# Invisible Interface for the Immersive Virtual World

Tetsuro Ogi[1, 2, 3], Toshio Yamada[1], Koji Yamamoto[3], Michitaka Hirose[2]

[1] Gifu MVL Research Center, TAO
Iutelligent Modeling Laboratory, The University of Tokyo
2-11-16, Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan
{tetsu, yamada}@iml.u-tokyo.ac.jp
[2] Research Center for Advanced Science and Technology
The University of Tokyo
4-6-1, Komaba, Meguro-ku, Tokyo 153-8904, Japan
hirose@cyber.rcast.u-tokyo.ac.jp
[3] Mitsubishi Research Institute
2-3-6, Otemachi, Chiyoda-ku, Tokyo 100-8141, Japan
koji@mri.co.jp

**Abstract.** Immersive projection technologies such as CAVE can generate a high presence virtual world. However, it is difficult for the user to experience the immersive virtual world in the real workplace, such as the design room or the conference room, because this type of display system requires a large space in order to install the screen. In this study, an invisible interface was developed for the immersive virtual world by integrating a transparent immersive projection display and cellular phone interface technologies. By using this system, the user in the real world can experience the high presence virtual world in an immersive environment. This system was applied to several fields of application, such as augmented reality and telecommunications.

## 1 Introduction

Virtual reality technology is advancing from the conception stage to practical use in various fields of application. For example, the three-dimensional design model of a new product is often visualized in the virtual environment, or remote researchers are able to communicate with a high quality of presence in the shared virtual world [1][2]. In these practical applications, it is desirable for the user to be able to experience the virtual environment in the real workplace [3].

On the other hand, immersive projection technologies such as CAVE and CABIN have become very popular as virtual reality display systems [4][5]. These display systems project high-resolution stereo images onto large screens, and generate more highly immersive virtual worlds than those experienced with the ordinary head mounted displays. However, this kind of display system needs a large space in which to set up the equipment, because it consists of large display screens. Thus, when the user wants to use an immersive projection display, he must go to the particular room in which CAVE or CABIN is installed. Therefore, it is difficult for the user to experience the immersive virtual world using CAVE or CABIN in the real workplace, such as the design room or the conference room.

In this study, an invisible interface that allows the user to experience the immersive virtual world was developed by integrating the transparent immersive projection display and cellular phone interface device technologies. In this system, the user in the real workplace can experience the virtual world in the immersive environment. This paper describes the concept of the invisible immersive interface, system configuration of the prototype system and some applications using this technology.

## 2 Invisible Immersive Interface

The invisible immersive interface is a concept of a computer-augmented environment in which the user can experience a high presence virtual world in the real workplace, such as the design room or the conference room. For example, it means that the designer can visualize the three-dimensional model of a new product in his design room or that remote researchers can communicate with a high presence in the conference room. Figure 1 illustrates the concept of the invisible interface for the immersive virtual world.

In order to realize this concept, the components of the virtual reality system, such as the display and the interface device, should be hidden in the real workplace without disturbing the user's view. Namely, it should be constructed as an invisible interface so that the user in the real world can experience the immersive virtual world.

Although an augmented reality system, such as the see-through head mounted display, is often used to experience the virtual world in free space, this method cannot generate such a high presence sensation as that generated by an immersive projection display [6]. In addition, special interface devices, such as the wand or the data glove are used in ordinary virtual reality and augmented reality systems. However, from the standpoint of the invisible interface, it is desirable for the user to experience the virtual world by only using a device that might be carried in their daily life.

In this study, a prototype of an invisible immersive interface was constructed that enables a user in the real workplace to experience the high presence virtual world by applying the immersive projection technology. In particular, the transparent projection display and cellular phone interface technologies were developed to realize this concept.

