13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No.3186

SIMULATION OF SEISMIC HAZARDS ON THE INTERNET USING VRML FOR BRIDGE STRUCTURES

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SUMMARY

This paper reviews the state of the art on risk communication to the public, with an emphasis on simulation of seismic hazards using VRML. Rapid growth computer technologies, especially the Internet provide human beings new measures to deal with engineering and social problems which were hard to solve in traditional ways. This paper presents a prototype of an application platform based on the Internet using VR (Virtual Reality) for civil engineering considering building an information system of risk communication for seismic hazards and at the moment in the case of bridge structure.

INTRODUCTION

Traditional computer applications in civil engineering are mainly for analysis, design and construction of buildings and other structures, which are basic components of social infrastructures. No doubt computer technology has been promoting productivities in the engineering aspect, but few successful efforts have been made in solving social and human related problems, such as disaster mitigation in cases of earthquakes, fires etc.. As computer technology is changing rapidly, people have more opportunities to cope with more complicated issues. On reviewing state-of-the-art computer techniques and relative applications, this paper discusses problems and challenges concerning implementing an information system of disaster mitigation for metropolises. Then, the paper presents a prototype of an Internet oriented platform with an initial implementation using Virtual Reality (VR).

TOWARDS DISASTER MITIGATION IN METROPOLISES

Computer applications in civil engineering are relatively less advanced comparing with other areas, such as mechanics. This does not mean that problems in civil engineering are simple. In fact, engineering codes, which design and construction works base on, 'filter' excessive complexities from nature and structures by statistics and past experiences and simplify design procedures. But natural disasters, such as

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earthquakes, fires, floods etc., again and again teach people more that their experiences and efforts are insufficient to protect social properties and human lives.

To take severe earthquakes as an example, catastrophic economic losses around the world are huge and increasing in last decade. The 1995 earthquake in Kobe, Japan (Fig. 1) and the 1999 earthquake in Chi Chi, Taiwan, for instance, caused losses about $120 and $10 billion respectively. Loss estimates for a repeat of the 1923 Tokyo earthquake exceed $1 trillion [15]. Metropolises are vulnerable under attacks of severe earthquakes. The disaster causes not only damage to buildings, structures but problems in society.

Earthquakes, as a kind of natural catastrophe, are of low frequency but high consequence. It is difficult to accumulate experiences. Though proper handling of seismic behavior of a building or a structure is essential, it is still quite a local issue on concerning disaster mitigation for metropolises. During the 1995 Kobe earthquake, the traffic service system in the emergency situation experienced substantial difficulties as considerable damage happened in elevated bridges (Fig. 1) [16]. Collapsed buildings can also block roads. Fires during the earthquake may ruin several areas within a city for lack of emergent rescue (Fig. 2).

Figure 1 Collapse of elevated bridges in 1995 Kobe earthquake

All the above-mentioned issues will cause losses of lives directly or indirectly. During an earthquake, city infrastructures such as power supply, electronic communication etc. might be out of their functions. Communication with the public becomes quite important for saving lives and keeping order of the society. To find efficient ways for communication should be a problem.

Figure 2 Areas damaged by fires during the Kobe earthquake

On conducting an information system of risk communication and disaster mitigation for metropolises, following basic targets are set so far as concerned for the application platform:

1) High precise simulation for natural disasters (such as earthquake generator according to faults) and structures (such as recreation of damage and collapses of structures)

2) Integrated applications and data which can represent major factors of infrastructures for a living metropolis

3) Be capable of providing and distributing information, which is useful to and can be easily accessed by estate owners, city administrators and the public, establishing mechanism to communicate with the public reciprocally

The platform is targeted to provide information for all the stages of before, during and after disaster happenings in metropolises.

