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# A STUDY ON OBJECT ORIENTED SEISMIC DISASTER PREDICTION - APPLICATION TO EVALUATION OF EARTHQUAKE GROUND MOTION -

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## ABSTRACT

A GIS is developed for the effective use of information for earthquake disaster mitigation. Data structures on information of disaster mitigation including fault data, soil data, and building data are analyzed using object-oriented approach. The dependency and spatial relationship among data sets are clarified, and databases are established. The GIS is designed as an integration system of a map system, data analysis systems and a wave analysis system. The GIS is implemented using X-Window and the application to earthquake disaster mitigation for Nagoya, Japan is presented.

## KEYWORDS

GIS; GUI; Object-Oriented Design; Earthquake Disaster Mitigation.

## INTRODUCTION

The prediction of damage level due to an earthquake, the immediate evaluation of the level once it occurs, and the support plan for the restration after the earthquake are important factors for seismic disaster mitigation. To deal with these factors appropriately, it is necessary to estimate the response of soil and structures during the earthquake based on the information. Since the amount and the variety of information is such enormous, the visual interactive support system in network environment using computer is required in order to search for data quickly and accurately and to analyze these data. Realtime earthquake disaster mitigation system become a popular subject in Japan (Ohta, 1994, Noda and Meguro, 1994). For realtime disaster mitigation, urban information needs to be prepared ahead of time, the disaster prediction system must be constructed, and the results should be visualized immidiately on a map.

In this paper, the integration of many databases related to earthquake disaster mitigation such as information on the source of earthquakes, soil, and city is discussed. The integrated analysis support system is also constructed to visualize the information from database and to analyze many conbined data interactively. Soil information and urban information around Nagoya, Japan are integrated. This system is designed as a object oriented GIS as designed by Fukuwa *et al* (1994). Information in this sytem is not only visualized, but also designated as an object. Many analysis methods in this system are designed as a button object and can be selected. This system is constructed using X-lib, X-toolkit, and Tcl/Tk on X-Window Release 6.

## CONSTRUCTION OF DATABASE

The characteristics of an earthquake ground motion at a site is determined by fault property, the path from the fault to the site, and soil property. The seismic resistance performance of the site needs to be examined considering the motion on the soil surface, which is obtained by multipling the motion on the bedrock by the amplication factor of the soil at the site. The motion on the bedrock is estimated based on the characteristics of the fault property and the path from the fault to the site. In this section, seismic information is classified as shown in fig.1 and arranged by OMT (Rumbaugh, 1991).

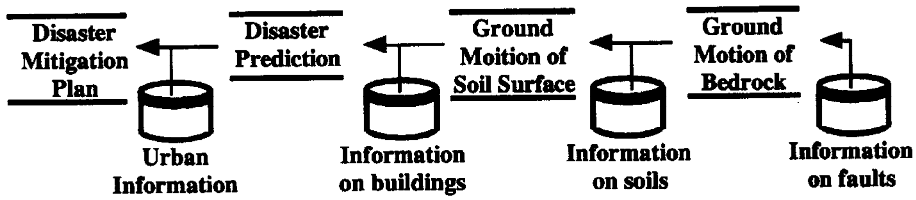


Fig. 1. Seismic information

### Information on faults and paths

The simulation of a motion on the bedrock under a site requires the information on the hypocenter and the path between the hypocenter and the site. As the information on the hypocenter, at least the location of the epicenter, the depth of the seismic center, and the magunitude of the earthquake are required. In order to get such information, active fault data (Fig.8A), hypocenter catarogue (Fig.8D) can be used. To estimate near-source spectra, the size of the fault and propagation process of destruction should not be ignored. The detail fault models of several past earthquakes (Fig.8B) are available (Sato, 1989) to estimate the bedrock motion considering the propagation process of destruction. If records of the strong motion are available, the bedrock motion on a large earthquake can be estimated considering the fault scaling by semi-empirical method. These factors are closely related one another in such a relation as the active fault - the hypocenter - the strong motion. Individual digital database on active fault data, past earthquake data, and strong motion records are collected. The database on fault parameters presented by Sato (1989) are constructed, and these database are integrated as shown in Fig.2. A precision method can be used if the deteal information such as fault parameters is available, otherwise a plain method with other data can be used.

