A NEW CLASSIFICATION METHOD FOR HIGH SPATIAL RESOLUTION REMOTE SENSING IMAGE BASED ON MAPPING MECHANISM

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ABSTRACT:

Image classification is a challenging problem of high spatial resolution remote sensing image. On the basis of analyzing and summarizing the research actuality of remote sensing image classification technology, this paper proposed a new object-based image classification method based on mapping mechanism for high spatial resolution remote sensing image. The classification framework used a special mapping strategy to fit in the special data format and content of high spatial resolution remote sensing data. First, the multi spectral image was segmented by multi scale watershed segmentation and at the same time classified by a traditional pixel-based classification method (maximum likelihood); then the pixel-based multi spectral classification result was mapped to the segmentation result by area of dominant principle to get the object based multi spectral classification result. In order to make good use of the information in the pan image, it was also segmented, and the final classification result was gotten by mapping the object-based multi spectral classification result to pan image segmentation result. Experiment results show that the mapping mechanism based classification algorithm for high spatial resolution remote sensing data can make use of the information both in pan and multispectral bands, integrate the pixel-based and object-based classification method, and finally improve the classification accuracy.

1. INTRODUCTION

With successful launches of a series of high spatial resolution remote sensing satellites, a new era of geospatial data acquisition and processing technology has come. With the improvement of remote sensing image resolution, high spatial resolution images contain more information, which have made it possible for humans to observe the earth in detail. The abundance information, on one hand, has promoted application of remote sensing, but on the other, also brings new challenges to the remote sensing data analysis technology. One challenge is that traditional image classification technology can no longer satisfy the needs of high spatial resolution remote sensing image classification.

High spatial resolution satellite (such as IKONOS SPOT5 or Quick Bird) remote sensing data has plenty of spatial information. How to take advantage of the plentiful structural information for a better classification result has been paid more attention by many researchers recently. Pixel-based classifications have difficulties with high-resolution data because of high spatial variation (Ehlers *et al.* 2003). Using only spectral information for classification cannot lead to accurate interpretations because the differentiation between land use/cover classes depends not only on spectral information but also on spatial (contextual) information of the image data (Gong *et al.* 1992).

The traditional method of classification of high-resolution images has been proved to have several drawbacks, such as low classification accuracy, very limited spatial information to be derived and salt-and-pepper effects(Chen *et al.* 2012). Most domestic and international research uses an the improved traditional classification algorithm to classify them(Chungan Li & Guofan Shao, 2012). Object based image analysis has proven its potentials in many remote sensing applications, especially when using high spatial resolution data.

In order to incorporate spatial and spectral information into image data classification, the traditional way to make a remote sensing data classified is firstly try to fuse the remote sensing data, which make the multispectral images have the same spatial resolution with the pan image. However, it has two disadvantages: fusing the remote sensing data will cost a lot of time, which make the computational efficiency lower, and what is more important is due to the fact that the fused image data is not an accurate image representation but an image estimation which may affect the remote sensing data classification results.

On the basis of analyzing and summarizing the research actuality of remote sensing image classification technology, taking advantage of spectral and spatial features of high spatial resolution remote sensing image together, this paper proposed a new object-based image classification method based on mapping mechanism, specifically for high spatial resolution remote sensing image. The classification framework used a special mapping strategy to fit in the special data format and content of high spatial resolution remote sensing data. First, the multi spectral image was segmented by multi scale watershed segmentation and at the same time classified by a traditional pixel-based classification method (maximum likelihood); then the pixel-based multi spectral classification result was mapped to the segmentation result by area of dominant principle to get the object based multi spectral classification result. In order to make good use of the information in the pan image, it was also segmented, and the final classification result was gotten by mapping the object-based multi spectral classification result to pan image segmentation result.

IKONOS and SPOT-5 satellite data were applied to make a series of experiments and comparative analysis on the mapping mechanism based classification method. Experiment results show that the mapping mechanism based classification algorithm for high spatial resolution remote sensing data can make use of the information both in pan and multispectral bands, integrate the pixel-based and object-based classification method, and finally improve the classification accuracy.

2. METHODOLOGY

This section details watershed transformation, multi-scale segmentation, region merging and mapping algorithm, maximum likelihood classification (MLC) applied to multi spectral high spatial resolution remote sensing image and mapping mechanism integrate the pixel-based classification result and object-based segmentation result. The flow chart of the proposed object-oriented classification is shown in figure 1.