Starting work on simulation of a real bridge in the system

The pedestrian bridge reported herein is a cable-stayed-type with two-span continuous steel box girder (Figure 3). It has a two-plane multistory cable system. The total bridge length is almost 179 m and the width of the road deck is about 5.25 m. The bridge is adjacency to a boat race stadium and connects the stadium and a bus terminal. After big boat races, more than 20 000 people sometimes pass over the bridge within 20 min or so, and the bridge becomes very congested; as many as 2000 pedestrians walk simultaneously on the bridge (Figure 3). Under this situation, not only vertical vibration but also noticeable lateral vibration in the girder was often observed. Some of the cables also vibrated with large amplitudes. This bridge is at Saitama Prefecture in Japan. A very exiting feature of this bridge is that it vibrates obviously due to pedestrians. So we can compare real vibration and virtual model of vibration of bridge structure. Figure 3 shows a view of this bridge in congested condition. In this situation bridge starts vibrating.

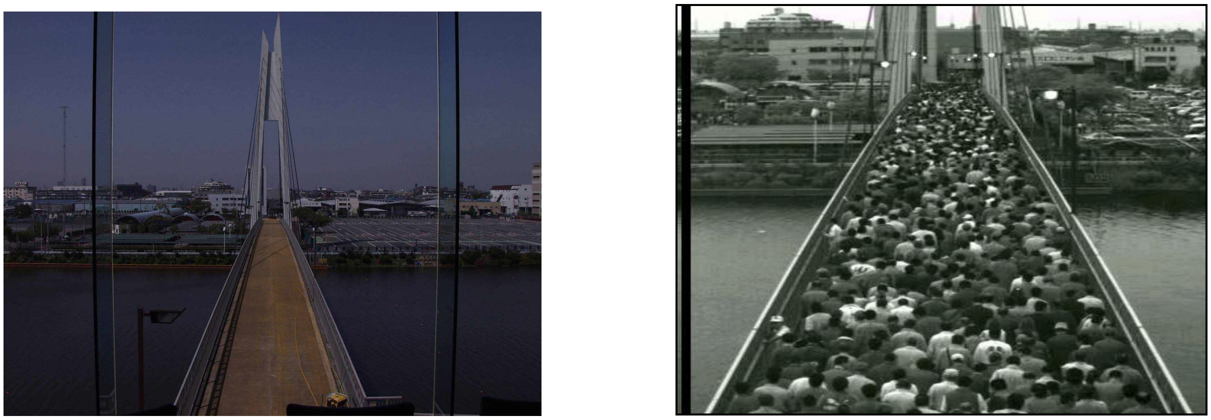

Figure 3 A view of real site, Toda Bridge(left) in Japan and Congested condition of it (right)

This bridge is located at Saitama prefecture in Japan. Since the area around this bridge is called TODA, people used to call the bridge with the same name: TODA Bridge.

ANALYSIS AND COMPUTING SEISMIC RESPONSE OF THE BRIDGE IN SAVE

A general-purpose dynamic analysis program for bridges, GDABS (Graphical Dynamic Analysis of Bridge Systems) has been implemented (figure 4). A general-purpose dynamic analysis program for bridges, GDABS (Graphical Dynamic Analysis of Bridge Systems), has been developed. GDABS implements 3D models of bridge structures presented in previous section. Newmark-β method is employed in this program for numerical integration. Algorithms of matrix manipulations, such as solving linear equations, computing eigenvalues, are coded on referring Reference.

