DEVELOPMENT OF A SEISMIC RISK ASSESSMENT METHOD BY ESTIMATING BUILDING INVENTORY USING HIGH RESOLUTION SATELLITE IMAGERY DATA AND DIGITAL VIDEO IMAGERY DATA WITH GEO-LOCATIONAL DATA:

Manabu WATANABE, Haruo HAYASHI, Masasuke TAKASHIMA, Kei HORIE, Satoshi TANAKA, Kouichi HASEGAWA, Go URAKAWA
Graduate School of Informatics, Kyoto University
Research Center for Disaster Reduction Systems Disaster Prevention Research Institute, Kyoto Univ. Gokasho, Uji, Kyoto 611-0011, JAPAN
Tel:+81-774-38-4283, Fax:+81-774-38-4283, E-mail:nabe@drs.dpri.Kyoto-u.ac.jp

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ABSTRACT: In developing countries, there are many buildings which are very vulnerable against earthquakes, and many people have been victimized. It is indispensable to assess seismic risk for reduction of those damages, but in developing countries it is often difficult to obtain building inventory data for seismic risk assessment. The purpose of this study is to develop a practical method to estimate the quantity and type of buildings according to GESI method using a high resolution satellite imagery data and digital video imagery data with geo-location.

1. INTRODUCTION

Assessing the damage to buildings is indispensable. For risk assessment of building structure, the following three questions should be answered: 1) What kinds of earthquakes could occur, 2) How vulnerable local building structures are, and 3) How many building structures exist. As for the first question, which concerns seismic hazard, a global seismic hazard map is available through the Internet from the GSHAP site[1)]. As for the second question, which concerns the vulnerability of building structures, damage assessment techniques such as the GESI method[2)] is available to help evaluate structural damage potential in developing countries. As for the last question, knowing how many building structures exist in the target area, which is about putting together building inventory, is the most expensive and time consuming question to be answered. Therefore it is essential to develop a practical, economical and quick method for estimating building inventory, suitable for developing countries.

2. METHOD

We developed the method to estimate building inventory by the following procedure: 1) We set Marikina City, Metro Manila, Philippines as study area. There is the West Valley Fault which may cause a 7.0 magnitude earthquake. 2) In Marikina City, we selected a learning field and divided it by four sizes of grids using the imagery of IKONOS. 4) We classified the grids in the area into some different land classification categories at every grid size and found out the best appropriate size. 5) With the best appropriate size of grids, we estimated the quantity of buildings in entire Marikina city area using the building footprint data. 6) We conducted a field investigation at the learning field using a digital video camera connected with GPS. 7) We identified the type of building using the video imagery data. 8) With the best appropriate size of grids, we estimated the quantity and the type of buildings in entire Marikina city area according to GESI method using the field investigation results. 9) Finally we suggested a procedure of estimating building inventory.

In this study, it is our purpose to propose a way to estimate building inventory in a "quick and dirty" manner using IKONOS imageries, a high resolution satellite imageries and digital video camera connected GPS. IKONOS gave us 4 imageries data made of digital numbers (DN), which are red, blue, green, and near infrared. There have been developed many applications analyzing visual imageries obtained by LANDSAT/TM in the various areas of earth observation. But we can't categorize urban area into each building by LANDSAT/TM 30m grid. IKONOS has 1m grids and it's provides a sufficient resolution for the analysis of building inventory.

The digital video camera with GPS is the system Uji GIS Research and Development Support Center developed. The system can convert geo-location data into voice data and show the image with geo-location data on GIS. Using this function, we analyzed the imagery data and found out where buildings are, how many buildings there are, and what types of building there are.

3. LAND CLASSIFICATION BY CLUSTER ANALYSIS

In Marikina city, we selected a learning field shown in figure 1 because of the diversity of the land cover. And we set four sizes of grids, 25m, 50m, 100m, 200m. As for 25m grids, one grid has 625 cells, and each cell has DNs of 4 bands, that is, each cell has distribution of data. We conducted cluster analysis of the distribution of data. One DN data of IKONOS has 2048 level, and it takes too much time if we do cluster analysis using this 2048 level. Then we converted the 2048 level of DN data into the 32 levels. And we conducted visual analysis of IKONOS imagery at each classification and decided the most appropriate classification to estimate the quantity of buildings. We showed the result of the most appropriate classification on figure 2. We did the same analysis at 50m, 100m, and 200m grids, too. At 25m grids we classified the learning field into 7 categories, which were River (RV), Green Land (GL), Bare Land (BL), Factory (FC), Normal Residential 1 (NR1), Normal Residential 2 (NR2), and Dense Residential (DR), and at 50m, 100m, 200m grids, into the 7 categories and 1 category, Riverside (RS).

