VR Application for Transmission of Synthetic Sensation

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Abstract

Telecommunication with realistic sensation is becoming a topic of growing concern. For such types of telecommunication systems, it is crucial to provide wide fields of view. However, when Head Mounted Displays are used to provide a wide field of view, the time delay which occurs between head movements and displayed images presents a serious problem.

To address this problem, a new telecommunication system called the "Virtual Dome" was developed. The system consists of a rotating camera head unit, communication unit and graphics workstation. The rotating camera head unit gathers the complete image of the surrounding area from a remote location while the graphics workstation generates the virtual spherical screen inside of which the user can experience the visual sensation of being in the remote location. Since the two subsystems work asynchronously, the time delay between head movements and the displayed image while looking around is minimized. The Virtual Dome makes it possible for us to experience better realistic sensations associated with being in a remote place.

Keywords : Artificial Reality, Visual Sensation, Communication with Realistic Sensation, Telerobotics, Head Mounted Display

Category : Communication with Realistic Sensation

1 INTRODUCTION

Telecommunication with realistic sensation is becoming a key issue in many application fields such as space telerobotics. One of the important factors associated with providing visual sensation is the dynamic field of view which changes interactively according to the head movements of the user. In conventional telecommunication systems with Head Mounted Displays (HMD), the effect of time delay caused by a transmission time bottleneck is problematic. In this paper, a new system which uses a virtual environment is proposed and its potential is discussed.

2 Telecommunication and the Effect of Time Delay

2.1 Presenting Realistic Sensation

Recent advances in hardware and software innovations have allowed us to move closer to the goal of providing realistic visual sensations which can be transmitted from remote locations to a centrally located observer. Among the various factors which were considered to influence the quality of effective visual sensations (i.e. field of view, stereo sensation, resolution, and image refresh rate, etc.), attention was focused on the field of view as a means of significantly improving the quality of realistic sensations when they had to be transmitted from one remote place to another. Essentially, fields of view were classified into two types: Static Field of View (SFOV) and Dynamic Field of View (DFOV). SFOV refers to the viewfield which is presented when the user's head is in a fixed position and DFOV refers to the frequently changing viewfield which is observed when the user moves his/her head in a random fashion.

Some experiments conducted by Hatada demonstrated that if the SFOV is less than 20 degrees, the quality of realistic visual sensations becomes very poor [1]. In addition, it was also shown that a SFOV of at least 80 to 100 degrees was required to generate suitable realistic sensations.

For the DFOV, the HMD has found useful application because it is capable of providing a significantly wider field of view as well as a DFOV when the user moves his/her head interactively.

2.2 Problems with Conventional Telecommunication Systems

A conventional telecommunication system which uses the HMD is shown in Figure 1. In this system, the camera head system is directly connected to the human operator. The spacial position sensor determines the head movement of the human operator and the camera system moves accordingly so that the required image can be displayed to the HMD.

One of the most serious drawbacks in using this type of conventional HMD telecommunication system is the time delay which exists between head movements and displayed images. To provide realistic sensations, displayed images should be timely refreshed according to head movement. If the coordination is insufficient, and there exists considerable time delay between head movement and picture refreshment, we can never achieve the realistic sensation of looking around in 3-D space. Moreover, if time delay is greater than a certain limit, the user may become dizzy or nauseated.

Several experiments have concluded that this type of time delay is harmful to the human operator in understanding the remote situation around him [2, 3]. One experiment focused on target tracking performance by measuring the effect of time delay on performance when an operator was asked to follow a sinusoidally moving object (Figure 2). Typical results are shown in Figure 3. When the time delay was small, subjects could track the target easily. However, when the time delay was

