DETECTION OF BUILDING CHANGES BY INTEGRATION OF AERIAL IMAGERIES AND DIGITAL MAPS

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ABSTRACT

This paper proposes a new approach for building change detection with aerial imagery and topographical map. One of the most novel and effective operations in our approach is to make use of pseudo-stereography effect to detect the change candidates while eliminating unrelated candidates generated by minor differences in camera's orientation parameters. Change detection of buildings is realized in three steps: image adjustment, candidate identification and candidate refinement. Image adjustment includes rectification, color adjustment. Candidate identification, which is a combination of image difference, edge detection, line following, segmentation, and correlation (for disparity evaluation), generates the most possible changed areas, called change candidates. Image adjustment reduces the number of unrelated candidates in change candidates. In addition to shape analysis methods, it also integrates topographical map data, which are rectified to the imagery. The position and area of change candidates are checked against that of building and road in topographical map to determine whether they are caused by changes of building. As a result, most of the unrelated change candidates on roads, empty space, fields and so on can be eliminated. We have applied the proposed approach to a number of real world imagery pairs to verify its validity. Experimental results show that even for imageries of densely populated area, the correct rate of change detection is above 90% while keeping the rate of detection above 60%. Compared to approaches dealing with similar problems, our approach requires less computing resources and is more robust in the case of densely populated area.

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. But it also has the shortcoming of requiring veteran operators in order to maintain its reliability and efficiency. In order to further increase 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. Some of the typical ones are listed in the reference of this paper. The approaches adopted in most of the researches can be summarize as follows:

1) detect the shapes of buildings
2) utilize the shadow of buildings
3) analyze the projection of building
4) make use of continuous images
5) make use of 2 dimensional or 3 dimensional models
6) make use of height information (high resolution DEM)

The above 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 above approaches are hardly applicable.

In this paper, we propose a method which incorporates pixel, edge, stereo matching and existing digital (vector) information. First, the outline of the proposed method will be described in section 2. Next, the detailed algorithms are described in section 3. The experimental results and the evaluation of the proposed method are described in section 4 and 5 respectively. The last section presents the conclusions.

2. CONFIGRUATION OF PROPOSED SYSTEM

Fig.2 shows the configuration of the proposed system.
The aerial imageries taken periodically are first digitized as image files. Then the corresponding images are rectified by manually specifying tie points. The color distribution is then adjusted so that they look more similar to each other.
We applied two methods for extracting the candidate of changed buildings. One is color difference with noise reduction. The other is disparity detection along edge elements. The two results are then combined to form intermediate candidates, with less unrelated areas (those

not related with the change of buildings, such as cars, tress, lawns etc.). To further reduce unrelated candidates, existing vector information, that is road polygons and building polygons are used to reduce the number of candidates so that most of them are related to building changes.

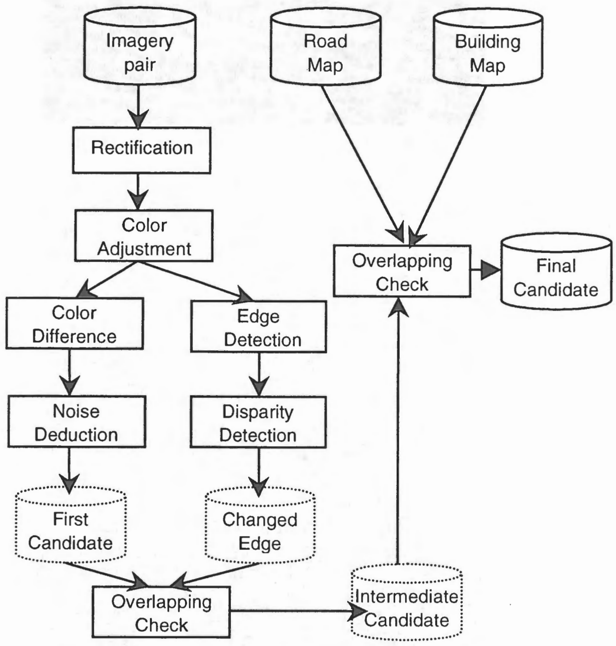


Fig.1 Configuration of Proposed System

3. DETAILED ALGORITHMS

3.1 Preprocessing

To ensure precise detection of changes, aerial imageries are taken in the same season, at about the same time of the day and at the about the same location. Yet many factors such as climate, conditions of film development, scanning condition etc. will inevitably make the imageries of corresponding area different, even though there is not any changes. To reduce the influences of such factor to the minimum, the following method are adopted:

(1) Rectification

4 or more tie points are specified on the corresponding images. Then with the minimum squared error method, the parameters a1,..., a8 for projection transform (eq. 1) are calculated. Here, the coordinates of (x,y) and (x',y') are those of image pixels before and after rectification.

