GIS-INTERNET ARCHITECTURES

Kristin Leukert, Wolfgang Reinhardt
University of the Federal Armed Forces Munich
AGIS – Study group GIS
Werner-Heisenberg-Weg 39, 85577 Neubiberg, Germany
Kristin.Leukert@unibw-muenchen.de
Wolfgang.Reinhardt@unibw-muenchen.de

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ABSTRACT

The World Wide Web (WWW) gains more significance and there is an increasing demand for GIS applications in the Internet. Most GIS software companies offer Internet Map Server (IMS) in their product family. Maps as well as geo data can be delivered through the WWW by means of IMS.
This paper gives an overview of current GIS-Internet architectures. We focus on presenting and evaluating the deployed Web technology especially on the client side. Different kinds of geo data transferred over the Internet are compared. A typical application is given. Finally realised GIS-Internet architectures are pointed out by means of nine state-of-the-art products from leading GIS companies. The results of the investigation show that the various IMS have in general a similar architecture. The product suites range from out-of-the-box with possible extensions to complete application environments. Basic functionality like zoom, pan and attribute query is implemented in all IMS under consideration. Additional functionality like complex analysis has to be programmed. The current commercial IMS are designed for queries and visualisation of data or analysis results.

KURZFASSUNG

Das World Wide Web (WWW) gewinnt immer mehr an Bedeutung und es besteht eine große Nachfrage nach GIS-Anwendungen im Internet. Mittlerweile bieten nahezu alle GIS-Softwarefirmen Internet Map Server (IMS) in ihrer Produktpalette an. Mit Hilfe der IMS können Geodaten und Karten über das WWW zugänglich gemacht werden.
Dieser Bericht gibt einen Überblick über aktuell verwendete GIS-Internet Architekturen. Der Schwerpunkt liegt auf der Vorstellung der derzeitigen Webtechnologie auf der Server sowie der Client Seite. Ein kurzer Abschnitt beschäftigt sich mit der Art der über das Internet übertragenen Geodaten und abschließend werden die bis dato realisierten GIS-Internet Architekturen anhand von neun "state-of-the-art" Produkten verschiedener GIS-Hersteller aufgezeigt. Die Untersuchungen zeigen, daß die Architekturen der verschiedenen IMS ähnlich sind. Die Produktpalette beinhaltet neben vorgefertigten ("out-of-the-box") aber erweiterbaren Lösungen auch komplette IMS Entwicklungsumgebungen. In allen IMS sind Basisfunktionalitäten wie zoom, pan und Attributabfrage vorhanden. Zusätzliche Funktionalitäten, wie z.B. komplexe GIS Analysen müssen selbständig programmiert werden. Die zur Zeit kommerziell erhältlichen IMS sind auf Abfragen und Datenvisualisierung bzw. Visualisierung von Analyseergebnissen zugeschnitten.

1 INTRODUCTION

The Internet respectively the WWW has developed rapidly in the last years and this new development strongly influences also the GIS field. Using Web technology in GIS offers the possibility to develop easy to use GIS applications for occasional users which are not experts in GIS. Besides this technology allows for flexible use and access to up-to-date data stored on various servers. To establish such easy to use applications it is required that:

- Data has to be prepared according to the application.
- Software tools and methods for the application have to be provided on a server.
- The user interface should be simple and browser based.

The majority of the commercial available GIS-Internet products are systems to provide information by visualisation and presentation of analysis results. The IMS which are reviewed in this paper belong to this category. Products and services for the distribution of data through the Internet as well as web-enabled GIS and distributed GIS services will

gain importance in future (e.g. Terra Bavaria – disposal of cadastral data, www.geoware.de). This paper presents the possible potential of use of GIS on the Internet. Only IMS are investigated.

2 WWW - GENERAL FUNCTIONALITY

Webbrowsers, like Netscape Communicator or Microsoft Internet Explorer, can nowadays be referred as standard equipment of a PC. With an appropriate network authorisation it is possible to connect to the WWW with a webbrowser, either by clicking on a link in an HTML* (Hypertext Markup Language) page or by typing a Uniform Resource Locator** (URL). The request is transferred to the addressed webserver through the Hypertext Transfer Protocol (HTTP Protocol). The according HTML-page is invoked on the server and transferred to the webbrowser where it is displayed. A detailed description of the WWW functionality is presented in (Assfalg et al., 1998).
The following sections present and discuss briefly different possibilities to link GIS to the WWW. These solutions run partly on the server and partly on the client side. The webbrowser is considered as a client, which sends requests to the webserver. First we present solutions particularly based on the server side and then on the client side.

