MULTILEVEL OBJECT BASED IMAGE CLASSIFICATION OVER URBAN AREA BASED HIERARCHICAL IMAGE SEGMENTATION AND INVARIANT MOMENTS

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ABSTRACT:

With the availability of very high resolution multispectral imagery from sensors such as IKONOS and Quickbird, it is possible to identify small-scale features in urban environment. Because of the multiscale feature and diverse composition of land cover types found within the urban environment, the production of accurate urban land cover maps from high resolution satellite imagery is a difficult task. In the present study, a multilevel object based classification method based on hierarchical segmentation and shape descriptors was proposed.

Hierarchical segmentation was first performed by multichannel watershed segmentation and dynamics of the contours in watershed. Traditional watershed transformation defined for gray level image was extended to multispectral image segmentation by computing multispectral gradient image through a vector based approach, which uses extended dilation and erosion operations. The hierarchical multispectral image segmentation was then conducted by an improved method for dynamics of the contours. After segmentation, spectral features and shape features from different segmentation levels were calculated and combined in subsequent classification. The shape features used in the study were the Hu's invariant moments, the useful shape descriptors. A hierarchical object based classification method was proposed, which combined pixel based and object based classification methods. The vegetation classes and shadow area were extracted by pixel based classification and a post classification processing. Non-vegetation classes were classified through an object based classification, which combined the spectral and shape features at multiple scales.

The proposed method was compared with several classification methods, using a subset of Quickbird image covering Beijing urban area. The results showed that the proposed method produced higher overall classification accuracy, compared to other classification methods.

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1. INTRODUCTION

With the availability of very high resolution multispectral imagery from sensors such as IKONOS and Quickbird, it is possible to identify small-scale features in urban environment. Automated and semiautomated methods for the classification of urban land cover types are of great interest. Because of the multiscale feature and diverse composition of land cover types found within the urban environment, the production of accurate urban land cover maps from high resolution satellite imagery is a difficult task. For urban land cover classification using very high resolution imagery, the object based method (strategy) was widely accepted and applied. The prerequisite of object based analysis is image segmentation. The quality of segmentation results directly affects the accuracy of the subsequent image classification. For most previous studies, the aim of image segmentation is to find a single good segmentation result (Carleer et al., 2005; Plaza and Tilton, 2005). However, some studies showed that multilevel (hierarchical) image segmentation results were more appropriate for real applications (Bruzzones et al., 2006; Carleer et al., 2005; Carleer and Wolff, 2006). Thus, development of multilevel segmentation method is urgently required for many applications. On the other hand, since high resolution image usually has limited spectral resolution, the accuracy of the classification using spectral information alone is very limited. Thus, incorporation of spatial information in urban land cover classification would lead to higher classification accuracy (Bruzzones et al., 2006; Carleer and Wolff, 2006; Zhang et al., 2006).

In the present study, a multilevel object based classification method based on hierarchical segmentation and shape features was proposed.

2. METHODS

2.1 Introduction

High spatial resolution image have relatively coarse spectral resolution. Thus, the accuracy of classification using spectral information alone is very limited. However, high resolution imagery contains abundant spatial details and structure. Thus, the inclusion of spatial information in high resolution image classification over urban area could lead to higher classification accuracy. Urban land cover classes found in very high resolution imagery can roughly categorized as three groups: vegetation cover, non-vegetation man-made cover, and shadow area. Generally, vegetation classes, such as grass and tree, are relatively easy distinguished using spectral information of the high resolution imagery (e.g. Shackelford and Davis, 2003). However, the man-made cover classes are difficult distinguished because of their similar spectral signatures. So, much effort is given to identify the different man made classes (i.e. non-vegetation classes) (e.g. Shackelford and Davis, 2003). Shape feature and other spatial information were used in high resolution image classification over urban area (Bruzzone and Carlin, 2006; Zhang et al., 2006; Carleer and Wolff, 2006). In the previous studies, the shape feature was used for all land cover types. However, in this paper the shape feature was only used for man made classes (Bruzzone and Carlin, 2006; Zhang et al., 2006; Carleer and Wolff, 2006). We proposed a hierarchical classification method which is based on multilevel segmentation results. The method first extracted the vegetation classes and shadow by pixel based classification and a post classification processing. The non-vegetation classes were classified by a multilevel object based classification which combined spectral and shape features at multiple segmentation levels. In this study, multilevel segmentation was produced by an extended and improved method of dynamics of contours in watershed transformation.

The procedure for the hierarchical classification method is shown in Figure 1.

