Water Dome –An Augmented Environment-

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Abstract

The purpose of this research is to demonstrate the influence that a water dome has on a person. The following approach was used for this study:
(1) A water display was used as a projection screen;
(2) The illusion of being under water was created; and
(3) Experiments with water domes of various sizes were carried out.
Water display is a head mounted type water membrane. When the display is projected, the inside surface acts as a concave mirror that can reflect the hand and face of a participant. Water dome is a hemisphere eight meters in diameter. Participants were allowed to see the real world through a transparent wall of water on which computer-generated images were projected. A water dome has the advantage of engaging a participant's five senses as it enhances the surrounding environment. We developed a water dome that incorporates the points of view of both the artist and the engineer.

1. Introduction

1.1 Background•

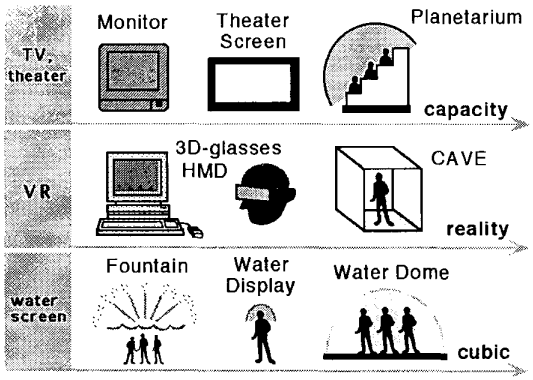

Figure 1. Display sizes

Recent investigations have demonstrated that a three-dimensional screen can play an important role in a virtual environment. It has been proposed that a wide-angle display such as Omnimax, a spherical screen, might be used to create a virtual immersion experience for its viewers[1]. It is clear that these cubic displays are suitable for the creation of three-dimensional space[2] [3]. While fountain technology has been developing for water screen applications over the past 15 years, projected images have been used in conjunction with mist and streaming water at some theme parks. Figure 1 shows examples of screen sizes. The sense of being surrounded and immersed depends on how much the screen is enlarged. Recent trends in screen shapes are three-dimensional. Large screens emphasize the feeling of being entertained. Dome-shaped displays have been developed primarily to enhance the visual field by surrounding a participant with a curved surface. However, this system offers more than the sense of sight alone. For instance, the screen walls eliminate outside sound and amplify inside sound. Therefore, we proposed that water serve as a display material. The use of a water dome enables participants to really experience the space.
Visitors may see the real world as it is projected through a thin wall of water with the sound of the rain. The water dome is proposed as a method to challenge all five senses in a virtual reality experience.

2. System Design

2.1 The size of the water display

Falling water creates a water display when it strikes an object. In particular, a laminar flow creates a smooth and thin water membrane. A turbulent flow such as water gushing from a pipe does not create a membrane. Figure 2 lists the technical elements of a water display. We first verified the six prerequisites for a water display. The construction of a water dome has its roots in fluid dynamics. We observed a combination of a flat and a

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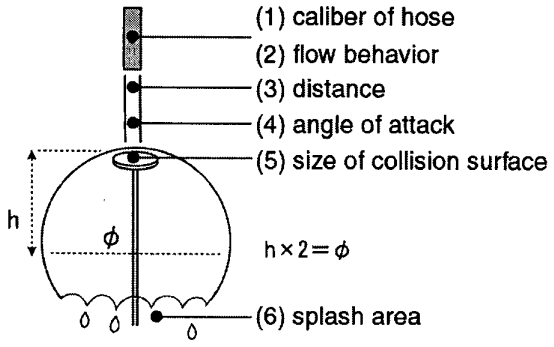


Figure 2. Elements of water membrane

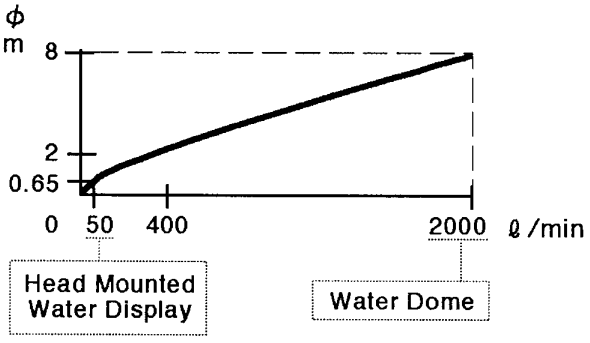


Figure 3. The diameter of water display

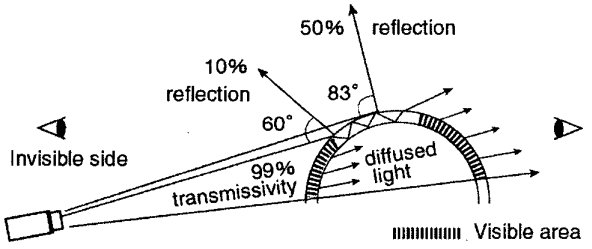
circular surface, and we concluded that a gentle stream is the best for constructing a hemisphere with a water membrane[4]. We next collected data and examined the relationship between the quantity of the water to be used and the diameter of the water exhibit.

