CHINESE GEOGRAPHICAL SCIENCE
Volume 15, Number 2, pp. 157–161, 2005
Science Press, Beijing, China

EXPLORATION ON METHOD OF AUTO-CLASSIFICATION FOR MAIN GROUND OBJECTS OF THREE GORGES RESERVOIR AREA

ZHANG Bao-lei[1,2], SONG Meng-qiang[1], ZHOU Wan-cun[1]

(*1. Chengdu Institute of Mountain Hazards and Environment, Chinese Academy of Sciences & Ministry of Water Conservancy, Chengdu 610041, P. R. China; 2. Graduate School of Chinese Academy of Sciences, Beijing 100039, P. R. China*)

ABSTRACT: Taking TM images, SPOT photos and DEM images as the basic information, this paper had not only put forward a kind of manual controlled computer-automatic extraction method, but also completed the task of extracting the main types of ground objects in the Three Gorges Reservoir area under relatively high accuracy, after finishing such preprocessing tasks as correcting the topographical spectrum and synthesizing the data. Taking the specialized image analysis software—eCognition as the platform, the research achieved the goal of classifying through choosing samples, picking out the best wave bands, and producing the identifying functions. At the same time the extraction process partly dispelled the influence of such phenomena as the same thing with different spectrums, different things with the same spectrum, border transitions, etc. The research did certain exploration in the aspect of technological route and method of using automatic extraction of the remote sensing image to obtain the information of land cover for the regions whose ground objects have complicated spectrums.

KEY WORDS: automatic extraction; ground object; identifying functions; Three Gorges Reservoir area

CLC number: S762 Document code: A Article ID: 1002-0063(2005)02-0157-05

1 INTRODUCTION

With the development of remote sensing technology, the study and application of the automatic classification method using computer had achieved satisfying development. From spectrum statistical classification to the neural network classification method of imitating human vision law, from the introduction of expert in professional system to the establishment of image analysis system using reasoning model (LUO, 2002), they had improved the classification precision to certain degree in different aspects, and the classification result of routine methods (LIU, 2002). However, all these researches were based on the experiments of small area, and the applications of automatic extraction to obtaining the main types of land use were very scarce in the large scale of area. At the same time, the spectrum characteristics of ground objects on RS images of the Three Gorges Reservoir area are very complicated. Besides the different seasonal characteristics, the images would also have such characteristics as the same thing with different spectrums, different things with the same spectrum, and border transitions, etc. (ZHOU and SUN, 1987), so it was necessary to adopt a large amount of auxiliary materials and field data to achieve the desired result. Aiming at resolving the problem of great variances of remote sensing image in the Three Gorges Reservoir area, this paper, combined with lots of auxiliary materials, has extracted the main ground-object types in Three Gorges Reservoir area utilizing a new automatic extraction method.

2 STUDY AREA

The Three Gorges Reservoir area in this research referred the area with flooded loss after building the dam. The region lies in 28°56'–31°44'N and 106°14'–111°28'E, crossing over two gauss projection with an area of 58 351km^2. It extends from Yichang City of Hubei Province in the east to Jiangjin City of Chong-

Received date: 2005-01-11
Foundation item: Under the auspices of the Construction Committee of Three Gorges Reservoir Project (No.SX[2002]00401) and Chinese Academy of Sciences (No. KZCX2-SW-319-01)
Biography: ZHANG Bao-lei (1979–), a native of Linyi of Shangdong Province, Ph.D. candidate, specialized in the application of RS and development of GIS. E-mail: blzhang@mails.gscas.ac.cn

qing in the west, and from the southern foot of Daba Mountain in the north to the northern fringe of Yunnan-Guizhou Plateau in the south. This region lies in the intersection of three big tectonic elements, which are the Daba Mountain fold zone, eastern Sichuan fold zone and Sichuan-Hubei and Hunan-Guizhou upheaval zone. The topography rolled violently with the average elevation of about 1000–1500m. The climate belongs to the subtropical monsoon climate, with clear four seasons and average annual temperature of 18.1℃. The present vegetation, mainly evergreen broad-leaved forest, is mostly artificial forest or natural secondary forest. The obvious vertical climate change, and mountain's trend, slope and exposure cause uneven distribution of heat and water resources, which in turn results in the difference of land cover. The soils of the region are mainly purple soil, yellow soil and yellow-brown soil.