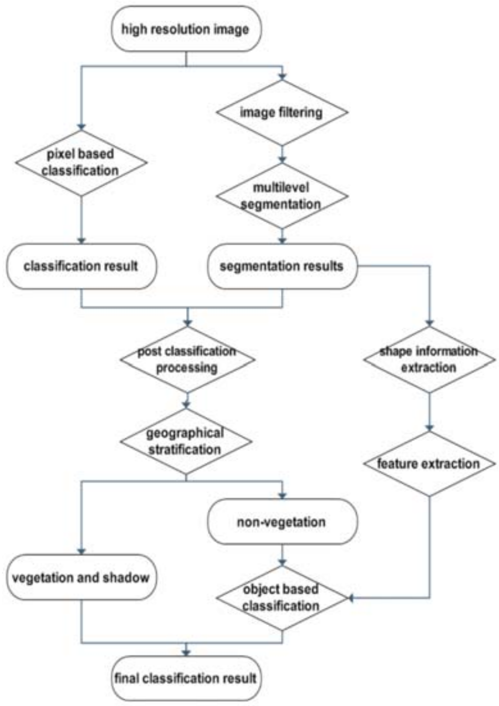

Figure 1 The procedure for hierarchical classification proposed in the study

2.2 Hierarchical segmentation by extended watershed transform and dynamics of contour

Traditional watershed transformation is defined for gray-level image. As most other image segmentation methods, the watershed transformation produces a single segmentation result. Najman and Schmit (1996) proposed watershed based hierarchical segmentation using dynamics of watershed contours. However, the method can not be directly used for multispectral image segmentation. In this paper, the method of hierarchical segmentation by dynamics of contours was first extended to multispectral image segmentation and then the algorithm was improved to produce more accurate segmentation results.

Traditional watershed transformation was extended to multispectral image segmentation by computing multispectral gradient image through a vector based approach, which uses extended dilation and erosion operations (Li and Xiao, 2007). The hierarchical multispectral image segmentation was then conducted by dynamics of the contours (Najman and Schmit, 1996). The hierarchical segmentation produced multilevel results, where low level objects are fully contained within the high-level objects.

In the original algorithm proposed by Najman and Schmit (1996), only the situation that two basins meet is processed. However, in reality there are probably more than two basins meet. Thus, we proposed a method to deal with the situations when more than two basins meet.

Since watershed transformation is sensitive to noise and texture features, the filtering is conducted on the original image. The levelings (Meyer, 2004), a new morphological tool, was used for the filtering, in order to remove small objects or meaningless structures.

2.3 Shape information extraction

The shape features used in the study were the Hu's invariant moments (Hu, 1962), a useful shape descriptor which is used in high resolution image analysis in recent years. There are 7 invariant moments, which are invariant to translation, rotation and scaling (Hu, 1962).

The invariant moments were computed for each segment in order to extract its shape features used in subsequent object based classification.

2.4 Pixel based classification and post-classification processing

Pixel based classification was conducted by Maximum Likelihood classifier using spectral information alone. Since there is obvious salt-and pepper appearance. A post classification method was adopted to improve the classification result. The pixel based classification result was combined with the segmentation results through the overlay technique and majority rule. For each segment, the majority class of per-pixel classification and its fraction were calculated. If more than a certain threshold (usually 50% or higher value) of the pixels of a particular segment were categorized in one class (i.e. majority fraction .0.5), the segment was considered to belong to that class. Instead of using the segmentation result at a single level, the segmentation results at multiple levels were used. The method runs from the segmentation result at the high level (coarse level) to that at lower level (fine level). If a segment at a high segmentation level is not classified (i.e. there is no any class taking a fraction of the segment higher than the given threshold), the procedure will go down the finer level, until the finest level. If a segment is not identified on the finest segmentation level, the pixels of the segment were classified according to the 3×3 majority-filtered per-pixel classification output. After the post classification processing, the vegetation classes and shadow were masked out.

2.5 Object based classification incorporating multilevel shape information

The non-vegetation area was then classified by incorporating multilevel shape features. For each level of segmentation, spectral features and shape features were obtained for each segment. Thus, there are many features obtained. Feature extraction method was applied to select the appropriate subset of features for final classification. The Principal Component Analysis (PCA), a classical feature extraction method, was adopted in the study.

An object based image classification method was implemented, which considers each object as the basic processing unit, and allow the traditional pixel based classifier to be used in the object classification. The Support Vector Machines (SVMs) was used as a classifier in the study. The SVM is a recently developed statistical learning method and widely used for image classification with many successful cases.

3 DATA AND STUDY AREA

A subset of Quickbird image covering Beijing urban area was used to evaluate the proposed method. The image was acquired in September, 2003. The multispectral and panchromatic images were fused to produce a multispectral image with pixel size of 0.61m. The image fusion used in the study (Figure 2) is produced using the Gram–Schmidt procedure implemented in the ENVI software package.

