EARTHQUAKE RISK EVALUATION USING LANDFORMS PROCESSED BY UNSUPERVISED CLASSIFICATION METHOD

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ABSTRACT

We present an earthquake risk evaluation using landforms classified by unsupervised method and a Digital Elevation Model (DEM) 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.

Index Terms – Earthquake Damage Estimation, Digital Elevation Model, Decision Support, International Rescue Team

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) 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. INTERNATIONAL RESCUE TEAM OF JAPAN

The Japanese government dispatches the International Rescue Team of the Japanese Fire-Service (IRT-JF) to a disaster stricken country as a team specialized in rescue operations of the Japan Disaster Relief Team. The IRT-JF consists of 599 rescue specialists selected from 62 fire departments throughout the country.

They are specialists with abundant field experience, and have the ability to decide and act reliably under any circumstances. They are called up and dispatched within 24 hours to areas stricken by a large-scale disaster somewhere in the world. The IRT-JF has been dispatched 15 times since 1986. For example after the 2008 Sichuan earthquake, the IRT-JF consisting of 17 specialists carried out a rescue operation in China.

Figure 1. The IRT-JF operating in the disaster site damaged by the 2008 Sichuan earthquake in China.

3. PROPOSED METHOD

Just after the time when a tremendous earthquake occurs, headquarters of disaster relief teams need actual damage information of the struck area to determine where rescue teams must be dispatched for an effective rescue operation. However it is difficult to get the information from a seriously damaged region, since the telecommunication system may be damaged by the shock of an earthquake. Therefore we are trying to apply earthquake damage estimation method using earthquake information (magnitude, location of source, detailed ground conditions) and an earthquake engineering model.

3.1. Estimation of seismic intensity and damage using an earthquake engineering model

Earthquake intensity can be evaluated by means of magnitude and by a distance attenuation equation as shown in Figure 2. Seismic intensity is calculated by the following equations.

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

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

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. R is calculated for typical landform types - hill, plateau, fan, reclaimed land, etc. ([1] Matsuoka et. al, 1994).

The probability of destruction in Japan caused by an earthquake can be estimated using an empirical relationship between V_{max} and the number of collapsed wooden houses damaged by past earthquakes. We can calculate the estimated number of collapsed wooden houses for the stricken area from

$$D = N \cdot r \qquad (3)$$
$$SI = 1.18 \cdot V_{max}$$
$$r = 1.21 \cdot 10^{-4}(SI - 30)^{1.51}, \quad (SI > 30)$$
$$r = 0, \quad (SI \leq 30) \qquad \text{([2] Miyakoshi et. al, 1997).}$$

Where, r is the damage ratio of wooden houses, and N is the number of wooden houses in each mesh. The number of collapsed wooden houses (D) is calculated by multiplying N by r.

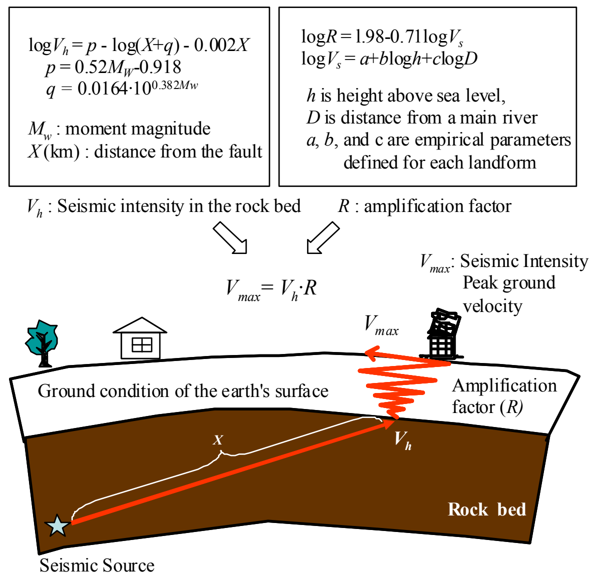
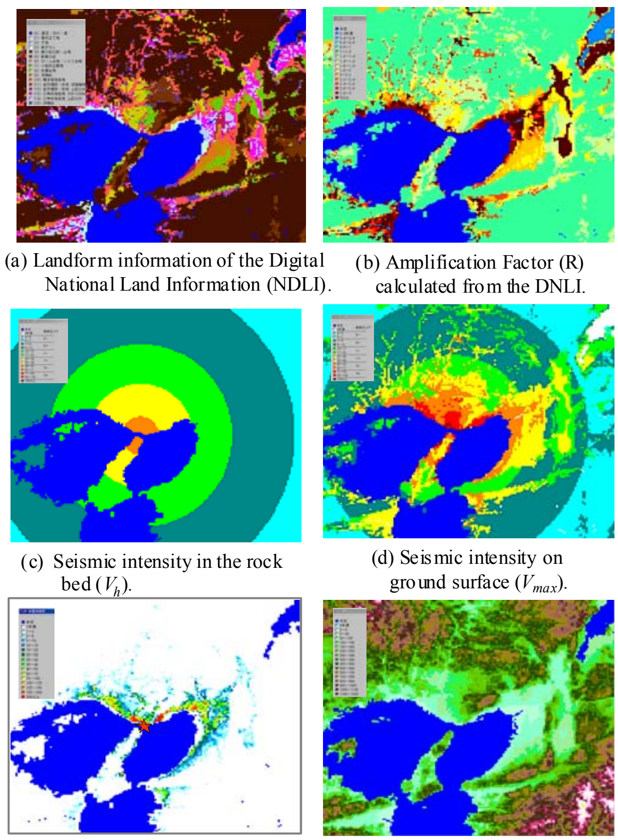


