Simulation of Seismic Hazards on The Internet using VRML for Bridge Structures

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Abstract

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.

Key words: Virtual Reality, VRML, FEM, TODA Bridge, Earthquake, Simulation

1. Introduction

The advent of risk-informed regulation creates new challenges for risk communication, including how to explain the process of risk informed regulation and effectively communicate risk informed decisions to the general public. The objective is to propose a new method and idea for communication of a risk particularly in the case of seismic hazards. 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 seismic hazards. Then, the paper also presents a prototype of an Internet oriented platform with an initial implementation using Virtual Reality (VR).

2. The idea of using VR for risk communication and developing a system called SAVE

There are four key elements for an effective communication system: [1]

1. Trust and credibility are the basis of all successful communication efforts:

G = T + C

(Goal is to build trust & credibility.)

2. Everyone's views and beliefs are shaped by their perceptions:

P = R

(Perception equals reality).

3. There are tools and techniques you can use to improve the effectiveness of your communication:

T + T = EC

(Tools & techniques equal effective communication).

4. Effective communication requires commitment:

EC = C

VR can be applied as a technology to improve the effectiveness of communication. Actually the best way of communication is Verbal Communication. It can be considered as a real communication. VR is the closest way to reality. Using VR we tried to make a real time communication system which is so similar to a verbal communication. VR can effect directly on second and third factor and indirectly on two other factors.

Difficult concepts in numerical analysis for structures such as FEM and risk analyze especially for common people, have limited structure analysis in engineer's confine merely. Earthquake is a disaster that takes place with different probabilities in different regions so people do not care about their structure dynamic design adequately. This matter makes a big problem in existing communication and simulation system in the case of seismic hazards to the public. In addition to conduct numerical computations, one of the most important and exciting technology for engineering application might be man-machine interface, or most commonly called user interface (UI) or graphical user interface (GUI). Tremendous efforts have been made to achieve good communication between human beings and computers since the initial work of computer graphics from later '60. Virtual Reality (VR), which becomes more popular recently, is one of the most important technologies [2]. VR through the Internet has been noticed as an important technique for human-computer interaction [3]. Efforts have been made to promote human interactions with computer based systems more effective and smooth using techniques including VR [4]. Engineering oriented applications have also employed VR technique for presentations and interactions. Reference [5] used a CAVE (CAVE Automatic Virtual Environment) to implement an interactive finite element analysis (FEA) system, which can provide an easy way to access numerical results visually. Reference [6] implemented a virtual wind tunnel for dynamic visualization of CFD (Computational Fluid Dynamics) using immersive virtual environments. VR utilized in landscape visualization has great potential to generate practical panorama representation to serve architects [7]. Reference [8] introduced a system for landscape design using Virtual Reality Modeling Language (VRML) on the web. To combine with web based Geographic Information Systems (GIS), Reference [9] discussed about to build virtual cities on the web with a project of Virtual London. While virtual reality aims to create pure artificial world, another useful technique named augmented reality (AR) supplements the real world with coexisted computer-generated virtual objects [10]. Reference [11] showed an interesting application, the MagicBook, which has potentials in education as well as engineering applications. Some techniques for refining the user interface of mobile augmented reality systems were presented in Reference [12]. As the VR technology becomes mature, especially with the promotion of the Internet based technologies such as VRML, which allows navigation and simple interaction with 3D world on general PCs, people are thinking more about simulations of the real world and society. Reference [13] examined a multi-user virtual environment over the Internet, the Activeworlds, which allows people to build their own world and can simulate geographic and social interactions in a simple level that reflects to the real world. As an example of engineering applications, Reference [14] described concepts of the virtual building from design, construction and maintenance perspectives. The virtual building was defined as "a formalized digital description of an existing or planned building which can be used to fully simulate and communicate the behavior of the real building in its expected contexts". It can be seen that continuous endeavors are needed to achieve the target.

In a brief, techniques for user interface, such as VR, are more popular, powerful and affordable. On the other hand, the popularity of the Internet makes unprecedented opportunities for distributed communications between men and machines.

Traditional applications in civil engineering, such as structure analysis and design systems take GUI technique from Computer Aided Design (CAD) as core parts of applications [15]. Though a lot of details from analysis, design and construction are involved in applications, it is difficult to reuse and share the data resource as it is expected by implementing the virtual building. To separate data resource from applications based on web environment and techniques might be a good attempt to promote both a versatile data resource and flexible applications.

To build an application platform for disaster mitigation in the case of seismic hazards, state-of-the-art computer techniques, notably the Internet and VR technologies, as it can be seen from the above review, provide more opportunities for making a complex system which is capable to solve both engineering and social problems. The system is called SAVE which stands for Survive in Avatar Virtual Earthquake.

Figure 1 Congested condition of TODA Bridge

3. Starting work on simulation of a real bridge in SAVE

The pedestrian bridge reported herein is a cable-stayed-type with two-span continuous steel box girder. 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. 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 1 shows a view of this bridge in congested condition. In this situation bridge starts vibrating. 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.

