Development of Methodology to Identify the Areas where Buildings are Broken down by Earthquake using Airborne Laser Technology

by

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ABSTRACT

This paper describes the efforts to develop methodology to identify the areas rapidly where buildings are broken down by an earthquake using airborne laser technology. By applying this methodology to large earthquakes, it is expected to reduce the number of people who cannot move under broken buildings and die several days after the earthquakes. This development was invoked by the bitter experience in the 1995 Hyogo-ken Nanbu Earthquake.

KEYWORDS: Airborne Laser Technology, Hyogo-ken Nanbu Earthquake, DSM, DEM

1. INTRODUCTION

More than 6,000 people died by the Hyogo-ken Nanbu Earthquake which took place on 17th January 1995. In this earthquake, breakdown of wooden houses caused large number of deaths. If identification of broken buildings was made rapidly and rescue works were focused on those buildings, many lives could have been saved. With such thinking, development of methodology to identify the areas rapidly where buildings were broken down by an earthquake started in 2003 as a part of the research project “Development of the system managing real time information for disaster mitigation.”

This development is to be concluded in the fiscal year of 2005. In this paper, results obtained so far as well as issues to be solved are described.

2. PAST EXPERIENCE

In Japan, two-storied wooden houses are dominant in most of cities excluding its central part. In 1995 Hyogo-ken Nanbu Earthquake, a number of these houses broke down, which caused many deaths of people living there. According to the Fire Department of Kobe city which was severely damaged by earthquake, the rate of survivors among people taken out of broken houses by rescue activities significantly decreased after three days passed (Figure 1). Therefore, even rough identification of the areas where buildings are broken down rapidly, let’s say within 24 hours, is very important so that rescue activities can be focused on these areas, which can eventually lead to reducing number of deaths.

The use of aerial photo seems to be promising for such identification. In the case of the 1995 Hyogo-ken Nanbu Earthquake, however, it was observed that many houses were broke down by the collapse of the first story and looked similar to houses without damages on the aerial photos. Identification of breakdown housed can be done by 3 dimensional measurements of stereo photos, but it must take considerable amount of time. On the other hand, airborne laser survey can measure the height of object directly, thus it seems very promising for this kind of identification.

3. AIRBORNE LASER SURVEY

Airborne laser survey uses an active sensor that measures the distance from the sensor to the ground (roofs of houses, leaves of trees, or whatever) on which the laser beam is reflected (Figure 2). The reflected data of the laser beams are received by a sensor onboard. Furthermore, aircraft positions and attitudes are calculated using a combination of GPS data both on the aircraft and on the ground, aircraft acceleration and its three-axial attitude data measured by an Inertial Measurement Unit (IMU). These data are combined to calculate the three

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dimensional positions of the objects on which the laser beams are reflected. The objects can be various such as ground, roofs of houses, leaves of trees. Thus very accurate height information on earth surface can be surveyed far easier and faster than before by airborne laser survey. The accuracy of height obtained by airborne laser survey is about 15 cm, so it is easy to detect height difference of meter order.

In Japan, accurate surveys covering certain amount of area conducted by public sector must follow the Work Regulations which is stipulated in the "Survey Law." It may take some time before new survey technology is taken into the Work Regulations. Although airborne laser survey is relatively new technology, various research works have been conducted including the field of disaster mitigation (Nakata et al., 2003, Sekiguchu et al., 2004). As a result, the Work Regulations on it is already available and thus it has become a popular survey method for getting very accurate height information. For instance, Geographical Survey Institute, which is a National Surveying and Mapping Organization of Japan, prepared grid type digital elevation model (DEM) of 5m interval for major cities such as Tokyo, Osaka, and Nagoya. These DEM data are or will be available in CD-ROM.

The typical work follow of airborne laser survey is as Figure 3. Therefore, in order to identify breakdown buildings within 24 hours, working time required for each step should be reduced as well as the proper work flow should be defined for natural hazards such as an earthquake.

4. OUTLINE OF THE DEVELOPMENT

The outline of the development is as follows.

<<Goal of the development>>

To identify the areas where buildings are broken down by an earthquake within 24 hours using airborne laser technology

<<Terms of development>>

Three years from the fiscal year 2003 to 2005

<<Research items>>

(1) Specifications of data acquisition in the case of natural disasters
(2) Reducing time required for data transfer
(3) Data analysis for identifying areas where buildings are broken down
    a. The case when laser data of the areas before the earthquake are available
    b. The case when laser data of the areas before the earthquake are not available
(4) Development of a manual for making developed methods operational

The goal of the development is set as "within 24 hours" because it can be used another two days for rescue activities focusing on the areas where severely damaged by an earthquake, which can save many lives who otherwise might die. Regarding the second research item, it comes from the fact that it takes long time to transport acquired data from airport to data processing center.

