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Automatic Registration of Aerial Image and Digital Map for Detection of Earthquake Damaged Areas

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Abstract. In this paper, we propose an automatic detection method of the areas damaged by an earthquake. We use aerial images that are taken before and after the earthquake. To detect the damaged areas, we register these two aerial images. It is difficult to register two aerial images by using only the image information, and hence, we use digital map for registering them. First each aerial image is registered to the digital map by using the perspective transformation. Then we detect damaged areas by computing the differences between the registered images. The damaged areas can be detected automatically and correctly by our method.

1 Introduction

In a natural disaster, we should grasp the damaged areas widely and rapidly for supporting the rescue activities. The aerial images are useful for the activities because we can collect the area information widely and rapidly in the images. However analysis of the image taken after the earthquake is difficult. This is because the image information is complex and difficult to extract the change of shapes of roads and buildings. Two images taken before and after the earthquake are useful to detect the damaged areas. If these two images have to be registered manually, it may be troublesome for detecting the damaged areas from many images taken by various locations. In many methods of detecting the damaged areas from the aerial images, the images are not automatically registered [1–4]. Several studies have tried to show disaster information on GIS (Geographical Information System). To register the aerial image with the digital map is useful for this study and we can use GIS information to determine the damaged areas.

In this paper, we propose a new method of automatic detection of the damaged areas from the aerial images. For this purpose, we use the digital map, and we use automatic registration method of the aerial images and the digital map. In several studies, the registration methods by corresponding the points on the images have been proposed [5, 6], however, it is difficult to detect the points automatically and to obtain stable results. In our study, we apply the matching method to the edge information of the aerial image and the digital map.

2 Summary of Our Method

As shown in Fig.1, we first register each aerial image with the digital map respectively using the edge information in the aerial image and the digital map. Then, we extract the damaged areas by computing the difference of colors of two pixels in the same location. We judge whether the colors of each registered pixel pair can be regarded as the same in consideration of the difference of lighting conditions. In the color difference computation, we use hue, lightness, and saturation of each pixel. Finally, we extract the damaged areas by classifying the difference of colors.

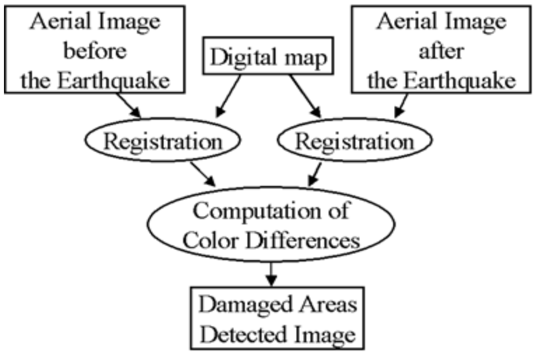


Fig. 1. Flow of our method

In the following sections, we describe our method as follow. First, we describe the method of automatic registration of the aerial image with the digital map. Then we describe the method of automatic detection of the earthquake damaged areas. Finally, we show our experimental results.

3 Automatic Registration Method

3.1 Preprocessing

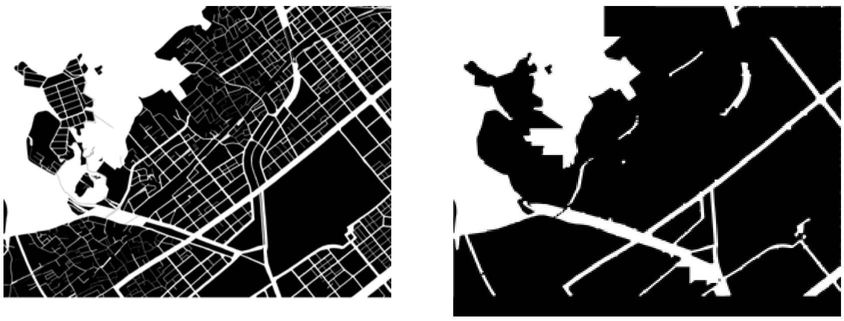
Aerial Images For preprocessing of the aerial image, we transform the color aerial image to the gray-scale image, then we apply the median filter to the image for eliminating the noise. Finally, we apply the Sobel filter to the image for obtaining the edge vector intensity(r) and the direction (θ) . These equations are described as follows:

$$r = \sqrt{{S_x}^2 + {S_y}^2}, \tag{1}$$

$$\theta = tan^{-1}\frac{S_y}{S_x}, \tag{2}$$

where S_x is the horizontal gradient and S_y is the vertical gradient.