2.1 GIS linkage to the WWW - on the server side

Figure 1 shows schematically the communication between webbrowser, webserver and GIS server. On the webserver side there are basically five possibilities to realise the GIS-connection to the World Wide Web: Common Gateway Interface (CGI), Webserver Application Programming Interface (API), Active Server Pages (ASP), Java Server Pages (JSP) and Java-Servlets. JSP and Java-Servlet solutions are not further described, please refer to literature (JSP 1999, Servlets 1998). The user on the client side does not need knowledge about the linkage of the IMS at the server side, but the system administrator respectively application developer should be familiar with these techniques.

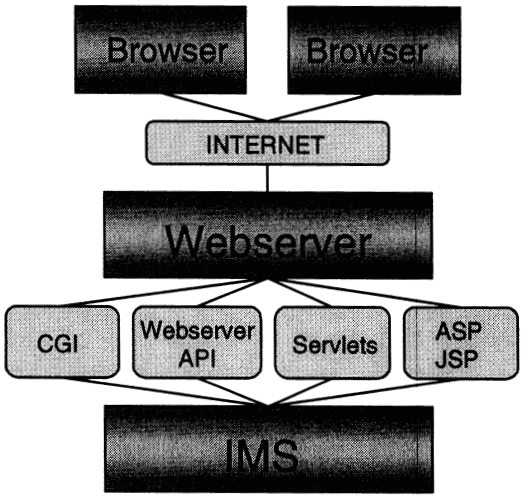


Figure 1. GIS linkage to the WWW - on the server side

2.1.1 CGI. A webserver can start programs, e.g. PERL Scripts. This can be used to build up a connection to a database server. The linkage is started and finished for each request from a client to the server. Performance of the webserver will decrease with the number of parallel users. An erroneous CGI-program cannot influence the webserver process because it runs separately in its own address space. Further advantages of CGI are the independence of programming languages and the easy way of implementing (Pyung-Chul, 1996, Zhong-Ren, 1997).

2.1.2 Webserver-API. The functionality of the webserver can be extended or modified via a programming interface on the webserver. In contrary to CGI the Webserver-API calls are specific for the webserver but they offer a better performance. There is less overhead, functions are loaded in the address space of the server process and no additional processes have to be started. A disadvantage of this technology is that erroneous program code can evoke a server crash. With a product specific API the application gets dependant of the webserver's manufacturer. Server upgrades can require adaptations and linking of API-codes (Pyung-Chul, 1996).

2.1.3 ASP. Active Server Pages are a server side scripting environment from Microsoft. It is possible to develop dynamic and interactive webserver applications. By means of ASP HTML, scripts and server side components can be combined to web-based applications. ASP can only be used in combination with Microsoft's webserver, the Internet Information Server (IIS). There is a PERL module which provides an Active Server Pages port to the Apache HTTP Server. Programming (using ASP and IIS) can be done in one of the following script languages: VisualBasic script,

* HTML: Description resp. Edition language for WWW-pages. It consists of commands, which formats a document for the presentation with a Browser.

** URL: In WWW-Terminology the adress of a document is named URL. Normally that is the domain adress of the computer, which provides the requested document.

Java script, PERL and REXX. A request of any webbrowser calls an ASP-file at the IIS. Scripts which are included in this ASP-file refer to components on the server. The components contain the logic of the application, e.g. the linkage to a database. The results of the request are send back to the ASP-file. The webserver transforms the results e.g. in an HTML-document and transfers it to the webbrowser. ASP dissolve a weakness of CGI: For each request of the same CGI-application a new process is started. In contrary ASP is integrated in the IIS-system. An application is processed by several DLL-calls (DLL's are loaded once). ASP are proprietary technology from Microsoft (ASP, 1999).

2.2 GIS linkage to the WWW - on the client side

In general a webbrowser can handle HTML-documents and embedded raster images in the standard formats GIF, JPEG or PNG. To deal with other data formats like vector data, video clips or music files the browser's functionality has to be extended. The following sections describe three common possibilities (figure 2) to extend the functionality of a webbrowser.

