Object-Oriented Displays: A New Type of Display Systems — From Immersive Display to Object-Oriented Displays —

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ABSTRACT

In this paper, we propose the concept of the "Object-Oriented Display," which should enable an operator to perceive and operate a virtual object as if it were a real one.

The Object-Oriented Display (OOD) is a new type of display system in which the surfaces of the display surround the ***object*** and not the operator. The purpose of the OOD is the presentation of virtual objects, whereas the purpose of ordinary display systems is the presentation of the virtual environment.

In this project, we also describe the design and implementation of three types of object-oriented displays, (i) The MEDIA-A (MEDIA-Ace), (ii) The MEDIA^3 (MEDIA-Cube) and (iii) The MEDIA X'tal (MEDIA-Crystal).

The MEDIA-A is a type of object-oriented display that is compact, light, and inexpensive. It consists of a single LCD panel and a tilt sensor.

The MEDIA^3 consists of four LCD panels in the shape of a cubic body. A position and orientation sensor is installed in the MEDIA^3. Using the MEDIA^3, a virtual object is adequately displayed by controlling the image displayed on each LCD panel, corresponding to the position of the operator's head. Thus, the virtual object appears in the MEDIA^3 in its entirety. Therefore, the operator can recognize easily and intuitively the three-dimensional form and structure of the virtual object.

For the MEDIA X'tal, on the other hand, we use optical projection. The MEDIA X'tal solves several problems which occur when using ordinary display devices for the OOD.

1. INTRODUCTION

In this paper, we describe a new technology for co-creative communication. In co-creative communication, we must share the same virtual space and/or virtual object by using techniques for computer visualization, virtual reality, augmented reality, and mixed reality. When a user operates a virtual object in the virtual space, handling is one of the most important factors, which enable an operator to perceive and operate the virtual object as if it were a real one. When using traditional display systems for virtual reality such as HMD, the operator CANNOT handle the virtual object. Therefore, it is very difficult for the operator to recognize where the virtual object is in three-dimensional space. Worse than anything else, the operator cannot tell whether he is holding the object or not. The cause of this problem is that, using traditional display system, the operator can see the virtual object but CANNOT touch it. To solve this problem, many kinds of haptic displays have been developed. The most important technique for a virtual reality system with haptic feedback is the fusion between visual space and haptic space. The ideal haptic display is the WYSIWYF (What You See Is What You Feel) [1] display. One method to accomplish a WYSIWYF display is by using force and/or a haptic feedback device. The other method is by using a visual display device that can be handled, in other words, by using the display not only as visual display but also as a haptic display. The operator handles and/or operates a virtual object by handling and/or operating the display system. We named such a display system an "Object-Oriented Display."

The visual display systems used in the world of virtual reality are divided into the following three kinds.

(1) Traditional flat-displays systems, such as CRT or Screen.
(2) Display systems of the type which is looked into through the window of the virtual objects, such as Head-mounted Display[2].
(3) Display systems that present a virtual environment around the operator, such as CAVE[3] or CABIN[4].

The Object-Oriented Display (OOD) is a fourth type of display system in which the surfaces of the display surround the *object* rather than the operator. The purpose of the OOD is the presentation of virtual objects, whereas the purpose of the previous three types of display systems is the presentation of the virtual environment. For example, when using CAVE or CABIN, an operator is located inside the display system and looks at the outer virtual world through the display. On the other hand, in the case of the OOD, an operator is located outside the display system and observes the inner virtual object through the display surface. In the next section, we will describe how to implement the OOD.

2. IMPLEMENTATION

In this section, we will describe three different implementations of the OOD. These are (i) The MEDIA-A (MEDIA-Ace), (ii) The MEDIA³ (MEDIA-Cube) and (iii) The MEDIA X'tal (MEDIA-Crystal).

MEDIA-A

The MEDIA-A (MEDIA-Ace) is a type of object-oriented display that is compact, light, and inexpensive (See Fig. 1). The MEDIA-A consists of a single LCD panel with a tilt sensor, an A/D converter, and a graphic engine. When the operator tilts the MEDIA-A, the angle of inclination is measured by the tilt sensor and digitized by the A/D converter. According to the angle of inclination, the graphic engine simulates the movement of the virtual object under the influence of gravity and outputs the image of the virtual object (See Fig. 2).

