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A Method of Mutual Tele- Existence in a Virtual Environment

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Abstract

A method is proposed to project human being into a mutual virtual environment in real time. Each one of the human users of the virtual environment is inside of a booth, of which turning circular mechanism plays the roles of both the display of the virtual environment in which all the users are projected and the input device to get the three dimensional moving picture of the user inside the booth. Each user can see the three dimensional figures of other users working in real time in the mutual virtual environment. In this paper, the concept is proposed, the method is described, and an experimental system is designed and constructed. The constructed experimental system, in which the functions of input device and display device were separated for the simplicity purpose, successfully demonstrated the feasibility of the idea.

1.Introduction

Real time projection of a human being into a computer generated virtual environment is quite useful and sometimes indispensable, especially for such applications as tele- conferences, networked collaboration and networked services. Though much efforts have been made to realize the projection of human beings into the same computer generated virtual environment in pursuit of tele- conferencing, available systems at present [1] use three dimensional human models with numbers of polygons, and usually provide unrealistic images of the human if operated in real time or need too much computer power in order to make it work in real time. From the practical standpoint , it is much desirable if the human projection can be done using real images of the human being rather than using a time consuming model of the human being who is being projected. Recently researches are being conducted to construct virtual environments by using real images without using three dimensional polygon models [2,3,4]. They need, however, human assistance or heavy signal processing by computers, and therefore, are not for real time use.

Projection of human beings into a virtual environment can be regarded as a kind of tele- existence (telexistence) in a virtual environment. Plural humans tele- exist in the same environment. From this view point, the authors have been working on the research for the improvement of the teleoperation by feeding back realistic sensory information which the remote robot or the virtual human in the virtual environment has acquired to the operator with a sensation of presence, the concept which was born independently both in Japan and in the United States. It is dubbed telexistence in Japan and telepresence or virtual reality in the United States [5- 16].

Telexistence is an advanced type of teleoperation system which enables a human operator at the controls to perform remote manipulation tasks dexterously with the feeling that he or she exists in a remote anthropomorphic robot in the remote environment, e.g., in a hostile environment such as those of nuclear radiation, high temperature, and deep space, or in a virtual human in the computer synthesized environment.

In our first reports [7,12], the principle of the tele- existence sensory display was proposed. Its design procedure was explicitly defined. Experimental visual display hardware was built, and the feasibility of the visual display with a sensation of presence was demonstrated by psychophysical experiments using the test hardware. A method was also proposed to develop a mobile telexistence system, which can be remotely driven with the auditory and visual sensation of presence. A prototype mobile televehicle system was constructed and the feasibility of the method was evaluated [17]. In order to study the use of the telexistence system in the artificially constructed environment, the visual telexistence simulator was designed, a quasi- real- time binocular solid model robot simulator was made, and its feasibility was experimentally evaluated [18].

The first prototype telexistence master slave system for remote manipulation experiments was designed and developed [19,20], and a preliminary evaluation experiment of telexistence was conducted. An experimental telexistence system for the virtual environment was designed and developed, and by conducting an experiment n the virtual environment was demonstrated experimentally [22,23]. Quantitative evaluation of the telexistence manipulation system was conducted through tracking tasks by using a telexistence master slave system designed and developed [24]. A method of constructing virtual haptic space was proposed, and an experimental hardware was made based on the proposed method [25]. It was shown that an object shape with vertices, edges and surfaces could be represented. Concave edges as well as convex edges were successfully represented using the test hardware.

Through these experimental studies, it has been demonstrated that human beings can tele- exist in a mutual remote environment and/or a computer generated mutual environment by using the telexistence system constructed. However, it was not possible to project the real time figure of a human being into the virtual environment using the system. In order to have a natural three dimensional figures of the human beings in a mutual computer generated virtual environment, it is necessary to build a telexistence system which can project real human beings into the virtual environment in real time.

In this paper, a method is proposed to project plural human beings into a virtual environment in real time. An experimental hardware system is constructed, and the feasibility of the method is demonstrated using the test hardware.