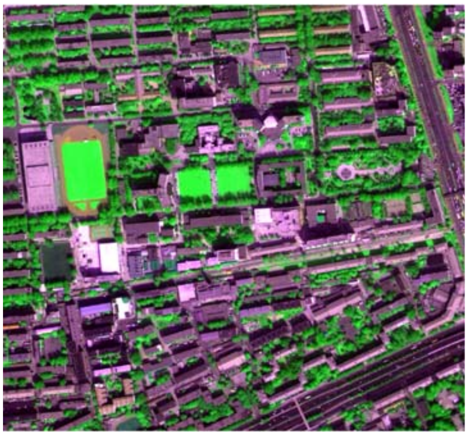

Figure 2 Quickbird image of study area

4 RESULTS AND DISCUSSION

Figure 3 shows portions of the original image and segmentation results by the algorithm of Najman and Schmit (1996) and the algorithm improved in the paper. From the figure, the small segments (regions) which are very apparent in result by the original algorithm are substantially reduced in the result by the improved algorithm.

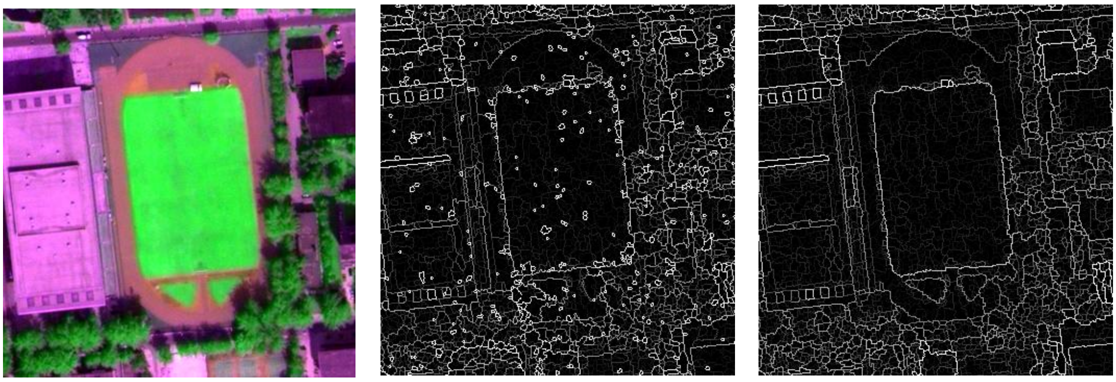

Figure 3 A portion of pan-sharpened multispectral image (a) and the segmentation results by the algorithm by Najman and Schmit (1996) (b) and the improved algorithm in this paper (c). The different gray levels of the lines in (b) and (c) represent the values of contour dynamics.

The multilevel segmentation results by the algorithm improved in the paper were shown in figure 4. These segmentation results were produced by setting different threshold values for original segmentation result like that shown in figure 3c. These multilevel segmentation results constitute a hierarchical (or multilevel) representation of land cover classes (objects), where low level objects are fully contained within the high-level objects. At each segmentation level, the spectral features and shape features were calculated for each segment. The spectral feature used in the paper is mean value for each segment. The shape features are 7 Hu's invariant moments for each segment. PCA was applied to spectral and shape features, respectively. Finally, 7 PCs from 12 spectral features (4 bands for each segmentation level) and 10 PCs from 56 shape features (at two segmentation levels) were used in final classification.

