A CHANGE DETECTION METHOD WITH HIGH RESOLUTION IMAGES BASED ON POLYGON AUTOMATIC VALIDATING

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ABSTRACT:

In Beijing, the earth surface changes has reached 5% each year, and artificial detection with high resolution images has been applied to peccancy building monitoring and road change detection. The main problem of artificial detection is its low efficiency and existing omitted changes. Therefore, a practicable automatic or semiautomatic change detection method with high resolution images is needed.Because of abundant details and coarse textures in high resolution images, traditional automatic or semiautomatic pixel-based change detection method can not get satisfiable detection results. Therefore, in this paper, considering the characters of high resolution images and algorithmic automation, an **object-oriented** change detection method with **high resolution images** based on **polygon automatic validating** is presented. The main technical flow of the new method includes five steps, which are new image preprocessing, change detection and extraction, polygon processing, polygon automatic validating, artificial polygon edit and statistics output. The principle and main steps of the method will be detailedly introduced.In order to evaluate this change detection method, the relative experiments are carried out. The main image sources are IKONOS and QuickBird of urban and suburban in Beijing. The detection results are compared with practical change results by artificial interpretation. According to experimental analysis, the advantages of this method are concluded: firstly, this method can keep polygons completeness and have less omitted polygons. Secondly, according to statistics of operational time, this method can save artificial edit workload and improve the whole detection efficiency. Thirdly, this method can eliminate lots of wrong detection polygons and improve the overall accuracy.

1. INTRODUCTION

Beijing as the political and cultural center of China is rapidly developed. According to the relative statistics, the earth surface change in Beijing has reached 5% each year and the main changes are concentrated in the central urban area and conjoint districts of urban and suburban (Gu C.L., 1999, Fang X.Q., Zhang W.B. etc., 2002, Beijing Statistical Yearbook 2005, 2005).

As the reduction of images acquisition periods and the improvement of the resolution of images, remote sensing detection techniques have been applied in many fields. For example, with these high resolution images, artificial detection between two periods becomes available and has been applied to peccancy building monitoring and road updating in Beijing (Mou F.Y., Zhang Z.X. etc., 2007). However, there is a main problem for artificial detection, which is low efficiency and existing omitted changes. Therefore, a practicable automatic or semiautomatic change detection method with high resolution images is needed.

Because of abundant details and coarse textures in high resolution images, traditional automatic or semiautomatic pixel-based change detection method can not get satisfiable detection results (Liu Y., Zhang J.X. etc., 2003, Zhao Y. S., 2003). In this paper, combining the characters of high resolution images, an object-oriented change detection method with high resolution images based on polygon automatic validating is presented and relative experiments are carried out to investigate its feasibility and accuracy.

2. METHOD WORKFLOW AND PRINCIPLE

2.1 Workflow

The main technical flow of the new method includes five steps, including new image preprocessing, change detection and extraction, polygon processing, polygon automatic validating, artificial polygon edit and statistics output. The workflow is listed in Figure 1.

2.2 Principle of Main Steps

The principles of these five steps are introduced briefly as below.

1) New Image Preprocessing

In the new image preprocessing step, geometric correction, automatic cutting, and spectral match are necessary for the new image. The geometric correction or relative matching is performed with the precise satellite parameters. The mean square errors should be below 0.4pixel, generally between 0.2 and 0.4pixel (Meng L.M., Xi J.,2003). Automatic cutting is automatically completed according to the map sheet ranges for fast post processing. For spectral match, overall histogram match and local histogram match methods are acquired. The median filter algorithm can be applied to remove the noises of the new image.

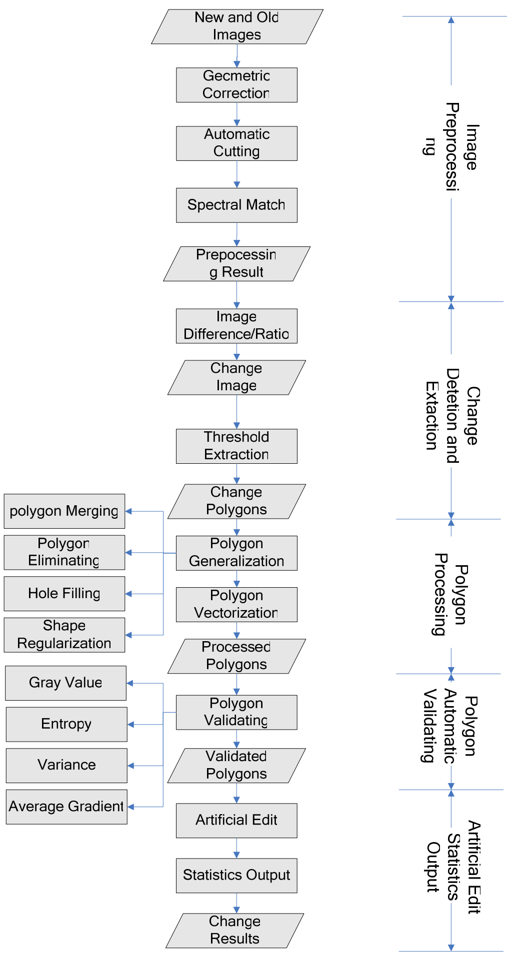

Figure 1. Workflow of Change Detection with High Resolution Images based on Polygon Automatic Validating

