CHANGE DETECTION IN URBAN AREA BASED ON STEREO IMAGE PAIRS FROM DIFFERENT DURATION

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ABSTRACT

Change detection is very useful for update of GIS and Digital Map. It can be based on comparing either new single image with old one (single image analysis) or new stereo image pair with old one (stereo image analysis). In this article both single and stereo image analyses are tested. The single image analysis includes four steps: First, the registration of new and old images. Second, image matching and relative rectification between old and new images and extraction of the regions with low matching quality. After features extraction in these regions, the straight lines are detected. Then, based on some analysis between old/new images and rectified new/old images, the changed houses and roads can be detected. In the stereo image analysis, new and old digital surface models (DSMs) are created automatically respectively by image matching firstly. By comparing the new and old DSMs the changed regions are extracted. After line features extraction in these regions, Building-changes could be explored. In this paper, change detection of man-made objects on urban area from single and stereo image analysis and their combination are introduced. The corresponding theory and experiment are presented and analyzed.

1. INTRODUCTION

Rapid development of urban makes the data update more often than ever. However, manual handling of data update is a formidable task. An automatic or even semi-automatic way of data update will increase the speed of data update greatly. Change detection is an important content of image understanding (Lillestrand, 1972). It provides change detector automatically correlating and comparing two sets of imagery taken of the same area at different times and displaying the changes and their locations to the interpreter (Shepherd, 1964). Change detection techniques have been widely used in change analysis of land use, monitoring of shifting cultivation, study of seasonal changes in pasture production, crop stress detection and other environmental change detection (Singh, 1989). It can also be used in data update of GIS. Up to now, for the change detection of man-made objects, such as buildings and roads, little research had been done (Cushnie, 1989). However, the change detection of man-made objects is more important for urban GIS data update.

Because of repetitive coverage at short intervals and consistent image quality, remotely sensed data from Earth-orbiting are often used for change detection (Fung, 1987). However, the spatial resolution of remote sensing imagery is not high enough for change detection of man-made objects in urban area, and the aerial images can be used in urban change detection. In this paper, change detection of man-made objects based on aerial images is introduced. It includes single image analysis, stereo image analysis and their combination.

The single image analysis includes four steps: The new and old images have to be registered firstly. Then image matching is performed between registered images, and the regions with low matching quality are extracted. After features are extracted in these regions, the straight lines are detected. Finally, the changed houses and roads can be detected based on some analysis between registered images.

As well known, changes of man-made objects of urban area are certainly 3-dimendional real objects' changes. House is a typical 3-dimendional real object whose change will cause the change of height of DSM. If we could make use of the height information to assist the detection of house change, it will do well for the improvement of the detection's efficiency and performance. In the stereo image analysis, new and old digital surface models (DSMs) are created automatically respectively by image matching firstly. By comparing the new and old DSMs the changed regions are extracted. After line features extraction in these regions and gradient histogram analysis, Building-changes could be explored.

This paper presents a new approach to combine the height information and gray information of house as one kind of data fusion technology to detect the change of house in urban area. The corresponding theory and experiments are introduced and analyzed below.

2. SINGLE IMAGE ANALYSIS

2.1 Registration of the New Image and Old Image

The images used in the procedure of change detection must be registered prior to matching stage. Some feature points were selected in old/new image and their conjugate points were searched out from the new/old image by two-dimensional image matching method. It was performed in the VirtuoZo Digital Photogrammetry System (Zhang, 1996). The conjugate points were selected as control point pairs of relative registration automatically and semi-automatically. The feature extraction operator, area-based matching and local multiple point matching were applied based on the dynamic hierarchical image pyramid. The interactive actions in both semi-automatic and manual modes enable the operator to add user-defined related points, if required. Points selected by the operator can be on either the old or new image, and their homologous points were determined by image matching. The epipolar theory was used for the registration by resampling the new/old aerial image to produce registered image pair, so that the subsequent image matching can be implemented by searching in small area.

