Transparent Cockpit

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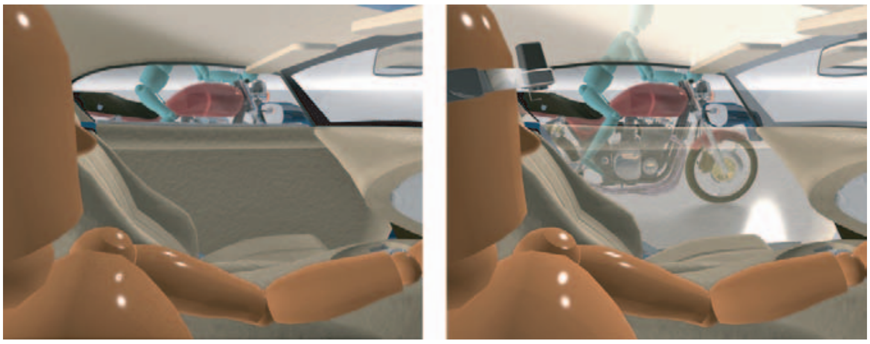

Figure 1: *Image of Usual Cockpit (left) and the Transparent Cockpit (right).*

1 Executive Summary

We propose a "transparent cockpit" that is aimed toward improving the operativeness, safety, and comfort during controlling a vehicle. In the transparent cockpit, the interior appointments of the vehicle are virtually transparent; this is enabled by using the retro-reflective projection technology.

2 Project Overview

A wide field of view is imperative during controlling a vehicle such as a car or an airplane or a helicopter. However, the space to set up windows is limited; consequently, the field of view from the cockpit of the vehicle is insufficient. Therefore, when we drive a car through narrow streets, when we park a car in small parking lots, and when we back up a car, the operativeness is fairly bad. Moreover, some accidents are caused due to a narrow field of view because the drivers cannot recognize a walking person or other obstacles. In addition, a narrow field of view induces a cooped-up feeling.

Therefore, we propose a transparent cockpit in which the interior appointments of the vehicle are virtually transparent. In such a cockpit, the area occluded by the door can be seen as that from an actual window (Figure 1).

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Figure 2: *Implementation of the Transparent Cockpit. The lower part of a person riding a bicycle can be seen through the interior appoitments of the car.*

The principle of a transparent cockpit is very simple. First, the images captured by cameras (set up outside of the vehicle) are transformed into images as seen from the driver's viewpoint. Next, the transformed images are projected from a head-mounted projector (HMP) [Inami et al. 2000] using a retro-reflective projection technology (RPT) [Kawakami et al. 1998]. Then, the objects covered with a retro-reflective material are virtually transparent, and the operator of the vehicle can see the outside view through the door, roof, and so on.

We implemented our proposed system on an actual car. Figire 2 shows the view from the driven with wering HMP. The lower part of the person riding a bicycle can be seen through the interior appointments of the car.

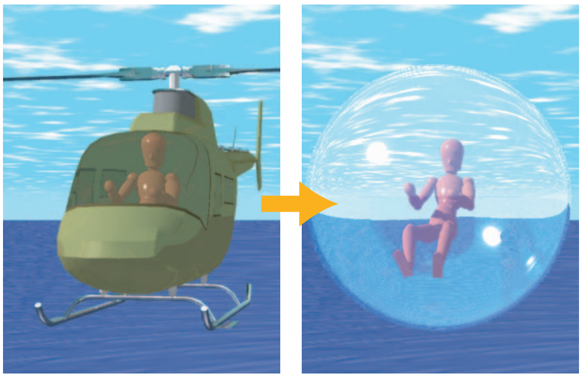

Figure 3: *The Ultimate Goal of this Project.*

3 Vision

The transparent cockpit can improve the operativeness, safety, and comfort during controlling the vehicle. For example,

- The driver can conveniently drive a car through narrow streets and back up the car because he or she can see the side of the road and the back of the car (operativeness).
- The number of accidents would decrease because the driver can recognize a walking person or other obstacles (safety).
- The driver has a wider visibility of the sky or the landscape; therefore, he or she may experience a liberating feeling as that obtained while driving a convertible (comfort).

