DEVELOPMENT OF COASTAL MANAGEMENT INFORMATION SYSTEM FOR MAHARASHTRA STATE, INDIA – A MAPSERVER BASED OPEN SOURCE APPROACH

Ravinder Dhiman1, Arun B Inamdar2, Labanya Banerjee3
1 Research Scholar, Centre for Urban Science and Engineering
Indian Institute of Technology, Bombay, India, rdhiman@iitb.ac.in
2 Professor, Centre of Studies in Resources Engineering
Indian Institute of Technology, Bombay, India, abi@iitb.ac.in
3 GIS Analyst, University of Texas,
Dallas, USA, labanya.iitb@gmail.com

KEYWORDS: Web GIS, Coastal resource, shoreline, stakeholders, Mumbai

ABSTRACT

Coastal resource management is a significant component of sustainable development of the dynamic coastal zone in Maharashtra state harboring coastal megacity Mumbai, rich biodiversity and other important coastal features located on the west coast of India. Different stakeholder requirements and conflicts about coastal resource planning demand a systematic approach to fill a critical gap on the subject of information, knowledge, data and GIS services contributing to planning and implementation of the strategic shoreline management plans in the state. In this context, present paper discusses an open source Web GIS framework namely CMIS (Coastal management information system) which was designed to integrate data, knowledge and GIS mapping services. CMIS is developed using Mapserver application open source platform and p.mapper framework for widespread functionalities and configurations based on PHP/Map Script. It is based on the usage of summative evaluation among different coastal experts. CMIS consists of three key components – First, Data Centre houses different datasets for expert stakeholders e.g. bathymetry, beach profile, tides etc.; second, Knowledge Centre is developed for common stakeholders containing downloadable reports relevant to coastal information and development projects; third and last, Web GIS based online mapping tool called CMIS Online is for assessment of coastal resources. CMIS online is a GIS based dynamic mapping application, served over the internet which comprises various coastal features as dynamic layers including common GIS functionalities like zoom, panning, measurement and spatial queries etc. This paper describes the methodology of development and implementation of CMIS as a prototype and how it will continue in the future as an open ended process.

1. INTRODUCTION

All stakeholders require a validated information system that would aid them in managing their work and in turn should help manage and develop the Maharashtra Coast in a sustainable manner. So, the coastline has an enduring requirement for an efficient and effective web based Management Information System that can address the present and future requirements of all associated coastal experts and stakeholders. In an initial attempt to assess the expectations from Coastal Management Information System (hereafter CMIS), views were sought from several coastal experts and decision makers from all four coastal districts of the state during requirement analysis phase. The very common requirements were 1) the need of an integrated system inclusive of data and knowledge under one umbrella, 2) need for an interactive interface, a dynamic themed map containing the various coastal features as its layers available via internet, and also the 3) need for a query-able, themed, dynamic map made GIS as inseparable part of this system. Since this GIS based framework had to be served over the World Wide Web, the concept of Web GIS was introduced. After the initial requirement analysis, CMIS was designed as a Web GIS based system comprising two other silos of data and knowledge which would aim at being a complete solution to all Maharashtra coast related queries. Novelty of this research is the open source Web GIS component of the system and rich collection of useful data. Web GIS or web based GIS is a term coined to define the use of GIS for spatial analysis, querying and visualization of large-volume data served through internet. The use of open source Web GIS has made it possible to graphically represent all the important aspects of the Maharashtra Coast. GIS facilitates in bringing the whole coast to the computer screens of the users and making it web enabled has removed all geographic and time bound limitation which otherwise could have been an obstacle for the users to explore CMIS completely. Coast being the meeting place of land and water, is one of the most fragile and precious natural resource. Sustainable development and protection of the coastline necessitates timely decisions and accurate management. This well known fact was further emphasized when feedback was collected from coastal engineers and experts. To aid in this process of decision making and management, a lot of entities contributed, most distinguished among them are raw data, compiled reports and an

emerging technology which allows spatial and geographic features to be studied, analyzed and displayed using GIS. Thus, as an integrated outcome, a Coastal Management Information System (CMIS) is proposed to be developed for the coast of Maharashtra. The major objective of this research is to come up with a Management Information system for the Coast of Maharashtra which can be used by decision makers and stake holders, effectively.

