A STRATEGY OF CHANGE DETECTION BASED ON REMOTELY SENSED IMAGERY AND GIS DATA

Zhang Xiaodong*, Gong JianYa, Li Deren

State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS), Wuhan University, P.R.China. xdzhang@lmars.whu.edu.cn

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ABSTRACT:

Geometric co-registration errors and results of object extraction (such as classification and pattern recognition) are the two main factors, which greatly affect the results of change detection in traditional methods. Unfortunately, the geometric co-registration accuracy and results obtained by the object extraction methods can not satisfy imagery change detection in practice at present. Considering the change detection based on remotely sensed imagery and GIS data, GIS data can direct detection, because our interesting objects are included in the GIS data. To overcome the influences of geometric co-registration and object extraction errors, a new change detection method is needed to develop. The paper proposes a holistic solution strategy, which is based on areal features and iteratively solves geometric co-registration, feature extraction and change detection simultaneously. Some concepts and key techniques are introduced in the paper. Finally, the data of a QUICKBIRD image and corresponding 1:2000 topographic map of a district in Shanghai, China is chosen to test the strategy presented in the paper. The change detection precision of 83.33% is gotten, that proves the new strategy is efficient and applicable.

1. INTRODUCTION

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989). Timely and accurate change detection of Earth's surface features provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources. So, it can be usefully applied to the various fields, such as environmental inspection, urban planning, forest policy, updating of geographical information and the military usage. In general, change detection involves the application of multi-temporal datasets to quantitatively analyze the temporal effects of the phenomenon. Because of the advantages of repetitive data acquisition, its synoptic view, and digital format suitable for computer processing, remotely sensed data, such as Thematic Mapper (TM), Satellite Probatoire d'Observation de la Terre (SPOT), radar and Advanced Very High Resolution Radiometer (AVHRR), have become the major data sources for different change detection application during the past decades. Many papers (Singh 1989, Mouat et al. 1993, Deer 1995, Copoin and Bauer 1996, Jensen 1996, Jensen et al. 1997, Yuan et al. 1998, Serpico and Bruzzone 1999) have summarized the current methods of change detection.

As follows, there are general change detection processes between multi-temporal observations.

1. Make sure the content of change detection
2. Select data
3. Preprocess data
4. Extract the temporal features of detected objects
5. Change detection
6. Evaluate accuracy

For the purpose of more correct pixel-pixel analysis, a geometric co-registration operation is necessary to make geometric information of the images to be same. The precision of geometric correction has prodigious influence on the change detection results, low precision can lead to a mass of false change (Carvalho et al. 2001, Stow and Chen 2002). Townshend et al. (1992) quantificationally researched the influence of geometric correct error on change detection results using Landsat Mss data. Then he considered that the precision should be less than 0.2 pixels if we wanted to obtain 90% detection accuracy. The geometric co-registration accuracy is related to many factors, such as the precision of matching points and geometric model, so in practice, the accuracy of sub-pixels level is generally difficult to be obtained.

Change detection aim is to discover temporal differences of the same objects at different time. In this way, we firstly should extract objects features before change detection, and describe them. When T1 and T2 data are remote sensing images, the feature of detected object can be the image gray, and can also be the extracted features by classification or other pattern recognition methods. And these extracted features should reflect the temporal change of ground objects.

After radiometric co-registration and geometric co-registration are accomplished, change information can be extracted from the images with various algorithms. The change detection is the core of the whole process, it also determines the data preparation. A good detection method should be robust.

The change detection is a complex process, because it relates to many process steps. And many factors have influence on the precision of detection results, such as the accuracy of geometric co-registration, the precision of radiometric co-registration or normalized accuracy, the extraction of temporal features for detected objects, the knowledge of the operator, the change detection methods, the analysis ability and experience, etc.. In

* Corresponding author
E-mail:xdzhang@lmars.whu.edu.cn
Fax:+86-027-68778229

these factors, the accuracy of geometric co-registration, the precision of radiometric co-registration, the extraction of temporal features for detected objects and the change detection methods are more important. When the detection method based on post classification is adopted, the detection accuracy is the product of each classification result precision of different temporal remote sensing images (Stow et al. 1980). In current situation, these effect factors are difficult to overcome, specially in high-resolution images, such as QUICKBIRD and IKONOS. Because the observed contents in high-resolution images are richer than those in middle- or low-resolution So we should research change detection methods further from new view to improve the accuracy and reliability of the results.