3 DATA PREPARATION

3.1 Data Sources

The research took TM images of October in 2002 (30m) and SPOT photos of the study area (10m) as the basic information, and took TM images of 1992 as references. The auxiliary materials included:

(1) The DEM images of the study area on the scale of 1:50 000, and the slope and aspect images that derived from the DEM images;

(2) The land use/cover maps of each county on the scale of 1:100 000, the forest cover maps of some counties on the scale of 1:10 000 and the land-use planning maps of some counties on the scale of 1:50 000;

(3) TM4/TM3 (ZHOU, 2001) data layer that was produced through the method of writing models in software-Erdas 8.6;

(4) T-NDVI (Firstly the NDVI of August and March were calculated. Then their difference was calculated out to get T-NDVI).

3.2 Image Preprocessing

To reduce the precision of automatic extraction, topographical spectrums correcting was carried out in the subsystem of RS images preprocessing (SHRESTHA and ZINCK, 2001) by the formula as follows:

$$NB_i = 255\left(\frac{OB_i}{\sum OB_i}\right), i=1 \text{ to } n \quad (1)$$

where NB_i is the normalized luminance value of each pixel; OB_i, the luminance value before normalization; i, wave band.

The needed data such as seven wave bands of TM images, SPOT photos, DEM images, slope and aspect images, T-NDVI images and TM4/TM3 images should be corrected strictly and separately with the error within one-pixel. Then all data were overlaid to form one image including 13 datum layers by the way of sampling in 8 bits. Finally, in order to reduce the quantity of data and regional difference of the image to make it easy to be treated and extracted, the images to be interpreted were cut according to the range of each county. If one county crosses over two projection areas, it was necessary to produce two images according to the border of projection inside the county (PAN and ZENG, 1994). The extraction process was carried out according to the range of each county.

4 EXTRACTION PROCESS

4.1 Segmentation

Segmentation is a region-merging technique starting with one-pixel object (FENG and FLEWELLING, 2004). In numerous subsequent steps, smaller image objects are merged into bigger ones. The heterogeneity criterion consists of two parts: a criterion for tone and a criterion for shape. The spectral criterion is the change in heterogeneity that occurs when merging two image objects as described by the change of the weighted standard deviation of the spectral values regarding their weightings. The shape criterion is a value that describes the improvement of the shape with regard to two different models describing ideal shapes. The formation of segmentation follows three principles listed below:

(1) The description of spectral or color heterogeneity (h_{color}) is the sum of the standard deviations of spectral values (σ_c) in each layer weighted with the weights (w_c) for each layer (c). In many cases the exclusive minimization of spectral heterogeneity leads to branched segments or to image objects with a factually shaped borderline. The formula is:

$$h_{color} = \sum_c w_c \sigma_c \quad (2)$$

(2) Compact heterogeneity (h_{cmpct}) that is described by the ratio of the *de facto* border length (l) and the square root of the number of pixels (n) forming this image object. The formula is:

$$h_{cmpct} = \frac{1}{\sqrt{n}} \quad (3)$$

(3) Smooth heterogeneity (h_{smooth}) that is the ratio of the *de facto* border length (l) and the shortest possible border length (b) given by the bounding box of an image object parallel to the raster. The formula is:

$$h_{smooth} = \frac{1}{b} \quad (4)$$

The compact heterogeneity and the smooth heterogeneity form the shape heterogeneity (h_{shape}).

