# Distance Learning in Tele-immersion Environment

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## Abstract

*Distance education using the high-resolution video image has become popular according to the expansion of broadband networks. However, conventional distance learning systems lack the feeling of presence and have difficulty to utilize the three-dimensional information. This paper proposes the tele-immersive distance learning system that uses the video avatar, database interface and several interaction techniques in the shared virtual environment.*

## 1. Introduction

According to the recent spread of the broad-band network services, distance learning systems that utilize high resolution video images have been used in several classes in the universities or the preparatory schools [1][2]. By displaying teacher's figure and teaching materials on the large screen, the students in the remote places can attend the class. However, the current distance learning systems using the video images have some inconveniences.

First, lack of the feeling of sharing the space between the teacher and the students is pointed out. In the current system, though the video image and the voice data are mutually sent, they communicate through the two-dimensional screen frame. Therefore, it is difficult for the students to feel they are in the same classroom with the teacher, and they often have passive attitude as if they were watching television.

Next, it is required that the positional relationship between the teacher and the teaching material can be represented correctly, to achieve a smooth lecture. When the teacher's figure and the teaching materials are displayed in the same video, the sizes of the displayed teaching material are small though the teacher's gesture is represented correctly. On the other hand, when the teaching material is displayed on the other screen, the positional information such as the teacher's pointing are not correctly represented, so that the students often misunderstand to which screen they should pay attention and they lack concentration.

Moreover, since the three-dimensional information cannot completely be represented using the two-dimensional video image, it is difficult to perform the remote education using an experimental apparatus or a model with the same presence as the face-to-face class. In the science and engineering class, learning through the active experience such as the experiment or practice is important. Therefore, it is expected to realize a distance learning that effectively uses the three dimension space, to achieve a remote education through the active experience [3].

In this study, tele-immersion environment was constructed by connecting several immersive projection displays and the distance learning system that utilizes the shared virtual space was developed. This system displays the teacher's figure and the teaching materials in actual sizes using the stereo-image, and the students can experience a remote education with high presence as if they are in the same classroom. This paper describes the construction of the tele-immersive distance learning system developed in this study and the result of the evaluation experiment in which it was actually used for the university class.

## 2. Desired Functions for Distance Learning System

In order to construct a distance learning system using the shared virtual space, several functions are required. First, it is necessary to generate a feeling of sharing the same space between the teacher and the students. In order to generate this feeling, the function that enables remote users to communicate with each other sharing the synchronized three-dimensional world should be constructed.

Next, it is necessary that both the teacher and the students can recognize the other person’s figure correctly. The teacher's figure should be displayed on

the students' site and the students' figures should be displayed on the teacher's site.

Moreover, it is desired that the teaching materials and the whiteboard can be used in the shared space to achieve the smooth lecture. For example, the teacher gives explanations using the teaching materials such as the PowerPoint slides or the three-dimensional models. The whiteboard is used for the teacher and the students to discuss with each other while drawing characters or pictures freely.

In addition, the pointing function is also necessary. This function is used to indicate the important point on the PowerPoint slide or on the three dimension model. In order to realize the correct pointing in the shared virtual world, the framework to express the positional relationship among the teacher, students and the teaching materials is necessary.

## 3. System Construction of Tele-immersive Distance Learning System

In this study, the tele-immersive distance learning system was developed to meet the elemental functions described in the previous chapter. This chapter explains several technologies that are implemented in this system.

(1) Networked immersive environment

In this study, tele-immersion environment was constructed by connecting several immersive projection displays via the broad-band network. As immersive projection displays, CS Gallery at the University of Tsukuba and AR View at the Tsukuba Research Center was used [4]. CS Gallery is a CAVE-like immersive projection display that has three screens at the front, right and floor. AR View is an augmented reality display that uses large half-silvered mirror. These immersive projection display environments were connected through the JGN2 (Japan Gigabit Network 2) and the Tsukuba WAN (Tsukuba Wide Area Network) network as shown in Figure 1. JGN2 is a high-speed testbed network for research and development operated by NICT (National Institute of Information and Communications Technology), and the backbone has 20Gbps bandwidth. Tsukuba WAN is a network that connects several research institutes in the Tsukuba Science City using the 10Gbps optical access ring.

