EARTHQUAKE RISK EVALUATION USING LANDFORMS PROCESSED BY UNSUPERVISED CLASSIFICATION METHOD

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1. INTRODUCTION

A strong earthquake can cause tremendous destruction in an urban area such as structure collapse and conflagration. When the disaster is too serious, rescue and medical activity cannot be carried out by individual countries acting alone. Accordingly, cross-border cooperation on countermeasures against disasters is very important. Many relief teams were dispatched to large disaster sites from many countries in the world, for example after the 2004 Indian ocean tsunami and the 2007 Sichuan earthquake. It is necessary to resolve the following issues so that the above mentioned operations are carried out effectively.

1. The relief operation plan and its logistics must be drawn up based on disaster risk evaluation beforehand. Therefore, it is required that the risk evaluation simulation of earthquakes is workable for the entire world.
2. Actual damage information of a struck area is absolutely necessary for rapid countermeasures against the disaster. This information is very useful for decision-making to determine where rescue teams are dispatched.
3. It is necessary to build a communication system for information sharing between the headquarters and disaster site.

The risk evaluation requires the use of databases containing the distribution of and information pertaining to ground conditions, population densities, and structures etc. Each database consists of two dimensional mesh data managed by the Geographical Information System (GIS). Data associated with the ground conditions include the amplification factor of seismic intensity and, perhaps more importantly, information required to calculate ground motions. However, detailed investigation of the ground conditions requires a large investment of time and money and complete coverage is not yet available for the world. Even if detailed data for an area exist, it is not always available to the public.

In this paper, we present an earthquake risk evaluation using landforms classified by unsupervised method and a Digital Elevation Model (DEM) observed by SAR in order to get ground condition without surface study. The classified landforms are adopted for the amplification factor in order to calculate the peak ground velocity (V_{max}) of the ground motion. We demonstrate the performance of the proposed method by mean of evaluation of earthquake intensity of the 2008 Iwate-Miyagi earthquake in Japan.

2. PROPOSED METHOD

At the beginning of operation of countermeasure against disaster, headquarters of disaster relief teams need information of the struck area to determine where rescue teams must be dispatched for an effective rescue operation. Therefore the earthquake data observed by seismometers and analysis of the hypocenter determination are extremely important. At first, we explain earthquake damage estimation method based on information of the epicenter and earthquake engineering models.

2.1. Estimation of Seismic intensity using an earthquake engineering mode

Earthquake intensity can be evaluated by means of magnitude and by a distance attenuation equation as shown in Figure 1. Seismic intensity is calculated by the following equations describing decay by distance from epicenter.

$$\log V_h = p - \log(X+q) - 0.002X \qquad (1)$$
$$p = 0.52M_W - 0.918$$
$$q = 0.0164 \cdot 10^{0.382Mw}$$

$$V_{max} = V_h \cdot R \qquad (2)$$

V_h is velocity of ground motion in the rock bed, V_{max} is peak velocity on the surface, and R is amplification factor due to soft ground surface. The amplification factor (R) for each landform is very important information needed to calculate ground motion of the ground surface. Matsuoka et al. proposed the method that the R is calculated for typical landform types - hill, plateau, fan, reclaimed land, etc. of the Digital National Land Information (DNLI) in Japan [1].

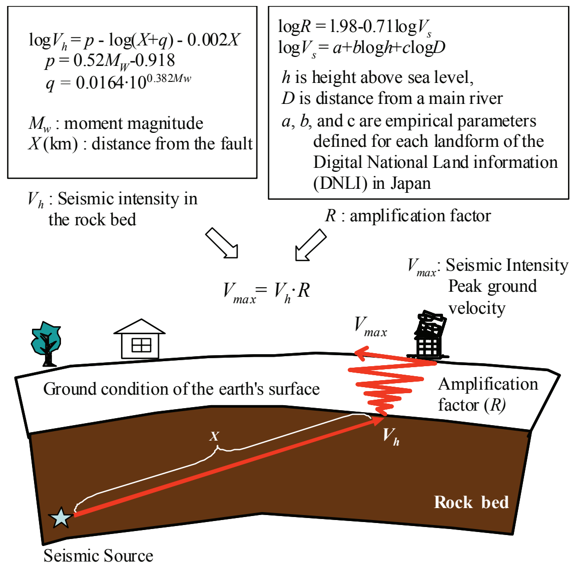

Figure 1 Method to calculate seismic intensity on ground surface.

