A HYBRID METHOD BASED ON IMAGE SEGMENTATION AND PIXEL-BASED CLASSIFICATION FOR TIBETAN PLATEAU LAKE EXTRACTION FROM REMOTE SENSING IMAGE

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ABSTRACT: The change of Tibetan plateau lake has the important effect on the global climate change. Thus, it is necessary to develop the method of high- precision extraction of Tibetan plateau lake. In this paper, we develop a hybrid method combining pixel-based classification and image segmentation for Tibetan plateau lake extraction. First, support vector machine (SVM), a commonly used classification method, is used for remote sensing data land cover classification. In the process of classification, the land cover of the lake, snow, and the other class are used for choosing the training sample. Second, watershed transform method is used for remote sensing image segmentation. In order to get better perform of the segmentation of the lake land cover, NDWI is taken as the input feature except for the original spectral bands. Third, vote principle is used to get the final Tibetan plateau lake information by combining the classification and image segmentation result. Finally, in order to illustrate the efficiency of the proposed method, the extraction result from NDWI is compared to the proposed method. The experimental result shows that the new method has the better performance for Tibetan plateau lake extraction.

1. Introduction

Lake detection has the tight relationship with the climate change globally and locally, thus, there are more and more scientific research on the issue of change of lake monitoring. Tibetan plateau is proven to have an important effect on the globel climate change by scientists. The area of Tibetan plateau lakes takes 49.5 percentage of the whole lakes in China[1]. Meanwhile, they are the highest, maximum amount, largest lake group in the world. The traditional observation technology is limited because of the complex in the terrain and climate, such as high altitude and hard to climbed mountain, harsh climate, and dangerous for survive.

Remote sensing technology provides a promising mean of observing Tibetan plateau lakes. To prompt the extraction accuracies of lake, the direct method is to use the high spatial resolution remote sensing data. Due to the development of the remote sensing technology, more high-spatial resolution remote sensing image can be obtained, such as SPOT-6, SPOT-5, IKONOS, Quickbird, GF-1, Worldview, and Geoeye. These data source can be used to extract lake information with high accuracy. However, the scale of the Tibetan plateau lake is high, there may need several images to cover the lake region. Thus, lake extraction involves plenty of work, such as image fusion, geometric correction. These work may lead to reduce the extraction accuracy.

Therefore, the middle spatial resolution remote sensing data is more viable as the data source. In this paper, we proposed a hybrid method to extract Tibetan plateau lake based on object-based image analysis (OBIA) technique, which presents the information in the imagery by meaningful image objects, is proposed for the high spatial resolution remotely sensed imageries. In traditional OBIA technique, there are two sequential steps including image segmentation, and classification. We, here, execute the two steps in parallel.

First, support vector machine (SVM), a commonly used classification method, is used for remote sensing data land cover classification. In the process of classification, the land cover of the lake, snow, and the other class are used for choosing the training sample. Second, watershed transform method is used for remote sensing image segmentation. In order to get better perform of the segmentation of the lake land cover, NDWI is taken as the input feature except for the original spectral bands. Third, vote principle is used to get the final Tibetan plateau lake information by combining the classification and image segmentation result. Finally, in order to illustrate the efficiency of the proposed method, the extraction result from NDWI is compared to the proposed method.

Image segmentation algorithms are to divide the image into meaningful separate regions which are homogeneous with respect to one or more properties such as texture, color, brightness, etc. They mainly include four categories: characteristic feature threshold or clustering, edge detection, region growing or extraction, and iterative pixel classification. There are many application of image segmentation in the remote sensing field, such as watershed transform (Xiao et al. 2010, Karantzalos and Argialas 2006), region growing (Baatz and Scha¨pe 2000,) and Markov random field models (Y. Li and P. Gong 2005) , fuzzy image-regions (Lizarazo & Elsner, 2009).

In this paper, we propose a hybrid algorithm combining the mean shift filter algorithm and watershed transform for the image segmentation. Fistly, meanshift filter is used to obtain a smooth result with good edge gray level change in feature space. Then, Canny's edge detector with the fitting parameter is adopted to retrieve the image gradient. Finally, marker-based watershed transform is used to segment the remote sensing image. The experimental segmentation results show that the proposed hybrid algorithm can overcome the over-segmentation efficiently; meanwhile, it can be used to obtain better segmentation results by using this algorithm.

