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8—19 Detection of Building Changes from Aerial Imageries through information fusion

Wei Lu*, Takeshi Doihara*, Yoshino Matsumoto*
Research Institute
Asia Air Survey Co., Ltd.

Abstract

In this paper, an improved approach of detecting building changes with aerial imageries has been proposed. This approach first makes uses of image pixel's color, structure's edge information and their correlation to filter out the candidates at relatively high speed. Then existing vector topographical map information and previously processed data are used for more precise analysis to get rid of unrelated changes. Experiments with actual data shows that the proposed approach has obtained success rate of above 90% while keeping the retrieval rate above 70%.

1 Introduction

Recently, in Japan, many local governments have adopted the method of surveying building's change with the aid of aerial imageries. This method is far more efficient than visually inspecting every building by investigators on the ground. But it also has the shortcoming of requiring veteran operators in order to maintain its reliability and efficiency. In order to further improve the applicability of this method, more reliable and less costly method is expected.

Detection of building change through image processing technology is one of the most widely researched approaches. There have been many researches reported on change detection[1-10]. But most the proposed approaches are most effective for the following type of areas:

1) the density of building is low
2) image resolution is high
3) the color or gray scale for building's surface are close to uniform
4) the shape of building's roof is of polygon

But since most of the cities in Japan are densely inhabited, the existing approaches are hardly applicable.

This paper proposes a new approach for building change detection with aerial imagery and topographical map. It first retrieve the candidates of changed building by applying a series of image processing techniques, which assures maximum recovery rate and high processing speed at the same time. Then existing map information and previous processed result are made use of to eliminate unrelated changes, so that recognition rate are improved to a practical level while recovery rate is maintained at high value.

In the following sections, the system configuration is described in section 2, the filtering of candidates of changed buildings is described in section 3, the selection of building related changes are described in section 4, the experimental results of this proposed approach with real world data is presented in section 5. Section 6 summarizes the whole approach.

2 System Configuration

Fig.1 shows the configuration of the proposed approach, which is an expansion of our existing system[11]. The input data are pairs of digitized aerial photos taken a certain period apart, usually a year apart. The output is the candidates of regions where building change may have most probably happened. The detection of changed building are performed

***Address**: Asahiseimei Build. 3F, 8-6 Tamura-cho, Atsugi-shi, Kanagawa-ken, 243-0016, JAPAN
E-mail: luwei@ari.ajiko.co.jp

mainly in two stages:1) candidate filtering and 2) candidate selection. The first stage consists of calculation of color difference, edge detection, disparity calculation and overlapping checking. The output is the areas where building changes most likely happened. Section 3 gives more detailed description about this stage. Since there are also changes caused by cars, fields, trees and so on, more precise analysis of changed areas are performed by the second stage. It consists of comparison of candidate area's position with existing topographical map information and checking of the shape information against those previously processed. More detailed description will be give in Section 4.

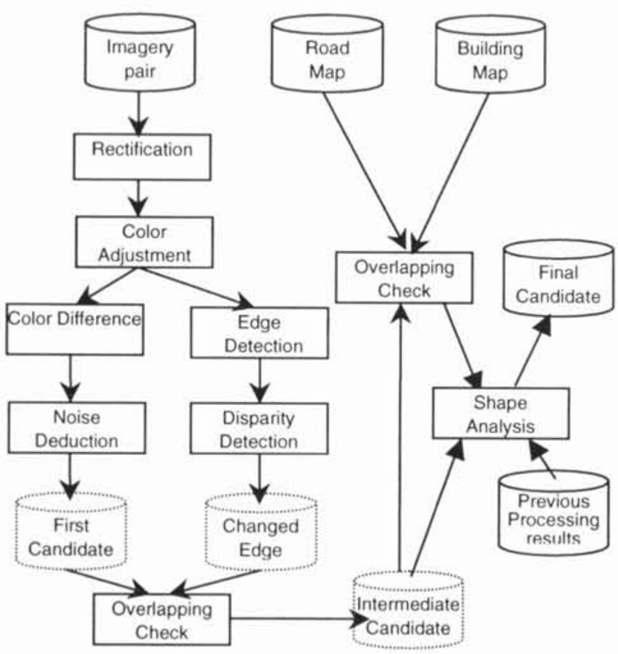

Fig.1 Configuration of Proposed System

3 Candidate Filtering

Since most of the image processing techniques are time consuming, one of the most primal targets for constructing practical system is speed improvement while maintaining optimal processing result. In our approach, this is obtained by the following approach:

