Automated Detection of Damaged Buildings using Aerial HDTV Images

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ABSTRACT

In order to seek the possibility of automated detection of damaged buildings from aerial television, the characteristics of high-definition television (HDTV) images taken after the 1995 Kobe earthquake were investigated. The relationships between the degree of building damage and the color indices and edge intensity from the aerial images were examined by image processing techniques. The characteristics of building damage were defined on the basis of hue, saturation, brightness and edge intensity. Using the threshold values of these parameters, the typical areas were classified into damaged and undamaged pixels. A texture analysis was further conducted to these pixels and damaged buildings were identified. The extracted damage distribution by the proposed method agreed well with ground truth data and visual inspection of the HDTV images.

INTRODUCTION

Several methods for gathering information on damage due to natural disasters are available, such as field surveys, aerial television imagery, aerial photography and satellite imagery. Aerial television images, by means of which each and every building in a large area can be easily and quickly monitored, may provide effective information at an early stage of emergency response. The authors have already reported a preliminary study on the possibility of visual identification of earthquake damage using aerial high-definition television (HDTV) images [1]. However, the visual inspection requires a long time to cover a large area. Hence, an automated detection method is requisite.

In this paper, the characteristics of severely damaged wooden buildings were examined using image processing of aerial HDTV images taken after the 1995 Kobe earthquake. The identification of damaged areas was performed using the satellite optical/SAR images taken before and after the earthquake [2, 3]. But, for aerial images, it is impractical to prepare pre-earthquake images. Hence, we only use aerial HDTV images taken after the event. The pixels corresponding to damaged and undamaged buildings are identified using hue, saturation, brightness and edge intensity of the images, and they are aggregated by a texture analysis. The extracted damage distribution by the proposed method is compared with ground truth data.

AERIAL HDTV IMAGES AND THE STUDIED AREA

Aerial shootings from helicopters for the area affected by the Kobe earthquake started shortly after the event by the Japan Broadcasting Corporation (NHK). These images were taken at a 30-45 degree angle from the vertical direction, from a height of about 300m by NHK's HDTV cameras. In this study, we used some of these images taken 10 days after the event. The HDTV images were converted to RGB image data prior to use. One of the images used in this study is shown in Fig. 1. The spatial resolution of this image is approximately 9cm and 17cm for near and far distances from the camera, respectively. The area covered in this study includes several blocks (about 200m x 230m = 46000m^2) in Nishinomiya City [4]. In this area, many wooden buildings suffered severe damage due to the earthquake.

The damaged buildings in the studied area had already been extracted visually [1]. In the visual extraction, the building damage level was classified into three categories: collapsed, damaged and undamaged. The outlines of undamaged buildings were clearly observed in the images while for collapsed buildings, the images were seen to be vague due to the mixture of building debris, e.g. the roofing tiles, soil under the roofing tiles, exterior walls. Hence, in this study, the image characteristics of the area representing collapsed buildings were examined using color indices and edge elements.

Fig. 1 Aerial HDTV image used in this study

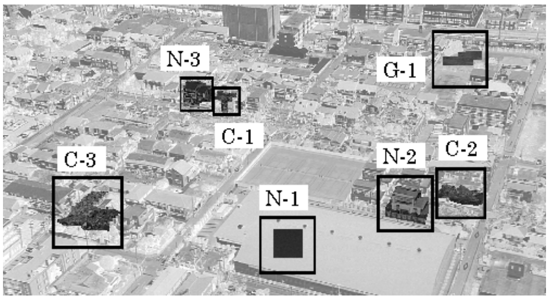

Fig. 2 Selected damaged and undamaged buildings

QUANTIFICATION OF IMAGE CHARACTERISTICS OF DAMAGED BUILDINGS

Typical areas representing collapsed buildings (C-1, 2, 3), undamaged buildings (N-1, 2, 3) and bare ground (G-1) were selected from the aerial image as shown in Fig. 2. The number of pixels for each object extracted from the image was different because they were selected based on the area of each building. The roofs of some of the damaged buildings had already been covered with blue vinyl canvas sheets as the images were taken 10 days after the earthquake. This characteristic (blue vinyl canvas sheets) of damaged buildings was not used in this study.