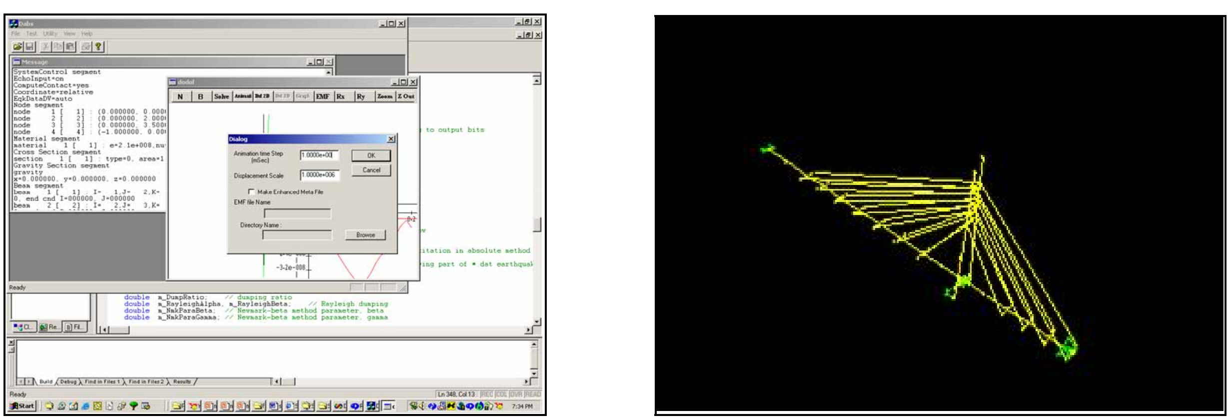

Figure 4 The bridge analyzed by GDABS, a view of GDABS's GUI

Written in C++, GDABS takes advantages of object-oriented programming to realize numerical models for bridge structures. A free-formatted text file input interface has been designed to model bridge structures and to give computing and output conditions.

PROTOTYPE OF THE APPLICATION PLATFORM

To achieve targets of the application platform for disaster mitigation, nowadays advanced computer technologies, as reviewed in previous part of this paper, can help people to cope with engineering and social problems which were hard to solve in traditional ways. A distributed application platform based on the Internet is a reasonable solution for hosting such a complex system with versatile resources. Furthermore, the Virtual Reality (VR) technology, which becomes more mature, can play an important role on performing 3D detailed presentation for various purposes.

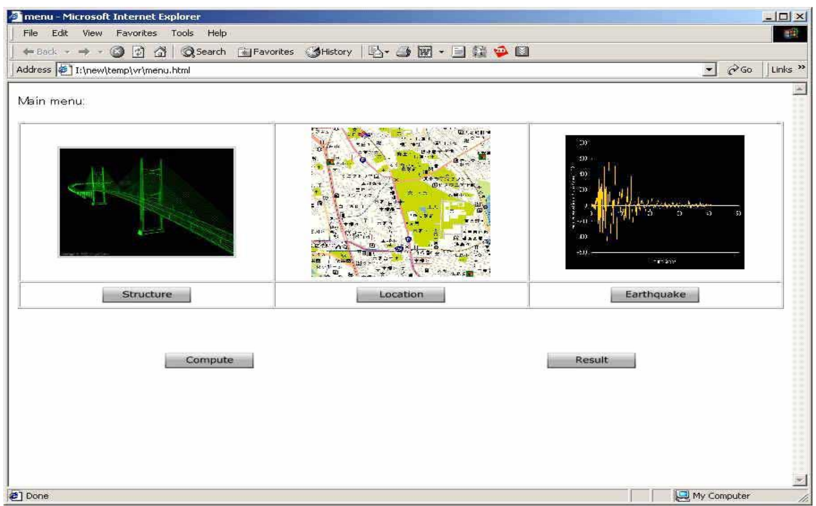

Figure 5 A view of interface of the system

It can be seen, to establish an information system of risk communication and disaster mitigation for metropolises, a complex system is needed. To meet targets set for the application platform, following functions are concerned for implementation:

1) Data management, to collect and to keep updating data (geographical, structural data etc.) with unified format.

2) Precise simulation of physical phenomena and consequences, including ground motion, structure seismic response, fire etc. in both macro and micro levels.

3) Evaluation of damage and economic losses based on simulations from scenarios.

4) Presentation and communication, to show results to different audiences (such as professionals, governors, estate owners and the public) with different methods; to collect information from the public.

5) Integration of the system, to bring all the above together for a living system.

6) Robustness, performance of the system and ways of communication during occurrences of disasters

Fig. 5 illustrates concepts of the interface of the platform. Each functional parts are liked together without considering their physical locations. General audiences have their entry point at a web server with web browsers and client-end applets and applications; while professionals can utilize resources along with the platform, such as to access databases, to invoke dense computations and to cooperate with others.