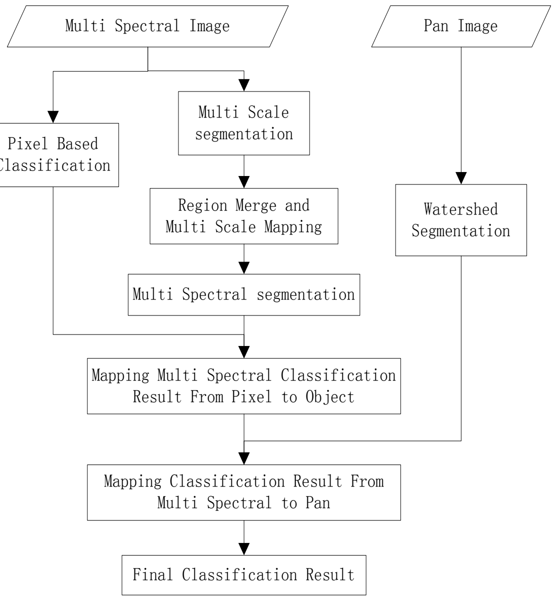

Figure.1 The flow chart of proposed classification method

2.1 Watershed Segmentation

Image segmentation is very essential and critical to image processing and pattern recognition. Watershed transformation is a powerful mathematical morphology technique for image segmentation and subsequently a lot of algorithms for its implementation have been proposed.

Watershed algorithm is a good choice for the high resolution image with large amount of data because of its fast segmentation speed. The idea of watershed is drawn by considering an image as a topographical surface (John Goutsias, 2000). Suppose we pierce holes at every regional minimum and dip the image surface into water, then water will flood areas adjacent to regional minima. A regional minimum is a connected plateau from which it is impossible to reach a point of lower gray level by an always-descending path. As the image surface is immerged, some of the flood areas will tend to merge. When two or more different flood areas are touched, watershed lines (i.e. dams) are constructed between them. When finished, the resulting networks of dams define the watershed of the image.

We apply the labeling watershed segmentation algorithm to segment the pan and multi spectral image. Morphological operators were used to attract the gradient of the image, which provide the watershed segmentation algorithm with labeled areas.

2.2 Region Merging

However watershed algorithm is very sensitive to the noise and detail information, and high resolution remote sensing image is very complex. So it's easy to make an over-segmentation. In order to obtain a concise region representation, post-processing are applied to resolve the over-segmentation. Post-processing (region merge) merges regions according to certain criteria for a more concise region presentation.

Region merge is an important method to further reduce the over segmentation. Two neighboring regions can be merged into a single region if they are similar enough. The region merging algorithm presented here makes use of the spectral and texture properties of regions as its merging criteria. This section describes the criteria considered in this merging process.

A flow chart of region-merging algorithm is presented in figure 2. After the segmentation through multi scale region transformation is obtained, the associated regional parameters, weight of spectral heterogeneity and weight of texture heterogeneity are applied to an iterative region-merging algorithm outlined as follows.

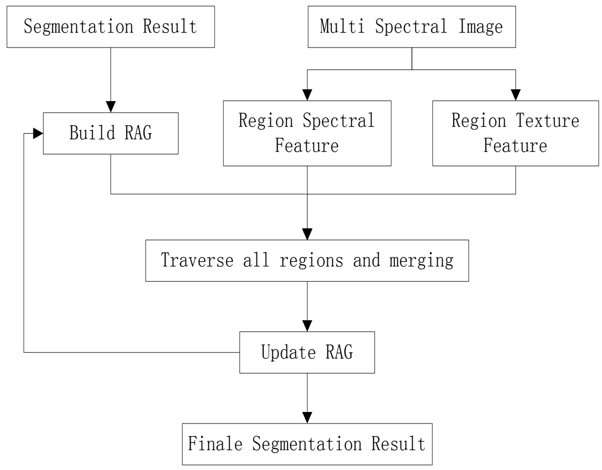

Figure.2 The flow chart of region merging for multi spectral image

Traditional region-merging algorithms are based on spectral heterogeneity. Although such information is abundant in high resolution remote sensing images, complications due to noise and influence among objects are high for these cases as well. Merging regions by the spectral criterion alone will yield suboptimal results. For this study, a mixed criterion was implemented that combines both spectral and spatial heterogeneity criteria as developed.

2.3 Maximum Likelihood Classification (MLC)

There are many image classification algorithms for remote sensing images. Each algorithm has its unique advantage and weakness. In this paper, we focus on the application of the mapping mechanism in high spatial remote sensing images classification. Theoretically, all the pixel-based classification method can be applied in the proposed algorithm. Therefore, in order to improve the efficiency of the whole approach and make it more simple, the maximum likelihood classifier is chosen with the advantages of simple and rapid.

