

A METHOD FOR BUILDINGS CHANGE DETECTION BASED ON VERTICAL EDGES EXTRACTION

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ABSTRACT:

This paper proposes a method for buildings change detection. Vertical edges of buildings are extracted in pairs of aerial images respectively, taking advantage of the character that vertical edges intersect at their vanishing point without fail. The ground coordinates of the vertices on each vertical edge are calculated according to projection difference and the principle of frontage intersection. And the changes of buildings are detected by carrying on the change analysis using these coordinates and the three dimensional city models. Finally, experiments are given. The results show that the approach proposed by this paper is feasible and the changes of buildings can be detected accurately.

1. INTRODUCTION

City is the centre of population, economy, infrastructure and culture in the earth. With the rapid developments of the economy, the changes of cities are more and more prominent. And the researches on urban change detection are widely considered by scholars. At present, there are two kinds of researches on urban change detection. For one hand, the changes on the ground are analyzed by using kinds of remote sensing images. For example, the expanding of cities, the changes of land cover and land use, and so on(Li et al. 2005; Hassiba and Youcef 2006; Song et al. 2006; Di et al. 2008). It has the vital practical significance to urban sustainable development(Wang et al. 2006). On the other hand, the changes of some specific features (for example buildings, roads and so on) are detected according to the aerial images, orthographic map, and other GIS data(Liu et al. 2002; Zhang et al. 2005). It can provide the basis of planning timely and effectively for the decision-maker. And this plays a vital role in urban planning, construction management and economic development(Liu et al. 2002). Therefore, how to obtain the urban change information accurately appears quite urgent.

This paper focuses on the changes of buildings in urban. Vertical edges of buildings are extracted in pairs of aerial images, taking advantage of the character that the vertical edges intersect at their vanishing point without fail. Then, the ground coordinates of the vertices on each vertical edge are calculated according to the projection difference and the principle of frontage intersection. Finally, the changes of buildings are obtained by carrying on the alternating change analysis using these coordinates and the three dimensional city models.

2. VERTICAL LINES EXTRACTING

Vertical edges are the necessary characteristic of buildings(Tang et al. 2004). They have important significance to building's description because they can supply both the building's positional information and the elevation information.

In the aerial images, the buildings' vertical edges are mainly consisted in the straight lines which are extracted from the edge information. According to the knowledge of photogrammetry, it is known that vertical edges of buildings are a group of parallels which are vertical to the horizontal plane, and intersect at the vanishing point. Moreover, aerial images are got by the way of central projection, and camera's lens is the centre of projection. In the photographic moment, the camera's main axis is vertical to the horizontal plane approximately (inclination angle of images are smaller than 3 degrees(Li et al. 2001)). As a result, the principal point can be regarded as the vanishing point(Tang et al. 2004), and the vertical edges can be detected according to examining whether the straight lines extracted in aerial images pass through the principal point.

Suppose that point O is the principal point of an aerial image, line l is a straight line detected in the image, and line l locates at the image block P. The right bottom corner of image block P is at (x_1, y_1) , and the left top corner is at (x_2, y_2) . P locates at the first quadrant which is shown in Figure 1 (the cases of image block P locates at other quadrants are similar to this).

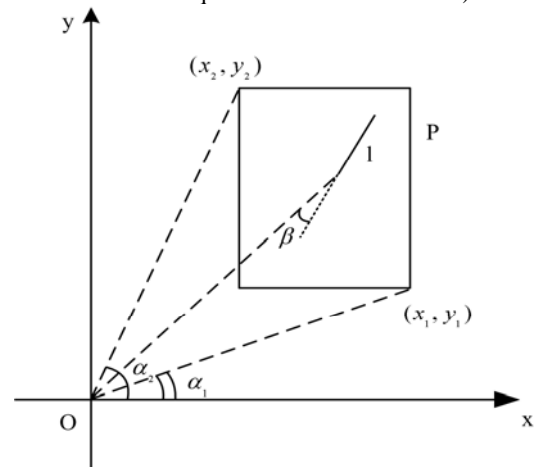


Figure 1 The restriction of vertical edges
Suppose that k is the slope of a vertical edge. Then the scope of

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k is decided by the location of P in the aerial image. Connect the principal point and one end of line l which is nearer to principal point. Suppose β is the angle between this connective line and line l, and calculate the value of β , which can be examined whether line l is one of vertical edges. If the value of β is smaller than the threshold δ_1 , then line l is regarded as one of vertical edges which pass through the principal point. Otherwise, line l is not vertical edge. In conclusion, the vertical edges in image block P should satisfy the following conditions:

- 1) $ctg\alpha_1 < k < ctg\alpha_2$ ($ctg\alpha_1 = \frac{x_1}{y_1}, ctg\alpha_2 = \frac{x_2}{y_2}$);
- 2) $\beta < \delta_1$.

