Building segmentation from high resolution satellite optical image with GIS data as prior information

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Abstract – In this paper, a building extraction method based on segmentation is proposed. The high-resolution satellite imagery and GIS data are used in our application. The method assumes that roof of buildings have homogeneous intensity and regular shape and construct a building model according to the hypothesis. Main steps of method include: data preprocessing, objects segmentation using the fuzzy connectedness segmentation algorithm, initial building candidate post-processing, Polygonal approximation of building and Building polygon Evaluation. Experimental results show the efficiency of the method but improvement is still needed.

Keywords: High resolution satellite optical image, Building extraction, Segmentation, GIS(Geographic information system), map updating

1. INTRODUCTION

In rapid developing regions, urban growth is so rapid that period for updating the map becomes shorter than before. In Beijing the map is updated for every two years. But map updating is a tired work and fallible if the data is acquired through on field exploration. Satellite imagery is an efficient tool to perform –at least partially— map updating with the help of the image processing technique. Acquired images can be processed automatically in order to extract the relevant ground elements, such as building, road, vegetable and so on.

Automatic extraction of man-made objects, specially buildings and roads, from remote sensing images, has been an active research topic in image processing field for many years. Various approaches have been proposed and different strategies are applied according to, on one side, image characteristics – resolution, sensor, temporal acquisition, etc.-- and on the other side, specific purpose of the process. Due to the building is a primary element in the map, our interest focus on building extraction from very high resolution optical images. Though, high-resolution imagery offers a more detailed description of the observed scene, the complexity and diversity of the information make the image interpretation even more difficult. In order to ease the difficulty and make the processing more robust, additional knowledge or different data source(images, DSM, GIS) are applied together.

Early methods focus on building extraction based on a monocular image mainly. Methods are applicable for the simple buildings with flat-roofed and rectangular shape. 3-D cue consisting of shadows cast by the roof and walls associated with it are useful evidences to identify the building candidate. The methods are effective for simple buildings only, but complexity and time consume is shorter compared to other method. The methods include [2,3,4]. Multiple images can provide more reliable cues to infer 3-D building structures and are widely available now. Recent work has focused on the stereo or multi-view analysis to detect building with more complicated shape and modeling the building in 3D. Some methods extract local features, such as junctions or lines, from single images, generate a 3-D building structure by matching the features. These kinds of methods can deal with building with complex shapes but may suffer from computational complexity, specially when the complexity of building shape increase[5,6]. DSM(digital surface model) can provide the dense and reliable altitudinal information which facilitate the building extraction task and increase the detect rate. DSM can be acquired by directly measure or correlation calculation from stereo image. After DSM data is created, rough building models can be acquired by processing the DSM, then they are refined with the features from image. Related Methods include [7,8,9].

In the method, we use panchromatic Quickbird optical image with resolution of 0.6m/pixel at nadir and GIS(Geographical Information System) data with scale of 1:10,000. The GIS data is created in the Beijing cartographic system. In order to remove deformation caused by geographical reference frame, Quickbird image was projected into a Beijing cartographic system and was rectified from deformations caused by terrain using a Digital Terrain Model (DTM) before used. GIS data and image are registered manually.

In this paper, a segmentation based building extraction method is proposed and promising results are acquired. First, aim of the method and survey of the building extraction method are introduced. Then our method flowchart is displayed. Each step of the method is described in detail in next section. We give some experimental result and remark in section 4. Section 5 is the conclusion of the method. Finally, papers related are listed in the reference.

2. FLOWCHART OF THE METHOD

Elements on the ground, such as building, road, in Quickbird optical image can be identified from the background clearly and details on the element can also be seen clearly. Following is a small region in urban of Beijing. In figure 1, most of roof of buildings have homogeneous intensity and regular shape. So building model can be defined as 1) region with homogeneous intensity; 2) region with regular shape usually rectangle or polygon with orthogonal angle. The first characteristic reflects radiometric characteristic of building and segmentation algorithm is used to separate it from background. The second characteristic is related to the shape of the building and it can be used to evaluate probability of segmented building belonging to a building.

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Figure 1. An example of building in image

We use fuzzy connectedness segmentation algorithm, which is first introduced by Jayaram K. Udupa et al[10,11] for medical imaging applications, to extract the building from the background. Then we use polygon to represent the boundary of the building approximately. According to the model of building, we define a criterion to score the polygon that represents the probability of belonging to a building. Following is the flowchart of our method.

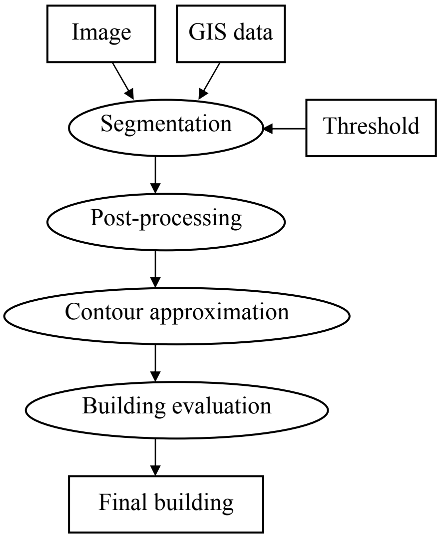

Figure 2. Flowchart of the method

3. METHOD DESCRIPTION

3.1 Initial building candidate block segmentation

Segmentation algorithm applied is the fuzzy connectedness algorithm. The algorithm is provided a seed point first, then image is transformed into fuzzy connectedness image in which value of the point represent the familiarity of the point with seed point. At last, building is extracted using threshold to the fuzzy connectedness image.