2. LITERATURE REVIEW

The coast represents one of the most important boundary zones on planet earth, making the dynamic three way interface between land, sea and the overlying atmosphere. These three very distinct but interlinked environments meet at the ever changing line of the shore. As a linear feature, the coastline in principle occupies no area, yet it has enormous significance due to its proximity to the vast majority of population, its role in biodiversity and its importance as the source of marine degradation. The coast can be seen as a cultural and conceptual frontier, representing a transition zone between the known and the comparatively unknown (Carter, 2013). Hence development of an information system for coastal zone management and deploying it over the internet would help in bridging the knowledge gap. Because of its dynamic nature the coastal system is one of the most hazardous locations to live in, flooding and erosion being the most dangerous among them. These reasons have led to the rise of Integrated Coastal Zone Management (ICZM), a framework that can help man live harmoniously with nature (Carter, 2013). For ICZM, data will form a spatial component, and GIS has obvious relevance to this task, and has the potential to contribute to coastal management in a number of ways like: i) ability to handle larger database and to synthesize, integrate data from a much wider range as compared to manual methods, ii) development and use of standards for coastal data definition, collection and storage, which promotes compatibility of data between projects and departments and consistency of approach at any one site over time (Kennedy-Smith, 1986; Bartlett et al., 2000). In the mid-1960‘s, Roger Tomlinson recognized that digital computers could be used quiet effectively to map out and analyze the vast quantities of information being generated and collected. One of the conclusion of the initial effort was the decision that computerization was going to be the best alternative for developing management plans out of the generated data. Based on geospatial data base and supported by the computer hardware and software, it carries out collection, management, operation, analysis, simulation of spatial data in real-time and provides spatial and dynamic geographic information. Because GIS has the strong function of data analysis and spatial analysis, it is closely applied in all aspects of Management Information systems, in this case for the coast (Rubio & Haihong, 2010). Since the spatial data are large in size, integration of GIS data with the map is a challenge for GIS developers. In the conventional process, every time the request will be processed by the server and the response is sent back to the client. Since this is a time consuming process, the performance of the system will not be good. To address this issue, the AJAX was introduced to integrate with the GIS web service. By integrating AJAX with GIS web services, the map and the spatial data can be loaded efficiently into the client browser and loading time can be minimized. GIS web services are self- contained, self- described modular component of geospatial application which can be accessed through standard protocols. GIS web services can be applied to various applications like Geomarketing, construction and coordination, eGovernance, natural resources, urban planning, emergency response etc. Its approaches are used to propagate, share and access geographical information. AJAX is an approach for interactive web applications, which can retrieve data from the server asynchronously in the background without interfering with the display and behavior of existing page (Sakairi et. al., 2008).Since GIS data will be loaded from various locations, loading and integration of GIS data with the map is more complex, besides reloading of map and data in the browser takes more time. To solve these problems, an architecture which encompasses AJAX technology integrated into GIS Web Services is used. OGC recommendation (OGC, 2007) in GIS web service includes three fundamental elements known as Web Map Service (WMS) (Yuan & Bian, 2007) (Long et. al., 2008) for creation of map application visualized by the web browser. Web Feature Service (WFS) is for client to make web based access to the geo data in the form of GML (Geographical Markup Language). Web Coverage Service (WCS) is for continuous stream of GIS data processing. The main challenges of geospatial data are, bulky size, complexity during loading at client side, delay in reloading and rendering, heterogeneity, multiple sources and locations for complex problems (Tu & Abdelguerfi, 2006).

3. STUDY AREA

The Coast of Maharashtra popularly known as Konkan is the area for which the Information System has been developed. The Konkan coast has a large coastline covering an area of 700km, not only it is long, but also has a population of 2,48,07,357 people (Census, 2011). It is also a home to exotic flora and fauna, busy ports and beautiful tourist locations. Konkan constitutes a narrow belt between the western mountain range (regionally

known as Western Ghats) and Arabian Sea about 720 km from the River Tapi in the north up to the River Terekhol in the south and encompasses five districts viz. Thane, Greater Mumbai, Raigad (earlier Kolaba), Ratnagiri and Sindhudurg (earlier was a part of Ratnagiri). The coastal zone of Maharashtra extends from latitude 15°43'N to 20°10'N and longitude between 72°39'E to 73°30'E. In the north of Mumbai, it is wide up to 100 km, which gradually narrows towards south and near Vengurla, it is hardly 40 km. The coast is indented with number of beaches, 15 rivers, and five major estuaries with over 30 backwater regions. According to the surveys by the State Government agency, the total area of all the coastal districts is 30645.5 km^2 comprising built up land (1.58%), agricultural (44.14%), forests (19.48%), wastelands (28.72%), waterbodies (4.13%) and land under grasslands, mining areas and saltpans (1.95%) (Figure 1). In spite of so much prominence and importance, surprisingly the Maharashtra coastline did not have any information system that would be a repository of Data and Knowledge about the coast.