In the distance education, the teacher exists at one site, and the students exist at the other site. In this environment, a virtual space of wide field of view can be experienced at both site, and the feeling of sharing the space can be generated between both users.

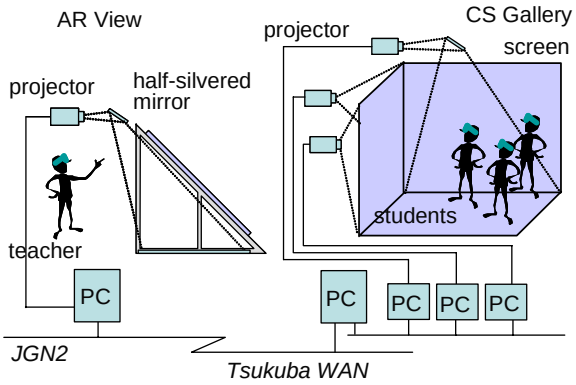


**Figure 1. Network immersive environment**

(2) Video avatar

Next, video avatar technology was developed as a technique to display the figures of the teacher and the students in the shared virtual space [5]. In this method, the user's figure is captured by a video camera, and is transmitted to the other site to be integrated in the shared virtual world. By displaying the realistic teacher's image in the immersive virtual world, the students can feel the sense of sharing the space that cannot be felt from the video conference or the computer graphics avatar. The teacher can also recognize whether the students are listening to his lecture, by looking at them in the virtual world.

In this system, the user's image is captured by the IEEE1394 camera (Sony DFW-X710), and only the user's figure is segmented from the background using the background subtraction method in every frame. Figure 2 shows the method of generating a video avatar. The video avatar can be used for the communication in the shared virtual world by executing this process in real time. The resolution of the video avatar image is 640×480, and it is captured at the frame rate of 15Hz.

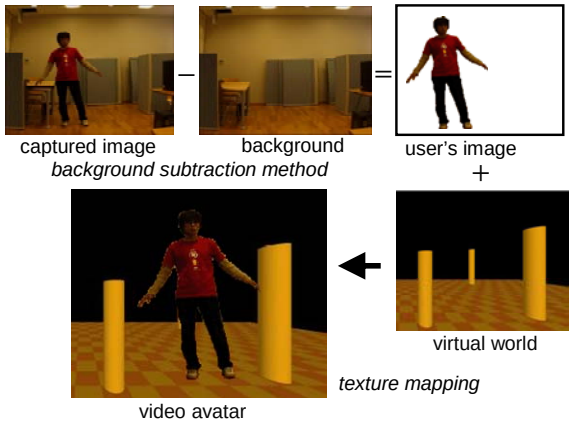


**Figure 2. Video avatar generation method**

(3) Database interface

As a mechanism to share the teaching material data in the immersive virtual environment, the database interface named CCBASE (Cyber Communication data BASE) was developed [6]. When the user inputs the keyword in the virtual world, a SQL query is sent to the database through the network and the data retrieved from the database is visualized. In this system, the retrieved data can be shared between remote places since the operation commands are transmitted to each other. In the distance learning, the teaching materials such as the PowerPoint file, image data and three-dimensional model are stored in the MySQL database. And when the teacher accesses the necessary data, they can be shared between the teacher site and the students site.

The keyword used for the data retrieval is inputted using the virtual keyboard. And the retrieved data is visualized using the book metaphor in the virtual space as shown in Figure 3. The image data and the PowerPoint slides are visualized being texture mapped onto the pages, and the three dimension model is directly displayed at the position of the page. Therefore, the user can browse the retrieved data by turning over the pages of the visualized book and the necessary data can be taken out to the virtual space.

**Figure 3. Data retrieval using book metaphor**

(4) Interaction devices

In order to enable the teacher to point at the PowerPoint slide or to draw characters and pictures on the whiteboard in the shared virtual world, several interaction functions are necessary. In this system, Ascension Flock of Birds motion tracker is used to measure the positions and directions of the user's viewpoint and the controller device. As for the controller, SONY PlayStationan2 analog controller in which the position sensor was installed is used. By using this device, the interaction functions such as the virtual stick, 3D marker and virtual keyboard were implemented.