2) Change Detection and Extraction

In the change detection and extraction step, considering algorithmic automation and efficiency, pixel-based image difference algorithm is acquired to detect changes. For the change extraction, an automatic single-threshold segmentation algorithm (Gu J., Zhang H.W.,2007, Haralick R.,Shapiro L.G., 1985) with mean (E) and variance (σ) two parameters is adopted(Figure 2).

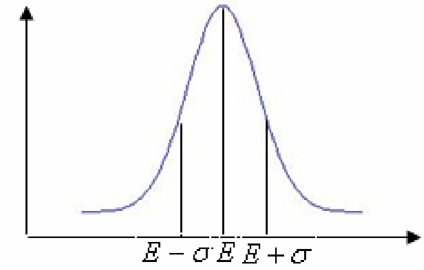

Figure 2. Single-threshold Segmentation

Whether the pixel is changed is judged by the formula listed as below:

$$\text{Value(i, j)} = \begin{cases} 1, & Gray(i,j) \in [E-\sigma, E+\sigma] \\ 0, & Gray(i,j) \in (-\infty, E-\sigma) \cup (E+\sigma, +\infty) \end{cases} \quad 1)$$

For panchromatic images, the extraction algorithm can be used directly. But for multi-spectral images, the change detection image is processed firstly by principal component analysis (PCA), and then with the first principal component image, changes can be extracted by the extraction algorithm.

3) Polygon Processing Step

In the polygon processing step, polygon generalization and polygon vectorization are helpful to reducing workload of polygon automatic validating and artificial polygon editing.

For polygon generalization, polygon merging, polygon eliminating, hole filling and shape regularization are acquired. Among them, the polygon merging is realized by connectivity analysis and the small polygon eliminating is realized by the morphological operators. The hole filling is realized by the seed filling algorithm (Zhang S.X., 1991). The shape regularization is realized by the regular border detection, and in this paper the rectangular border is acquired(Figure 3).

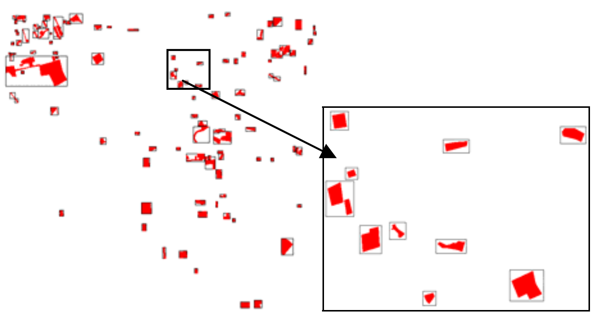

Figure 3. Change Detection Results and Rectangular Borders

For polygon vectorization, the Polygons are vectorized to Coverage or shapeFile format by edge tracking. After the polygon preprocessing mentioned above, the vector polygons and polygon borders can be acquired.

After those steps mentioned above, with high resolution images wrong detection polygons with right detection polygons are synchronously acquired. The main reason for this is that abundant details contained in high resolution images influence the pixel-based change detection results. In order to reduce this kind of wrong detection cases, a polygon automatic validating step is added.

4) Polygon Automatic Validating

In the polygon automatic validating step, except gray information, texture information and neighborhood information of original images are also chosen to make decision together. For texture information, the variance index representing information content are acquired. For neighborhood information, the average gradient index is acquired. In order to compare these indexes between new and old images, the correlative coefficient index is used.the main formulas are listed below:

The correlation coefficient index of gray information (Geng Z.,2007) is calculated by 2):

$$r_{grey} = \frac{\sum_i \sum_j (g1_{i,j} - \overline{g1})(g2_{i,j} - \overline{g2})}{\sqrt{\sum_i \sum_j (g1_{i,j} - \overline{g1})} \sqrt{\sum_i \sum_j (g2_{i,j} - \overline{g2})}} \quad 2)$$

