

WEBGIS SIMULATOR FOR PROMOTION OF SEISMIC RETROFITTING AND COMMUNITY DISASTER MITIGATION ACTIVITIES

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ABSTRACT :

One of the most important aspects of disaster mitigation in urban areas is the preparations residents take to make their own houses, towns and their living environments safer. This paper describes a newly-developed information system dedicated to promoting such actions and describes its application to the community disaster mitigation practices of the residents themselves. The system is based on a simulator that provides realistic scenarios, based on actual seismic hazards, in order to help each resident gain awareness of his/her own hazard level, and to comprehend the need and methodology for preparations. The simulator is built around a web-based online geographic information system (WebGIS) and integrates a series of subsystems to provide features including a high-resolution hazard map system capable of making three-dimensional birds-eye overviews, a system for evaluating earthquake ground motion at a specific location as well as a system for simulating the earthquake effects and the possible collapse of a wooden house at the site, including risks of falling indoor furniture. Furthermore, to provide additional information on seismic hazards and disaster mitigation, various related programs that utilize online systems including WebLog, Wiki and other interactive interfaces have been incorporated. The system is also designed to assist user-groups that want to discuss and make preparations against disasters. The WebGIS-based system also makes it possible for user-groups to create and maintain their own disaster maps, and use those maps for disaster mitigation activities in their community. The system is already in use by various local communities and continuous development is projected.

KEYWORDS: Hazard maps, Wooden house, Geographic information system, E-learning, Workshops

1. INTRODUCTION

In seismically active areas, it is impossible to protect people without making efforts to mitigate earthquake damage. As the greatest amount of damage resulting from earthquakes has historically been caused by collapsing buildings, it is necessary to make buildings as safe as possible, as soon as possible. Ideally, this is the responsibility of building engineers, but since most buildings are private assets, the effectiveness of a building's retrofit also depends on the level of each resident's awareness.

Disaster mitigation can be considered from the following four viewpoints: people, knowledge, possessions, and money. For example, the promotion of seismic retrofitting requires the development of resident awareness (people), the establishment of laws and systems that promote seismic retrofitting (knowledge and systems), the development of inexpensive and effective reinforcement methods (possessions and technology), and the creation of programs and economic incentives (money). The most important and difficult factor is the creation of awareness, especially in developed countries, because other three viewpoints have almost overcome in such countries. To develop resident awareness, it is important to train leaders tasked with the dissemination of information (people), develop effective methods for dissemination of an effective education curriculum for

disaster prevention (knowledge), create educational materials for dissemination (possessions), and convince people that the process is affordable (money).

However, because the number of disaster prevention experts is relatively small, it is difficult to reach each resident directly. This is because, as shown in Figure 1, the development of each resident's awareness requires not only the cooperation and efforts of various experts; the participation of mediators that have the ability to contact local residents is also needed. (These include volunteers, community leaders, non-profit organizations, mass media, teachers, cooperatives, enterprise groups, and student circles.) To motivate such people to participate in disaster prevention activities, it is necessary to cultivate awareness and create environments where the mediators can actively assist in the development of resident awareness. One way to create such an environment is to develop useful educational materials.

Disaster prevention activities start with the awareness of one's own risks regarding earthquakes. If people are aware of the risks they face, they can learn the causes of such risks and find ways of avoiding them. At that point, each organization or family can plan and implement countermeasures. After that, it is a good idea to repeat the PDCA (Plan-Do-Check-Action) cycle as shown in Figure 2. The difficult part is creating an environment where people can become fully aware of how earthquakes occur. This step requires the efforts of people who can motivate residents into obtaining a proper level of awareness as well as the production of useful educational materials. In response to that need, this paper describes a newly-developed information system designed to promote such actions, and describes their applications to the community disaster mitigation practices by the residents themselves.