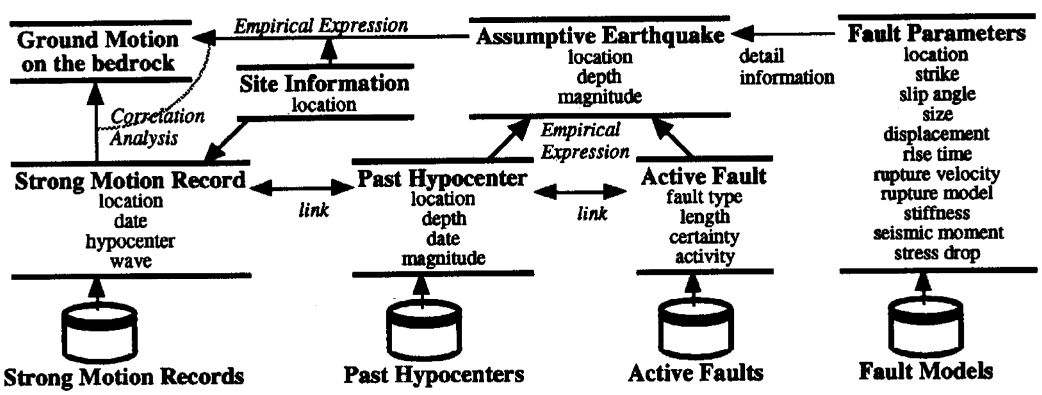


Fig. 2. Information on faults and paths

### Information on soils

Amplification property is different from soil to soil. In order to grasp the property, a soil velocity structure on the site is required. The soil velocity structure is directly estimated using ps-loggings. On the point for which no ps-loggings are available, the soil velocity structure is empirically estimated using boring-loggings shuch as the depth, the N-value, the soil kind, and the soil age. The interpolation between the discrete boring-points is required. The amplification property at long period must be estimated based on the structure at deep layers. If no boring-loggings at deep layers are available, rough soil structure maps such as a layer contour map and a layer cross section map can be used. In order to estimate the soil property under a strong motion, non-linear analysis is required using $G$-$\gamma$ and $h$-$\gamma$ relations.

The soil database around Nagoya was constructed. The data structure of database is shown in Fig.3. As the information on the interpolation and deep layers, contours of layer surfaces in the Geotechnical Data of Subsoils in Nagoya (JSSMFE-*Chubu* Blanch, 1988) and several other literatures were degitized. In order to estimate empirically the soil velocity structure from boring-loggings, the empirical expression is derived by the linear multiple regression model between ps-loggings and boring-loggings. In order to consider non-linear property of soil, the database on the dynamic deformation property of each layer age in the Geotechnical Data of Subsoils in Nagoya was constructed. As a result, when ps-loggings are not available, the soil velocity structure is estimated by empirical expression using boring-loggings. When boring-loggings are not available neither, the soil velocity structure is estimated using rough soil structure maps.