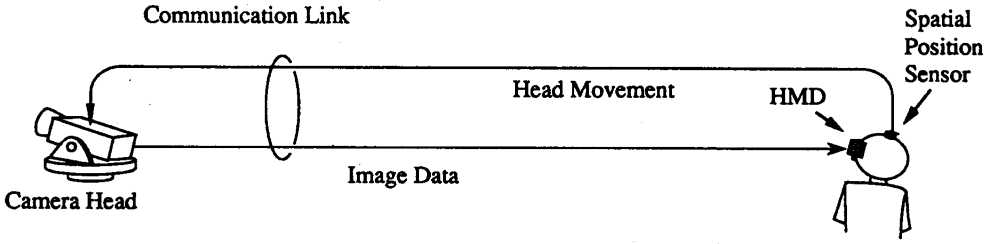


Figure 1: Concept of Conventional Telecommunication with HMD

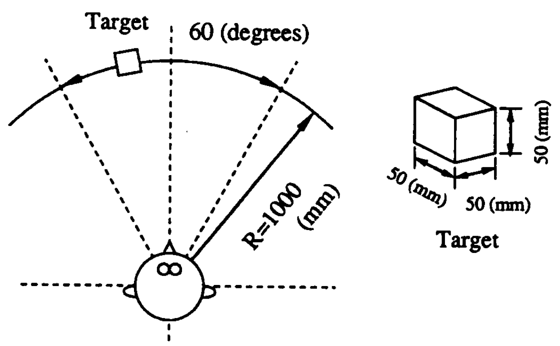
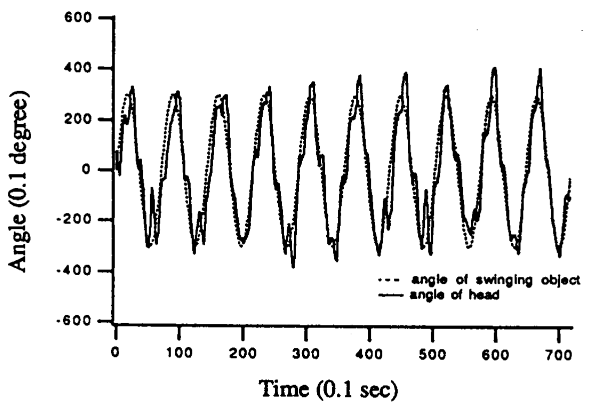
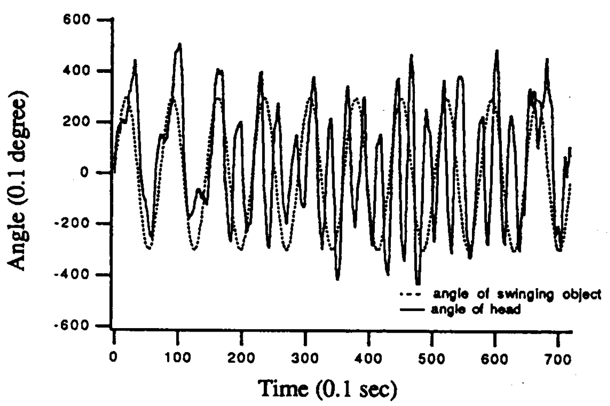


Figure 2: Set Up for Tracking Experiment



(a) Time Delay=0.7(sec), Frequency=0.14(Hz)



(b) Time Delay=1.3(sec), Frequency=0.14(Hz)

Figure 3: Typical Target Tracking Motion

beyond a certain limit, subjects experienced tracking difficulties. A summary of the results of this experiment are shown in Figure 4. The performance was measured in terms of time delay and swing frequency and evaluated by the normalized mean squared error from the target location.

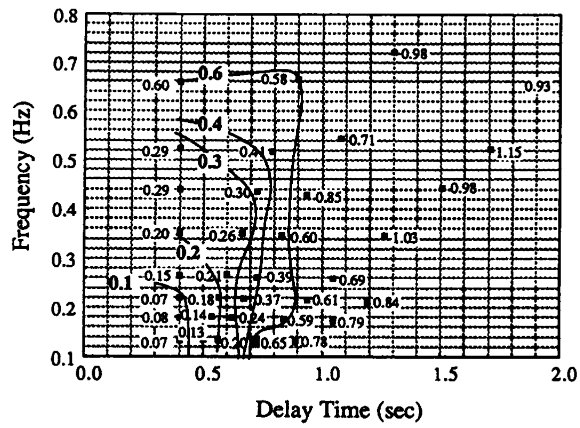


Figure 4: Tracking Performance

Another experiment measured the effect of time delay on users when they were asked to remember spatial positions of virtual objects under various time delay conditions. The results of these experiments demonstrated that time delay should be less than 900 milliseconds or so for acceptable results.