2.2 Matching and Detecting Boundaries of the Changed Areas

2.2.1 Separating the Low Contrast Area from Other Areas: There are some areas with low contrast in the image. These areas will reduce the reliability of image matching. So the low contrast areas must be separated from other areas before image matching. If an area is defined as low contrast area in both old and new images, it was considered that no change happened in the area. If an area is defined as low contrast area in only old/new image, it was considered that this area is maybe "changed area ". If an area is not low contrast area in both old and new images, the image matching and some other methods were applied to determine whether change happened in the area.

2.2.2 Image Matching: A global image matching with probability relaxation method is used. To ensure the reliability of the matching results, as well as fast processing, an image pyramid is used. At the top of the image pyramid (with lowest resolution), a coarse grid is established in the old/new image and matched to the relatively registered image. Matching results on higher levels were the approximations of a finer grid on subsequent levels with higher resolution. The compatibility coefficients used in the relaxation matching consist of matching quality and geometry constraints. The reliability factor for each conjugate pair described the matching reliability and helped extracting the changed areas. The correlation coefficient

$$p = S_{xy} / \mathrm{sqrt}\,(S_{xx} * S_{yy})$$

was used in image matching procedure, where S_{xy} is the covariance of registered image windows, S_{xx} is the variance of old registered image window and S_{yy} is the variance of new registered image window. Because the correlation coefficient is an unvariation of radiation distortion, it can remove the effects of the differences in brightness and contrast between the old/new and registered images due to the different photographing times and conditions.

2.2.3 Detection the Boundaries of the Changed Areas: After image matching, the candidate areas changed can be acquired based on the matching reliability and contrast of gray level. The unreliable areas and the low contrast areas only in one image were selected. Some neighbor areas were combined and the very small areas were removed by the method of mathematical morphology. The edge following was performed in the candidate changed areas, then the ranges of candidate areas changed were acquired.

Now the candidate changed areas had been found out. But whether they were changed in fact and what kind of change happened, were not known. Some changes were maybe other kind of changes (such ass sensor changes), instead of man-made object changes, which we interested in. Further study was needed to determine it.

2.3 Straight Line Detection

The changed man-made objects are often related with houses and roads. The houses and roads usually presents regular form, and can be described by line features. Comparing the line features in candidate changed areas, the changes of man-made objects and other objects, such as trees, can be detected.

The Gaussian-Laplacian operator was used to detect edges in candidate changed areas on both registered images. Then, the zero crossing points were extracted as edge points. In order to acquire the vector data, a contour following procedure was applied and the vector lines were extracted from the double feature edges. The basic principle of Hough transformation is to transform curves from image domain to parameter domain. Then the parameters of the curve can be determined by detecting the point with the maximum in the parameter domain. So the curve can be extracted from the image. After acquiring the line points by LOG operator, Hough transformation was used to extract straight lines. Because the calculation was only for the line points, the speed increases greatly. The equation of straight line is

$$p = x \cos a + y \sin a$$

where p is the length of vertical line from origin to the straight line, and a is the angle between the vertical line and x-axis direction. A straight line can be determined by a pair of parameter (p, a). The straight line can be determined by detecting the point with peak value in parameter domain. Figure 1 shows the results of edge extraction, and Figure 2 shows the Extracted straight lines.