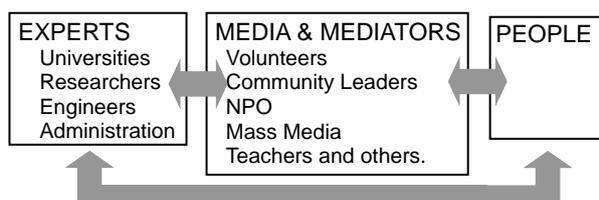


Figure 1 Development of resident awareness by experts and media cooperation

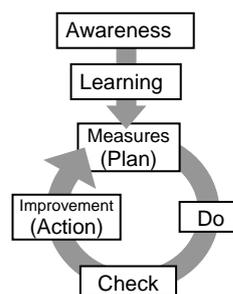


Figure 2 Procedure for disaster prevention activities

2. OUTLINE OF WEBGIS SIMULATOR AND ITS APPLICATIONS

Figure 3 shows the procedures for improving community disaster mitigation activities by use of the proposed disaster information and education system. The system is based around a simulator that provides realistic appraisals of hazardous conditions in order to help each resident become aware of the hazards in his/her own environment and learn both the necessity for, and the actual steps involved, in preparing for those hazards. While the system can also be used as a tool to assist facilitators in carrying out disaster prevention activities, its primary purpose is to encourage residents to carry out disaster prevention activities themselves by providing them with the education materials that will help them regard earthquake dangers as familiar and solvable problems.

A series of subsystems have been integrated using WebGIS to provide the following tools: a high-resolution hazard map system capable of showing expected earthquake shaking intensity and liquefaction based on the actual geological conditions of an individual site; a three-dimensional birds-eye view system that shows the history of specific areas; a simulation system for earthquake ground motion utilizing high-resolution surface soil models; a system for simulating the possible collapse of a wooden house after considering the site's predicted earthquake ground motion (as well as a simulation system that shows the risks posed by falling furniture). To provide additional information on seismic hazards and disaster mitigation, various other online e-learning tools based on WebLog, Wiki and other interactive interfaces have been developed and introduced.



Figure 3 Outline of procedure for improvement of community disaster mitigation potentials and activities

With these systems, residents can easily acquire knowledge on earthquake hazards, seismic activity evaluation methods, and practical ways of retrofitting their houses and securing their furniture. Web-based technologies make possible not only the integration of the subsystems, but also easy and interesting ways to utilize the system at any time.

The system is also designed to be available for user-groups that want to discuss and make preparations against disasters using the WebGIS map system. This system is designed to make it possible for users to create, maintain and use their own disaster response maps for disaster mitigation activities. The function is an effective way to support residents who wish to lead community disaster mitigation activities.

3. WEBGIS-BASED SIMULATOR FOR PROMOTION OF SEISMIC RETROFITTING

3.1. *WebGIS high-resolution hazard maps*

Figure 4 shows examples of the WebGIS view windows. Figure 4 (a) is a start window. The two maps show different (yet related) features for the same area and are connected in terms of movement and magnification/reduction. Using them, it is possible to analyze various damage prediction results by comparing aerial photos and topographical data. With this system, residents can also readily understand earthquake damage predictions.

Community disaster prevention starts with learning about the community. Users can select the information he/she wants to study from the menu on the left side of the window, while referring to the map. The map scale and display area are selected by mouse operations. For example, if a resident clicks on the location where he/she lives, the window shown in Figure 4 (b) displays the address and an information outline of the selected area with details such as: estimated seismic intensity, liquefaction risk, characteristics of the topography and the ground, industrial, commercial, and residential characteristics, building characteristics, and the age distribution of residents.

Figure 4 (c) shows 40 years of change for an area using aerial photos while Figure 4 (a) shows a comparison of the predicted seismic intensity and an aerial photo. Figure 4 (d) shows a comparison of the predicted liquefaction and a topographical classification map. The sample area is located on a hill where a valley and a ridge meet. Examining these figures help residents comprehend the risk of seismic shaking and potential liquefaction (which are strongly related to topographical features) and observe how things have changed over the past decades.