A global fuzzy relation, $\mu_{(c,d)}$, called fuzzy connectedness between two points 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. P_{cd} is any path(a sequence of nearby elements starting from point c and ending at point d) that between the point c and point d. Its strength, $\mu_{P_{cd}}(c,d)$, can be defined as minimum affinity of pairwise elements along the path P_{cd}. Affinity, μ_k, is the fuzzy relation that can be calculated using equation (3).

$$\mu(c,d) = \max_{p \in P_{cd}} \mu_{P_{cd}}(c,c_1) \qquad (1)$$

$$\mu_{P_{cd}}(c,d) = \min[\mu_k(c,c_1), \mu_k(c_1,c_2), \ldots, \mu_k(c_k,d)] \qquad (2)$$

$$\mu_k(c,d) = \mu_\alpha(c,d)[w_1\mu_{\psi s}(f_a(c), f_a(d)) + w_2\mu_{\Phi s}(f_a(c), f_a(d))] \qquad (3)$$

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. Parameters w1 and w2 are weights for two components and the sum of them equals to 1. The component, $\mu\alpha$, is equal to 1 when c and d belong to a four neighborhood and 0 otherwise.

The component, $\mu_{\Psi s}$, is the homogeneity-based component, which expressed as a weighted average of in homogeneities 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. It is formulated in equation (4).

$$\mu_{\Psi s}(c,d) = 1 - \frac{\left|D^+(c,d) - D^-(c,d)\right|}{\sum_{e\in B_{cd}(c)} \omega_{cd}(\|c-e\|)} \qquad (4)$$

$$D^+(c,d) = \sum_{\substack{e\in Bcd(c)\\ e'\in cd(d)\\ s.t. c-e=d-e'}} [1 - W_{\Psi s}(\delta^+_{cd}(e,e'))]\omega_{cd}(\|c-e\|) \qquad (5)$$

$$D^-(c,d) = \sum_{\substack{e\in Bcd(c)\\ e'\in cd(d)\\ s.t. c-e=d-e'}} [1 - W_{\Psi s}(\delta^-_{cd}(e,e'))]\omega_{cd}(\|c-e\|) \qquad (6)$$

The component, $\mu\Phi s$, is the object-feature-based component, which is formulated in (7) using object membership function Wo and background membership function Wb. Woos,Wbs and Wψs, are exponential functions.

$$\mu_{\Phi s}(c,d) = \begin{cases} 1, & if c = d, \\ \frac{W_{os}(c,d)}{W_{bs}(c,d) + W_{os}(c,d)}, & if W_{os}(c,d) \neq 0, \\ 0, & otherwise \end{cases} \qquad (7)$$

1) Seed point calculation

A seed point defined in the algorithm should be a point that belongs to the object to be extracted. GIS map of building can provide the location of the building in the image, we select geometrical center of GIS map of building as seed point. The x and y coordinate of seed point is defined as:

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

$$seed_y = \frac{\sum_{i \in Obj} y_i}{number} \quad (9)$$

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

2) Statistics calculation

The other parameters used in segmentation algorithm are statistics that describe the characteristic of the object and its background. 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. 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.

We select the trained areas for objects in image according to the eroded buildings in GIS. It can eliminate points of background caused by matching discrepancies from trained areas of buildings. The areas around buildings can be used as the trained areas for background.

3) Segmentation threshold selection

Threshold has an important influence to the segmentation result. After a fuzzy connectedness image is calculated, an appropriate threshold should be provided to acquire the building candidate. We propose two different threshold selection principles to segment building from fuzzy connectedness image.

a) Threshold selection based on area difference of building

Building in GIS data can provide some prior information, such as area of building, shape of building. Assuming that buildings do not change between the image and GIS data, Area of segmented building in image is same as area of building in GIS data almost. We propose a threshold selection principle that minimizes the area difference of building in GIS data and building extracted from image. In (10), C is the area of building in GIS data and it means the prior area of corresponding building in image. Value of point in fuzzy connectedness image ranges from 0 to 1. Threshold, Ti, increase with a step of 0.01 from 0 to 1, and Ai means area of segmented building with threshold Ti.

$$t = \min_{0 \le T_i \le 1} |A_i - C| \quad (10)$$

b) Threshold selection based on score of the segmented building

According to the segmentation experiment, shape of segmented building changes if threshold increase from 0 to 1 with a step of 0.01. Threshold applied should assure that shape of segmented building is similar to model of the building. That is, segmented building has rectangular shape or combined rectangular shape. First, contour of segmented building is approximated using polygon. Then a criteria is defined to score the polygon. Threshold that gives highest score for the building is selected as final threshold.