The overall fuzzy value (f) is computed based on the spectral heterogeneity and the shape heterogeneity as follows:

$$f=wh_{color}+(1-w)h_{shape}$$

$$h_{color}=\sum_c w_c(\sigma_c^{merge}-(n_{obj1}\sigma_c^{obj1}+n_{obj2}\sigma_c^{obj2}))$$

$$h_{shape}=w_{cmpct}h_{cmpct}+(1-w_{cmpct})h_{smooth}$$

$$h_{cmpct}=n_{merge}\frac{l_{merge}}{\sqrt{n_{merge}}}-(n_{obj1}\frac{l_{obj1}}{\sqrt{n_{obj1}}}+n_{obj2}\frac{l_{obj2}}{\sqrt{n_{obj2}}}) \quad (5)$$

$$h_{smooth}=n_{merge}\frac{l_{merge}}{b_{merge}}-(n_{obj1}\frac{l_{obj1}}{b_{obj1}}+n_{obj2}\frac{l_{obj2}}{b_{obj2}})$$

where f is the overall fuzzy value; c is the data layer; w is the user-defined weight for color (against shape) from 0 to 1; w_c is the weight of layer c; h_{smooth} is shape heterogeneity; h_{cmpct} is compact heterogeneity; n_{merge} is the object size after merged, n_{obj1} and n_{obj2} are the object 1 and object 2 before merged; l is the object perimeter and b is the perimeter of the bounding box; l_{merge}, l_{obj1} and l_{obj2} are the object perimeter after merged and before merged—the merged object, object 1 and object 2; b_{merge}, b_{obj1} and b_{obj2} are the perimeter of bounding box after merged and before merged—the merged object, object 1 and object 2.

Throughout the segmentation procedure, the whole image is segmented and image objects are generated based upon several adjustable criteria of heterogeneity in color and shape. Adjusting the so-called scale parameter indirectly influences the average object size: a larger value leads to bigger objects and vice versa. Additionally the influence of shape as well as the image's channels on the object's homogeneity can be adjusted. During the segmentation process all generated image objects are linked to each other automatically. In the research, the criteria of heterogeneity in color and shape were 0.7 and 0.3 respectively, and the density and smooth degree of shape heterogeneity were assigned the proposition of 0.7 and 0.3.

4.2 Identifying Function

Each layer's mean value was calculated from the layer values of all n pixels that formed an image object using the following formula:

$$\overline{c_l}=\frac{1}{n}\sum_{i=1}^{n}c_{li} \quad (6)$$

where $\overline{c_l}$ is the average value of the lth layer in each spot; n is number of pixels; c_{li}, feature value range, for 8 bits data the value range is [0 , 255].

On all datum layers, the average value of each spot ($\overline{c_l}$) and the fuzzy value (f) have formed a functional relationship, which is the identifying function and can be revised according to the need. The identifying function is the window of human-computer interaction. It is the fuzzy value (f) that interprets the classification of spot to be differentiated. The concrete principle is that: firstly, compare the fuzzy value in each layer of the all samples and pick out the largest ones; then compare the selected value and choose the sample whose fuzzy value was still the largest one; finally, merge the spot into the type that the sample represented. At last, the spots with the same average value ($\overline{c_l}$) were merged into the same type.

4.3 Sampling

The main purpose of the research was to extract dry land, paddy field, construction land, forestland, grassland, shrub land, river, and surface-form water body automatically.

The expression forms of the above types were analyzed to form the sampling standard. In the sampling process, it is better to select the samples in mass in the main layers and delete the ones with large deviation on these data layers. Number of samples should be moderate. Few samples could not give the trend of identifying function, while too many samples made the mean attribute value distribution too wide to show the characteristic of differentiated function correctly. The choosing of the samples could not be finished at one time. It was connected with differentiated function and automatic classification. If the deviation between the extraction result and the factual result was too great, some samples should be reselected and even deleted. The sampling process and classification were the course that human and computer interacted many times.

4.4 Selecting Wave Bands

It was not the case that every datum layer was helpful to extraction. In order to confirm the best data layer needed in the classification course, the average attribute value of every sample on all datum layers should be noted separately.

And the distributing range of average attribute of every kind of ground object sample was drawn out to form a distributing curve (Fig. 1). This curve was analyzed and the layers that the ground object types could be distinguished more obvious on the curve were assigned to the needed layers.

