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Internet based environmental monitoring information system and its application in Yili Prefecture

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Abstract: With the development of Internet technologies, Internet Based Information System (IBIS) arises with more advantages: Firstly, it is convenient for users to use owing to the introduction of Internet technologies. Secondly, it benefits greatly the data dissemination and data sharing based on Internet. The most important but not the last is that we can establish the information service network supported by its technologies and the facilities of information highway. So, it would be significant to design IBIS to realize the data collection, sharing and dissemination on Internet. There are many factors affecting regional environment. So it is not easy to realize the integrated environmental monitoring. Given this, we designed the Internet based environmental monitoring information system. By the virtue of the Internet based environmental monitoring information system, the management and storage of environmental monitoring data would be easier, which lays the foundation to actualize the environmental monitoring efficiently.

Key words: environmental monitoring; GIS; information system; Internet; Web GIS; Yili Prefecture

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1 Introduction

Traditionally, data structure is mainly classified into two kinds: vector and raster. The data storage, management and updating are huge tasks in the implementation of information system. How to deal with the difficulty that common web Browser cannot display the vector data supported by GIS, and how to implement updating and dissemination of vast amount of data for the IBIS are two urgent questions to be solved (Chen *et al.*, 2000; Li and Gong, 1998; Luo and Lu, 1999; Yuan and Gong, 1997). Under such macro background, the design and implementation of IBIS have become the focuses to be discussed in GIS industries and research fields.

The main question to be solved is that the Browser cannot support and display the vector data while GIS does most of its spatial analyses based on vector data (Gong and Yuan, 1998; Zhang, 2000). Therefore, a new method should be put forward to actualize GIS function based on Internet, i.e., to have the Browser support vector data. At present, there are two kinds of technical methods to deal with such questions: one is to be solved on Client side; the other is to be solved on Server side (Liu and Liu, 2000). The former is to plug in plug-in modules or controls in order to expand the function of Browser and make it support the vector data and offer methods and property to change the display capabilities; the latter is to use the relative software on the Server and to realize the transformation from vector format to GIF or JPEG format supported by Browser, then to transfer them to Client while request from Client can be transferred to Server by Common Gateway Interface (CGI) or Active Server Page (ASP). In recent years, most international GIS software providers have pushed out Server platforms based on Internet/Intranet and using HTML Browser to offer the mutual information function of spatial maps. Taking the design and

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implementation of Internet Based Environmental Monitoring System of Yili Prefecture as an example, we analyzed the techniques to design and implement IBIS as well as applied it to monitor and assess the environment of Yili Prefecture.

2 Methods

We applied MapXtreme, a Web GIS map application Server based on Internet/Intranet, to design and implement the Internet Based Environmental Information System of Yili Prefecture. By integrating the functions of MapInfo and MapX, a well known GIS software, users can access MapXtreme based on Browser by Internet/Intranet technologies and gain the GIS functions provided by MapXtreme such as map display, zoom, pan, accessing the information of maps, drawing thematic maps, carrying out geographical analyses and so on (Liu and Liu, 2000), which, in some sense, can meet the requirements of dynamic environmental monitoring and analyses.

During the development of Web GIS applications using MapXtreme, the developers can focus on the control and maintenance of maps and database and the implementation of map application, which make MapXtreme adaptable to the organizations with large amount of information and users. Furthermore, to use Web Browser as an interface on the Client of MapXtreme application benefits the combination of GIS and other systems and brings a united and integrated information system for users.

2.1 Hierarchical structure

There are three levels in a classic MapXtreme system. The top level is Internet technology, in which the well-developed TCP/IP technologies and CGI, HTML standards have been adopted to guarantee its standard, openness and advance. The bottom level is map platform "MapInfo Professional" and MapX controls based on ActiveX (OCX). After more than ten years' development, MapInfo Professional has became stable and flawless in acting as the kernel of spatial database; MapX, in some sense, is an OCX control with abundant mapping functions and offers a lot of components based on Objective Linking and Embedding (OLE) technologies. MapXtreme is situated in-between the two levels. As a new module of map application function in Server, it adopts many kinds of new technologies containing built-in development tools, distributed application modes, etc. That is, MapXtreme basically does not change the original GIS system functions on Server and almost bears all the analytical functions on Client.