3.2 Building candidate block post-processing

Due to small structures or noise and small structures along the boundary of buildings, initial segmented building need further processing. Mathematical morphology method is used to eliminate the holes on the roof and small structures on the boundary of the building.

3.3 Polygonal approximation of building

In order to analyze the shape of segmented building, contour of building should be detected and described using polygon approximately. In processing of polygon approximation, a parameter, which reveals the approximation accuracy of polygon, has an important influence on result. The suitable value is usually between 0.01 and 0.04. Then, polygon should be improved by removing redundant points, which are caused by the imperfect segmentation on the boundary. The points removed include point with an angle of 180 degree or point with short border. At last, we modify the location of points with angle of near 90 degree to get the points with angle of 90 degree.

3.4 Building polygon Evaluation

We evaluate polygonal approximation of building using intrinsic shape characteristic of the building polygon and information related to the original image. Shape characteristics of polygon are area, angle of vertex and the number of sides. Shape area within a defined range increase the score of building. Number of shape side within a defined range should be given a high score. Shape with vertex angle around 90 degree increase the score. Edge image is also used to score the polygon. Canny algorithm provides the edge information of the image. Then distance image is created by distance transform of the edge image. Sum of point value corresponding to the contour of polygon can be defined as a score that indicate the similarity of building polygon to the building in the image. If building polygon is more similar to the building in the image, the score is lower. Finally, whole score of building polygon is the weighted sum of all score. The score of polygon denotes the probability of polygon belong to building.

4. EXPERIMENT AND DISCUSS

Figure 3 show the Quichbird image used. Segmented building is show in figure 4. Figure 5 show extracted building polygons. Building that is suitable to the model of building can be extracted accurately and the score of building polygon is high. However, the method can extract part of the building for which intensity distribution over the roofs is not uniform. This shows the sensibility of the approach to the intensity distribution over the roofs: uniform region are easily detected, while no flat roofs or roofs covered by shadows are missing.

5. CONCLUSION

In this paper, we define a building model and propose a building extraction strategy using segmentation method. The data used in experiment are high-resolution satellite imagery and GIS data located in urban area of Beijing. GIS data provide prior knowledge of building in image, such as location and shape of building. They are useful for segmentation algorithm to acquire some parameters. Finally, building polygon is created by polygonal represent contour of segmented building and score of building polygon is given.

6. REFERENCES

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Figure 3. Quickbird image

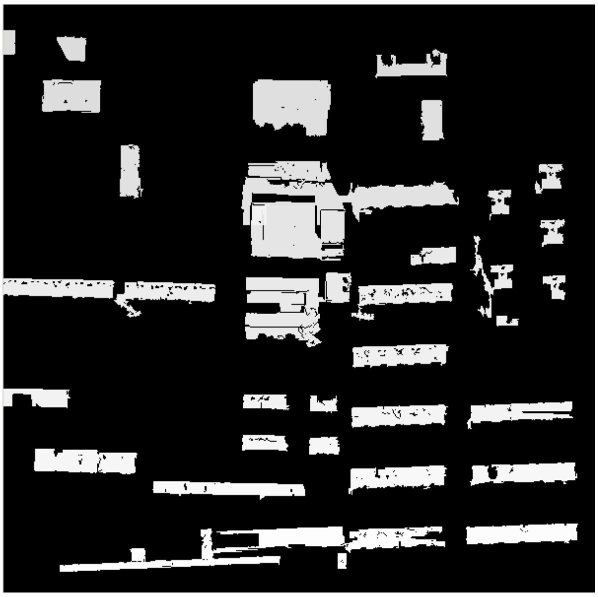

Figure 4. Segmented buildings

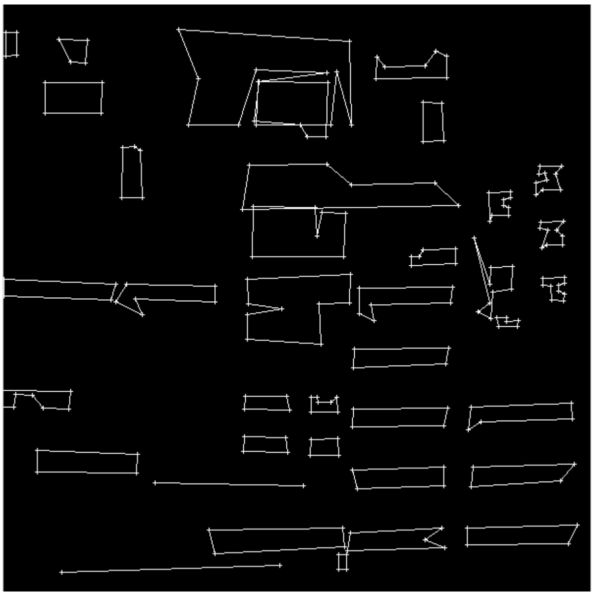

Figure 5. Extracted building polygons