Development of Earthquake Damage Estimation System and its Result Transmission by Engineering Test Satellite for Supporting Emergency Response

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Abstract

Drawing on its extensive experience with natural disasters, Japan has been dispatching Japan Disaster Relief (JDR) team to disaster-stricken countries to provide specialist assistance in rescue and medical operations. The JDR team has assisted in the wake of disasters including the 2004 Indian Ocean Earthquake and the 2008 Sichuan Earthquake in China. Information about the affected area is essential for a rapid disaster response. However, it can be difficult to gather information on damages in the immediate post-disaster period.

To help overcome this problem, we have built on an Earthquake Damage Estimation System. This system makes it possible to produce distributions of the earthquake's seismic intensity and structural damage based on pre-calculated data such as landform and site amplification factors for Peak Ground Velocity, which are estimated from a Digital Elevation Model, as well as population distribution.

The estimation result can be shared with the JDR team and with other international organizations through communications satellite or the Internet, enabling more effective rapid relief operations.

Keywords: *Earthquake Disaster, Digital Elevation Model, Landform Classification, Site Amplification Factor, Earthquake Damage Estimation System, Japan Disaster Relief Team, Engineering Test Satellite, Emergency Response*

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1. Introduction

In Japan, the inability of damage estimation led to the inappropriate disaster response in Hanshin Awaji Great Earthquake, 1995, and raised the “void of disaster information” issue. Since then, various efforts in systems reconfiguration, research and development fields such as in human resources, disaster planning reworking, and seismic sensor installations were made to solve this problem. The earthquake damage estimation technique has been used to pre-calculate the anticipated casualties for building disaster plans, and nowadays it is viable to use the system in real-time damage estimation thanks to the improved computing power, GIS software and geographic databases.

In the meantime, 2010 Haiti Earthquake killed 300,000, destroying 300,000 buildings. 2008 Sichuan Earthquake caused over 90,000 casualties, and the Indian Ocean Earthquake and Tsunami took more than 300,000 lives. For these developing countries, the international emergency disaster aid from the countries of advanced disaster prevention capabilities, such as Japan, is very important because such natural disasters could render infrastructures and resources inoperable, and thus preventing local rescue operations.

In this paper, the Simplified Earthquake Damage Estimation System is outlined, as well as the earthquake damage estimation technique using Digital Elevation Model(DEM) for assisting international rescue teams and using communications satellites to transmitting this estimation result to the rescue teams on or in transition to the site are introduced.

2. Simplified Earthquake Damage Estimation System and Global Earthquake Damage Estimation System

The Simplified Earthquake Damage Estimation System can compute and display the Peak Ground Velocity (hereafter referred to as PGV), buildings damage, number of deaths and fire breakouts instantly upon given only the magnitude(M) and epicenter information(latitude, longitude, and depth) of an earthquake.

To enable speedy post-earthquake damage estimations, it is equipped with topography and buildings/population distribution databases in 1km grid covering the whole Japan, and employs the damage estimation model that performs computations by using the national numerical data and the Attenuation Curve for PGV. Currently in Japan Fire and Disaster Management Agency, estimation results from the Simplified Earthquake Damage Estimation System are sent to the mobile devices of personnel to help in initial decision making.

