DAMAGE REDUCTION BY CULTURE BASED METHOD SUPPORTED BY SPATIAL TEMPORAL GIS
- COLLABORATIVE RESEARCH WITH DUZCE MUNICIPALITY TURKEY -

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Abstract: Spatial temporal GIS named DiMSIS (Disaster Management Spatial Information System) have been developed mainly focused on applying local government applications after the great HANSHIN earthquake of 1995 in Japan. This spatial temporal GIS which has been enhanced to have multi language support would be common core system to support Risk Adaptive Regional Management Information System (RARMIS) concept proposed after the experiences of emergency response of the HANSHIN Earthquake. Data structure to describe spatial temporal data is also enhanced to the one named KIWI+ (related to the data structure of Japanese Industry Standard for car navigation system). Disaster information and daily regional information can be described uniformly by connecting to spatial and temporal position which is universal. Emergency tasks of local government are composed of elements of daily tasks which are rational for each organization. Quickbird image data is used to detect changes and also integrate map database developed separately. DiMSIS with Quickbird data is also applied to Bam earthquake (Dec. 2003) for the case study. In this paper, we report this case study about the implementation process to the local government using spatial temporal GIS and satellite image data.

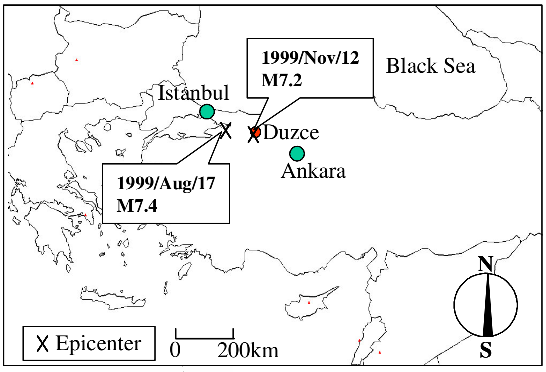
1. INTRODUCTION

Spatial temporal GIS named DiMSIS and its database structure called KIWI+ have been developed mainly focused on applying local government applications after the great HANSHIN earthquake of 1995 in Japan. Suitable system for mitigating damage has been surveyed through the case studies to apply the system to Japanese local governments and Turkish local government Düzce (the city experienced 2 big earthquakes in 3 months in 1999). Countermeasures taken by each local government have been different according to their background.

Through the experience with disaster and recovery support activities obtained as a result of the Great Hanshin Earthquake, we have developed the information system that can use after immediately the disaster, and researched the implementation process to the local government. RARMIS (Risk-Adaptive Regional Management Information System) concept [1] is the output of these activities, and to realize this concept, the spatial temporal GIS called DiMSIS have been developed. On the basis of these output, at the Düzce city which was severely damaged by the 1999 Turkey Earthquakes (Fig. 1), we have supported the recovery activities using DiMSIS since 2000.

Older wood houses had heavy damage in HANSHIN, however, not in Düzce where new buildings had more damage than old wood houses that were built using experiences integrated for long time. New residential district with new houses has been built at safer area in the suburban nut field area in Düzce, but Kobe was different. Suitable survey and measurement procedure is also different. This means optimum assistance before and after the natural disasters are different. Turkish government raised tax to support sufferers and people accepted to pay for others because it was caused by uncontrollable natural power. Turkish government and World Bank developed two new residential area with 10,000 apartment house in a suburban part of the city where is analyzed as one of most stable. This hilly area used to be hazel nuts field. Precise measurement data set are made part by part for the construction. Map database of city area is existed, however these data is not integrated. Düzce local governments requested updated mad data of damaged area. They also needed cadastral data and land data all over the area for new urban planning such as developing new road between the areas and country area. Quickbird data is used to collect this information.

In this paper DiMSIS which is provide as a platform of spatial temporal GIS with multi-language version and KIWI+ for database structure specification to those who agreed our proposes of collaborative development and some of analyzed result of earthquakes is introduced. Quickbird data application to integrate map database is mentioned and attempts to apply the system to earthquake of Bam city in



The two earthquakes occurred on August 17th and November 12th, produced significant human and physical damage in the northwestern part of Turkey. Over 17,000 were killed and many people lost their homes. Economic loss was 16 billion US dollars, which correspond to 7% of Turkish GNP. The number of dead caused by the first earthquake was about 270, and about 800 died in the second earthquake in Düzce city. Düzce is summarized about 2,300 buildings were judged as heavily damaged or collapsed, 2,500 buildings as middle damaged among the 11,000 buildings by the two earthquakes.

