IOP Conf. Series: Earth and Environmental Science **17** (2014) 012271 doi:10.1088/1755-1315/17/1/012271

Design of the Resources and Environment Monitoring Website in Kashgar

Z Huang[1,2] , Q Z Lin[1], Q J Wang[1]

[1] Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing, 100094, China

[2] University of Chinese Academy of Sciences, Beijing, China, 100049

E-mail: huangzhang@ceode.ac.cn

Abstract. Despite the development of the web geographical information system (web GIS), many useful spatial analysis functions are ignored in the system implementation. As Kashgar is rich in natural resources, it is of great significance to monitor the ample natural resource and environment situation in the region. Therefore, with multiple uses of spatial analysis, resources and environment monitoring website of Kashgar was built. Functions of water, vegetation, ice and snow extraction, task management, change assessment as well as thematic mapping and reports based on TM remote sensing images were implemented in the website. The design of the website was presented based on database management tier, the business logic tier and the top-level presentation tier. The vital operations of the website were introduced and the general performance was evaluated.

1. Introduction

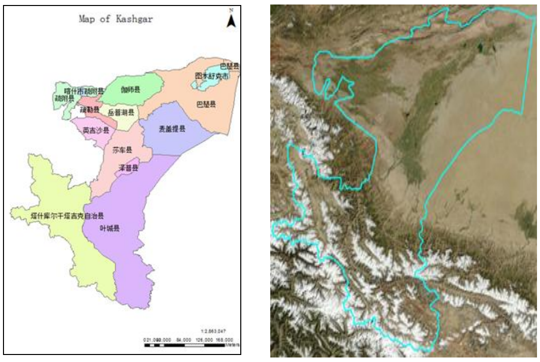
The technology of building geographical information system (GIS) has been extensively studied in recent years [1-4]. Browsing and editing of geographic data are supported by most of the web geographical information system (web GIS), however, many useful spatial analysis functions are ignored. As Kashgar, Xinjiang Province, China is rich in the ample natural resources, it is of great significance to monitor the resource and environment situation in the region using remote sensing (RS) images.

The purpose of building resources and environment monitoring website in Kashgar is to analyse and process thematic information (water, vegetation, ice and snow), to generate thematic products, and eventually to implement the monitoring of environmental indicators. Through analysing TM images, functions of water, vegetation, ice and snow extraction, task management, change assessment as well as thematic mapping and reports were implemented in the website. With the implementation of certain spatial analysis functions, remote sensing images are directly used for the dynamic monitoring application, which gives a good example on extending the functionality of web GIS. As large numbers of TM images can be collected and processed by RS technology and many useful spatial analysis functions are available in existing GIS technology, with the combination of RS and GIS technology, the website performs well on processing speed, supports cross-platform and provides the best user experience.

[1] Institute of Remote Sensing and Digital Earth, CAS No. 9 Dengzhuang South Road, Haidian District, Beijing 100094, P.R. China

2. Study area and data

Kashgar, Xinjiang Province, is located on the northwest of China, at the east longitude between 71°39' and 79°52' and the north latitude between 35°28' and 40°16', covering the area of approximately 162,000 square kilometers. The elevation within the study area ranges from 1100 m at the Taklimakan Desert to over 8800 m at the crest of Chogori Mountains. The region is comprised of one county-level city and eleven counties as illustrated in figure 1(a). Due to complex terrain conditions and climate differences, the region can be roughly divided into five areas: Kashgar plain climate zone, the desert climate zone, the hilly climate zone, Pamir climate zone, and Kunlun Mountain climate zone, which is rich in natural resources including water, vegetation, ice and snow as shown in figure 1(b). As the source of the river system in Kashgar is located in the glaciers or mountain snow cover, with the change of season, the water and snow coverage change significantly. There are different kinds of plant resources in this region. And the region's existing forest covers an area of 355,300 hectares with the forest coverage rate of 2.75%.



(a) (b)

Figure 1. (a) The administrative map of Kashgar; (b) the overview of remote sensing images of Kashgar.

A multi-temporal dataset consisting of seven Landsat 5 Thematic Mapper (TM) images of Kashgar from year 2000 to 2005 was used to extract the resource coverage and produce change detection results. The sensors carried on the Landsat have a scan range of approximately 179 km from the south to the north and 183 km from the west to the east with a data update period of 16 days. The spatial resolution of TM is 30m (80m for RBV and MSS sensors). The TM images were transformed into surface reflectance using the FLAASH atmospheric correction model in the software of ENVI V4.8 [5]. TM reflectance data were projected to Universal Transverse Mercator (UTM; zone 43, 44; World Geodetic System 1984).

3. Design of the website

The key steps of building the website was generally illustrated in figure 2. As can be seen, cached and dynamic map service were shared online after image data were published to the ArcGIS server. With the use of geoprocessing tools (ENVI for ArcGIS Server), image analysis models were built and published as online services to implement different image processing functions. With these services integrated into web GIS applications, the website was built and open to clients. Clients can have good interactions with these services via the Internet.

