4. Damage Detection from the Air and Space

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. Satellite remote sensing, which can monitor a large area, may provide effective information on determining damage distribution for recovery activities and restoration planning. We have already reported spectral characteristics of the damaged area by comparing satellite optical images with the detailed damage survey results on the 1995 Hyogoken-Nanbu (Kobe) earthquake, and have attempted to identify the damage distribution from the satellite optical images (Matsuoka and Yamazaki, 1998). This chapter aims to identify large-scale slope failures which occurred in the mountainous areas in central Taiwan during the Chi-Chi earthquake, to evaluate the possibility of damage detection based on pre- and post-event satellite images.

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 (Hasegawa et al., 2000a) and proposed an automated detection method for heavily damaged buildings based on the images after the Kobe earthquake (Hasegawa et al., 2000b), considering the use for early damage identification after major natural disasters. In this chapter, a brief summary on the procedure of the automated detection method from the Kobe earthquake is given. Then the proposed automated detection method for building damage is applied to the aerial HDTV images taken after the 1999 Chi-Chi, Taiwan earthquake.

4.1 Extraction of the Areas of Slope Failure using SPOT Images

4.1.1 SPOT/HRV Images and Processing

Large-scale slope failures occurred in the forest covered mountainous districts such as Gwu-Guan, Jio-Fun-Ell-Shan and Hoyen-Shan as shown in Figures 4.1.1 (The Japanese Geotechnical Society, 2000). The slope failures changed the vegetation areas into bare grounds. Although the application of the normalized vegetation index (*NDVI*), using a multi-spectral image to evaluate a vegetation area, is a general approach, we examined the possibility of panchromatic images, which contain higher ground resolution than multi-spectral images, as a tool to detect surface changes. The data used in this investigation were SPOT/HRV panchromatic images taken on June 24th, 1999 as a pre-event image, and on September 27th, 1999 (6 days after the event) as a post-event image. The ground resolution of these images is approximately 10m and the wavelength captured by this sensor is in a visible light range. Figures 4.1.2 shows the pre-event image and post-event one, respectively.

Because the digitized values in the satellite images were different depending on the observation situation and the surface conditions, the digital number (*DN*) correction was required before starting this investigation. First of all, clouds and cloud shadows covering the area were removed by using proper threshold values. For the *DN* correction, we cut the area of interest and calculated the histogram of the *DN* in each image. Then all the *DN*s in two images were corrected so that the value of the average and standard deviation become 128 and 51, respectively. In the image matching process, the ground control points (GCP) were selected based on the Sequential Similarity Detection Algorithm (SSDA). The pre- and post-event images were subjected to the affine geometric correction and were registered. The nearest-neighbor method was used for re-sampling the *DN* in the pixels. In the registered and corrected images, the forest areas and bare soil show approximately 110 and 160 to 250 in panchromatic *DN* values, respectively.

(a) Gwu-Guan

(b) Jio-Fun-Ell-Shan

(c) Hoyen-Shan

Figure 4.1.1. Slope failures in mountainous areas (The Japanese Geotechnical Society, 2000).

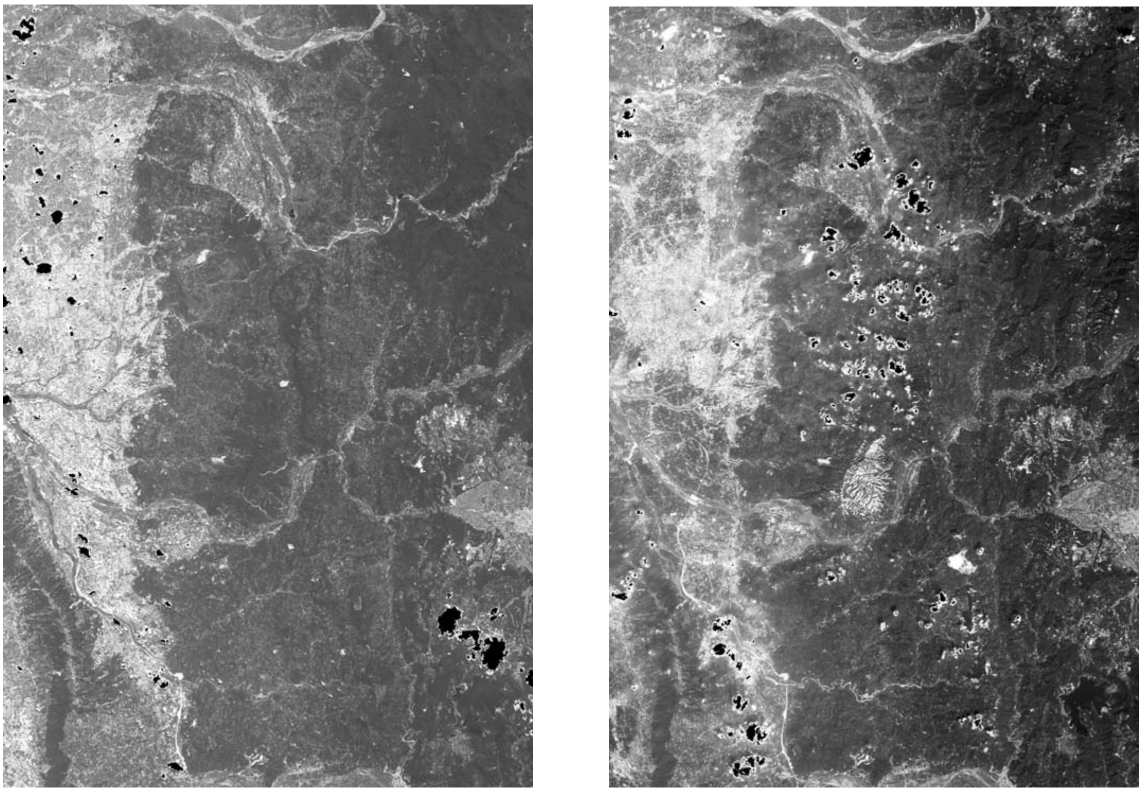
4.1.2 Characteristics of Satellite Images in the Damaged Areas

We overlaid the two images and calculated the values of the normalized difference (*ND*). The *ND* is expressed as follows:

$$ND = \frac{DN_a - DN_b}{DN_a + DN_b} \qquad (4.1.1)$$

in which DN_a and DN_b indicate the digital number of pixels after and before the earthquake, respectively. As the DN_a in the post-event image increases, the *ND* value increases.