2.Projection Method of a Human Being into a Virtual Environment

Figure 1 shows a proposed booth for tele- existence in a mutual virtual environment. Each of the human user is inside of a booth, of which virtual wall can be used not only for a display of the virtual environment in which all the users are projected but also for an input device to get the three dimensional moving picture of the user inside the booth. The booth is surrounding by a circular mechanism which continuously turns at a relatively high speed carrying pairs of a video camera and an array of liquid crystal display (LED).

The LED vertical scanned panel display, which virtually make a cylindrical wall display 360 degrees around the user as it goes around the user. The vertically scanned CCD video camera, which is arranged at the position to cover the corresponding LED panel display, takes the picture of the user virtually from all angles of the line of sight as it turns around the user. The color of the

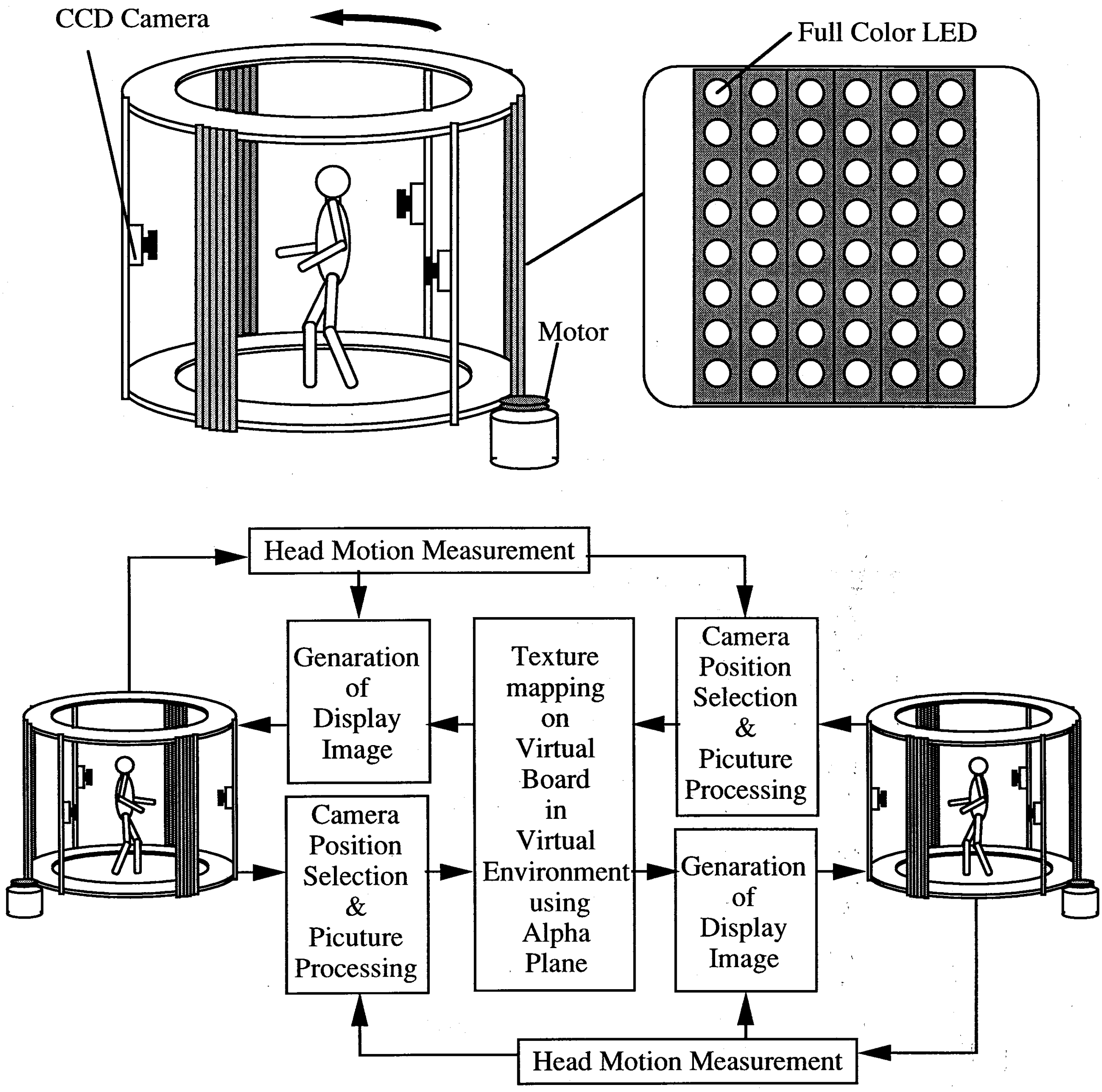


Fig.1 Conceptual Diagram of the Real Time Human Projection System.