Combining remote sensing images and GIS data in change detection has great application potential, and is the developmental trend (D.Lu 2004). This paper puts forward a holistic strategy of change detection based on remote sensing images and GIS data, namely, the geometric co-registration, the extraction of image features and change detection are iteratively synchronously done. The presented method can overcome the shortcomings of traditional methods, such as the error accumulation and transfer caused by data co-registration and feature extraction. The accuracy and reliability of change detection results will be improved. The rest of the paper is organized as fellows. In Section 2 a detailed description of the presented method is given. The experiment and results analysis are presented in Section 3.Finally, conclusions are summarized in Section 4.

2. THE ITERATIVELY HOLISTIC METHOD

The holistic process is based on remote sensing images and GIS data, and the geometric co-registration of images and GIS data, the extraction of features and change detection are synchronously gone along. The traditional method which is sequential is firstly to extract features from remote sensing images, then to match features between GIS data and remote sensing images, at last to carry through change detection. The integrated method using GIS knowledge to direct feature extraction of detected objects is better in theory.

According to the integrated idea, we can consider the holistic process of change detection as the course of features match based on area objects between GIS data and remote sensing images. The area objects in GIS data are considered as the reference to extract homonymous objects in remote sensing images. If they are similar, we consider no change, or else label the changed objects. The process is little different from the general match, because the connotative precondition of the general match is that the homonymous ground objects are existent, namely no change has happened.

The match methods ordinarily include the following parts: 1) feature space 2) similar measurements 3) search space 4) search strategy. According to different application condition and purpose, we should adopt different methods to optimize the four aspects. Considering the actual condition and application purposes between GIS data and remote sensing image, we research the four aspects of matching frame. Based on analysis and consideration mentioned above, we bring forward an integrated remote sensing and GIS approach in the detecting changes. The flow chart is showed in Fig.1.

2.1. The preprocessing of GIS data

The rich information, such as point, line, area, attribute and the topology relation among every entity, is stored in GIS. In order to improve the efficiency and reliability, GIS data must be processed first. In this paper, the following methods are adopted to do it.

1. Select area objects mapped in actual scale from GIS data and describe the features of the polygons.
2. Compute the area of the each polygon according to its coordinates and sort polygons in the area size from large to small.
3. Compute the similar feature measurements for every matched polygon. The similar measurements computation will be discussed in Section 2.3.
4. Confirm Label points of matched polygons.

A point is introduced in order to carry out the automatic process. With the point, GIS data can offer guidance in extracting the homogeneous areas in the image. And the corresponding point in the imagery will be considered as the seed for the feature extraction. In order to resist the effect of the geometric error at most, we request the point had better to be located near the center of polygons. The feature of the point is similar with that of Label point in GIS data, here, we call it the same name.

There are many methods to compute the Label point, such as computing the coordinates of polygonal center of gravity and the intersection point of most midlines. These methods can't assure the point is near the center, specially for the concave polygon. So we adopt a method based on mathematic morphology to compute the Label point to overcome the shortcoming.

2.2. The computation of geometric transform parameters

The core content for co-registration is to compute the model parameters of geometric transform. According to the geometric transform model, we can achieve the geometric co-registration by transforming coordinate to cartography reference frame. The general geometric transform models include affine transform, polynomial transform and perspective projection transform. The affine transform is common. We use affine transform as geometric transform model, and need three reference points at least for getting the parameters. Firstly, three pairs of points are appointed by an operator. In GIS data, we can compute the polygon which the specified point belongs to, according to its coordinates. In remote sensing imagery, we consider the point as the seed, and extract the homonymous polygonal area by iterative method. The extraction approach will be discussed in Section2.4. The centers of gravity of homonymous polygons are respectively computed, and the centers of gravity are considered as the matching points. The polygonal center of gravity is independent on scale and rotation. We consider them as matching points, and the random error can be eliminated. So the method has great stability. The original values of affine transform parameters are computed with the three pairs of matching points. Using the affine transform approximately, the matching point of a Label point in GIS data can be forecasted.