Digital Map The digital map is composed of vector data, and it contains city block data, road data, railroad data, etc. We use the road edge vector data in the digital map. When we register the digital map data with the aerial image data, we apply geometric transformation to the road edge data. The computation time increases in proportion to the total number of the edge vector data. For shortening the computation time, we reduce the number of the edge data. In the reduction, we eliminate the edge data of the narrow road from the map. First, we extract the road edge vector data from the digital map and make a road map image. Then we reduce the narrow road regions by applying erosion and dilation operations several times to the road map image. Finally, we extract the road edge data by matching the original digital map data with the road map image. The total number of the road edge vector data is reduced to about 30% of the original data by the processing (Fig.2).



(a) before reduction

(b) after reduction

Fig. 2. Reduction of vector data

3.2 Transformation Method

We apply geometric transformation to the digital map data (road edge vector data) and register the digital map with the aerial image. If the aerial image is taken from the direction perpendicular to the land surface, we can obtain the correct results by applying the affine transformation to the digital map data (Eq. 3). However, it is difficult to take the aerial image from such direction correctly. Therefore, we cannot register the image with the map by applying the affine transformation. In our method, we apply the perspective transformation (Eq. 4). This transformation takes more computation time compared with the affine transformation. To reduce the computation time, we use two stage transformation method. First, we apply the affine transformation and obtain the affine transformation parameter values approximately by changing the parameters and computing registration similarity. Secondly, we apply the perspective transformation by using the affine transformation parameter values and obtain the perspective transformation parameter values correctly.

$$\begin{aligned} X &= a \cdot x + b \cdot y + c \\ Y &= d \cdot x + e \cdot y + f \end{aligned} \tag{3}$$

$$\begin{aligned} X &= \frac{A \cdot x + B \cdot y + C}{G \cdot x + H \cdot y + 1} \\ X &= \frac{D \cdot x + E \cdot y + F}{G \cdot x + H \cdot y + 1} \end{aligned} \tag{4}$$

$$\left\{ \begin{array}{l} a \sim f \text{ :affine transformation parameters} \\ A \sim H \text{ :perspective transformation parameters} \\ (x, y) \text{ :coordinates before the geometric transformation} \\ (X, Y) \text{ :coordinates after the geometric transformation} \end{array} \right\}$$

3.3 Registration similarity

When we register the digital map with the aerial image by applying the geometric transformation, it is difficult to register them by using the edge intensity. This is because many edges may be detected from the regions on the image except for the road edges. Therefore, we use the edge directions for the registration. We use the similarity measure P as follows:

$$P = \frac{\Sigma |S|}{\Sigma |S| + \Sigma |A|} \tag{5}$$

where ΣS indicates total sum of the points which have high edge intensity in the aerial image and have the same edge direction with the digital map data, and ΣA indicates total sum of the points which have high edge intensity in the aerial image and have the different edge direction with the digital map. We compute the similarity measure P by transforming the road edge vector data of the digital map and matching the data with the edge vector data of the aerial image. We obtain optimum perspective transformation parameters where P is the maximum value.

4 Damaged Areas Detection Method

We detect earthquake damaged areas by using registration results. First, we compute the color differences of registered pixels of two aerial images, and we extract the damaged areas having large color differences on registered pixels.

We classify the areas into damaged area and non-damaged area. Some of the areas, such as shadow areas, cannot be classified by the image color information, and we describe the area as undetermined area. For classifying the areas, we use Hue-Lightness-Saturation(HLS) color model [1, 7]. Let H_b, L_b, and S_b be hue, lightness, and saturation of a pixel of "before earthquake image", and H_a, L_a, and S_a be hue, lightness and saturation of a pixel of "after earthquake image". T_a, T_b, T_L, and T_H, are the thresholds and they are determined by a preliminary experiment.