Edge elements for these typical areas were detected. The intensities of edge elements were calculated by a general gradient filter with a 3 x 3 pixel window and were allocated to one byte value. The relationship between the edge intensity value and the cumulative percentage of relative frequency is shown in Fig. 3. Observing the data for undamaged building (N-1) and ground (G-1), it is found that their edge intensity values are almost all distributed in the range of 0-32. For collapsed buildings (C-1, 2, 3), it is found that the intensity values are almost all (95%) distributed in the range of 0-90.

The variance of the edge intensity was calculated from the images of the selected areas because the edges of middle

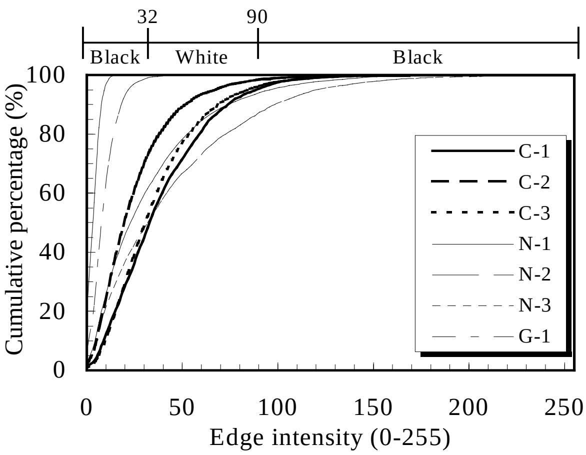

Fig. 3 Relationship between edge intensity value and cumulative percentage of relative frequency

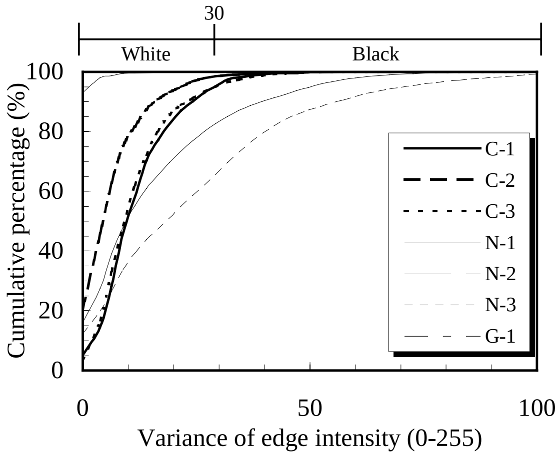

Fig. 4 Relationship between variance of edge intensity and cumulative percentage of relative frequency

intensity (32-90) existed in not only collapsed buildings but also in undamaged buildings. The variances in the edge intensity were evaluated for the area of 7 x 7 pixels and were allocated to one byte value. The relationship between the variance of the edge intensity and the cumulative percentage of the relative frequency is shown in Fig. 4. For the collapsed buildings, it is found that the variance values are almost all (95%) distributed in the range of 0-30.

Color indices such as hue, saturation and intensity (HSI) were also calculated using the RGB values for the selected areas. The relative frequencies of hue for the collapsed buildings are distributed in the range of 92.0-148.0 degrees (this color range is from red to yellow) as shown in Fig. 5. These values are justified by the fact that the soil under roofing was exposed. It is also found that brightness (intensity) lies in the range of 0-175.0 and saturation lies in the range of 0-90.0 for the collapsed buildings.

The pixels satisfying all these conditions on edge intensity and color indices are shown in Fig. 6. The figure indicates that the distribution of the identified pixels is almost coincidental with the areas of collapsed buildings.

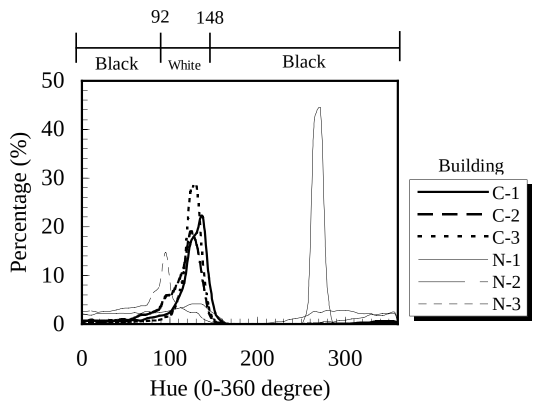

Fig. 5 Distribution of relative frequency of hue (averaged using 7 x 7 pixel window) for the selected building areas