Maximum likelihood classification (MLC) is a method for determining a known class distribution as the maximum for a given statistic (Scott and Symons, 1971). MLC is, in fact, widely used in remote sensing, in which a pixel with the maximum likelihood is classified into the corresponding class. Suppose there are m predefined classes, the class a posteriori probability is defined as(Liu et al, 2011)

$$P(k \mid x) = \frac{P(k)P(x \mid k)}{\sum_{i=1}^{m} P(i)P(x \mid i)} \quad (1)$$

where P(k) is the prior probability of class k, P(x | k) is the conditional probability of observing x from class k (probability density function). In the case of normal distributions, the likelihood function, P(x | k), can be expressed as(Liu et al, 2011)

$$L_k(x) = \frac{1}{(2\pi)^{\frac{n}{2}} \left| \sum_k \right|} \exp\left(-\frac{1}{2}(x-\mu_k)^T \sum_k^{-1} (x-\mu_k) \right) \quad (2)$$

where $x = (x_1 x_2 \ldots x_n)^T$ is the vector of a pixel with n bands; $L_k(x)$ is the likelihood membership function of x belonging to class k; $\mu_k = (\mu_{k1}\mu_{k2}\ldots\mu_{kn})^T$ is the mean of the kth class; $\sum_k = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_{nn} \end{pmatrix}$ is the variance covariance matrix of class k.

2.4 Classification Category Mapping Mechanism

The high spatial resolution remote sensing image often contains two types of images, including one pan band and four multi-spectral bands. Taking IKONOS for example, the pan band with the resolution of 1 meter and four multi-spectral bands with the resolution of 4 meters. It can be seen from figure 3 that the pan image of the high spatial remote sensing data has the most part of the spatial information, while the multispectral images have the most part of the spectral information.

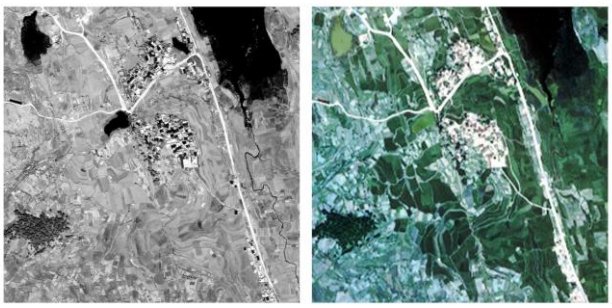

Figure 3. The comparison of pan image and multi spectral image (Left: pan image; right: multi spectral image)

In order to make full use of pan and multi spectral image information, image fusion is widely used. In image fusion process, the spatial detail in panchromatic image is injected into the corresponding n-band multi spectral image. Then the fused image was used in the subsequent application. The effect of fusion directly determine the subsequent application accuracy.

The proposed classification framework used a special mapping mechanism to make full use of spatial and spectral information of high spatial resolution remote sensing data. In the presented method, the high spatial resolution raw data instead of the fused image was directed applied based on mapping mechanism, because the fused image is an image estimation which may brings in spectral distortion and affects the accuracy of classification results. Figure 4 shows the space mapping relationship between the pan and multi spectral image, taking resolution ratio 1:4 for example. One pixel in multi spectral image corresponds to sixteen pixels in panchromatic image.

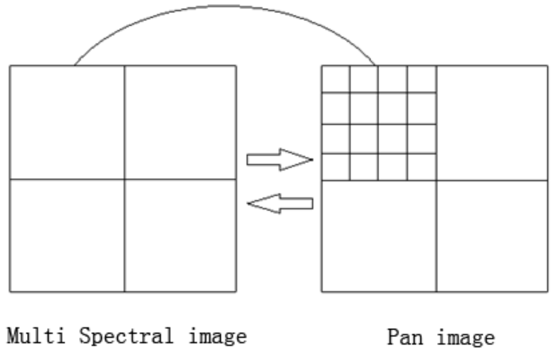

Figure 4. The space mapping relationship between multi spectral and pan images, taking the resolution rate of 1:4 for example

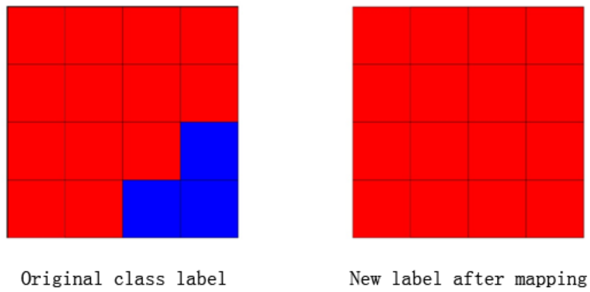

Figure 5. Mapping mechanism by area dominant principle, the area of red is large than blue, so after mapping, the region label changed to red