2.2 System's characteristics

MapXtreme realizes its central management of software and data in Server, which greatly reduces the consumption of management and maintenance. Making use of the continuity of MapX and SpatialWare, developers can develop a three-layer spatial information serving system, i.e., Web Browser—MapXtreme—Spatial Ware.

MapXtreme offers a complete set of tools for the application development of Web GIS based on Internet/Intranet. MapXtreme combines MapX, ASP and other technologies to compose an integrated Web GIS solution. ASP application Server and WebSite development tools offer a complete set of kit to develop Web GIS application system. MapXtreme uses the common data interface to access attribute database (SQL SERVER, Oracle and so on) such as ODBC, DAO and OLE Data interface.

The opening structure of MapXtreme makes it work in Web Server. In addition, MapXtreme can display maps in the Web Browser of PC or Unix with special Plug-ins.

MapXtreme offers an all-around and powerful map function to meet users' requests including thematic mapping analyses, buffer analyses, object editing, target searching, accessing Lotus Notes, map displaying, layer control, spatial query, accessing all kinds of attribute data, etc. MapXtreme can represent and analyze data using thematic maps and support greatly the creation of thematic maps.

3 Design and implementation

3.1 Yili Prefecture

Yili Prefecture lies in the western part of Xinjiang Uygur Autonomous Region of China, ranging from

42°14'16''N to 44°50'30''N and 80°09'42''E to 84°56'50"E. It extends 350 km from east to west and 280 km from south to north. The total area amounts to 56,148.83 km^2. It neighbors Bayingolin Mongolia Autonomous Prefecture to the east and Kazakstan to the west with a borderline around 390 km. It borders Aksu Prefecture in the southern boundary and shares the same boundary with Bortala Mongolia Autonomous Prefecture northward. It connects the northeast corner of Usu county of Tacheng Prefecture. Yining city is a political, economic and cultural center of Yili Prefecture.

3.2 Physical implementation

The network center is located in the Yining City, and branch centers are at each county. Internet links the center and branch centers. The center owns Web Server and database Server; the branch center owns database server (actualizing real time dynamic data updating) and data acquiring components to realize the updating. Each node of the System is distributed in real entity and has no close connection because it spans large areas of space and has different kinds of network structure. They, connect each other to form a united network based on the Internet. For a user outside the network, he is a single client receiving passively information service. Such kind of characteristics makes the System easy to update new data, which can accumulate data and information for environmental monitoring. Different network centers obey the united data storage regulation. Data updating is in the charge of each branch center while the data management is the responsibility of network center. The design of the System obeys the "central management and distributed data collection" principle which benefits timely updating and united dispatch of data. There are three components in the system: Navigation component with the function including Zoom In, Zoom Out, Pan, Full Extent, Zoom To Selected, Zoom Previous, Zoom Backward; Query component with the function including Identify, Query Builder, Find, SelectByRect, SelectByLine, SelectByPolygon, SelectByCircle, Display, Clear selection and Tool component with the function including Measure, Map units, Buffer, Map Print, Layer Attribute, Export, Close. Figure 1 is the main window for one sub-module of the System. Figures 2 and 3 show the implementation of "Query" and "Buffer" function respectively. It is convenient for users to customize analyses based on their demands.