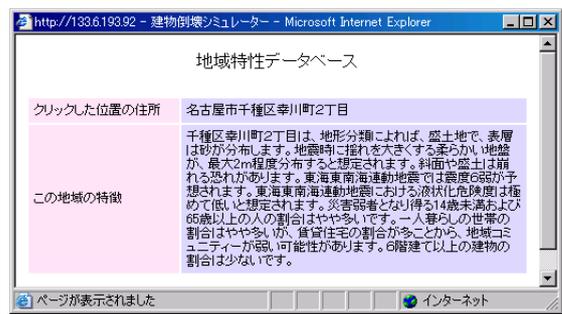
Changes in the area's topographical features are also shown in figure 4 (e) and 4 (f) using a three-dimensional birds-eye view. The view is a composite of aerial photos that takes into consideration data on sea level states. Observing changes to the sea level over the past 40 years, at each point, make it possible to show the distribution clearing and filling (in the lower right of Figure 4 (f), the blue area shows clearing and the red area shows filling). This view is created by real-time three-dimensional programming, which is a common technique in the field of dynamic and interactive web content development. As shown in Figure 4 (f), it is possible to change the screen by moving the mouse and to make position changes (including moving, revolving, zooming in and out on the screen and changing the point of view) by dragging the mouse. It is also possible to review past history of the area by dragging the time bar. Because residents can easily visualize the changes in topography around their houses, they can more fully understand the relation between seismic activity and topography.

3.2. *Simulator of seismic ground motion at a specific site*

We developed algorithms for estimating the soil velocity structure shallower than the engineering bedrock and estimated seismic ground motions at the position of the engineering bedrock by the statistical Green's function method. We used this information to estimate the surface soil structure at a certain point and then constructed an earthquake response simulation system. As shown in Figure 5, if a point on the GIS is clicked, the system gives soil model estimates for that point. After the soil response is calculated, the system displays an animation of



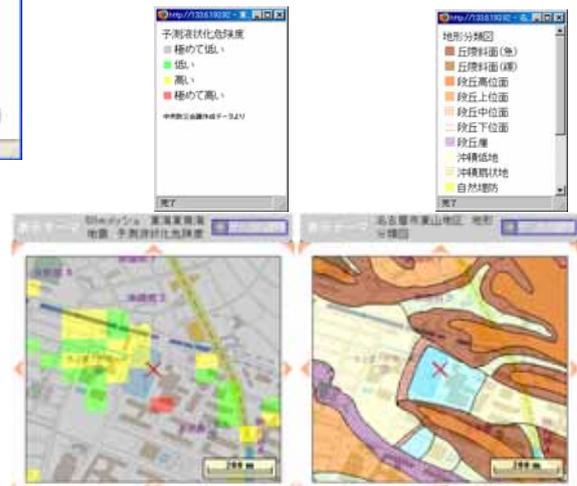
(a) WebGIS window example



(b) Outline of selected area (in Japanese)



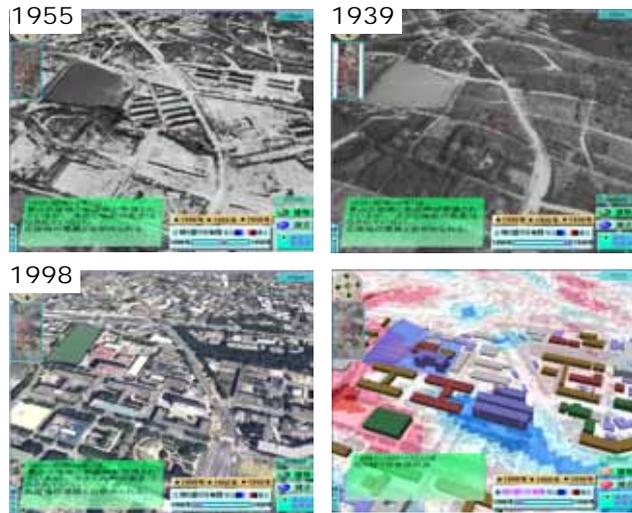
(c) Aerial photos (left:1963, right:1998)



(d) Potential liquefaction(left), topological classification (right)



(e) Three-dimensional birds-eye view of WebGIS



(f) Changes to topographic features over 40 years

Figure 4 High-resolution hazard map created via WebGIS and its effective application from a three-dimensional birds-eye view

earthquake occurrence and the soil response for the site, as shown in the right side figure. This simulation enables residents to see the vibrations applied to their houses and comprehend the relation between soil hardness and its response. Photo 1 shows a specially-developed shaking table facility that allows a realistic experience of simulated ground motions and building responses.