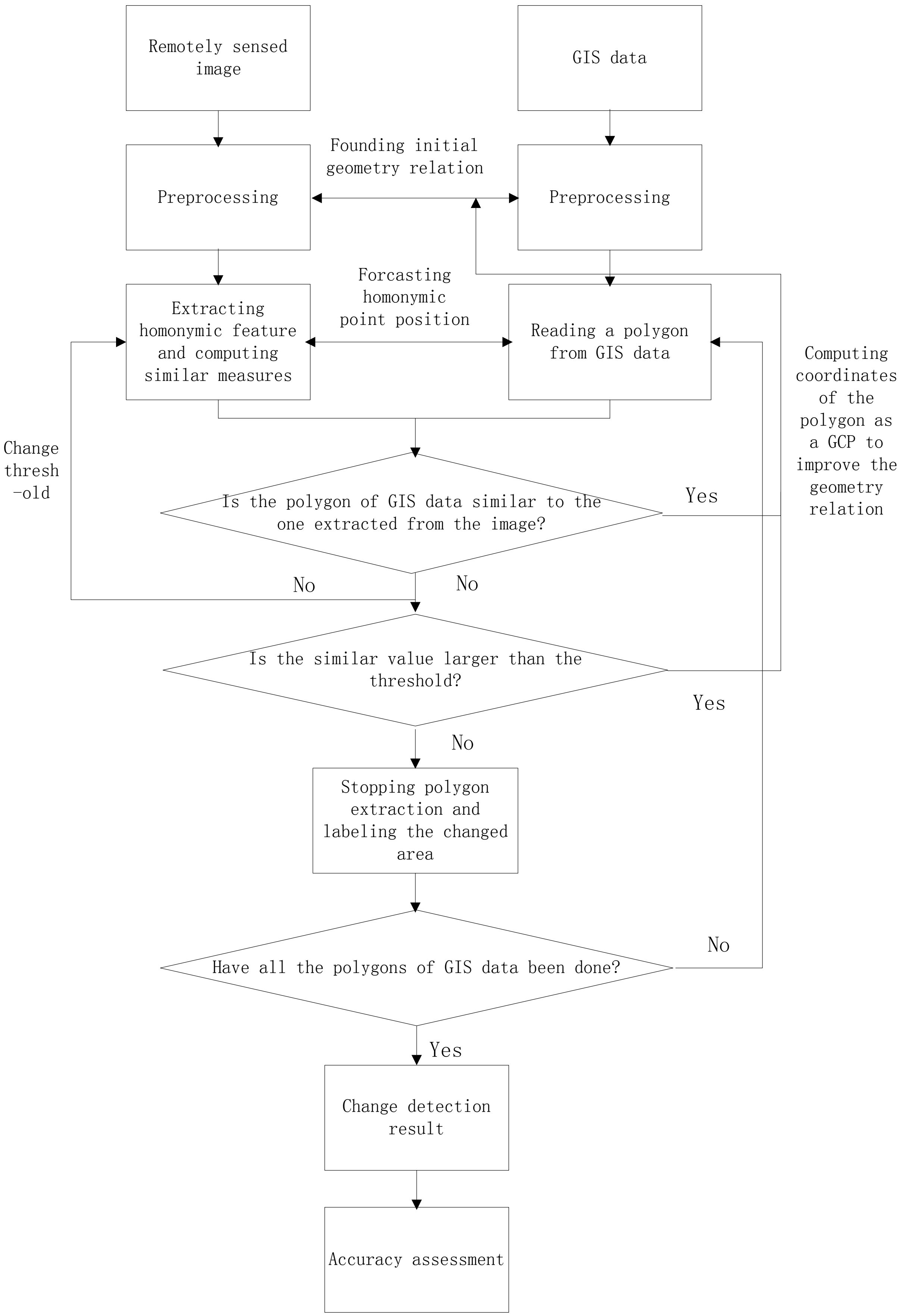

Fig.1. Flow chart of the iteratively holistic method based on remote sensing imagery and GIS data

