MVA2002 IAPR Workshop on Machine Vision Applications, Dec. 11 - 13, 2002, Nara- ken New Public Hall, Nara, Japan

13—11

Quantitative Evaluation of Damaged Areas of a Big Earthquake Detected by Image Processing and GIS Information

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Abstract

In this report we compare the damaged areas by an earthquake detected by using image processing from aerial photographs with the actual damage data, to evaluate the performance of image processing algorithm used. For comparison we utilized a GIS (Geographic Information System), which can manage and analyze spatial information systematically. The algorithm to be evaluated is the one using edge information to identify the damaged areas by an earthquake, proposed by the authors. As a result, a significant portion of burnt areas can be detected by the algorithm, thresholding the detected connected regions by their sizes. A possibility of detecting areas of totally damaged houses is also discussed.

1 Introduction

When a wide-area natural disaster such as a big earthquake occurred, the range and seriousness of its damage should be quickly grasped in order to make a plan for life/property supporting activities. With human works only, it is difficult to estimate the damage in a global view. For this reason we investigated usability of image processing techniques applied to aerial photographs[1] – [3]. However, whether this technique is really helpful for the purpose depends on crucially the correctness of the result of image processing. We evaluated quantitatively the result of our method by comparing it with the real damage data.

This work is a part of the design of information system for rescue and restoration after a big disaster.

2 Procedure of evaluation

We use ten aerial photographs taken three days after the Hanshin-Awaji Earthquake to cover about 2km square of Nagata ward of Kobe city, Japan[4] . We digitized these ten photographs in about 0.4m (in real scale) resolution. As a platform for comparing the damage areas detected by image processing with the real damage data[5], we utilize a GIS (Geometric Information System), ArcView GIS 8.1.

We follow the steps below.

Step 1 Damaged areas are detected from the aerial photographs by image processing to be described in 3.

Step 2 As shown in Figure 1, the aerial image and the detected damaged areas image are mapped onto the digital map[6] in the GIS.

Step 3 Then each damaged area detected is converted from a set of pixels to a polygon.

Step 4 We compare detection areas with the real damage data mapped on GIS, and evaluate the performance of image processing algorithm. The real burnt areas and the real totally damaged building areas are shown in Figure 2 and Figure 3, respectively. These data show the damage as areas, not as individual buildings.

Figure1 Mapping aerial photographs onto the digital map

Figure 2 Real burnt areas

Figure 3 Real collapsed areas

3 The algorithm to be evaluated

The algorithm to be evaluated here is the one developed by the authors to determine the damaged areas by a big earthquake from the aerial photographs taken immediately after the earthquake. Ideally, aerial images should be prepared before the disaster (i.e., in an ordinary situation), which can be compared with the aerial images taken after the disaster. However, sometimes such before-disaster images can not be supplied immediately. For this reason we consider here the case that only aerial photographs after the earthquake are available.

The algorithm uses edge directions and edge densities in local areas. Figure 4 shows an input aerial image (the original is colored; only its lightness component is shown) and three edge direction maps for a damaged area, railroads, and non-collapsed buildings. In the damaged area of collapsed buildings, the edges have short lengths and random directions. On the other hand, in the non-damaged area of railroad tracks or buildings, the edges point to mostly one direction or the direction perpendicular to it. From this fact, damage detection in consideration of the direction and density of edges is performed.

For this purpose, first we apply Sobel edge detector to the lightness image of a color aerial photograph and obtain edge intensities and edge directions. We extract edge points by thresholding obtained edge intensities. Then, for the extracted edge points, we apply two, slightly different, filtering processes and compare their results in order to determine the damaged areas.

First we calculate the histogram of the directions of the edges in a window of 30×30 pixel size centered at each pixel from the detected edge points. For the size of the window is roughly the same as that of a common house in the aerial photographs, this filter can take account of surrounding damage condition. Figure 5 shows typical examples of histograms of the edge directions for a damaged area region and a non-damaged area region.

As stated we apply two filtering process: in the first filtering, we detect areas with 600 edge pixels or more and all frequencies in the edge direction histogram are lower than another given threshold (60, in the experiment). In the second filtering, the threshold for the number of edge pixels is lowered a little. i.e., we detect areas with 550 edge pixels or more while the threshold for frequencies is kept at 60. Naturally the areas detected by the second filtering (with lower threshold) include the areas obtained by the first filtering (with higher threshold). The results of these two types of filtering are candidates of the damaged areas by the earthquake. We detect from them the burnt areas by fire and the areas of collapsed buildings (hereafter we call them collapsed areas).