Figure 2. Method to calculate seismic intensity.

3.2. Example of earthquake damage estimation

The result of the earthquake risk evaluation is using in for determining disaster prevention planning and fire fighting tactics in Japan. By using the estimation relation described above, the Simplified Earthquake Damage Estimation System (SEDES) is utilized in the Fire and Disaster Management Agency of the Japanese government. This system provides useful information for urgent response activities of the headquarters offices which have responsibility for countermeasures against disasters. In order to evaluate earthquake intensity and damage, we need much data, such as landform, population, structures, etc., which are stored as two or three dimensional mesh data by means of a Geographical Information System (GIS).

Figure 3 shows the data and a simulation result in case of the 1995 Kobe earthquake in Japan. Figure 3 (c) and (d) show the Seismic intensity in rock bet (V_h) and on ground surface (V_{max}) respectively. The difference between two images indicate that the amplification factor (R) for each landform is very important information needed to calculate detailed ground motion of the ground surface. However, detailed investigation of ground conditions is costly, such work is not performed everywhere in the world. Even if detailed data for an area exists, it is not always open to the public. Therefore, based on the similarity between a the amplification factor (Figure 3(f)) and DEM (Figure 3(b)), we proposed a supervised landform classification method using a neural network and high resolution DEM to obtain typical landform types - hill, plateau, fan, reclaimed land, etc. anywhere in the world ([3] Hosokawa et. al, 2001).



(a) Landform information of the Digital National Land Information (NDLI).

(b) Amplification Factor (R) calculated from the DNLI.

(c) Seismic intensity in the rock bed (V_h).

(d) Seismic intensity on ground surface (V_{max}).

(e) Number of clasped wooden house.

(f) Digital elevation Model (DEM).

Figure 3. Data example and simulation results in case of the 1995 Kobe earthquake in Japan.

3.3 Landform classification method using unsupervised method

In this paper, 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 4 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,

$$M = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix} \tag{4}$$

$$\tan\theta = \frac{\sqrt{(a+d+g-c-f-i)^2 + (a+b+c-g-h-i)^2}}{6D} \tag{5}$$

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.