2.3. The similar measurements

It is very important to define the comparability measurements for matching features, and it is the rule to judge the homonymous features. The reliability, stability and correctness of the result largely depend on them. In the paper the following features of a polygon are adopted:

1. The area of a minimum enclosing rectangle
2. The width and height of a minimum enclosing rectangle
3. The area of a polygon
4. The perimeter of a polygon
5. The shape of a polygon

These features make up of a set of comparability measurements from coarseness to precise. Although a measurement of them can't exactly determine the matching polygon, but the all measurements can reduce the selective range. With the restriction of cursorily geometric location calculated, we can find the matching polygon. We adopt the improved Freeman codes (Milan Sonka et al.) to describe the polygonal shape.

2.4. The extraction method of polygonal features for area objects

A region is expressed as strong relativity of grey in imagery, and the pixels have some similar attributes, such as grey value and texture. An image can be segmented into different regions. Compared with point and line features, the area include more abundant information, which is very useful for matching reliability.

The region growth is a simple and effective segmentation method. Give a seed, beforehand define a threshold which is used to judge the coherence of pixels. When the difference of gray value of a pixel near seed with the seed is less than the threshold, we deem that the pixel and the seed belong to a same ground object. In the theory, the region growth can successfully segment different types of homogeneous regions. But in fact, when the method is applied to the remote sensing imagery reflecting the complex earth's surface, the results are not perfect. Because the earth's surface is very intricate, the strictly even regions are few. The same objects are expressed differently in the diverse surroundings. The effect of solar illumination also makes the gray values of the same objects dissimilar. These causes mentioned above generally lead to the regions looked like even to contain small nonhomogeneous parts. The feature areas extracted by the region growth may include many islands or holes. For example, there is an island in a lake, or there is a tree in a meadow. The polygon regions in GIS data express the condition of the earth's surface in some proportion, so the small objects may be omitted in relevant scale, such as the sole tree in a meadow. In order to match the polygonal features with the area objects in GIS data, the approach of extracting features from imagery must be self-adapted.

Because of the well relativity of the pixels in a region, the adaptively iterative method of region growth is adopted to extract the region features. The seed is obtained from the result of geometric transform of the Label point of the polygon in GIS data. The condition of iteration is given by the comparability measurements, and the iterative process can be stopped until the polygon extracted from imagery is most similar with the polygon in GIS data. The threshold of gray consistency is increased gradually with the iterative times from zero. These steps mentioned above automatically carry out the adaptive extraction of image regions combining with GIS data.

2.5. The searching strategy

Different application need adopt different searching strategy for matching, and the searching strategy should be optimized according to special application in fact. In this paper, in the course of matching corresponding features, the following searching strategy is introduced with the guidance of the result of geometric transform for the Label point of the polygon in GIS data.

1. The result of geometric transform for the Label point of the polygon in GIS data is regarded as the seed for extracting the region of the homonymous polygon in imagery. The area of minimum enclosing rectangle of polygon in GIS data is considered as the comparability measurement. Gradually increase the threshold of gray consistency, then extract the polygonal regions in imagery. The threshold of comparability measurement for polygonal area may be determined in advance, and the threshold needn't too strict. We extract and register every polygon satisfying the threshold from imagery, and regard these polygons as candidates.
2. The width and height of the minimum enclosing rectangle of polygon are considered as the comparability measurement. Then select similarly polygons from the result gained in the step (1).
3. The area of the polygon is considered as the comparability measurement. Then select similarly polygons from the result gained in the step (2).
4. The perimeter of the polygon is considered as the comparability measurement. Then select polygons from the result gained in the step (3).
5. Select similarly polygon from the result gained in the step (4). And select the polygon having the maximum similarity in shape codes.

After processing, the regions that can match with the polygons in GIS data are considered no change, or labeled as changed area and exported. The coordinates of centers of gravity of the matching polygons are appointed as control points and the model parameters are recomputed by least-square method. So, the model parameters can be refined step by step.