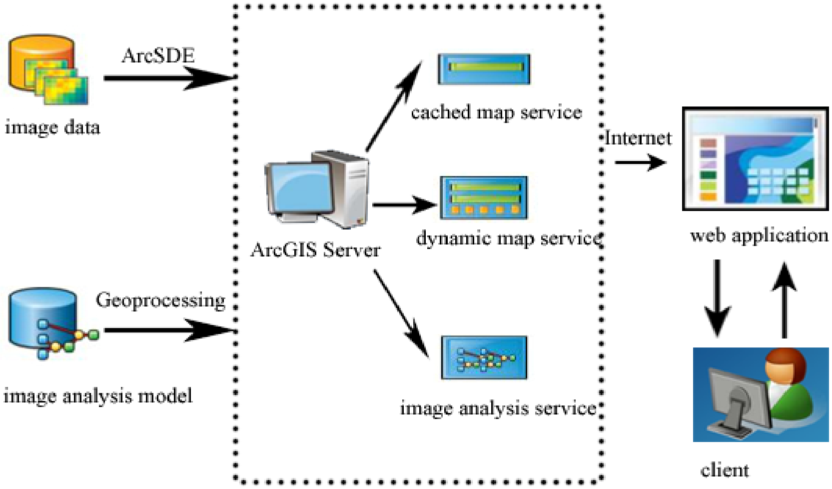


Figure 2. Website building chart.

The design of the website was presented in this study based on the database management tier, the business logic tier and the presentation tier.

3.1 The database management tier

The Oracle database was used to store and manage data. ArcSDE from ESRI Company was used as the spatial data engine for high-efficiency operation [6], which played a fundamental role in a multi-user GIS. The standard database interface was provided for both spatial and non-spatial data. Raster data were stored as the equidistant image tiles to improve the query and retrieval efficiency. The advanced indexing method was adopted to facilitate quick access to massive image data. The database related functions such as data insertion, modification, deletion, and query were developed. Each remote sensing image was assigned with a unique identification number. The records of images and their corresponding shape files after the information extraction were stored in the database.

3.2 The business logic tier

Basic operations like map browsing and data editing were supported. Regular operations with regard to the processing of remote sensing images were divided by four major modules: information extraction, task management, dynamic monitoring, and thematic information.

Figure 3. Flow chart of information extraction.

In the information extraction module, after selecting and editing training samples by human-computer interaction, the feature index extracted from surface resources was fed back to the server for automatic extraction in the next step. The data processing sequence for information extraction using TM images was illustrated in Figure 3. With polygons drawn by the client, training sample areas were created. Spectral Angle Mapper (SAM) was used in the information extraction, which determines the similarity of two spectrums through a variant denoted as the spectral angle. The average spectrum on selected sample areas was regarded as the reference spectrum and the spectral angle threshold was set to be 10 degree. Through the raster calculator, SAM was implemented on the entire image. Then the result image was converted to the vector format, facilitating the statistics on the area of shape objects produced. The filtering and aggregation algorithms were applied to reduce the number of small polygons in the shape files.

In the task management module, a message box was designed to remind clients of the time to complete the task set by themselves earlier. Each task was composed of three elements: the time to complete the task, the resource type and the ID of the image to be processed. A timer was set in the module.

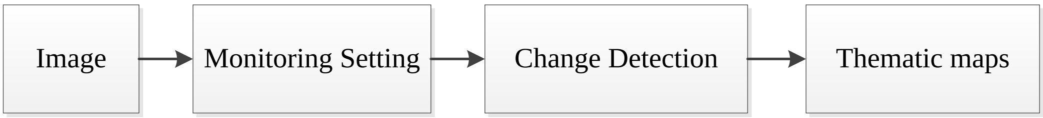


Figure 4. Flow chart for dynamic monitoring processing.

In the dynamic monitoring module, results were immediately generated based on the monitoring range, type and period set by the client. The dynamic monitoring processing sequence was illustrated in Figure 4. The range was determined by either the name of a certain county or city in Kashgar or by the polygon drawn by the client. The types were comprised of vegetation, water, ice and snow. The time period was determined by a start date and an end date. After the setting, an overlay analysis was implemented. Then the coverage change of natural resources was chronologically displayed in the histogram as illustrated in figure 5.