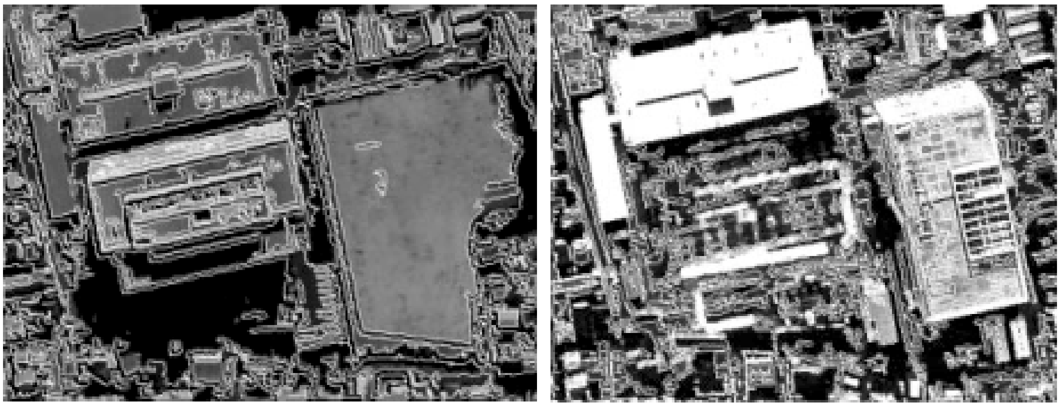


Figure 1. Results of edge extraction

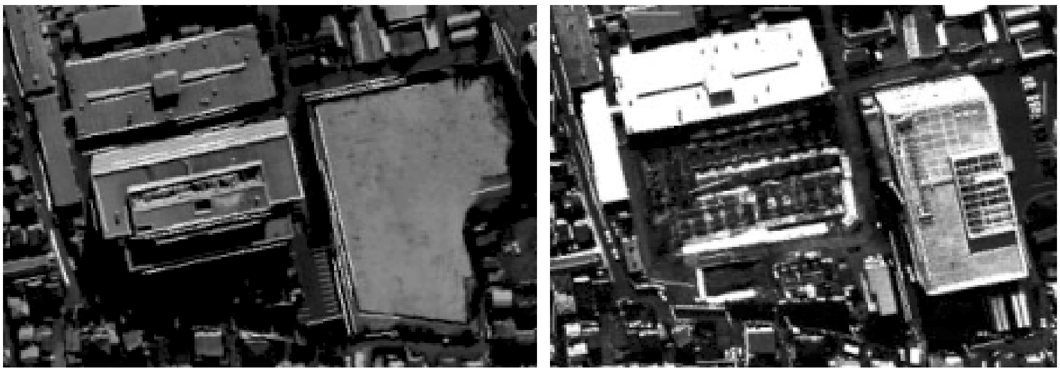


Figure 2. Extracted straight lines

2.4 Analysis of Changed Areas

When the feature extraction procedure was finished in the candidate changed areas on both old/new and registered images, a number of straight lines on the images were obtained. Each straight line was determined by one vector (p, a). Assuming the set of the straight lines in a candidate changed area of old registered image is

$$O = \{(p_1, a_1), (p_2, a_2), \cdots, (p_m, a_m)\},$$

and the set of the straight lines in a candidate area of new registered image is

$$N = \{(p'_1, a'_1), (p'_2, a'_2), \cdots, (p'_n, a'_n)\}$$

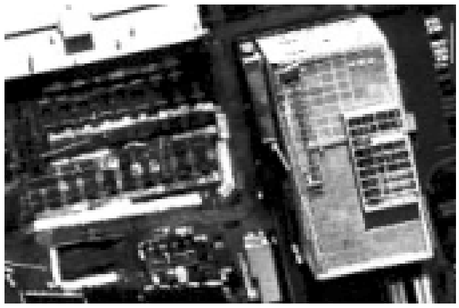


Figure 3. Detected new buildings

The distance between straight line (p_i, a_i) in O and straight line (p'_j, a'_j) in N is

$d_{ij} = [(p_i - p'_j) + (a_i - a'_j)],\ 1 \le i \le m,\ 1 \le j \le n.$

If min (d_{ij}) was smaller than a threshold T_{ml}, then relative two straight lines are matched. Otherwise no straight line in set O was matched with the straight line in set N. When the percent of matched straight lines was lager than the threshold T_{ca}, the candidate areas should be a changed area, and it should be the change of the man-made objects. The validity of the results by single image analysis is about more than 65 percents in the experimental images.

3. STEREO IMAGE ANALYSIS

3.1 Generation of New DSM and Old DSM

DSM contains the heights of objects and can be more quickly and conveniently generated on a digital photogrammetry workstation. The heights are very useful for the change detection of urban area. In the paper, the DSMs for the two different stereo image pairs of the same urban area are utilized Virtuozo digital photogrammetry workstation (Zhang, 1996). Figure 4 shows the parallax contours from partial result of the image matching, where houses appear as lumps. Old and new DSMs are generated based on the result of the image matching.