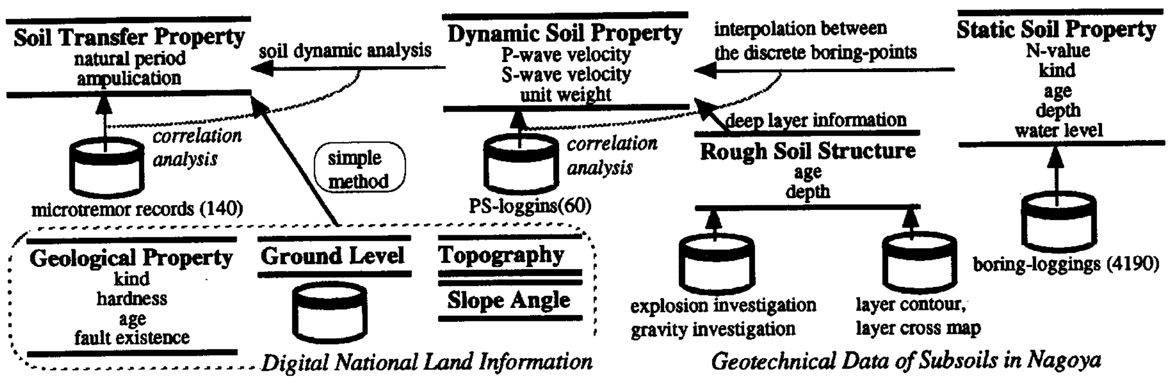



Fig. 3. Information on soils

Information on buildings

The building distribution in a site is an important information for the disaster prediction, the improvement plan, and the rescue plan. Important attributes such as building structural type, age, number of floors, and usage can be obtained from building ledgers . The attributes of each building is required in the analysis of micro area, while total results in a macro area are required in the analysis of the macro area such as city and prefecture. In order to analyze continuously from a macro area to a micro area, it is necessary to systematize the class of administration areas on computer such as prefectures → citys → towns → blocks → buildings, and to construct a framework which interactively visualizes arbitrary level of total results for many kinds of condition patterns of building attributes. The visualization of each administration area requires polygon of the area; however, construction of the database of the polygon of administration area requires a lot of work. When databases on the polygon are not available, these total results are transformed into mesh and are visualised as shown in Fig.4.

Urban information

Grasping traffic networks such as roads and railways is important especially on the rescue plan. The seismic resistance capacity of each road or railway should be estimated, and the reinforcement should be carried out if necessary. Grasping lifeline networks such as electricity, gas, and tap water is important on secound disaster mitigation and restration plan. Predictions of earthquake injury and mortality require to grasp the population composition during day and night. The seismic resistance capacity of public facilities such as shelters and hospitals should be evaluated. In this system, databases on roads, railways, public facilities, political boundaries, coast lines are constructed using the Digital National Land Information. The Digital Map 10,000 and the ZENRIN Towns Map are also used as ditail geogralic information. At a result, many kinds of data can be analyzed considering the constitution of the city and the location.

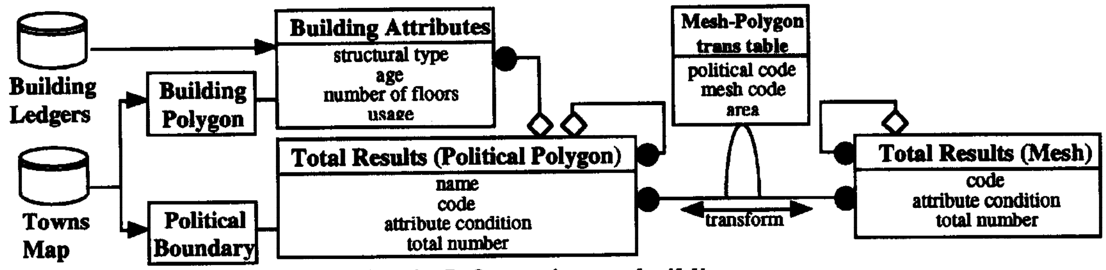



Fig. 4. Information on buildings

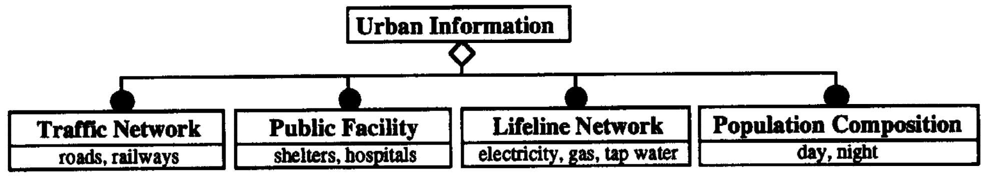



Fig. 5. Urban information

## CONSTRUCTION OF SYSTEM

### Constitution of system

There are many types of information on the urban earthquake disaster prediction. Cross analyses of these data are important on the disaster mitigation. The object oriented visual interactive framework are required for these analyses. On the framework, objects in many kinds of database are shown together on one map, objects are analyzed in detail if necessary, and results are shown immidiately on the map. The wave analysis system is also required to invoke many kinds of wave operation such as multiplication. The system introduced in this parer is the integrated earthquake disaster prediction system which consists of the subsystems : a map system, individual systems, and a wave analysis system. Data flow image is illustrated in Fig.6.