The average gradient (Jia T., Chen W.J. etc.,2003) and the relative correlation coefficient index are calculated by 3) to 5):

$$grad1(i,j) = |g1(i+1,j) - g1(i,j)| + |g1(i,j+1) - g1(i,j)| \quad 3)$$

$$grad2(i,j) = |g2(i+1,j) - g2(i,j)| + |g2(i,j+1) - g2(i,j)| \quad 4)$$

$$r_{grad} = \frac{\sum_i \sum_j (grad1_{i,j} - \overline{grad1})(grad2_{i,j} - \overline{grad2})}{\sqrt{\sum_i \sum_j (grad1_{i,j} - \overline{grad1})} \sqrt{\sum_i \sum_j (grad2_{i,j} - \overline{grad2})}} \quad 5)$$

The variance and the relative correlation coefficient index are calculated by 6) to 10):

$$\mathrm{var}iance1(i,j) = \frac{\sum_{i=0} \sum_{j=0} (g1(i,j) - mean1)^2}{L-1} \quad 6)$$

$$mean1 = \frac{\sum_{i=0} \sum_{j=0} g1(i,j)}{L} \quad 7)$$

$$\mathrm{var}iance2(i,j) = \frac{\sum_{i=0} \sum_{j=0} (g2(i,j) - mean2)^2}{L-1} \quad 8)$$

$$mean2 = \frac{\sum_{i=0} \sum_{j=0} g2(i,j)}{L} \quad 9)$$

$$r_{\mathrm{var}iance} = \frac{\sum_i \sum_j (\mathrm{var}iance1_{i,j} - \overline{\mathrm{var}iance1})(\mathrm{var}iance2_{i,j} - \overline{\mathrm{var}iance2})}{\sqrt{\sum_i \sum_j (\mathrm{var}iance1_{i,j} - \overline{\mathrm{var}iance1})} \sqrt{\sum_i \sum_j (\mathrm{var}iance2_{i,j} - \overline{\mathrm{var}iance2})}} \quad 10)$$

For each polygon, the mean of correlative coefficient of gray values, correlative coefficient of texture values and correlative coefficient of gradient values is the final index. Based on the average threshold extracted from training areas, when the final index is less than the threshold, the relative polygon will be seen as the wrong detection and be eliminated. With this method, partly wrong detection caused by phenomena of different gray values for the same objects can be avoided.

5) Artificial Polygon Edit and Statistics Output

In artificial polygon edit and statistics output step, the polygons and the borders can be further edited artificially and the relative statistical results can be summarized. Based on the judgement of polygon relationships, the vector polygons can be automatically added or eliminated when polygon borders are added or eliminated artificially, which will reduce the artificial edit workload. For the statistics output, the contents mainly include total area, change area, total polygon numbers and change polygon numbers.

3. EXPERIMENTS AND ANALYSIS

3.1 Experiments

In order to evaluate this change detection method, the relative experiments are carried out. The main image sources are IKONOS and QuickBird of urban and suburban in Beijing.

1) Main Detection Results

The main detection results of IKONOS suburban areas and QuickBird urban areas are listed in Figure 4 to Figure 7.

In Figure 5 and Figure 7, the practical changed areas which are extracted by artificial interpretation are colored by yellow, and the automatic validated results which are extracted by the change detection method are labeled by black rectangles borders and red polygons.

