Building change analysis between GIS Data and satellite image

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***Abstract*—In this paper, a novel hierarchical framework of building change detection using GIS data and image as input is introduced. The method includes two steps: building extraction and change analysis using extracted results and GIS data. Experimental results show that the method can meet the requirement but improvement is still needed.**

Keywords-change analysis; GIS Data; satellite image; building extraction

I. INTRODUCTION

The main question raised in change analysis from multi-temporal data imaging a same scene, is to be able to differentiate between "real" changes and changes due to artifacts – e.g. noise, illumination, weather effect. It has been an active research field for many years owing to a large number of applications in different aspects, such as urban planning, agriculture monitor and land use analysis[1]. The purpose of the present work is to detect changes between image and digital map provided from Geographic information system --GIS-- in urban areas, with a specific focus on buildings since they are the dominant "objects" and the most subject to change. The application is the digital map updating from outdated GIS data and newly acquired remote sensing image.

Many change detection methods have been developed. They can be classified according to the data they use. Large number of approaches deal with change between two low resolution images acquired from a same sensor, using simple pixel intensity difference [1]. For these, a basic assumption is that image grey level/color level is the same at pixels "unchanged" on the ground while intensity difference is caused by changes. They are prone of errors due to difference of view point, illumination and image noise. Some methods deal with changes between different data source, such as imagery and GIS data. Volker Walter proposed a framework based on classification: main steps include GIS-image registration, image classification with the help of prior GIS information, and at last comparison between the processed results and GIS data [4]. This method is suitable for low or medium resolution image, in which urban areas are considered as a whole and details (single building) can not be recognized.

High resolution images – pixel size of less than 5 meters on the ground — present new challenges due to the very rich information appearing in the image. Many details, such as substructures on the roofs, cars, or other "geometric noise", can be seen clearly. There are many shadows caused by elevated objects (trees or building mainly).

In this paper, we are interested in finding changes of buildings in urban areas between a panchromatic high resolution satellite image (0.6m/pixel resolution) and the building layer of high-scale GIS map (1:10000 scaling). We propose a change analysis hierarchical framework. We first assume that all buildings present in the GIS map may exist also in the image. We use this information as prior knowledge to initialize a segmentation step. The result of the segmentation provide a map on which to each building is assign a confidence level of non-change or uncertainty. Then uncertain buildings will be processed later. Under this strategy, unchanged buildings can be removed progressively, until obtaining the final map. Then shape analysis is performed in order to describe the object extracted from the image in term of a limited number of features to be compared to the GIS map. Change analysis is based on the estimation of a similarity factor between the GIS building map and the extracted objects, in the features space. The proposed strategy as described above provides the flexibility of combining different change detection algorithms.

The rest of paper is organized as follows: In section 2, a hierarchical overall framework of change detection is introduced. A change detection method based on segmentation is described in details in section 3. In section 4, experimental results are illustrated and analyzed. Conclusion is given in section 5.

II. A HIERACHICAL FRAMEWORK OF CHANGE DETECTION

Changes between the GIS data and image are caused by inconsistency of objects of them. There are many other factors that have influence on results of change detection, such as accuracy of registered data, accuracy of GIS data and correctness of the extracted objects. So it is difficult for us to distinguish changes which are caused by actual changes or incorrectness of extracted objects by one algorithm. In this condition, we proposed a hierachical framework of change detection. In each hierarchy, different change detection algorithm can be carried out independently and changes detected with high confidence are recorded. The ambiguous

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case will be identified in next stages using other change detect ion algorithm. Advantages of the framework include: combination of different validation algorithm, decreasing the change detection error. We have accomplished the algorithm of GIS data validation using segmentation algorithm and other algorithms of GIS data validation will be investigated.