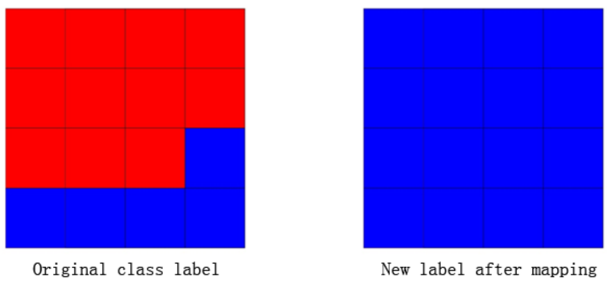

Figure 6. Mapping mechanism by category dominated principle, the blue is more important than red, so after mapping, the region label changed to blue even the area of red is larger than blue

There are two kinds of mapping mechanisms, one is area dominated principle, the other is category dominated principle. When using area dominated principle as mapping mechanism, the area of each class in the region is computed and the largest area class label will be assigned to the region as new label. The area of each class is most important. When using category dominated principle, the most important class label will be assigned to the region, nothing with class area.

3. EXPERIMENT AND RESULT ANALYSIS

To prove the effectiveness of this method presented above, the algorithm was implemented in MATLAB and ENVI for two high spatial resolution remote sensing images. IKONOS and

SPOT-5 satellite data were applied to make a series of experiments and comparative analysis between the mapping mechanism based classification method and pixel-based MLC method.

The classification experiment one is performed with the SPOT5 satellite remote sensing data, including the pan band with the resolution of 2.5 meters and four multi-spectral bands with the resolution of 10.0 meters. The size of multi spectral image is 300×300, and 1200×1200 for pan image.

The classification experiment two is performed with the IKONOS satellite remote sensing data, including the pan band with the resolution of 1.0 meter and four multi-spectral images with the resolution of 4.0 meters. The size of multi spectral image is 256×256, and 1024×1024 for pan image.

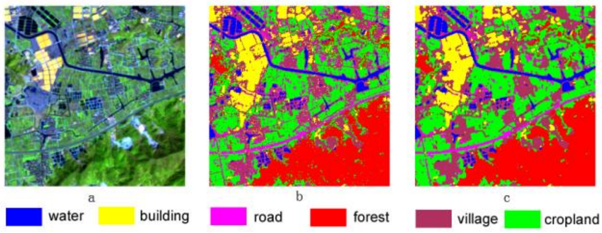

Figure 7. The SPOT-5 multi spectral image pixel-based classification result

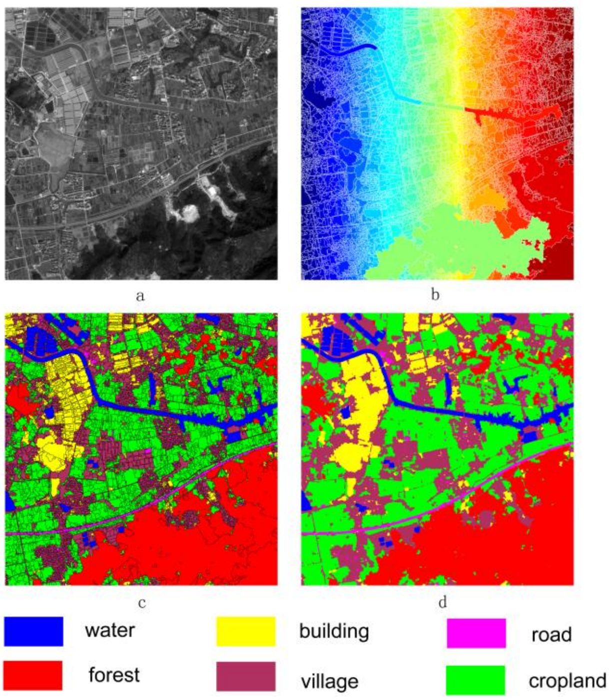

Figure 8. The SPOT-5 pan image classification result based on mapping mechanism

Figure 7 shows the classification result of SPOT-5 multi spectral image. A is the original image (RGB color synthesis), b is classification result by MLC, and c is the classification result after post-processing by majority.

Figure 8 shows the classification result of SPOT-5 pan image based on mapping mechanism. A is the original image, b is segmented by labeling watershed, and c is the object-based classification result after mapping from spectral image classification result within region boundary and d is the final object-based classification result without region boundary.