5. RESULTS OBTAINED

In this section, the results of development in the past years are described.

5.1 Specifications of Data Acquisition

Various items such as density of measurement by laser, flight height, scanning angle and side lap were discussed and appropriate specifications were defined although most of the items are limited by the hardware specifications. For instance, it was concluded that 1 m interval is required for identifying each house. Figure 4 shows the comparison of data with different measurement density.

5.2 Reducing Time Required for Data Transfer

In order to reduce time significantly, the methods to transfer laser data from aircraft to the ground while data scanning is on going were investigated. As airborne laser survey brings huge amount of data, onboard data compression method is investigated as well. The present status on these items including technology under development is reviewed. As a result, it is expected to reduce time to 1/5 – 1/10 in the ideal case.

5.3 Data Analysis for Identifying Areas where Buildings are Broken down

5.3.1 The Case when Laser Data of the Areas before the Earthquake are available

It is necessary to prepare grid type airborne laser data with the same interval and coordinate system.

After that, height change caused by an earthquake can be obtained by subtracting height of each grid point after the earthquake from the height at the same position obtained before the earthquake.

It was tested using tents whether height difference is actually detected or not. Data acquired when tents were properly built was regarded as the data before an earthquake. On the other hand, data acquired when they were improperly built were regarded as the data after the earthquake (Figure 5 shows such an example). Figure 6 is the result of height difference overlaid on the aerial photo corresponding to the tents setting shown in the Figure 5. This result shows deformation of tents can be detected by airborne laser survey.

5.3.2 The Case when Laser Data of the Areas before the Earthquake are not available

Data before an earthquake with required specifications are not necessarily available in operational phase. Therefore, method to identify damaged houses even though data before an earthquake are not available was investigated. Two methods were studied using existing airborne laser data of Shizuoka city. The one is to identify the areas block by block using randomly located airborne laser data. The other is to identify house by house using grid type data.

Assuming map data showing shapes of houses are available, average height at the roofs of houses for each block can be calculated by averaging laser data coming into the shapes of houses. The value calculated by averaging laser data reflecting out of shapes of houses can be regarded as the average height at the ground for each block. Average height of houses for each block can be obtained by subtracting the average ground height from the average height at the roofs of houses. The average height calculated by this method for the data of Shizuoka city was 5.3 m. Therefore, if the average height is significantly lower than 5.3 m, many houses in the block are considered to be broken down. The damage area was assumed as in Figure 7. In this area, height data were subtracted by 3 m if they came into the shapes of houses. Figure 8 shows the color map of average height of houses block by block. It is clear that assumed damaged areas are extracted.

The other method is to get the height of each house by subtracting DEM from DSM. Original data obtained from airborne laser survey show the heights of surface of the earth. They may heights of roofs of buildings, top of trees, or ground surface. These data is called DSM (Digital Surface Model). DEM is obtained by removing structures, trees or whatever which do not show ground surface and collecting only heights showing ground surface. To enable subtraction DEM from DSM, these models must be based on regularly spaced grid type data with the same grid. Therefore, this method takes longer time that the other one. Figure 9 show the color map showing height of buildings, from which candidates of breakdown houses can be identified.

6. ISSUES TO BE SOLVED

Although various results were obtained by the research of the last two years, there remain issues to be solved before this method becomes operational.

First, the developed method for identify breakdown houses is only applicable where 2 stories houses are dominant. So this method should be refined so that areas mixed with both 2 stories houses and higher stories buildings can be dealt with. Second, each component of work flow in Figure 3 was investigated, but it has to be checked whether it works properly as a whole. It is also very important to prepare a manual for this methodology so that it can be applied operationally.

7. CONCLUSION

The interim report was presented on the development of methodology of identifying the areas where buildings are broken down by an earthquake using airborne laser technology within 24 hours. Based on the whole workflow, which was investigated first, specifications on the airborne laser survey in such cases are defined. Possibility to reduce time for laser data transfer was also investigated. As a core part of development, methods to identify the breakdown houses are described. Finally, the issues to be solved to make this methodology operation are described.

