

OBJECT-ORIENTED PER-PARCEL LAND USE CHANGE DETECTION INTEGRATING GIS AND REMOTE SENSING

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ABSTRACT:

Urban is more sensitive to the change of land use/cover. The up-to-date information of land use/cover is very important for urban decision-making and sustainable development. Very high resolution satellite data are an alternative to monitor, update cartographic and geographic databases. In this paper, an object-oriented pre-parcel land use change detection approach integrating GIS and remote sensing is introduced. The change detection unit is defined by existing objects in a GIS databases, different image processing program are adopted based on the corresponding objects attributes. The approach mainly consists of two phases: first, land cover objects are identified using object-oriented image classification approach. Next, a rule-based system is set up to judge every parcel one by one whether or not change happened comparing to existing GIS. The result is marked as change, unchange and unclear, the *unclear* part will be decided further by interactive checking. In order to verify the application validity of the presented methodology, the part of Shanghai in China with the support of QuickBird data and GIS is tested, a satisfactory result is attained.

1. INTRODUCTION

Urban is more sensitive to the change of land use/cover. The up-to-date information of land use/cover is very important for urban decision-making and sustainable development. The traditional method to gain information on land use/cover in urban areas is based on the visual interpretation of very high resolution aerial photography. This process is both time consuming and expensive, doesn't meet the requirements of urban planners, urban decision-makers and managers.

Because of the advantages of repetitive data acquisition, its synoptic view, and digital format suitable for computer processing, remote sensed data have become the major data sources for different change detection applications during the past decades. Especially with the advent of very high resolution satellite imagery, such as provided by Ikonos, QuickBird, extends the range of satellite remote sensing monitoring from global scale, regional scale to urban scale. Using high resolution satellite image to monitor urban development, to update cartographic and geographic databases has been attracted more and more attention.

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). The basic premise in using remotely sensed data for change detection is that changes in the objects of interest will result in changes in reflectance values or local textures that are separable from changes caused by other factors such as differences in atmospheric conditions, illumination and viewing angles, and soil moistures. Because digital change detection is affected by spatial, spectral, thematic and temporal constraints, it is very difficult to automatic detect changes in remote sensing images. Till now, numerous change detection methods have been proposed using various techniques, data, and aimed at different applications. Lu et al (2004) group so much change detection techniques into two types: (1) those detecting binary change/non-change information, for example, us-

ing image differencing, image ratio, vegetation index differencing and principal component analysis; and (2) those detecting detailed 'from-to' change, for example, using post-classification comparison, change vector analysis and hybrid change detection methods. Although these methods have been successful in monitoring change for a myriad of application, no single approach is optimal and applicable to all cases (Lu et al., 2004). The type of change detection method employed will largely depend on data availability, the geographic area of study, time and computing constraints, and type of application.

In recent years, integrated GIS and remote sensing change detection method has been validated more effective than using remote sensing data only, especial in urban areas (Bock, 2003; Walter, 2000; Weng, 2002). With the fast development and popularization of GIS techniques, almost every urban has built various GIS for urban planning and management. Abundance data and connotative knowledge in these GIS database should be used to improve remote sensing image recognition and change detection. Integrated Remote sensing and GIS change detection studies have predominantly focused on providing the knowledge of how much, where, what type of change have occurred. The advantage of using GIS is the ability, one the one hand to incorporate different source data into change detection applications, on the other hand to provide a flexible environment for storing, analyzing, and displaying digital data necessary for change detection and database development.

In this paper, an object-oriented pre-parcel land use change detection approach integrating GIS and remote sensing is presented. In order to reduce processing loads of a huge amount of high resolution satellite data, the process unit of change detection is the parcel objects boundary defined by existing GIS database, not a whole image like before. Besides the spatial data, the land-use attributes of the parcel objects are also used to select sequent processing program. The approach mainly consists of two phases: first, land cover objects are identified using object-oriented image classification approach. Next, a rule-based system is set up to judge every parcel one by one whether

change happened comparing to existing GIS. The result is marked as “change”, “unchanged” and “unclear”, the “unclear” part will be decided further by interactive checking. The remainder of this paper is organized as follows. Study areas, data and pre-processing are introduced in section II. Image segmentation and object-oriented land cover classification are discussed in section III. Per-parcel rule-based change detection is explained in section IV. Finally some conclusion and future work are reported in section V.

