS

The static Web GIS is fine for the most basic geographical information distribution, but there are many reasons that you would want to extend the functionality. For example, the user may want to query the attribute information associated with a geographical feature. The simple and clumsy solution is to link every geographical feature with its attribute document; when a user chooses a selectable feature; its associated document is displayed. A better solution would be to run an application program at the server to query the spatial databases in order to generate the answer dynamically. This type of Web GIS is called as dynamic Web GIS (Fig. 2).

The dynamic Web GIS can be implemented via

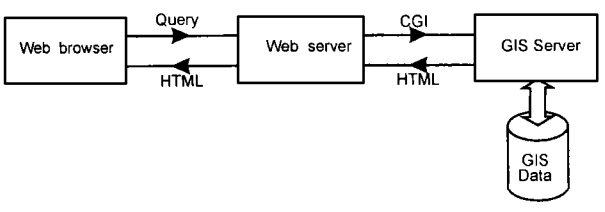

Fig. 2 Dynamic Web GIS

using commercial or homemade GIS tools.

Fig. 3 shows the ESRI Implementation using Arcview Internet Map Server or MapObjects Internet Map Server.

Fig. 4 shows the MapInfo implementation using its MapInfo ProServer products. Currently there are many implementations of dynamic Web GIS. Here are a few examples:

• Xerox PARC Map Server (PUTZ, 1994). It was created in June 1993 by Steve Putz, at Xerox Corporation's Palo Alto Research Center, as an experiment in providing interactive information retrieval via the World Wide Web. The Map Viewer is implemented as a Perl script that accepts requests for map renderings and returns an HTML document including an inlined GIF image of the request map. The map images are generated on the fly by the mapwriter program, which is a stand-alone UNIX command, which produces raster map images from two publicly available vector map databases. Options controlling the map renderings are encoded into the W3 URL strings and passed as command line arguments to the mapwriter program.

• REGIS GRASSLinks 3.0 (public access GIS). GrassLinks was developed by Dr. Suan Huse at the Research Program in Environmental Planning and GIS, REGIS, at the University of California, Berkeley. It is a World Wide Web interface to a GIS, offering public access to mapped information and providing GIS display and analysis tools. It utilizes public domain software, GRASS, from the US Army Corps of Engineers. There are many dynamic Web GIS which are implemented via GRASS and GRASSLinks.

• Arc/Info Atlas Application. This application has been developed as part of the work undertaken to make spatial data available over the WWW. It uses an AML program to format the results of the program as a bitmapped image and embed that image in an HTML document.

The main advantage of a dynamic Web GIS lies its ability to generate geographical map documents dynamically. However, it does have its drawbacks:

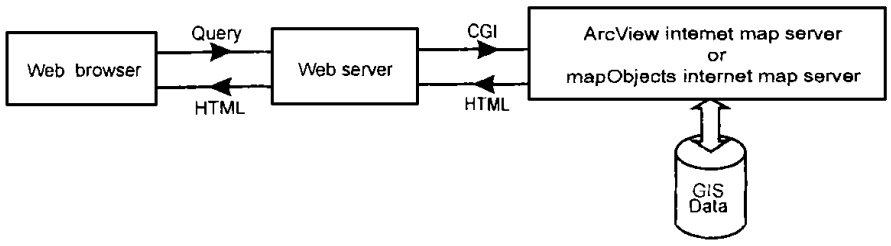

Fig. 3 Dynamic Web GIS using ESRI's Internet Map Server

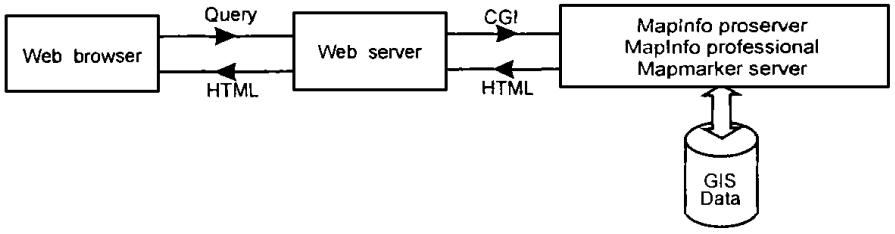

Fig. 4 Dynamic Web GIS using Mapinfo products

• Higher hardware costs. A dynamic Web GIS requires more powerful Web servers compared with a static Web GIS. If many users are browsing simultaneously, the server should have large memory and computing power in order to run CGI programs.

• Higher software costs. It is expensive to write and verify CGI programs.

• Degraded performance. Because of the extra time required to run CGI programs, it is relatively slower than a static Web GIS.

6 ACTIVE WEB GIS

The active Web GIS uses active geographical map documents rather than dynamic geographical map documents. The active documents runs at the client machine and can be interactively and continuously manipulated by the user. Thus the user can not only query geographical data but also analysis and update geographical data.

There are many approaches to create active documents such as Java, JavaScript, VBScript and so on. It seems to the author that Java is the main stream technology for developing active documents.

Java is both a language and a platform environment. As a language, Java can be characterized as platform independent, networked, object-oriented, general purpose, and multithreaded. It also has a rich set of development packages such as java.awt (for graphical user interface). As a platform environment, Java technology defines a machine-independent virtual machine in which Java programs can execute.

Currently, there are quite a few Java-based Web GIS available.

• DDViewer 3.0 (SOVIK, 1997). It is a Java-based interactive mapping application. Accessible through the WWW, DDViewer creates a client-server link between the user's desktop and a demographic data server located at NASA's SEDAC (Socioeconomic Data and Application Center). After the data is loaded from the server, the user may perform various tasks such as zoom in, zoom out, pan, recolor, query, and so on.

• ActiveMaps. It is developed by Internetgis.com. ActiveMaps 2.0, released in March, 1998, is written in Java, platform-independent, can be embedded in HTML documents. After ActiveMaps downloads from the server the vector data in the industry standard "Shapefile" format published by ESRI, the user can use ActiveMaps interactively.

Although it is expensive to create active geographical documents, An active Web GIS has many advantages compared with a dynamic Web GIS:

The active map document is a computer program written in Java and is platform independent while the dynamic map document is generated by a CGI program which can be written in Perl, C, C++, VB and is platform dependent.

- An active Web GIS allows a user to display and analyze geographical data more interactively and continuously than a dynamic Web GIS.
- An active Web GIS has lower requirement on the server computer than a dynamic Web GIS. An active document runs on the user's machine while a dynamic Web GIS has to run CGI programs and generate all the data at the server's machine.
- An active map document can use both raster and vector data while the response from a dynamic Web GIS is usually raster data. Thus an active Web GIS has less burden on network traffic than an dynamic Web GIS.

In general, an active Web GIS is superior to a dynamic Web GIS.

7 DISCUSSION

In this paper, three types of Web GIS have been discussed and compared. The current situation is that most of them belong to static Web GIS or dynamic Web GIS. Due to the advantages of active Web GIS, it can be predicted that there will be many active Web GIS implementations in the near future.

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