8. REFERENCES

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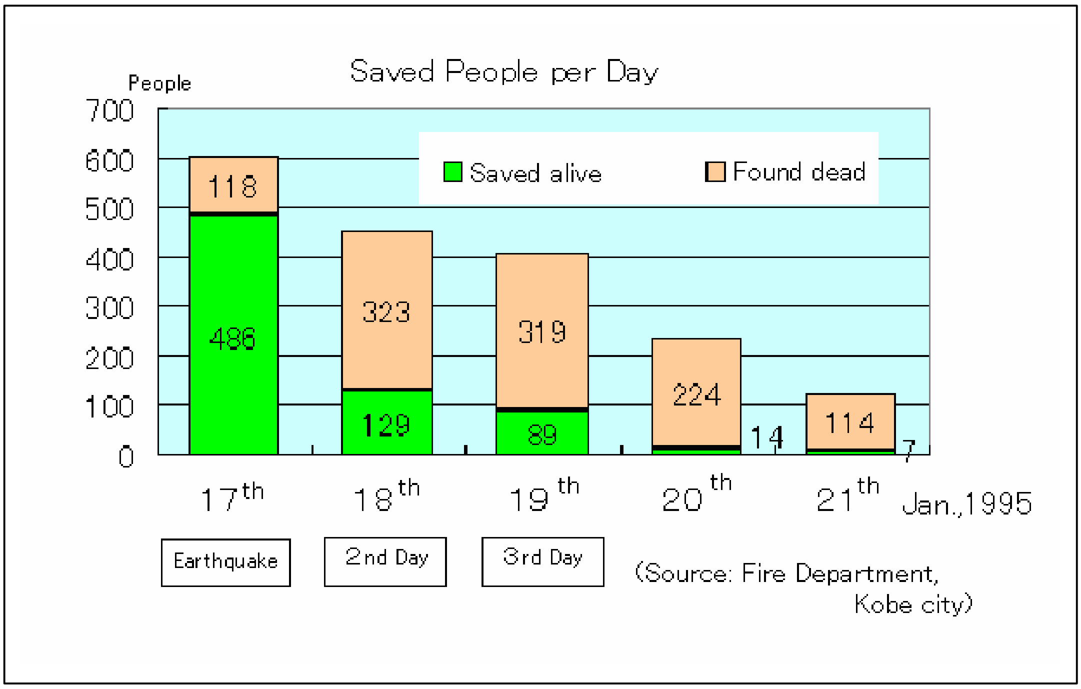