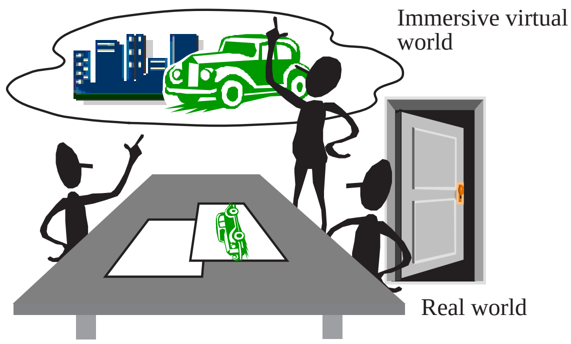


**Fig. 1.** Concept of Invisible Interface for Immersive Virtual World

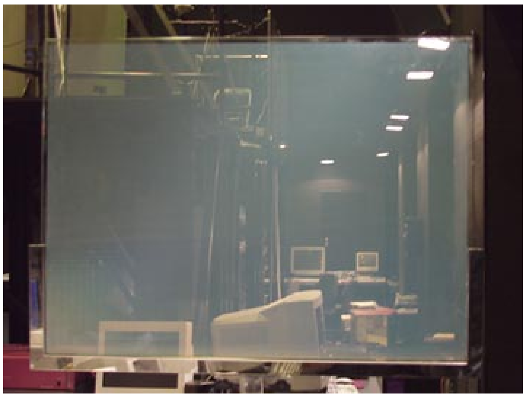

**Fig. 2.** Appearance of HoloPro Screen

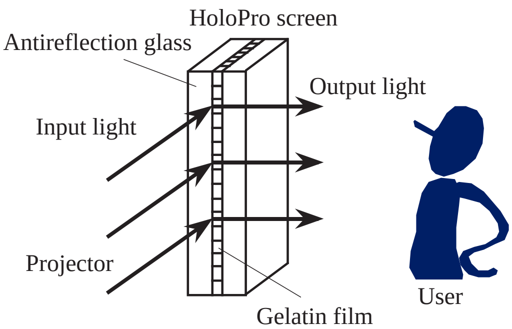


**Fig. 3.** Structure of HoloPro Screen

## 3 Transparent Immersive Projection Display

In order to generate a projection based immersive virtual world in the real workplace, a large screen display is necessary that does not obstruct the user's view. In this study, a transparent rear-projection screen known as HoloPro is used, which is made by G+B Pronova GmbH [7]. Figure 2 shows the appearance of the HoloPro screen, and Figure 3 shows the structure. Since this screen is constructed by laminating a gelatin light-directing film inside anti-reflective multi-layer glass, the screen itself is nearly invisible. Therefore, the image projected onto the transparent HoloPro screen appears as if it is floating in the air.

In this system, when the image is projected onto the screen from a specific angle between 35 degrees and 40 degrees, the incoming light is redirected in the direction of the viewer. Therefore, the projector can be placed on the floor or on the ceiling, hidden from the user's view. Moreover, since the polarization of the light is preserved when it goes through the screen, a polarizing filter method using high brightness projectors can be used to generate three-dimensional stereo images. This screen can also be used outdoors in daylight, because the projected image is hardly affected by the ambient light. By

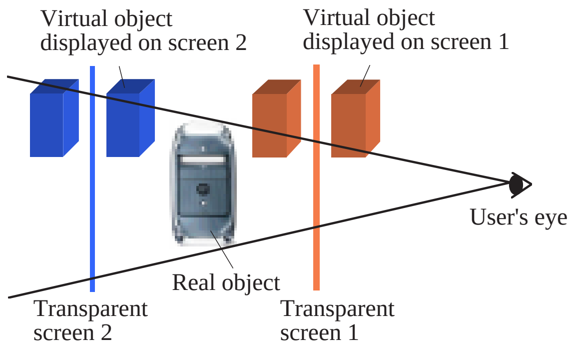


**Fig. 4.** Transparent Screen and Occlusion

using this transparent screen, a user in the workplace can experience an immersive virtual world that appears to be part of the real world as the need arises.