vertical line of the LED panel turns blue at the moment of the vertical scan of the corresponding CCD to ensure that the picture of the user is always blue backed. By this method stereo information of the user can be obtained from virtually any angle. When the system is used by plural users, each user's line of sight and relative position are measured by electromagnetic sensor and are used to select the appropriate picture of other users. The images of other persons thus selected are appropriately arranged three dimensionally in a mutual environment, and displayed to all the users.

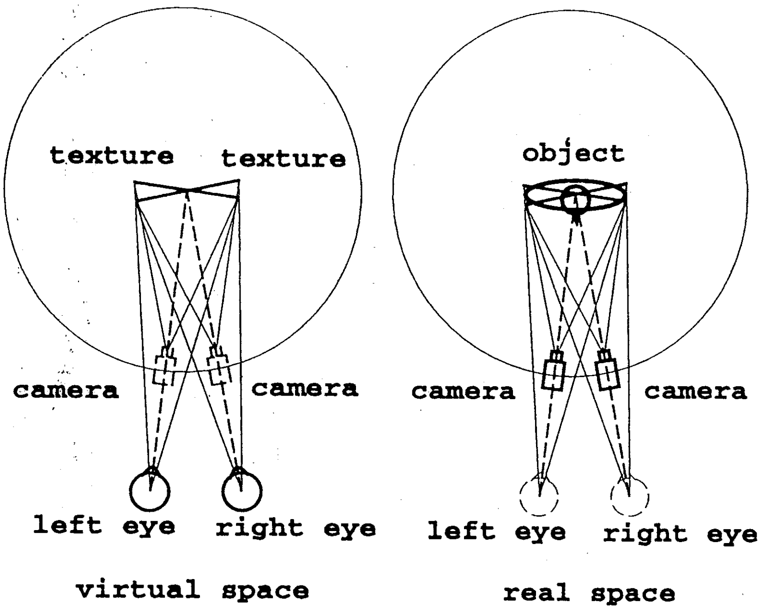


Fig.2 Observation Point in a Virtual Environment and Capturing Position at the Booth.

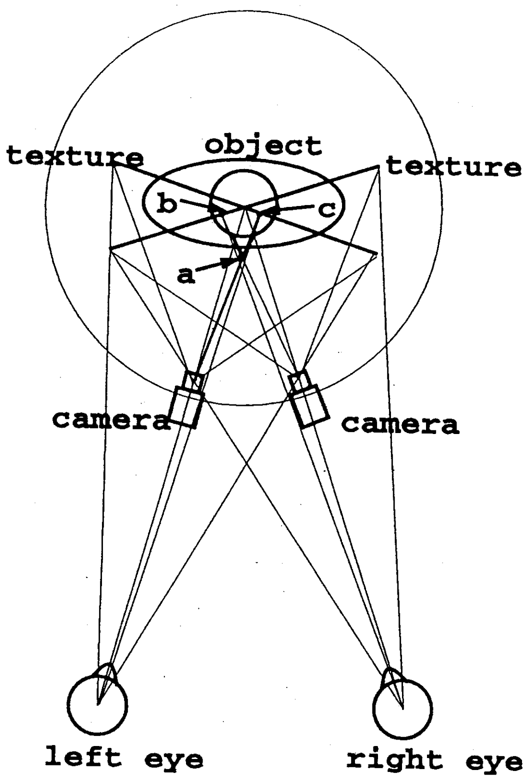


Fig.3 Texture Mapping on a Virtual Board (Alpha Plane).