Fig. 1 Damage of Düzce after Turkish Earthquake in 1999

Iran happened December 2003 is also mentioned.

2. REQUIREMENTS FOR RECONSTRUCTION MONITORING INFORMATION SYSTEM IN DUZCE

Duzce city is located in 200km from Istanbul east, and it is 75,000 populations. This city encountered both earthquakes of August 17th and November 12th in 1999. In this city, there were 11,000 houses at that time, and 2,300 houses received heavy damage and 2,500 houses did middle class damage. The two earthquakes caused about 1,100 deaths.

In Duzce city, damage factor analysis of a house and revival city planning on the basis of it were needed. Thus we began to develop the reconstruction monitoring information system using geographic information system from winter, 2000. The requests for reconstruction monitoring information systems that we get form the Duzce municipality though the activities are as follows:

(1) It is a system that is able to describe the ever-changing regional information.

(2) It is a system that can add the application software by Duzce city officers.

(3) It is a system that database compatibles with the other GIS/CAD.

3. RISK-ADAPTIVE REGIONAL MANAGEMENT INFORMATION SYSTEM

3.1 The Transition in Information Processing Requirements in Emergencies [2]

Changes can be represented in the following 5 stages of disaster (including the normal stage), and the transition is presented in Fig. 2

(1) Chaos Stage (the first few days after a disaster): Lifesaving is most important. ST GIS with latest database in undamaged computers are used for summarizing the damage information to assist decision making.

(2) Initial Operation Stage (for a few weeks after the chaos period): ST GIS is used to assist summarizing damaged house, lifelines, and so on to avoid 2nd damage by them.

(3) Early Recovery Stage (for several months after the initial operation stage): Temporally houses are supplied and certifications of damages are provided according to the damage level. ST GIS data is also used for new city planning.

(4) Late Recovery Stage (beginning after early recovery and continuing for several years): ST GIS is used to assist

(5) Normal stage (after recovery is complete): ST GIS is used registering change of the city to manage movement of people, tax for real estate, land and so on.

Given these five stages, in the "state-of-emergency" chaos and initial operation stages, the information processing system should function as a disaster response support system. In the early and late recovery stages, and in normal times when time pressures are not so intense, the information processing system should be positioned as a disaster prevention system.

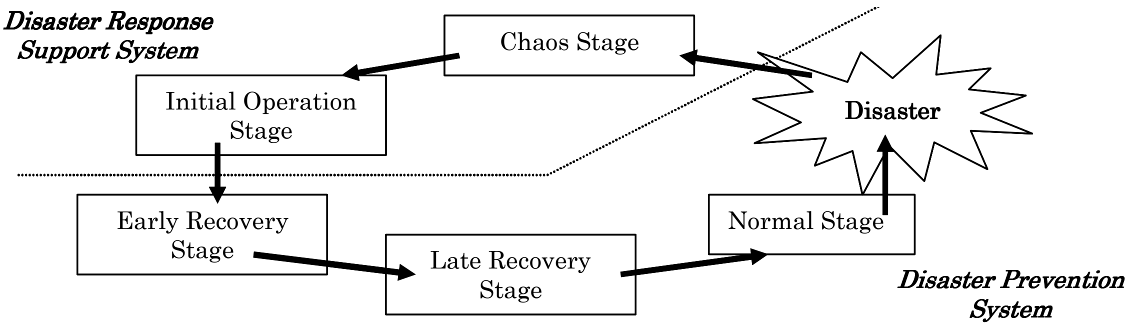


Fig.2 Stage of Disaster

In this Duzce case, the system they need in 2 above is considered as a disaster prevention system. However, in the frequent natural disaster stricken area like Japan and Turkey, it is important to design software to be able to use not only in recovery and normal stages but in all stages against the next disaster.

4. SPATIAL TEMPORAL GIS "DIMSIS"

To realize the technical issues of the RARMIS concept, we have been developing the spatial temporal GIS "DiMSIS" and KIWI+ database structure.

4.1 KIWI+ Format (A Spatial Temporal & Simple Topology - Open Database Schema: ST2-ODS)

The KIWI+ format is our proposed original format for spatial temporal GIS [3] [4]. In this format, spatial temporal objects can be handled on the basis of temporal management using the Space-Time Approach model [4], and by describing objects using the implicit description and calculation type of data model [5], a compact, easy-to-understand structure is obtained. In the following sections, the characteristics of this system are described.