In the field of telerobotics, there is often a certain distance between the telerobot and the human operator which causes a considerable time delay. Even if the telerobot is within the earth's satellite orbit and the human operator is on the ground, about 1 second is needed for one-way communication from the operator to the telerobot. If the telerobot is on Mars, the time delay involved will be between 3 to 21 minutes. In this situation, the time is already beyond the limit for providing suitable realistic visual sensations.

If the camera system of the telerobot is always directly connected to the human operator, time delay in the communication link may make it very difficult to satisfy the minimum time requirement mentioned above. Without any compensating technology, we cannot realize a satisfactory "looking around sensation".

3 Development of the Virtual Dome

3.1 Concept

To address the time delay problem, we proposed the design principle shown in Figure 5. The system was called a "Virtual Dome"(VD). The key principle of the VD is that the camera head movements and the human operator's head movements are basically asynchronous so that the communication delay on the communication line does not directly affect the performance of the looking around function using the HMD. By doing so, the time delay effect between head movements and the displayed picture while looking around is minimized.

The VD includes 3 subsystems; (1) a rotating camera head unit (CHU), (2) a communication unit (CU), and (3) a virtual space generator (VSG). The CHU continually scans its surrounding space to capture a complete image of the surrounding area at the distant location. Pictures are transmitted to the VSG via the CU. The hardware of the VSG, which is a type of Virtual Reality System, consists of a graphics workstation, an HMD, and a head rotation sensor. In the graphics workstation, the virtual spherical dome is constructed via a set of polygons. Images taken by the CHU are texture-mapped to the corresponding polygons. In such a way, the surrounding information from the remote site is copied onto the virtual dome. Images corresponding to field of view are displayed on the LCD screen of the HMD. By using the HMD, the human operator can look around the virtual dome from inside and experience the visual sensation of being present at a remote site.

3.2 BASIC IMPLEMENTATION

The current system under development is shown in Figure 6. The CHU, driven by two stepping motors for horizontal and vertical movements captures each polygon individually (Figures 7 and 8). The movement of the cam-

Figure 5: Concept of "Virtual Dome"

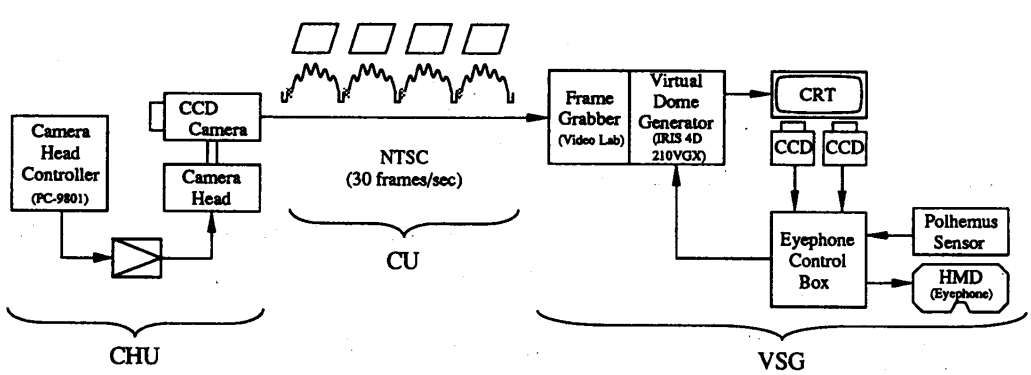


Figure 6: "Virtual Dome" System

era head is shown in Figure 9. In the CHU, a CCD color camera (SONY XC-711RR) with 4 millisecond shutter speed is used. The camera's view angle is 24 degrees in horizontal direction and 18 degrees in vertical direction. In these conditions, the CHU can rotate at a rate of 6 rpm without distortion of the image.

