テレイマージョン環境における地震データの可視化

Seismic Data Visualization in Tele-immersion Environment

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Abstract: In this research, interactive seismic data visualization system using tele-immersion environment was developed. In this system, user can see the visualized data in the three-dimensional virtual world and he can recognize the phenomenon intuitively. Since the seismic data can be displayed combined with terrain or plate data using the plug-in function of the OpenCABIN library, the user can effectively recognize the relationship between several data. In addition, by using the video avatar technology, the user can discuss with remote researchers while sharing the visualized data.

Keywords: Visualization, Immersive Projection Display, Seismic Data, Video Avatar.

1. Introduction

This research aims to construct high-presence data visualization and data mining environment by using immersive projection display. In the immersive projection display, user can experience visualized data with high quality of presence since the stereo images of huge data are displayed with wide field of view [1][2]. In this case, it is expected that the user can effectively analyse the phenomenon by accessing related information and visualizing them freely.

But currently, since an application program is developed for each combination of the visualized data or an integrated system which can be used to visualize any combination of data is constructed, the development of the visualization system is costly. So in this research, the data visualization environment was constructed in which the user can access necessary information and visualize them freely, and it was applied to the visualization of seismic data.

In Japan, a lot of earthquakes occur every day, and huge data set concerned with the hypocentral data are recorded by seismograph and they are stored in the database. It is often pointed out that surface plates of the earth or basement depth are closely related with the earthquakes [3]. Therefore the analysis of the relationships among these data would be applied to the earthquake prediction.

In this research, the data visualization environment in which the seismic data is visualized combined with terrain or plate data and the feature of the earthquake can be analysed in the three dimensional space was constructed. In addition, by constructing the networked immersive display, tele-immersion environment in which the remote users can discuss with each other while sharing the visualized data was constructed.

2. Tele-immersion Environment using CS Gallery

In this research, in order to visualize the data in the virtual world, a CAVE type immersive projection display named CS Gallery was used (Figure 1) [4]. The CS Gallery has three screens placed at the front, on the right side, and the floor side. This system displays passive stereo images and produces high-presence virtual world. In this system, three rendering PCs are used to render the image of the virtual world, one control PC is used to receive sensor data and controller data, and one database server is used to store the seismic data. When the user in the virtual world accesses the database, SQL command is sent from the control PC to the database server and the necessary data is retrieved using ODBC protocol.

The CS Gallery was connected to JGN2+ network that is operated by Ministry of Internal Affairs and Communications, and the tele-immersion environment was constructed among the CABIN at the University of Tokyo and CAVE at Kyoto University.

Figure 1: CS Gallery.

3. OpenCABIN Library

To develop our seismic data visualizing systems, we employed OpenCABIN library. OpenCABIN library is a fundamental software library for developing virtual reality applications. It absorbs differences kinds of display systems, so we can easily develop applications for a multi-screen stereoscopic display. In addition to the basic nature as a VR library, it has two special features that enable application programmers to develop VR applications easily: plug-in mechanism and master/renderer programming paradigm.

From a software engineering viewpoint such as implementation, testing, debugging, reusability, flexibility, and quality control, it is desirable to construct a system as several independent parts rather than as a big monolithic part. Because of limits of almost all OpenGL implementations, two or more processes cannot access to an OpenGL window. So an OpenCABIN library application is formed as plug-in software and it is loaded and executed by an OpenCABIN library execution environment at runtime. An execution environment can execute one or more plug-in applications simultaneously. As a result, even though each application visualizes a simple 3D object, virtual space becomes rich with a lot of 3D objects. An application user can freely select which object should be appeared in the virtual space at runtime.

An OpenCABIN library application consists of two parts: a master part and a renderer part. A master part is executed in a master process on a master computer, and controls the application's behavior by producing the application context. A renderer part is executed by renderer processes on renderer computers, and those processes render an application world according to reading the application context. A master part is guaranteed that it is always executed by a master process, so it is easy to develop applications which access outside servers via networks, and applications that share virtual space among CAVEs in remote places.

4. Seismic Data Visualization

4.1. Seismic Database

We developed seismic data visualization system using the tele-immersion environment. In this system, terrain data and plate structure data are visualized simultaneously with the hypocenters. Since these data have three-dimensional locations, we organize database tables to have locational data. Therefore the user can see and understand those information intuitively, and will find characteristics of the earthquakes and relationships among earthquakes, terrain shapes and plate structures.

Our system visualizes seismic data according to hypocentral data, terrain data, basement depth data, and plate data. Each datasets are managed in a database. The system retrieves required data from the database on demand. A user can manage displayed contents in the virtual world by adjusting combinations of the datasets. The table definitions of the database are shown in Table 1 to 4. Hypocentral data, basement depth data, plate data were provided by Earthquake Research Institute in the University of Tokyo. Terrain data were provided by Grid Technology Research Center in National Institute of Advanced Industrial Science and Technology. The hypocentral data consisted of latitude, longitude, depth, magnitude and the date when the earthquake occurred. Terrain data, basement depth data, and plate data consisted of altitude or depth partitioned in a constant gridded area.