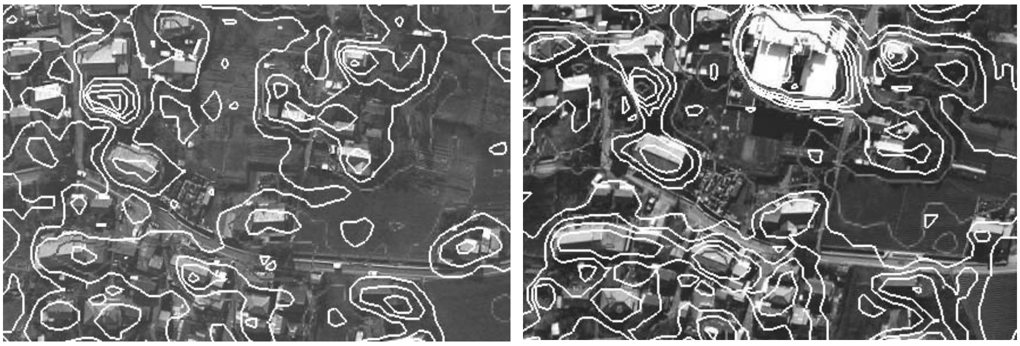
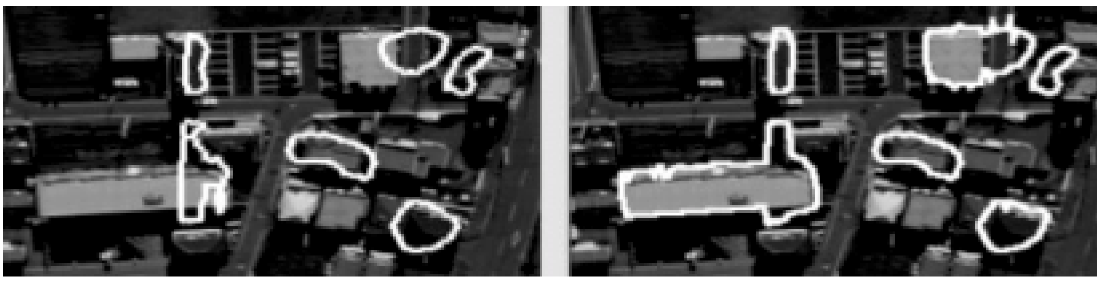


Figure 4 “Lumps” arising in the area with height obviously changed

3.2 Acquire the Potentially Changed Areas

The two DSMs are subtracted to generate a difference of DSMs. Contour lines can be generated from the difference DSM. In the contour graph, there is some area as lump, which represents an obviously changed area. The boundary of the lump is extracted by using traditional area tracing algorithm. After the area is obtained, the original image window of potentially changed areas can be acquired by the collinear equations. Figure 5a shows the lump areas with height change obvious.

The potentially changed areas, deriving from the image matching, may not contain the whole changed house sometimes. They should be extended to be suitable for the next processing. Region growing algorithm is used for the extension (Zhang, 1996). Figure 5b shows the extended areas from those shown in Figure 5a.



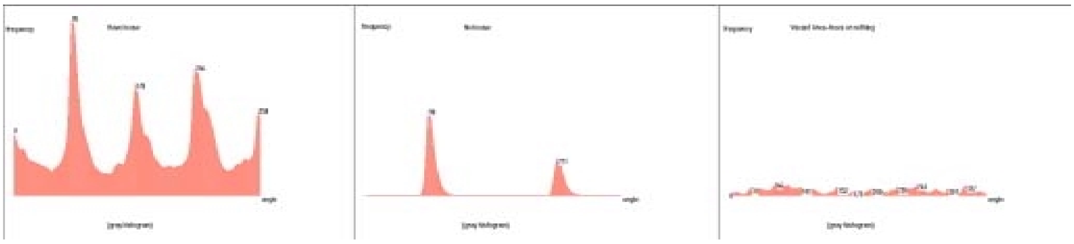
a) b)

Figure 4. Potentially changed area

3.3 Analysis of Gradient Direction

As well known objects such as houses, trees, which are higher than the terrain surface, will be modeled as lumps in DSM. For detecting the houses changed and reducing the false rate, we need to distinguish the areas belonging to the building and those belonging to other objects, such as trees. The histogram of gradient directions can be analyzed. In building's gradient direction histogram, there are usually four peaks representing four directions with internal of 0, 90, 180, 270 degree respectively, or there are two higher peaks with some lower peaks. And there are only two peaks, which internal is 180 degree, for the roads. There is no peak for the trees.