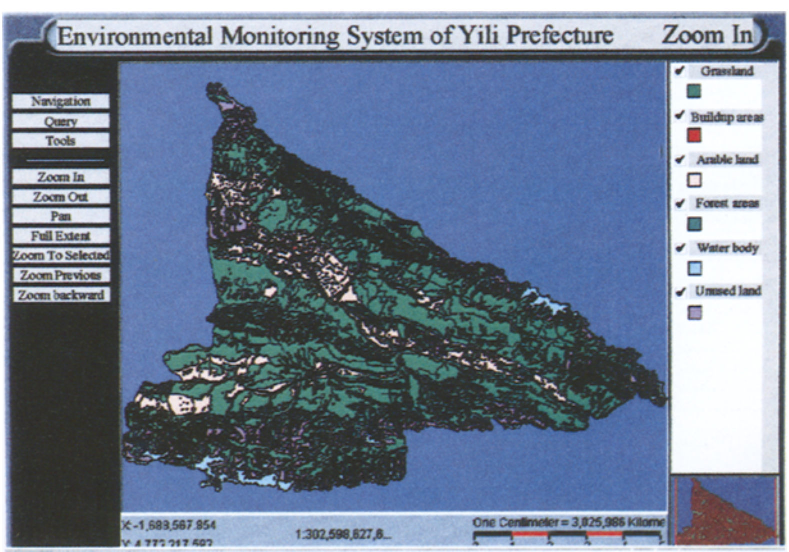

Figure 1 Main window for one sub-module of the System

3.3 Data updating

Data acquisition involves a huge amount of task for the management and maintenance of the System. Viewed on clients, it is the question of how to get the needed data. For the System manager, it is the question of how to realize the dynamic data updating. These two processes are all involved in the dynamic updating of data. For example, when a user accesses the System in a branch center, he firstly has to input the username, password, and then the System starts up a certain user interface in line with the users' authority certification. If he is a common user, the System will start up the components of distributed data acquisition according to the metadata request and display the corresponding regional data. If he is a System manager and wants to update data, the metadata Server of the System will refresh the metadata database based on the received request and send out instruction to the users to update the database located in server.