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

(2) Color Adjustment

After rectification, the colors of pixels in the image pair is adjusted according to the following equation:

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

where, μ and σ are the average and variation of the colors of all the pixels.

3.2 Extraction of First Candidate

From the result of preprocessing, the difference of color (eq.3) of corresponding pixels is calculated to determine the candidates of changed building area. Here, I(i,j) is the color of the pixel at coordinate (x,y).

$$C_{ij} = \begin{cases} 1, & (D_{ij} \geq th_{intensity}) \\ 0, & (D_{ij} < th_{intensity}) \end{cases} \qquad (3)$$
$$D_{ij} = | I^1(i,j) - I^2(i,j) |$$

To erase random noises, erosion and dilation are performed for the above result, which eliminates areas with width less than 2 pixels.

3.3 Extraction of Changed Edges

When a pair of stereo aerial imageries is placed at a proper distance from each other and a proper distance a way from one's eyes, a 3 dimensional scene can be obtained, as though the eyes were placed where the camera was when the imagery was taken. When the image pair is taken at the same position but at different time, regions with no changes at all will look like a plain in the above situation. Whereas regions with change buildings, cars or trees will look as if they are above or below the ground, which is a kind of pseudo-stereo image and very effective for visually detecting changes from aerial imageries.

To make use of the above-mentioned pseudo-stereo phenomenon, we apply stereo matching to the image pair to identify the change more precisely. Since the calculation cost of stereo matching is comparatively high and the changes of building cause most significant changes along their boundaries, we only need to calculate the disparity along edge elements as follows:

1) Extract edge element
2) Trace the edge element and erase those whose length is less a predefined threshold $th_{edgeLength}$
3) Calculate the correlation with equation (4)

$$R_{ij} = \max_{l,m \in R} (r_{(i,j,l,m)}) \qquad (4)$$
$$r(i,j,l,m) = 1 - \frac{1}{K} \bullet \frac{\sum_{x=-L}^{L} \sum_{y=-M}^{M} F(x,y,i,j,l,m)}{\sigma_1 \sigma_2}$$
$$F(x,y,i,j,l,m) = [I^1(x+i, y+j) - \mu^1(i,j)][I^2(x+l, y+m) - \mu^2(l,m)]$$
$$K = (2n+1)^2 \bullet (2m+1)^2$$

4) Calculate the ratio of pixels whose correlation is less than a predefined threshold $th_{edgeDegree}$. If the result is less than $th_{edgeRatio}$, take it as a candidate of changed edge.

The candidates obtained from color difference are then checked against the edge difference for more precise detection. In the proposed system, we check the degree of overlapping between color difference area and changed edge. Those with number of overlapped pixels above a predefined threshold is taken as intermediate candidates of changed building.

Deletion of Unrelated Objects

When digital information such as road polygon and building polygon are available, we can use them to further erase unrelated changes from the intermediate candidates based on the following assumptions:

1) Roads do not change much with a certain period.
2) Building polygons are roughly correct

In the proposed system, intermediate candidates are purified in the following steps:

1) Get tie point between image and maps and overlap then with each other.
2) Erase candidates lying within road regions.
3) Erase candidates lying outside building regions except those whose shape is of rectangles.

4. EXPERIMENTAL RESULTS

To verify the applicability of the proposed system, we use the following sample imageries for experiments.

Scale	1/5,000 to 1/7,000
Scanning resolution	400dpi
Ground resolution	About 32 to 45cm/pixel
Size of one image	About 2000pixelX2000pixel
File size	About 12MB

Fig.2 and Fig.3 shows part of the original images.
Fig.3 shows the result of color difference. The black lines are the boundary of the candidate's region. Obviously, they are caused not only by the change of buildings, but also by cars, trees and open spaces.
Fig.4 shows the result of edge detection.
Fig.5 shows the result of detection of changed edge, which correspond to the boundary of changed building area.
Fig.6 shows the result of intermediate candidates of changed building by combining the results shown in Fig.3 and Fig.5.
Fig.7 shows the overlapping result of building polygon with the sample image.
Fig.8 shows the final candidates by using building and road polygon information to erase unrelated areas.