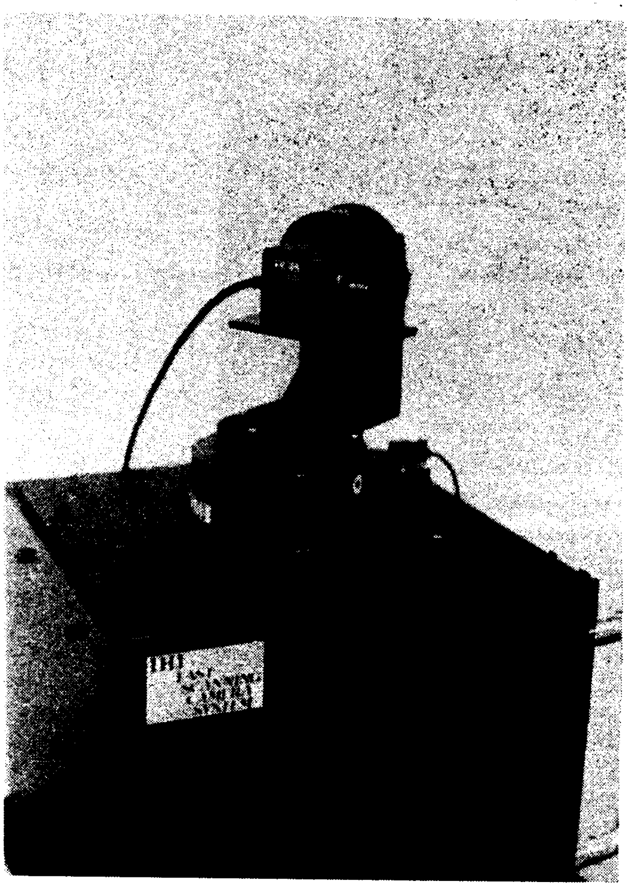


Figure 7: Camera Head Unit

The images are transferred to the VSG through the CU interface, which is currently an NTSC channel. A Frame Grabber (Video Lab) is used to digitize these images at a speed of 30 frames per second. The resolution of the digitized image is 64 × 48 pixels and the depth of each pixel is 24 bits (8bits × 3 (RGB)).

For the VSG which generates the virtual spherical dome, a graphics workstation (IRIS 4D 210VGXB) is used. The shape of the Virtual Dome is shown in Figure 10. This dome is composed of 15 polygons in the horizontal direction and 6 polygons in vertical direction (90 polygons in total). We can experience a range of approximately 60 degrees above and 45 degrees below the horizontal plane.

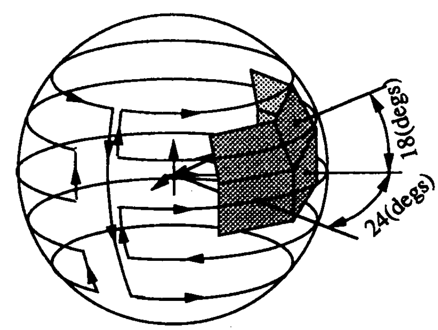


Figure 9: Movement of Camera

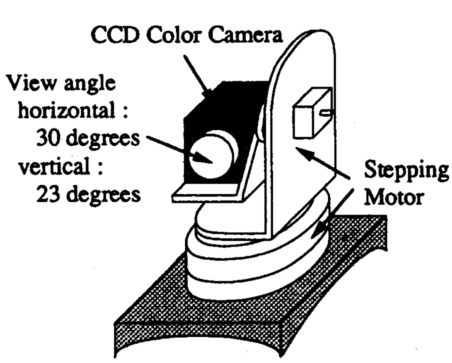


Figure 8: Rotating Camera Head

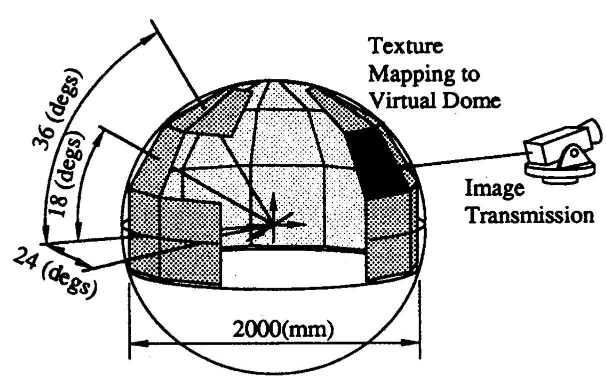


Figure 10: Shape of "VD"

