URBAN IMPERVIOUS SURFACE EXTRACTION FROM VERY HIGH RESOLUTION IMAGERY BY ONE-CLASS SUPPORT VECTOR MACHINE

P. Li, H. Xu, S. Li

Institute of Remote Sensing and GIS, School of Earth and Space Sciences, Peking University, Beijing 100871, P R China - pjli@pku.edu.cn

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ABSTRACT:

This paper proposes a new method for extracting impervious surface from VHR imagery. Since the impervious surface is the only class of interest (i.e. target class), the One Class Support Vector Machine (OCSVM), a recently developed statistical learning method, was used as the classifier. Rather than use samples from all classes for training in traditional multi-class classification, the method only requires samples of the target class for training. The classification was conducted on object level. The proposed method was evaluated and compared to existing methods using Quickbird image from Beijing urban area. The results showed that the proposed method outperformed the existing method in term of classification accuracy. The method provides an effective way to extract impervious surface from VHR images.

1. INTRODUCTION

Impervious surface is defined as any materials that water cannot infiltrate, and has been recognized as an important indicator in urban environmental assessment and valuable input to planning and management activities (Lu and Weng, 2009; Yuan and Bauer, 2006). The extraction of impervious surface from remote sensing imagery has continued to be an important problem for more than three decades. In recent years, the increasing availability of very high resolution (VHR) imagery, such as IKONOS, Quickbird and GeoEye-1, provides great opportunity for detailed impervious surface mapping in urban areas. Although some methods using VHR images have been developed (Lu and Weng, 2009; Yuan and Bauer, 2006; Goetz et al., 2003; Cablk and Minor, 2003; Zhou and Wang, 2008; Roeck et al., 2009), obtaining highly accurate land cover and impervious surface information from VHR imagery remains challenging, thus new methods and techniques are still required. However, since there is extensive occurrence of shadows in VHR imagery caused by high buildings and trees in dense urban areas, which leads to the reduced or total loss of spectral information in the shaded areas, an important problem to be addressed is to identify the impervious surfaces in shaded areas (Lu and Weng, 2009). As in general land cover classification of urban areas using VHR images, object based methods are also commonly used to extract impervious surfaces (Cablk and Minor, 2003; Yuan and Bauer, 2006; Zhou and Wang, 2008).

2. METHODS

In this study, we adopted a two-stage object based method to extract impervious surface. At the first stage, shadow areas were identified at object level generated by image segmentation. At the second stage, shadow areas and non-shadow areas were separately classified to extract impervious surface, using one-class Support Vector Machine (One-class SVM or OCSVM).

Prior to these two stages, multilevel hierarchical segmentation using the proposed method was first carried out, different levels of segmentation results were then selected for each stage. For example, since shadow extraction at the first stage and shadow classification at the second stage require different levels of segmentation detail, shadow extraction was conducted at a coarse level of segmentation, whereas the shadow classification was conducted at a fine level of segmentation. On the other hand, non-shadow areas were classified at an appropriate segmentation level, different from the levels for shadow detection and classification. After all classes were extracted, impervious surfaces in both shadow areas and non-shadow areas were aggregated to a single class, i.e. impervious surface.

2.1 Multi-level segmentation

In this study, an improved watershed transformation method (Li et al., 2010), was adopted for high resolution multispectral image segmentation. However, other image segmentation methods can also be used to produce segmentation results.

In the image segmentation method by Li et al. (2010), multispectral gradient proposed by Li and Xiao (2007) was first used to extend the watershed transformation to multispectral image segmentation, and then the dynamics of watershed contours proposed by Najman and Schmits (1996) was adopted to reduce the oversegmentation in initially segmented image and produce multilevel segmentation results.

After the dynamics of watershed contours (Najman and Schmits, 1996) were obtained, a threshold is applied to the values of the contour dynamics, in order to remove the watershed lines that have less significance and to produce a final segmentation result. The details for algorithm for computation of contour dynamics can be found in (Najman and Schmits 1996, Lemarechal et al. 1998, Schmitt 1998).

2.2 OCSVM

The OCSVM is a recently developed one-class classifier and has been widely used in ecological modeling (Guo et al. 2005), and remote sensing classification (Sanchez-Hernandez et al. 2007) as well as change detection (Li and Xu 2009). In the OCSVM training process, only samples from the target class are used. Thus, it is suitable for the situations where only one class or some classes (but not all classes) are of interest and easy to sample or measure; the other class might be very difficult or expansive to measure. Therefore, the boundary between the two classes has to be estimated from data of the only available target class. The task is to define a boundary around the target class, such that it encircles as many target examples as possible and minimizes the chance of accepting outliers (Tax 2001).

Scholkopf et al. (1999) developed an OCSVM algorithm to deal with the one-class classification problem. The OCSVM may be viewed as a regular two-class SVM where all the training data lies in the first class, and the origin is taken as the only member of the second class. The OCSVM algorithm first maps input data into a high-dimensional feature space via a kernel function and then iteratively finds the maximal margin hyperplane, which best separates the training data from the origin.