Figure 3 demonstrates that as the flow rate of a pump increases, the diameter of the water dome increases as well. We experimented with water displays ranging in diameter from ten centimeters to eight meters. A water membrane loses its smoothness when the diameter of the fountain exceeds two meters. At that point, its form changes into streaming water. Regardless of how the water flow is changed, the water display retains a hemisphere that can be entered. In addition, a curtain of water formed by multiple water jets forms a background suitable for image projection.

2.2 Light reflection in a water display

The water dome creates a transparent film of water upon which lights may be projected[5]. Figure 4 shows the reflection on the water display. When a projector is set up in the rear of the display, only participants who stand in front of the display may observe the lights. Projected images are invisible to the visitor who is located next to the projector. The light reflection depends on the angle of incidence to the surface of the water. As the angle of incidence increases, the percentage of the light reflection on the surface of the water increases as well. Therefore, the top arc of the water display reflects half of the light so that it shines the brightest. The center of the display becomes the screen, which shows penetrated and diffused light that makes up the projected images. A participant who faces the projector through the water display may see the images clearly. Consequently, it is advantageous to set up the projector at an oblique angle in order to avoid having any participant directly face a light source.

Figure 4. Reflection on the water display



3. Presentation

3.1 Water display

The water dome is empty inside. We examined the inner water display for the sense of sight, hearing, touch, and feelings that it would convey. Figure 4 shows a head-mounted water display that we developed in 1998[6]. The water circulates through the pipes with a 50-liter per-minute pump. The water display is formed on a doughnut-shaped pool that is 70 centimeters in diameter. A participant may duck under the edge of the pool and stand beneath the water. The viewer's head remains dry because the inside of the dome is empty; however, the water display sometimes creates a refreshing light rain that moistens the face of the viewer. Visitors can enjoy seeing and hearing the water from

Figure 5. Head mounted water display

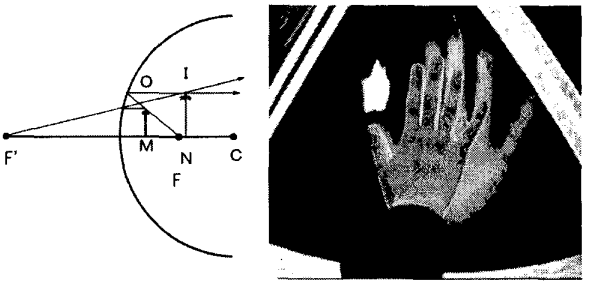


Figure 6. Projected image

inside the display. The sound from the dome is concentrated inside the dome, and the falling water blocks the sound from outside the dome. The water display provides an unusual experience providing a viewer with a watery 360-degree view.

We would first like to explain how the water reflects from the display. When the display is illuminated, the inside surface acts as a concave mirror that can reflect the hand and face of a participant. Figure 6 shows the reflection of a hand as it is raised to the surface. As a hand comes closer to the water membrane, its image becomes larger, and as a hand is withdrawn, the image becomes smaller.

We next examined the projection effect. Figure 7 (left) shows projected letters of the alphabet that are scattered on the water display. Only vague images can be seen on the water. The display area requires medium ambient light. Too bright an environment is not suitable for a water dome. Considering the nature of the reflected images and the need for low ambient light, we designed a new way to view the images on the water display. Figure 7 (right) shows reflected images of a user's hand emerging on the water display. By moving the hand closer to the reflected images, the images became clearer. The proximity of the hand to the water makes a reflection even in a brightly lit environment. By moving one's hand, one can search for invisible information. The reflected images cannot be seen from the outside of the display

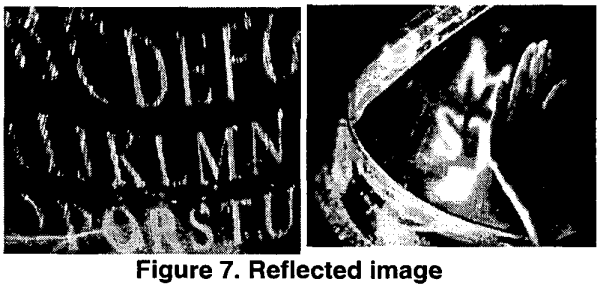


Figure 7. Reflected image

because the phenomena are virtual images.