Table 1: Hypocentral data.

North Latitude	East Longitude	Depth (km)	Magnitude	Date
36.3005	139.9837	40.68	0.8	2003-01-01
36.0927	138.739	153.97	1.7	2003-01-01
36.29	139.6655	121.42	1.3	2003-01-01

Table 2: Basement depth data.

North Latitude	East Longitude	Depth (km)
36.5	138.5	3.05772
36.5	138.511993	2.80123
36.5	138.524994	2.66092

Table 3: Plate data.

North Latitude	East Longitude	Depth (km)
36.5	138.5	151.826996
36.5	138.516998	151.102997
36.5	138.533005	150.371002

Table 4: Terrain data.

North Edge in North Latitude	West Edge in East Longitude	South Edge in North Latitude	East Edge in East Longitude	Filename
36.605122	139.804632	36.589522	139.820232	N36.605122_E139.804632.dat
36.605122	139.820232	35.589522	139.835832	N36.605122_E139.820232.dat
36.605122	139.835832	35.589522	139.851432	N36.605122_E139.835832.dat
36.605122	139.851432	35.589522	139.867032	N36.605122_E139.851432.dat

Though the altitudes of terrain are measured in accordance with gridded latitude and longitude, our system always retrieves altitude data in somewhat large area. So, we partitioned altitude data into some gridded areas, and stored the area data of the altitudes as a file in the database. Therefore we define a database table for storing terrain data as latitudes and longitudes of an area, and a filename that stores altitudes of that area, as shown in Table 4.

4.2. Combined Display of Visualized Data

Our seismic data visualization system consists of plural applications. Each application displays single dataset such as hypocentral data, terrain data, basement depth data or plate data. They were developed using OpenCABIN library. Because each dataset includes locational information such as latitude and longitude, these data can be merged at the same location. A user can select any combination to visualize them because of the plug-in feature provided by OpenCABIN library, and see what she/he wants. Figure 2 shows that a user was operating the visualization system to visualize the hypocenter data and terrain data around Tsukuba city. In this system, images acquired from a satellite are texture mapped onto the terrain shapes. Each displayed sphere indicated a hypocenter: the sphere's position, color and radius indicated hypocentral location, depth and magnitude. She/he could understand each earthquake intuitively.

Figure 3 and 4 show that a user was seeing a combination among hypocenter, basement depth data and plate data. Views of combination among basement depth data, sea depth data, Pacific Ocean plate data and Philippine Sea plate data enabled a user to understand relationships of each data. Since each data has a locational data, it is visualized at the corresponding position in the virtual space using the plug-in function. When a plug-in application runs, a square toggle button appears in the virtual world. The user can change each plug-in displaying state by toggling corresponding button. For example, a user can switch the view from the combination of basement depth data and hypocentral data to the combination of Pacific Ocean plate, Philippine Sea plate and hypocenter at runtime.

Through the operation of this system, an expert found that the depths of hypocenters in west Japan is relatively shallow and hypocenters from Tokai to Kanto are distributed on a plane. Also we can apparently see that hypocenters are distributed along the plate.

Figure 2: A view of hypocenter data and terrain data combination.

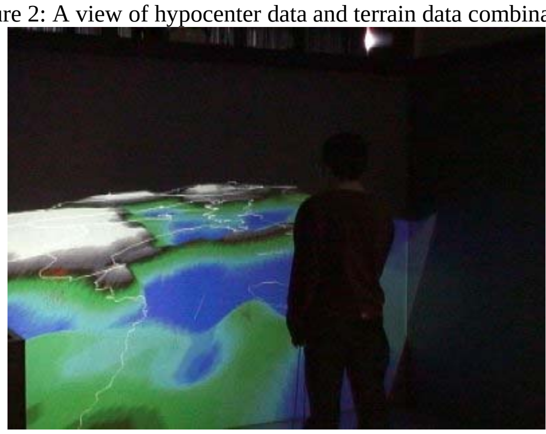

Figure 3: A view of hypocenter data and plate data combination.

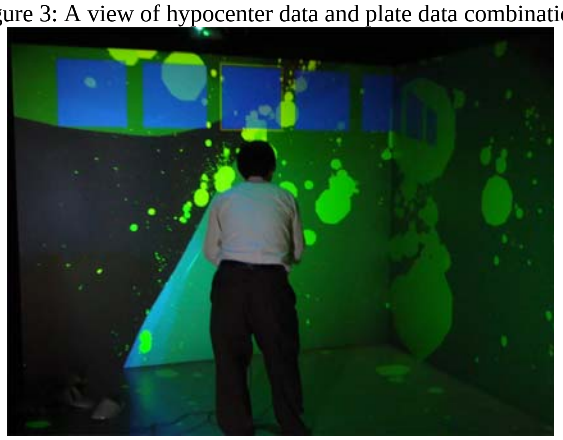

Figure 4: A view of hypocenter and plate data combination.