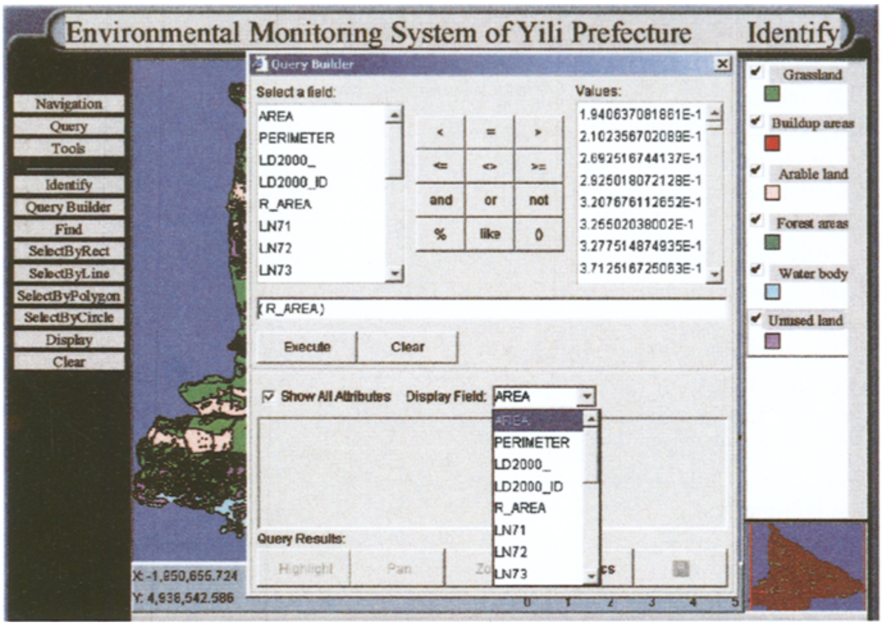

Figure 2 Implementation of "Query" function

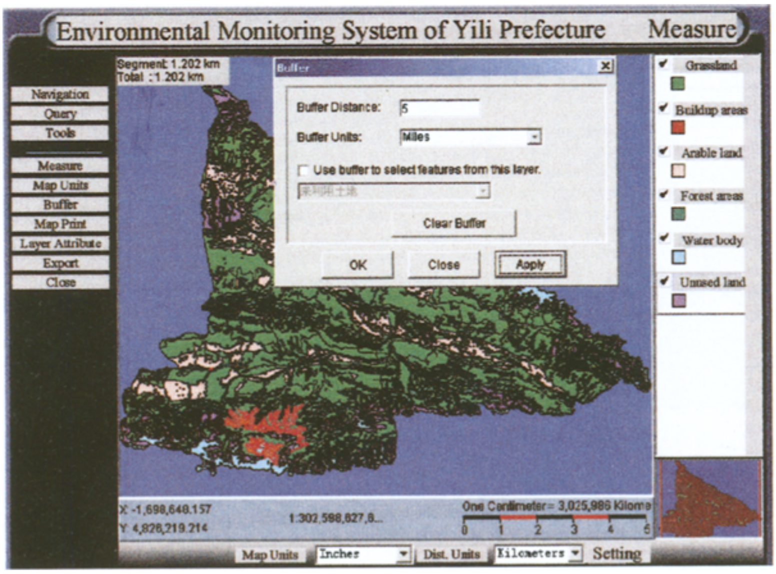

Figure 3 Implementation of "Buffer" analyses

4 Environmental monitoring and assessment

4.1 Methodology

Based on the remote sensing data, climatic, hydrologic data, etc., and using GIS as a tool to manage data, we select the proper environmental factors to realize the dynamic monitoring and assessment of Yili Prefecture. The design and implementation of Internet Based Environmental Monitoring Information System (IBEMIS) has realized the timely updating and collection of environmental data. This kind of method can reflect the conditions of environmental quality and their spatial distribution as well as has simple algorithm and the convenience of data updating. Therefore, it can reflect the dynamic change of regional environment.

In line with the regional characteristics of Yili Prefecture, we have created the analytical methods for multi-factors and environmental dynamic indices system supported by remote sensing and GIS. We established environmental factors group including soil erosion, land cover, moisture and temperature, and topographical conditions.

It is scientific and effective to use Analytic Hierarchy Process (AHP) to create the index system. Environmental dynamic monitoring is a very complex systematic project and needs a great deal of experienced determination (Liu, 1996; Zhang, 1998). By the virtue of the advantage of Analytic Hierarchy Process, we can realize the quantification of experienced determination to check and guarantee the consistency of decision makers' adjustment (Liu, 1996; Zhang, 1998), which guarantees the accuracy of the quantitative assessment and dynamic monitoring. Figure 5 shows the indexes system and weights got from the AHP analyses of Yili Prefecture. The attached values of each environmental factor are their corresponding weights, which, in some sense, show their influences on the environment of Yili Prefecture.

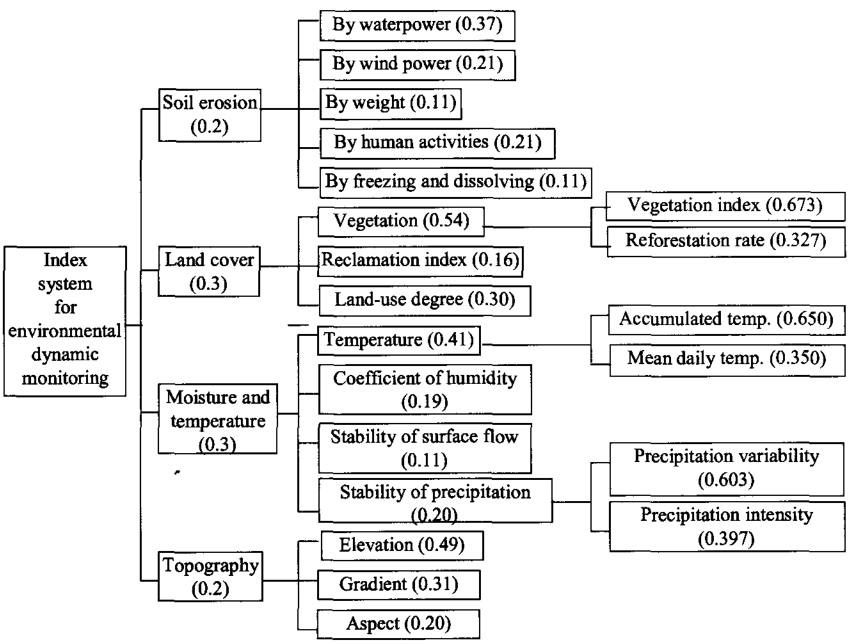

Figure 4 Index system for environmental monitoring of Yili Prefecture

However, it is difficult to analyze the post-determined of index system because the dimension of each index is not standardized. Even for a certain index, although we can determine its impact on environment by its real observational data, we can not represent its degree of influence on the environment comparable with other indices owing to the lack of a standard of determination. Therefore, we should standardize the indices. The sample method is to classify the indices from the low level to high level so as to reflect the environmental change from low to high quality. Table 1 shows the data source of each index and its evaluation method (Zhang, 1998).