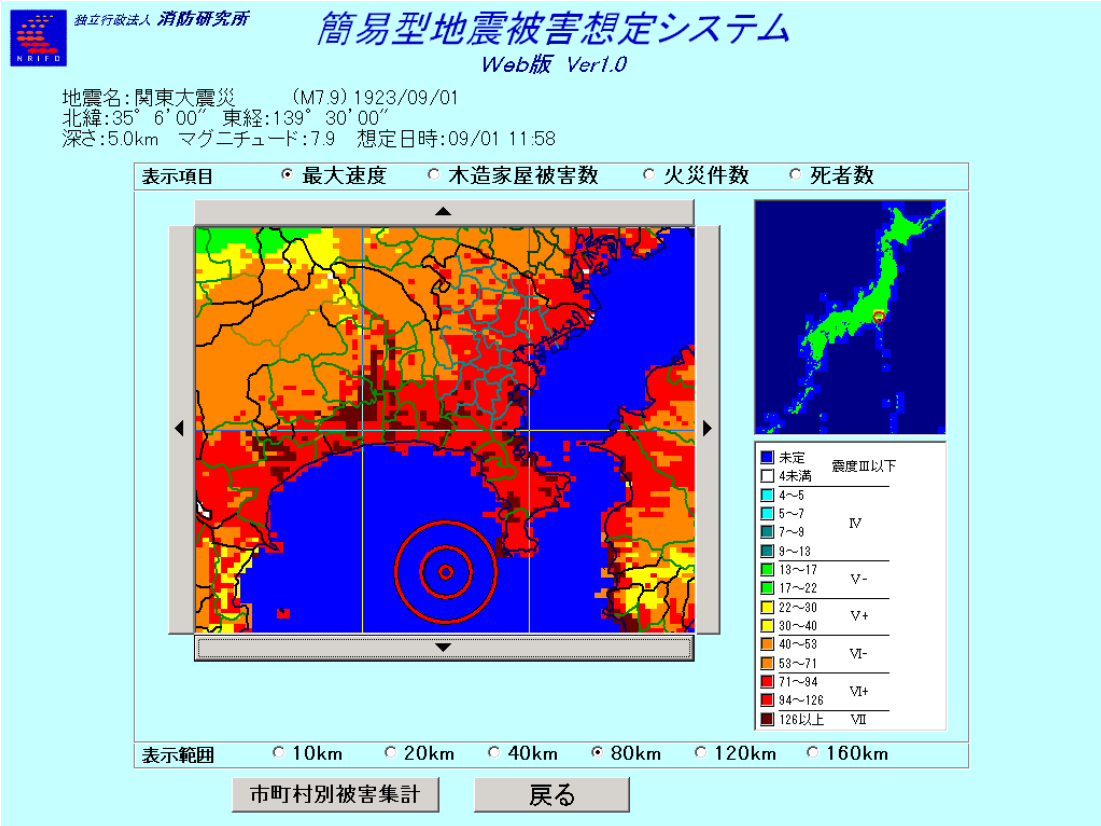

Fig.1 Simplified Earthquake Damage Estimation System

International rescue and aiding efforts have been made to support those countries with large scale natural disasters. In Japan, based on Japan Disaster Relief Team Law(the JDR Law) established in 1987 with intention to contribute to international cooperation, rescue teams assembled from fire fighters, police, and Japan Coast Guard have been practicing rescue operations in the disaster sites in 12 different countries over the world. They are also facing the similar, or even worse, difficulties of estimating overall damage distribution as it was seen in Japan, as well as the difficulties of making decisions for sending the teams and determining actual rescue sites.

From that stand point, the Global Earthquake Damage Estimation Systems, an extended version of the Simplified Earthquake Damage Estimation System, is being developed to enable a quick estimation of damage distribution estimation against earthquakes. Since the site amplification factors is not well established in many developing countries, the system uses numerical elevation data(DEM: Digital Elevation Model) as input and transforms it into the site amplification factors thus making it applicable world-wide. The system is introduced below with the analysis it performed on the 2010 Haiti Earthquake.