### Map system

The map system arranges objects on a map. Each class of objects is linked to the corresponding individual system which can be called by clicking the object with mouse. There are many types of information from macro data such as those shown in Fig.8A and B to micro data such as those shown in Fig.9C. In this system, these data can be used effectively; objects can be shown or hiden changing parameter on attribute conditions and scale conditions. The relationship between the map system and individual systems is shown in Fig.7. When the scale of the map is changed by mouse drag as shown in Fig.8A→C and Fig.8C→E in the map system, the system sends message 'redraw' to each individual system which actually knows how to draw. When the object is indicated in the map system, the map system sends message 'pickup' to the individual system. As a result, the integrated system is designed as an object oriented system; few modifications in the map system are required when a new individual system is added.

### Individual system

An individual system is designed for each class such as active fault system, soil system, and building system. These systems are called from the map system, and analysis data in the object communicating with the wave system and the map system. The result can be feed back to the map system. Examples of the soil system are shown in Fig.9C-F. By showing the boring points on the map system, arbitrary cross section of the soil at the site can be indicated. When the cross section of the soil is indicated, the soil cross section system is called, and the soil amplitude factors can be analyze in the system.

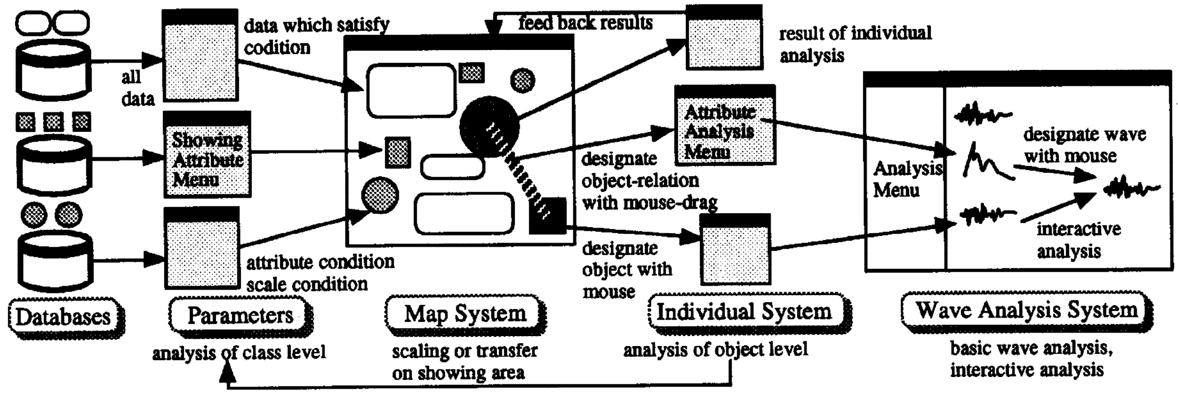


Fig. 6. System flow

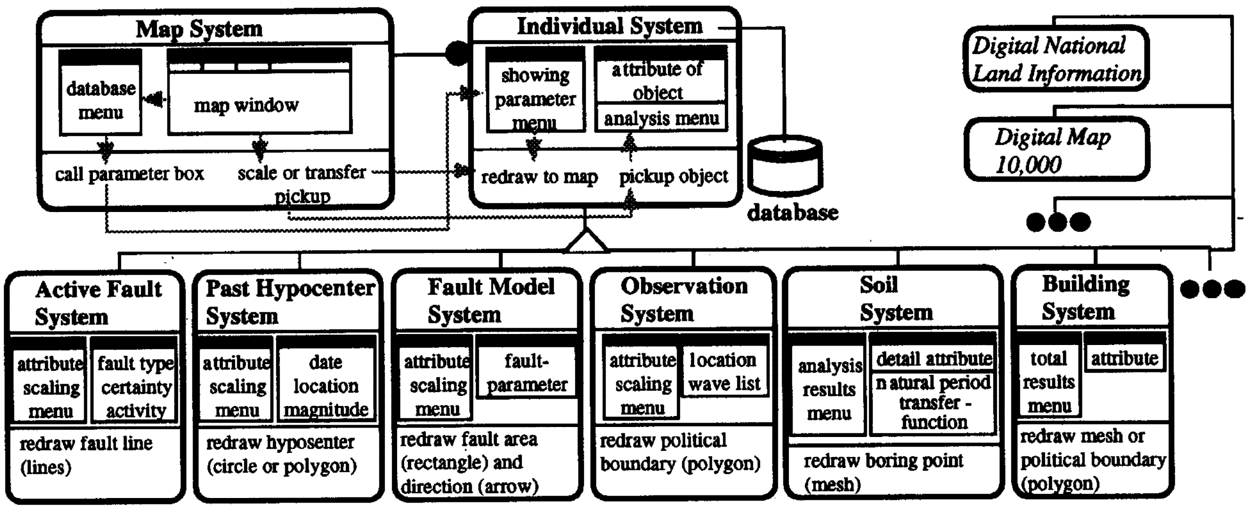


Fig. 7. Relation between map system and individual system

Wave analysis system

The wave analysis system invokes wave operation interactively. This system is called by one of individual system if necessary as shown in Fig.8H and 8F. It analyzes waves when the individual system requests. The interactive analysis in the wave system is also available using the button on GUI. Several basic command for wave analysis such as FFT is already available, addition and extention of new button is easy.

## EXAMPLES OF APPLICATIONS

An example for using information on fault property and path to simulate the motion on the bedrock is shown in Fig.8. Fig.8A-D illustrates the example of active faults, earthquake fault models, past hypocenters, and strong motion records. Fig.8E-H show examples of the simulated motion on the bedrock using these data effectively.

An example for using information of soil on Nagoya city is shown in Fig.9. Fig.9A shows the base heights of the alluvium from boring information and Fig.9B shows base heights of the alluvium digitized from the contour of the Geotechnical Data of Subsoils in Nagoya. Fig.9D shows the soil cross section map indicated with mouse drag. Fig.9E shows details of the boring indicated with mouse. When 'Transfer Function' button is push, the transfer function from bedrock to surface of the soil is estimated by the multiple reflection theory, and the result is shown in the wave analysis system as shown in Fig.9F. The motion of soil surface is estimated interactively multipling the transfer function by the motion on the bedrock in the wave analysis system. A predominant period map (Fig.9G), an amplitude map (Fig.9H), and a peak acceleration map are made repeating these steps for all area of Naogya.