Figure1 Number of people saved and days after Hyogo-ken Nanbu Earthquake

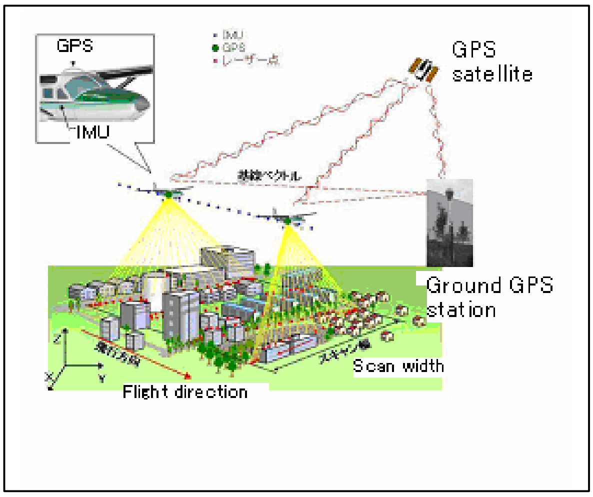

Figure 2 Airborne Laser Survey

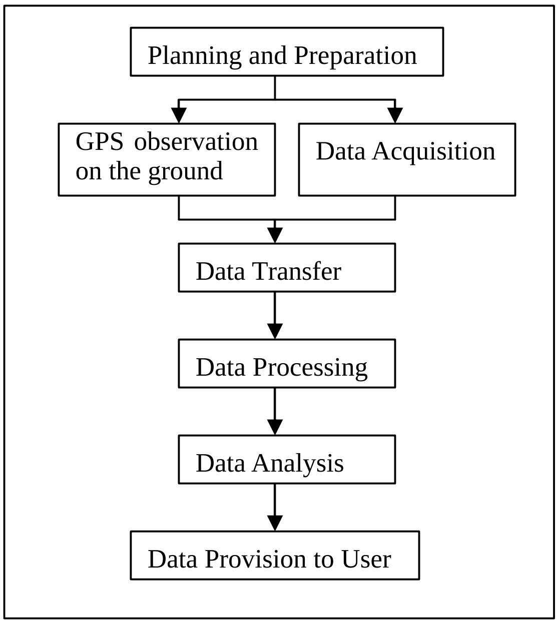

Figure 3 Work flow of airborne laser survey

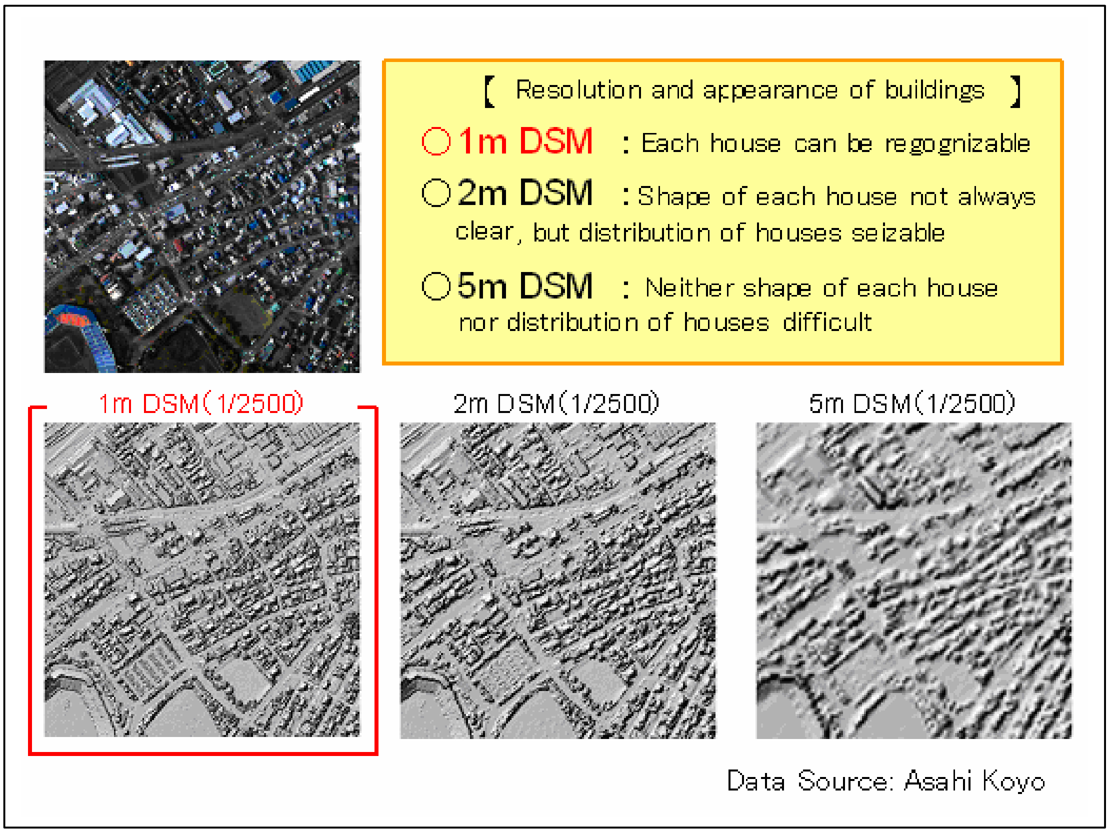

Figure 4 Resolution of laser data and appearance of buildings

Figure 5 Tents setting simulating breakdown of houses