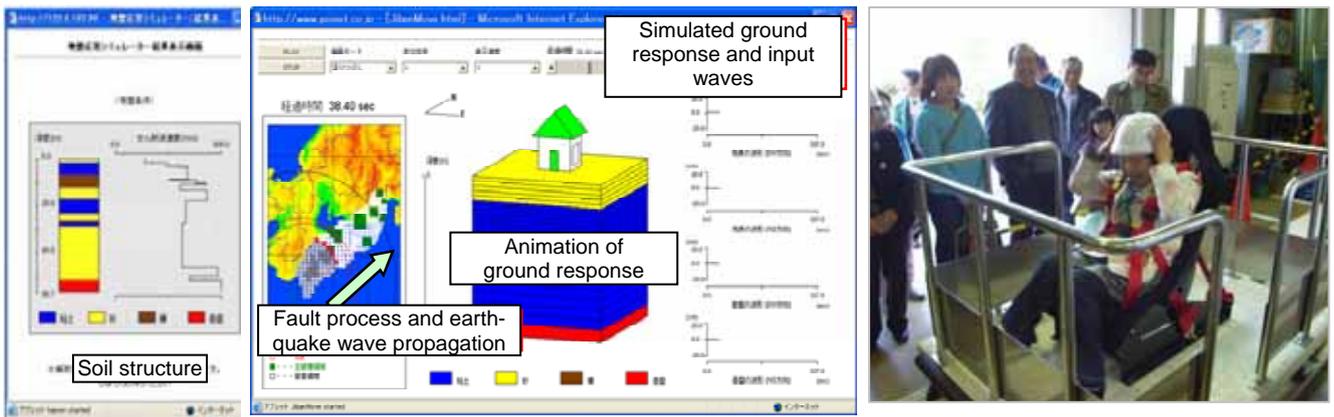
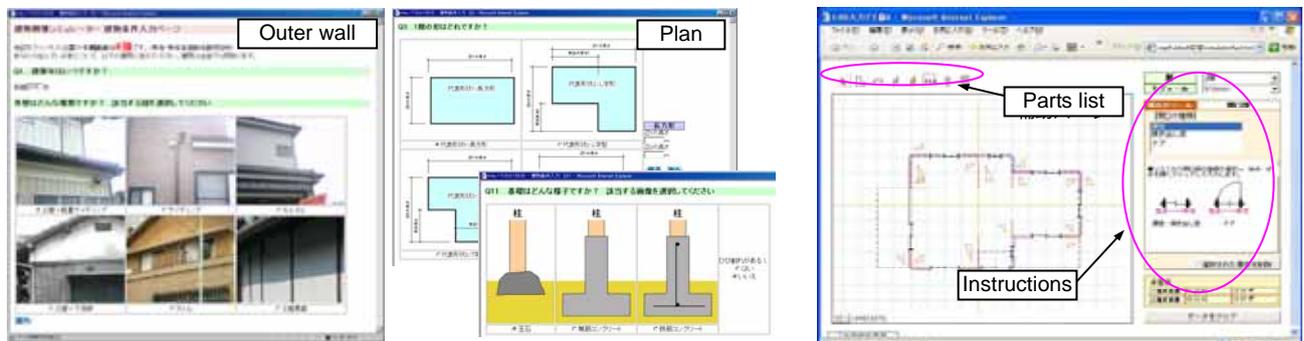


Figure 5 Earthquake response simulator for the ground surface of a selected site Photo 1 Shaking experience