2. STUDY SITE AND DATA

The study area is situated in the suburban area of Shanghai, in Southeast China. Relief is very flat, and elevation is about 4m. 0.6m resolution panchromatic (Pan) band and 2.4m resolution multi-spectral (MS) bands were acquired by QuickBird satellite on March 28, 2003. The quality of image is very good, without cloud. Both the Pan and MS data have 11-bit information content. The Pan band embraces spectral information spanning the visible and near infrared spectrum. The MS bands consist of four individual bands: Red, Green, Blue, and Near Infrared. Pan and MS image are all geometric corrected to Shanghai city coordinate system using ERDAS software. Adopting nearest neighbor resampling, a root mean square error of the second-order polynomial warping function of less than 0.5 pixels is achieved. In order to benefit from the high spatial resolution of panchromatic band and the spectral information of the multi-spectral bands wavelet transformation is applied to the image. The result is an artificial multispectral image stack with the spectral characteristics of the low resolution data and the high spatial resolution of the panchromatic image, namely Pan-sharpened MS images (PS-MS). Figure 1 shows a subset of the PS-MS image.

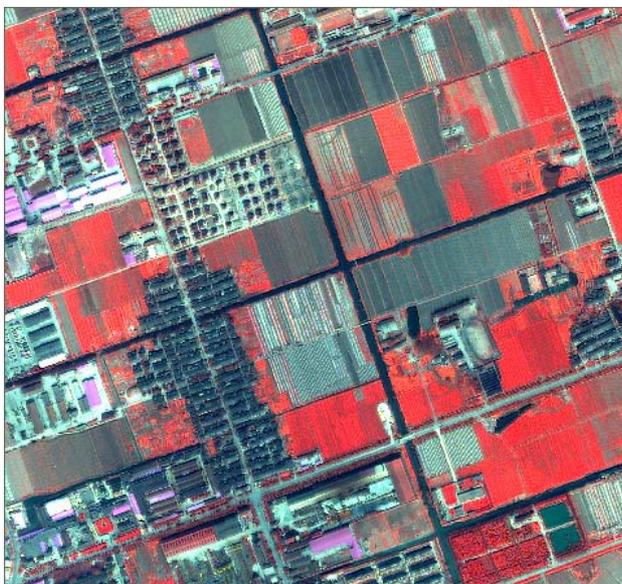


Figure 1: A false color image composite (4, 2, 1) of study area

The GIS data is cadastral database using the same Shanghai city coordinate system at a scale of 1:2000. The part corresponding to Fig.1 is shown as Figure 2. Cadastral database is a type of database using land parcels as spatial units to collect, store, and update the parcels' location, shape, rights, and land use information. The land use classification system in China from January 1, 2002 involves 3 categories on level I: Agricultural Land,

Construction Land and Undeveloped. They are subdivided further into 15 subclasses on level II and 71 subclasses on level III. Considering our main purpose is to detect two illegal land-use types which are cropland converting to construction land without register and storing land without development. We aggregated the land-use classes presented in this database into 6 classes: “cropland”, “fishpond”, “other agricultural land”, “residential, commercial, industrial land”, “commonland”, “transportation land” and “river”.



Figure 2: Cadastral parcels in study area

3. OBJECT-ORIENTED LAND COVER CLASSIFICATION

3.1 Classification Classes

The first step of land cover classification is to define classes of interested. The detailed level of classes is dependent on end-user requirements. For this study, attention is paid to illegal land-use discussed above, so the land-cover classification classes interested are cropland, impervious and water. Considering the spectral diversity among different croplands is huge, so cropland is subdivided into vegetated land, fallow land and vegetable greenhouse.

3.2 Image Objects Extraction

Improved spatial resolution does not always lead to better classification results for some classes, using conventional spectral classification. The classification accuracy is a function of two counteracting issues. The first issue is that finer spatial resolution results in a decrease in the number of mixed pixels; this factor should increase the classification accuracy. On the other hand the finer the spatial resolution, the larger the number of detectable subclasses. This implies high within-class spectral variances of some classes, which decrease their spectral separability. As a result, classification accuracies may decrease for some classes, such as complex urban and suburban areas, as spatial resolution becomes finer (Martinao et al., 2003).

In order to take advantage of spatial information better, an ob-

ject-oriented approach is logical especially for high-resolution image. Regions (image objects) can be obtained by segment. Segmentation is the partition of an image into a set of regions that are homogeneous with respect to some measurement, relevant to the application of interest. This is done by using watershed transformation and region growing referenced Wang (2005) and Jing (2003). The segmentation of a part of Fig. 1 is shown in figure 3(b). In order to detecting texture boundary, a large window of size 17 is used to calculate gradient values. At the same time this is disadvantage to localizing intensity/color edges. There exist some over-segmentation and under-segmentation, which will impact sequent classification somewhat.