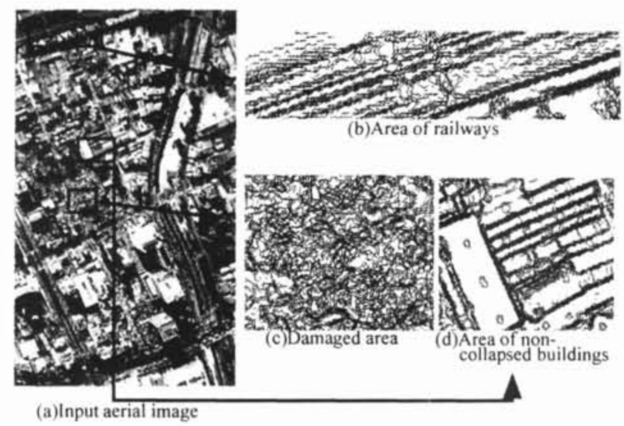

Figure4 Edge directions shown by needles

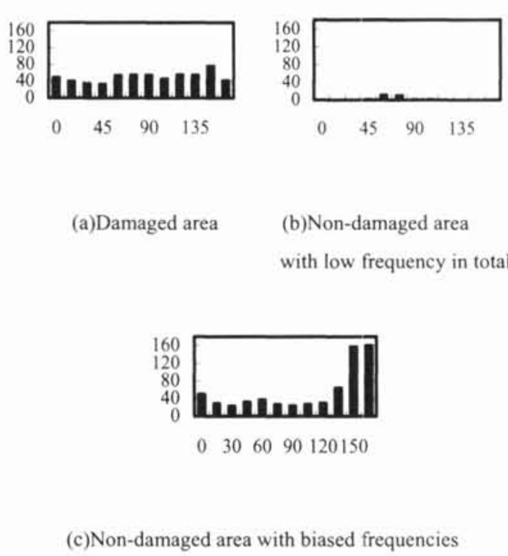

Figure 5 Typical histograms of edge directions

4 Detection of the damaged areas

4.1 Method of detecting burnt areas

For fires spread out to neighboring buildings, each burnt area tends to be large. Our method uses this feature to discriminate the burnt areas from the collapsed areas. Burnt areas are extracted as the connected components of size

3000 m² or more from the result of higher threshold filtering. The rest of its result is left for candidates of the collapsed areas.

4.2 Method of detecting collapsed areas

As shown in Figure 3, a lot of totally-collapse damage exist in one and the same part of the city. This is because weak houses against earthquake were built in the part around the same period, and the ground is also alike in one region. We detect collapsed areas based on this fact.

As shown in Figure 6, an area detected by the lower threshold filtering spread out surrounding the area(s) detected by the higher threshold filtering. If this expansion is large, the area is likely to be a collapsed area from the argument above. Otherwise, it might be a false detected area as damaged. Therefore, we determine that if the area added by the lower threshold filtering is equal to or more than 300 m², the whole area detected by the lower threshold filtering is a collapsed area.

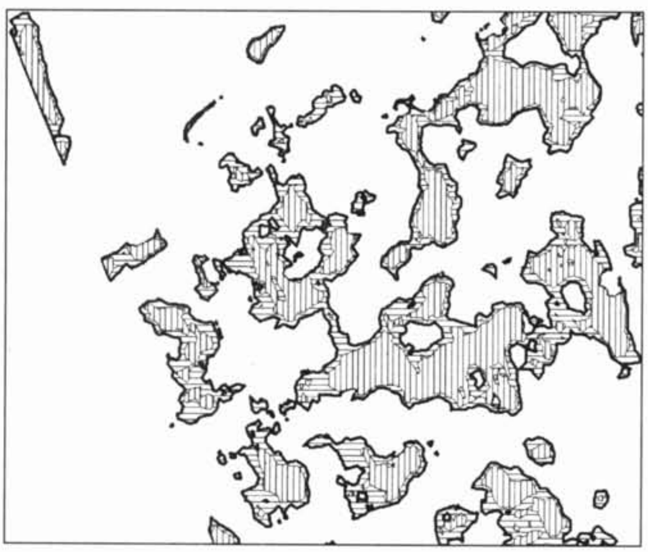

Figure 6 Detected areas by two filtering processes

Detected areas using the higher threshold filtering

Detected areas added by the lower threshold filtering

5 Result of evaluation

5.1 Evaluation of burnt areas detection

We compared the burnt areas detected by image processing (Figure 7) with actual burnt areas (Figure 2). As the result, 59.5% of actual burnt areas are detectable with image processing (hereafter all rates are area ratios) and 86.9% of detected damage areas are correct. Practically, comparison of Figure 2 and Figure 7 says that actual burnt areas can be detected almost correctly by image processing method proposed here.