3. CHANGE DETECTION FOR BUILDINGS

The ground coordinates of buildings and their altitudes can be calculated according to the location and length of vertical lines. Meanwhile, there is some information contained in the three dimensional city models. For example, the coordinates of each point which is typical structure point composing the building, the topological relationship of typical structure points, and the relationship of each surface of the building(Zhu and Lin 2004). Then, the changes of buildings in this area will be obtained by comparing these two kinds of data.

3.1 Localization of Vertical Edges

Edge extracting is needed before extracting vertical edges in aerial images. There are several operators for edge extracting, for example, Laplacian operator, Roberts cross operator, Sobel operator, Canny operator and so on. And Canny operator does well for enhancing the signal-to-noise ratio and the accuracy of localization(Canetti et al. 1999). Hough transform is used to detect straight lines after obtaining the edges in images. The main idea of Hough transform is detecting straight lines in images, taking advantage of the duality for points and lines. And the prominent advantage of Hough transform is that there is little influence of noise and interrupted curves(Zhang 1999).

The two vertices of building's vertical edge correspond to building's base and top separately in the object space. So, it is necessary to find out the relationship between the vertices of vertical edges and building's base before calculating their coordinates. According to the mode of projection, the vertices which is nearer to the principal point is building's base, and the farther one is building's top. The point of building's base located on the ground, so its coordinate can be calculated using the principle of frontage intersection. The point of building's top has the same coordinates as that of building's base in the direction of x and y. And the building's elevation will be calculated by the projection difference which is the length of vertical edges as well.

According to the principle of frontage intersection, a point's homonymy point in the other image must be found before calculating its ground coordinates. Usually, image matching is an effective method to find the homonymy points rapidly. However, there is much difference for building's texture in left image and right image, and it is not able to find the homonymy point accurately, using the method of image matching. Considering these problem, relative orientation is adopted to

renew the positional relationship between the left image and right image in the photographic instantaneous. Then, a point's homonymy point in the right image can be found according to its position in the left image and the element of relative orientation. There is a fact, what is worth to be noticed, that the position obtained according to the element of relative orientation is not the same as the position extracted in image directly, and the difference is existent. Therefore, another threshold δ_2 is needed to ensure the computational accuracy of the building's coordinates in the object space. If the difference is smaller than δ_2 , the average values of these two coordinates are regarded as the position of homonymy point, and calculate the position in the left image inversely corresponding to the average values. If the difference is larger than δ_2 , this vertical line is regarded as an incredible line, and it will not be used for later calculation. In this way, not only the homonymy points can be found accurately, but also the precision of vertical lines extraction can be enhanced after correcting the error. Then, the method of frontage intersection is used to calculate a point's ground coordinates, according to its coordinates in images.

Based on the coordinates of building's base, only a single image is needed to calculate the elevation of the building, depending on the projection difference of vertical edges in the image. As shown in Figure 2, point S is the perspective center, and a is the phantom image of line A which is one of building's vertical edges. Then, the building's elevation can be calculated as follows:

$$h = \frac{dH^2}{fD + dH} \quad (1)$$

- where
- f = focal length
 - H = flight height
 - d = projection difference of building's vertical lines in the image
 - D = length between the perspective centre and building's base in the object space

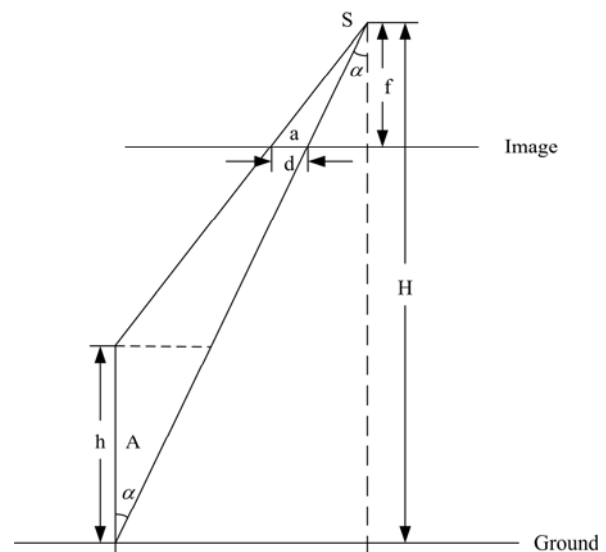


Figure 2 Calculation of building's elevation

The accuracy of building's vertical lines extraction is not high enough, because the result of extraction is usually influenced by many kinds of factors. Therefore, in order to guarantee the precision of building's coordinates, both the left image and the right image are used to calculate the building's elevation respectively, using the method mentioned above. In this way, there are two elevations can be obtained for each vertical edge. If the difference between these two elevations is small, the average of them will be regarded as the building's elevation. Otherwise, if the difference between these two elevations is large, that is to say, only the coordinates of building's base obtained from this vertical edge are credible, and the elevation cannot be regarded as the basis for change detection.