Cameras are turning around the human user "A" at a high speed as in Fig.1, and a picture of the blue backed user at any angle can be obtained by assigning the position of the capture. Figure 2 shows what timing the pictures of the object are captured. Suppose that human user "B" is observing the human user "A" in a mutual virtual environment from the angle shown in FIg.2 (left). Then in the real booth the pictures taken at the position shown in Fig.2 (right) are selected. The picture taken from the left position is used for the texture for the left virtual environment, and the picture taken from the right position is used for the texture for the right virtual environment.

In a virtual environment, virtual transparent boards (alpha plane) are placed as in Fig.3, and pictures taken from the two positions (left and right) are texture mapped on the boards, respectively. Blue back parts are not texture mapped, and they remain transparent. Corresponding

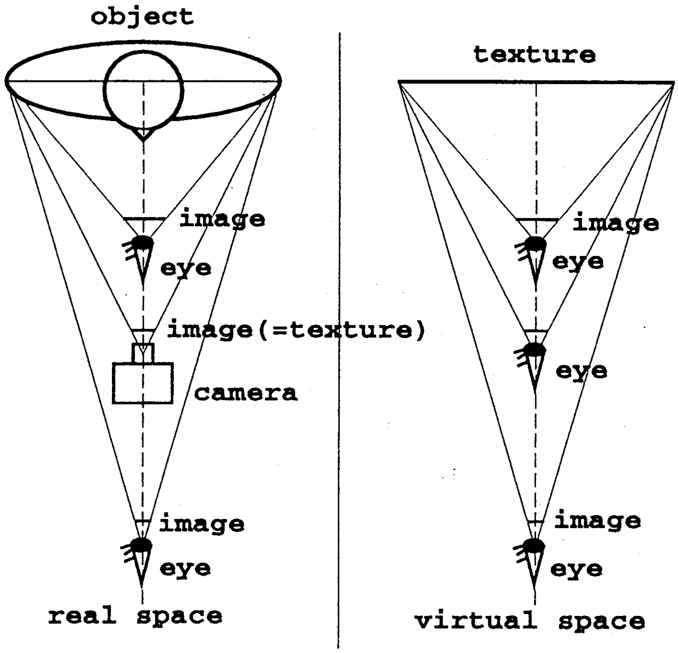
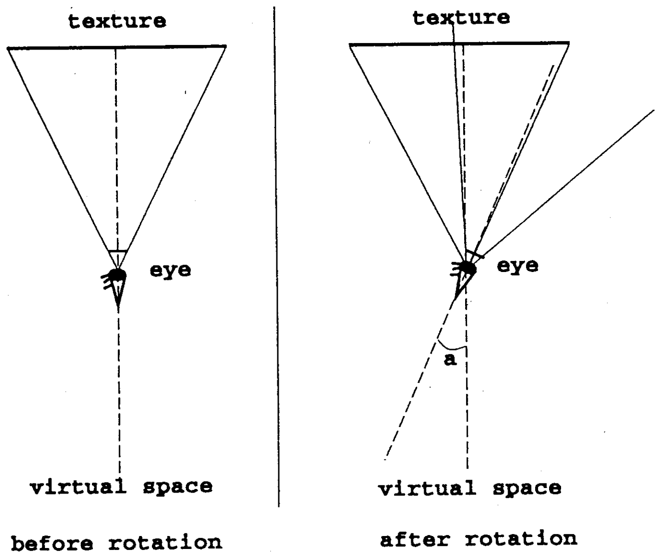


Fig.4 Distance Consideration.