Fig. 1 MEDIA-A

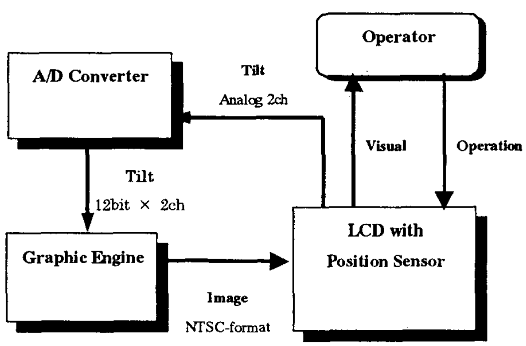

Fig. 2 Block diagram of the MEDIA-A

MEDIA³

The MEDIA³ (Fig. 3) [5], which is the first implementation of the OOD, was presented at SIGGRAPH '97. The MEDIA³ consists of four LCD panels in the shape of a cubic body (120mm x 160mm x 190mm, 1.5kg). A position / orientation sensor is installed in the MEDIA³. On the top face is the transmitter coil of the "POLHEMUS" sensor, which measures the 3-dimensional relative position of the receiver coil to the transmitter coil by using a magnetic field. Then, the operator puts on a sensor cap, which has a receiver coil. In this way, we can obtain the relative position of the MEDIA³ to the operator's viewpoint.

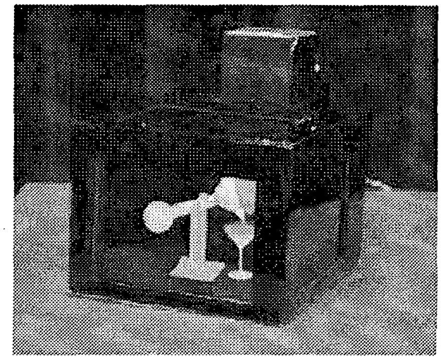

Fig. 3 MEDIA³ (at SIGGRAPH '97)

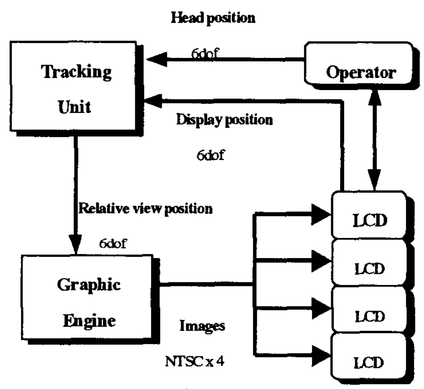

Fig. 4 Block Diagram of MEDIA³

These images are synthesized in the following way. First, we track the operator's head position by means of POLHEMUS sensor (60 per second / maximum, 20 par second / average) and calculate the operator's viewpoint. According to the obtained viewpoint data, the 3-dimensional data of the virtual object inside the MEDIA³, and the position of the four corners of the top-plane LCD of the MEDIA³, the perspective view for the top-plane LCD can be calculated in the following way (using OpenGL).

Using the MEDIA³, a virtual object is adequately displayed by controlling the image displayed on each LCD panel, corresponding to the position of the operator's head. Thus, the virtual object appears in its entirety in the MEDIA³. Furthermore, the MEDIA³ can display not only the surface form but also a section of the virtual object. Therefore, the operator can easily and intuitively recognize the virtual object's three-dimensional form and structure.

MEDIA-X'tal

The MEDIA-X'tal (MEDIA Crystal), a type of OOD that uses the technology named "X'tal Vision," uses optical projection. Before describing the MEDIA X'tal, we will illustrate the X'tal Vision optical system. We developed the X'tal Vision optical system to solve the occlusion contradiction problem. When we use STHMD (See-through Head-mounted Display) to mix the virtual and real environment, sometimes the operator sees a virtual object located behind a real object. Normally, nobody can see an object behind another object because of occlusion. This is an occlusion contradiction problem which causes a lowering of efficiency.

To solve the occlusion contradiction problem, we developed the X'tal Vision optical system. The following are the three key techniques of X'tal Vision:

1. Using an object covered by retro-reflective material as a screen;
2. Placing a projector into a position optically conjugated with the observer's eye by using a half-mirror;
3. Making the projector's iris as small as possible (by using a pinhole)

Each of these points provides the following advantages, respectively:

1. The observer can handle objects of arbitrary shape, looking at bright images projected on the surface of the object covered by retro-reflective paint;
2. There is no distortion of image, regardless of the shape of the screen;
3. A large depth of focus is obtained so that the screen can be located at any distance from the projector.

Moreover, the combination of the above technical points provides this system with additional merits:

- The brightness of the image does not vary in spite of the change of the distance between the projector and the screen (1+2);
- The observer's hands correctly occlude the displayed object (1+3);
- Stereoscopic images are obtained without glasses (1+2+3).

Fig. 5 shows the principle of X'tal Vision. The projector with a pinhole projects the image of the virtual object. The projected image is reflected by the half-mirror on a right angle and retro-reflected by the retro-reflective screen. Normal and retro-reflective materials differ in the following. In the case of normal material, a ray of light incident on the surface diffuses. In the case of retro-reflective material, an incident ray reflects a similar angle to the angle of incidence (See Fig. 6).