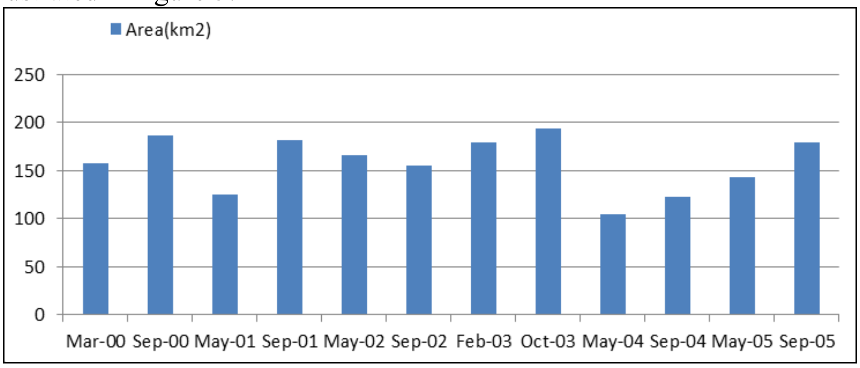


Figure 5. The histogram of the water coverage change of Yecheng County from 2000 to 2005.

In the thematic information module, thematic maps and reports were quickly produced according to the monitoring results. The renderer type of thematic maps included unique value renderer, proportional renderer, pie renderer and bar renderer. The scale bar, scale texts and north arrow can be added to the exported map for decoration. The reports were exported in the PDF format. A series of images generated during thematic map production was illustrated in figure 6. The original TM image was shown in figure 6(a) and training samples selected on the image were shown in figure 6(b). The vector graphics after the information extraction process were shown in figure 6(c). The thematic map generated with mapping rendering and decoration was shown in figure 6(d).

(a) (b) (c) (d)

Figure 6.(a) The original TM image; (b) training samples selected on the image; (c) the vector graphics ; (d) the thematic map.

3.3 The presentation tier

Controls were used to establish the four modules described above, like labels, textboxes, list-boxes, date-time choosers and buttons. The web page was composed of two toolbars, a table of contents, a menu strip, a tab control containing map display and page layout and another one containing the four modules. All the controls were conveniently arranged and placed.

4. Applications

Table 1. The Processing Time of the Information Extraction for Images [a]

Image ID	Number of Training Samples	Number of Shape Objects Produced	Processing Time (minute)
1	5	15742	3.51
2	3	908	1.19
3	6	18656	4.57
4	3	637	1.75
5	4	2977	2.24
6	2	2977	1.52
7	2	90	1.06
8	2	4452	1.14
9	2	5754	1.87
10	2	10373	1.88
11	2	1852	1.08
12	3	1287	2.73
13	3	12451	2.23
14	2	12	1.28
15	3	4556	1.45
16	3	18084	1.32
17	3	16616	1.56
18	3	298	1.23
19	3	965	1.83
20	3	26	1.41
21	6	15543	4.36
22	5	17842	3.89
23	6	19345	5.8

[a] The number of training samples and shape objects produced in the information extraction module influence the processing time for TM images.

In the information extraction module, after the client selected training samples, shape objects indicating the resource coverage were produced in the shape files. As can be seen in table 1, with the increase of the training sample number and shape objects, the processing time increased. However, the influence of the former was much greater than the latter on the processing time, which indicated that more time was required to extract the band information of training samples than to convert the raster data to vector format. The average processing time of the information extraction was 2.21 minutes for twenty-three images taken for illustration.

Fast responses were also generated after the client's operations in the dynamic monitoring module and the thematic information module. The four modules were closely connected. The results presented in the paper had profound implications for the use of Landsat TM imagery to monitor large areas through time.

5. Discussions and Conclusions

The website shows a good solution to TM image sharing and analysing online with the combination of RS and GIS technology. The main features of the system are as follows. Firstly, the data is quickly displayed and interacted with users. Secondly, results executed on the server by spatial processing models are efficiently displayed. Thirdly, the business data is conveniently displayed on the ArcGIS map services. With the use of ArcSDE as the database engine, quick access to massive image data can be conveniently achieved. Spatial analysis functions are flexibly built with the aid of geoprocessing tools.

However, the merging of multi-sensor image data is not well considered [7]. At present, only SAM [8] is implemented in code for the information extraction. Despite its sound accuracy of the information extraction, the accuracy might be further improved with other algorithms like Spectral Correlation Mapper (SCM) [9] and Cross Correlogram Spectral Matching (CCSM) [10] applied. Due to a little coding discrepancy, certain amount of system garbage is generated along with information extraction results and sometimes the image processing is comparatively time-consuming. Therefore, it seems necessary to modify the code to further improve the system performance.

Future efforts will focus on improving the website reliability and stability. Two main operations are implemented in the website, including information extraction and change assessment. While developed using TM data, the information extraction operation can also be applied to other multi-spectral data (e.g. ASTER) and hyper-spectral data (e.g. AVIRIS). More algorithms will be implemented in code to improve result accuracy in the information extraction module.

6. Acknowledgements

This work was financially supported by the National Science and Technology Support Program (No. 2012BAK15B05), National Natural Science Foundation of China (No. 41171280), and the National Science and Technology Support Program (No. 2012BAH27B05).

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