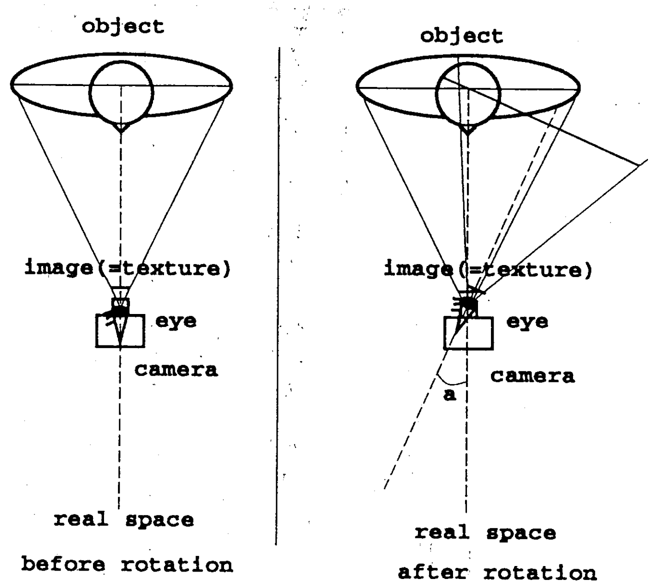


Fig.5 Rotation of the Line of Sight in Virtual Space. *Fig.6 Rotation in Real Space.*

points of the texture mapped figures on the virtual boards give rise the tree dimensional shape of the user "A", when observed by the user "B".

In the case of the distance change in the virtual environment, the texture mapped board made from the picture taken from the same direction can be used as an approximation. The situation is explained in Fig.4.

The same method of texture mapping works even if the user's eyeball turns. Figure 5 shows the situation that the human user is located at the position of the place of "before rotation," and turns his eye as is shown in "after rotation." This is just the same as in the real situation shown in Fig.6.

3.Test Hardware

Figure 7 shows the experimental hardware system constructed, and Fig.8 indicates the block diagram of the system. In this experimental system, human figure capturing function (input function) and display function (output function) were separated for the simplicity purpose. Display function was obtained using a head mounted display (HMD) with a Polhemas Sensor. For the human figure capturing, an experimental booth was constructed and used. Its blue back was physically constructed by using a cylindrical sheet of blue paper instead of electrically arranged blue back explained in the chapter 2.

A CCD Camera moved on a circular rail with an optical position sensor, and the captured image was transmitted by wireless. The captured image was transformed and processed as is described in the chapter 2:

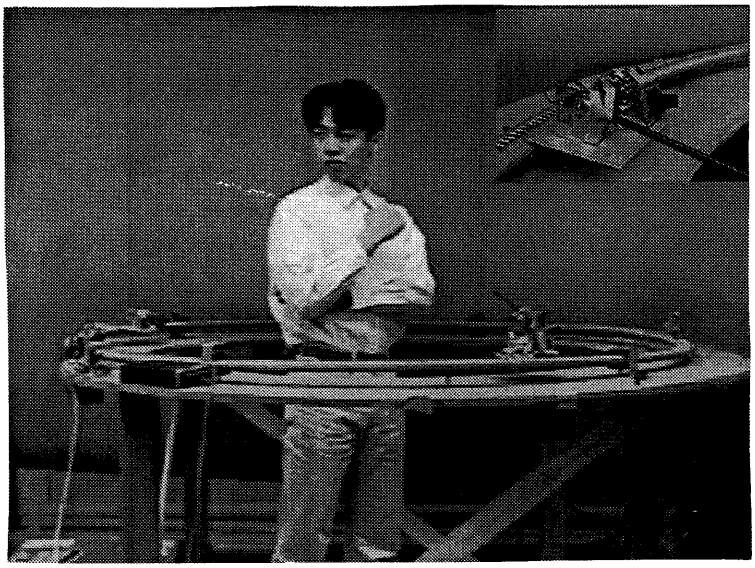


Fig.7 General View of the Experimental Hardware System Constructed.

(1) Capture the image of the human "A" against a blue background from the viewing angle of the human "B," which is measured by Polhemas Sensor mounted on the HMD of the human "A."
(2) Transform the size of the image to the real size of the human by using the distance data (the radius of the circle).
(3) Texture map the image on a virtual board, which is an alpha plane, on which blue color portion is set as the value of zero, i.e., transparent.
(4) Arrange the virtual board in the virtual environment according to the supposed position of the human "A" in the virtual environment
(5) Conduct perspective transformations from the left eye and right eye positions of the human "B" in the virtual environment.
(6) Display the generated pictures to the human "B" by the HMD, which gives rise to a three dimensional sensation of the human "A."