First, the virtual indication stick was implemented so that the teacher can point at the PowerPoint slide or other teaching materials. In the virtual space, it was difficult for the students to recognize the correct position and direction that the teacher indicated with his finger, because the teacher's figure is represented using the two-dimensional image of the video avatar. The virtual indication stick is visualized using the three-dimensional image at the position of the controller measured by the tracker, and it can be moved directly according to the user's hand movement. Since the position data of the controller is transmitted from the teacher site to the student site, the virtual indication stick can be shared synchronously between both sites.

Next, the function of putting a mark at the tip of the indication stick was implemented to record the track of the user's hand movement in the three-dimensional space. This function can be used to draw lines, pictures and characters by moving the controller in the air while pushing the button as shown in Figure 4. By using the 3D marker function, the teacher can put a mark not only on the two-dimensional materials such as the PowerPoint slide but also on the three-dimensional models. Since this marker information is also transmitted from the teacher site to the student site in real time, the same marker information can be shared in both sites.

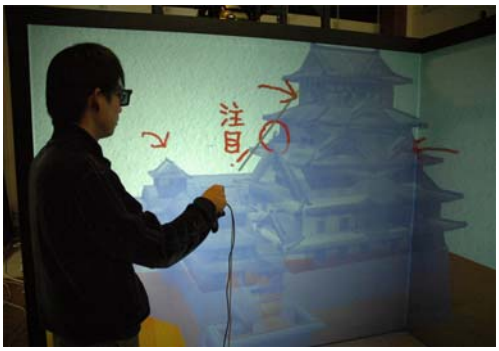


**Figure 4. 3D marker used in the virtual space**

Moreover, the virtual keyboard function was implemented to input characters in the immersive environment. In this function, the three-dimensional image of the keyboard is visualized in front of the user, and when the user reaches his hand toward the keyboard and presses the button of the controller, the corresponding character is inputted. Since the virtual keyboard is placed at the position of the controller, the user can move it and input characters at an arbitrary position in the virtual space. This function can be used to input the keyword to retrieve the data from the database.

(5) Virtual whiteboard

In this study, a virtual whiteboard that is used in conjunction with the above-mentioned interaction functions was developed. In the real class, the whiteboard or the blackboard is used to draw characters or pictures on it freely. In this system, the user can draw characters or pictures at the arbitrary position in the three-dimensional space by using the virtual whiteboard function. For example, the user can write characters using the virtual keyboard or draw lines using the 3D marker. When the virtual keyboard is used, the transparent whiteboard is represented in the three-dimensional space and the inputted character is displayed on it as shown in Figure 5. And when the 3D marker is used, the figure or the picture is drawn by moving the controller. Since the whiteboard can be placed at any positions, the user can draw characters and pictures freely in the three-dimensional space.


**Figure 5. Virtual keyboard and whiteboard**

## 4. Experiment on Distance Learning Using Immersive Shared Virtual World

(1) Experimental method

In this study, the tele-immersive distance learning system was applied to the actual class in the University of Tsukuba, to evaluate the effectiveness of this method. The class was “Virtual Reality Programming” in the college of information science, and the number of the students was nine. As an experimental environment, the CS Gallery at the University of Tsukuba and the AR View at the Tsukuba Research Center were used. These two sites are about 3.0km away.

In the experiment, the teacher stood in the AR View display and gave a lecture about “interactive three-dimensional computer graphics”. And the students gathered in front of the CS Gallery and listened to the lecture while looking at the teacher’s video avatar image and teaching materials. Since the viewing angle of the AR View is not so large, the students’ image was sent using the MPEG encoder and was projected on the side screen. The voice data was mutually transmitted using the voice channel of the MPEG encoder. In this environment, the lecture was given using the PowerPoint slides and the three-dimensional models for forty minutes. Figure 6 shows the system configurations at the teacher site.