4.1.1 Database Structure

The KIWI+ describes all geographical information in the forms of two elements: vector for shaping graphic data, and connector for relating attribute data (Fig.3). Each element has the following configuration, with the geographical data incorporating spatial temporal information being the main component:

(1) Vector element (VE): A VE is composed of the following main factors: element type ID, 2D co-ordinate sequence, Z information and T information.

(2) Connector element (CE): A CE is composed of the following main factors: element type ID, 2-D coordinate point, Z information, T information, as well as key information such as the display information and grouping information.

Z information has height and height displacement information like Fig. 4. The temporal factors can be resolved into four factors: generation start time (GS), generation end time (GE), extinction start time (ES), and extinction end time (EE) (Fig. 5). If the dates of generation and extinction cannot be identified, it is also possible to represent temporal error using these factors.

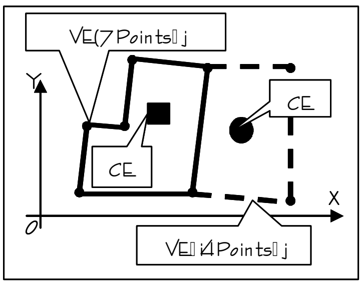


Fig.3 VE and CE

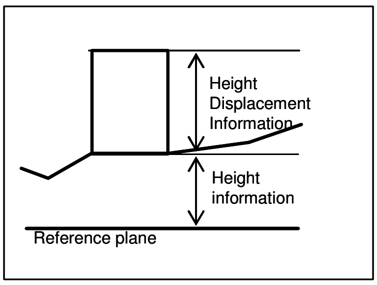


Fig.4 Z Information

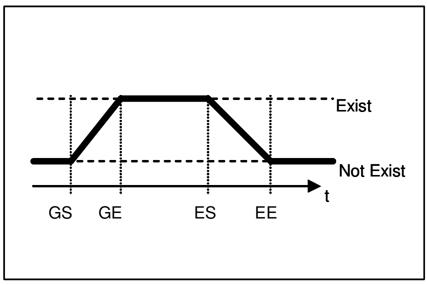


Fig.5 T Information

4.1.2 The concept of feature space

In order to utilize the data structure explained in 4.1.1 efficiently and to calculate the topological structure, the concept of feature space is introduced in the KIWI+ format.

(1) Definition of feature space

A set of objects with the same type ID is called a class group. In accordance with the objects they comprise, class groups can be classified into vector class groups and connector class groups. A set of correlated multiple vector class groups and multiple connector class groups is defined as a feature space.

(2) Spatial temporal analysis using feature space

A feature space has a physical significance as a factor in terms of spatial temporal analysis. As such, there are four types of feature space: point, line, area, and solid feature space (Fig. 6).

Defined as factors in a topological relationship, these correspond to points, lines, areas, and solids. Spatial temporal analysis is performed in feature space by relating vectors, which comprise geometric information, and connectors, in which attribute information is linked. Because these relationships are calculated in real time when a processing command has occurred, it is possible to dynamically supplement objects corresponding to topological structures.

4.2 System Constitution

DiMSIS has the constitution shown in Fig. 7. Core subsystem is made as OCX, so you can make the application program on several development environments (i.e. Visual Basic, Delphi, Borland C++).

(1) Geographic data comprised of vectors and connectors (KIWI+ format)

(2) Core subsystem that executes management, plotting, and search of geographic data

(3) Initializing information including feature space definitions

(4) Application subsystem that constructs a GUI and refers to and renews the attribute database

(5) Attribute database related to connector information

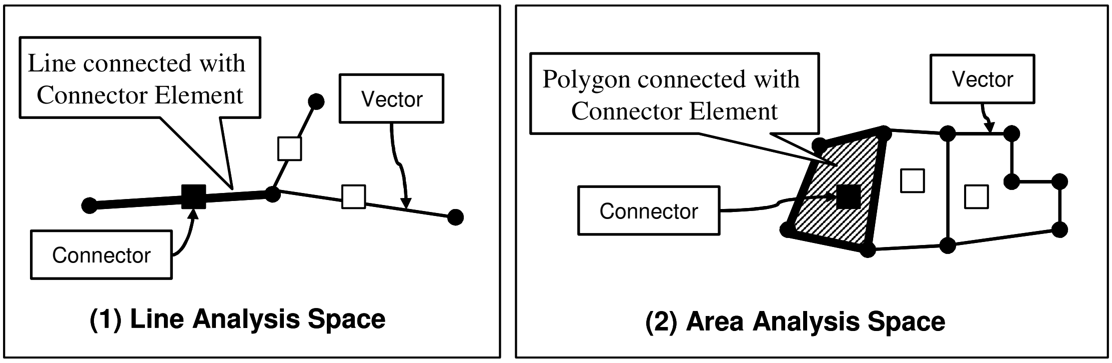


Fig.6 Feature Space (Line, Area)