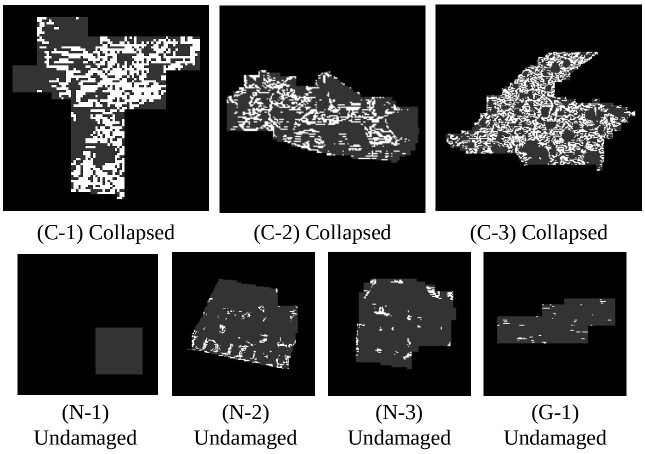

Fig. 6 Pixels satisfying edge intensity and color indices' threshold values for the selected areas

DETERMINATION OF DAMAGED BUILDINGS BY TEXTURE ANALYSIS

The selected pixels corresponding to the building debris were further synthesized to identify collapsed buildings. A texture analysis was introduced to calculate a local density of selected pixels. A 63 x 63 pixel window to a 31 x 31 pixel window are selected to be proportional to the image scale, depending on the location of the area in the image. In this example, the averaged areas with the selected pixel ratios equal or larger than 14% are almost equal to the collapsed building areas. Hence, this criterion is used for all the area in Fig. 1. Figure 7 shows the result of the texture analysis using this criterion. Compared with ground truth data [5, 6] and visual inspection results [1] shown in Fig. 8, the collapsed buildings are properly identified.

It should be noted, however, the procedure and threshold values proposed here may be affected by the local conditions of buildings and the patterns of damage. A further investigation is necessary to generalize the automated damage detection method.

CONCLUSION

Image characteristics of damaged buildings were investigated using aerial HDTV images taken after the 1995 Kobe earthquake. The degree of building damage was correlated with color indices and edge intensity from the aerial images by image processing. The characteristics of damage to wooden buildings were defined based on hue, saturation, brightness and edge intensity. Using the threshold values of these parameters, the typical areas were classified into damaged and undamaged pixels. The texture analysis was then introduced to these pixels and the damaged buildings were identified. The extracted damage distribution by the proposed method agreed well with the ground truth data and the visual inspection of the images.

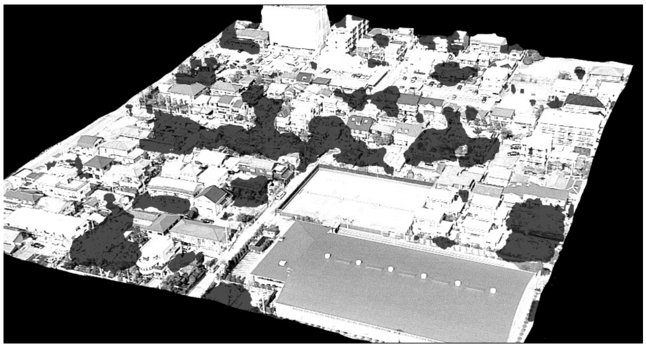

Fig. 7 Damaged buildings extracted by texture analysis

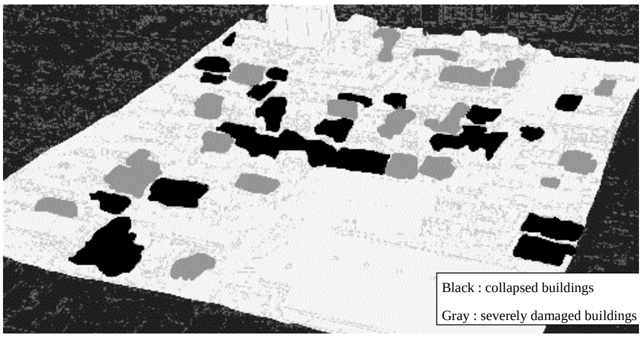

Fig. 8 Damaged/collapsed buildings by ground survey and visual inspection of HDTV images

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