

# Multimedia Virtual Laboratory on the Gigabit Network

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## Abstract

Multimedia virtual Laboratory is a distributed virtual environment in which remote researchers can communicate mutually sharing research resources though the broadband network. In order to realize this concept, immersive projection displays CABIN at the University of Tokyo and COSMOS at the Gifu Technoplaza were connected through the Japan Gigabit Network. In particular, stereo video avatar and immersive database interface technologies were developed. These technologies were implemented in the CABIN to COSMOS network, and the high presence communication sharing data in the virtual world was realized.

**Key words:** Immersive Projection Display, Shared Virtual World, Broadband Network, Video Avatar, Database Interface

## 1. Introduction

Recently, according to the advances in the broadband wide area networks, real-time transmission of a large amount of data such as three-dimensional models or video images has become possible between remote places. For example, the Japan Gigabit Network (JGN) was equipped by the Telecommunications Advancement Organization of Japan in 1998. JGN is a nationwide optical-fiber network and it has been used for research and development activities. This kind of network enables the remote researchers to collaborate sharing the research resources such as the computers and the data. In particular, a three-dimensional virtual world can be shared between remote places by connecting virtual reality environments through the broadband network [1].

This study aims at constructing a high presence shared virtual world in which remote researchers can communicate mutually as if they are in the same place, by connecting immersive environments through the JGN network. This type of research environment is called multimedia virtual laboratory (MVL). In order to realize this concept, it is necessary to develop a shared virtual world in which remote researchers can communicate with a high presence sensation accessing and sharing data.

This paper describes the prototype system of the multimedia virtual laboratory environment developed in this study, and in particular, the video avatar communication and the immersive database interface which are key technologies of the multimedia virtual laboratory are discussed.

## 2. CABIN to COSMOS Network

Multimedia virtual laboratory is a concept of distributed virtual environment in which remote researchers, research equipment and information are connected via the broadband network as if they are in the same place. Fig. 1 shows the concept of the multimedia virtual laboratory. In this example, the computer scientist, the experimental engineer and the designer are jointly working in the shared virtual world to develop an airplane. Although these researchers are not usually in the same place, the multimedia virtual laboratory enables them to meet and hold discussions through the network.

In order to realize the multimedia virtual laboratory, MVL Research Center was founded in the University of Tokyo and the Gifu Technoplaza in 1999. Fig. 2 shows the research environment of the MVL Research Center. At the University of Tokyo and the Gifu Technoplaza, large-screen immersive projection displays CABIN and COSMOS were developed and are used respectively [2][3]. CABIN is a multi-screen cubic display that has five screens at the front,