In addition, since the HoloPro screen itself is transparent, the black part of the displayed image would be see-through, and the user can therefore view both the projected image and the background of the real world simultaneously. Therefore, this screen can be used as an augmented reality system utilizing the optical see-through function.

This kind of transparent immersive projection display has some additional features compared with other augmented reality systems. For example, in the case of an optical see-through head mounted display, the real object cannot occlude the virtual object, because the screen plane is located in front of the user's eye. On the other hand, when a projection-based augmented reality system is used, the virtual object cannot occlude the real object because the screen is placed behind the object. In a transparent immersive projection display, a real object placed in front of the screen plane can occlude the virtual object, and the virtual object can occlude a real object placed behind the screen plane, as shown in Figure 4. Therefore, the real object and the virtual object can be located in various positional configurations by considering the position of the screen in the real world.

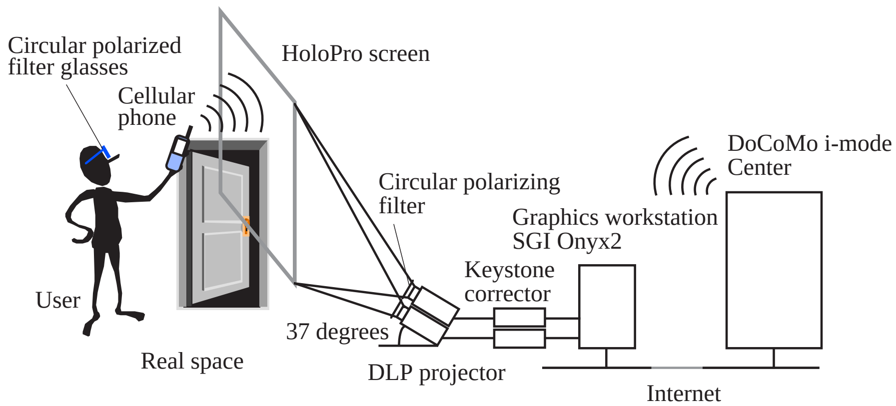


**Fig. 5.** System Configuration of Invisible Interface for Immersive Virtual World

Thus, by using the HoloPro screen, the user can experience the three-dimensional immersive virtual world and the augmented reality world in the real workplace. Figure 5 shows the system configuration of the transparent immersive projection display system constructed in this study. The diagonal size of the HoloPro screen is 50 inches (1000mm x 750mm), and an SGI Onyx2 graphics workstation is used to generate parallax images for the left and right eyes respectively. These two images are transmitted to the NEC LT140J DLP(Digital Light Processing) projectors through the Analog Way Keystonix KC-100 keystone correctors, and are projected onto the screen from floor level at the angle of 37 degrees. Circular polarizing filters are attached to the lenses of the projectors, and the user can then see the stereo images by using circular polarized filter glasses.

## 4 Cellular Phone Interface

Along with the transparent screen, the development of interaction technology with the virtual world displayed on it has been necessary. In general, in the CAVE-like immersive projection display, a special interface device called the wand is used [8]. In the real workplace however, it is desirable to employ an everyday device that is used in daily life for interactions with the virtual world. Therefore, in this study, we developed an interface technology using the i-mode function of the cellular phone.

The i-mode is an Internet access service for the cellular phone provided by NTT DoCoMo Inc., and which is currently used by about twenty million people in Japan [9]. For example, the user can access the Internet web pages by inputting the URL characters or selecting a bookmark using the dial buttons, and the information on the web page is displayed on the LCD of the cellular phone. Since this LCD window can also be used to display the menu or to confirm the characters that have been entered, the user can input a command using local feedback from the LCD without displaying the three dimensional input window in the virtual world.