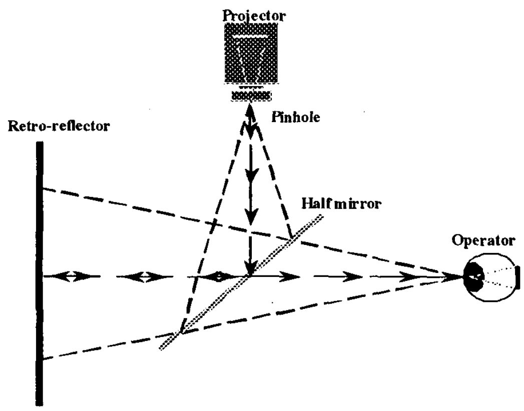

Fig. 5 X'tal Vision optical system

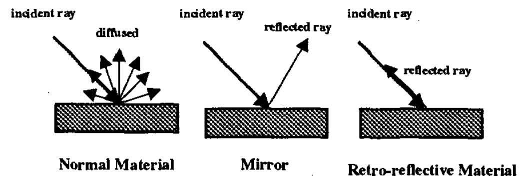

Fig. 6 Characteristics of a retro-reflector

We use the X'tal Vision optical system for the MEDIA X'tal (See Fig. 7). The MEDIA X'tal solves several problems which occur when using ordinary display devices for the OOD. Fig. 8 shows an overview of the MEDIA X'tal, and Fig. 9 shows a block diagram of the MEDIA X'tal.

Fig. 7 MEDIA X'tal (Media Crystal)

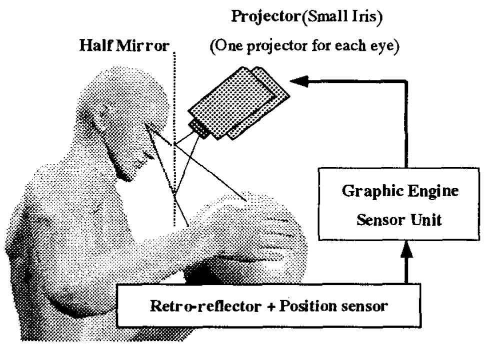

Fig. 8 Block diagram of the MEDIA X'tal

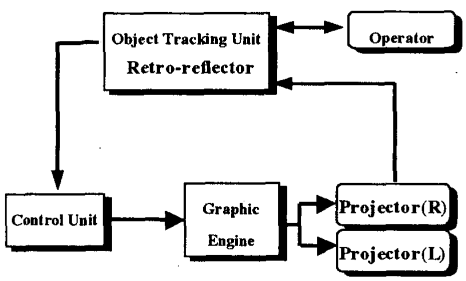

Fig. 9 Method of X'tal Vision

3. RELATIONSHIP BETWEEN OODs AND TRADITINAL DISPLAY SYSTEMS

OODs are display systems which surround an object. In comparison with traditional display systems, OODs are more conscious of the object. HMD is a display system that surrounds the operator's head, while CAVE or CABIN surrounds the operator's body. CRT, on the other hand, is located between the operator and the object. In the case of an object-oriented display, the display encloses the object. In other words, the purposes of OODs are the presentation of the virtual object, whereas the purpose of traditional display systems is the presentation of the virtual environment. OODs are *duality* of immersive display systems such as CAVE or CABIN. In the case of CAVE or CABIN, an operator is located inside the display system and can see the outer virtual world through the display. In the case of OODs, an operator is located outside the display system and sees the inner virtual object through the display.

4. APPLICATIONS

For the application of OODs, we suggest some examples. OODs are very useful for museum exhibits, for visualizing engineering or medical data such as CAD and MRI, and for communication, education and entertainment purposes. For example, we can use OODs for the simulation of a wind-tunnel test. OODs will allow us to get more intuitive and multilateral knowledge than when using a 2-D display. OODs can improve the operation of a virtual object to a greater extent than the usual display. Then, OODs are very useful to confirm shapes used in design and to show valuable exhibits in a museum. Therefore, we think that our device will be interesting for designers, researchers and museum staffs. OODs can also be a useful device for showing 3-dimensional crafting and assembly processes. When using an ordinary display, it is usually difficult to demonstrate how to make a 3-dimensional structural object. However, using OODs, this can be done easily because operator can directly compare the real object and the CG model.

As we have already mentioned, OODs can be used as an electric pop-up encyclopedia or a virtual museum. An operator can even touch and handle an object which would be dangerous or rare in the real world. Of course, additional programming will allow for more interaction between the operator and the virtual objects. OODs have a variety of possibilities for educational applications.

In addition, using computer networks such as the Internet, we can share 3-dimensional objects like documents, pictures, sounds or movies. For example, we can use OODs with a WWW browser. On a certain WWW-homepage, these are 3-dimensional data described in VRML, DXF, or other 3-D data format. An operator accesses this page and clicks on the object; then, the 3-dimensional data are downloaded, and the 3-dimensional object is shown by the OODs.

5. CONCLUSION

We aim at displaying a virtual object effectively to attendees by using the "Object-Oriented Displays". We propose the concept of the OODs. The MEDIA series (MEDIA-A, MEDIA^3 and MEDIA X'tal) are typical examples of "object oriented display".

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