Determination of the Areas with Building Damage due to the 1995 Kobe Earthquake using Airborne MSS Images

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***Abstract*-In multi-stage remote sensing performed by NASDA just after the 1995 Hyogoken-Nanbu (Kobe) earthquake, stricken areas were observed by the airborne MSS, which has twelve bands between visible and thermal infrared. In this study, after some training areas were selected in Nada Ward using a GIS data based on field damage survey, spectral characteristics of damaged and non-damaged buildings were investigated. Then, the distribution corresponding to the damage level of buildings in the hard-hit area of Kobe City was estimated by the maximum likelihood classifier. The estimated result of areas with burned and severely damaged buildings was relatively in good agreement with the field survey data. An application of this method, based solely on the post-event image, to early damage assessment systems can be expected.**

I. INTRODUCTION

In the 1995 Kobe earthquake occurred on January 17th, 1995, over 5,000 people were killed as a direct result. Mostly after the event, seismic monitoring and early damage assessment systems combined with seismometers and GIS-based inventory data were developed in Japan [1]. However, if estimation is carried out inaccurately by the systems, it is possible to cause indirect losses due to several misjudgments in a disaster recovery process. Airborne remotely sensed images can be taken more quickly, with higher spatial resolution than that of satellites. Therefore, it can be expected to apply the airborne remote sensing for detecting damage information due to natural disasters for the response and recovery activities at an early stage, without depending on information sent from within a stricken area.

Multi-stage remote sensing was performed by NASDA just after the Kobe earthquake [2]. It was pointed out that multi-spectral characteristics taken by airborne MSS were different between images of ordinary sites and those of liquefied and burned areas [3]. However, the multi-spectral characteristics for the areas with building damage were not enough investigated because the objectives of the project was a reconnaissance survey. In this study, we examined the multi-spectral characteristics of the areas with building damage, and attempted the detection of areas with severely damaged buildings, utilizing not only high spatial resolution characteristics but also multi-spectral feature of the airborne images.

TABLE I
SPECIFICATION OF THE AIRBORNE MSS IMAGE

band	wavelength (μm)	band	wavelength (μm)
b02	0.41 - 0.46	b09	0.69 - 0.72
b04	0.49 - 0.53	b11	0.76 - 0.80
b05	0.53 - 0.57	b12	0.82 - 0.90
b06	0.57 - 0.60	b15	1.52 - 1.72
b07	0.60 - 0.65	b16	2.06 - 2.45
b08	0.65 - 0.70	b17	8.00 - 12.00
acquisition date	Jan. 24, 1995 (10:13-11:00am)		
IFOV	2.5 mrad		
altitude	2,500 m		
observation width	4,000 m		

II. AIRBORNE MSS IMAGERY

Table 1 shows specification on the airborne MSS imagery. Twelve images from visible to thermal infrared bands with IFOV of 2.5mrad were taken by the project one week after the Kobe earthquake. Figure 1 shows the location of the observed (light gray) and the studied (dark gray) area in this study. The area within the red polygon indicates that seismic intensity in the JMA scale is VII. The image data were acquisitioned from the altitude of about 2,500m. The spatial resolution on the ground surface was about 8m, after some influences occurred by topography and posture of the airborne were corrected.

III. EXTRACTION OF URBAN AREAS

The correction of the atmospheric effect [4] is necessary for an accurate identification. In this study, a simple method for the atmospheric correction was attempted. A target area with 1024 lines x 512 columns was selected from the sea, in order to remove the heterogeneous influence due to this effect. Then, the average of *CCT* in the area was approximated by a polynomial expression for every bands, except for a thermal infrared band (b17) because the average of *CCT* did not change for this band.

Using the thermal infrared band (b17), the surface temperature of objects in the image can be obtained [2]. As a result, the area with $CCT \leq 40$ was defined as cloud-covered,

Fig. 1. Observed (light) and studied (dark) areas in this study. Hatched area and red polygon indicate Nada Ward and seismic intensity VII in the JMA scale, respectively.