2. Methodology

2.1 Classification by SVM

SVM based classifiers have considerable potential for remote sensing image classification There are lots of comparative research work having shown that it can obtain more accurate classification than other popular techniques such as neural networks, decision trees, and probabilistic classifiers including the maximum likelihood classification (Foody & Mathur, 2004a; Huang et al., 2002; Melgani & Bruzzone, 2004). SVM is a effective and discriminative classifier model relying on two assumptions. First, transforming data into a high-dimensional space may convert complex classification problems (with complex decision surfaces) into simpler problems that can use linear discriminant functions. Second, SVMs are based on using only those training patterns that are near the decision surface assuming they provide the most useful information for classification.

2.2 image segmentation

First, mean shift method is used to smooth the multispectral remote sensing data. Second, we take the watershed transform for image segmentation.

In the process of meanshift smoothing, spatial and multispectral kernels are involved into this method. For the traditional meanshift smoothing, Let n data points x_i, i=1, 2, …, n in the d-dimensianl space R^d, the multivariate mean shift vector denoted by $m_G(x)$ can be computed with $G(x)$ in the point x. The mean shift is defined as

$$m_{h,G}(x) = \frac{\sum_{i=1}^{n} x_i g(\| \frac{x - x_i}{h} \|^2)}{\sum_{i=1}^{n} g(\| \frac{x - x_i}{h} \|^2)} - x \tag{1}$$

where x is the center of the kernel, and h is the bandwidth of the kernel. Therefore, the $m_{h,G}(x)$ is the difference between the weighted mean and x as the center of the kernel which can be defined as

$$G(x) = cg(|x|^2) \tag{2}$$

where $g(x)$ is called the profile of the kernel $G(x)$; c is normalization constant;

Given the K_{h_s,h_h} is the kernels, which defined by

$$K_{h_s,h_h} = \frac{C}{h_s^2 h_h^p} k\left\{\left\|\frac{x^s}{h_s}\right\|^2\right\} k\left\{\left\|\frac{x^h}{h_h}\right\|^2\right\}$$

where h_s, h_h control the level of smoothing.

After smoothing, the first fundamental form based on the vector field model (Sapiro and Ringach 1996) is used to retrieve the gradient.

Let $\mathbf{I}(x, y)$: $\mathbf{R}^2 \rightarrow \mathbf{R}^N$ be a multispectral image with bands $\mathbf{I}_i(x, y)$: $\mathbf{R}^2 \rightarrow \mathbf{R}$, i = 1, ..., N. The value of $\mathbf{I}$ at a given point (x_0, y_0) is a N-dimensional vector in $\mathbf{R}^N$, then the multispectral image can be seen as a vector field. The difference of image values at two points $P = (x_0, y_0)$ and $Q = (x_1, y_1)$ is given by

$$\Delta \mathbf{I} = \mathbf{I}(P) - \mathbf{I}(Q). \tag{3}$$

When the Euclidean distance $d(P, Q)$ between P and Q tends to zero, the difference becomes the arc element

$$d\mathbf{I} = \frac{\partial \mathbf{I}}{\partial x} dx + \frac{\partial \mathbf{I}}{\partial y} dy \tag{4}$$

and its squared norm is given by

$$dI^2 = \begin{pmatrix} dx \\ dy \end{pmatrix}^T \begin{Bmatrix} \sum_n \left(\frac{\partial I_n}{\partial x}\right)^2 & \sum_n \frac{\partial I_n}{\partial x} \cdot \frac{\partial I_n}{\partial y} \\ \sum_n \frac{\partial I_n}{\partial x} \cdot \frac{\partial I_n}{\partial y} & \sum_n \left(\frac{\partial I_n}{\partial y}\right)^2 \end{Bmatrix} \begin{pmatrix} dx \\ dy \end{pmatrix} = \begin{pmatrix} dx \\ dy \end{pmatrix}^T \begin{Bmatrix} G^{xx} & G^{xy} \\ G^{yx} & G^{yy} \end{Bmatrix} \begin{pmatrix} dx \\ dy \end{pmatrix} \qquad (5)$$

This quadratic form is called the first fundamental form. It allows the measurement of changes in a multispectral image. The extreme of the quadratic form (3) are obtained in the directions of the eigenvectors of the 2×2 matrix

$$\mathbf{G} = \begin{pmatrix} G_{xx} & G_{xy} \\ G_{yx} & G_{yy} \end{pmatrix} \qquad (6)$$

and the values attained there are the corresponding eigenvalues. Simple algebra shows that the eigenvalues are

$$\lambda_{\pm} = \frac{G_{xx} + G_{yy} \pm \sqrt{(G_{xx} - G_{yy})^2 + 4G_{xy}^2}}{2} \qquad (7)$$

The multispectral edge gradient can be defined by

$$f = \sqrt{\lambda_+ - \lambda_-} \qquad (8)$$

After getting the multspectral gradient f, the watershed transform that is a powerful tool for image segmentation, is used to obtain segmentation result. The theory of watershed transform image segmentation can be expressed as follow. A grey-level image may be seen as a topographic relief, where the grey level of a pixel is interpreted as its altitude in the relief. A drop of water falling on a topographic relief flows along a path to finally reach a local minimum. Intuitively, the watershed of a relief corresponds to the limits of the adjacent catchment basins of the drops of water.