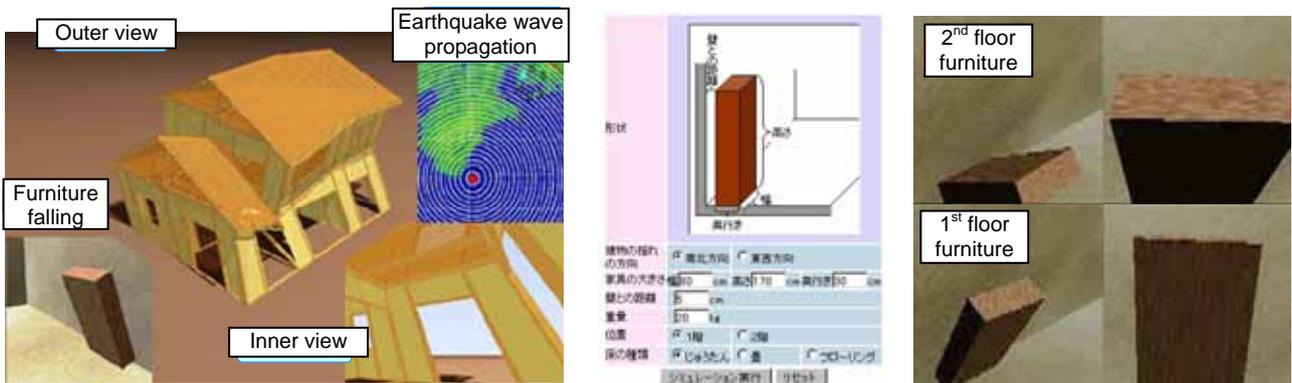
3.3. Simulator for earthquake damage to wooden houses and falling furniture

This system was developed as a way for residents to check the seismic capacity of their own houses. There are two input methods for two-story wooden houses. One, shown in Figure 6 (a), is a relatively simple method that allows residents to input basic details on their houses, such as the year of construction, using web-based choices. The other, shown in Figure 6 (b), is a more detailed input method and takes into consideration the actual plans of the house using an online Web-based CAD system. For both methods, as described in section 3.2., earthquake response analysis will be performed for the generated model subjected to the simulated earthquake ground motion at the site. Figure 6 (c) shows the animated result of response analysis. Simulation results that show house collapses will be referred to websites dedicated to seismic activity evaluation and retrofit in order to encourage the user to begin countermeasures. If the house does not collapse, the falling furniture simulator begins. The user will then be asked to input the floor on which the furniture is placed, the



(a) Simple input method using webpage-based choices

(b) Detailed input method using Web-based CAD



(c) Animated response simulation results

(d) Input window and the results of the furniture falling simulator

Figure 6 Simulation of house damage and falling furniture based on an individual's house and furniture

size and weight of the furniture, the type of floor furnishings, etc. Once this is done, the furniture’s response is analyzed based on the response waveform and displayed as an animation, as shown in Figure 6 (d), after which, the user is guided to websites promoting the safety of indoor environments.

4. LEARNING TOOLS WITH EFFECTIVE INTERFACES

The next step for residents who have become aware of their seismic risks and the importance of disaster mitigation action is education. To facilitate this, we have developed and tested various learning tools and materials regarding ground vibration and building responses, seismic capacity and effectiveness of retrofit, and other related knowledge. These include a series of vibration experiment education materials collectively known as “BURURU” (Fukuwa et al. 2008), which demonstrate fundamental and important points by use of simple physical tools and online simulation software. One of the most popular examples of the BURURU series is a paper model two-story house kit and user manual that can easily be downloaded and printed. The paper model can be used to explain the importance of roof weight, the effects of cross bracing, and the balance of walls. Such hands-on educational materials are effective for supplementing virtual information systems. Other types of e-learning assets have also been prepared concerning disasters and disaster mitigation. For example, in order to show the effectiveness of furniture falling countermeasures, videos showing comparative experiments on shaking tables (using by various prevention methods) can be viewed on the Internet. These tools make it easy to confirm the effects of falling furniture prevention measures.

To assist in the development of such e-learning materials, we have utilized new technologies to create and navigate between numerous online resources. One such is an application of the “Wiki” system, which we have used as the foundation of a disaster mitigation knowledge database. Figure 7 shows an example. The Wiki system is widely used on the Internet and has proved to be an effective method of building databases because it operates by soliciting the collaboration and contributions of many users. Another example is an interactive conversation interface designed to provide easy access to the web-based e-learning system. If a user verbally asks the system for answers to even vague questions, an appropriate reply will be generated using familiar web-address navigation tools (Figure 8).