4. MATERIALS AND METHODOLOGY

4.1. Data Used

The data used in CMIS has been collected from two sources, Maharashtra Remote Sensing Application Center (MRSAC) and Maharashtra Maritime Board (MMB). A considerable amount of processing has been applied to the data received from the MRSAC to bring it into best suitable form for CMIS. The data available in the Data Centre page of CMIS has been procured and processed by MMB. Since this data set will be made available for download to the visitors of the site, care has been taken that it is supplied in a format that is easy to download, save and explore. While most of the data has already been collected, processed and made available in the aforesaid format, the process is being continued for the rest of the data set. Unlike Data Centre, Knowledge Centre houses some pre-compiled reports. The Knowledge Centre has two parts, the first one is the Web GIS based Service and other one is a rich database of reports and lists about the various projects going on along the Maharashtra coast. Table 1 provides a list of available data in the Data & Knowledge Centre pages respectively. Preprocessed and validated datasets in ESRI shapefile format (.shp) is used in CMIS online interface and enlisted as different layers in the ToC (Table of Content) section at pmapper window (Figure 5). The datatype is vector in forms of line, point and polygons for different feature classes (Table 2).

4.2. Software Used

Mapserver, Apache Server, P.mapper, ArcGIS, NetBeans IDE

4.3. Methodology

CMIS is designed on the basis of Three-Tier architecture to make all the layers and components independent. Major advantage of this architecture is it allows to run any tier independently on different machines. This three tier architecture houses presentation layer containing presentation logic, business layer containing business logic and data layer containing data access logic. Presentation layer represents client side whereas Business and Data layer are located at server side and all are connected bidirectionally with another database server (Figure 1).

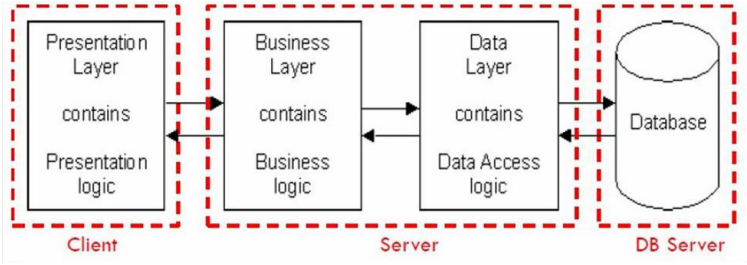

Figure 1 Three Tier Architecture of CMIS (Source: Manos Papagelis, 2012)

The input to this model follows a top down technique while the output follows a bottom up one. User sends the request through the web browser, which is a component of the top most layer or the Presentation Layer. The request is then passed on to the middle layer where the complete business logic of the application is stored, this layer analyzes the request and decides on which module must be invoked to serve this request, and the data input required. Based on this assessment, the Data access layer is requested for the data required to process the request. On receiving the request, Data access layer reverts back with query and Business logic layer

runs the algorithm for that particular module, performs required calculations and comes up with a solution for the query. Once the result is obtained by the Business logic layer, it is passed on to the Presentation layer. It is now responsibility of the Presentation layer to convert this result into an appropriate format so the end user can appreciate it. The web browser (a component of the Presentation layer) fulfills this task by employing two emerging technologies of JavaScript and AJAX. It is only on successful connection and communication between the three components of this model, the system runs smoothly. Making the three layers logically connected and physically separated takes care of the speed of the system. Also since all the modern web browsers today come with in-built plug-ins for JavaScript, the user can have an access to high quality services, on the fly, without having to download or install anything (Manos Papagelis, 2012). CMIS functions using support from many servers, which includes GIS server, web server etc. The OGC has stringent specification for every GIS based server that is used for rendering dynamically generated maps over the internet. During the development of CMIS, care was taken to see that all the services provided by this system are OGC compliant. The Open Source community is very active when it comes to Geospatial technologies; they function under GNU Lesser General Public License (LGPL) and GNU General Public License (GPL), where the source codes of their projects are available for modification and redistribution by General Public (GNU General Public License, 2013). The open source GIS product that has been adopted in the development of CMIS is MapGuide Open Source which is a web based platform that facilitates quick development and deployment of web mapping applications and geospatial web services (MapGuide Open Source, 2012). It also features an interactive viewer that includes support for functions such as feature selection, attribute display, map-tips and operations such as buffer, select by radii/polyogon and measure. It supports all latest and popular geospatial file formats, data bases and standards. It can be installed on both Windows and Linux and supports Apache and IIS web servers. It offers extensive PHP, NET, Java and JavaScript API‘s for application development. MapGuide Open Source is licensed under LGPL. Microsoft Windows has been selected as the major platform OS on which CMIS is developed. MapGuide is basically a CGI program which is a Common Gateway Interface of standard set of rules for running scripts and programs on the web server. It specifies what information is communicated between the Web Server and the client‘s Web Browser. Such files are known as CGI scripts, they are written using Java Script. When a request is sent to the MapGuide, it uses information passed in the request URL and the Mapfile to create an image of the requested map. The request may also return images for other mapping tools like legends, scale bars, reference maps etc. The values are then passed through the CGI variable replacement technology, to the client browser.