In the aerial photographs used here, burnt damage was separable by using the threshold for the size of the detected area, because there are only burnt areas of big size actually in the region under experiment. However, small-scale fire damage may occur in other regions. In such a case, we may use the feature that the detected burnt areas do not expand so much by the lower threshold filtering after detected by the higher threshold filtering.

Figure 7 Detected burnt areas

5.2 Evaluation of collapsed areas detection

We compared the collapsed areas detected by image processing (Figure 8) with actual collapsed areas (Figure 3). The result is that 35.9 % of actual collapsed areas were detected correctly, though only 7.6% of actual collapsed areas were detectable.

As shown in Table1, compared with our former detection method without two-stage filtering [1]-[3] the correct rate increased 11.3%, at the cost of decrease of the detection rate from 13.0% to 7.6%. This is because non-reliable damage areas detected are removed by the criterion using two-stage filtering described in 4.2. Figure 9 illustrates this effect. It shows a part of the detected area after the area-of-expansion thresholding is applied. All overdetected damaged areas (horizontal hatching) are removed correctly and only few falsely detected areas (diagonal hatching) are seen.

Of course in other parts of the image, some actual collapsed areas are erroneously removed by the thresholding after the second filtering, though they are correctly detected in the first filtering. This results in the drop of detection rate. It is necessary to examine this problem further, considering the trade-off in the damage detection from a larger point of view.

The reason why the detection rate of the collapsed area is so low is as follows. In the actual damage data houses which were too heavily damaged to live without whole reconstruction are classified into "collapsed". Most of them can not be seen so damaged from the aerial view, unless their roofs are badly destroyed. Thus all we can do is supposed to be detecting such totally damaged buildings visible from the air and guess the possible damage in their surroundings.

A closer investigation of the overdetected areas reveals that they include many parking lots and areas with parking cars. This is because the density of edges becomes high in those parts. However, the places where cars are stranded immediately after an earthquake should be detected in many cases. We may obtain such useful information by combining those areas and the streets in GIS.

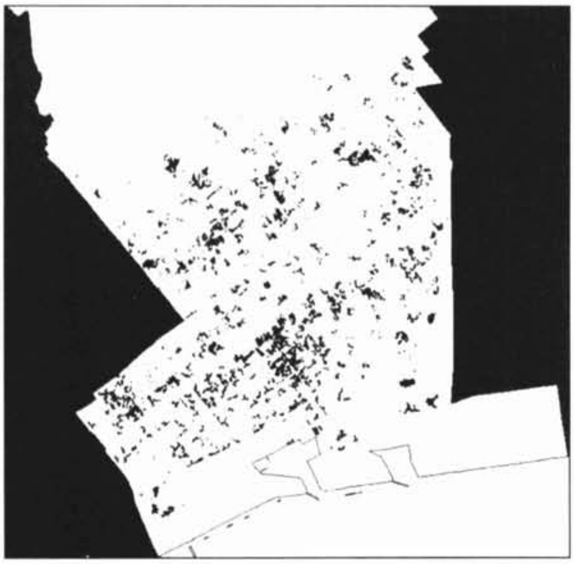

Figure 8 Detected collapsed areas

Figure 9 Part of the detection result of the collapsed areas by two filtering

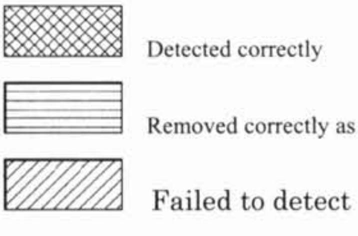

Table 1 Comparison of the evaluation results

		detection rate	correctness rate
burnt areas	former method	52.6 %	77.7 %
	new method	59.5 %	86.9 %
collapsed areas	former method	13.0 %	24.6 %
	new method	7.6 %	35.9 %

6 Conclusion and future works

Evaluation of the detected areas as damaged from aerial photographs taken after a big earthquake is performed. The result shows that burnt areas by fire can be practically detected. A possibility of detecting areas of totally damaged buildings which can be visually judged from an aerial photograph is also shown.

The detection method of collapsed areas should be improved in the further study. Integration of damage information and rescue/restoration support information acquired by various means based on GIS is another challenging goal in this research.

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