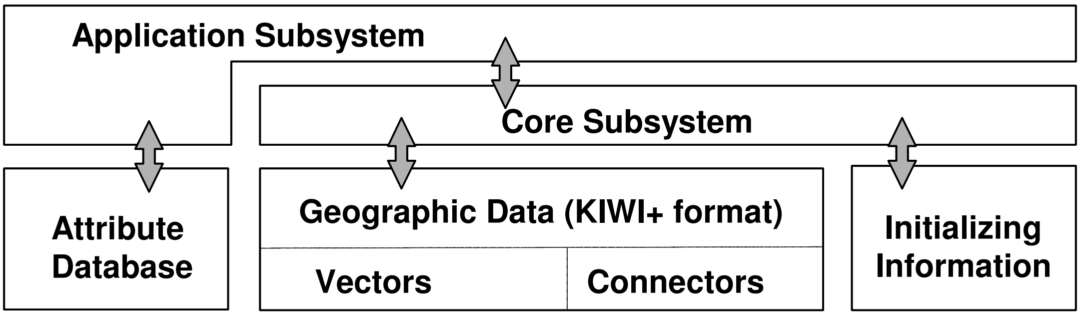


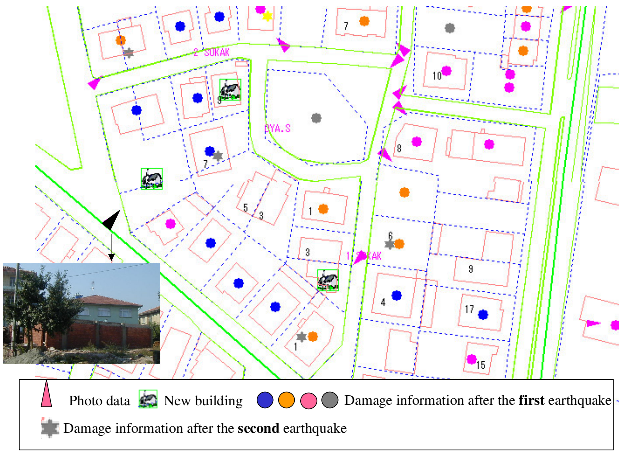
Fig.7 System Constitution

5. CONSTRUCTION OF DAMAGE DATABASE AND DAMAGE ANALYSIS SYSTEM BASED ON SPATIAL TEMPORAL INFORMATION SYSTEM

The application of DiMSIS to analysis of damage and recovery after two earthquakes in Turkey is different from the case of application to Hanshin-Awaji Earthquake. Firstly, damage and recovery data related to photograph were constructed by public officers in Düzce. After Hanshin-Awaji Earthquake, DiMSIS evolved to multi-country adaptive system. Multi-language can be used in DiMSIS and functional developing kits are available in Turkish to build local people's own system according with their preferences or regional cultures. Duzce's case shows that multi-country adaptive concept as well as other system concepts is accepted by local people. Secondly, damage and recovery analysis after two earthquakes damage really requires spatial-temporal information of people's activity as well as damage. If the second earthquake occurrence day and time are changed, the result on number of causalities might have been changed. Spatial-temporal analysis approach is necessary for Düzce 's case to understand the potential impact of two earthquakes. In addition, impacts of two earthquakes may cause larger mental damage for the people in this area compared to just one earthquake occurred. Comparative study of two country's case, Japan and Turkey in long-term recovery context is necessary. To reconstruct building damage data in spatial-temporal format is the first step to investigate further research on Turkey Earthquakes. Mapping of the building damage due to the two earthquakes can be done by other GISs, but a spatial-temporal GIS has the advantage that we can make an extended analysis by adding refuge pattern data after the first and second earthquakes and also monitor the recovery process after the disaster. More expansive results as well as recovery supports are expected by storing the information over time

The GIS data for the Uzunmustafar area in Düzce city, which is the target area of this research. Fig. 8 shows an example of the constructed database.