5. RESULTS

A dedicated homepage (Figure 2) costal management information system for Maharashtra coast with all required capability and features has been developed inclusive of a web interface with three major silos and some other common links on the webpage like events, report a problem, gallery, CMIS logo on top left corner and contact us etc. Home link is the first webpage displayed on the request of the browser showing the brief description about the project and login, registration facility for the expert/stakeholder. Link to GIS Portal is connected to the CMIS online, which is the dynamic mapping application tool with major required GIS functionalities. It displays the GIS based political map of India and Maharashtra coastline with a set of GIS enabled layers. A detailed element based description of CMIS has been shown in figure 3 which includes 1) a map, 2) list of layers, 3) reference map, 4) legend, 5) scale bar and a basic GIS toolbar.

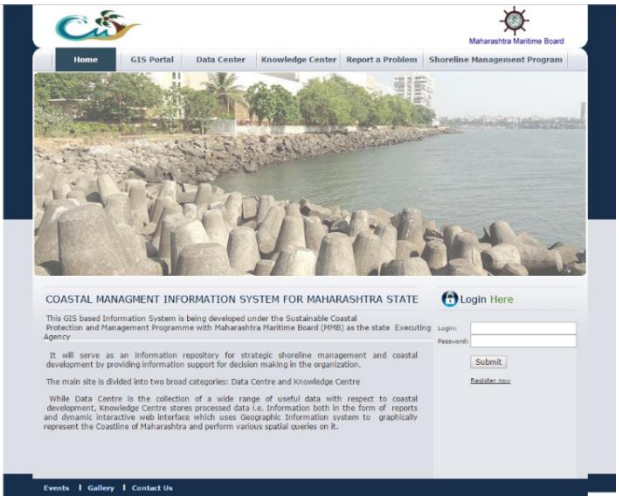

Figure 2 Homepage of CMIS

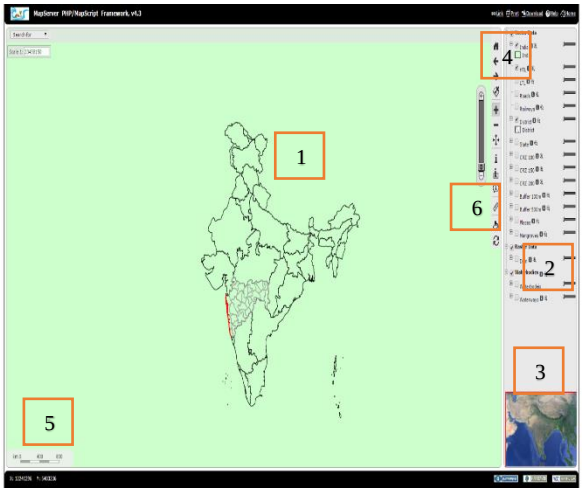

Figure 3 Elements of CMIS

CMIS online supports all basic GIS functionalities like home, back, forward, zooming, panning, refresh map, select, identify, measurement, layer transparency and custom scale etc. in a user friendly manner. A detailed description with examples of major functions is shown in figure 4.