Gradient direction histogram analysis is only limited on the feature points. Figure 6 shows the different histograms from the areas of house, road and trees.



(a) Houses (b) Roads (c) Trees or Nothing

Figure 6. Direction Histograms

3.4 Results of Stereo Image Analysis

All together 132 areas are extracted from the difference of DSMs. After extending those potentially changed areas, the gradient direction histogram is analyzed to determine really changed areas and change's type. 105 changed areas are searched out, to be considered as changed ones, and the validity is 67 percent. Figure 7.shows a part of the results.

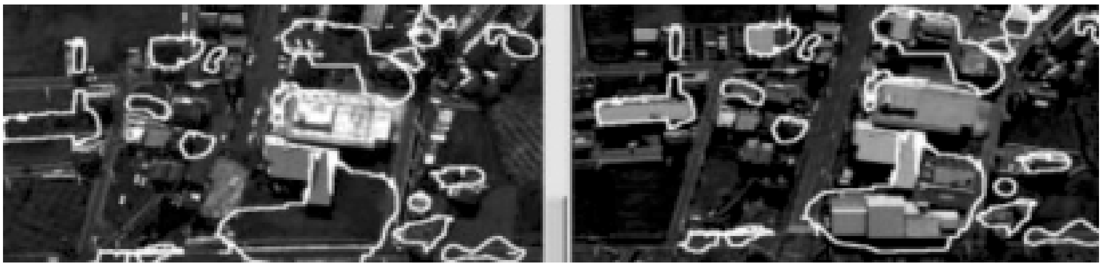


Figure 7. Detecting house changed areas by Gradient Direction Histogram Analysis

4. COMBINITION OF SIMGLE IMAGE ANALYSIS AND STEREO IMAGE ANALYSIS

The validity of either single and stereo image analysis is about near 70 percent. It is not very high. In order to improve the performance of the change detection, the combination of two analysis methods is needed. One way is synthesizing the results of single image analysis based on the epipolar line theory, mentioned above, and ones of stereo image analysis. Another way is that the analysis of gray level (single image analysis) is based on the results of analysis of DSM. That is the two orthoimages are created based on the two DSMs first, instead of relative registration between new and old images by epipolar line theory. Then, the image matching is performed between the new and old orthoimages directly, and the results of DSM comparison and image matching are synthesized.

One way of the synthesis is that the single image analysis is based on the result of the result of stereo image analysis. In this way, there are 182 candidate regions detected by DSM comparison. After synthetic analysis, 112 regions are determined as changed regions, among which 73 regions are really changed. 70 regions are determined as not changed, Among which 66 regions are really not changed. The validity is (73 + 66) / 182 = 76.37%. It can also be on the following way. The candidate areas changed from difference of DSMs are combined with those from image matching. Then, Analysis of gradient direction is used in the combined candidate areas to confirm the changed regions. All together, 220 candidate regions are detected by DSM comparison and gray analysis. 159 regions are determined as changed regions, among which 105 regions are really changed. 61 regions are determined as not changed, Among which 55 regions are really not changed. The validity is (105 + 55) / 220 = 72.73%. Figure 8 shows a part of the result. The regions with white boundary in right image window of figure 8 are changed, and the regions with gray boundary are not changed. The validity of first way is little higher than second one, but there some changed region lost in the first way. Anyway, the validity of each synthetic way is higher than any single analytic method.

Figure 8. Result of Change Detection

5. CONCLUSION

The traditional method of single image analysis in change detection, based on remote sensing images, can be used based on aerial images also. The new method of stereo image analysis is suitable for change detection using aerial stereo image pairs, and it is simple, easy to operate. However, the validity of the results by only any one method is not very high. The combination of two methods is necessary for improving the performance of the change detection.

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