However, the detailed landform information such as the DNLI is not is available for everywhere in the world. The landform classification method is required so that risk evaluation simulation of earthquakes is workable for the entire world.

2.2. Landform classification method

Next we explain a landform classification method using a high resolution DEM made from satellite observations to obtain the amplification factor (R) anywhere in the world. Figure 2 shows a block diagram of the proposed method which classified the landform classes using feature vector consisting of the following four kinds of elements.

1) Elevation and 2) standard variation of the elevation in 3x3 window.

3) Angle of slope

The angle of slope θ, is calculated based on information contained in the DEM using following equations,

$$M = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix} \qquad (3)$$

$$\tan\theta = \frac{\sqrt{(a+d+g-c-f-i)^2 + (a+b+c-g-h-i)^2}}{6D} \qquad (4)$$

Where a, b, c, d, e, f, g, h and i denote elevation, and M defines the relationship of each grid position. D denotes the grid size of the DEM.

4) Undulation feature

The change of angle, L, is computed using an image processing techniques called a Laplacian filter.

$$L = 4e - (b + d + f + h) \qquad (5)$$

The undulation feature is obtained by smoothing L using an image processing filter. The four elements of the feature vector are matched using a geometric correction method. As a result, the feature vector is produced as four images with a resolution of approximately 1km.

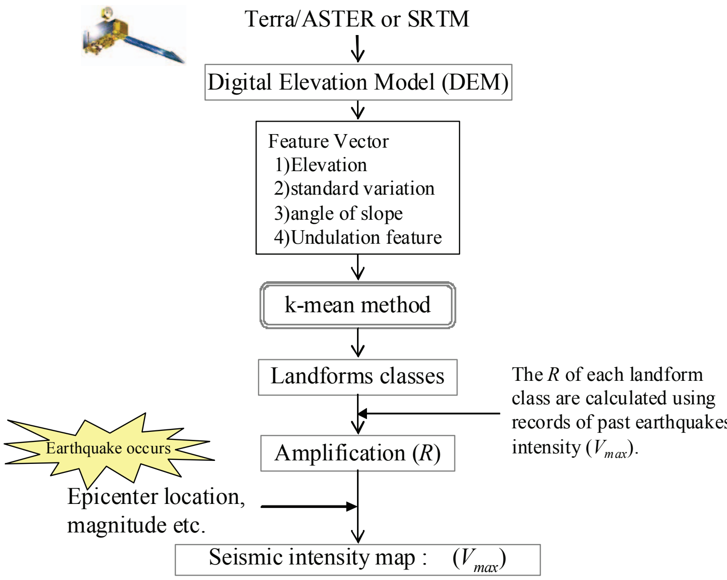

Figure 2 Data process flow

3. SIMULATION RESULTS

The experimental study area is a rectangular stretch of Tohoku section in Japan. This area was damaged by the 2008 Iwate-Miyagi Nairiku earthquake which occurred at 08:43 on Jun 14 (Japan local time, Jun 13, 23:48 (UT)). The hypocenter is located at N 39 deg, 1.7 min, E 140 deg. 52.8 min, Depth = 8 km, (Magnitude was estimated at 7.2) by JMA, Japan Meteorological Agency. Figure 3 (a) shows the DEM of the study area and (b) shows classified landform classes. Figure 4 (a) and (b) are estimated distribution of seismic intensity (V_h and V_{max}) in case of the 2008 Iwate-Miyagi Nairiku earthquake based on the R calculated for each landform classes using past earthquakes records. Figure 4 (c) shows the actual V_{max} distribution observed by seismometers.