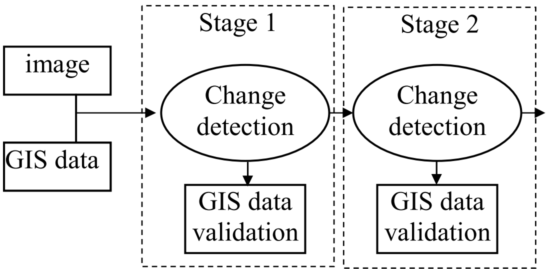

Figure 1 hierachical framework of change detection

III. CHANGE DETECTION BASED ON SEGMENTATION

The method consists of three steps: fusion between image and GIS data, extraction of objects in image using segmentation approach, change decision according to the objects in GIS data and extracted objects.

Preprocessing of the data is required since original GIS data are in vector format (1D representation). They are therefore first converted into a 2D image. We consider here only the building layer.

A. A Recall on the Fuzzy Connectedness Segmentation Approach

Our segmentation method is a fuzzy connectedness segmentation approach which has been proposed by Udupa et *al* in 1996. The main idea of this method lies in describing objects in image using fuzzy logic. Graded composition and hanging togetherness properties are the important characteristics that are considered. In the following, a simple introduction of this segmentation algorithm is given, details can be found in [2,3].

Affinity, a local fuzzy relation, is defined as a strength of local hanging togetherness of every pair of nearby image elements in the image. Affinity is determined by their spatial nearness as well as how similar their image intensities and intensity derived features are, which is also a value between 0 to 1. Equation (1) is the definition of affinity μk used in our application. The components, μ_α, $\mu_{\Psi s}$ and $\mu_{\Phi s}$, represent spatial nearness of two elements, image intensity similarity and image intensity difference similarity respectively. w1 and w2 are weights for two components and sum of them equals to 1. The component, μ_α, equate to 1 when c and d belong to a 4 neighborhood and 0 otherwise. The component, $\mu_{\Psi s}$, is the homogeneity-based component, which expressed as a weighted average of inhomogeneities between corresponding elements in the hyperballs centered at c and d and of radii related to the local scale of the object at c and d, respectively. The component, $\mu_{\Phi s}$, is the object-feature-based component, which is formulated in equation (5) using object membership function Wo as well as background membership function Wb. In equation, elements, W_{os}, W_{bs} and $W_{\psi s}$, are exponential functions. And they need 6 parameters which are computed later.

$$\mu_k(c,d) = \mu_\alpha(c,d)[w_1\mu_{\psi s}(f_a(c), f_a(d)) + w_2\mu_{\Phi s}(f_a(c), f_a(d))] \quad \textbf{(1)}$$

$$\mu_{\Psi s}(c,d) = 1 - \frac{\left|D^+(c,d) - D^-(c,d)\right|}{\sum_{e\in B_{cd}(c)} \omega_{cd}(\|c-e\|)} \quad \textbf{(2)}$$

$$D^+(c,d) = \sum_{\substack{e\in Bcd(c)\\ e'\in cd(d)\\ s.t.c-e=d-e'}} [1 - W_{\Psi s}(\delta^+_{cd}(e,e'))]\omega_{cd}(\|c-e\|) \quad \textbf{(3)}$$

$$D^-(c,d) = \sum_{\substack{e\in Bcd(c)\\ e'\in cd(d)\\ s.t.c-e=d-e'}} [1 - W_{\Psi s}(\delta^-_{cd}(e,e'))]\omega_{cd}(\|c-e\|) \quad \textbf{(4)}$$

$$\mu_{\Phi s}(c,d) = \begin{cases} 1, & if c = d, \\ \dfrac{W_{os}(c,d)}{W_{bs}(c,d) + W_{os}(c,d)}, & if W_{os}(c,d) : \\ 0, & otherwise \end{cases} \quad \textbf{(5)}$$

A path from c to d (a sequence of nearby elements starting from c and ending at d) has a strength that is the minimum affinity of pairwise elements along the path. A global fuzzy relation, called fuzzy connectedness between c and d, which has a value in [0, 1] , is defined as the largest of the strengths of all paths between c and d.