1. Calculating color difference as initial area candidates
2. Retrieve edge segments and calculate the correlation along them and take those with low correlation value as edge candidates
3. Combine the results by the above two procedures by checking their position relationship and take the overlapped ones as candidate of changed building, with the area showing the range and edge the position

Here, all the procedures are performed with the preprocessed image pair. The preprocessing includes rectification and color adjustment by equation (1) and (2).

$$x'^2 = \frac{a_1 x + a_2 y + a_3}{a_7 x + a_8 y + 1}$$
$$y'^2 = \frac{a_4 x + a_5 y + a_6}{a_7 x + a_8 y + 1} \qquad (1)$$

$$X'^2 = \frac{\sigma_X^1}{\sigma_X^2} X + \frac{\sigma_X^2 \mu_X^1 - \sigma_X^1 \mu_X^2}{\sigma_X^2} \qquad (2)$$

Color difference is chosen for filtering out the initial candidates because it is the most prominent and reliable features of changed objects, and the processing time is minimum. The procedure of "Noise deduction" eliminates those candidate areas with area less than targeted threshold, which depends the resolution of the image and the minimum change areas to be detected.

The correlation along edge segments is the equivalence of pseudo-stereography effect, which is the phenomenon when viewing the image pairs as stereography. Since building structures always have edge segments and any changes has the most prominent disparity along the edges, the changes can be precisely and efficiently detected by calculating disparity only along the edge segments.

4 Candidate Selection

Since the candidates filtered from original image pairs still contains regions not related to building changes, further analysis are necessary to select only those generated by building changes. In our approach, two sources of information are used for this purpose.

First, existing topographical map data, which are rectified to the imagery, are used to verify the possibility of existence of building change. The position and area of change candidates are checked against that of building and road in topographical map. Candidate regions lying within building areas are given higher possibility. Those outside of building areas are eliminated if their shape is not building like. Here, the analysis of building is performed in the same method as in the second step that follows. Regions that fall within the road regions are eliminated since road do not change often and the possibility of new buildings on a previous road region is very low.

Second, when imagery of the same district has been processed, the retrieved candidates and final candidates are taken as teacher data, which will be sued to train a back-propagation type neural network. The network is then used to analysis the shapes of the newly retrieved candidates.

The features used for shape analysis are as follows:

- area
- area of convex
- peripheral
- elongation
- width and height along the elongation axis
- area/area-of-convex
- area/(width*height)
- width/height

The teacher data are grouped as regions of changed buildings inside and outside of building area of topographical map, partial or overall changes, and regions of non changed buildings.
As a result, most of the unrelated change candidates on roads, empty space, field and so on can be eliminated.

5 Experimental Results

We have applied the proposed approach to a number of real world imagery pairs to verify its validity. Fig.1 shows part of an imagery pair taken in two consecutive years, with coordinates adjusted. Experimental results show that even for imageries of densely populated area, the success rate of change detection is above 90% while keeping the retrieval rate above 60% when teacher data is not used. Here, the retrieval rate and success rate are defined as follows:

$$\text{retrieval rate} = \frac{total-number-of-correct-candidates}{totao-number-of-changed-buildings}$$

$$\text{success rate} = \frac{total-number-of-correct-candidates}{total-number-of-candidates}$$

(a) photo taken in 1995

(b) photo taken in 1996

Fig.1 An example of aerial photo pairs(partial)

When the neural network trained by the teacher data is used the recognition rate and recovery rate becomes above 90% and 70% respectively.

Fig.2 shows the result of color difference only, with many unrelated candidates caused by non-building changes. Fig.3 shows the processing result of final change candidates.