Figure 4.1.3 shows the image of the *ND* value overlaid on the pre-event panchromatic image for the area of interest.



(a) Image taken on 06/24/99 (b) Image taken on 09/27/99

Figure 4.1.2. SPOT/HRV panchromatic images of the strongly affected area by the Chi-Chi earthquake; Black areas indicate masking by clouds (Refer to color figure 4).

The color from blue to red was allocated to the pixels that have the *ND* from small to big. Black colored areas indicate the areas of cloud. In this figure, yellow to red colored areas distributed in the mountainous region are relatively in good agreement with the large-scale slope failures shown in Figure 4.1.4 by JGS (2000). Generally, the *DN* in the visible range for vegetation areas is smaller in comparison with that for bare grounds. It is conceivable that the *DN* was raised in the areas of the slope failures due to the exposure of soil surface after the earthquake. The areas with color from yellow to red can be seen around the clouds because the removal of the cloud areas was insufficient. However, other areas, dotted in the mountainous region, could be several small slope failures occurred due to the earthquake. We need to confirm the validity of this result by a detailed field survey in the further.

4.1.3 Summary

We examined the reflectance characteristics of the slope failure areas due to the earthquake, using SPOT/HRV panchromatic images taken before and after the Chi-Chi earthquake. In the post-event image, the digital numbers corresponding to the slope failure areas were high in comparison with other mountainous areas, because the vegetations were striped out and the bare soils appeared after the strong ground shaking. We calculated the normalized *DN* difference between the pre- and post-event images in order to emphasize the *DN* change and created a pseudo color image to extract the areas of slope failure. The extracted damage distribution agreed well with the large-scale slope failures, identified by the damage survey of Japanese Geotechnical Society. Although several small areas were also identified from this estimation, it is necessary to confirm whether the areas correspond to slope failures/landslides or not based on more detailed damage survey data.

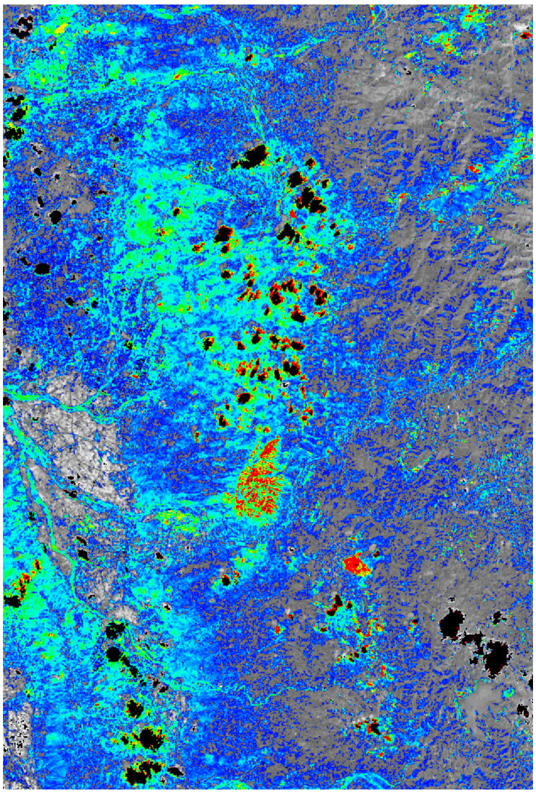


Figure 4.1.3. Pseudo color image of *ND* values overlaid on the pre-event panchromatic image. Red color may correspond to slope failures and landslides (Refer to color figure 5).

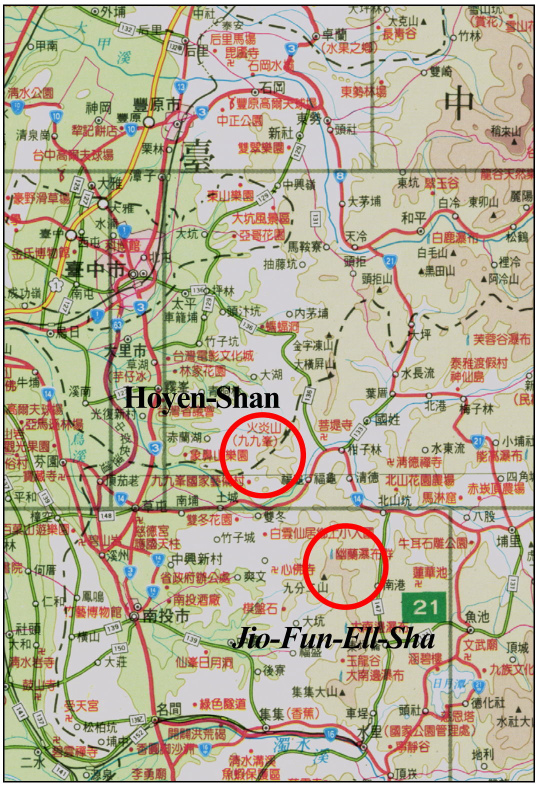


Figure 4.1.4. Location of huge-scale slope failures (The Japanese Geotechnical Society, 2000).