The above picture shows still simple and basic ideas for conducting the system. To introduce the Internet into the system is not only for it can integrate resources and applications for a collaborative solution but also for it can be an effective way of reciprocal communication in a society. Traditional applications (such as a seismic analysis program) provide solutions, as shown in the upper part of Fig. 6, by local computation, which means both user and machine are in a same physical location. To shift traditional applications into a web-oriented environment, generally speaking, interfaces should be separated from the main applications and the interface for output should be able to perform on the client end (Fig. 6). This makes it possible for people to access applications from the web.

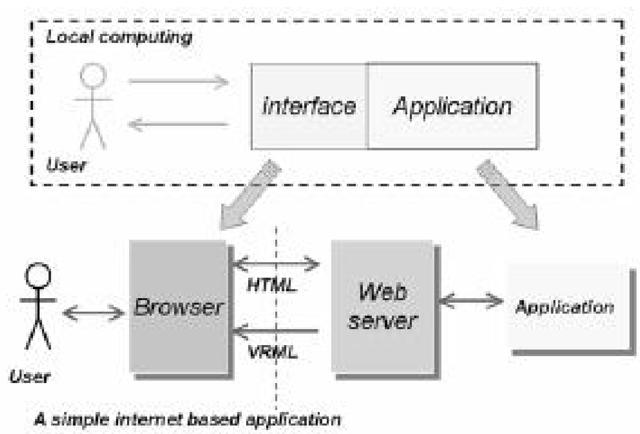

Figure 6 A perspective view of the distributed platform

In a complex system, no single application can complete the task for final solutions. Fig. 6 shows a distributed environment based on the web. For communications between applications at server's part and also between client-end applets/applications and server applications, XML (Extensible Markup Language) will play an important role. XML has been claimed the most exciting and significant thing to hit the Internet since HTML.

XML is a metamarkup language by providing arbitrary structures for one to make his/her own markup language. For sharing data among applications for seismic analysis, a special XML, which might be called Structure XML or StructureML, can be initiated for purposes of structure analyses, damage evaluation, result presentation etc..

SIMPLE IMPLEMENTATIONS WITH VR

As a first step towards developing this platform, a post-processor of a dynamic structure analysis program has been implemented with VR based on simple web application.

The term of Virtual Reality originally referred to Immersive Virtual Reality, which means that users become fully immersed in an artificial 3D world that is completed generated by computers. Nowadays, the term VR is also used for applications without fully immersive. The boundaries are becoming blurred.

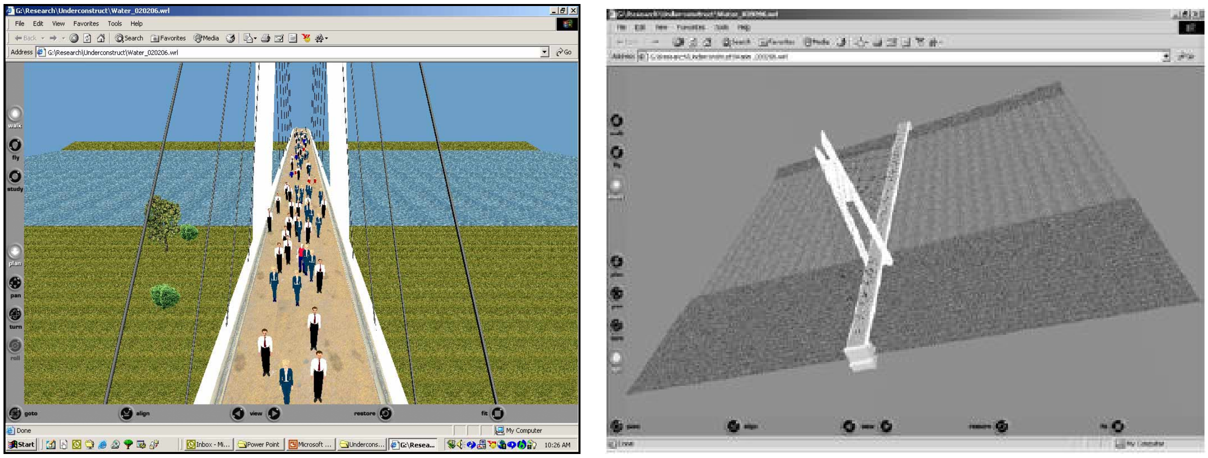

Figure 7 VR model of cited bridge (Toda Bridge), its seismic response during KOBE earthquake (right) and human behavior during earthquake (left)