3.2 Algorithm in Change Detection for Buildings

The changes of buildings, occurred in a certain area, can be detected by comparing the building's coordinates calculated by vertical edges and the corresponding building's model obtained from three dimensional city models. The detection is divided into two parts. The first part is the position change detected in planar. The second part is the change detection for elevation, and this part is based on the premise that there are no planar changes for the building's position. Finally, the buildings' changes, occurred in this area, are detected by eliminating the buildings gradually which are not changed. In order to obtain all of the changes in the area, the bidirectional detection is carried on when detect the changes in planar. The changes are detected both on the buildings' model based on vertical edges and on the vertical edges based on the buildings' model.

The flow chart for detection on the buildings' model based on vertical edges is as shown in Figure 3. Take compare between the coordinates of buildings' outlines and the coordinates of buildings' base calculated by vertical edges, and detect whether there are points close to the buildings' base in the three dimensional city models. The allowance error of the distance is ϵ . Moreover, some internal structures of buildings (for example corridors and verandas) often have different colour with the wall, and these will display different pixel values in the aerial images. Usually, it is also regarded as the vertical edges when extracting. However, these are not characteristic lines which compose the building models, and they do not exist in the building models. Therefore, vertical edges need to be analyzed whether to be contained in a certain building model. Find out the nearest building model to vertical edge, and search the maximum value and the minimum value in the direction of X and Y respectively. Then, rectangular is established with its left bottom corner located on (x_{min}, y_{min}) and its right top corner located on (x_{max}, y_{max}) . If the vertical edge locates in this rectangular, then it is contained in this building model. After complete the judgment for each vertical edge, the vertical edges are divided into two parts, namely the buildings added newly and the buildings which has not be changed in their planar position. The further detection for building's elevation is carried on under the precondition that the building has not been changed in planar position. Compare the building's elevation with the elevation calculated by the length of vertical edges, and the changes of building's elevation can be obtained according to the difference between these two elevations.

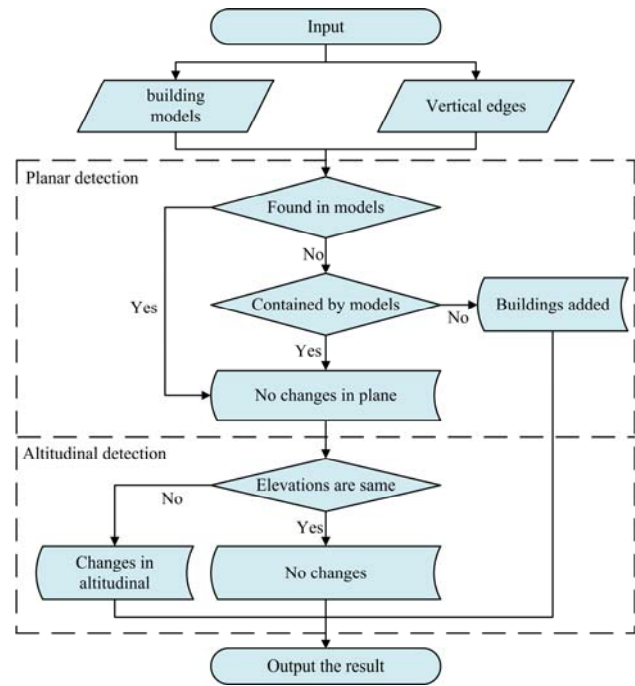


Figure 3 Flow chart for detection based on vertical edges

It can detect the destroyed buildings for the detection based on building models, which makes up the disadvantage of detection based on vertical edges. Check every building in building models one by one, and the buildings which are not analyzed by the detection based on vertical edges are destroyed buildings.

4. EXPERIMENTS AND DISCUSSION

In order to confirm the feasibility of the change detection method proposed above, pairs of aerial images got in 2007 and the building models in Wuhan are used to carry on the experiments. The aerial images are got by digital camera, and the focal length is 101.4mm. The size of images is 11500 pixels*7500 pixels, and each pixel is 0.009mm. The building models are established using the software named CC-Modeller which is exploited by Swiss Federal Institute of Technology Zurich. The experiments are carried on using two groups of data respectively. One group is the buildings whose structures are complex, and another group is herringbone buildings whose structures are simple relatively. The same thresholds are set in these experiments. δ_1 is 0.4, δ_2 is 3 pixels and the allowance error is 1 meter. Figure 4 is part of the experimental result which intercepts from the first group. Figure 4a) is the building models, 4b) and 4c) are the results which demonstrated the vertical edges extracted from left image and right image in corresponding images respectively. The black lines in images are vertical edges. Because the difference of pixel values, the vertical edges extracted from left image and right image are not identical. Detect the changes according to vertical edges and building models, and the result shows that there are no changes in this area.