– Case 1 ($S_b < T_b$ and $S_a < T_a$) : both low saturation
  if | L_a - L_b | $\geq T_L$, then the pixel is in the damaged area.
  Otherwise, the pixel is in the non-damaged area.
– Case 2 ($S_b \geq T_b$ and $S_a \geq T_a$) : both high saturation
  if $|H_a - H_b| \geq T_L$, then the pixel is in the damaged area.
  Otherwise, the pixel is in the non-damaged area.
– Case 3 ($S_b < T_b$ and $S_a \geq T_a$) or ($S_b \geq T_b$ and $S_a < T_a$): one in low saturation,the other high
  if $|H_a - H_b| \geq T_H$ and $|L_a - L_b| \geq T_L$, then the pixel is in the damaged area.
  if $|H_a - H_b| < T_H$ and $|L_a - L_b| < T_L$, then the pixel is in the non-damaged area.
  Otherwise, the pixel is in the undetermined area.

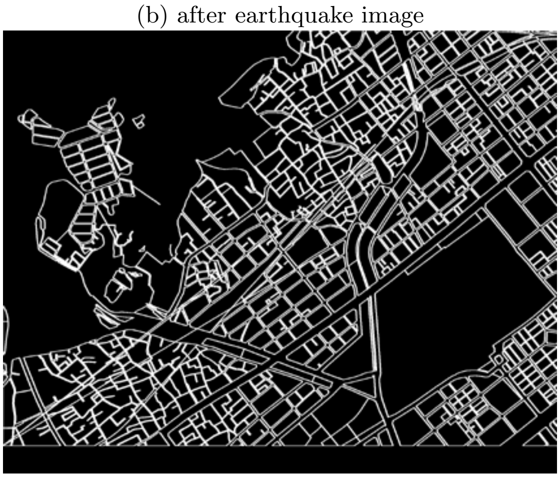
5 Experimental Results

We used two aerial images of Kobe city in Japan. One image is taken 100 days after the Hyogoken-Nanbu Earthquake [8], and another is taken 5 years after the earthquake [9]. We used the latter as "before earthquake image". The size of each image is 2580×1830 pixels. Fig.3(a) shows "before earthquake image". Fig.3(b) shows "after earthquake image". Fig.3(c) shows the road edges in the digital map.

W have applied two stage transformation method to these data. We have first applied the affine transformation, and then we have applied the perspective transformation. Fig.4 (a) shows the registration result by applying the affine transformation, and Fig.4 (b) shows the registration result by applying the perspective transformation. The black lines indicate the road edges in the aerial image. The white lines indicate the road edges computed by the perspective transformation. As is shown in Fig.4 (a) , the white lines do not match with the black lines by the affine transformation. As is shown in Fig.4 (b) , the white lines match with the black lines by applying the perspective transformation. The correctness of the automatic registration is the same as the manual registration. Fig.5 shows the results of the registration between the digital map and each earthquake image. Fig.6 shows the result of the detected damaged areas by computing the color differences. In this figure, damaged areas, non-damaged areas, and undetermined areas are shown in black, white, and gray, respectively. We applied the proposed method to five scenes of the images. In each image, more than 80% of the extracted areas are correctly the areas where the buildings are collapsed.