$$L=4e-(b+d+f+h) \tag{6}$$

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

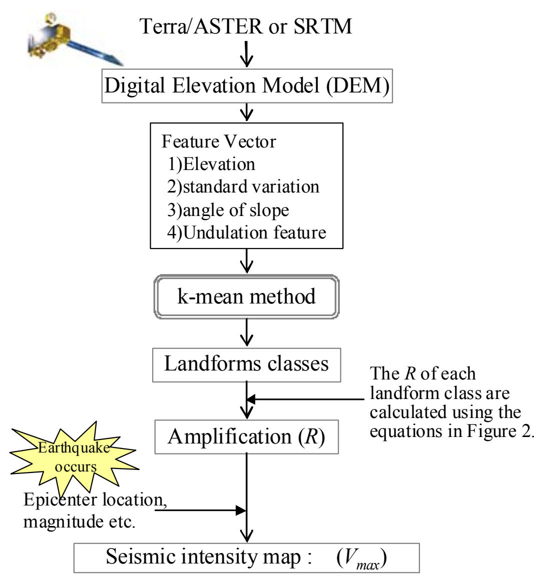
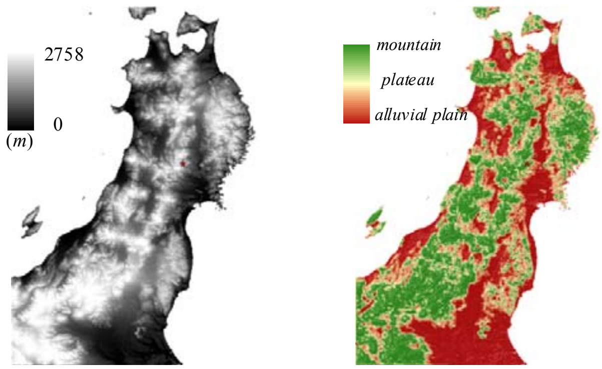


Figure 4. Data process flow

4. SIMULATION RESULTS

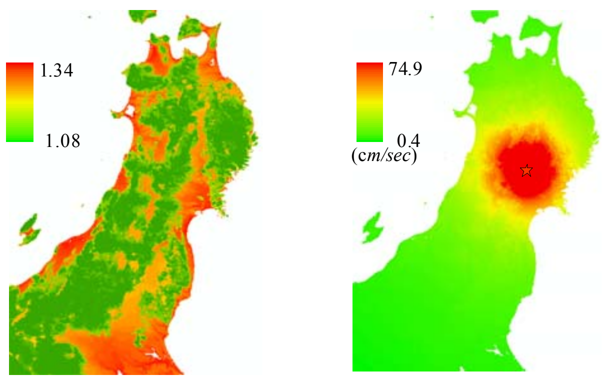
The experimental study area is a rectangular stretch of Tohoku section in Japan. This area was damaged by the 2008 Iwate-Miyagi Nairiku earthquake which occurred at 08:43 on Jun 14 (Japan local time, Jun 13, 23:48 (UT)). The hypocenter is located at N 39 deg, 1.7 min, E 140 deg. 52.8 min, Depth = 8 km, (Magnitude was estimated at 7.2) by JMA, Japan Meteorological Agency.



(a) The DEM

(b) Classified landform classes

Figure 5. The DEM and a classified result of the study area.



(a) Amplification factor (R) based on classified landform class

(b) Estimated distribution of seismic intensity (V_{max})

Figure 6. Simulation result of the study area.

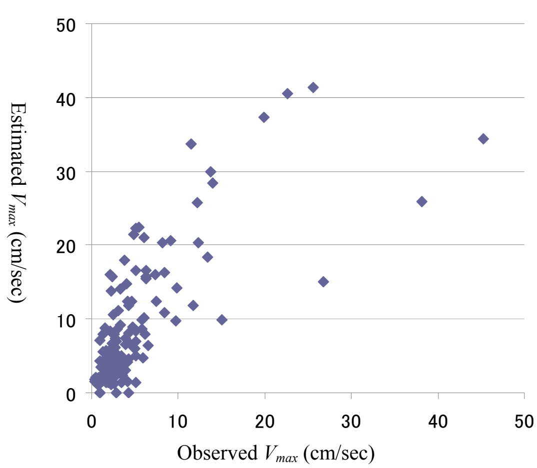


Figure 7. Comparison between estimated and observed seismic intensity.

Figure 5 (a) and (b) show the DEM and the classified landform of the study area respectively. Figure 6 (a) shows the amplification factor (R) calculated from the classified landform classes. Figure 6 (b) is estimated distribution of seismic intensity (V_{max}) in case of the 2008 Iwate-Miyagi Nairiku earthquake. Figure 7 shows comparison between the estimated and observed seismic intensity. The proposed method provide a result rerated with actual seismic intensity observe in the striked 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 is obtained which corresponds with the actual recorded after the event. In future study, we are planning to apply the method to other area in future study.

5. REFERENCES

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