2.3 Impervious surface mapping

After multilevel segmentation was carried out, a hierarchical classification strategy was adopted using the OCSVM and multilevel segmentation results. Since shadows are common in the VHR images, the OCSVM was first used to extract the shadow areas at a coarse level of segmentation. After that the shadow areas and non-shadow areas were separately classified using the OCSVM and different levels of segmentation to extract the impervious surface. Finally, the impervious surface from both shadow areas and non-shadow areas were merged to produce a final impervious surface map. In each step, only samples from the class of interest are used to train the OCSVM. For example, in the stage of shadow extraction, only samples from shadow areas were used in the training process. This is different from traditional classification methods, where samples from all classes are required.

2.4 Result evaluation

In order to validate the proposed impervious surface mapping method, a method based on the use of traditional SVM and multilevel segmentation results was also used to extract the impervious surface. After multilevel segmentation results were obtained, the SVM classifier was first used to classify the image of the study area into several land cover classes, such as grass, tree, soil, impervious surface and shadow. The obtained shadow areas were then further classified using the SVM to several land cover classes, including impervious surface. Finally, the classification result from both shadow and non-shadow areas were merged to an impervious/non-impervious surface map, where the classes, such as tree, grass and soil were merged to a class non-impervious surface.

3. DATA AND STUDY AREA

A Quickbird image of Beijing urban area, acquired in September of 2003 was used in the experiment. The Quickbird imagery contains four multispectral bands with 2.44m resolution (Blue, Green, Red and NIR) and a panchromatic band with 0.61m resolution. In this study, the multispectral and panchromatic images were fused to produce a four-band pan-sharpened multispectral image with pixel size of 0.61m. The image fusion was carried out using the Gram-Schmidt procedure (Laben and Brower, 2000). A subset of the pan-sharpened multispectral image with size of 1800 × 2800 pixels was finally used in the study (Figure 1). The image subset covers a portion of the suburban area. The land cover types in the area include tree, grassland, soil and impervious surface (building, road).

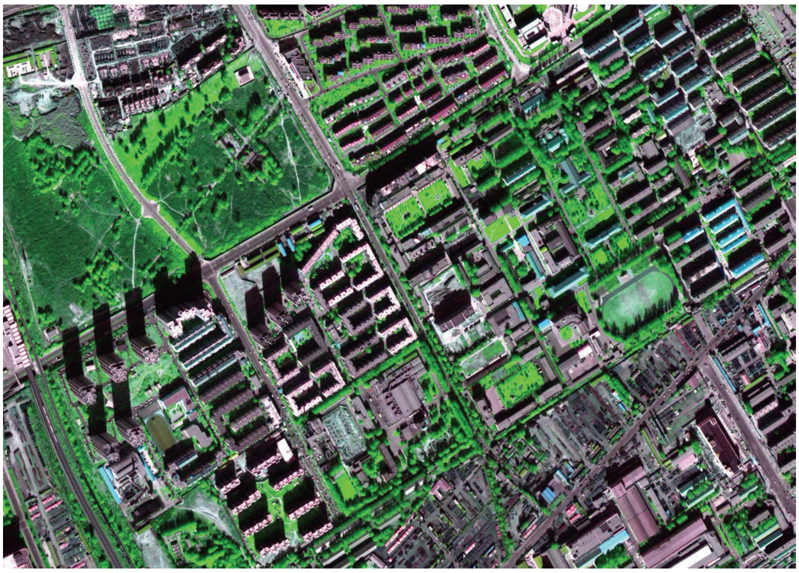

Figure 1 Quickbird image of study area (Bands 3, 4, 2 as R, G, B)

4. RESULTS AND DISCUSSION

The impervious surface was extracted using the proposed method and the method based on traditional SVM, respectively. Table 1 shows the impervious surface mapping results. From the table, both overall accuracy and Kappa coefficient of the proposed method are higher than those of the method using the SVM. The producer's accuracy and user's accuracy of the impervious surface are also acceptable. In particular, the higher user's accuracy of the impervious surface indicates that the proposed method produced less commission error that the existing method using the SVM. From Figure 1, although the results from two methods showed very similar appearance, the result from the proposed method are more homogeneous inside the class.

Table 1 Impervious surface mapping results using different methods (all in %)

	OA	Kappa	Accuracies for impervious surface	
			PA	UA
Multi-class SVM	83.93	73.20	91.68	79.34
OCSVM	88.56	77.27	81.87	96.51

OA, Overall accuracy; PA, producer's accuracy; UA, user's accuracy.

A

B

Figure 2 Impervious surface mapping results using different methods: *A*, multi-class SVM; *B*, One-class SVM. Black: impervious surface, white: non-impervious surface

5. CONCLUSION

This paper proposed an impervious surface mapping method based on OCSVM and object-based classification method. The results showed that the proposed method outperformed the existing method using traditional SVM. One of the advantage of the proposed OCSVM based method is that it only requires the samples from the target class (or class of interest). Further work will focus on evaluation of the proposed method using more datasets and how to fuse the proposed method and existing method to achieve higher accuracy.

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