Figure 4 IKONOS Panchromatic Suburban Images in 2004 and 2005

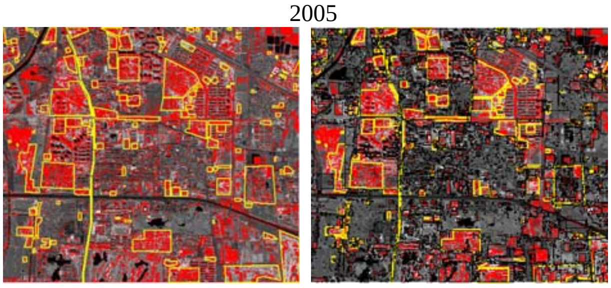

Figure 5 Difference Results and Automatic Validated Results

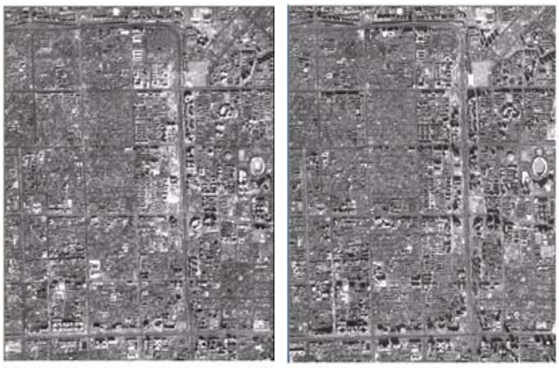

Figure 6. QuickBird Panchromatic Urban Images in 2003 and 2005

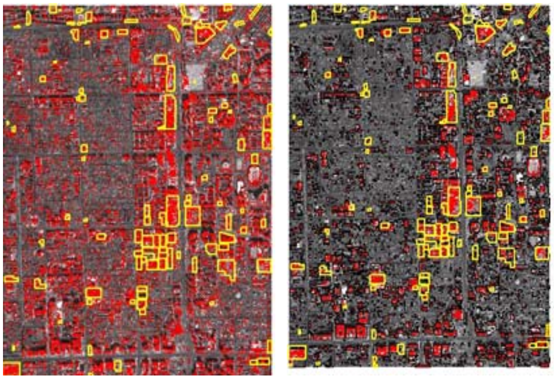

Figure7. Difference Results and Auto Validated Results

2) Statistics Output and Accuracy Assessment

For IKONOS suburban images, the practical change area percentage is 12.02% and the automatic validated result is 19.61%. For QuickBird urban area, the practical change area percentage is 3.06% and the automatic validated result is 12.30%.

The operational time for both kinds of images is listed in Table 1, while the time of preprocessing doesn't include the geometric correction time.

Automatic Detection Time Statistics		
Steps	IKONOS/min	QuickBird/min
Preprocessing	1	1.2
Change Detection	0.5	0.6
Polygon Extraction	0.8	1.2
Polygon Processing	2.6	5.5
Polygon Validating/ Edit	20	35
Total Time	24.9	43.5
Artificial Detection Time Statistics		
Steps	IKONOS/min	QuickBird/min
Preprocessing	3	4
Artificial Edit	33	52
Total Time	36	56

Table 1. Operational Time Statistics

Accuracy assessment is carried out with the pixel-based method and the polygon-based method. For the pixel-based accuracy assessment method, 500 sampling points are randomly selected, while there are 97 changed (C) points and 403 unchanged (U) points and the accuracy evaluation results are listed in Table 2.

Images	**Class**	**Ref.**	**P.A.**	**U.A.**	**T.A.**
IKONOS	C	97	58.76%	61.96%	85%
	U	403	91.32%	90.20%	
QuickBird	C	124	62.90%	89.66%	89%
	U	376	97.61%	88.86%	

Table 2. Pixel-based Accuracy Evaluation Results

The accuracy evaluation is carried out based on error matrix. The relative indexes include Producer Accuracy (P.A.), User Accuracy (U.A) and Total Accuracy (T.A.). P.A. represents changed feature detection percentage (the correctly detected changed point number to the real changed number). U.A represents changed feature correctly detection percentage (the correctly detected changed point number to the changed number detected by the method). T.A. represents the total feature correctly detection ratio (the correctly detected point number to the total sample number).

For the polygon-based accuracy assessment method, the accuracy evaluation results are listed in Table 3, in comparison of practical changed polygons and detected changed polygons.

Images	**Practical Changed**	**Detected Changed**	**Correct Percentage**	**Largest Omitted Area(m^2)**
IKONOS	102	98	96.08%	2968
QuickBird	106	106	100%	0

Table 3 Polygon-based Accuracy Assessment Results

3.2 Result Analysis

According to experimental results and analysis, the advantages of this method are concluded that:

Firstly, this method can keep polygons completeness and have less omitted polygons. By polygon processing and validating, most of change polygons are extracted and the number ratios of the corrected extracted polygons are all more than 95% according to Table.3. Besides, the polygon borders are helpful to further artificial edit.

Secondly, according to statistical operational time, this method can save artificial edit workload and improve the whole detection efficiency. By polygon automatic validating, the time of artificial edit is reduced by about 20% based on Table 1.

Thirdly, this method can eliminate lots of wrong detection polygons and improve the overall accuracy. Especially the wrong detection polygons which have different spectrum for the same object caused by seasonal and atmospheric changes, such as vegetation, lakes, building roofs, are eliminated from the detection results. For suburban, the average area percentage of the automatic eliminated polygons to the total wrong detection polygons is 61.25% and for urban that is 24.83%. The average overall accuracy values are 85% and 89% based on pixel evaluation.

4. CONCLUSIONS

According to experiments, it also indicates that this method cannot eliminate all wrong detection polygons, such as the wrong detection caused by building shadows, so there are higher wrong detection percentage in urban than in suburban. For these cases, artificial edit is needed. Besides, in this paper, the texture information and the neighborhood information are considered to validate the polygons. There are other information such as shape information and other indexes such as gray co-matrix, which could be chosen to validate the polygons. The comparison and analysis will be the further researches.

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