3. Experimental Result

In this paper, the research region is over Tibetan plateau lake. The Thematic Mapper (TM) remote sensing data from Landsat Satellite having a spatial resolution of 30m is used as the experimental data. The classification result of the remote sensing data is illustrated in Fig.1

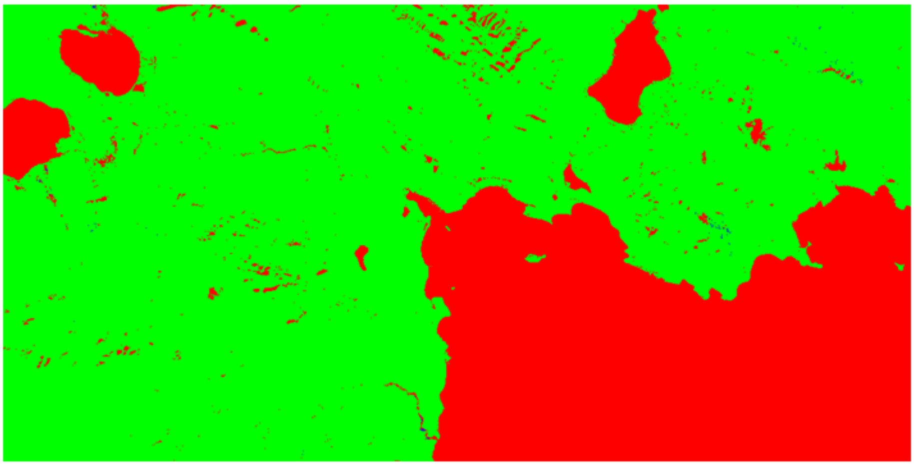

Fig.1 The classification result

In the classification map

We can clearly see that there are a lot of speckles in the whole classification map, even though all lakes are recognized. In the speckles, there are some ground recognized by mistake, and some ground is recognized correctly. In order to remove these wrong speckles, we first segment the remote sensing image, and cover it with the classification map. The image segmentation by using watershed transform is shown in Fig. 2

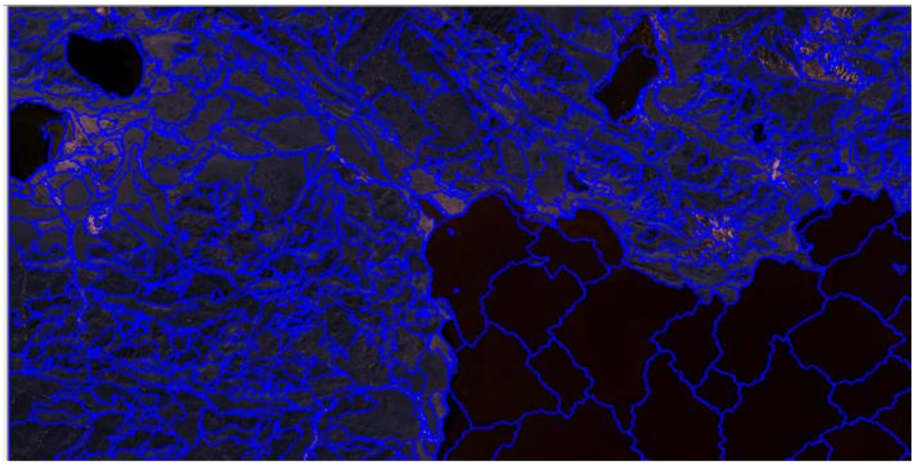

Fig.2 Image segmentation result

We take each segment as one object. When the number of pixel that is classified as lake class in this object take over 50 percentage, this segment is classified as lake class. The classification result is illustrated in Fig. 3.

Fig.3 Lake extraction result

We can see clearly that all lakes are extracted correctly, and the "lakes" classified by mistake are removed perfectly.

3. Conclusion

In conclusion, a hybrid method based on image segmentation and pixel-based classification for Tibetan Plateau lake extraction is proposed in this paper. In the new scheme, we combine image segmentation that is based on mean shift smoothing and watershed transform, and SVM classifier to extract Tibetan Plateau lake. First, the TM image is classified into several ground object including the class of lake. Second, this remote sensing image is segmented. Finally, the classification and segmentation result is combined to get the final lake extraction. The experiment result shows that the proposed method demonstrates promising performance in hyperspectral data.

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