Table 1 Data source and evaluation for each index

Index no.	Index name	Data source	Evaluation method
1	Accumulated temp. (≥ 0 ℃)	Meteorology station	0 ~ 10
2	Mean daily temp.	Meteorology station	0 ~ 10
3	Coefficient of humidity	Meteorology & hydrology station	0 ~ 10
4	Stability of surface flow	Hydrometric station	0 ~ 10
5	Variability of precipitation	Meteorology & hydrology station	0 ~ 10
6	Intensity of precipitation	Meteorology station	0 ~ 10
7	Soil erosion by waterpower	Remote sensing	0 ~ 10
8	Soil erosion by wind power	Remote sensing	0 ~ 10
9	Soil erosion by freezing and dissolving	Remote sensing	0 ~ 10
10	Soil erosion by weight	Remote sensing	0 ~ 10
11	Soil erosion by human activities	Remote sensing	0 ~ 10
12	Vegetation index	Remote sensing	0 ~ 10
13	Growth rate of re-forestry	Remote sensing	0 ~ 10
14	Reclamation index	Remote sensing	0 ~ 10
15	Land use degree	Remote sensing	(0~1)×10*
16	Elevation	DEM	0 ~ 10
17	Gradient	DEM	0 ~ 10
18	Aspect	DEM	0 ~ 10

*Note: there are four values to be selected in the parentheses: 0, 0.25, 0.5 and 1.0, which represent unused, physically reused, artificially reused and hard to be reused levels of land (after Zhang Zengxiang *et al.*, 1998.)

The standardization formula of factors is as follows:

$$x_i' = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}$$

where x'_i is the standardized value; x_i is the original value; $x_{\max}$ and $x_{\min}$ represent the maximum and minimum values of original value respectively.

4.2 Models

The environmental dynamic monitoring mainly represents the integrated situations of regional environment in temporal series actualized by the spatial processes of different thematic analyses. In fact, the study on environmental monitoring analyzed specially the environmental change including its regional distribution and quantitative characteristics in a certain period so as to master the speed and laws of environmental evolvement and serve us to understand and predict the future of regional environment.

The creation of environmental dynamic monitoring regards the basic analytical cells as its objective, the thematic indices as its dynamic monitoring task and gets the changing amounts of each factor by the mathematic operation. The formula is given as follows:

$$\Delta E_p = (E_p^j - E_p^{i-j})/(t_i - t_j) \qquad (p = 1,2, \ldots;\ t_i = 1,2, \ldots;\ t_j < t_i)$$

where ΔE_p represents the change of analytical cell p in the period t_i-t; E^i_p represents the environmental situation of t_i; and E_p^{i-j} represents the environmental situation of t_j.

4.3 Results

According to the design of environmental dynamic monitoring and assessment models, each environmental factor should be classified and evaluated based on its impact on the regional environment after its standardization. The determination of environmental quality has the same principle with the thematic factors, that is, to be represented by values ranging from 0 to 10 and embodied by the environmental integrated indexes with no dimensions (the higher its value, the better its environmental quality).

The integrated index of environmental quality of Yili Prefecture of 1995 is 6.63. It can be classified into 9 levels (Figure 5). There is no 10th level in environmental quality. The 7th level takes the main part and occupies 56.09% of the total area. It is distributed in a series of valleys including Yili River valley, Tekesi River valley and Kunes River valley. The 6th and 8th levels rank the second and third in their areas occupation and each of them occupies about 17% of the total areas. They are mainly distributed in the valley flat of large rivers such as Yili River, Tekesi River, Kunes River, etc. The above three levels are the most important agricultural production bases and livestock breeding areas and occupy more than 90% of the total area.