Fig. 8 Damage and Recovery Situation after the First and



Second Earthquakes (Small Damage, Medium Damage etc.)

6. ACTUAL CONDITION OF BUILDING DAMAGE

6.1 Classification of Building Damage

The evaluation type of the three damage data sets is based on the evaluating criteria based on the central government. The criteria can be explained as follows.

1) Small damage: There is no damage to the supporting system (foundation and pillar). For example, the surface of the partition wall has cracks.

2) Medium damage: Supporting system is damaged. Beam is damaged and pillar has small cracks. Wall is partly damaged. Supporting power becomes weak but concrete is not crushed and steel rod is not cut down.

3) Heavy damage and collapse: Supporting system is severely damaged. Pillar and concrete wall are heavily cracked and collapsed. Buildings are partly and completely collapsed and lean. In the second evaluation by the central government in Düzce city, the evaluation criteria “collapse” is used.

6.2 Statistical Trend in Buildings Damage by First and Second Earthquakes

Fig.9 is a map of Düzce city’s total damage. The heavily damaged area is the central part of the city and there are relatively high RC buildings. The damage types classified by number of stories. The ratio of medium and heavily damaged buildings over 3 stories becomes abruptly significant. It is known that there are many high RC buildings in the central part of the city and the damage degree in this area thus becomes high.

Building damage status on a more detailed spatial scale. This is the damage situation for each building in Uzunmustafar, which is one of the highly damaged areas in Düzce city. A star indicates the damage type, classified by the star types. It is painted over for the heavily damaged or collapsed buildings and hatched for the medium damaged buildings. Quite a few buildings are classified as heavily damages or medium damaged. In DiMSIS, the attributes are stored as these types of marks, and in general, the map objects with attributes are called connectors. Basically, we collect, sort, analyze and merge the connectors when we need to summarize and analyze the data in an arbitrary spatial scale. Base on the built GIS database, we can conduct a damage analysis for the first and second earthquakes.

7. INTEGRATING MAP DATABASES USING QUICKBIRD IMAGE DATA

Quickbird image data (QB data) showed in fig.10 was captured January 2003. Individual map database set of city area, new area developed by government and World Bank area by vector data are gathered. These three database set are measured independently with absolute coordinate. Matching has done by following procedure.

1) Give factor to QB data to match to map database of city area.

2) Add database of new area and check offset of image and vector data comparing certain object such as buildings or edge of roads.

3) Move vector data by the offset to match to the QB data.

This procedure can be justified because by the first step all the vector data and QB data has a good match all over the city. QB data of all area captured and corrected as uniform data can be treated as same accuracy.