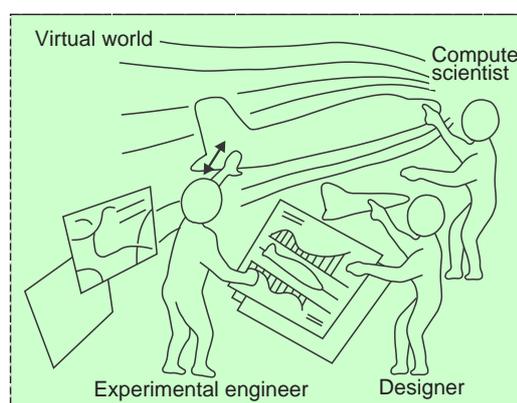


Fig. 1 Concept of multimedia virtual laboratory

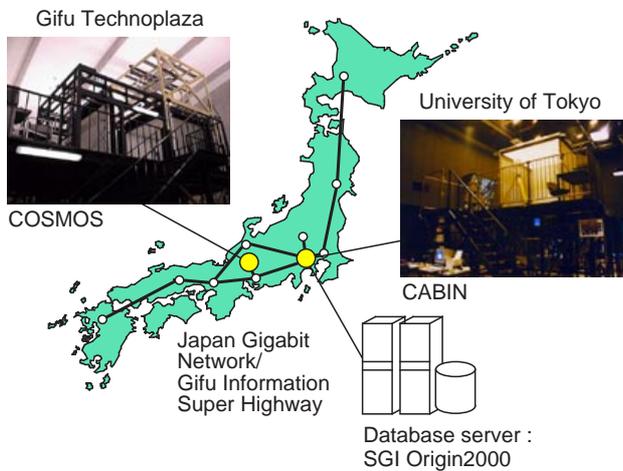


Fig. 2 Research environment of MVL Research Center

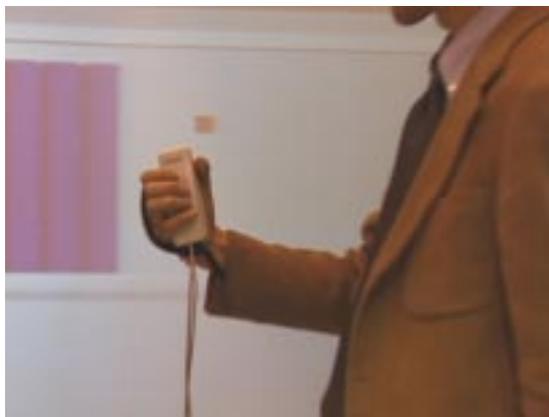


Fig. 3 Handykey Pointer used in the immersive projection display

on the left, right, ceiling and floor, and COSMOS is a complete immersive display that has six screens by adding the back screen. These displays can generate a highly immersive virtual world by surrounding the users with stereo images projected on the multiple screens.

In the immersive projection display such as a CAVE, a joystick type input device called wand is generally used [4]. This type of device is useful for walkthrough or handling object in the three-dimensional virtual world. However, it cannot be used to input characters that is an indispensable function to access database system. Therefore, in this study, Handykey Pointer was developed by combining the position sensor Polhemus Ultratrak Pro with the handy keyboard Twiddler made by Handykey Corporation [5]. This device can be used to input characters and point objects by one hand in the CABIN and COSMOS as shown in Fig. 3.

In this study, CABIN and COSMOS were connected by 155Mbps ATM using the JGN network and the Gifu Information Super Highway to construct a prototype system of the multimedia virtual laboratory. Therefore, in the networked environment between CABIN and COSMOS,

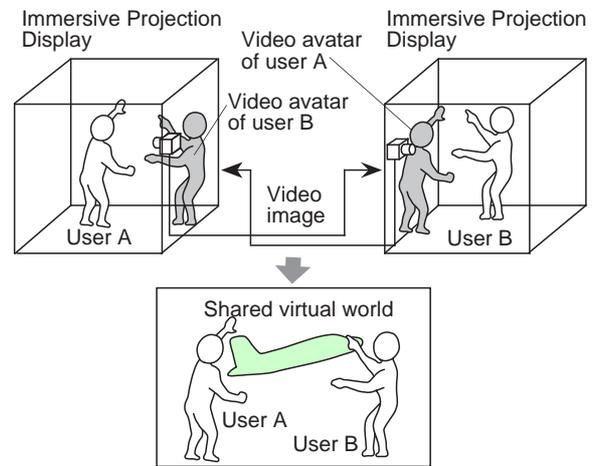


Fig. 4 Concept of video avatar communication

remote users can share the virtual world with a high quality of immersion. In addition, in order to use this environment for the multimedia virtual laboratory, it is necessary that the remote researchers can hold a discussion with high presence sensation while sharing the data such as design models or simulation data in the virtual world. In this environment, the database server SGI Origin2000 was also connected to the network so that the users can easily access data from the virtual world. Thus, the framework of the multimedia virtual laboratory in which remote researchers can access database interactively from the shared virtual world was constructed. In the following chapters, several technologies implemented in the prototype system of the multimedia virtual laboratory were described.

### 3. Video Avatar Communication

#### 3.1 Concept of Video Avatar

In order to realize a high presence communication in the shared virtual world, it is necessary that the users can see the other user's figure mutually. For the communication method in the distributed virtual world, the computer graphics avatar is often used to represent the participant's figure [6]. This method can represent the user's action in the three-dimensional virtual world. However, it is difficult to represent the facial expression of the user, because it is created using the computer graphics polygon model.