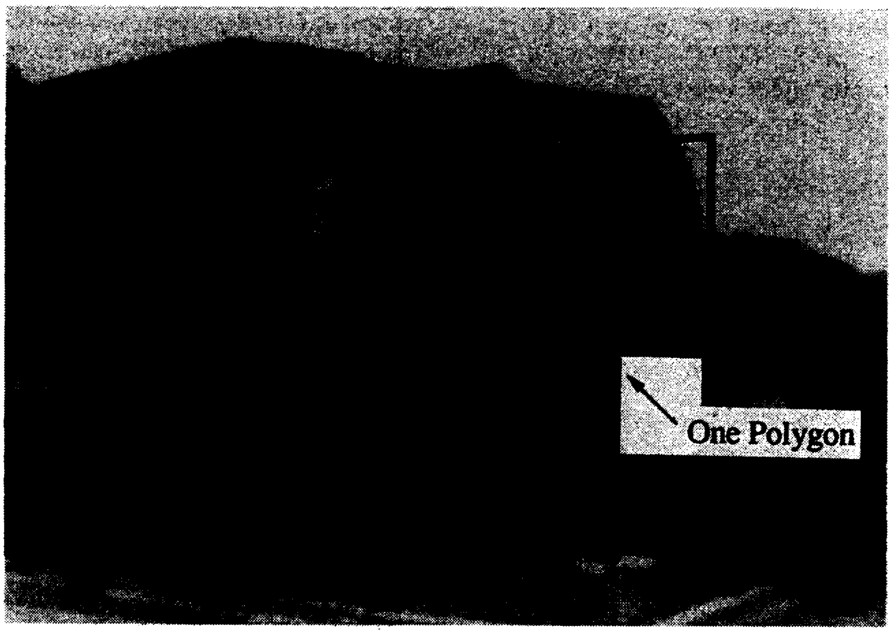


Figure 11: Displayed Image on HMD

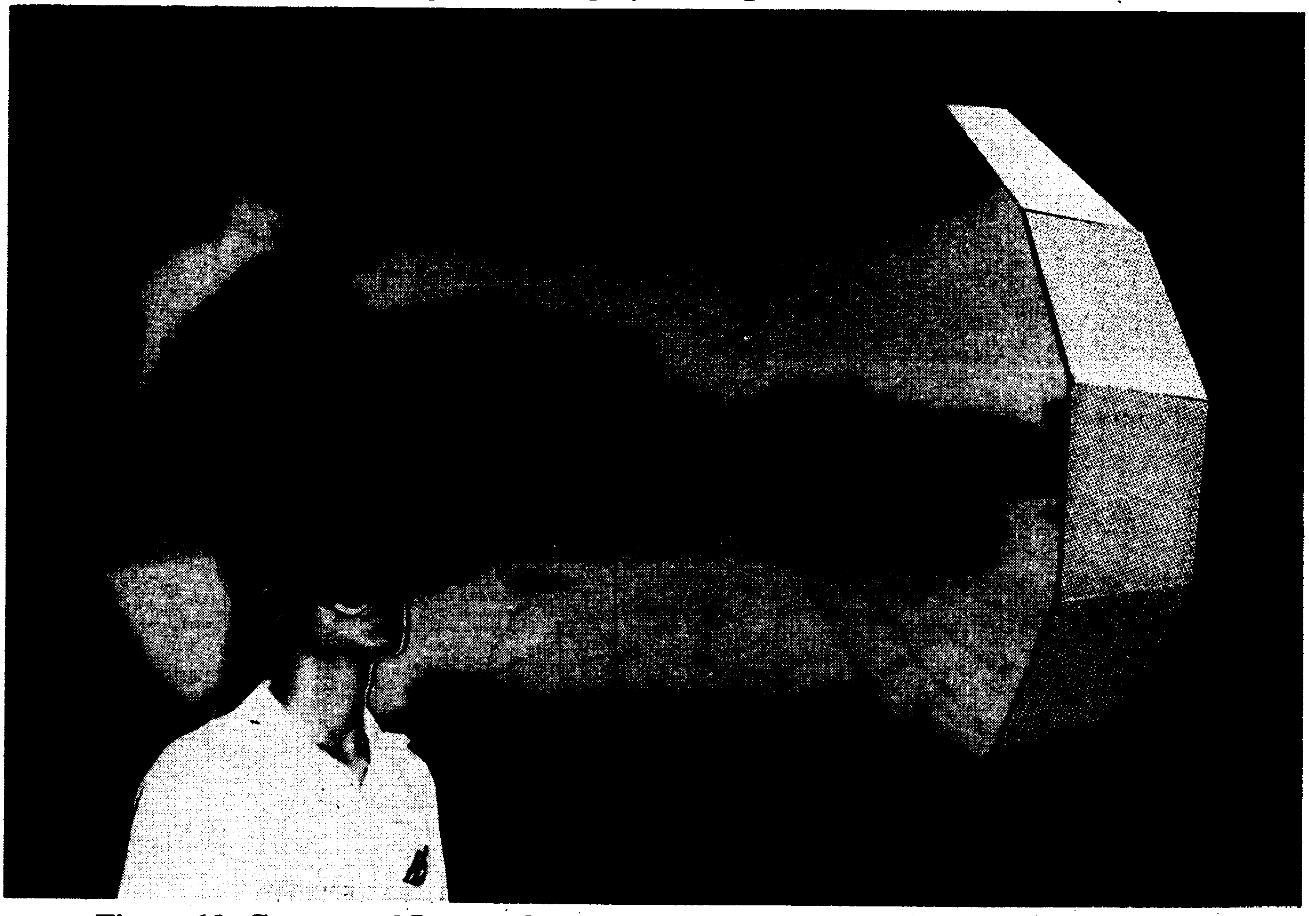


Figure 12: Conceptual Image of the Virtual Dome as Shown by This Prototype

4 Improvement and Potential of the Virtual Dome

At the basic implementation level, a few simplifications were made to lower the overall cost of building the system and to avoid some technical difficulties. As a next step, the following improvements are being considered and currently under implementation.

4.1 Use of Data Compression for Image Transmission

As mentioned before, the current CU uses the simple NTSC format, but a more sophisticated communication protocol capable of compressing image data could also have been implemented. For example, instead of the NTSC, ISDN (64 kbps or 128 kbps) with CODEC can also be used. In this case, the image is compressed at the camera head location since the capacity of the channel is much smaller than that of NTSC channels. By using these suggested methods, it will be possible to cost-effectively develop world wide communication systems with realistic sensation.

4.2 Sophistication of Camera Head Unit Hardware System Design

Concerning the CHU hardware design, the following alternatives for obtaining remote images can be considered.

(i) Make the camera head fluctuate and scan its surroundings.

(ii) Fix the camera and use a rotating mirror (Figure 13 (a)).

(iii) Obtain images using a fish-eye lens (Figure 13 (b)).

(iv) Use multiple cameras and electrical switching (Figure 13 (c)).

We have chosen the first method, but other methods must be also considered.

Software aspects should also be considered for the CHU movement. Currently, camera movements are uniform, that is, completely independent of the direction in which the human operator is looking. We must keep in mind that the rate of image capture capable in the CHU system and the refresh rate of the VD is limited and that refreshing all areas of the VD at the same rate is computational waste and will result in a bottleneck for the system's speed. Therefore, the refresh rate can be maximized in the area of the VD where the subject is directly looking to provide a clearer image. Other areas not being observed at that time can be refreshed at a much slower rate as they cannot be seen. Although not implemented in this study, this concept will play an important role in improving the prototype VD system's speed and realistic sensation.

