AN EFFECTIVE INTERACTION TOOL FOR PERFORMANCE IN THE VIRTUAL STUDIO - INVISIBLE LIGHT PROJECTION SYSTEM

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ABSTRACT

Virtual studios are now used for various programs such as news, weather forecasts, and educational programs. However, the performers in a virtual studio cannot directly see the surrounding virtual background or their virtual co-performers (i.e., virtual subjects). Therefore, performers must check the position of virtual subjects by watching a monitor, causing them to look away from the virtual subject. Viewers see an unnatural image in which the performer seems to be looking in the wrong direction.

To overcome this problem, we have developed an interaction support system called the Invisible Light Projection System. By using projector images, we made virtual subjects visible within the studio but invisible to the camera. This system has been used in actual NHK studio production. In this paper, we describe the system and how it can make virtual-studio production more effective.

INTRODUCTION

The virtual studio, introduced in the mid-1990s, is a video composite technique that uses images of performers shot in front of a chroma-key blue background (i.e., a blue screen) and virtual images created through real-time computer graphics (CG). Composite images made using the chroma-key technique create an effect by which performers seem to be inside the virtual images. The advantages of this technique are that the virtual images enable visual effects that cannot be created using an actual set, storage space is unnecessary, and changes in the virtual images can be made relatively easily.

However, some of the differences from standard studio video production can create problems in directing and shooting. For example:

a. To obtain key images of the performers, a blue screen must be used for shooting.

b. In blue-screen shooting, flat lighting is necessary, making it difficult to produce shadows of the performers in the composite picture.

c. Performers cannot directly see virtual subjects with which they need to interact.

Technical solutions to some of these problems have been developed. For example, the Axi-Vision[1] (developed by NHK) and Zcam[2] (developed by 3DV Systems) systems can detect the camera distance to the subject while shooting, enabling key signals of the performers to be cut out without using a blue screen. There is also a technique by which the key image of the performer is processed and composited as a shadow. However, a technique that allows performers to see virtual subjects is still needed. Otherwise, performers will have to continue watching virtual subjects through monitor images, which often causes them to look in an inappropriate direction. This is particularly obvious in HDTV productions, because of the image clarity. To overcome this problem, we have developed the Invisible Light Projection System. In this paper, we describe the composition and application of this system.

VIRTUAL SUBJECTS IN THE STUDIO

Current checking methods and their disadvantages

The usual method used to allow performers to check the position of virtual images has been to mark positions with tape on floors or walls, or, as shown in Fig. 1, to look at the image composite on a studio floor monitor.

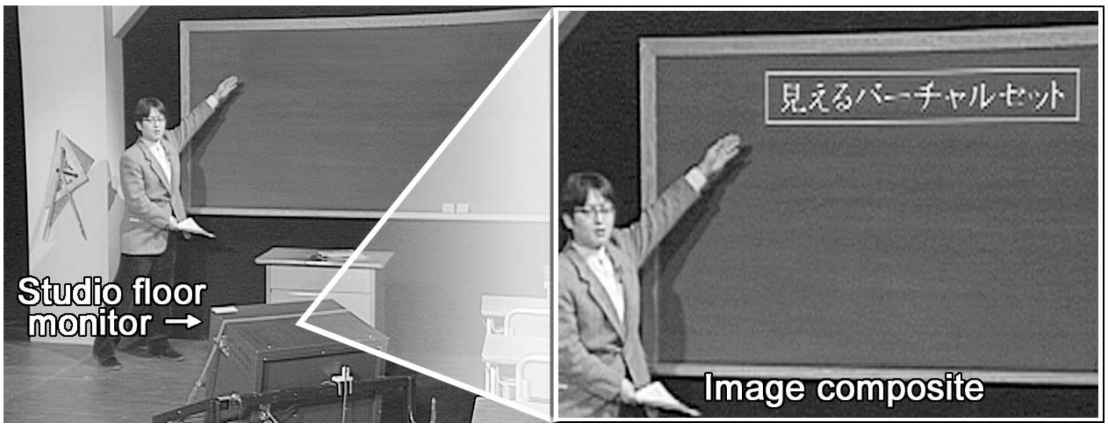

Figure 1 – Performer checking the CG composite title by looking at a studio floor monitor

The disadvantage of markers is that they cannot be used with moving virtual subjects, and that the use of too many markers can confuse performers. Also, a performer lacks a direct feel of what they are supposedly interacting with.

The alternative is for the performer to guess the relative distance between himself and the virtual subject by looking at a studio floor monitor that shows the composite image of the performer and the virtual image. This causes the performer to look at the monitor rather than at the virtual subject.