3.3 Features Extraction

After image segmentation, this means that the shape of each object should be represented by an image object. This shape, combined with further derivative spectral and texture properties, can be used to initially classify the image by classifying the image objects.

Spectral features in different bands are the main evidences for image objects classification. The four spectral bands of PS-MS image are all used as input channels. NDVI is based on the spectral behavior of chlorophyll, which absorbs red light and reflects NIR light, and very effective to discriminate vegetation and non-vegetation.

Texture features have been proved to improve effectively classification accuracy. Entropy is one of the most frequently used texture features. Moreover, observing the study area, we find that most objects are arranged along around north-east 20° and northwest 70° . The autocorrelation in spatial data can be depicted well by Semivariogram (Sun & Li, 2002). The equations to calculate the semivariogram are as follows:

For a north-east 20° analysis of spatial structure

$$\gamma_{n-e(20^\circ)} = \frac{1}{2m} \sum_{i=1}^n \sum_{j=1}^n [Z(i, j) - Z(i+1, j+3)]^2 \quad (1)$$

For a north-west 70° analysis of spatial structure

$$\gamma_{n-w(70^\circ)} = \frac{1}{2m} \sum_{i=1}^n \sum_{j=1}^n [Z(i, j) - Z(i+3, j+1)]^2 \quad (2)$$

where n = the window size

i, j = the pixel location

m = the number of data pairs, which depends on the direction and distance for calculation

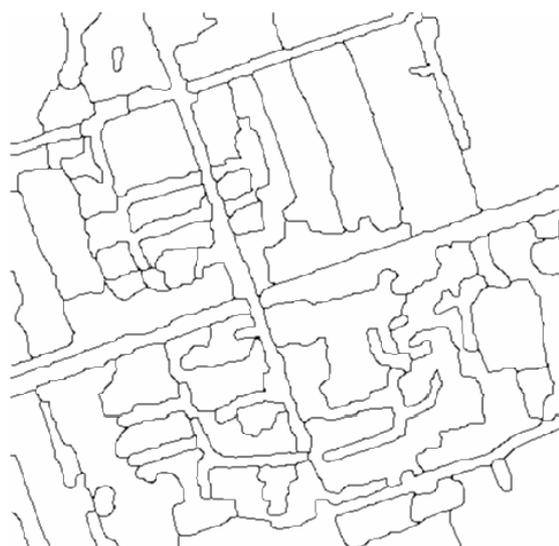
Considering most man-made objects in urban areas have regular shape, so Area, Compactness, Elongation etc. geometry features are used to auxiliary classification. There, Compactness is the Area ratio of image object and its minimum bounding box. Elongation is the measure of the extent of the object along the principal direction (corresponding to the major axis) versus the direction normal to it.

3.4 Classification Strategy and Result

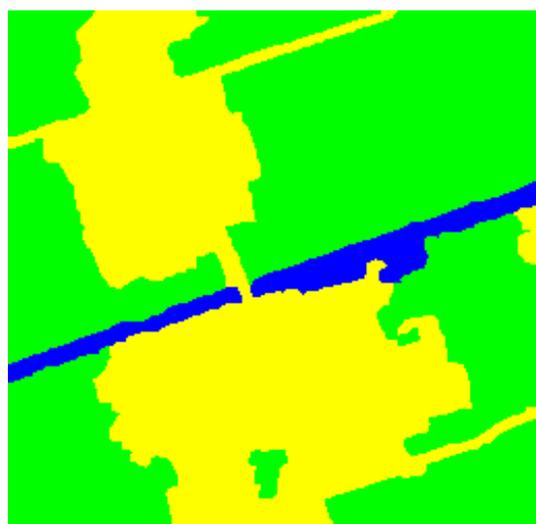
At first a set of hierarchical classification rules should be built based on typical training samples for every class. Then the classification procedure can be divided into 4 steps: 1) A separation of vegetation and non-vegetation is achieved. The objects are classified using 4 spectral bands and NDVI. This is because there is a blue plastic roof which NDVI is very high, and need



(a)



(b)



(c)

Figure 3: (a) is an enlarged part of Fig. 1, (b) is the segmentation of (a), (c) is the object-oriented classification map of (a)

to be eliminated from vegetation. 2) Fallow croplands are identified using panchromatic grey value and texture features. Comparing to others, the texture values of fallow croplands are all small, $\gamma_{n-e(20^\circ)}$ always larger than $\gamma_{n-w(70^\circ)}$, and the intensity value is between 300 ~500. 3) Water is discriminated from asphalt roof based on NDVI and geometry features mentioned above. 4) Vegetable greenhouse is the most difficult to recognize. NDVI, texture features and geometry features are all used to distinguish it from impervious. Whereas there are still a few objects can't be recognized, then classified them as "Unclassified". Figure 3(c) is the classification result of Figure 3(a). It is seen that most objects are classified correctly. Greenland in construction land isn't separated from cropland, and this has little impact to late change detection.