The ultimate goal of the transparent cockpit is that the driver should not feel as if "I am operating a vehicle," but "I am running or flying by myself" (Figure 3). This goal will be achieved in the next few decades.

4 Technical Innovations

There are three elements necessary for realization of the transparent cockpit; (1) The display that superimpose the outside image of the vehicle onto the real world. (2) The way of getting the image that surrounds the vehicle. (3) To generate appropriate images seen from any viewpoint in the vehicle.

We have already developed the "optical camouflage" technology [Inami et al. 2003] corresponding to (1). Now, we propose a system which enables (2) and (3). By using an imageprocessing technology that combines the images captured from multiple video cameras and using the head-mounted projector equipped with a position sensing device, (2) and (3) are achieved. We describe the detail of the system in following subsections.

In addition, we developed an algorithm for correcting the position of the virtual screen to correctly project the image of the objects that are at any distances.

4.1 System Configuration

Figure 4 shows a system diagram of the transparent cockpit. The process flow of this system is as follows:

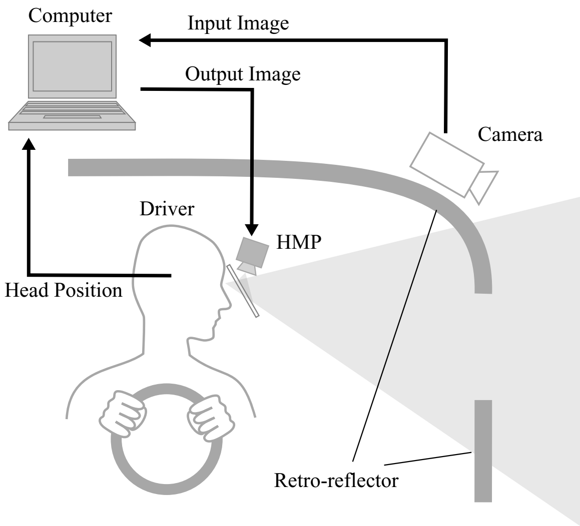

Figure 4: *System Diagram of The Transparent Cockpit.*

1. The multiple wide-angle video cameras are set up outside of the vehicle capture the images along each direction.
2. To generate a spherical image that surrounds the vehicle, the captured images are combined. Then, virtual screen is set up in a virtual world formulated in a computer and the spherical image is projected to the screen.
3. The viewpoint in the virtual world is determined by the operator's viewpoint measured using the position-sensing device in the HMP.
4. By applying the correction algorithm, the positions of the virtual screens are corrected.
5. The images seen from operator's viewpoint that is determined in 3 are rendered and projected onto the interior appointments coverd with the retro-reflective material from the HMP.

4.2 Correction Algorithm using Template Matching

In a conventional optical camouflage system, the distance from the viewpoint to the virtual screen needs to be assumed. Therefore, when there is a subject at a distance that is different from the assumption, the subject is projected at an incorrect scale and position (Figure 5). In the case of transparent cockpit, the subjects are at various distances (such as a walker, guard rail, buildings, a landscape). Therefore, the problem is critical in our system.

Then, we propose an algorithm for correcting the position of the virtual screen using template matching. The following is the process flow of this correcting algorithm (Figure 6). First, a small video camera is set up on the HMP that operator wear. The camera always faces the same direction as operator. Therefore, the image captured by the camera is nearly operators view.

"Image A" is captured by the small video camera near the operator's viewpoint. The gray-painted area represents the vehicle's frame covered with retro-reflective material. The other area is the view from the window. "Image B" is part of the spherical image generated by the images that the video cameras outside of the vehicle capture.