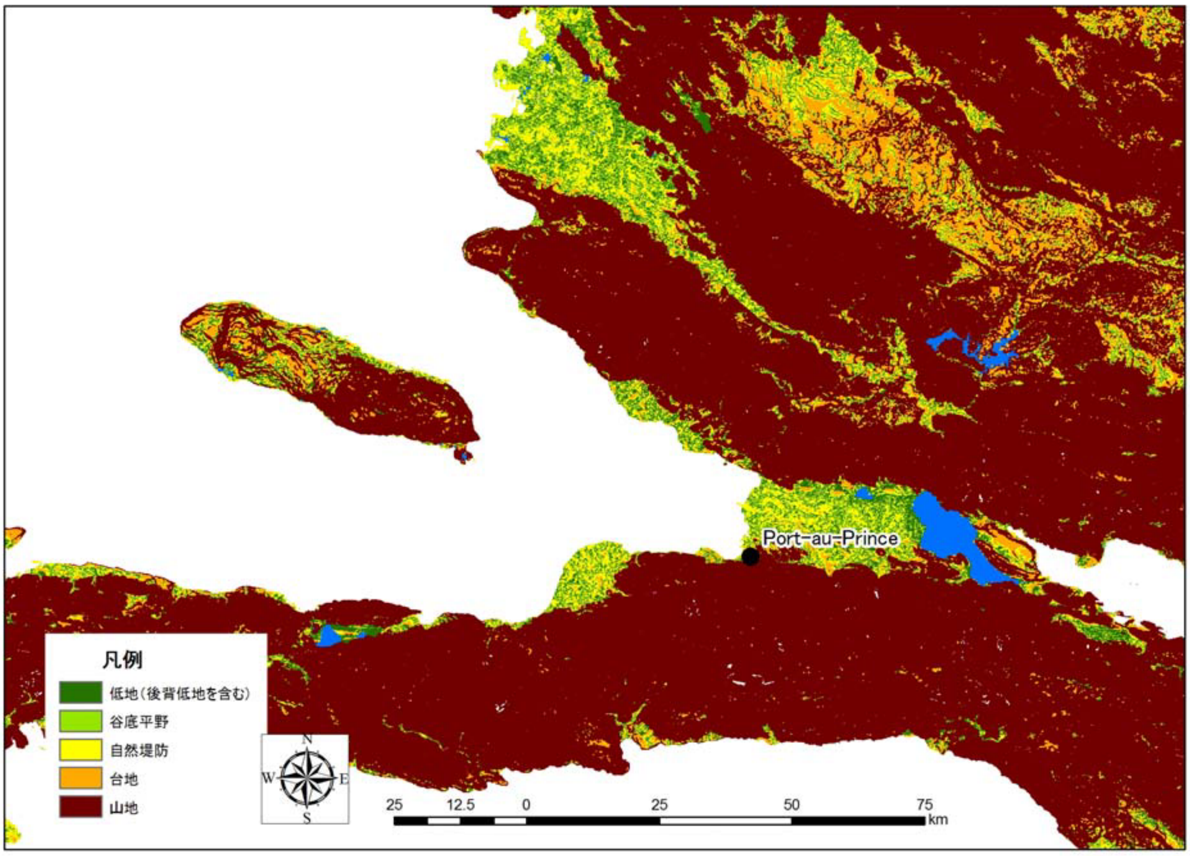

Fig.2 Landforms classification result of Haiti

The Haiti Earthquake on January 12th, 2010, a large-scale earthquake with magnitude 7.0, took more than 300,000 lives. By the DEM-using technique the authors propose, Haiti's landforms were classified by taking SRTM-3 as input DEM [1]. Without any site survey data, it was classified into 5 landforms: Mountain, Terrace, Natural Levee, Valley Bottom Lowland, and lowland including back marsh (Fig. 2). Haiti's landforms consist mostly of mountains, while lowlands are located to the north of Port-au-Prince, the capital of Haiti.

From the landforms classification result, the ground amplification were estimated using Midorikawa and Matsuoka's technique (1995)[2]. However, since there is no parameters for landform in Haiti, we used a modified parameters version after Midorikawa and Matsuoka. Si and Midorikawa (1995) developed attenuation relationship by regression analyses of recorded strong motion database, developed from 1968 to 1997[3]. we adopted USGS's epicenter information and attenuation relationship derived by Si and Midorikawa for estimation of PGV. Fig.3 shows estimated intensity distribution(JMA I).

Fig.4 shows the estimated buildings damage distribution for Haiti Earthquake. The LandScan2006, global population dataset published by the Ork Ridge National Laboratory, U.S.A., was processed to be used as buildings data for this computation. The unknown factors,