Therefore, in this study, stereo video avatar technology was developed [7]. This method represents the three-dimensional avatar using a live video in the shared virtual world. By transmitting the stereo video avatar mutually between remote places, the users can communicate with a high presence sensation. Fig. 4 shows the concept of video avatar communication in the networked immersive projection displays. In this method, the user's image is captured by a video camera placed within the immersive projection display, and a video avatar is created. This video avatar is sent to the other site and superimposed on the

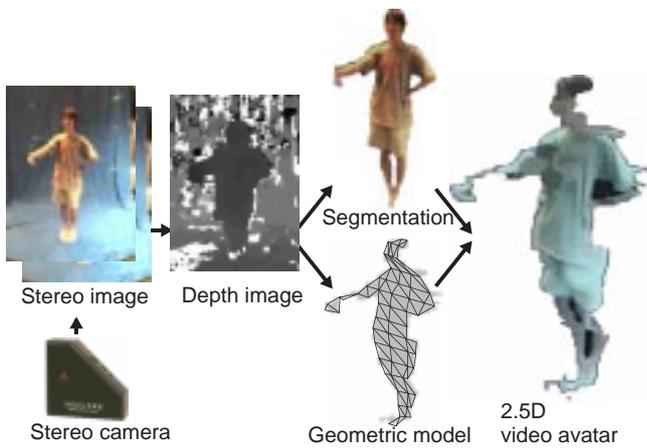


Fig. 5 Basic process of making 2.5 dimensional video avatar

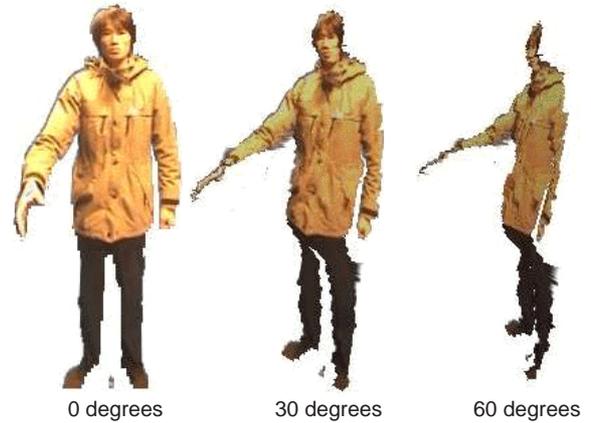


Fig. 6 Appearance of 2.5 dimensional video avatar seen from various directions

virtual world. By transmitting the video avatars mutually, remote users can communicate face to face in the shared virtual world.

### 3.2 Creation of a Stereo Video Avatar

Fig. 5 shows the basic process of making the stereo video avatar. In order to generate a three-dimensional video avatar, it is necessary to create a geometric model of the user while capturing the user's video image. Therefore, in this study, a stereo camera of the Triclops Color Vision made by Point Grey Research Inc. was used to capture the user's image [8]. By using the stereo camera, depth data can be calculated for each pixel in the captured image using the stereo matching algorithm. Since this stereo camera consists of two pairs of stereo camera modules along the vertical and horizontal base lines, it can create an accurate depth image. The resolutions of the captured color image and the created depth image are 320x240 pixels and 160x120 pixels respectively, and the calculated depth resolution was about 5.0 cm.

Once the depth image is created, only the user's image can be segmented from the background by the threshold of the depth value. In practical applications, the chroma key can also be used in combination with the depth key to create a clear image of the avatar. Additionally, a geometric model of the user is also created by connecting the three-dimensional pixel positions using a triangular mesh. Then, by texture-mapping the segmented user's image onto the geometric model, a stereo video avatar is generated. Since this avatar only has the surface model for the front side that faces toward the stereo camera, it is called a "2.5 dimensional video avatar".

### 3.3 Multi-camera System

Fig. 6 shows the appearance of a 2.5 dimensional video avatar seen from various directions. When the user sees the 2.5 dimensional video avatar from a viewpoint close to



Fig. 7 Video avatar superimposed on the shared virtual world

the camera position, avatar's image is well formed. However, when the user's viewpoint moves away from the camera position, the avatar's image becomes distorted, because it only has the surface model that faces to the camera position. Therefore, in this system, multiple stereo cameras were placed inside the immersive projection display and the closest camera to the other user's viewpoint was selected and used. By switching the selected camera according to the positional relationship between users, in effect, a quasi three-dimensional video avatar can be generated. Fig. 7 shows an example of the stereo video avatar superimposed on the shared virtual world. In this example, the user in the CABIN is talking to the video avatar in the shared virtual world.

Though this method uses multiple stereo cameras, only one pair of stereo cameras is used at any given time. So, the stereo video avatar can be generated in real-time. When a Pentium III 700MHz PC was used, the stereo video avatar was generated at a refresh rate of about 9.9 Hz, and the time delay was about 0.6 sec.