In this study, this Internet communication function of the cellular phone was applied to running the virtual reality application and communicating with the virtual world. Figure 6 shows the software construction of the i-mode interface with the virtual world. In this system, in order to experience the virtual world, the user accesses the web server

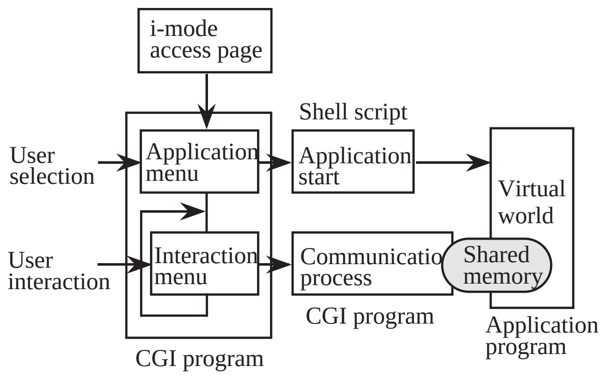


**Fig. 6.** Software Structure of i-mode Interface


**Fig. 7.** i-mode Menu for Walk-through Control

**Fig. 8.** Cellular Phone Interface with Pointing Function

of the SGI Onyx2 graphics workstation from the cellular phone through the DoCoMo i-mode Center. Selecting a menu item in the i-mode page starts the virtual reality application program. This i-mode page is written in CGI (Common Gateway Interface) script, and when the user selects the menu item, the shell script runs that starts the virtual reality application. By using this i-mode function, the virtual world suddenly appears by only operating the cellular phone without a computer terminal.

In the virtual reality application program, the user can also interact with the virtual world by using the cellular phone interface. After starting the application program, the CGI program displays the interaction i-mode page in the LCD on the cellular phone. When the user inputs characters or selects commands on the interaction page using the dial buttons, the communication process is generated and it transmits the interaction command to the application program through the shared memory. By using this method, the user can interact with the virtual world using the i-mode function.

For example, Figure 7 shows the interaction i-mode page for walk-through control in the virtual world. Although the i-mode web site is basically written using subsets of HTML, it also supports some individual functions corresponding to the cellular phone device. In this example, each key of the dial button is assigned to several movement functions, such as "go ahead", "turn right", "turn left", "go up" and "go down". Therefore, the user can walk through the virtual world freely by operating these keys.

In addition, the cellular phone can also be used as a pointing device as well as a key-input device by attaching a position tracker to it. In this system, a Polhemus electromagnetic sensor is used to track the position of the cellular phone. However, when the cellular phone communicates with the Internet to send the interaction command, it generates an electromagnetic wave that causes a tracking error. Therefore, the position tracker was attached about 8 cm away from the body of the cellular phone in order to reduce the influence of the electromagnetic wave as shown in Figure 8.

Thus, the type of cellular phone that is carried around in daily life can be used as an interface device that can provide both keyboard and wand functions. In this system, since the user can use his or her own cellular phone as the interface device, it can easily be manipulated to interact with the virtual world.

## 5 Application of the Invisible Interface

### 5.1 Experience of the Immersive Virtual World

In this study, by integrating a transparent immersive projection display with cellular phone interface technologies, an invisible interface was constructed with the immersive virtual world, and it was applied to several fields of application. Figure 9 shows an example of how the experience of the immersive virtual world can be displayed in the real world. In this example, a three-dimensional virtual town appeared before the user's eyes in the real world when he accessed the application program using the i-mode control, and he could walk-through the virtual town by operating the cellular phone in the immersive environment.