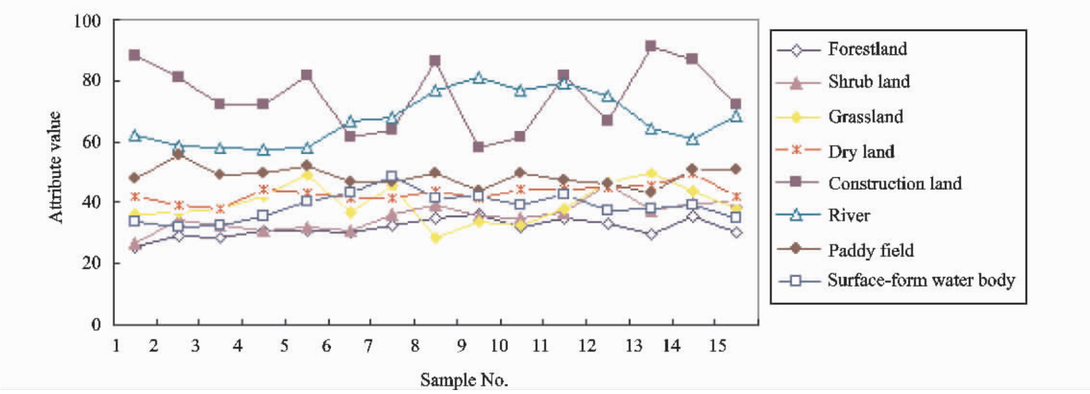

Fig. 1 Band ranges of main ground objects on TM3 (Fuling County of Chongqing)

4.5 Result Identifying Function

The identifying function was produced by using the selected layers and the auxiliary data. The identifying functions of each type were assigned (Table 1).

4.6 Result Exporting

The first-time extraction was carried out according to the above identifying function. It was very difficult to satisfy the final result by regulating the identifying function and classifying automatically only once. The extraction process did not need many times repeats through reselecting samples, reforming or modifying identifying function until the result of extraction satisfied the request. All subdivisions of ground object types were amalgamated. Finally, the results were exported in the form of vector and grid whose projections were turned into Gauss 48.

Table 1 Establishment of identifying function

Type	Establishment of identifying function
Dry land	Firstly, automatically formed identifying function from the layers of TM1, TM3, TM4 and SPOT; then delimited the elevation below 1800m and slope below 30 degrees
Paddy field	Firstly, automatically formed identifying function from the layers of TM1, TM2, TM3, TM4, TM5 and T-NDVI; then delimited the elevation below 1700m and slope below 30 degrees
Grassland	Firstly, sampling from the shady slope and sunny slope; secondly, automatically formed identifying function from the layers of TM1, TM2, TM3, TM4, TM5, T-NDVI and SPOT; thirdly, delimited the slope below 60 degrees
Forestland	Firstly, sampled from the shady slope and sunny slope; secondly, delimited the average value of TM4/TM3 above A (A was an analyzed value changing with different images); thirdly, automatically formed identifying function from the layers of TM1, TM2, TM3, TM4, TM7 and SPOT
Shrub land	Firstly, sampled from the shady slope and sunny slope; secondly, delimited the average value of TM4/TM3 above A (the same as that of forestland); thirdly, automatically formed identifying function from the layers of TM1, TM2, TM3, TM4, TM7 and SPOT
Surface-form water body	Firstly, delimited the average attribute value of TM5 below 20 and that of TM4 below 50; then automatically formed identifying function from the layers of TM3, TM4, and TM7
River	Firstly, delimited the average attribute value of TM4 below 50; then automatically formed identifying function from the layers of TM1, TM3, TM4 and TM5
Construction land	Automatically formed identifying function from the layers of TM1, TM2, TM3, TM4, TM5 and SPOT; the layer-TM6 can be used because of the existence of urban heat island effect

5 VERIFICATION

In this research, field samples and the spots from the SPOT photos were adopted to verify the extraction result in the qualitative and quantitative precision aspects respectively. The number of spots consistent with the verified spots in field were written down in the name of right spots and made their ratios as the qualitative precision. The ratio of the area of the right spots to the total area of verified spots was called quantitative precision. The verified results were shown in Table 2.