The typical computational time for image of about 2000X2000 is less than 20 minute CPU time, when performed on an PC of PentiumII 300.

Most of the undetected regions of (partialy) changed buildings have area less than that of cars, which, according to the 40cm resolution of our sample images, is difficult to distinguish from those caused by cars, shade, trees and so on. This can mostly be solved by using images of higher resolution.

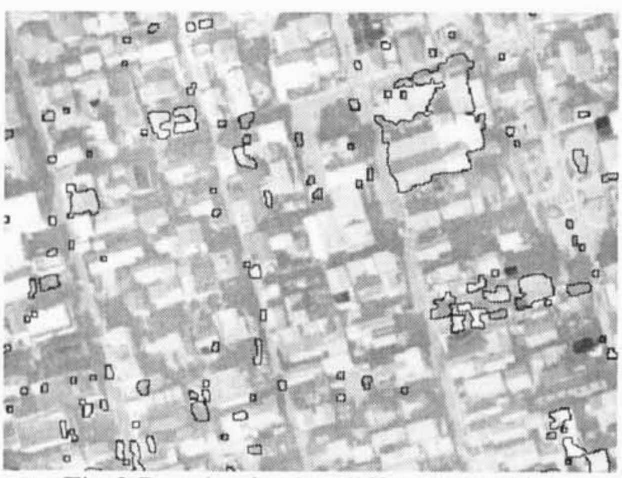

Fig.2 Result of color difference only

Fig.3 Result of final candidate detected by the proposed approach

6 Conclusions

The proposed approach in this paper makes use of psuedo- stereography effect and previous proccessed data to detect change of buildings from aerial photos. The experimental results show that the proposed approach is capable of detecting change of buildings at high speed and precision.

Since time consuming processings are performed only in areas of high probability, our approach requires less computing resources and is more robust in the case of densely populated area, when compared to approaches dealing with similar problems.

References

[1].R. Matsuyama, M. Nagao: Structural Analysis of Aerial Imagery. Journal of Information Processing Society of Japan, vol.20, no.5, pp.468-480, 1980

[2].D. M. Mckeown, W. A Harvey, J. MeDermott: Rule-based interpretation of aerial imagery. IEEE Trans. On PAMI, vol. PAMI-7, no.5, pp.570-585, 1985

[3].Z. S. Jain, Y. A. Chau: Optimum multisensor data fusion for image change detection. IEEE Trans. on Sys. Man and Cyber. Vol.25, no.9, pp.1340-1347, 1995

[4].Y.T.Liow, T. Pavlidis: Use of shadows for extracting buildings in aerial images. CVGIP, vol.49, 1990.

[5].D. M. McKeown: Information fusion in cartographic feature extraction from aerial imagery. Digital Photogrammetric Systems, Wichmann, pp.103-110, 1991

[6].X. Y. Jiang, H. Bunke: Line segment based axial motions stereo. Pattern Recognition, vol.28, no.4, pp.553-562, 1995

[7].M. Bejanin, A. Huertas, G. Medioni etc: Model validation for change detection. APRA, Image Understanding Workshop, pp.287-294, 1994

[8].R.Ohyama,Y. Ohsawa etc: Semi-automatic Detection of Land Usage Changes with Aerial Photograph with DTM, proc. of 6th Symposium of Functional Graphics Information System of IEICE, pp.1-6、1995

[9]. Z.C. Shi, R. Shibasaki: Automatic building detection from Aerial imagery through segmentation with wavellet and stereo matching. Journal of the Japan Society of Photogrammetry and Remote Sensing, vol.34, no.5, pp.36-44, 1995

[10].Z.C. Shi, R. Shibasaki: A study on automatic updating GIS database with aerial imagery. Proc. of 7th AM/FM International Conference Japan, pp.89-96, 1996

[11] W. Lu, T. Doihara, Y. Matsumoto: "Detection of Building Changes by Integration of Aerial Imageries and Digital Maps", Proc. of ISPRS Commission V Symposium, pp.344-347, Hakodate, Japan 1998