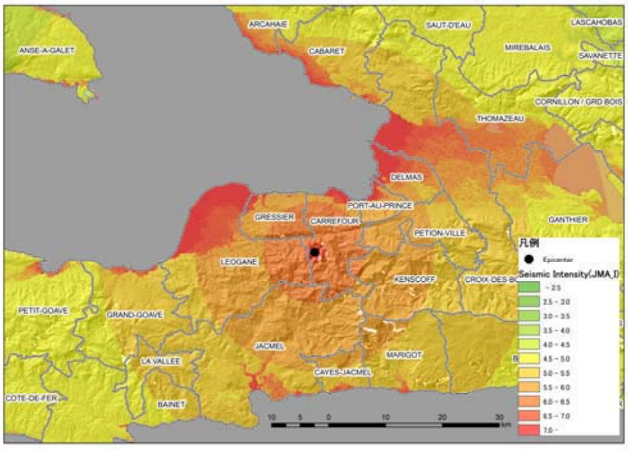

Fig.3 Estimated seismic intensity distribution in Haiti

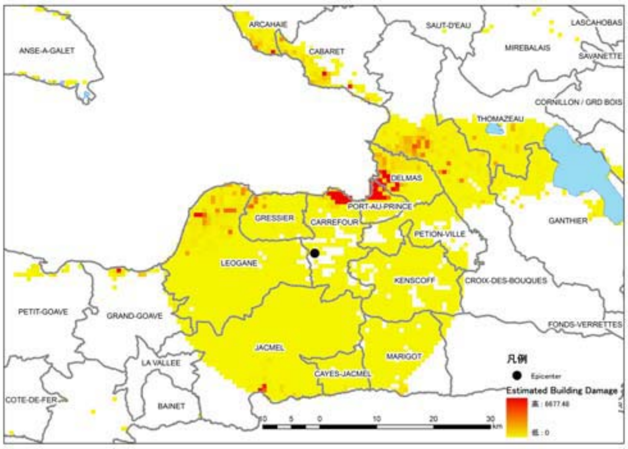

Fig.4 Estimated building damage distribution

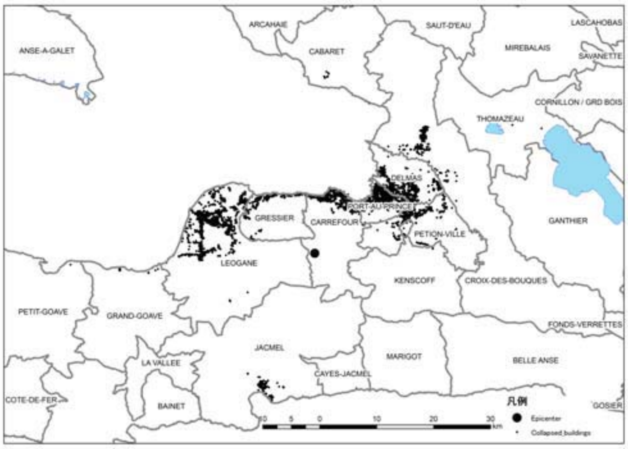

Fig.5 Damaged building using GeoEye

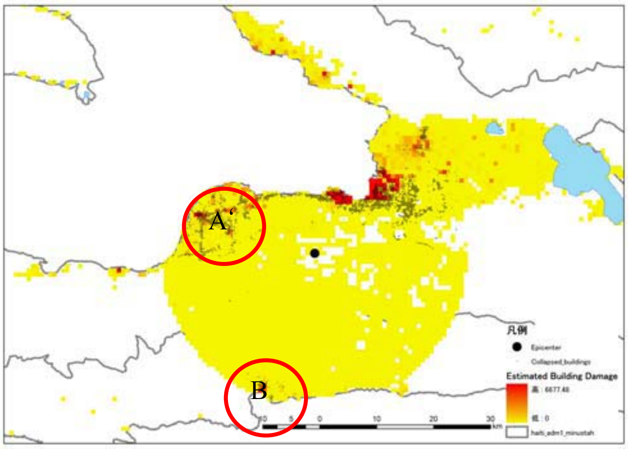

Fig.6 Estimated and actual building damage overlapped

such as building structures and damage functions, were substituted by the damage ratio which is being used by the Japan cabinet offices.

Comparing to the buildings damage plot (the black dots in Fig.5) that was compiled from the satellite imageries taken 1 day after the earthquake (50cm resolution, by GeoEye) confirmed the validity of the estimated buildings damage distribution. The estimation even displayed possible damages at Jacmel area (Area B in Fig. 6). This can also be found in the satellite imageries, but damages in Jacmel was not reported by any media at the time of the disaster. The total number of buildings damage implicated by international organizations is 300,000, where the estimated our results was 200,000.

If landforms classifications and the site amplification factors are pre-calculated from DEM, and with epicenter information provided by USGS, it is possible to make damage distribution estimations in a very short time period, comparable to the Simplified Earthquake Damage Estimation System. Such estimation result may have variances as we observed in Haiti’s case, however it can be a precious reference in making decisions for resource planning at the time of rescue operation initiation against disasters.

4. Communications Satellite-Based Support System and Testing

When a search and rescue team arrives at the disaster site, it is hard for the team to grasp the damage status of the whole area. In order to deploy efficient search and rescue operations, it is desirable to share damage information and the team status with headquarters and other rescue teams. In this study, a search and rescue activity supporting information system is developed on top of the earthquake damage estimation technique, by utilizing satellite communications and the Internet.

As shown in Fig.7, this system (1) builds global landform and site amplification factors to speed damage estimation computations. The automation of earthquake information acquisition and estimation result transmission is planned to be developed in the future.

(2) At post-disaster period, damage information is gathered, integrated, and uploaded to the system while the search and rescue teams are transferred to their sites.

(3) While search and rescue operations are in progress, damage estimation result, site maps, satellite imageries are shared with the teams and the headquarters through high-speed communications satellites such as WINDS.