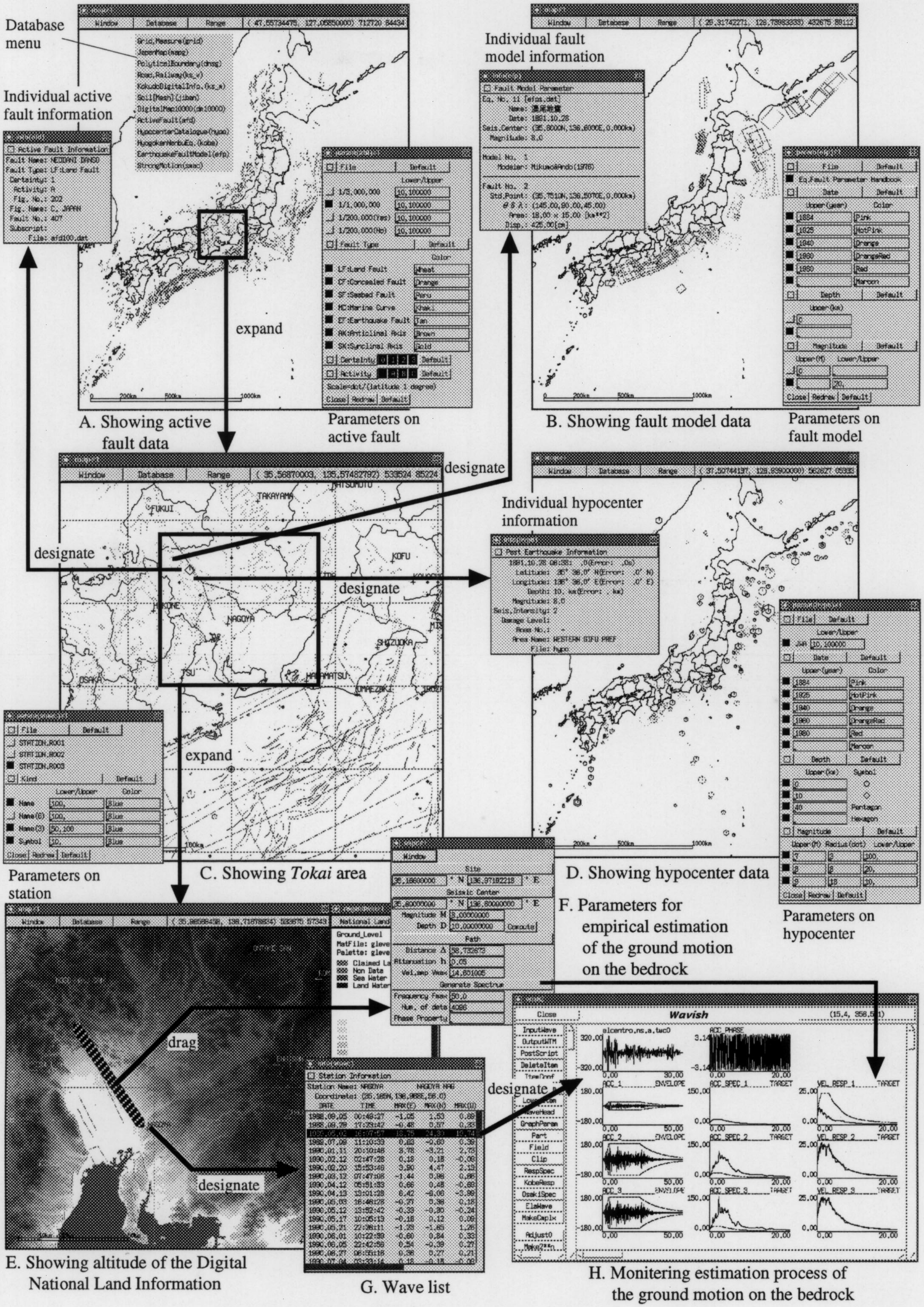



Fig. 8. Example for using information on faults and paths

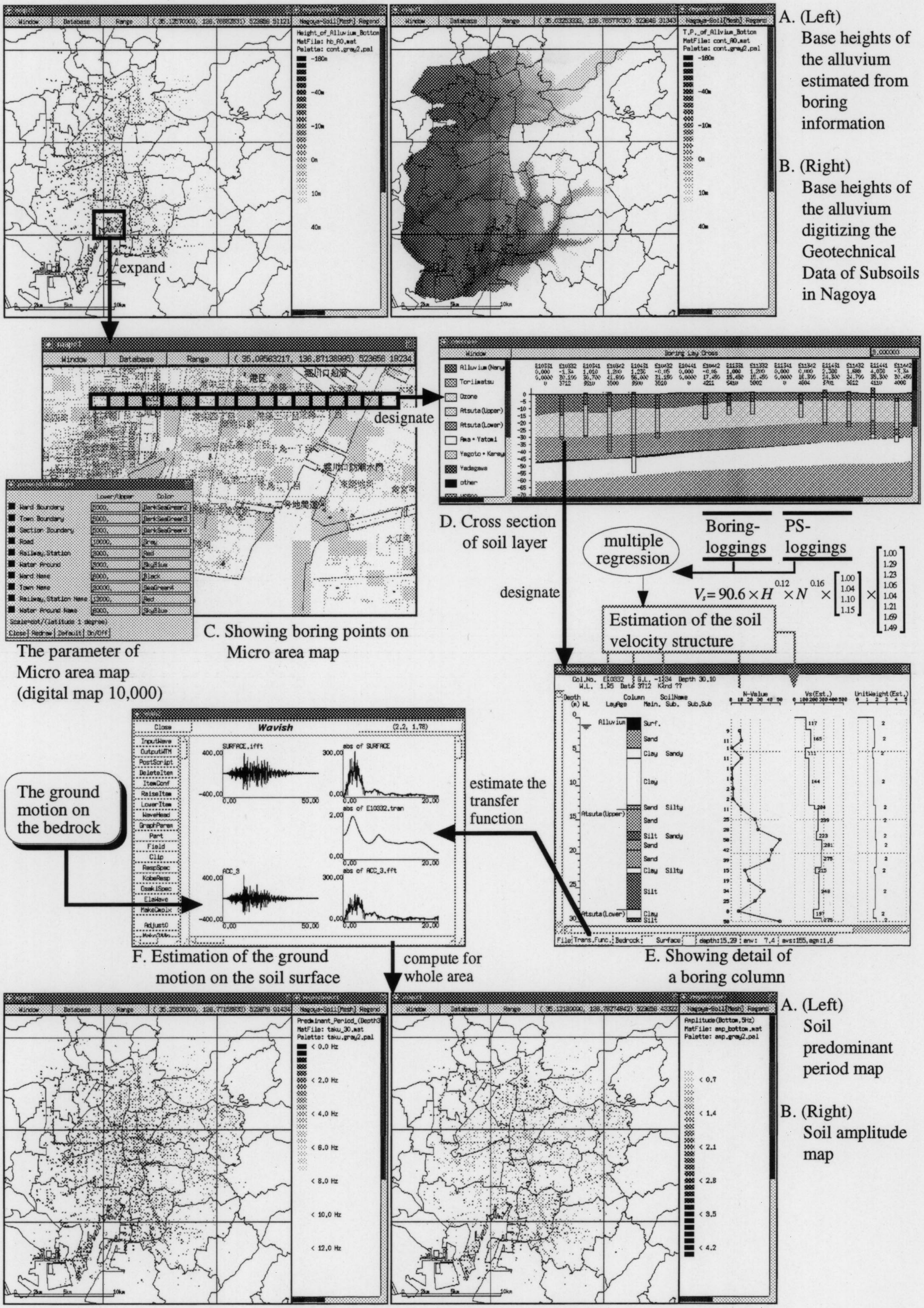
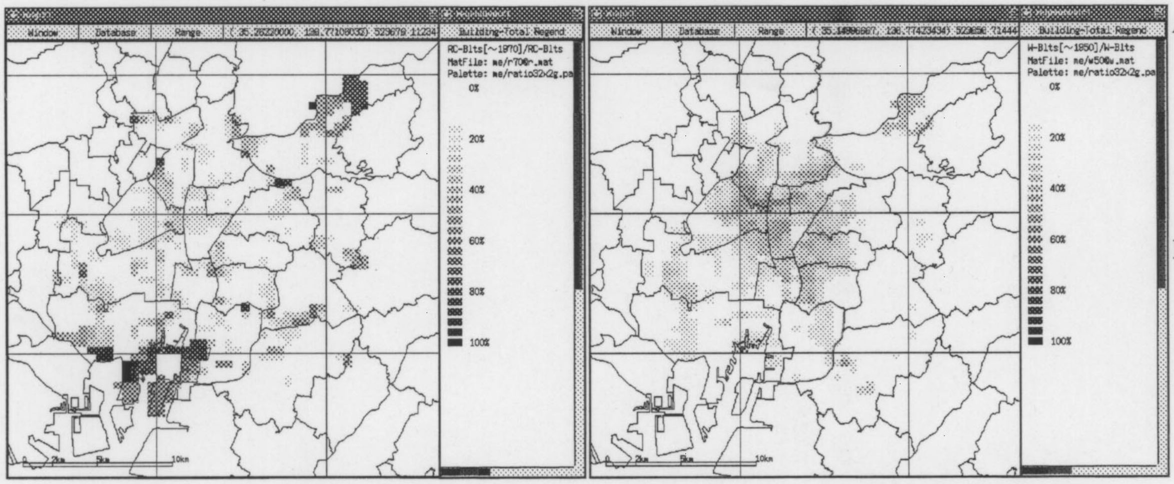



Fig. 9. Example for using information on soils




A. (Left)
Rate of RC buildings built before 1970 to all RC buildings

B. (Right)
Rate of wooden buildings built before 1950 to all wooden buildings

Fig. 10. Example for using information on building distribution

The map of the rate of RC buildings built before 1970 to all RC buildings is shown in Fig.10A. The map of the rate of wooden buildings built before 1950 to all wooden buildings is shown in Fig.10B. This system can estimate total results about arbitrary combination of attributes such as the type of structure, building age, the number of floors, and usage.

## CONCLUTION

In this paper, information on the earthquake disaster mitigation is consolidated and the integrated database is constructed to use effectively many kinds of databases on fault properties, paths from faults to sites, soils and buildings. The integrated urban earthquake disaster prediction system was also constructed to visualize these databases and to analyze them interactively. In future, it is expected to fulfill urban information such as roads and railways, and to introduce many kinds of hazard analysis methods. It is also expected to establish the expert system which can select automatically the suitable method and analyze database structures of these objects in detail.

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