A fuzzy connected object, $\Omega_\theta(o)$, of strength θ that contains any element o, is a fuzzy subset defined by the membership function:

$$\mu_{O_{\theta(o)}}(c) = \begin{cases} \eta(f(c)), & if c \in \Omega_\theta(o), \\ 0, & otherwise, \end{cases} \quad \textbf{(6)}$$

$$\Omega_\theta(o) = \{c \in C \mid \mu_{Ks}(o,c) \geq \theta\}$$

A fuzzy connected object, $\Omega_\theta(o)$, represents the extracted object. It can be acquired by using threshold to fuzzy connectedness image in which the value of each point represents the fuzzy connectedness strength between this point and seed point, o. In our application, edge information is introduced in fuzzy connectedness image calculation to reduce the computation.

B. Fusion Between Image and GIS Data

In this part, registration and parameters computation are achieved. To register building layer to Quickbird image, affine transformation is selected as the transform model and manually selected GCPS(ground control point) are used.

The segmentation algorithm requires several parameters, such as seed point and some statistics measurements.

1) Seed point

We choose centroid of buildings as a seed point. The x and y coordinate of seed point is defined as:

$$seed_x = \frac{\sum_{i \in Obj} x_i}{number} \qquad (7) \qquad seed_y = \frac{\sum_{i \in Obj} y_i}{number} \qquad (8)$$

Obj is a region in image corresponding to a GIS data building in GIS data, number is the quantity of pixels in the region.

2) Statistics calculation

We need 6 parameters in calculating the fuzzy connectedness scene for a given object. They are the intensity mean, intensity variance, intensity difference mean, intensity difference variance of object, intensity mean of background around object and intensity variance of background around object. So two trained areas are needed, one is used to calculate statistics of building and the other is used to calculate statistics of background around it. Due to the matching discrepancies, eroded buildings in GIS data are used as the trained areas for object. And areas around the buildings are trained areas for background.

3) Fuzzy connectedness image calculation

In fuzzy connectedness scene, value of each point represents the fuzzy connectedness strength between seed point and that point. For each building, there is a specific fuzzy connectedness scene corresponding to it.

C. Automatic Adaptive Threshold Selection

We propose an automatic threshold selection approach, which determines a threshold with the help of the corresponding object in the GIS data. First, the object in the GIS data is used as a mask to find a corresponding part in the fuzzy connectedness image. Then we calculate the cumulative histogram of it. An initial threshold can be computed which makes sure that the area from previous segmentation is 10 percent of the area of the object in GIS data. In equation (9), C is the area of building in GIS data, and Ai is the area of segmented building. When the threshold is reduced by a step, area of segmentation result will increase and k will decrease first then increase. We finally select the threshold that minimizes k.

$$k = |A_i - C| \qquad (9)$$

IV. Change Analysis

A change map can be created by comparing the buildings in GIS data and extracted buildings using the segmentation algorithm. In the change map, objects can be divided into two groups: unchanged buildings, uncertain buildings. Unchanged buildings means that buildings extracted from image correspond to the buildings in GIS data. Uncertain buildings include buildings that are failed to be extracted by segmentation algorithm and buildings that are not exist in image while still in GIS data.

Standards defined to classify the buildings into two classes include area, primitive direction, center of building, length of building along primitive direction, length of building along direction perpendicular to primitive. The unchanged building pairs are defined as those meet all of these standards. The rest of buildings are uncertain ones, which include changed buildings and building failure of recognition using segmentation algorithm.

V. Experiments and Performance Analysis

Panchromatic Quickbird optical image and building layer of GIS data are used in experiments. The image's resolution is 0.6m/pixel at nadir. It was projected into a Beijing cartographic system and was rectified from deformations caused by terrain using a Digital Terrain Model (DTM). The scale of the GIS data is 1:10,000, and its storage type is vector format.

Some experimental results are displayed in this section. In figure2, registered building layer in GIS data and image are overlaid together. The red rectangles represent the buildings in GIS data. In figure3, all the extracted buildings extracted by segmentation method are showed. The extracted results are tolerable for buildings with smooth roof, although some holes exist in the roof and boundary is coarse. For some buildings, extracted results are part of buildings or part of background around them. The segmentation result is a mainly element that affect change analysis of building. In figure 4, the classified buildings are displayed. The red ones represent the unchanged buildings and the blue ones are the uncertain ones due to failure of extraction or change of buildings.