Luckily there existed a building footprint data in the three fourths area of Marikina city, which was made by NAMRIA[3)] in 1995. Firstly we analyzed the averages number of the quantity of buildings of the each category by the data at 25m grids, and found out that there is a strong relation between the land classification categories and distribution of the buildings shown in table 1. And we found out the same result at other grids, too. Secondly we compared the variance of the distribution of buildings at four sizes of grids, and found that the variance at the 25m grids was the lowest except at the category of R. And that the variance was the lowest meant that there was the lowest distribution of the quantity of buildings from the mean, and that we could estimate the quantity most appropriately at the 25m grids. Lastly we decided to use the 25m grid and to use the 7 land classification categories, R, GL, BL, F, NR1, NR2, and DR.

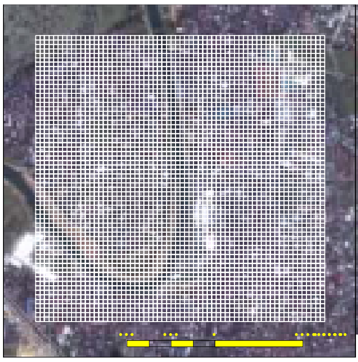

Figure 1 Learning Field

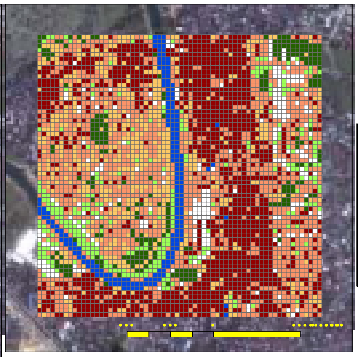

Figure 2 Land Classification

Table 1 Mean and Variance

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4. ESTIMATION OF THE LAND CLASSIFICATION AND THE QUANTITY OF BUILDINGS AT THE ENTIRE MARIKINA CITY AREA

4.1 Estimation of The Land Classification in Entire Marikina Area

When we estimated the land classification in entire Marikina city area at 25m grids, we decided that we estimated the land classification category of one cell as the category of the 7 categories which has the nearest distribution of DNs with the distribution of the cell in the Euclidian space. And firstly we calculated the average of DNs distribution of each 7 category in the learning field. Figure 3 shows the average of DNs distribution of each 7 category and the pictures taken at each area. We expressed the average of DNs distribution of each 7 category as (1).

$S_{(x,m,n)}$ • • 1•• x• 7, 1• m• 4, 0• n• 31• (1)

Here "x" means 7 types of land classification categories and "m" means four types of bands and "n " means the 32 levels of DNs. And we calculated DNs distribution of all grids in entire Marikina city area at 25m grids. As for a certain cell "A" in Marikina city area, we expressed the distribution of DNs of A as (2).

$A_{(m,n)}$ • • (1• m• 4, 0• n• 31) (2)

Finally we calculated the difference of 7 category S with the cell by equation (3).

$$S = \sum_{m=1}^{4} \sum_{n=1}^{31} (S_{(x,m,n)} - A_{(m,n)})^2 \qquad (3)$$

And we decided that the land classification of "A" was estimated into the category which had the minimum of S of 7 categories calculated by this formula. Figure 4 shows the result of the estimation of the land classification in entire Marikina city area.