It can be found out from the inspection result: the qualitative precision of surface-form water body, river, paddy field, dry land, construction land, forestland, shrub land, grassland were up to 90%. The qualitative precision for water body which included river and surface-form water body was above 93%, and the qualita-

Table 2 Verified results by field sample plots

Type	Verified spot number (A)	Right spot number (B)	Qualitative precision ($B/A\times100\%$)	Quantitative precision ($Sb/Sa\times100\%$)	Mixed with
Dry land	71	68	95.77	87.74	Grassland
Paddy field	66	61	92.42	85.62	Construction land (old city)
Construction land in countryside	64	59	92.18	84.21	Paddy field
Construction land in cities and towns	42	40	95.23	84.12	Paddy field
Forestland	111	100	90.01	80.38	Shrub land
Shrub land	85	78	91.76	83.51	Grassland
Grassland	45	41	91.11	82.34	Shrub land
River	50	49	98.00	90.13	Construction land
Surface-form water body	30	29	93.33	92.21	Paddy field

Notes: Sa is the total area of vertified spots; Sb is the total area of right spots

tive precision was above 92% for construction land, paddy field and dry land. The quantitative precision was not very high in the whole but still exceeded 80%, and the quantitative precision for water body which included river and surface-form water body was above 90%. The qualitative precision for the forestland, shrub land, and grassland was relatively low but the obscurity degree among surface-form water body, paddy field and construction was not very outstanding except the high obscure in the grassland and dry land. The extraction result of the water body was so high in both aspects of quantitative and qualitative precision that it could conveniently extract the body and analyze its dynamic changes. It is especially effective in the large inter-distributed region dry land and paddy field (such as the north of Chongqing, Changshou County, and Jiangjin City of Chongqing) using automatic extraction. While for the area with large coverage of vegetation, the accuracy rate was relatively lower, but it could still achieve the purpose of reducing workload and improve the quality of artificial classification after all.

6 CONCLUSIONS

The automatic extraction system of land cover could not only manage and use the data orderly, but also provide strong support of technology and data to the computer automatic extraction. It was necessary to popularize the automatic extraction of the main ground objects utilizing the software eCognition because the process was fast, simple and convenient; what's more the precision was guaranteed. It was useful in the aspects of dispelling the influence of shade to a certain extent and improving the extraction result to correct the topographical spectrum before extraction. The participation of auxiliary data in the form of identifying function produced artificially could solve such phenomena in a certain degree as the same thing with different spectrums, different things with the same spectrum, and border transitions, etc. in the course of manual interpretation. The automatic extraction course needed the intervention of the expertise, because the whole process was the repeat of human-computer interaction from choosing sample, forming the identifying function to automatic extraction.

REFERENCES

FENG C-C, FLEWELLING D-M, 2004. Assessment of semantic similarity between land use/land cover classification systems [J]. *Computers, Environment and Urban Systems*, 28(3): 229–246.

LIU Ya-lan, YANG Shou-yong, WANG Tao *et al*., 2002. A study on segmentation based classification approaches for remotely sensed imagery [J]. *Journal of Remote Sensing*, 6(5): 357–362. (in Chinese)

LUO Jian-cheng, WANG Qin-min, MA Jiang-hong *et al*., 2002. The EM-based maximum likehood classifier for remotely sensed data [J]. *Acta Geodaetica et Cartographica Sinica*, 31 (3): 234–239. (in Chinese)

PAN Xian-zhang, ZENG Zhi-yuan, 1994. Some technological problems in satellite data processing for land resources inventory in the area of Three Gorges of Yangtze River [J]. *Remote Sensing of Environment*, 9(3): 209–214. (in Chinese)

SHRESTHA Dhruba Pikha, ZINCK J Alfred, 2001. Land use classification in mountainous areas: integration of image processing, digital elevation data and field knowledge (application to Nepal) [J]. *International Journal of Applied Earth Observation and Geoinformation*, 3(1): 78–85.

ZHOU Cheng-hu, LUO Jian-cheng, YANG Xiao-mei, 2001. *Geographical Understanding and Anlysis of Remote Sensing Images* [M]. Beijing: Science Press, 46–47. (in Chinese)

ZHOU Wan-cun, SUN Yu-qiu, 1987. Remote sensing analysis of the environmental capacity of land cover in Three Gorges Reservoir area [A]. In: JIN Yi-xing, ZHENG Zhong (eds.). *The Collection of Thesis about Impact on Ecological Environment of the Three Gorges Projects and Countermeasure* [C]. Beijing: Science Press, 129–134. (in Chinese)