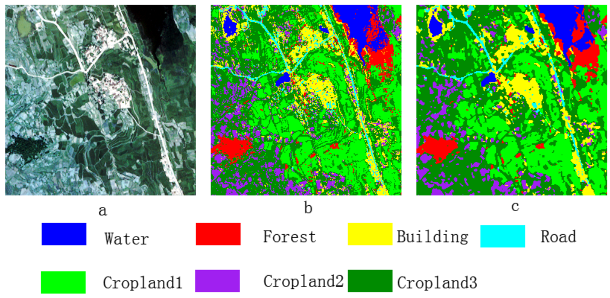

Figure 9. The IKONOS multi spectral image pixel-based classification result

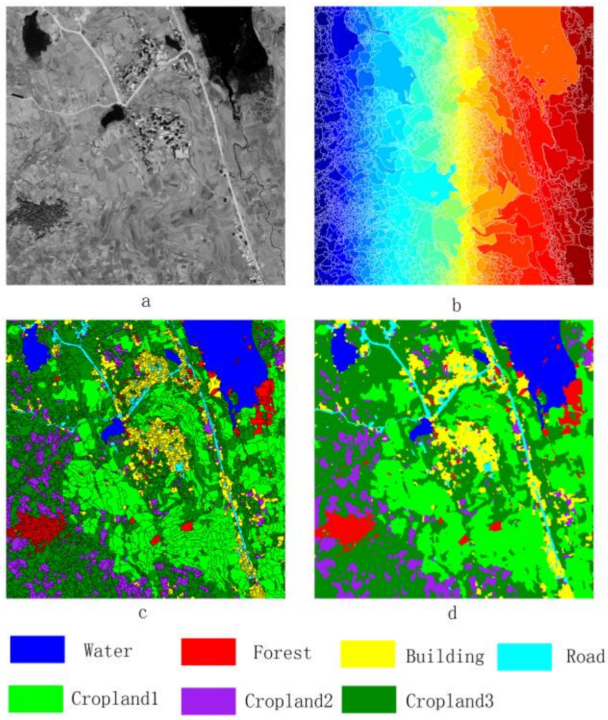

Figure 10. The IKONOS pan image classification result based on mapping mechanism

Figure 9 shows the classification result of IKONOS multi spectral image. A is the original image (RGB color synthesis), b is classification result by MLC, and c is the classification result after post-processing by majority.

Figure 10 shows the classification result of IKONOS pan image based on mapping mechanism. A is the original image, b is segmented by labeling watershed, c is the object-based classification result after mapping from spectral image classification result within region boundary and d is the final object-based classification result without region boundary.

It can be seen from the above experiment results that the proposed object-based classification method based on mapping mechanism can get more accurate boundary information and effectively reduce the plaques noise of the classification results than pixel-based method. The plaques noise in pixel-based classification result can be reduced through post-processing, such as clump and majority, but the post-processing will make the dislocation boundaries and influence the effect of subsequent application.

Figure 11 shows the local comparison of SPOT5 image classification result between the proposed method and MLC method, the left is classified based on mapping mechanism, the small middle is classified by MLC and the right small after post-processing. It can be seen from figure 11 that the proposed object-based classification method can obtain better classification result than MLC result. And the plaques noise is effectively reduced. Although the post-processing can restrain the plaques noise in pixel-based classification result, the boundaries of regions have been dislocated.

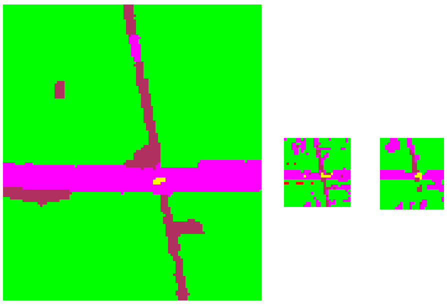

Figure 11. The local comparison of the SPOT5 image classification result

The classification algorithm based on mapping mechanism, can obtain better classification results than pix-based MLC classification results. Experiment results show that the mapping mechanism based classification algorithm for high spatial resolution remote sensing data can make use of the information both in pan and multispectral bands, integrate the pixel-based and object-based classification methods.

In this paper, the image segmented results play an important role in the process of the whole classification algorithm. For this reason, the choice of image segmentation algorithm is very critical. Future work will be concentrated on the improvement of image segmentation algorithm.

4. CONLUSION

A new classification algorithm for high spatial resolution remote sensing data based on mapping mechanism is proposed in this paper, in which pixel-based classification method and object-based segmentation and classification was integrated by mapping mechanism. The classification result tested with two data sets show that the presented method can make use of the information both in pan and multispectral bands, integrate the pixel-based and object-based classification method, and finally improve the classification accuracy.

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