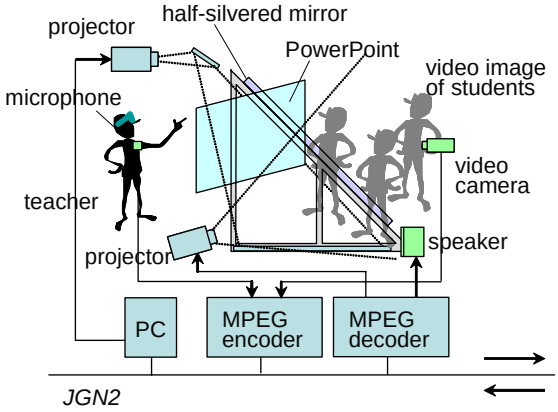


**Figure 6. System configuration at the teacher site used in the experiment**

After the class, the students were asked to answer the questionnaire to evaluate this system. The questionnaire included the following questions. 1) Was the lecture easy to understand? 2) Did you understand the teacher's gesture? 3) Was it easy to recognize the position indicated by the virtual stick? 4) Was it easy to recognize where the marker was drawn?. These questions were evaluated according to the five-grade system (5: excellent, 4: good, 3: fair, 2: poor, 1: bad). In addition, the students were asked to describe the impression of the class freely.

(2) Experimental results

Figure 7 and 8 show the appearances of this experiment at the University of Tsukuba site. In the experiment, the students seemed to concentrate the distance lecture as well as the face-to-face class. Even when the student raised his hand to ask a question, the communication of the question and answer was accomplished without any trouble.

Figure 9 shows the results of the evaluation, in which the average value and the standard deviation are shown for each question. From this result, the average value of the evaluation for question 1) was 3.4, and many students answered that the lecture was comprehensible. This means that the students could understand the lecture, and the class was well accomplished in the tele-immersion environment.

On the other hand, the evaluation for question 2) about the teacher's gesture was 2.0. Though this

question was given to examine whether the video avatar was effectively used to express the teacher's figure in the distance learning, the evaluation value was the lowest in four questions. It can be thought that this is caused by the imperfection of the segmentation of the teacher's figure. In the free description, some students pointed out that the segmentation of the teacher's video avatar was not clear and it often disturbed the concentration on the class.

As for question 3) about the virtual stick and question 4) about the 3D marker, the average evaluation values were 2.4 and 3.1 respectively. The direction indicated by the virtual stick was not recognized correctly, because the image of the video avatar that holds the virtual stick was represented by the two-dimensional image though the virtual stick is represented using the three-dimensional polygons. On the other hand, the position pointed at by the 3D marker was clearly recognized, because the marker leaves tracks directly in the three-dimensional space. In the free description, some students wrote the impression that the positional information pointed at by the marker was more comprehensible than the position indicated by the virtual stick.