Fig. 8 Data retrieval by keyword search in the virtual world



Fig. 9 Spatial data browsing in the three-dimensional world

## 4. Immersive Database Interface

### 4.1 Concept of Immersive Database Interface

In order to realize the multimedia virtual laboratory, it is necessary that the remote researchers can not only talk to each other but also share data such as design models or simulation data in the shared virtual world. Next, in this study, a framework of accessing database server from the three-dimensional virtual world was constructed.

When we manage documents in our office in the real world, we usually use a file and a bookshelf to arrange the documents. For example, some documents are filed and put on the right bookshelf, and other papers are put on the left shelf. In this case, these documents are managed using positional information in the three-dimensional world. On the other hand, when the computer is used to manage information, large memory and computation capability of the computer can be effectively utilized. For example, in the typical data accessing method of the keyword search, related data can be immediately retrieved from the database by simply entering the keywords.

In the virtual world, it is expected that the data accessing method that utilizes both advantages of the real world and the computer can be used, because the virtual world is a realistic world simulated by computer. In this study, an immersive database interface system was developed to access data from the shared virtual world.

### 4.2 Functions of Database Interface

The database interface developed in this study has the following functions to handle data such as photograph images or three-dimensional models in the immersive virtual world.

#### 4.2.1 Keyword Search

In order to access database from the three-dimensional



Fig. 10 Extracting data from the book into the virtual world

virtual world, a function of a keyword search using the Handykey Pointer was implemented. In this method, the user opens a data search window in the virtual world and inputs a keyword using the Handykey Pointer. From the inputted keywords, a SQL (Structure Query Language) query command is generated and it is sent to the database server. By using the SQL query command, the user can access an arbitrary database system on the network. When the data is retrieved from the database server and taken into the virtual world, the abstract data is visualized as a concrete object being filed in a book. Fig. 8 shows the example of retrieving data using the keyword search in the virtual world.

#### 4.2.2 Data Browsing

After retrieving data from the database system, the user can search a target data from the data filed in the book, by using various data browsing methods. The most simple data browsing method is turning over pages of the visualized book by key operation of the Handykey Pointer. The data filed in the book can also be scrolled spatially by flying

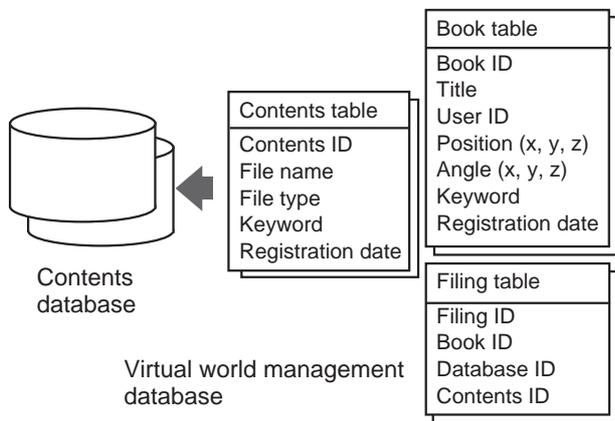


Fig. 11 Database structure for data management in the virtual world

data out of the book in the three-dimensional virtual world as shown in Fig. 9. This method is thought to be utilizing the characteristics of wide viewing field of the immersive projection display effectively.

When the target data is found, the user can take it out of the book and place it in the virtual world. Fig. 10 shows the example of extracting the selected data. In this way, design model or simulation data can be taken into the shared virtual world from the database server to discuss in the multimedia virtual laboratory.

#### 4.2.3 Data Management

Once the data is taken into the virtual world, positional information is linked to the data, and it can be treated as an object in the three-dimensional virtual world. For example, the user can grasp the visualized data and move it to the other place. By using this function, data can be replaced between books and filed according to the themes. These books can also be arranged put on the bookshelf in the virtual world. In this method, the three-dimensional positional information is effectively utilized in the same

way as the office in the real world. Therefore, the data management method using the book and bookshelf in the virtual world is thought to be applying a "office metaphor".

#### 4.3 Database Management

In this system, though the data taken into the virtual world was originally stored in the database server, it is also managed by using the database system in the virtual world. As for the database management system, INFORMIX-Universal Server is used to treat data without contradiction in the virtual world. Fig. 11 shows the data tables which were defined to manage data using books and bookshelves. Namely, the data taken into the virtual world is managed using the book table, contents table and filing table.

The book table records the position where each book is placed in the virtual world, and the contents table records the file format and the location of each contents data. And in the filing table, the relationship between each contents and the book that files contents data is recorded. By relating these data tables, the data taken into the virtual world can be managed efficiently.