A public demonstration of this display was given during the SIGGRAPH[7] 1999 exhibit in Los Angeles, CA, U.S.A. In a dark room, projected images may be observed directly on the water display. A high beam projects a sharper image on the water membrane. We prepared a variety of images from a variety of sources. A high-contrast source is easy to see on a water membrane. For instance, white letters on a black background or yellow stars on a blue background both project well. We projected the word for "water" in many languages: *Aqua* (Interlingua), *das Wasser* (German), *Voda* (Czech), and *Mizu* (Japanese). The projected letters stand out crisply against the background making an inviting and artistic statement. The projections were changed every five seconds. Since the water display is created with circulating water, attention is first paid to the falling water. Because the image on the water membrane is so weak and blurred due to the speed of the falling water, the image is not clearly recognizable. Participants approached the water display, read the letters, and told us what feelings the water display evoked. Figure 8 shows another sample of the water display with projected images. A projected star figure was most popular with the visitors. They were reminded of a planetarium and experienced a fresh feeling. When people stood under the water display, the moment they noticed the images, they were actually moved. This demonstration brought

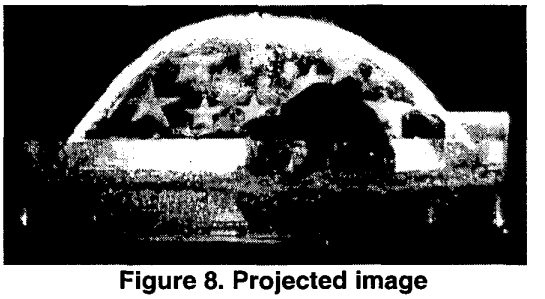


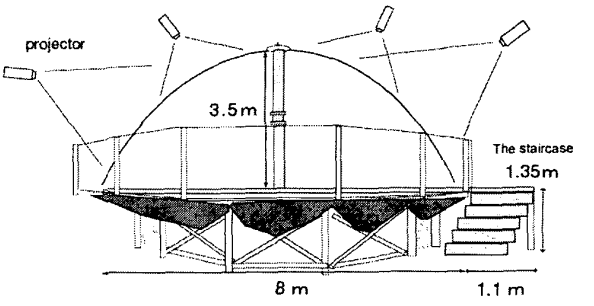
Figure 8. Projected image

Figure 9. Water dome project in Spiral, 1999

attention to the water display as a new medium, one that can serve as an information source because of the projected images.

3.2 Water dome

Finally, we studied the effects of a large version of the water dome. The first exhibit was a system for personal use. The head-mounted water display covers a viewer's head. It does not support users in communication with other people. Therefore, we created a water dome that many participants may enter simultaneously. A space was created that was surrounded with images and water. Figure 9 shows the water dome project on exhibit at the Aoyama Spiral Garden. The water dome was exhibited in Tokyo in November 1999. In order to accommodate 20 people, a stable stage with an eight-meter diameter and a water pipe with a four-meter height were used. A temporary pool was built under the stage. Two 1000-liter per-minute pumps spread the water out into the shape of a dome. The jets of water gushed out of the top creating a screen of water droplets. A screen of droplets produces a better screen than the seamless membrane produced by a transparent, continuous flow of water. Although the water form is changed, the light reflection and diffusion on the water surface remains unchanged. For this reason, the same images on the water surface could be seen from any angle, and four projectors were placed around the water dome. The content and the animation speed depend on the size of the water display. Because a water dome has a curved surface, the projected images are distorted. Taking that into account, geometric patterns of animation images were projected in high-contrast. The distortion of the images on the side of the water dome created a unique

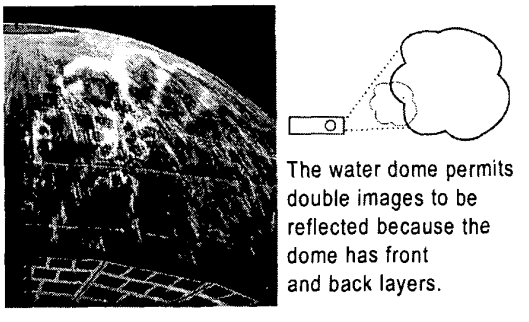


Depth 10m × Width 11m × height 4.6m (The body 10m in diameter)

effect. If the animation moves across the dome, it seems like more depth is acquired. The flowing water created a liquid dome vivid with color and sparkling on the water. In addition, the water dome permits double images to be reflected because the dome has front and back layers.