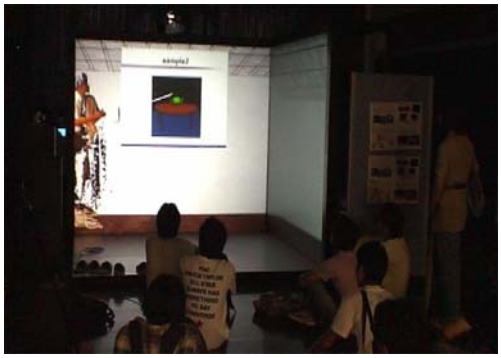

**Figure 7. Presentation using PowerPoint slide in CS Gallery**

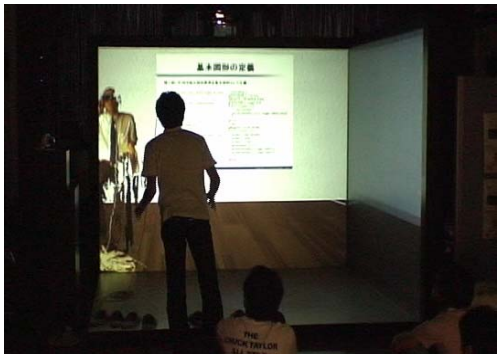

**Figure 8. Communication of question and answer in tele-immersion environment**

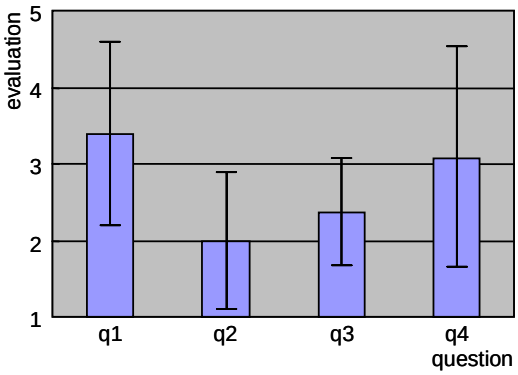


**Figure 9. Result of questionnaire**

## 5. Delivery Type of Distance Education

In the experiment described in the previous chapter, the virtual classroom was constructed by putting the teaching materials and the whiteboard in the computer graphics world. In this case, both the teacher and the students felt that they were in the virtual world that was not a real one. On the other hand, the delivery type of the distance education can be considered. This kind of distance education delivers the lecture together with the surrounding environment from the actual research site where the learning object exists to the student site through the network. Then, the students can attend the class while feeling as if they are in the place where the teacher and the learning object exist.

In this system, the scene at the teacher's site is captured by the stereo camera and it is transmitted to the student site as a stereo image to be integrated with the virtual world as a background. By experiencing the stereo video image in the immersive environment, the students can obtain the feeling that they are in the remote place where the learning object exists. Figure 10 shows the example of the delivery type of the distance education using the stereo background image. In this example, the teacher's figure is once segmented from the background and is superimposed on the stereo background image. In addition, the teaching materials such as the PowerPoint slides are also integrated in the virtual space. Since these images of the teacher, the background and the teaching materials are displayed separately, the positional relationship among them can be represented in the three-dimensional space.

**Figure 10. Delivery of distance education using the stereo video image**

## 6. Conclusions

In this study, the distance learning system that uses the tele-immersion environment based on the networked immersive projection displays was developed. This system implemented several functions such as the video avatar, database interface and virtual whiteboard, and it was applied to the actual class in the university. From the experiment, the following results were obtained.

・In the distance learning using the shared virtual space, the students were able to concentrate on the class and understand the lecture as well as the face-to-face class.

・In the distance learning system, it is important to represent the teacher's figure clearly, and the image quality of the video avatar should be improved.

・When the teacher indicated the position in the shared virtual space, the 3D marker that leaves the marks in the space was used more effectively than the virtual indication stick.

The future work will include improving both the quality of the video avatar image and the operation of the virtual stick and the 3D marker. Moreover, it is necessary to examine the method to give a lecture by using the three-dimensional teaching materials or the tools effectively in the tele-immersion environment. Especially, it is expected that this method can effectively be used in the class in which the students need active experiences such as the experiment or the practice. This method will be evaluated in various kinds of classes that include the delivery type of the distance education.

## 7. Acknowledgments

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## 8. References

[1] K. Aoki: Distance Learning Programs and Schools in Japan: From Correspondence Learning to E-Learning, Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2006, 2006, pp.1802-1806.

[2] J.W. Brackett: Satellite-based distance learning using digital video and the Internet, IEEE Mutimedia, 2006, Vol.13, Iss.4, pp.72-76.

[3] M. Kobayashi, K. Utsugi, M. Yamasaki, H. Takeda: Distance Learning of Chang'an in an Immersive Environment, ICAT 2003, 2003, pp.100-105.

[4] T. Ogi, T. Uchino: Dynamic Load-Balanced Rendering for a CAVE System, Proceedings of ACM Symposium Virtual Reality Software and Technology (VRST2006), 2006, pp.189-192.

[5] T. Ogi, T. Yamada, Y. Kurita, Y. Hattori, M. Hirose: Usage of Video Avatar Technology for Immersive Communication, Proceedings of First International Workshop on Language Understanding and Agents for Real World Interaction, 2003, pp.24-31.

[6] T. Ogi: Building Networked Immersive VR Applications Using the MVL Toolkit, The 14th International Conference on Artificial Reality and Telexistence (ICAT2004), 2004, pp.202-209.