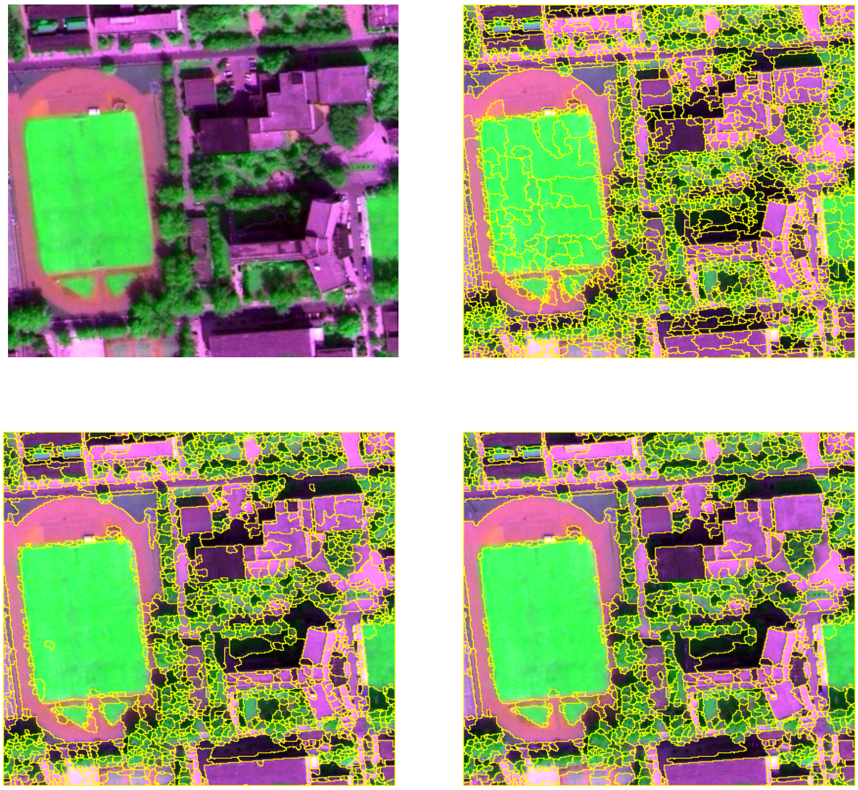

Figure 4 Portions of Quickbird image (a) (upper left) and segmentation results with different threshold values on the dynamics of contours: 15 (b) (upper right), 25 (c) (lower left), 35 (d) (lower right).

In order to evaluate the proposed method, other data combinations were also used in classification. The first is the pixel based spectral classification (A). The second one is hierarchical pixel based classification combining spectral and shape features (B). The third one is hierarchical object based classification with single level shape features (C).

The results showed that the proposed method produced the highest overall accuracy and Kappa among all data combinations (Table 1). This validates the effectiveness of the proposed classification method.

Table 1 Classification accuracies using different data combinations

Classification method	OA (%)	Kappa
A	78.21	0.7489
B	83.04	0.8047
C	83.86	0.8141
D	86.21	0.8411

The meanings of A to C are explained in the text. D: the hierarchical classification method proposed in this paper.

From figure 4a, in pixel based spectral classification, vegetation classes and shadow are accurately classified. However, non-vegetation classes such as different buildings are much confused. Another obvious feature in the spectral classification is that the areas between vegetation classes and non-vegetation classes are classified as other impervious surface. However, in classification result produced by the method proposed in this paper (Figure 4b) non-vegetation classes are also correctly identified.

5 CONCLUSIONS

This paper extended and improved a hierarchical segmentation by dynamics of watershed contours for high resolution multispectral image. Based on multilevel segmentation results, a hierarchical object based classification method was proposed for urban land cover classification, which combined the spectral and shape features. The experimental results showed that the proposed segmentation method could produce more accurate segmentation results. The hierarchical object based classification method resulted in higher overall accuracy, compared to other methods.

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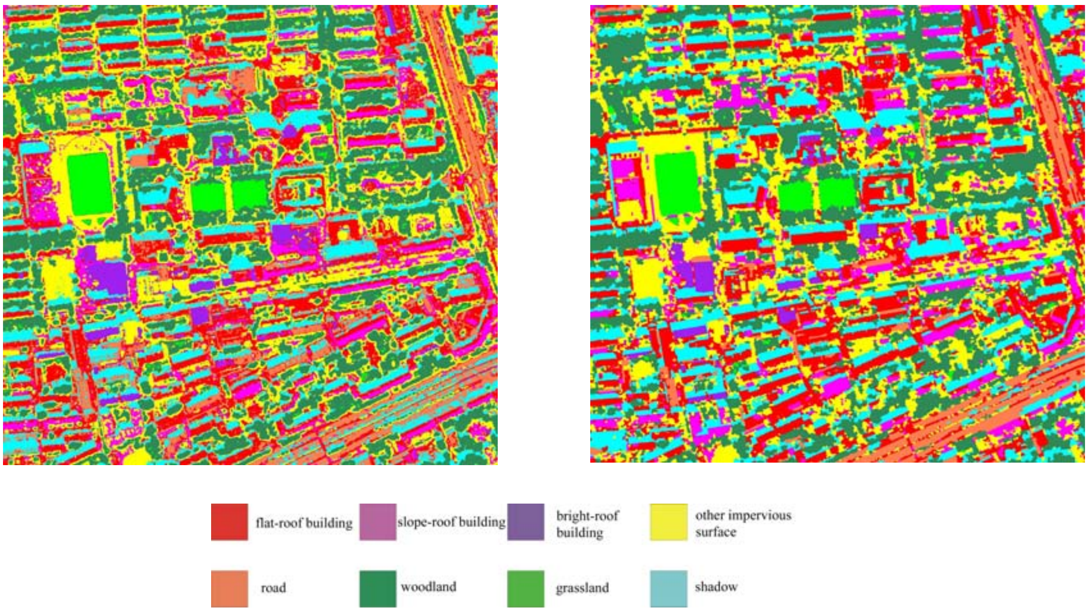

Figure 4 Results by pixel-based spectral classification and hierarchical object-based method proposed in the study