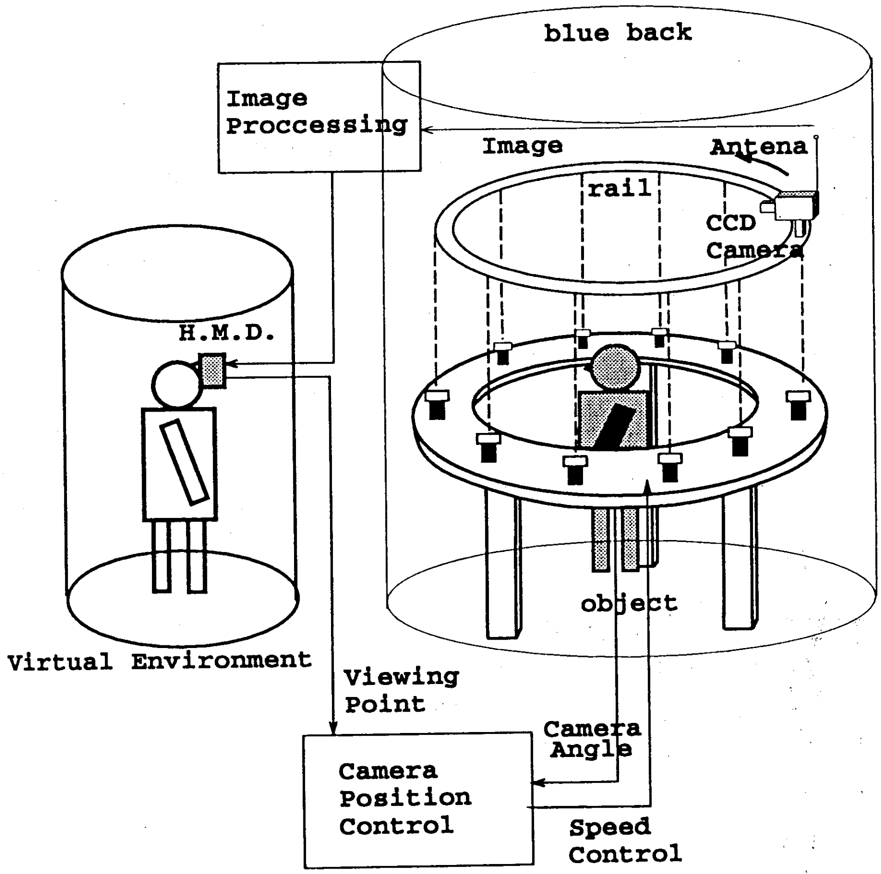


Fig.8 Block Diagram of Human Projection Booth.

Figure 9 shows the generation of the picture for display.

Figure 10 and Figure 11 shows experimental results obtained using the test hardware. In Fig.10 an observer moves parallel to the observed human, while in Fig.11 the observer goes around the observed human and occlusion of the observed human by a virtual object and occlusion of the virtual object by the virtual human are represented. This situation was observed by the observer naturally in three dimension through HMD.