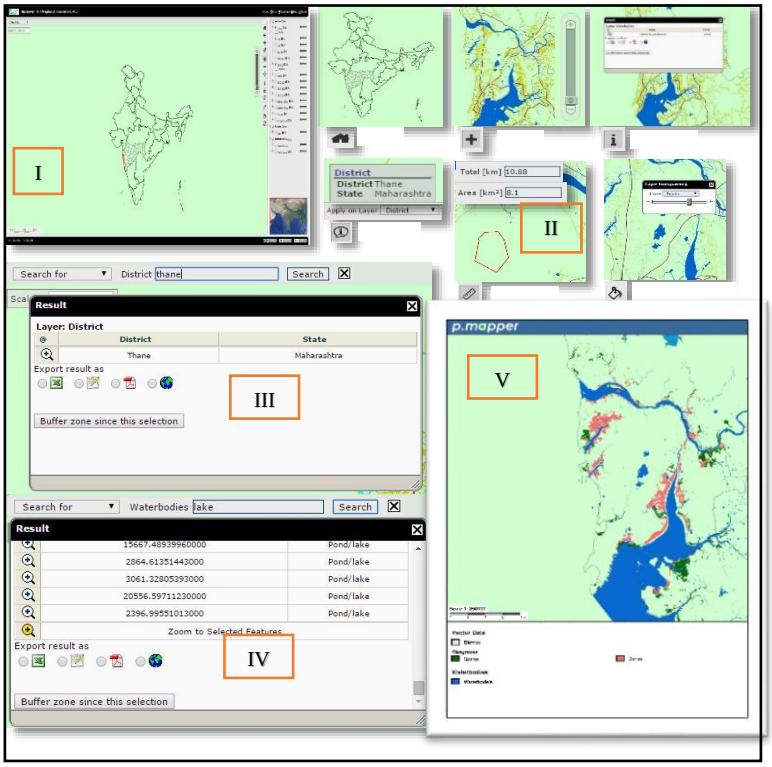

Figure 4 Functionalities - I) Interface, II) Functions, III) Query, IV) Results, V) Map

Next link on CMIS homepage is Data Centre, which is a repository of various datasets related to coastal features available for all stakeholders for free of cost in .docx, .xslx and .pdf file formats. This data collected by field visits and validated by MMB has been uploaded on the site with no further changes. Data has been arranged in different categories of location specific and data types to improve the user interaction. Knowledge Centre is linked next to Data Centre which serves the purpose of storing the processed and analyzed data in format of downloadable reports as per the user requirements. It includes the ready to use information for beginners and experts as well, in coastal domain. User can visualize and study the reports about clearance procedure of coastal projects, ongoing projects and programs in particular areas, past, pending and cleared projects, to maintain the transparency and other important information about coastal villages of Maharashtra. For the Sustainable Coastal Protection, and Management Investment Program (SCPMIP), Shoreline Management Organizations (SMO) will be established at each project site. Other silent features of this projects are – historical database management of fisher folks and coastal villages, statistics of fishing and census of these coastal communities, some important links to other relevant sites of Geo-portals by ISRO, Water Resources of India, National Wetland repository etc. Users can report a problem related to their query, data or any other associated issue by using the direct link which will be headed towards the administrator of the server and further, it will be forwarded depending upon the nature of the problem to various experts involved in the program.

6. DISCUSSION AND CONCLUSION

Authors have discussed the used technologies and their significance for CMIS in this section. The CMIS system is based on WebGIS technology which has the applications into all fields of the society and has expanded from the fields of traditional natural resource management to more commercial domains like traffic, healthcare etc. Development of an information system is a multidisciplinary approach and needs synchronization among many processes. Moreover, it's a continuous process, especially CMIS, which represents the dynamic shoreline as GIS layers. It can never be complete, as user's expectation and requirement from the system will change with the changing coastal features of the state. So CMIS will continue to be developed and modified. The Data Centre of CMIS stores coastal data collected by visiting each coastal location. Moreover, climate also plays an important role; some particular type of data may be available during monsoon while some other data

may be missing. While the structure has already been prepared, the storage capacity has to re- designed to accommodate the amount of data that will be generated. At present, CMIS Online link contains only vector layers, its capabilities can be extended in the future by accommodating raster images such as aerial photographs/satellite images of the area under study. Increasing the number of queries that can be addressed is yet another area which needs to be enriched in future. The spatial queries addressed currently, work on one layer at a time, the system can be extended to work on multiple layers. Since, at present, the system does not deal with an extensive number of layers, 'Pre Caching' or 'tiling' of layers has not been performed. Pre Cached or tilled layers will be absolutely necessary when the number of layers increases, it will help in maintaining the speed of the application. The field of WebGIS is advancing at an amazing pace and present design of CMIS tries to use the technologies currently available that best suit the present requirements of CMIS. The servers and API's used in developing CMIS must be updated and is required to be changed at regular intervals to improve its performance.