Fig. 2 Sample image taken in 1995

Fig. 2 Sample image taken in 1996

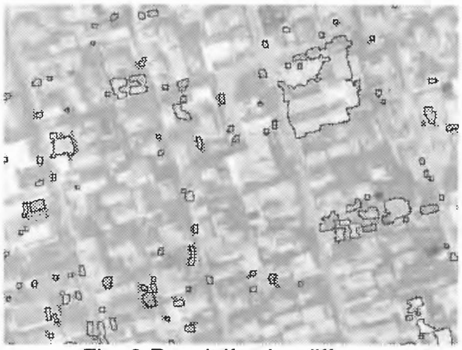


Fig. 3 Result if color difference

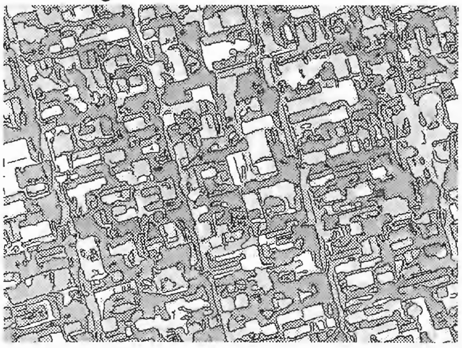


Fig. 4 Result of edge detection

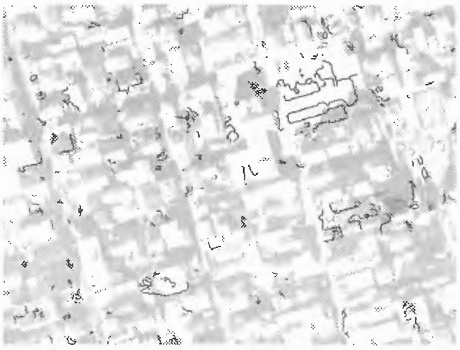


Fig. 5 Result of changed edge detection

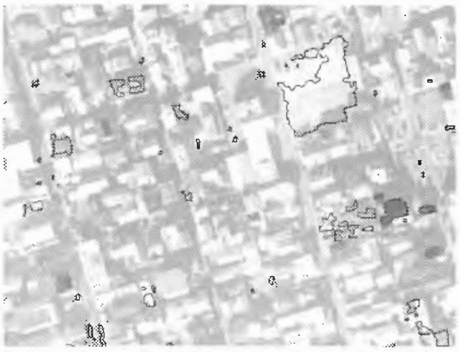


Fig. 6 Result of intermediate candidate

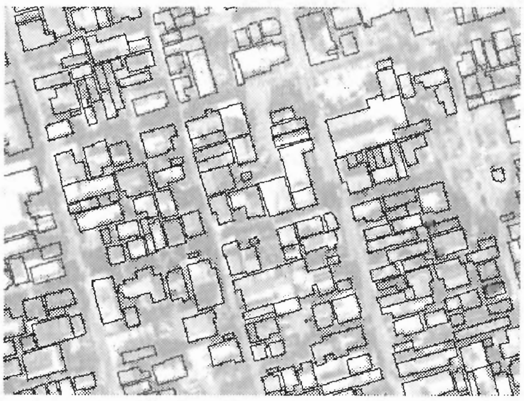


Fig.8 Result of overlapping road polygon with image

Fig.9 Result of final candidate detection

5. EVALUATION AND DISUSSIONS

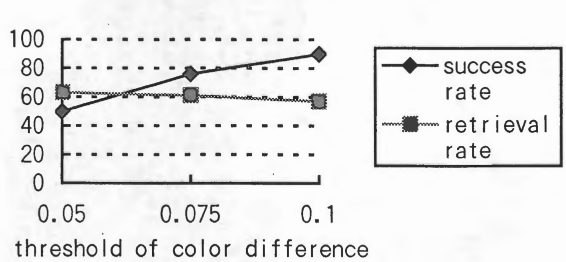
To evaluate the proposed system quantitatively, we use the following parameters, where the total number of changed buildings are visually detected by operator.

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

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

Graph 1 shows the relationship between retrieval rate, success rate the threshold for color difference.

Graph.1 Retrieval and success rate



The total calculation time for the sample image requires less than 20min on a Pentium 200MMX CPU.

Since psedo-stereography effect is used in the proposed system, the rate of is relatively constant with the change of threshold. The success rate can be raised to over 90% by adjusting the threshold for color difference. Many of the changes are difficult to detect with the approaches described in the introduction due to the deteriorative conditions.

The rate of retrieval rate is about 60% for the sample image. Yet this is still not very satisfactory when applied to practical daily works. Yet, since the number of total changed buildings here are based the most rigorous criteria, which defines any minute changes such as increase in floor area, partial reconstruction etc., the proposed system can be effectively applied to areas that requires less vigorous criteria.

6. CONCLUSIONS

In this paper, we proposed an approach for detecting changes of buildings with aerial imageries. It requires only a pair of images of the same region taken at different period. The psedo-stereography effect is utilized for more stable and precise detection of building's changes, and is modified for less calculation cost. We plan to further incorporate more technologies such as shape clustering, topology analysis etc. to improve the success and retrieval rate.

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