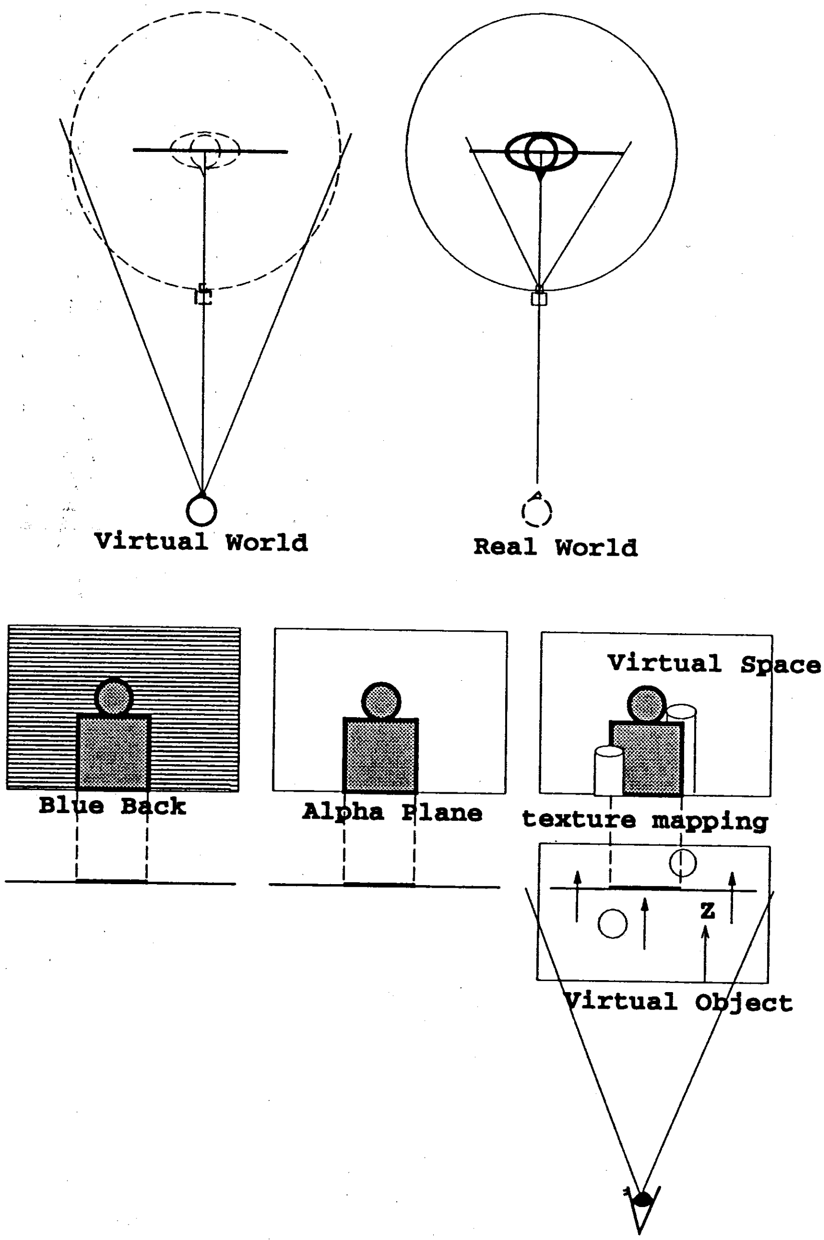


Fig.9 Generation of the Picture for Display.

4.Conclusion

A method is proposed to project humans virtually in a mutual virtual environment using captured real pictures of the human beings. Each user is inside a booth, which both displays the virtual environment and captures the picture of the user in real time from the view points of other users. The captured image is texture- mapped on a virtual board (alpha plane) in the mutual virtual environment at the position of the observed virtual human, the direction of which is arranged by