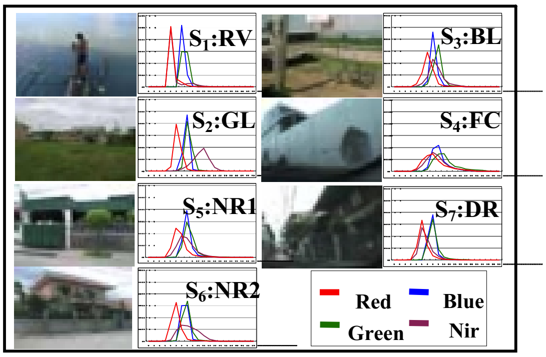

Figure 3 DN distribution and pictures of each categories

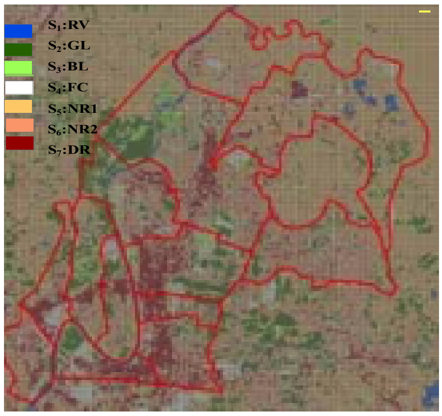

Figure 4 Estimation of the land classification

4.2 Estimation of The Quantity of buildings Using a building footprint data

Firstly when we estimated the quantity of buildings in entire Marikina city, we set the average number of buildings at 25m grids in each 7 category obtained in the learning field as the average number of buildings in each grids estimated into 7 categories. Secondly when we divided Marikina city area into 4 divisions as figure 5 shows, there existed the building footprint data at area 2,3, and 4. Therefore, we compared between the quantity of buildings counted by the data and estimated by our method at area 2, 3, and 4, and examined the accuracy of this method. The table 4 shows the number of the cells (C) estimated into each category, the estimated quantity of buildings (Q) which was the number of the cells times the average number of buildings of each land classification category, the quantity of buildings (F) counted by the building foot print data at correspondent cells, and the error rate (E). I represented E as equation (4).

$$E = 100 \times (F - Q) \div F \qquad (4)$$

As table 4 shows, we got the certain degree of accuracy of the estimation at each category, and because the amount of the quantity of buildings in the area 2, 3, 4 estimated by our method was 58992.68 and the quantity counted by the building footprint data was 50346, we decided that we got the high accuracy about the amount of the quantity of our estimation.

4.3 Estimation of The Quantity of buildings by the field investigation in the Learning Field

In the learning field, we selected as a target area of field investigation 8 areas, 196 grids which contains all 7 categories. As for the investigation, we moved around by a car and shoot digital video imagery data for about three hours on November 21, 2003. We set the video camera in the car and made it at an angle of 45 degrees of the direction of movement of the car, and moved at a speed of around 10 kilometers-per-hour and shoot digital video imagery data.

By using the digital imagery data with geo-location data, we counted the quantity of buildings in target cells. Table 3 shows the result that we counted on the GIS system the quantity of buildings at all target cells and made it into the average of building number at each category. And at entire Marikina city area, we estimated the quantity of buildings using the result of the field investigation by our estimating method. Consequently we decided that we got the high accuracy about the amount of the quantity**,** because the amount of the quantity of buildings in the area 2, 3, 4 estimated by our method was 58614.77 and the quantity counted by the building footprint data was 50346 as the table 6 shows.

Figure 5 Marikina city area

Table 2 Estimation of quantity of buildings by footprintdata

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Table 3 Estimation of quantity of buildings by the field investigation

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5. ESTIMATION OF THE TYPE AND THE QUANTITY OF BUILDINGS AT THE ENTIRE MARIKINA CITY AREA BY THE FIELD INVESTIGATION

We identified the types of buildings according to GESI Method using the digital video imagery data connected with geo-location data taken by field investigation at the learning field. Firstly we assessed the types of buildings by table 4, secondly the quality of design, construction, and materials of buildings by table 5. Finally we summed up the score of quality, construction, and materials, and decided by table 4 the vulnerability curve of buildings. Then if we get the data of PGA of the target area, we could decided the damage level from four levels as table 6 shows by using figure 7. And when we assessed the type of buildings according to GESI Method, we referenced the research by Hasegawa et al[4). in which they assessed according to GESI method the type of buildings of major facilities, a city hall, hospitals, schools and so on.