**Fig. 9.** Experience of Immersive Virtual World

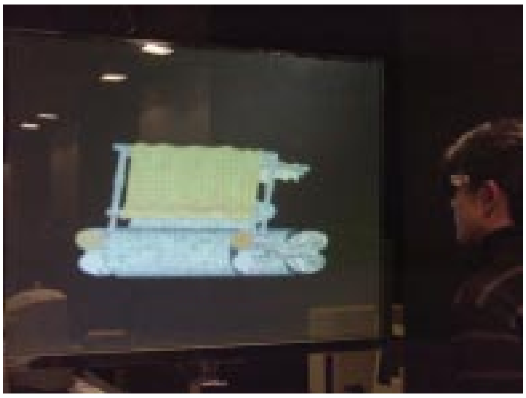

**Fig. 10.** Visualization in Augmented Reality World

**Fig. 11.** High Presence Communication Using Video Avatar

### 5.2 Experience of the Augmented Reality World

Figure 10 shows another example of the application being used to the experience the augmented reality world. In this example, since the background image of the three-dimensional model that is being displayed is black, the real object behind the screen can be seen through the transparent screen. In this case, the user can view the three-dimensional computer graphics model as if it was floating in the real world. By applying this method, the designer would be able to visualize a three-dimensional design model in the real workplace of his design room to inspect and discuss it.

### 5.3 High Presence Communication

The authors have been studying a high presence communication method using the video avatar in the shared virtual world generated in the immersive projection displays at CABIN and COSMOS [10]. In this technique, the user's image is captured by a stereo video camera, and then the user's figure is segmented from the background as a three-dimensional live video image. This video image is transmitted to the other site via the broadband network, and is superimposed on the shared virtual world. By using this method, remote users can communicate with each other with a high quality of presence. In this study, the video avatar technology was applied to communications in the networked real world. Figure 11 shows an example of video avatar communication in the real workplace. In this example, remote users could communicate with each other in the real world by projecting a transmitted video avatar image onto the transparent screen without superimposing on the virtual world.

In these examples, an invisible immersive interface was used effectively to experience the virtual world or augmented reality world in the real workplace.

## 6 Conclusions

In this study, an invisible immersive interface was constructed as a framework in which the user could experience the immersive virtual world in the real workplace by integrating transparent immersive projection display and cellular phone interface technologies. Since the three-dimensional virtual world can apparently be displayed in the air by using the transparent wide screen, the user in this system can experience an immersive virtual environment in the real world. In addition, since the type of cellular phone that is regularly carried in daily life is used as the interface device, the user can interact with the virtual world using an implement that he or she is accustomed to using. This system was applied to several fields of application, such as accessing the immersive virtual world, experiencing the world of augmented reality and for high presence communications. Future work will include the application of this technology to practical applications to evaluate the effectiveness of this method.

## References


1. Scharm, H., Breining, R.: How Automoive Industry Uses Immersive Projection Technology, 3rd International Immersive Projection Technology Workshop (1999) 133-144
2. Leigh, J., DeFanti, T.A., Johnson, A.E., Brown, M.D., Sandin, D.J.: Global Tele-Immersion: Better Than Being There, ICAT'97 (1997) 10-17
3. Encarnacao, L.M., Barton III, R.J., Bimber, O., Schmalstieg, D.: Walk-up VR: Virtual Reality beyond Projection Screens, IEEE Computer Graphics and Applications, Nov./Dec. (2000) 19-23
4. Cruz-Neira, C., Sandin, D.J., DeFanti, T.A.: Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE, Proceedings of SIGGRAPH'93 (1993) 135-142
5. Michitaka Hirose, Tetsuro Ogi, Toshio Yamada: Integrating Live Video for Immersive Environments, IEEE Multimedia, Vol.6, No.3, July-September (1999) 14-22
6. Fuchs, H., Ackerman, J., Displays for Augmented Reality: Historical Remarks and Future Prospects, Mixed Reality, Ohmsha (1999) 1-40
7. http://www.holopro.com/
8. Browning, D.R., Cruz-Neira, C., Sandin, D.J., DeFanti, T.A., Edel, J.G.: Input Interfacing to the CAVE by Persons with Disabilities, Virtual Reality and People with Disabilities (1994)

9. http://www.needocomo.com/i/index.html
10. Tetsuro Ogi, Toshio Yamada, Ken Tamagawa, Michitaka Hirose: Video Avatar Communication in Networked Virtual Environment, INET 2000 The Internet Global Summit Proceedings (2000)