A practical way to perform VR, especially along the Internet, is to use VRML, which stands for Virtual Reality Modeling Language [17], [18]. VRML is an open standard for 3D multimedia and shared virtual worlds on the Internet (ISO/IEC 14772-1: 1997). It is the de facto standard for sharing data between CAD (3D modeling) and animation programs. VRML is a text based scene description language. It is not a programming language but can have scripts, like JavaScript.

VRML can be used to present structures and to convey 3D scene from the Internet. Fig. 7 shows a suspension bridge authored with VRML. The model bridge can be displayed interactively using a web browser with a VRML plug-in.

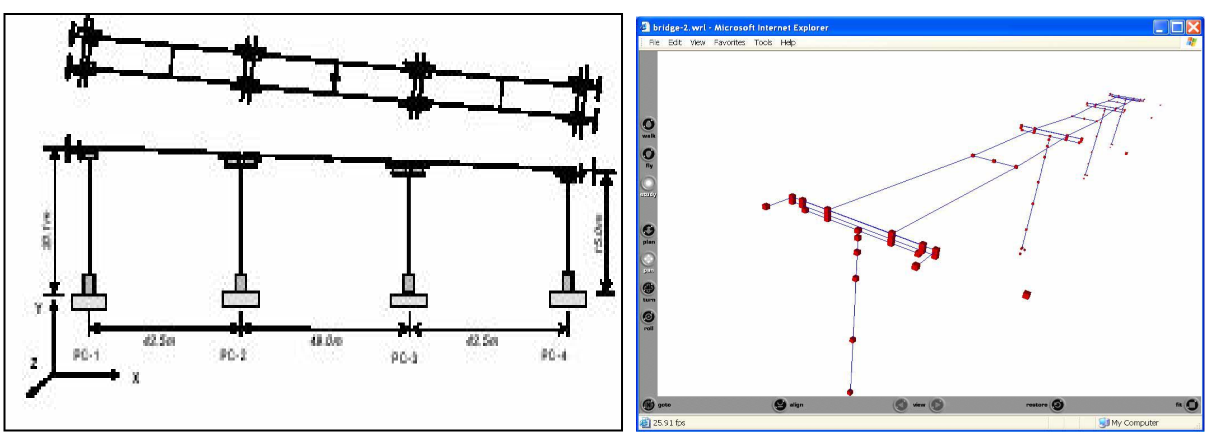

Figure8 Seismic analysis of a steel elevated bridge (left) and the response presentation using VRML through Internet Explorer (right)

More practice of VR has been made based on a work of a general-purpose 3D dynamic analysis program for bridges. The program performs seismic analysis of elevated bridges based on precise 3D modeling [19]. Fig. 7(left) shows a three-span steel bridge analyzed by the program. A new output interface of this program has been added to convert results of dynamic response of the bridge into VRML. Animations of vibration can be seen through a VRML viewing tool, such as a web browser with VRML plug-in (Fig. 7-right). Good results are obtained on promoting seismic response presentations using VRML. Users can navigate through the scene to find more details of seismic response of the bridge, which are difficult to be acquainted by traditional 2D charts.

CONCLUSIONS

Upon reviewing relative computer techniques and discussing demands on conducting an information system of risk communication and disaster mitigation for metropolises, this paper depicts challenges faced by engineering professionals to solve not only engineering but economic and social problems. To meet this multidisciplinary task, the paper presents a perspective of solutions with a distributed application platform based on the Internet and VR technologies. Techniques to shift traditional engineering applications to web environment and to share data according to XML have been discussed. As a first step towards this platform, simple implementations with VR have also been demonstrated.

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