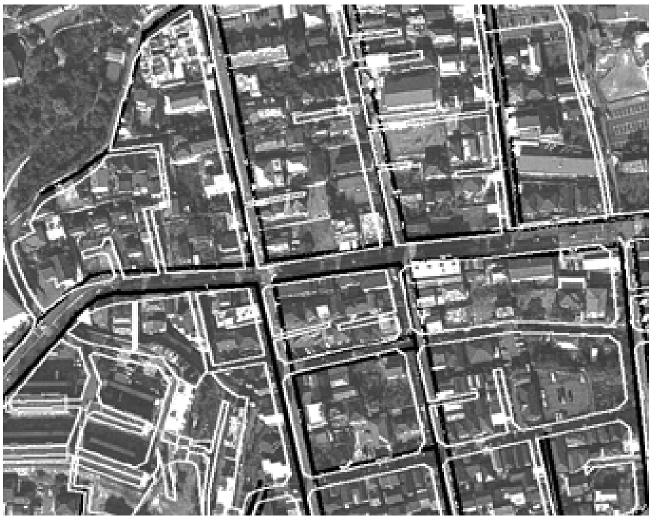
(a) before earthquake image

(b) after earthquake image



(c) road edge data in the digital map

Fig. 3. Experimental data

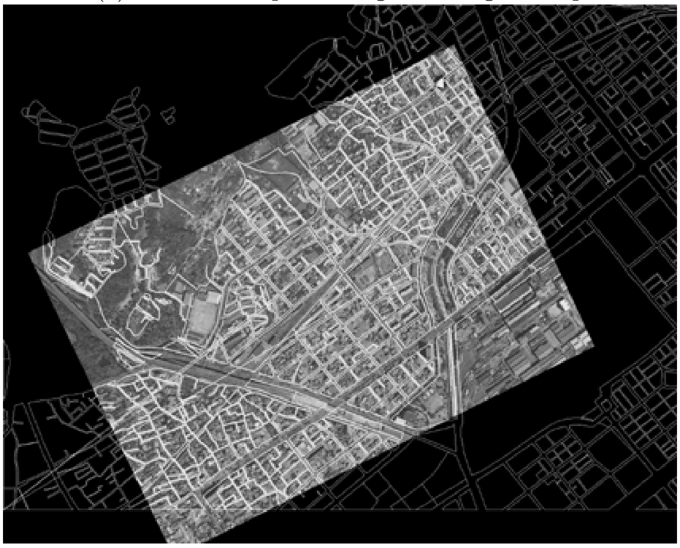


(a) registration result by the affine transformation

(b) registration result by the perspective transformation

Fig. 4. Registration by two methods

(a) before earthquake image with digital map



(b) after earthquake image with digital map

Fig. 5. Registration by the perspective transformation

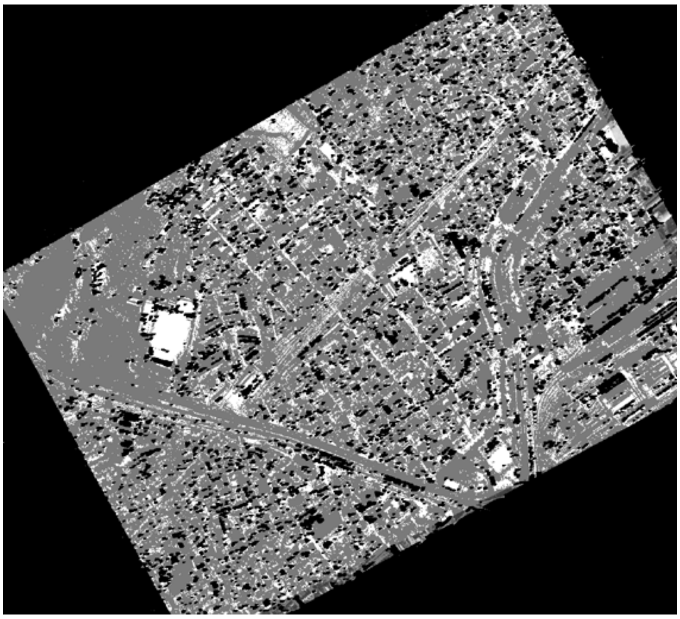


Fig. 6. Detected damaged areas

6 Conclusions

We proposed a method of automatic detection from the aerial images. We registered between before and after earthquake images automatically using digital map information and perspective transformation method. From the experimental results, we can detect the earthquake damaged areas. In the detection results, most of the undetermined areas are the shadow regions and cannot be classified only by using the color values. The analysis of the shadow regions (undetermined areas) is a future work. For analyzing those areas, we may have to use not only the pixel color values but also the boundary shapes of the buildings and roads. Other future works are to reduce the computation time of automatic registration by using the hierarchical matching method [10, 11].

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