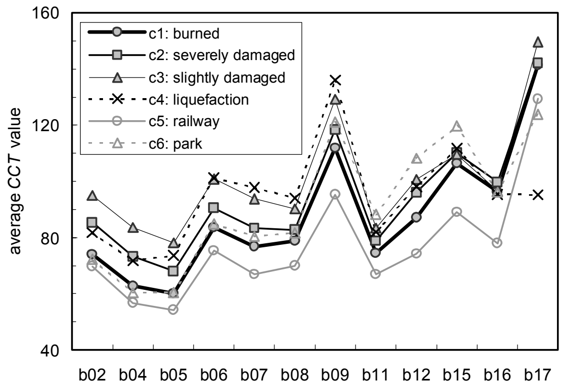

Fig. 2. Multi-spectral characteristics for the training data

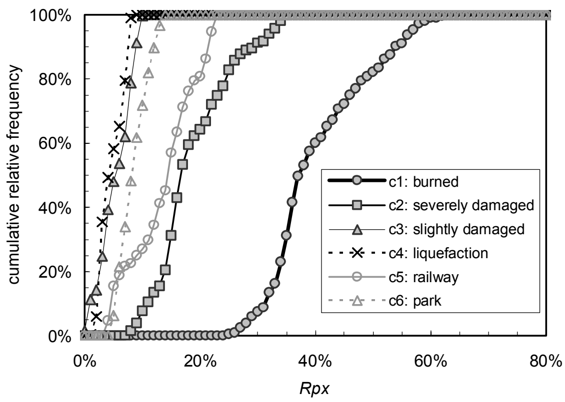

Fig. 3. Result of the texture analysis for the training data

because the temperature was about zero (Cels.) when *CCT*=40 in b17. The pixels defined as "clouds" were excluded from the area for the atmospheric correction as mentioned above.

In order to remove the areas of the sea and vegetation from the image, their spectral characteristics were examined together with those of building areas after the atmospheric correction. "Sea" was determined by $CCT \leq 60$ in b09, which is a visible red band. "Vegetation" area was decided as $0.26 \leq NDVI$ calculated by both b12 of near infrared and b08 of visible red band.

IV. Detection of Areas with Building Damage

A. Selection of Training Data

Training data of each 400 pixels in the three categories for low-rise buildings such as "burned (c1)", "heavy damaged (c2)" and "slightly damaged (c3)" were selected from Nada Ward, where is located in the east part of Kobe City (hatched area in Fig.1), using the GIS data constructed by a field damage survey [5]. Most of building areas selected as "c3" were covered with blue vinyl canvas sheets. It was very difficult to select a training area of non-damaged low-rise buildings, because the area was relatively rare in Nada Ward, and the area was mixed with blue vinyl canvas sheets and a little vegetation. Adding further "liquefaction (c4)", "railway (c5)" and "park (c6)" categories, the average of the training areas for the six categories was calculated as shown in Figure 2. According to the comparison of the spectral profiles for "c1", "c2" and "c3", the differences in the average value among their training areas were almost remained in the visible bands (b02-b09). The average was slightly smaller, as the damage level of buildings increases, because of the blue vinyl canvas sheets which covered the building damage of "c3". On the other hand, the area of liquefaction (c4) has small average values in visible blue (b02, b04), green (b05) and thermal infrared (b17) bands, and has relatively large average values in visible red bands (b07-b09). The average values for "railway (c5)" were lower than those for building damage "c1" and "c2" in all the bands. As a little vegetation was included in "park (c6)", the average value for "c6" was increased in the near infrared bands (b11, b12). Between near and middle infrared bands (b11-b16), "c2", "c3" and "c4" have similar spectral profiles one another.