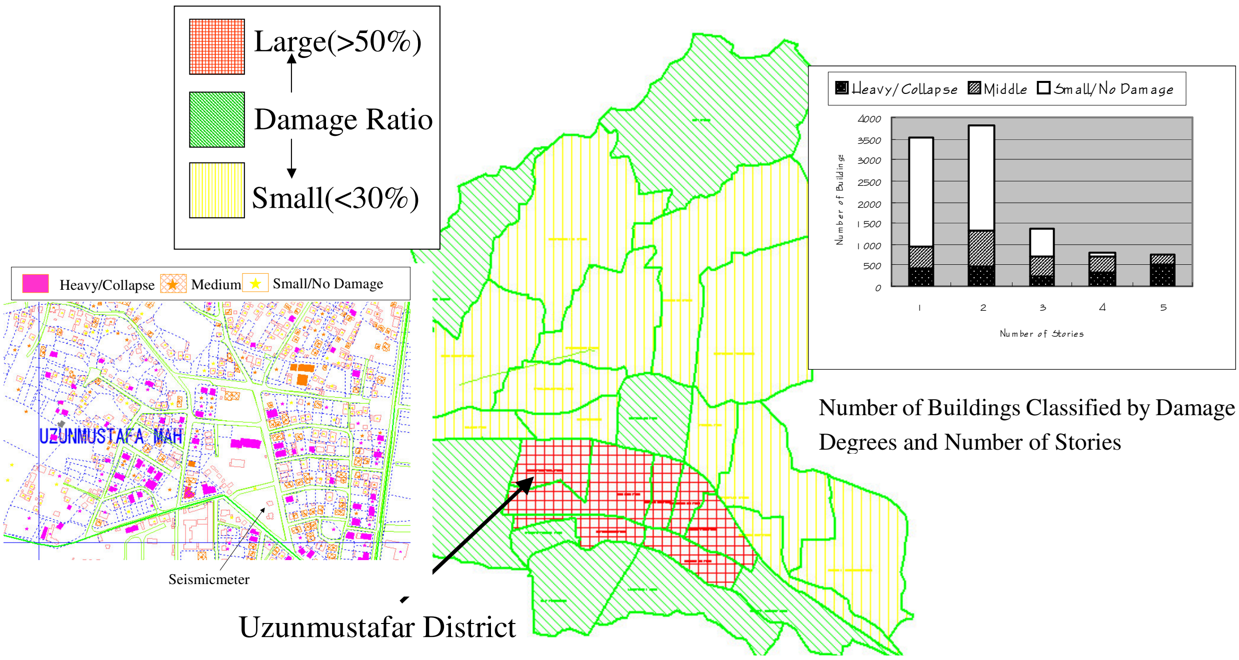


Fig. 9 Building Damage Status after the Second Earthquake

Fig10. Quickbird image data and integrated vector data

8. APPLYING QB DATA TO BAM EARTHQUAKE

Bam map database is required to analyze the damage of earthquake, however, such database was not available. QB image of before the earthquake is used to make vector data shown fig.11. Image comparison using QB images before and after the earthquake shown in fig. 12. Changed areas are detected automatically by image processing procedure in a 10 minute. Some change located out of the house area is detected. House damage is detected by selecting detected area by the outline of houses by vector data[5].

9. SUMARY

Spatial temporal GIS named DiMSIS has been developed after the Hanshin earthquake which is enhanced by applying for Duzce earthquakes at Duzce local government.

Quickbird image data is used for detecting change of city after the earthquake and also integrating the database set developed individually. QB image data and DiMSIS is also applied for analysis of Bam earthquake where map data was not available.

DiMSIS is wished to be one of the platforms of spatial temporal GIS which is developed focusing to realize culture based GIS with multi language(of cause including Turkish language). DiMSIS has been opened to who agreed to our concept of collaborative development.

10. ACKNOREAGEMAENT

This research is done as activities of “Special Project for Earthquake Disaster Mitigation in Urban Areas”, which was started by the Ministry of Education, Culture, Sports, Science and Technology of the Japanese Government started in April 2002.