Figure 10 shows the projected images on the dome. Therefore, participants could be observed standing under the projected water hemisphere. They appeared to be colored with floating blue waves, pink flowers, and white rings. Participants inside the dome watched the images that were being projected on the inner side of the dome while they simultaneously experienced a fresh wind blowing from the floor. The impressions that the spectators reported are sensual. The feelings arise with water ever present. They report sensations that often accompany deep breathing, and the pleasures associated with dream-like sights. The display makes it possible to superimpose images on the surface of the dome. Actually, the water dome is a see-through screen. The scene on the inside of the dome may be clearly seen from the outside of the dome. Participants on the inside of the dome may forget that people on the outside of the dome may see

Figure 10. The projected image on the dome



The water dome permits double images to be reflected because the dome has front and back layers.

them. The inside of the dome is much more stimulating

than the outside. The exhibit of the water dome in Tokyo attracted 13,323 people. People of all ages and nationalities enjoyed the water dome. The project provided people with sensations of fun, comfort, surprise, and relaxation.

4. Augmented Reality

4.1 Use of a water screen

Since the baroque era in Europe, fountains have been constructed in the center of cities. Italy has many examples of such fountains that still serve as gathering places. Such fountains still serve to light up the nights. Fountains were popular gathering places because of their relaxing atmosphere. Water has a comforting power. In addition, it can now be used as a medium for graphic arts.

There is a good example of a water screen currently in use at Disneyland. It has a fan-shaped stream that is created by multiple jets of pulsing water. The fountain is transparent so that images may be projected on it. When I saw the fountain at Disneyland, a real actor portraying Mickey Mouse had a fight with a virtual witch projected on the fountain. Mickey sometimes appeared in front of the fountain and sometimes hid behind the fountain. This was a good example of the entertainment potential of the use of the water screen as an augmented reality. At this time, not much thought had been given to the role that spectators might play. Spectators currently watch the show passively from a distance. Therefore, the following section focuses on special features of the water dome.

4.2 Water display and interaction

Water dome visitors may view a variety of images while surrounded by water. Spectators can become participants and play active roles in the water dome experience. Participants' opinions have ranged from "amazing," "wonderful," and "cool" to "I don't know how to describe it." The water display presents multiple elements regarding water, and participants feel fresh sensations involving all five senses. It is reasonable to suppose that the water dome is an interactive art on the grounds that it prompts people to respond independently. Interactive art and virtual reality share certain similarities in that both deal with experiences of representation. The water display demonstrates an augmented reality. The water dome changes the environment for the viewer. Even when the exhibition was held in a simple atrium of the Aoyama Spiral Garden in Tokyo, participants felt as if the world were altered. Some people wanted to experience the water dome under the stars. An outdoor use[8] of the water dome is a logical next step. During the day, a water dome serves as playground equipment that allows people to experience what it would feel like to stand at the backside of a waterfall. When evening comes, it will work as a screen for graphic images.

It is especially important to emphasize the concept that water domes are transparent displays. The aspect of transparency distinguishes the water dome from cubic screens that may simultaneously be observed from inside and outside. Using water as a display material enables projection from either side. Therefore, if we prepare two projectors and project another image source on the water display from an opposite side, we could see both images on each surface because the light does not interfere and penetrate the water display. At this point, a new water dome system that consists of plural images with multiple projectors is being investigated. It is possible to divide water dome surfaces into screens for multiple projectors. In the future, it is not inconceivable that every town might have a fountain functioning as a medium for presenting information. Moreover, it may be possible to project the actions of participants onto the water screens of the dome.

5. Conclusion

This paper is a description of water domes that have been investigated and implemented. A water dome has the advantage of engaging a participant's five senses as it enhances the surrounding environment. In addition, the possibility of image projection, interaction, and enlargement was also examined. Participants were allowed to see the real world through a transparent wall of water on which computer-generated images were projected. The water dome proved to be popular with spectators. A spherical screen provides a person with deep involvement. Furthermore, it has the capacity to serve a small audience. The potential of the water dome might be compared to inventions such as the Imax projection system and planetariums. Fountains may take many forms; however, we would like to continue to develop the water dome because of its special characteristics. A dome was built in London as a part of the recent millennium celebration. It is in that same spirit that we are creating our current water domes. Literally, an artist often tries to change prevailing points of view. Our hope is that the water dome will make a contribution to the quality of life. Future water domes could be used by the entertainment industry in amusement parks or as exposition presentations, and they might even find uses in common towns as fountains for the projection of information.

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Acknowledgement

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