4.3. Communication with Remote Location

Our system can visualize hypocentral data with terrain, basement depth and plate data, and enables us to understand the relationships among these data intuitively. Moreover we extended it to tele-immersion environment and enabled a user to analyze seismic data with remote users using the video avatar technology. We can use this technology to communicate with each other and share a virtual world at the same time. In this technique, a video camera keeps taking a user's movie, and in each captured image, the system removes a background, and obtained human images are transmitted via network to the remote site in realtime. An example of intermediate results while creating video avatar is shown in Figure 5. The video camera we used was Sony DFW-X710 IEEE 1394 camera. It captures a image at 640 x 480 pixels resolution by 15 fps. And background subtraction method was used for extracting a human image. The method we used is to obtain human image from differences between pre-recorded background image and captured image.

Background image

Captured image

Result of background difference

Figure 5: An example of intermediate results of creating video avatar.

A video avatar is displayed in the virtual world. A position of the corresponding avatar indicates the location of the remote user. For example, when the remote user walks through in the virtual world, corresponding avatar position is changed. By sending video avatar images between distant places each other, remote users can see the other's figure and can discuss in the virtual world.

We implemented the video avatar function as an OpenCABIN application. Using our avatar application, any visualization application can be extended to a cooperative working system easily. Figure 6 shows an example view of combining video avatar into an application that visualizes hypocentral data.


Figure 6: A view of hypocenter data and video avatar combination.

5. Data Sharing Experiment

In this research, an experiment on sharing seismic data between remote places was conducted using the tele-immersion environment among CS Gallery at University of Tsukuba, CAVE at Kyoto University and CABIN at the University of Tokyo. In this experiment, multiple processes of the video avatar communication program between each pair of sites were plugged in, and the communication among multiple sites could be realized. The appearance of the video avatar communication among three sites is shown in Figure 7.

Table 5 shows the performance of each process measured at University of Tsukuba site. Although video camera captured images at 15 Hz and they were sent to Kyoto University and the University of Tokyo sites at over 15 Hz, the performance of receiving data was decreased at 6 to 7 Hz. This is thought to be caused by the concentration of the calculation load on the control PC. When the only video avatar was displayed, each renderer ran at about 27 Hz. Although this rendering performance was hardly changed when the basement depth and the plate data were visualized, it had decreased until about 13 Hz when the hypocenter data was added.

In this system, the same PC was used to send and receive the video avatar data as well as to perform the function of the master. Therefore, increase of the performance at one site would affect the performance at the other sites. So it was necessary to tune the performance in order to enhance the overall performance.

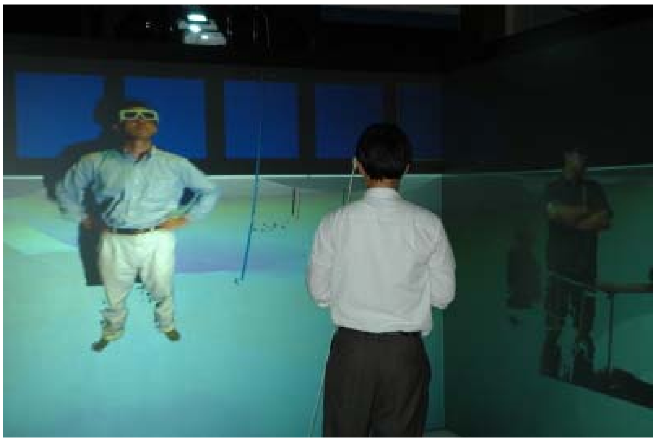
Figure 7: A view of data sharing experiment.

Table 5: The performance of experiment among three locations.

	Avatar	Avatar Basement depth	Avatar Basement depth Plate	Avatar Basement depth Plate Hypocenter
Record avatar	15.001	15.001	15.002	15.000
Send to Tokyo	22.357	22.319	22.390	22.067
Send to Kyoto	22.467	22.435	22.353	22.488
Receive from Tokyo	6.463	6.144	6.118	6.116
Receive from Kyoto	7.404	7.354	7.682	7.548
Master	13.562	13.574	13.554	13.573
Renderer	27.122	27.172	27.102	13.568

6. Conclusions

In this research, the data visualization environment was constructed using the networked immersive virtual environment. In this environment, the remote users can share the visualized data and analyze them, by visualizing the combined data freely in the three dimensional virtual space. In this case, plug-in function and master/renderer mechanism of the OpenCABIN library were effectively used. In future works, we are planning to develop an interactive data analysis method, and extend it to the visual data mining in the tele-immersion environment.

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