ESTIMATION OF BUILDING DAMAGE RATIO DUE TO EARTHQUAKES AND TSUNAMIS USING SATELLITE SAR IMAGERY

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1. INTRODUCTION

For quick and stable estimation of damaged areas due to earthquakes and tsunamis all over the world using satellite SAR, this paper presents the damage detection model which is based on likelihood functions for severe building damage ratio on the basis of dataset from JERS-1/SAR images observed the 1995 Kobe earthquake and its detailed ground truth data. The model is then applied to JERS-1/SAR images taken over the areas affected by large tsunami due to the 1993 Hokkaido Nansei-oki, Japan earthquake. The accuracy of the proposed damage estimation model is examined by comparing the results of the analyses with interpretation from the aerial photo taken after the event.

2. LIKELIHOOD FUNCTION FROM JERS-1/SAR

The JERS-1 satellite launched by Japan in 1992 was operational until 1998, and made observations of the region affected by the 1995 Kobe earthquake. This satellite was boarded with a radar sensor (SAR). We used SAR images for before and after the earthquake (before: May 17, 1994; after: May 4, 1995) and the data for building damage [1], used as the ground truth data. Following Nojima et al. [2], the regression discriminant function for building damage was calculated from two characteristic values, the correlation coefficient and the difference in backscattering coefficient of pre- and post-event SAR images. First, following accurate positioning of the two SAR images, a speckle noise filter with a 21×21 pixel window [3] was applied to each image. The difference value, d, was calculated by subtracting the average value of the backscattering coefficient within a 13×13 pixel window of the pre-event image from the post-event image, and the correlation coefficient, r, was also calculated from the same 13×13 pixel window [4][5].

Then, these indices were overlapped with the data for building damage, and 2,000 pixels were randomly extracted from areas corresponding to each of the seven damage severity rankings (total of 14,000 pixels) to create a training sample. Fig. 1 shows a scatter diagram of d and r for each damage severity ranking. A regression discriminant function, a method of multiple-group discrimination, using d and r of the seven damage severity rankings, for a quantitative evaluation of the severe damage ratio, is shown in equation 1.

$$z_{Rj} = -1.277\ d - 2.729\ r \tag{1}$$

Here, Z_{Rj} represents the discriminant score derived from JER-1. After an examination of the frequency distribution of Z_{Rj} for 2000 pixels for each damage severity ranking, we generated a modeled likelihood function for estimating the severe damage ratio, the curves for the average values and the average values ± standard deviation of the severe damage ratio estimated from Z_{Rj} is shown in Fig. 2.

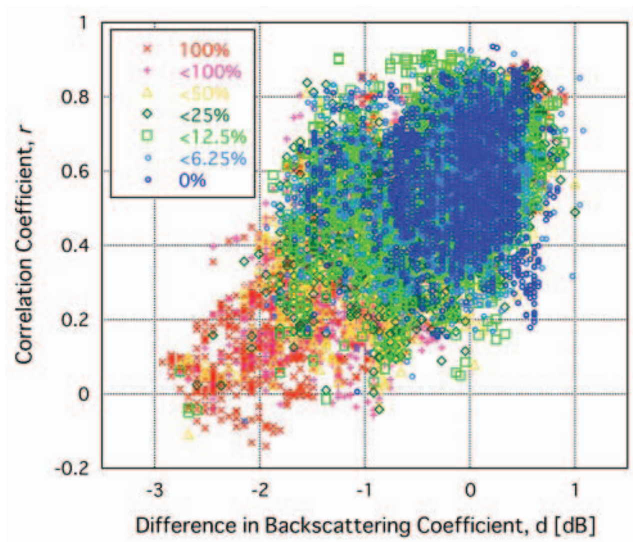

Fig. 1. Scatter diagram of difference in backscattering coefficients and correlation coefficients for each damage severity ranking.