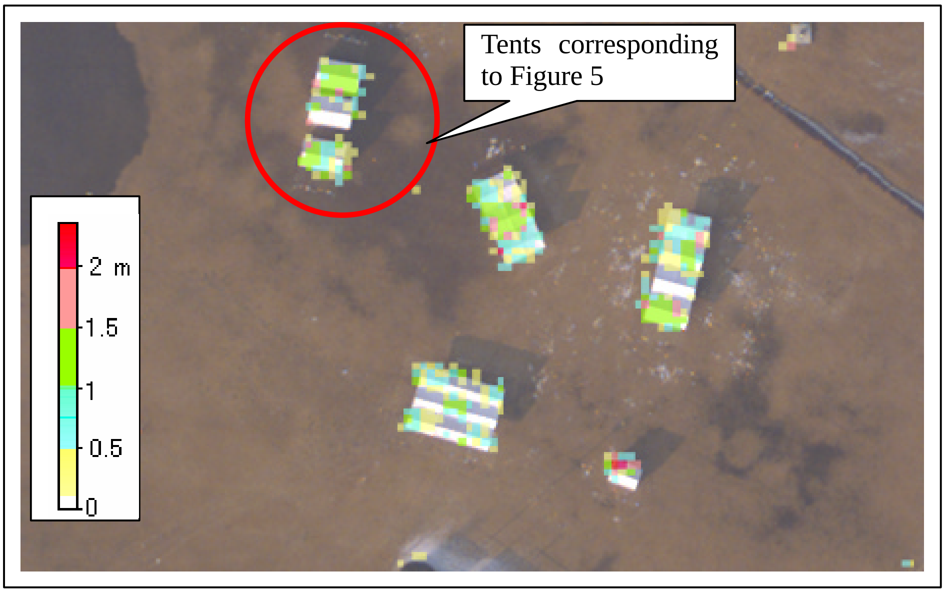

Figure 6　Height difference caused by different tents setting

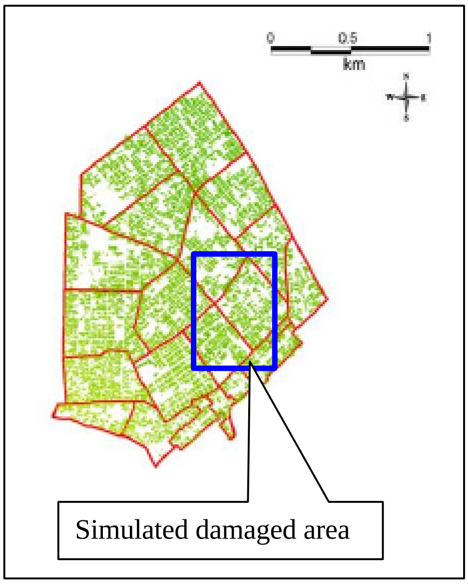

Figure 7　Test area in Shizuoka city

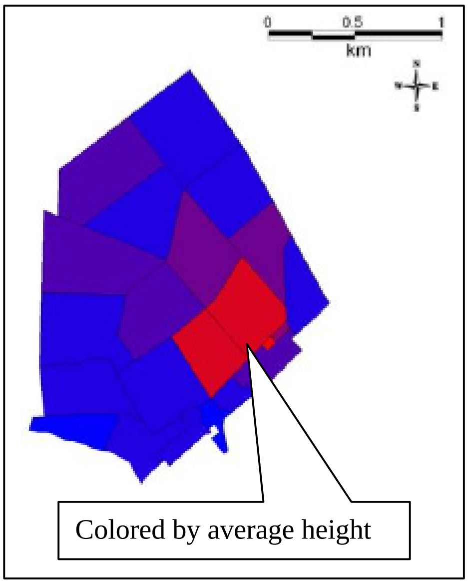

Figure 8　average height of houses for each block

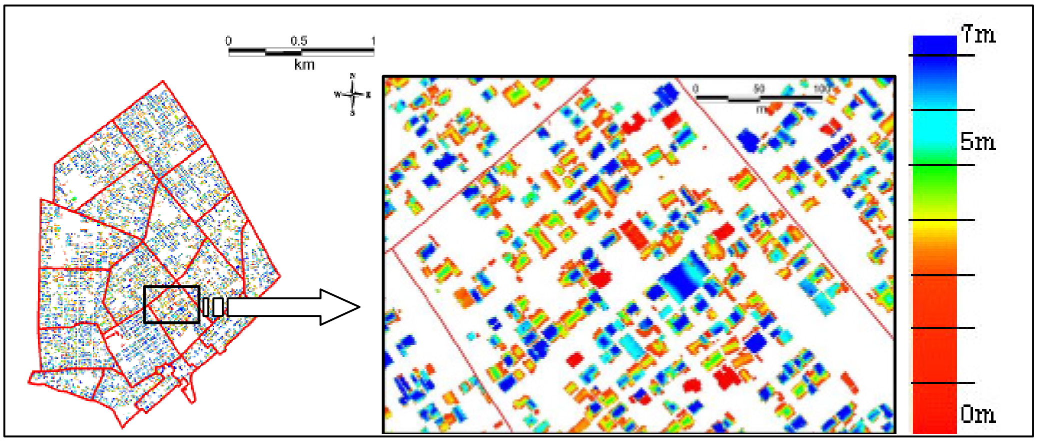

Figure 9 Height of each house in test area obtained by DSM and DEM