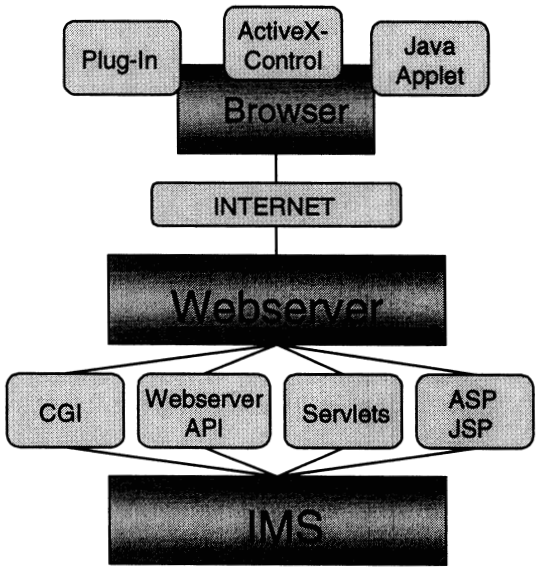


Figure 2. GIS linkage to the WWW – on the client side

2.2.1 Plug-Ins. Plug-Ins are additional applications which have to be installed on the client side to extend the functionality of the Netscape webbrowser. The manufacturer of the IMS provide plug-ins mostly for free. E.g. to display vector data with a webbrowser a plug-in is required. The user loads the plug-in and installs it on his or her PC. A plug-in which is stored on the local harddisk has access to the system resources of the client. This can cause security problems. There is no problem if the user trusts the supplier of the plug-in. User who visit a web page only once may refuse to load and install the software. There is a problem of versions and distribution: plug-ins have to be maintained and new versions have to be distributed. Downloading can be automated (Zhong-Ren, 1997).

2.2.2 ActiveX-Controls. ActiveX from Microsoft is based on the Object Linking and Embedding (OLE)* standard and extends the functionality of Microsoft's webbrowser (Internet Explorer). An ActiveX-Control is a software component which executes tasks. It is able to communicate with other programs. ActiveX-Controls are comparable with plug-ins. But plug-ins are specific for browsers and ActiveX-Controls can be used in the Internet Explorer as well as in programming languages or applications which support OLE. ActiveX-Controls are embedded in HTML-code and after a request they are downloaded from the server and automatically installed at the client PC. The user gets for security reasons a certification from whom the ActiveX-Control is delivered. Downloading can be automated. For every different data type an ActiveX-Control has to be created. ActiveX-Controls are restricted to the Microsoft Windows operating system (Zhong-Ren, 1997, ActiveX, 1999).

2.2.3 Java Applets. Applets are invoked in a HTML-document and executed in a webbrowser on the client side. After a request applet class-files are downloaded from the server and executed on the client PC without interaction from the user. For security reasons an applet can generally only access the server from which it was downloaded and no system resources of the client. There is no problem of versions or distribution because the user always gets the up-to-date applet from the server. With Java Database Connectivity (JDBC) and JDBC-ODBC Bridge an applet can access a database for example. Java applets are platform independent (Zhong-Ren, 1997, Applets, 2000).

2.2.4 Summary. When using plug-ins as extension for browsers the user has normally to download the plug-in once and install it locally on his or her PC. The browser extension with applets is more comfortable for the user – the applet is loaded automatically with the invocation of the respective HTML-page and executed on the user's computer. The transmission of the application additionally to the data (e.g. geo data) involves additional net load. Applets are thus favoured for: small applications, often changing applications, occasional users. Plug-Ins offer advantages in large applications which are used often.
ActiveX-Controls have the disadvantage that they are restricted to Microsoft's operating system and Internet Explorer.

* OLE: Object Linking and Embedding - Communication standard for Microsoft based applications

3 TYPE OF TRANSFERRED GEO DATA

A decisive question for using GIS in the Internet is the form of data (vector or raster) which is used to transfer the data to the client. In principle it is possible to use raster as well as vector data. It should be mentioned that the transfer format is independent from the format the data is stored on the server. In most applications geo data is stored as structured objects in form of vector data in a proprietary format. For the data transmission to the client the map is converted in raster or a suitable vector format.

When raster data is transferred a standard webbrowser without extension can be used since webbrowsers can display GIF and JPEG. Only a kind of screenshot in form of a raster image is send to the client. That means the data on the server has to be converted to a raster format. The data volume is due to the known image size of X * Y pixels estimable and the original data on the server is safe as only an image is sent to the client. A disadvantage of using raster data is the lack of comfort of handling. Single objects cannot be highlighted by moving over them with the mouse. In addition a server contact is necessary per each request from the client but with a high performant infrastructure, e.g. Intranet, that does not cause problems.

Vector data can handled only in a standard webbrowser with extended functionality (e.g. using plug-ins). The user gets a more comfortable handling with vector data. For example single objects can be selected directly or highlighted. One more advantage using vector data is the possibility of local processing, it is not necessary to contact the server per executed browser action. Disadvantages of vector data are manufacturer dependence as well as changing data volume because the amount of data can vary depending of the selected area. Transferring vector data may endanger the copyright of the owner of the original data, since with tricks a user could store the transferred data locally.