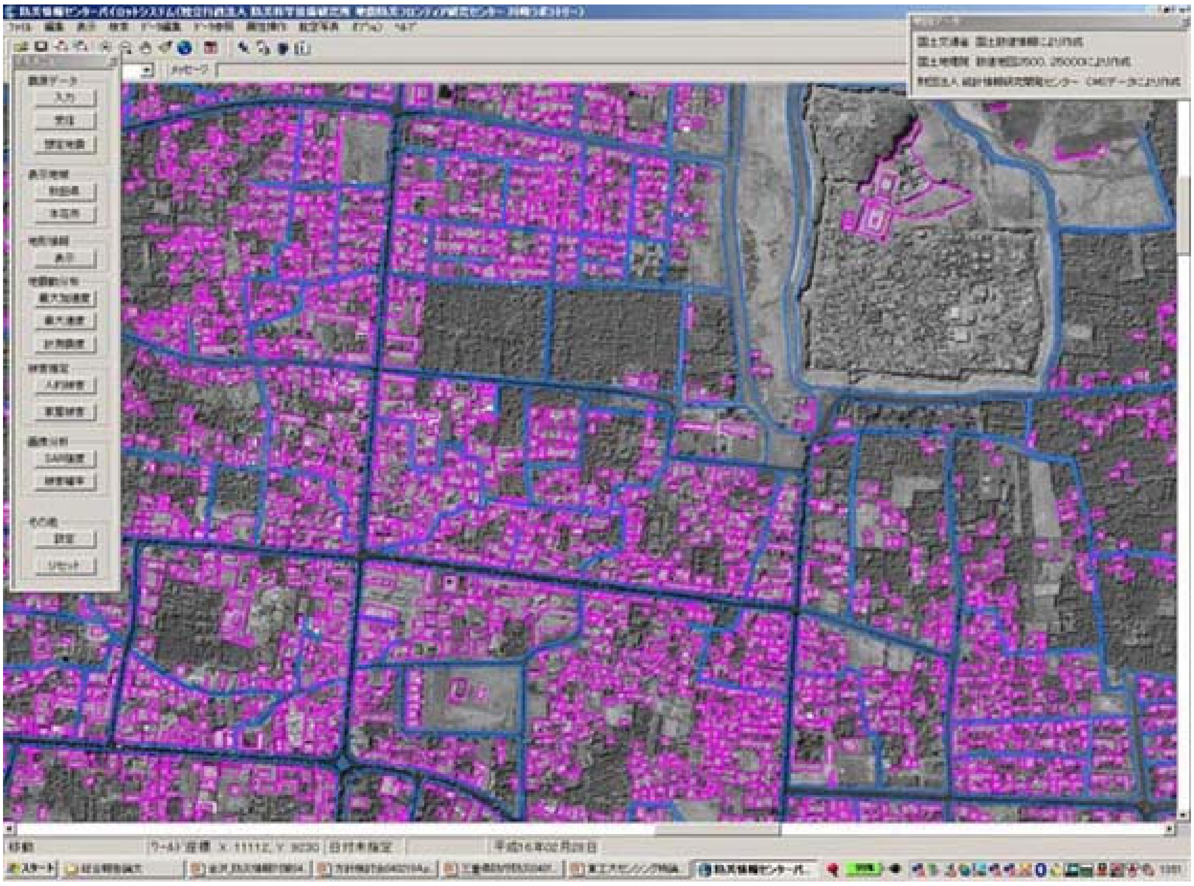


Fig11. Bam vector d and Quickbird image data before the earthquake

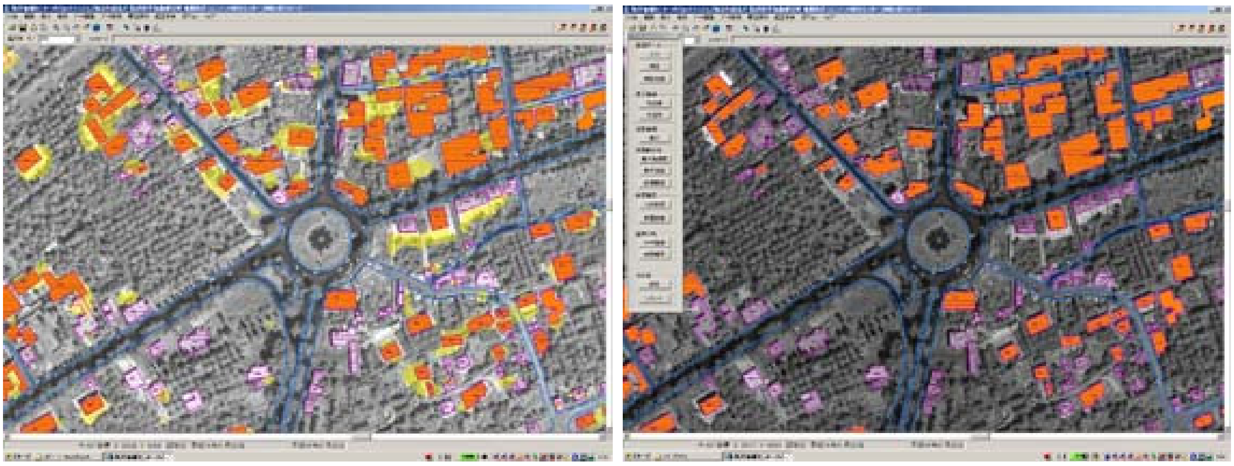


Fig. 12 Damaged house detected by comparison of Quickbird image data before and after

REFERENCES

[1] M. Hatayama, F. Matsuno, S. Kakumoto, and H. Kameda (1999) Development of Rescue Support System and its Application to Disaster Drill in Nagata Ward, Kobe City -For Realizing Risk-Adaptive Regional Management Spatial Information System (2)-, GIS'99 Conference Proceedings, pp.175-178.

[2] S.Kakumoto, M.Hatayama, H.Kameda, T.Taniguchi (1997) "Development of Disaster Management Spatial Information System (DiMSIS)", Proc.GIS'97 Conf., pp.595-598.

[3] M. Hatayama, K. Kakumoto, and H. Kameda, (2001) Development of Dynamic Management Spatial-temporal Information System - Application for Temporal Analysis of Census Data -, GIS2001 Conference CD-ROM.

[4] http://www.kedm.bosai.go.jp/

[5] http://www-kosugi.pms.titech.ac.jp/media20040129/index.htm