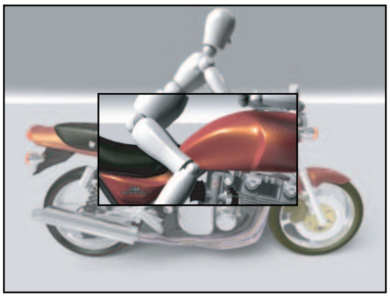

Figure 5: *Gap between the Real Object and the Projected Image. Center of the image is the real object seen from the window of the vehicle. The other is the projected image.*

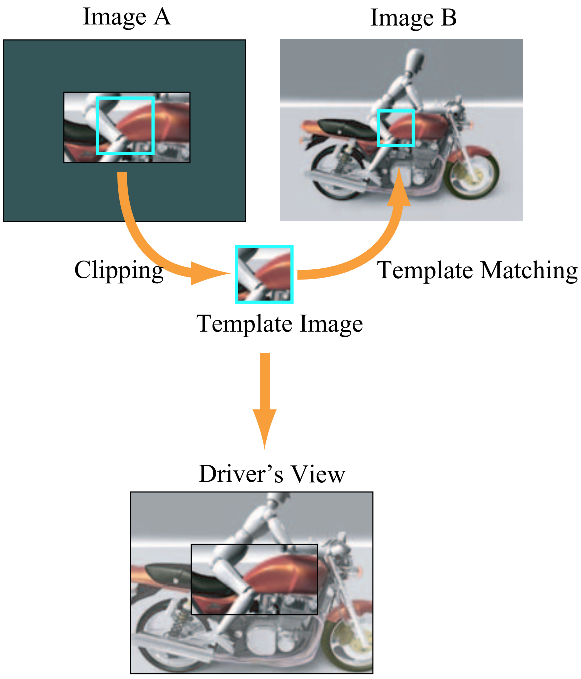

Figure 6: *Correction Algorithm. Image A is captured by a video camera on the X'tal visor. Image B is part of the spherical image.*

The window area in image A is obtained from the position information of the operator's viewpoint measured by a position sensing device on the HMP. First, as a template, an image with a suitable size is clipped from the window area in image A. Next, it searches image B for the place where the correlation with the template image is the highest. Then, the correction value is calculated as the position and scale of the template image in image A corresponds with the template matching result. As a result, the position of the virtual screen is determined. The position of the virtual screen can be corrected in real time by performing this process for each frame of the images captured by the video camera.

By using this algorithm, the subject viewed by the operator is projected at the correct distance, and the gap between the real-world image and the projected image gets canceled.

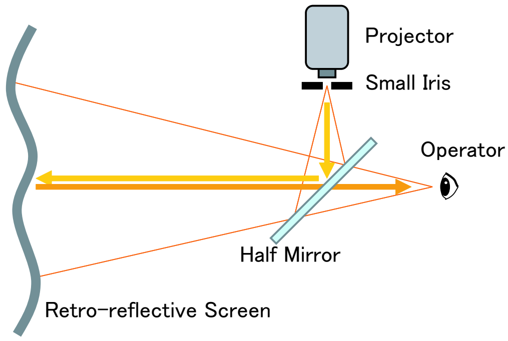

Figure 7: *The Principles of RPT.*

4.3 Prototype Implementation

We did a qualitative evaluation experiment of this system. We actually implemented the prototype of the transparent cockpit on a car. As a result, it was confirmed that the driver can see the outside view that can't seen in usual cockpit such as the side of the road, traffic signs on the road, parking lot line, and so on.

5 Context

A head-mounted display (HMD) [Sutherland 1968] or IPT systems such as CAVE [Cruz-Neira et al. 1993] are famous examples of visual displays used in virtual reality systems. They are very useful, but they also have some problems. For example, one of the problem with HMD is the trade-off between high resolution and a wide field of view. On the other hand, IPT system imposes a shadow of the user's body on the virtual environment and the interaction of the user's virtual body with the user's real body. Thus, visual display of virtual reality is still developing. Based on this background, we developed the X'tal vision [Kawakami et al. 1998] at SIGGRAPH 98.

5.1 Retro-reflective Projection Technology (RPT)

X'tal vision employs the RPT that uses an optical projection technique. Figure 7 shows the principles of the RPT. The image of a virtual object is projected through a pinhole. The projected image is reflected by the retro-reflective screen.

Then, at SIGGRAPH 99, we applied a HMP to a visuo-haptic display using a camouflage technique [Inami et al. 2000]. By using this method, a user can observe a stereoscopic virtual object with an approximately accurate occlusion relationship between the virtual and the actual environments; the user can actually feel the object.