The system was tested and demonstrated at the 8th APEC Ministerial Meeting on the Telecommunications and Information Industry, October 30 to 31, 2010, by National Institute of information and Communications Technology (NICT), Tokyo Fire Department, National Research Institute of Fire and Disaster (NRIFD), and National Electronics and Computer

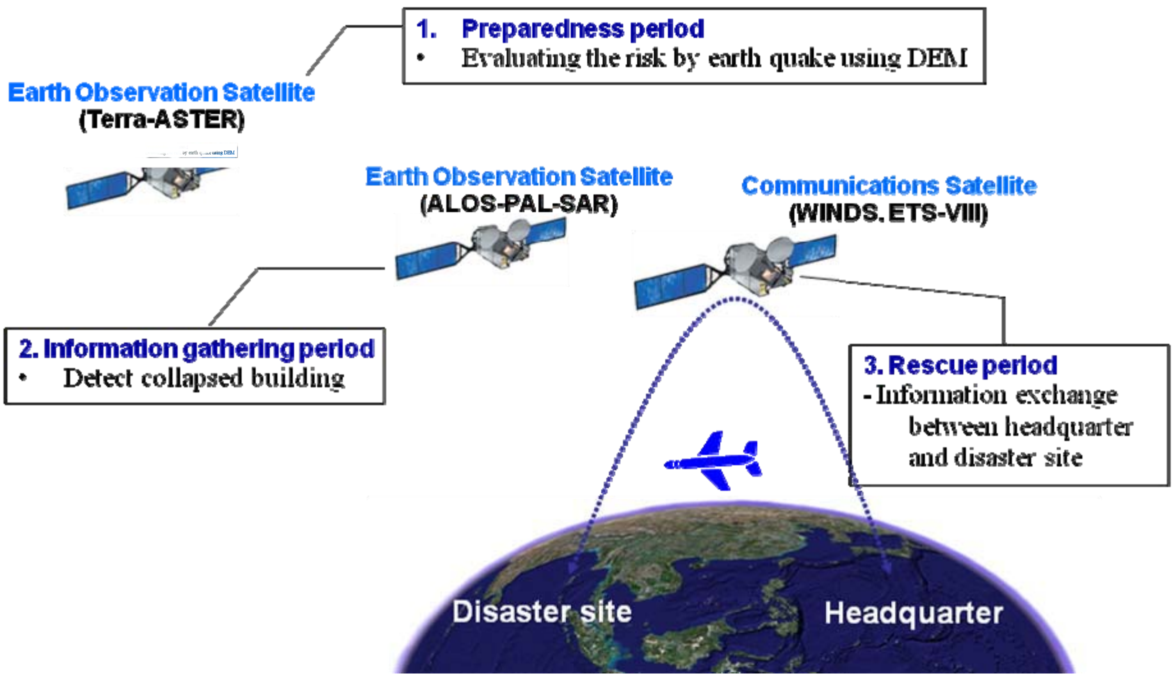

Fig.7 Information Support System for International Rescue Team

Technology Center of Thailand (NECTEC). Bankoku Shinryokan in Okinawa, Japan and NECTEC in Bangkok, Thailand are connected by a satellite communication channel (WINDS: high-speed Internet satellite Kizuna) to test the system for search and rescue operation information sharing using the earthquake damage estimation system and high-definition TV conference systems. The demonstration was based on the scenario that assumes Chiang Mai, the largest city in northern Thailand, was hit by a virtual large-scale earthquake, and an international rescue team (JDR) was sent to the site, being supported together with the rescue headquarter located in Japan by the system under demonstration. JDR team, represented by Tokyo Fire Department personnel, cooperated with the headquarters by sharing data, reporting status and receiving commands through the supporting information system. The system was evaluated very positively on its effectiveness by the participating search and rescue team.

Fig.8 System testing and demonstration at APEC Ministerial Meeting on the Telecommunications and Information Industry

5. Conclusion

In Miyagi・Iwate Earthquake, 2008, the presence of mobile communication blank zones affected disaster information transmission. Generally, even rescue teams that operate in an urban area of Japan could face the situation of communication difficulties similar to what international rescue teams experience if the communications infrastructure was damaged by the disaster. A communication system that integrates satellite and ground communications would be ideal as the means of consistent and reliable communications system for disaster information sharing.

Now that the system is at the state of prototype completion, it is planned for the estimation accuracy improvement and rescue operation-friendly user interface development.

It is a pleasure to thank those who made this testing and demonstration at APEC Ministerial Meeting on the Telecommunications and Information Industry possible: Tokyo Fire Department, Japan International Cooperation Agency, and other participating organizations to name a few.

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