3. EXPERIMENT AND ANALYSIS

3.1. Experiment

The Quickbird image which is taken on Nov.7th, 2002 and locate in ShangHai, China is chosen as the experimental data. The size of the image is 884×884 pixels, and its resolution is 0.6 meters, and it is Ortho Ready Standard. This image is showed in Fig.2. The region is fairly flat, and it mainly includes plantations, ponds, vegetation, rivers and buildings. Here, plantations and ponds are the main change objects. GIS data of 1998 which scale is 1:2000 is adopted. The GIS data covers the same place as the image. After preprocessing the GIS data, 149 polygons are selected, shown in Fig.3.

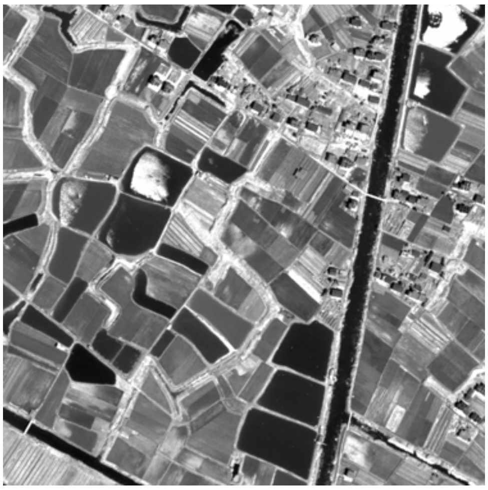

Fig.2.The QUICKBIRD image, Shanghai, Nov.7, 2002

Fig.3.The GIS data,Shanghai,1998

The points artificially given by the alternant way or computed by the model of cursorily geometric transform for imagery are regarded as the seed points. According to the iterative method introduced in Section2.4, the polygonal features are extracted. In the process, the thresholds of the comparability measurements respectively defined as follows: the area of the minimum enclosing rectangle is 0.5 to 1.5 times, the width and height of the minimum enclosing rectangle are 0.8 to 1.2 times, the polygonal area is 0.5 to 1.5 times, the polygonal perimeter is 0.5 to 1.5 times and the difference of the polygonal shape coding is less 10%. The corresponding polygon features of GIS data are references of the thresholds. After holistically iterative processing, the detection results are gotten showed in Fig.4. In the figure, the marked polygons with the number are the changed objects.

3. 2. The results analysis of change detection

According to the GIS data updated in 2002, the change detection results are contrastively analyzed. We find that the actually changed objects are 25 in the detected 30 objects. There are three types of change in the changed objects: 1) the farmland becomes the building. 2) Because of the change of cultivation, the massive farmland becomes the plats. 3) Because of the development of breeding industry, farmland becomes pounds. According to the numbers showed in the Fig.4, the actual change is listed in the Table1.

Table1 Ground objects change types

Change type	The number of polygon
Farm become buildings	10 8 6 7 9 1 11 12 13 14 16 20 19 22
the massive farmland becomes the plats	30 5 28 15 21
farmland becomes pounds	27 26 2 23 24 25

All of the actual changes are successfully detected. The total accuracy is about 83.33%, and the rate of false detection is about 16.67%, because of the five polygons detected falsely. Because the iteratively holistic method overcomes the effect of false changes caused by the geometric co-registration, the result is reliable.

4. CONCLUSIONS

The results of some related processes, such as features extraction of the detected objects in the remote sensing imagery and geometric co-registration between GIS data and remote sensing imagery, have obvious influences on the results of change detection based on the remote sensing imagery and GIS data. In this paper, an iteratively holistic change detection method is introduced and the key techniques are presented in detail. The approach regards the polygons of area objects as features, and extracts the features of area objects in imagery making use of the cursory transform relation between imagery and GIS data. Then define the feature similar measurements to control the adaptively iterative extraction of imagery features and change detection. The search strategy is discussed from cursory to fine. The approach breaks through the traditionally serial frame (the preprocessing and change detection are done respectively in traditional frame). The features extraction, matching and change detection are synchronously processed with iterative method in the presented method. Therefore, these steps are inter-restriction and inter-checkout. The experimental result indicates that the precision can reach up to 83%, and proves the new method is really feasible.

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Fig.4.The change detection result (the change polygons marked by numbers)

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