4.3 Supporting 3-D Images

3-D images were not used in the current system. For distant objects, binocular viewing was found not to be very effective. However,

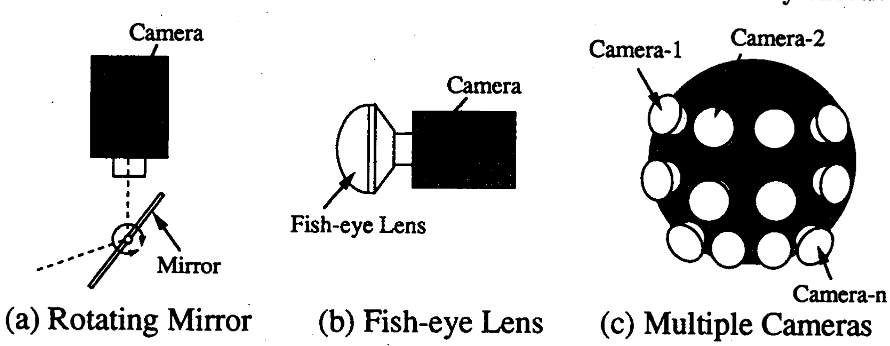


Figure 13: Other Camera Head Systems

binocular viewing is important for displaying the objects that are nearby. Thus, we are currently examining various possibilities.

First, the simplest method is to use 2 cameras in the CHU. Images from both cameras can easily generate stereo images. However, if we must consider head tilting, the required solution becomes much more complex. Moreover this system would only support static stereo viewing and not moving stereo vision.

Second, if we can detect the location of the nearby objects using sensors, computer graphics may be used to generate these objects. In this case, images on the dome are used only for the background to present better realistic sensation and to make it easy to realize and act in virtual world (Figure 14).

Third, if we can measure approx 3-D shapes of surrounding world by other methods such as radar scanner or computer vision, we can reconstruct an 3-D world model of the distant place in the VSG. In this case the shape of VD may no longer be spherical but uneven (Figure 15).

By using the second and third method, we can generate a pseudo 3-D world. This would enable us to not only look around by rotating our heads, but to look underneath a chair, around a corner, or down into an open box or container.

4.4 Integration with Other Sensations

To realize other modes of interaction, such as those involving auditory sense or tactile sense, further research is required in these respective areas, and also on how to integrate these different types of interaction modes with each other and how to make up the model of a remote world in a workstation for the effective transmission of realistic sensations.

4.5 Observation System or Virtual Trip

If several VDs are used together, an effective observation system can be constructed to cover very wide areas of a remote place (Figure 16). CHUs can be strategically positioned in the districts of concern within the large area and the districts will be drawn by texture mapped real images, while other districts, not monitored by CHUs, and of less importance,