Basically the presentation at the client can be realised with vector as well as raster data. The choice of the transferring data form (vector or raster) should consider the application and the existing infrastructure. Software products which offer optional transferring of vector or raster data may provide advantages. They may allow a preselection with raster data and afterwards loading of the actual vector data with the possibility of subsequently processing locally.

Different consortia develop future standard formats for transferring data over the Internet. The Open GIS consortium for example presents GML (Geography Markup Language). GML shall enable the transport and storage of geographical information in XML (Extensible Markup Language – universal format for structured documents and data on the web). Geographic information includes both properties and the geometry of geographic features (www.opengis.org). The World Wide Web Consortium (W3C) submits Scalable Vector Graphics (SVG) which is a language for describing 2-dimensional vector and mixed vector/raster graphics in XML (www.w3.org). In the next years we will see if one or more of these proposed languages become a standard which is used by the commercial GIS Internet Map Server.

4 SELECTED INTERNET MAP SERVERS

In this section we give an overview on nine of the most common commercially available Internet Map Servers. Table 3 includes the following information:

- Type of transferred geo data
- Used technique for the linkage to the webserver (Microsoft Internet Server API is abbreviated with ISAPI and Netscape API is NSAPI)
- Available platforms of IMS
- Necessary browser extensions for presenting vector data
- Offered data interfaces

More information on these IMS can be found on the web pages of the GIS companies (ArcView IMS, 1999, GeoMedia Web Map, 2000, GeoMedia Web Enterprise, 2000, MapGuide, 1999, MapObjects IMS, 1999, MapXtreme, 2000, SICAD IMS, 1999).
The overview of the Internet Map Servers shows that similar architectures are used. The product suite contains:

- IMS as out-of-the-box but customisable and expandable tool
- IMS as development environment

All IMS offer basis functionality like zoom, pan and attribute query. Additional functionality like e.g. complex GIS analysis has to be programmed. At the time the IMS are tailored for queries and visualisation of data respectively

presentation of analysis results. The type of transferred data format to the client is both raster and / or vector data. When deciding for an IMS one should pay attention to the offered data interfaces to use existing geo data without problems.

IMS	Type of transferred geo data	Linkage to webserver	Platform of IMS	Browser extension	Data interface
ArcView IMS 1.0a (ESRI)	Raster	ISAPI, NSAPI	UNIX, WIN 95, WIN NT	not necessary, applet *	Shapefiles, Coverages, SDE Layer, ...
MapObjects IMS 2.0 (ESRI)	Raster	ISAPI, NSAPI	WIN 95, WIN NT	not necessary, applet *	Shapefiles, Coverages, SDE Layer, ...
ArcIMS 3.0 pre-release (ESRI)	Raster, Vektor (internal ESRI format)	CGI, ISAPI, NSAPI, ASP, Servlets	UNIX, WIN NT	applet	Shapefiles, Coverages, SDE Layer, ...
SICAD Internet Suite Millennium Ed. IMS (SICAD Geomatics)	Raster	CGI	WIN NT	not necessary, applet *	SICAD Vector data, Raster formats
MapXtreme NT Vers. 2.0 (MapInfo)	Raster	CGI, ISAPI, NSAPI, ASP	WIN NT	not necessary, applet *	MapInfo format map, Raster formats
MapXtreme Java Vers. 2.0 (MapInfo)		CGI, ISAPI, NSAPI, Servlets	WIN NT, UNIX, ...	applet	
MapGuide 4.0 (Autodesk)	Raster, Vektor (MWF)	CGI, ISAPI, NSAPI	WIN NT	plug-in (Netscape), ActiveX-Control (Microsoft), Java viewer	Shapefiles, Coverages, DGN, MapInfo, ...
GeoMedia Web Map 3.0 (Intergraph)	Raster, Vektor (Active CGM)	ASP	WIN NT	Plug-In (Netscape), ActiveX-Control (Microsoft)	MGE, Shapefiles, Coverages, Map Info, FRAMME, Oracle SDO, Access, ...
GeoMedia Web Enterprise (Intergraph)					

Table 3. Selected Internet Map Servers
(* applet for more comfortable handling)