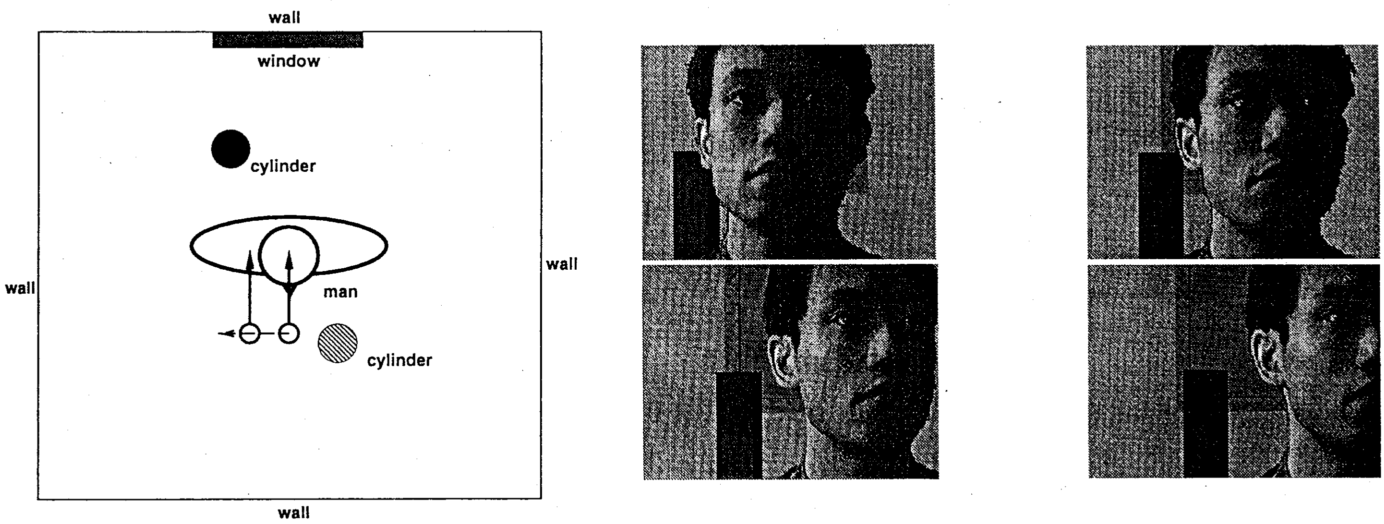


Fig.10 Experimental Result [Parallel Movement].

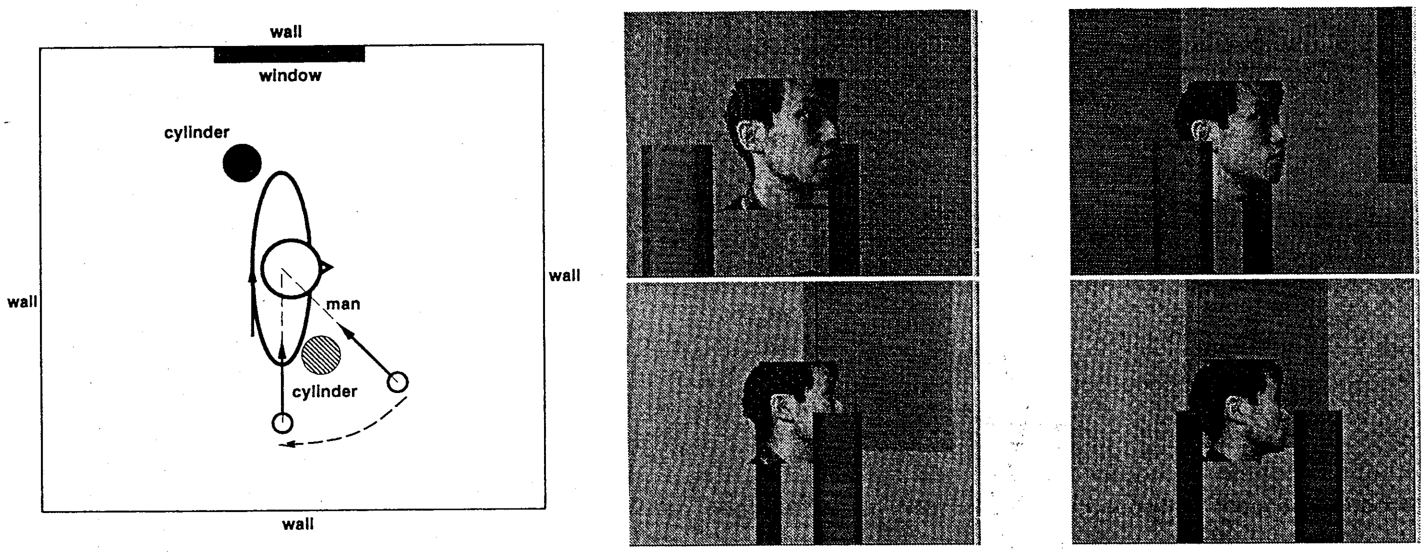


Fig.11 Experimental Result [Occlusion by a Virtual Object].

the viewing direction of the observing human. The observing human sees the computer generated virtual environment with the figures of other users occluding or being occlude by virtual objects in the virtual environment changing according to the observer s movement in real time.

An experimental hardware was constructed based on the concept. Although it separated the functions of display and capture and were not operated in real time, observers all reported that they saw convincing three dimensional figure of another user in a computer generated mutual virtual environment. Thus the test hardware successfully demonstrated the feasibility of the concept. The authors are constructing the second version of the hardware system with full specification based on this feasibility experiment.

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