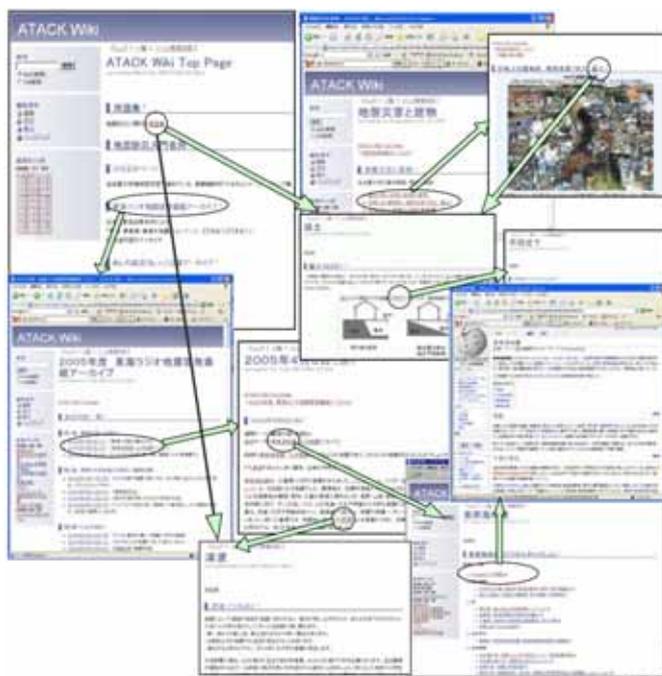


Figure 7 Wiki for disaster mitigation knowledge base



Figure 8 Bururu interactive conversation interface

5. SUPPORT SYSTEM FOR COMMUNITY DISASTER MITIGATION ACTIVITIES

Developed systems have been tested during actual community disaster mitigation activities. One of the most popular uses of the system is the creation of hazard maps by residents that are based on their own knowledge and information. Figure 9 shows an example of an online community hazard map created by the proposed system in conjunction with a newly developed input interface based on “WebLog.” WebLog is a popular interface for making web-based diaries known as “blogs”, and can provide an effective foundation for the continuous activity needed to make and use such maps. Photo 2 shows active discussions during a workshop of community members. If facilitators or leaders can guide the group discussions, it is not necessary for each participant to use the computer system individually.

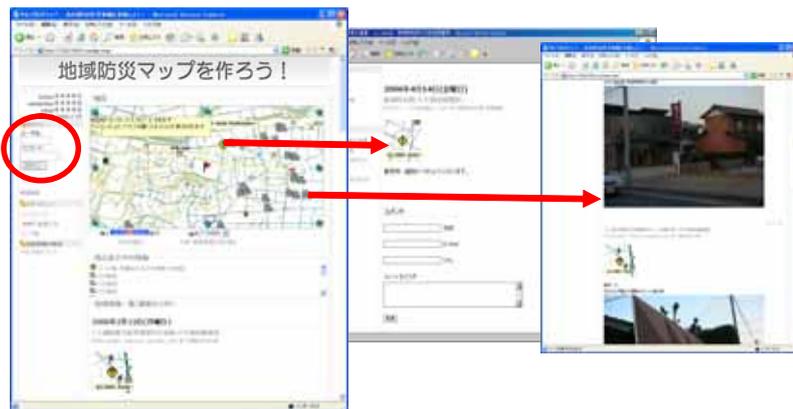


Figure 9 Community disaster mitigation map system produced by WebGIS with WebLog interface



Photo 2 Community disaster mitigation workshop using newly developed systems

6. CONCLUSION

In this paper, we discussed the development of a disaster information system built around a simulator that provides realistic seismic hazard scenarios in order to help each resident become aware of his/her own hazard level and learn the need for, and methods of, home seismic retrofitting. It is clearly shown that WebGIS-based systems are capable of providing a hazard map database in an easy-to-understand interface. Furthermore, it can be easily seen that the simulator is effective in helping individuals evaluate their own environments as they pertain to ground shaking, earthquake response, possible house collapse and indoor safety. The system has also proved to be an effective part of community disaster mitigation activities.

In April this year, a fully-active version of this system was activated on the Internet website of Japan's Aichi Prefecture government, and a separate institution was also opened in Aichi prefecture to provide information on disasters and disaster mitigation activities utilizing the proposed system along with various other kinds of realistic educational materials. Application of the system to various communities is ongoing and new developments are expected for the future.

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