#### 5. Prototype of Multimedia Virtual Laboratory

In this study, by integrating the stereo video avatar and database interface technologies, a prototype system of the multimedia virtual laboratory was constructed, and the communication experiment was conducted using the CABIN to COMOS network. Fig. 12 shows the system configuration of the experimental setup of the multimedia virtual laboratory. In this experiment, various types of data such as design models, photograph images and simulation results were stored in the database server. And the users in the CABIN and COSMOS accessed these data and took them into the shared virtual world to hold a discussion by transmitting their video avatars mutually.

In this experiment, two stereo cameras were used on each

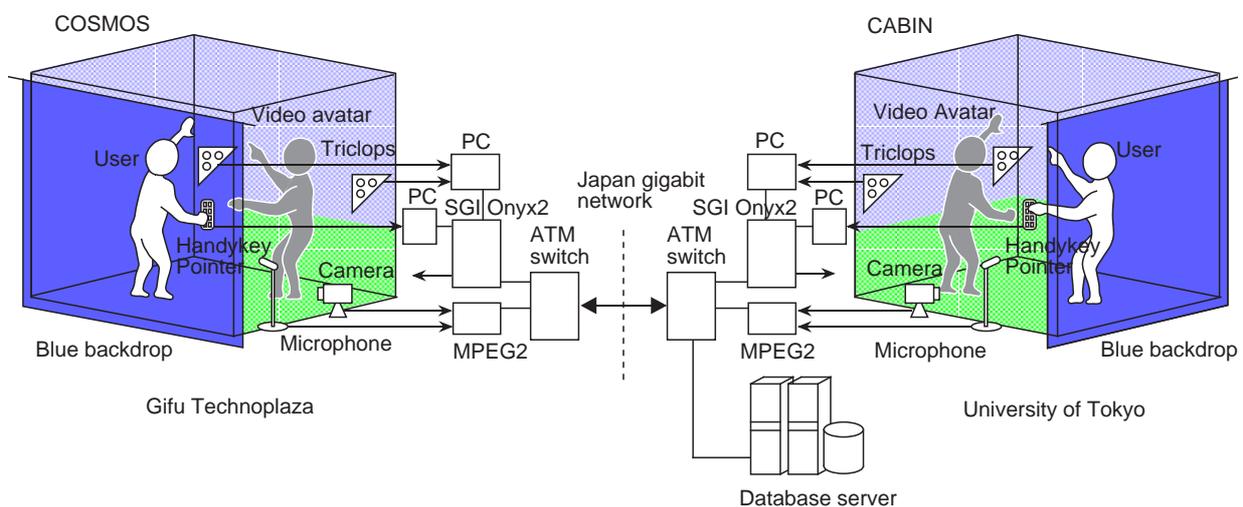


Fig. 12 System configuration of the prototype system of the multimedia virtual laboratory



Fig. 13 Example of the communication in the multimedia virtual laboratory



Fig. 14 Example of accessing data in the multimedia virtual laboratory

site to switch the geometric models of the video avatar, and the data of the video avatars were transmitted every refresh time of making video avatar. In order to transmit these data, about 40Mbps bandwidth of the network was used. Additionally, an MPEG encoder and decoder were used to transmit the scene to and from the opposite site, and they are also used to send the voice of the video avatar. On the other hand, in order to share the data in the shared virtual world, only the operation command was transmitted mutually, and the database server was accessed from each site respectively. In this way, the prototype system of the multimedia virtual laboratory enabled the remote researchers to communicate with high presence sensation while accessing data freely in the shared virtual world. Fig. 13 and Fig. 14 show the examples of the communication sharing data in the prototype system of the multimedia virtual laboratory.

## 6. Conclusions

In this study, the concept of the multimedia virtual laboratory was proposed, and the research environment was constructed by connecting the immersive projection displays CABIN and COSMOS through the broadband network. In particular, in order to realize a high presence communication sharing data in the multimedia virtual laboratory, stereo video avatar and database accessing method were developed. These technologies were implemented in the prototype system of the multimedia virtual laboratory, and the communication experiment was conducted.

The concept of the multimedia virtual laboratory also includes the functions of the multimodal communication and the interactive usage of the supercomputer. Future work will include improving the functions of the prototype system and applying this framework to the practical applications such as collaborative design or discussion between remote places, and the effectiveness of this system will be evaluated.

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