B. Detection of Building Damage Area

The maximum likelihood classifier was used for the six training areas selected from Nada Ward. Every training area was classified as it is with the accuracy of 60-90%. In order to detect the distribution of heavy damage on buildings such as "c1", the pixels extracted as "c1" were further synthesized to decrease surplus pixels and make areas with heavy damage on buildings easy to identify. The texture analysis was introduced to calculate the local density of extracted pixels (*Rpx*). *Rpx* was defined as the ratio of the pixels extracted by the classification result of "c1" versus the number of pixels in a window approximating one district size. The window of 21x21 pixels was selected for the texture analysis. Figure 3 shows the cumulative relative frequency of the training data.

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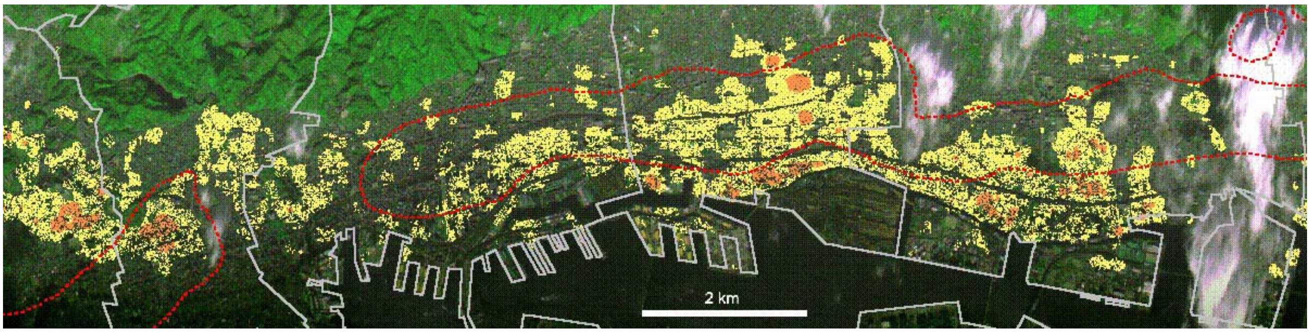

Fig. 4. Estimated result of the areas with heavy building damage

Fig. 5. Result of the field survey on building damage

When 10%≤*Rpx*, "c1" and "c2" have the extracted pixels of more than 90% by the analysis. The areas with 25%≤*Rpx* were guessed as the heavy damage with mainly burned and severely damaged buildings, because the pixels of 99.5% in "c1" and 17.3% in "c2" were extracted. No pixel was extracted from the other training areas. The area with heavily damaged buildings was detected as the pixels simultaneously satisfying both the area identified by the texture analysis of "c1" and the area classified into "c1", "c2" and "c3" by the maximum likelihood classifier. The distributions of 25%≤*Rpx* (orange) and 10%≤*Rpx* (yellow) by this study are shown in Figure 4. In Figure 5 showing the result of the field survey [5], orange and yellow colors represent the areas with burned or severely damaged buildings, which have more than 30% in one district. The area of 10%≤*Rpx* seems to correspond to the area with the severely damaged buildings, particularly in Nada Ward. By 25%≤*Rpx*, the burned areas could be roughly detected not only in Nada Ward but also in Hyogo Ward. From this result, it can be expected that the distribution of hard-hit areas on buildings is estimated, based solely on the post-event multi-spectral airborne images.

V. Conclusions

Using the airborne MSS images taken one week after the Kobe earthquake, the spectral characteristics of areas with building damage due to the earthquake were investigated. A simple correction of the atmospheric effect was performed by the multi-spectral images except for a thermal infrared band. For extracting an urbanized area, influences of clouds, sea and vegetation were removed from the acquisitioned images. In the range of visible to near infrared bands, the average of *CCT* for the training data on building damage was slightly decreased as the damage level got higher. The heavy building damage area was detected by the maximum likelihood classification and the texture analysis. By this approach, the areas with burned and severely damaged buildings were identified in the hard-hit area of Kobe City.

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