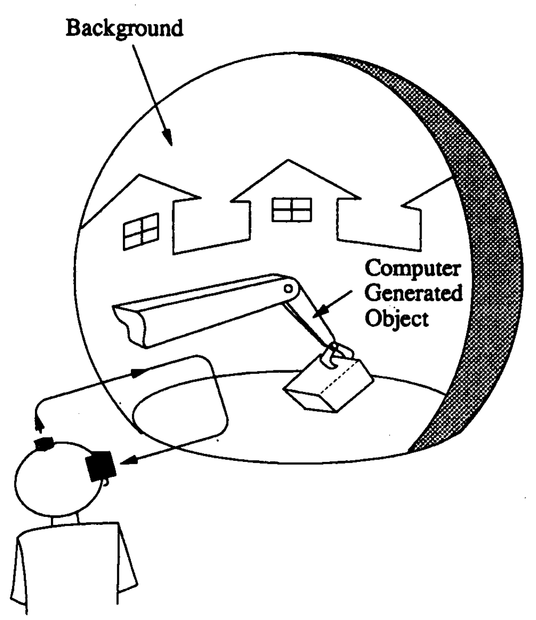


Figure 14: Virtual Dome used to Provide Background

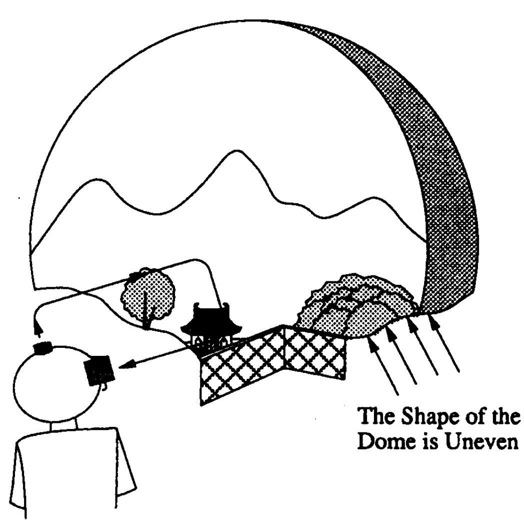


Figure 15: Making the Shape of the Dome Uneven

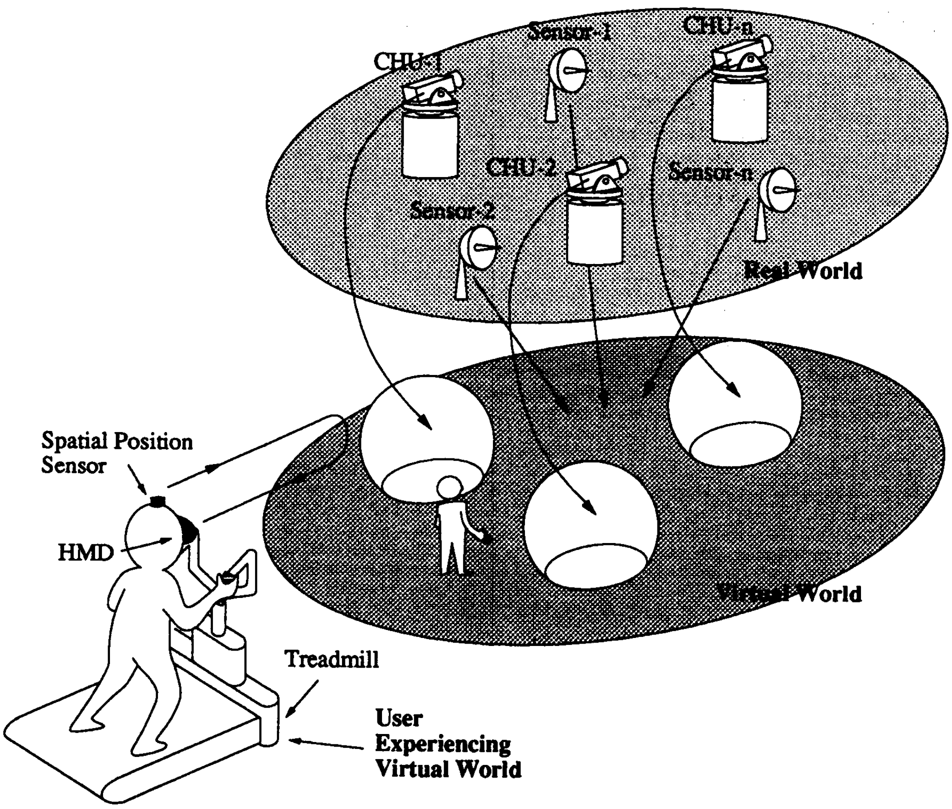


Figure 16: Large Scale Virtual Dome Observation System

can be observed using conventional computer graphics based on simple sensors to obtain information. To virtually navigate through this remote location, a Virtual Walkthrough system could be integrated with the VDs to allow effective observation and of large areas.

5 CONCLUSIONS

The "looking around" capability is an important function for achieving communication with realistic sensations. For the improvement of time delay effects associated with conventional telecommunication systems using the HMD, we proposed new design principle using a virtual environment as a buffer. By using the Virtual Dome system, it is possible to effectively support this looking around capability.

A buffering mechanism such as a virtual dome is inevitable for communication with realistic sensations - particularly when the delay time of the communication channel is lengthy.

Further research will involve using other types of information from the remote place and applying them with the Virtual Dome.

6 ACKNOWLEDGMENT

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