There were many buildings identified as type D in the area of NR1 or NR2, which meant relatively less vulnerability, and many buildings identified as type E in the area of DR, which meant relatively high vulnerability. As a result We found out the strong relation between the 7 categories and the types of buildings identified according to GESI Method.

There were over half buildings identified as type D in the categories of NR1 and 2 and we set Buildings there as type D. And in the area of DR, 9 of buildings were identified as type E, 8 as type D, 6 as type F, 3 as type G of 27. As for risk assessment, it is normal to assess the risk higher, and we set buildings in the area of DR as type F. In the area of BL and FC, we set as type D. We showed the buildings identified according to GESI method as examples in figure 8. Finally, we estimated the quantity and types of buildings in entire Marikina city area as table 7 shows.

6. CONCLUSION

As the result of this study we here suggested a procedure to estimate building inventory according to GESI method using IKONOS imagery data and the digital video camera connected with GPS as figures 9 shows. As a result of this study we developed an effective method to estimate building inventory in case of absence of it in developing countries, and we will continue this study to develop a more practical and economical and quick method to assess seismic risk on the basis of GESI method in the developing countries.

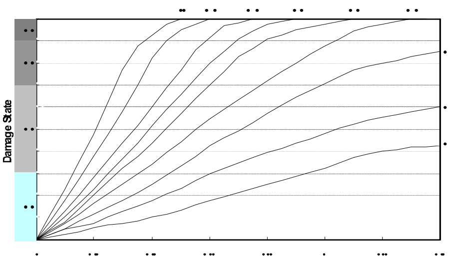

Figure 7 Vulnerability cureve

Table 4 Building Types

Building Types	0	1	2	3	4	5	6	7
Wood	A	A	B	B	C	C	C	D
Steel	A	B	C	C	D	D	E	F
R/C	B	C	D	E	E	F	G	H
R/C, steel with masonry infill walls	C	D	D	E	E	F	G	H
Reinforced masonry	C	D	D	E	E	F	F	F
Unreinforced masonry	E	E	F	F	G	G	G	H
Adobe	N/A	N/A	G	H	H	H	H	I
Stone rubble	N/A	N/A	G	H	H	H	H	I
Lightweight shack	N/A	N/A	N/A	H	H	H	H	I

Table 5 The quality of three elements of buildings

[illegible]	[illegible]

Table 6 Damage level

[illegible]	[illegible]

Table 7 Estimation of building inventory

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Figure 8 Identification of••buildings according to GESI Method

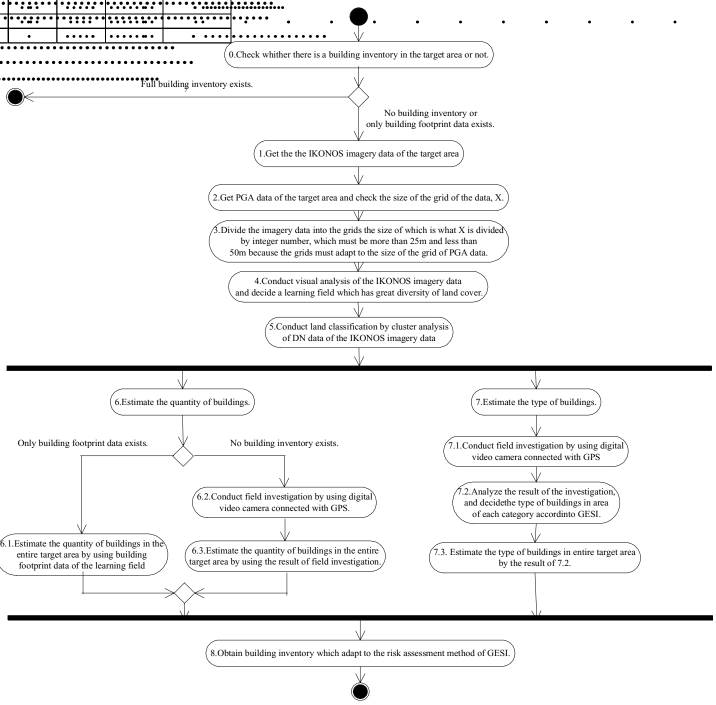

Figure 9 Procedure of estimating building inventory

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