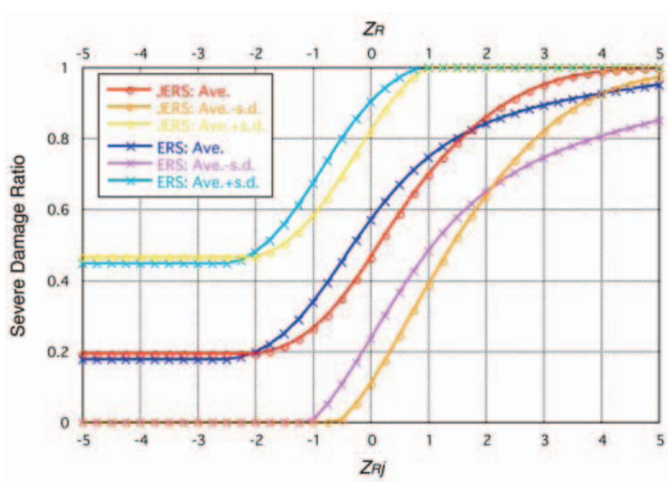

Fig. 2. Relationship between the discriminant scores Z_{Rj} (this study) and Z_R [2], and severe damage ratio (average values and standard deviations).

3. APPLICATION TO THE HOKKAIDO NANSEI-OKI EARTHQUAKE TSUNAMI

On July 12, 1993, the Hokkaido Nansei-oki, Japan earthquake occurred. The hypocenter of this Mw=7.7 earthquake was located northern offshore of Okushiri Island. Many houses and port facilities built along the coastline of Okushiri Island were washed away by repeated tsunamis, and fires broke out in Aonae district burned approximately 200 houses. The number of completely destroyed houses was 1,157 [6]. Following this earthquake, JERS-1 observed the damaged area on August 21, 1993. As a pre-earthquake image, we selected an image taken on July 8, 1993. We applied the proposed damage detection model to this event. Fig. 3 shows the estimated severe damage ratio (average values) obtained through the discriminant scores Z_{Rj} of the JERS-1 images. When compared to the post-tsunami aerial photo in Aonae, there is good agreement between the coastal areas with high concentration of severely damaged buildings and areas with high damage ratio estimated from the JERS-1 images.

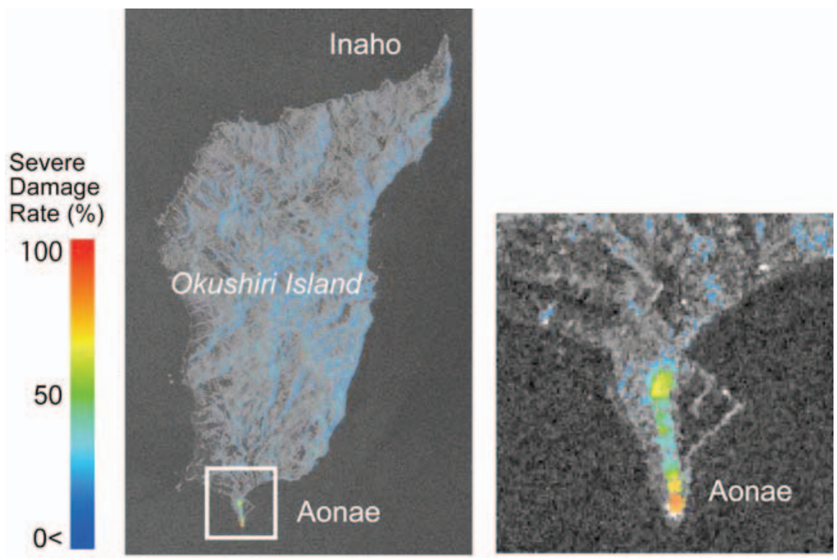

Fig. 3. Distribution of severe damage ratios (average values) estimated from JERS-1 images of Okushiri Island and Aonae district.

4. CONCLUSION

We proposed a modeled likelihood function for severe building damage ratio from discriminant scores obtained via regression discriminant analysis, using the difference values and correlation coefficients from pre- and post-event JERS-1/SAR images of the areas affected by the 1995 Kobe earthquake, as well as damage severity rankings obtained from building damage data of the quake, as explaining variables. Furthermore, we applied the proposed model to JERS-1/SAR images of the 1993 Hokkaido Nansei-oki earthquake tsunami, and examined the accuracy of the proposed model through comparisons with interpretations of post-tsunami aerial photo.

5. REFERENCES

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