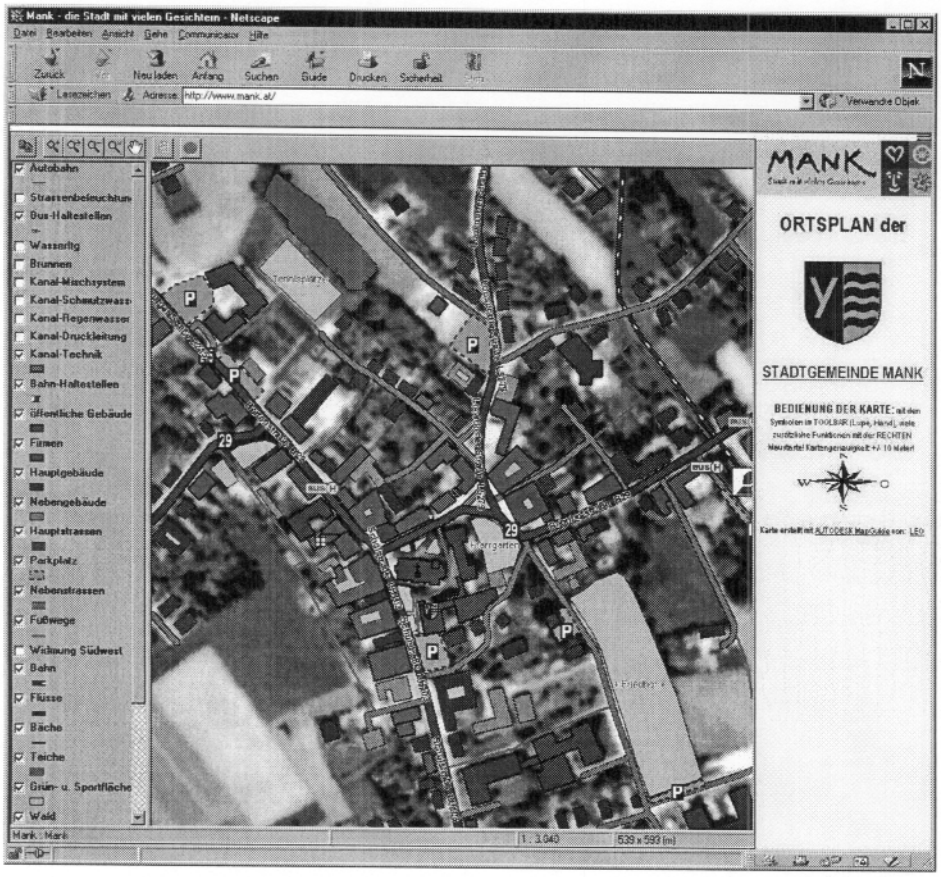
5 APPLICATION EXAMPLES

In the meantime Internet Map Servers have entered many fields of applications. In general they are used to provide applications which allow for database queries and the visualisation of the results. These applications are used in various fields like:

- Tourism Information Systems
- Interactive visualisation of statistical data
- Site locator („Find the next ATM, shop, ...“)
- Traffic Information Systems
- Fleet management

Further fields of applications are described in (Reinhardt, 1999). Figure 4 gives an example of a City Information System (Tourism Information System) which uses Autodesk MapGuide. In this application vector and raster data (here:

aerial photograph) can be handled. With this application at first an overview map of Austria is presented. For the orientation of the user major rivers and federal countries are presented. With the zoom function (upper icon line) one can e.g. zoom in to the city of Mank. The smaller the selected region the more themes are shown in the map ("logical zoom"). The themes can be switched on and off in the toolbar on the left side. Figure 4 shows a view in which among others information like street name and house number for a single house are displayed or the name of bus stops and the according bus lines. After a double mouse click on a building (e.g. a hotel) the corresponding web page (if available) is invoked.
Besides the functionality already mentioned the application offers tools for distance measuring, buffer zone calculation and a print functionality which plots a map in a specific scale with a map title, a north arrow and a legend.



Various GIS Web applications based on other GIS products could be found on the Internet sites given below (references).

Figure 4. Example of a City Information System (www.mank.at)

6 CONCLUSIONS

This paper presented basic web technologies and currently used GIS-Internet architectures. The overview of these IMS shows that similar architectures are utilised at present in commercial IMS's. A general rating of the different technical implementations cannot be given because it depends on the kind of application and the existing infrastructure.

All major GIS companies have realised the possibilities of GIS on the Internet and accordingly offer Internet mapping products. Using standard Internet technology in general allows for cost-efficient and rapid access to geo data as well as the development of easy to use user interfaces. The end user do not necessarily need to buy a complex GIS system to work with geo data. The presented product palette is a first step in the development of GIS in the Internet. Future developments will use the potential of the Internet for flexible and interactive GIS applications in a higher degree.

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