4. PER-PARCEL LAND USE CHANGE DETECTION

The rule-based land use changed detection is performed on the basis of the before classified land cover objects. In order to reduce processing loads of a huge amount of high resolution satellite data and make full use of the information of existing GIS, we check the parcel one by one.

Firstly, the land-use attribute of a parcel is read in GIS environment, if the attribute is "commonland" or "transportation land" or "river", then turn to next parcel directly. The reason is that the classes have nearly no possibility to exist illegal land-use interested. If the attribute is other classes but area is less than 500m², then marked as "unclear" directly. Because it is difficult to judge correctly small areas with existing registering error, noise, shade, segmentation error etc. influencing factors. For the remainder, the subset image defined by the bounding box of the parcel boundary is cropped from PS-MS image to proceeding land-cover classification.

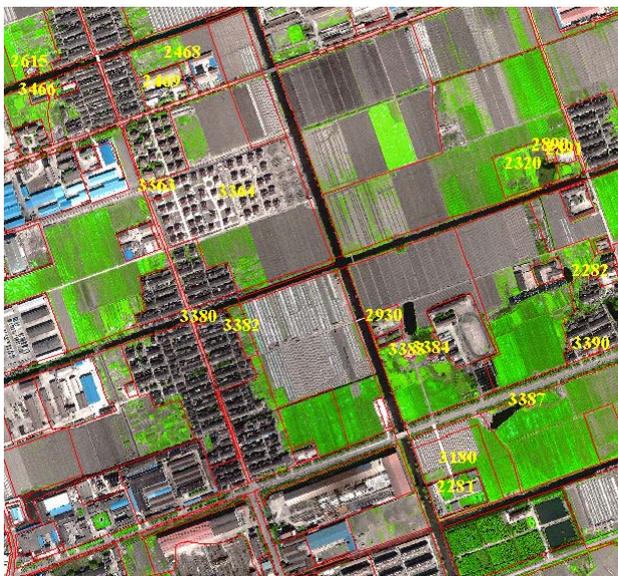


Figure 4: The detection result of the area covered by Fig. 1

The rules of change detection are based on the percentage of each land-cover class in parcel boundary. Comparing to the land-use attributes in GIS, the estimate results are divided into "change", "unchanged" and "unclear". The rules are very simple, but can detect almost illegal land-use parcels. For example: If the land-use attribute is "residential, commercial, industrial

land", the percentage of "impervious", 1) >0.7, marked as "unchanged"; 2) <0.5, marked as "change"; 3) else, marked as "unclear".

The estimate results are recorded in GIS and can be displayed in screen for interactive checking to find those parcels where illegal land-use occurred, or which were collected wrongly. In the test of 219 parcels, the omission is 0. The sum of "change" and "unclear" is less than one third of all parcels. Even the "change" and "unclear" are all affirmed further by manual work, the efficiency is also increased. Of course, the more perfect the rules, the better the effect. The threshold is very important for the status of the study areas and the operator's experience. Figure 4 shows the detection result of the area covered by Figure 1 in GIS environment, the parcel boundaries (Red color) is superimpose on PS-MS image (RGB), the IDs of the parcels marked as "change" and "unclear" display in yellow. Obviously, the number of manual check is reduced greatly.

5. CONCLUSION

Detecting the changes of the earth surface cover by utilizing the repetitive observational ability of satellites is an important aspect in the research of remote sensing. Especially, with the launch of high-resolution commercial satellite, such as Ikonos, QuickBird, change monitoring range is extended to urban scale. However, there is still no a "best" change detection approach, and change detection analysis remains an active research topic.

In this paper, a change detection approach integrating GIS and high resolution satellite image is developed. The method takes advantage of both spatial and attributes information in existing GIS to reduce process loads and to automatic detect illegal land-use in urban areas. The method belongs to one of post-classification comparison, so the classification results impact the late change detection effect. In order to improve the land-cover classification accuracy, object-oriented classification approach is adopted. Due to the complexity of urban areas, there still remain a few unclassified objects, even misclassification. In future work, additional data, such as LIDAR, should be introduced to improve classification accuracy and subdivide classes. Of course, the change detection flow and rules should be expanded for better application.

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