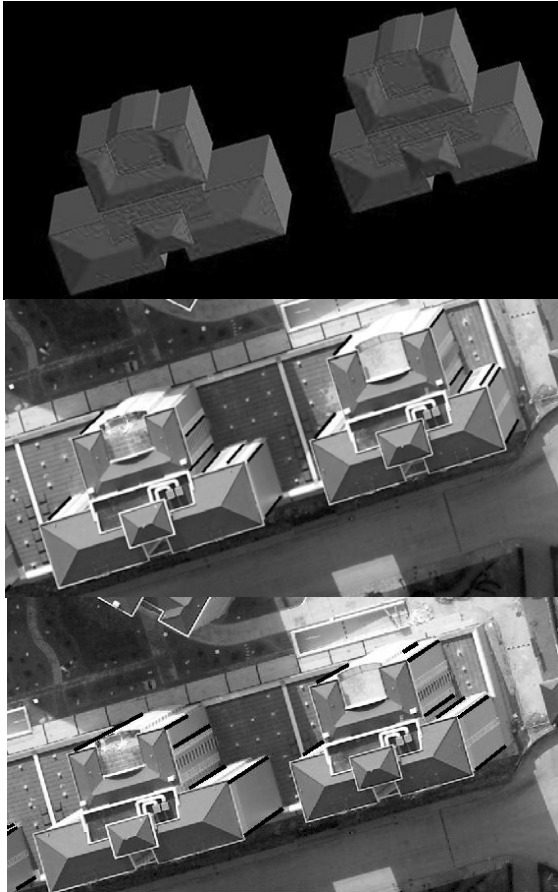


Figure 4a, b, c. Part of the experimental result which intercepts from the first group. a) building models(top), b), c) vertical edges extracted from left image and right image respectively(middle and bottom).

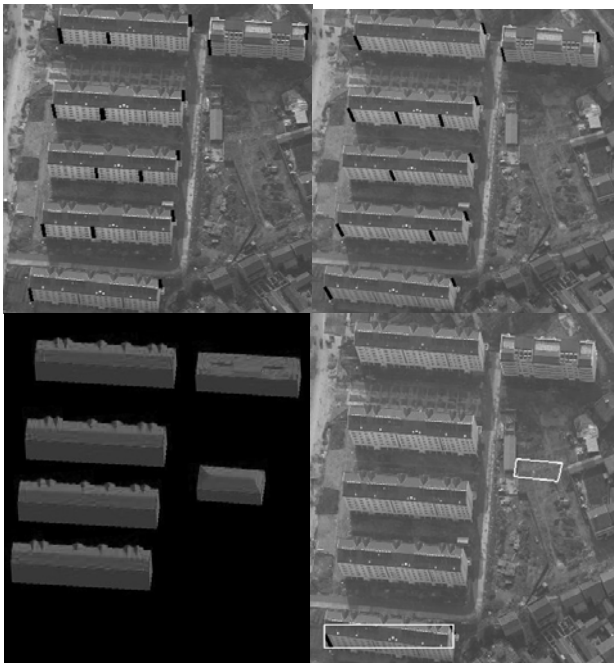


Figure 5a, b, c, d. Part of the experimental result which intercepts from the second group. a) b) vertical edges extracted from left image and right image respectively(left top and right top), c) buildings model(left bottom), d) result of change detection(right bottom).

Similar to Figure 4, Figure 5 is part of the experimental result which intercepts from the second group. Figure 5d) is the result of change detection. In the result, the regions identified by the white rectangle are the changes occurred in this area. The region identified by a white rectangle alone indicates that a building is destroyed, and the region identified by a white rectangle as well as some vertical edges indicates that there is a building added newly.

It is found that the change result is more credible for the complex buildings. It is shown in the image that the outline of herringbone building is constituted by four vertical edges. One of them is covered, and one of them can not be extracted as a vertical edge because the pixel values have little difference around it. As a result, two credible vertical edges can be extracted most in the images, and this will certainly influence to the result of change detection. However, regarding the complex buildings, there are more vertical edges can be extracted for a certain building in the images. This is advantageous to describe and orientate the buildings more accurately, and the changes for the buildings can be detected more exactly.

5. CONCLUSION

The methods of image subtraction and image ratio are usually adopted by the traditional change detection. This paper proposes a method for buildings change detection based on the vertical edges and building models. The typical characteristics of the objects which are focused on are extracted first. The correction of extraction's errors is carried on for several times, and the precision of vertical edges extraction is insured. This method is possible to neglect other factors which may influence the detection result, and focuses on the objects which is concerned. In this way, the accuracy of change detection can be enhanced to a great extent. Compared with the traditional change detection methods, it is active and purposeful detection. It has certain value in theory and application. But its widespread serviceability needs to be enhanced further.

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