The area percentages of other levels in environmental quality are much lower. The 1st, 2nd, 3rd, 4th and 5th levels occupy 0.04-4% of the total area. The 1st, 2nd and 3rd levels are distributed in the mountainous regions and high basins including Zhaosu Basin with an elevation of more than 2,600 m. The 4th and 5th levels are distributed in hilly area with elevations ranging from 800 m to 1,500 m, where the agriculture without irrigation and stock raising industries develop rapidly. The 9th level ranks the first in the environmental quality but its area occupation is much lower, belonging to arable land situated in the alluvial plains of Yili River.

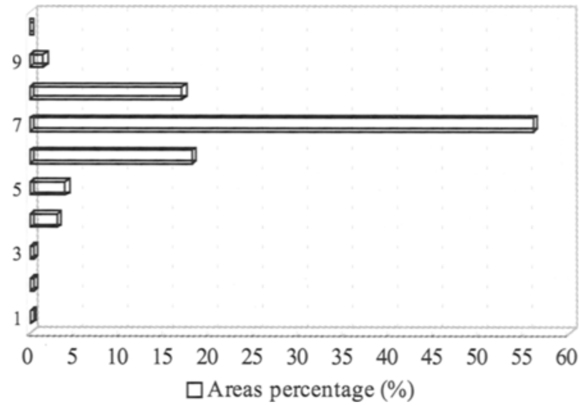

Figure 5 Areas percentage for each integrated environment index of Yili Prefecture in 1995

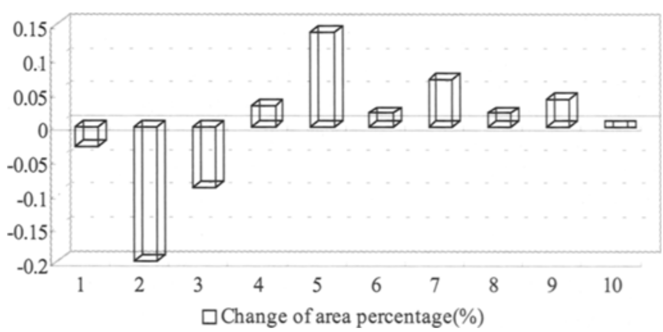

Figure 6 Net change of area percentage for each integrated environment index
(Notes: values illustrated in the graph are the subtraction balances for each integrated environment index during 1995-2000)

The environmental conditions of the year 2000 bear the same characteristics with that of 1995 except that the integrated environment index has gone up to 7.33, which shows the improved trend of environmental quality. Figure 6 shows the change of area proportion for each integrated environment index. There is no obvious change in the distribution of integrated environment index compared with that of 1995. The 7th level still takes the main part of the total, with an even higher percent of areas. The area percentages of the 1st, 2nd and 3rd levels have reduced by 0.03, 0.20 and 0.09 while those of 4th and 5th levels improved by 0.03 and 0.14, which result from the implementation of the feasible environmental protection measures in these years.

5 Conclusions

The IBEMIS has solved the difficulty confronting Web GIS. Combining vector data closely with attribute data, it has actualized the data sharing of environmental information based on Internet. It applies the structure pattern of Client/Server and Web Brower/Web Server, which realizes the real time updating and dissemination on the Internet. By the application of MapXtreme on Server, it responds rapidly to the accessing requests of Internet users for spatial map information and its relative attribute data, actualizing the query and updating of environmental information.

By the comparison of the distribution patterns of environment indices of the years 1995 and 2000, we found out that the regional environmental quality of Yili Prefecture had turned better, which also reflected the effect of integrated development and environmental protection. A series of measures to protect environment, especially the wide application of biologic measures, have began to take effect in environmental protection by controlling soil erosion, improving the vegetated cover, etc.

With the popularization of GIS technologies, to disseminate information based on Internet will become an important trend for the development of GIS. The combination of GIS and Web, as a key technique to realize the Digital Earth, has become a new research focus on the Geo-information Science (Zhao and Yang, 2000). The methods and platform we used in this paper are just a preliminary trial to realize data dissemination, data sharing and dynamic handling based on Internet, and its processing courses, more or less, have some referential values.

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