4. 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. 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. 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.

5. Internet Oriented Platform for SAVE

As the Internet tools of the information, communication, and computing technology revolution became integrated into the risk communication, the traditional classroom reliance on the lecture format becomes increasingly anachronistic. There are dozen to perhaps hundreds of accessible web sites that contain materials that maybe appropriate to the teaching of Risk.

However, 'visiting' web pages by pointing, clicking, reading and viewing can only engage the public superficially. SAVE's server software can be linked to the other computer programs (called common gateway interface or CGI scripts) that create new documents 'on the fly' in response to remote requests from the user. Distributed Java 'applets' and scripts can empower the public with dynamic content within a web page. A Virtual Attractive Model (V.A.M) guides user to communicate to server as a virtual friend. V.A.M teaches to the user what's earthquake, VR, SAVE, how to cope in real earthquake and examines the user. Using user's answers (*post* method in *html form*), computation and image generating starts at server-side. Users can survive longer in virtual earthquake of SAVE according their ability to learn from and reply to V.A.M. *Compatibility*, *Flexibility* and *Simplicity* principles make it necessary to test SAVE under different platforms and OS such as Mac, PC, Win, Unix, IRIX. 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.

It can be seen, to establish an information system of risk communication and disaster mitigation for seismic hazards, 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

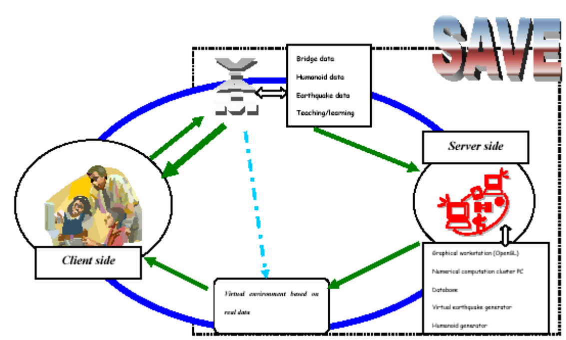

Figure 2 Outline of the system

Fig. 2 illustrates concepts of this 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. 2, 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. 2). This makes it possible for people to access applications from the web.

In a complex system, no single application can complete the task for final solutions. Fig. 2 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..

6. 4D model of structure and simulation of seismic response during KOBE earthquake

VR is a strong tool that can help us to mitigate earthquake disaster by showing real data in a virtual and attractive world to the public. VRML (X3D) has opened a new window to combine VR and Internet programming. SAVE starts using VRML to show earthquake risk to the mass. A special player for SAVE is under development so that user will not confuse to select a plug in viewer program from Internet. Simulation of seismic response is 4D simulation because it depends on time. In the other hand torsion, deformation and deflection occurs during vibration simultaneously, standard codes of VRML are not able to generate such a complicated scene. So a new node developed to make the vibration using extrusion an interpolation. Getting user's face picture, height, weight and using body weight distribution factors make user's model in SAVE. 2D picture is modified into 3D one to be compatible in 3D VR world.

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.

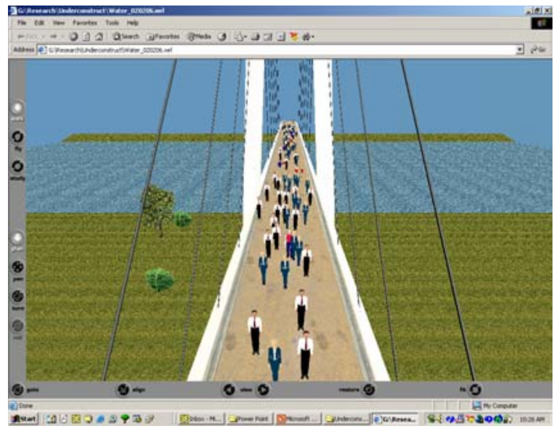

Figure 3 VR model of TODA bridge and its seismic response during KOBE earthquake

A practical way to perform VR, especially along the Internet, is to use VRML, which stands for Virtual Reality Modeling Language [16], [17]. 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. 3 shows a cable-stayed bridge authored with VRML. The model bridge can be displayed interactively using a web browser with a VRML plug-in.

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 [18]. 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.

7. Conclusion

S.A.V.E. as an attractive and interactive web-based risk communication tool using virtual reality in the case of an earthquake was developed. At the moment, SAVE ver1.0 is developed. This version is designed for earthquake load only. Since all vibrations have similar simulation in graphic world, in next version of SAVE, wind load will also be applied. For this purpose, SAVE is extendible. Using SAVE, user can learn something about earthquake and see itself in a virtual environment during earthquake, and feel it. The purpose of this study is communication to common people. Upon reviewing relative computer techniques and discussing demands on conducting an information system of risk communication and disaster mitigation for seismic hazards, 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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