CMIS Online is the main attraction of the system; it is the WebGIS based mapping service where dynamic, GIS enabled layers are used to represent various coastal features. These layers can be turned on/off, overlaid on each other etc. Displaying attributes of selected feature classes, buffer analysis are some of the functions it performs. "Report A Problem" and "Shoreline Management Program" are two more important aspects of the system. The former one is a form based interface for the common man to communicate his coast related problems to the MMB authorities by answering some simple questions accompanied by a brief description of the problem and a photograph, if possible. The major objective behind development of CMIS is Sustainability, the capacity to endure. By using CMIS significantly, the stakeholders and decision makers can aim at better coastal protection and sustainability. CMIS wishes to make its users realize that coastal protection and management is not just protecting the sea and shoreline, but go beyond that and explore the untapped opportunities offered by the dynamic shoreline and sea.

REFERENCES

1. ArcGIS, E. S. R. I. (2012). 10.1. *Redlands, California: ESRI*.
2. *Ashwini Otta. (2013). Sustainable Coastal Protection and Management Program Maharashtra. 2nd Stakeholders' Workshop*
3. Bartlett, D. J. (2000). Working on the frontiers of science: applying GIS to the coastal zone. *Marine and coastal geographical information systems*, *1*.
4. Bray, R. (2008). MapGuide open source. In *Open Source Approaches in Spatial Data Handling* (pp. 131-152). Springer Berlin Heidelberg.
5. Carter, R. W. G. (2013). *Coastal environments: an introduction to the physical, ecological, and cultural systems of coastlines*. Elsevier.
6. Kennedy-Smith, G. M. (1986). Data Quality-A Management Philosophy. In*Proceedings of Auto Carto London* (Vol. 1, p. 381).
7. Li, Z., Hui, L., & Bing, L. (1998). Geographic information system in the Internet age. *Acta Geodaetica et Cartographica Sinica*, *27*(1), 9-15.
8. License, G. G. P. (2007). Version 3. *Free Software Foundation. http://www.gnu.org/copyleft/gpl.html*. [May, 13, 2016].
9. Long, K., Liu, Y., & Luo, X. (2008, October). Emergency Accident Rescue System in Freeway Based on GIS. In *Intelligent Computation Technology and Automation (ICICTA), 2008 International Conference on* (Vol. 2, pp. 247-250). IEEE.
10. M.Papagelis. Web App Architecture. http://queens.db.toronto.edu/~papaggel/courses/csc309/docs/lectures/webarchite ctures.pdf [Dec. 15 2015]
11. *Maharashtra Maritime Board. Internet: http://www.mahammb.com/, [May. 22, 2016]*
12. *Open Geospatial Consortium , Internet: http://www.opengeo-spatial.org/,2007 , [Sep. 2015]*
13. OSGeo, F. D. O. (2010). Feature Data Objects (FDO) Data Access Technology. Open Source Geospatial Foundation.
14. Ruibo, J., & Haihong, X. (2010, October). Design and implement on Distribution Information Management System based on WebGIS. In *2010 International Conference on Computer Application and System Modeling (ICCASM 2010)* (Vol. 11, pp. V11-129). IEEE.
15. Sakairi, T., Tamada, T., & Nakata, H. (2008, August). GIS Crisis-management systems using Ajax technology. In SICE Annual Conference, 2008 (pp. 3043-3046). IEEE.
16. Sheppard, E. (1995). GIS and society: towards a research agenda. *Cartography and Geographic Information Systems*, *22*(1), 5-16.
17. Stojanovic, D., & Djordjevic-Kajan, S. (2001). Internet GIS Application Framework for Location-Based Services Development. *Proc. 7th EC-GI*.
18. Tao, Z. H. O. U. (2003). The implementation and development of WebGIS.*Journal of Xinyang Teachers*

College (Natural Science Edition), *1*, 033.
19. Tu, S., & Abdelguerfi, M. (2006). Web services for geographic information systems. *IEEE internet computing*, *10*(5), 13.
20. Yang, C., Wang, Y., Wang, X., Dong, P., & Liu, D. L. (2001). Review of the main technologies of WebGIS. *Journal of Image and Graphics*, *6*(9), 886-894.
21. Yuan, Y. I. N. G., & Bian, F. (2007, September). An open sharing and interoperating platform for spatial information based on GIS web services. In*2007 International Conference on Wireless Communications, Networking and Mobile Computing* (pp. 5943-5946). IEEE.
22. Zhang, S., & Kang, Z. W. (2006). Design and Implementation of .NET-based WebGIS System. *Computer Engineering*, *8*(5), 106.