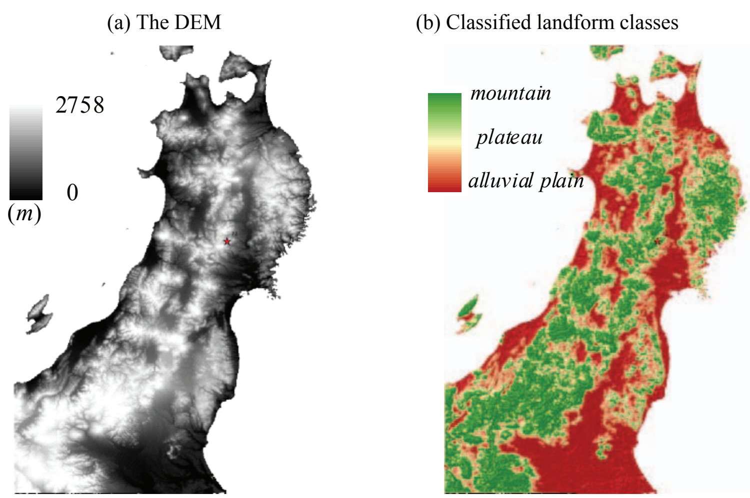

Figure 3 The DEM and a classified result of the study area.

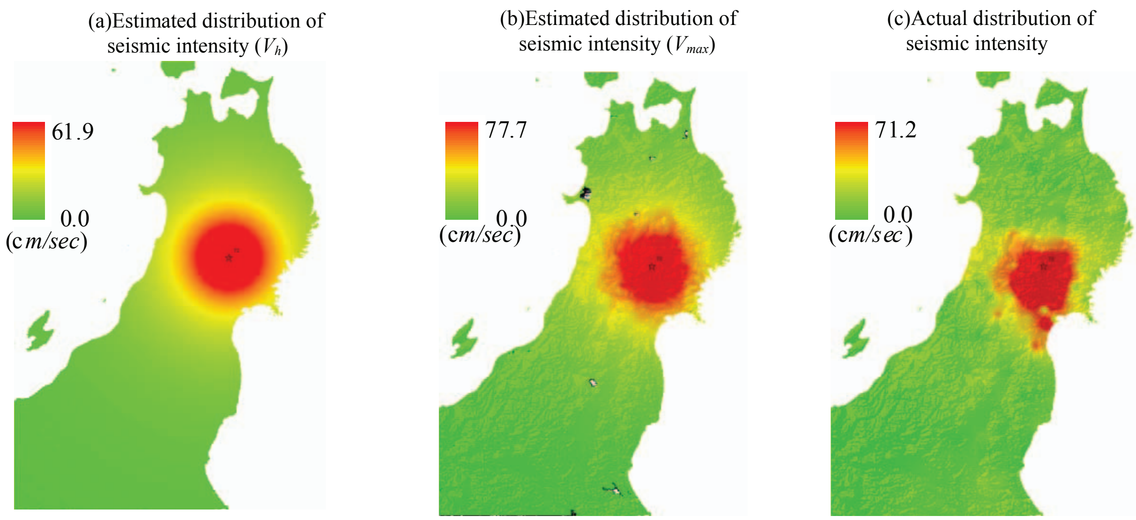

Figure 4 Simulation result of the study area.

4. CONCLUSIONS

In this paper, we present an earthquake risk evaluation method using landforms classified by unsupervised method and DEM. The classified landforms were applied to an earthquake intensity evaluation of the 2008 Iwate-Miyagi Nairiku earthquake in Japan. As a result, a V_{max} distribution was obtained which corresponds with the actual damage recorded after the event. We are planning to apply the method to other area in future study.

REFERENCES

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[2] Masafumi Hosokawa, Byeong-pyo Jeong, Osamu Takizawa and Masashi Matsuoka, "Disaster Risk Evaluation and Damage Detection Using Remote Sensing Data for Global Rescue Operations" , XXIth International Society for Photogrammetry and Remote Sensing (ISPRS) Congress 2008, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Vol.XXXVII, Part B8, Commission VIII pp.183-186, China (Beijing) , 2008