There are 76 buildings, and number of the unchanged buildings is 34. Although this method can not check out the changed buildings directly, it reduce the number of buildings for next stage, and the changed buildings can be detected finally.

VI. Conclusion

In paper, a novel hierarchical framework of building change detection using GIS data and image as input has been presented. The proposed approach is based on building segmentation at first, then differentiation with the GIS map. The segmentation step is performed with a fuzzy logic algorithm using prior knowledge given by the GIS data. We introduced an automatic thresholding method. Global geometrical parameters are used to represent the object in GIS and from segmention method. Change analysis is performed according to comparison between the parameters. Experimental results show encouraging results.

References

[1] Srinivas Andra, Omar Al-Kofahi at el, Image Change Detection Algorithms: A Systematic Survey, got from web.

[2] J. K. Udupa and S. Samarasekera, Fuzzy connectedness and object definition: Theory, algorithms, and applications, image segmentation, Graphical Models Image Process. 58, 1996, 246–261.

[3] Punam K. Saha, Jayaram K. Udupa, Scale based fuzzy connected image segmentation: theory, algorithms, and validation, Computer Vision and Image Understanding 77, 145-174(2000).

[4] Volker Walter and Dieter Fritsch, Automated revision of GIS databases, Proceedings of the eight ACM symposium on advances in geographic information systems Washington, 129-134. 2000.

[5] Brian Pilemann Olsen, Hybrid Raster/Vector Change Detection for Map Database Update, Proceedings DSAGM 2002, pp. 416.

[6] Rafael C. Gonzalez, Digital Image Processing, Publishing House of Electronics Industry, 2002.

[7] Yingshi Zhao, Principles and Methods for Remote Sensing Application and Analysis, Beijing: Science Press, 2003.

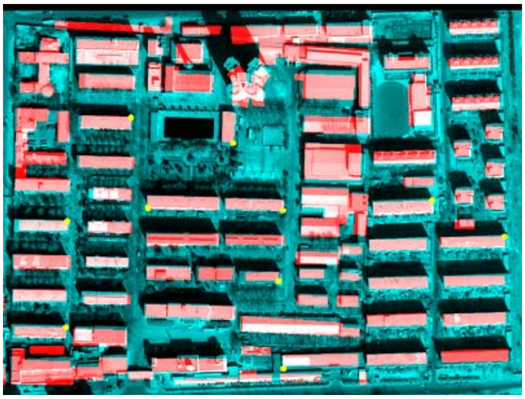

Figure 2 Overlay of registered building layer and image

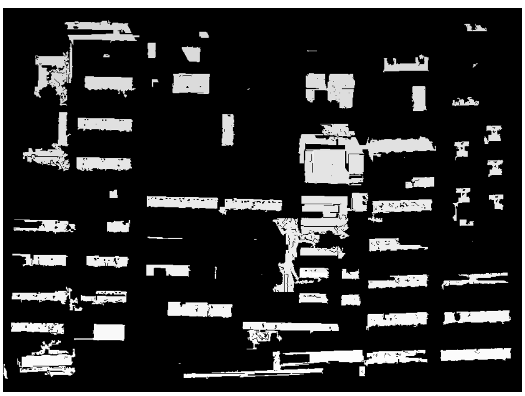

Figure 3 Extracted buildings

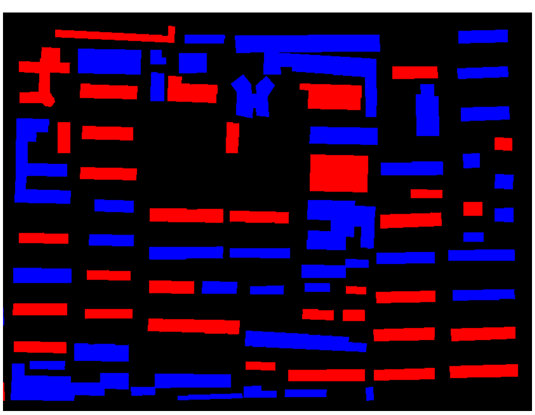

Figure 4 Change map