5.2 Optical Camouflage

Optical camouflage [Inami et al. 2003] is a type of active camouflage that uses RPT (Figure 8). The object that needs to be made transparent is painted or covered with a retro-reflective material. Then, a projector projects the background image onto the material making the masked object virtually transparent. The transparent cockpit employs the optical camouflage technique.

Figure 8: *Optical Camouflage [Inami et al. 2003].*

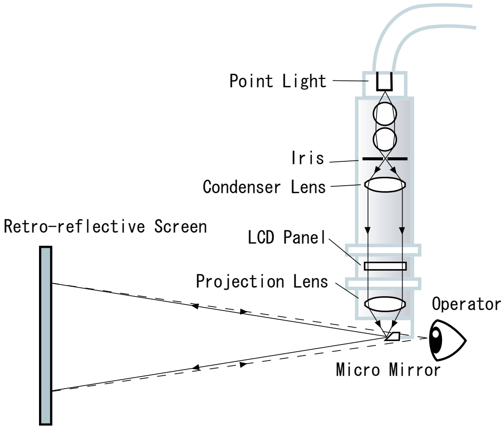

Figure 9: *The Principle Construction of the X'tal Visor.*

5.3 X'tal Visor

We developed an X'tal visor [Sonoda et al. 2005] at SIGGRAPH 2005. The X'tal visor is a display of the RPT. Figure 9 shows the principle construction of the X'tal visor. Here, the large half-mirror shown in Figure 7 is replaced with an all-reflective micro mirror. As the mirror size is fairly small, the X'tal visor can display images without covering the wearer's face and therefore enables natural open face-to-face communications.

5.4 ITS

In recent years, technologies in the form of intelligent transport systems (ITSs) have been developed that support driver's recognition capabilities and judgment; these systems have been mounted on cars. For example, the "night view system" [Toyofuku et al. 2003] uses near-infrared light to illuminate pedestrians and road topography during nighttime, providing the driver with a wider view than that obtained with high beams, regardless of whether the driver is driving with low or high beams. The transparent cockpit is highly compatible with these technologies. In the transparent cockpit, information obtained by using these technologies can be displayed on the doors or the roof.

6 User Experience

We will set up a full-scale cockpit at an exhibition site. The cockpit has windows, and the outside surroundings can be observed. The part without the window is covered with a retro-reflective material. Five or more cameras are set up outside of the cockpit, and they capture images of the appearance of the exhibition site.

We will modify the HMP; it will be more compact, light, and comfortable. The attendees wear the improved virsion of the HMP; while sitting in the cockpit, the attendees can experience that the cockpit is actually transparent at the door and ceiling regions. Each person requires about ten minutes to complete this procedure.

Additionally, we will construct a smaller setup to form an easy-to-use system. So that many people can experience the transparent cockpit, each person would take about five minutes to complete the procedure.

References

CRUZ-NEIRA, C., SANDIN, D. J., AND DEFANTI, T. A. 1993. Surround-screen projection-based virtual reality: The design and implementation of the cave. In *Proc. of Computer Graphics*, vol. 27.

INAMI, M., KAWAKAMI, N., SEKIGUCHI, D., YANAGIDA, Y., MAEDA, T., AND TACHI, S. 2000. Visuo-haptic display using head-mounted projector. In *Proceedings of IEEE Virtual Reality 2000*, 233–240.

INAMI, M., KAWAKAMI, N., AND TACHI, S. 2003. Optical camouflage using retro-reflective projection technology. In *Proceedings of the Second IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR '03)*.

KAWAKAMI, N., INAMI, M., MAEDA, T., AND TACHI, S. 1998. The object oriented displays. In *Conference Abstracts and Applications (SIGGRAPH 98)*.

SONODA, T., ENDO, T., KAWAKAMI, N., SUZUKI, Y., AND TACHI, S. 2005. X'tal visor. In *Conference Abstracts and Applications of ACM SIGGRAPH2005*.

SUTHERLAND, I. 1968. A head-mounted three dimensional display. In *Proc. fall Joint Computer Conference, AFIPS Conf. Proc.*, vol. 33, 757–764.

TOYOFUKU, K., IWATA, Y., HAGISATO, Y., AND KUMASAKA, T. 2003. The "night view system" using near-infrared light. In *SAE 2003 World Congress & Exhibition*.