With either method, the need to act naturally while being unable to see the virtual subject places a heavy burden on a performer’s acting skills. As a result, thorough rehearsal prior to shooting is necessary, and poor performance that necessitates additional re-takes often prolongs the production time.

Actors in movies and commercials must also look at CG co-actors. In these situations, the actors are guided by another actor who substitutes for the CG image, or by a marker ball attached to a pole. The actor can see the substitute for the CG, enabling him to maintain proper eye contact, so he can concentrate on his own performance. These substitutes are erased from the final composite image during post-production. While this method can be used in television production, its cost makes it impractical and the need for post-production work makes it unsuitable for live broadcasts.

Under these circumstances, there is a definite need for an interaction support system designed for use in television production.

Our solution

To show performers the position of virtual subjects, we used projected light as an interface. Projected light can be used to mark the position of a moving virtual subject, and can be turned off when not in use. Further, by applying time-division to the projected light, we have created an interface that is not detected by television cameras.

The NTSC video signal is a continuous image of 59.94 fields. Under normal shooting conditions, one field is approximately 16.7 ms. The CCD camera, which is the standard camera for television production, has an electronic shutter function. When the shutter is set to 1/100, the exposure time is 10 ms per field, leaving the remaining 6.7 ms as unexposed time. By controlling the projected light so that it is intermittent and turned on only during the non-exposure time, we made it "invisible" to the camera. To confirm the validity of this principle, we did an experiment using camera-synchronized electronic control and time division applied to laser light. We adjusted the laser light so that it was emitted only during the non-exposure time of a CCD camera whose shutter speed we set to 1/100 (Fig. 2). As expected, we found that the projected laser light did not appear in the CCD camera images. Since this interface is visible to the human eye, but invisible to the camera, we named it Invisible Light.

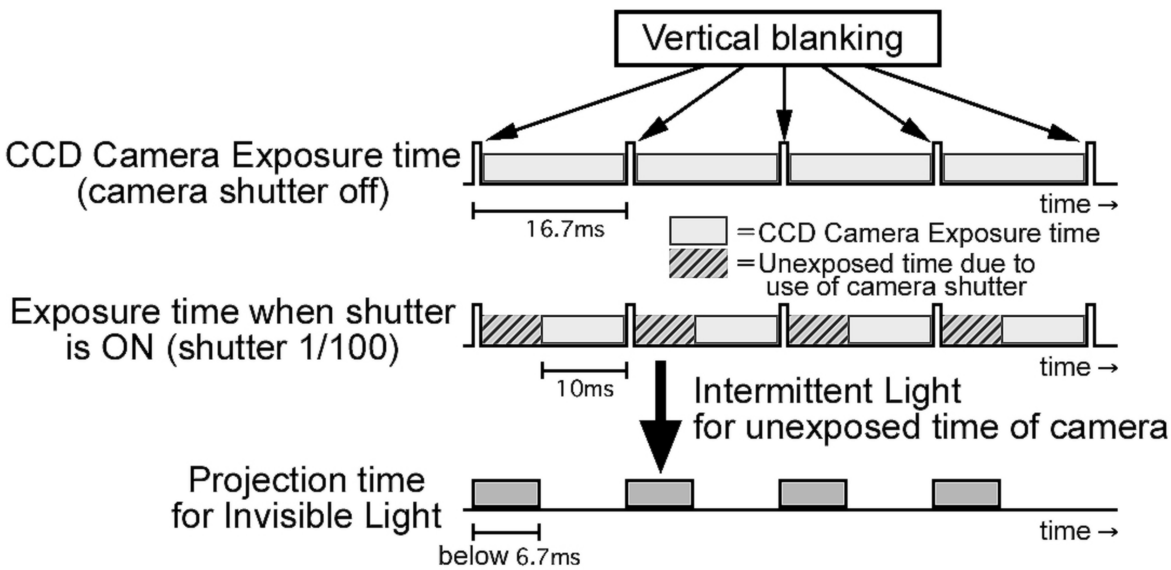

Figure 2 – Timing of Invisible Light

We then used Invisible Light in a demonstration to indicate the position of a moving virtual subject to a performer. The performer was able to follow an Invisible Light image that was projected onto the studio floor and the performer's movements were synchronized with the corresponding CG image. Because the Invisible Light did not appear in the television camera image, conventional image compositing could be applied. The composite image showed the performer chasing a randomly moving CG ball while apparently maintaining steady eye contact with the ball. These results confirmed that Invisible Light was an effective means of establishing the position of virtual subjects. However, since laser light could be dangerous to the performer, we had to use a different type of projected light for positioning. Also, to create positioning forms other than a single point – for example, characters and complex images – we had to develop a new projection system.

THE INVISIBLE LIGHT PROJECTION SYSTEM

To display video images with Invisible Light, we decided to control the projector light by using liquid crystal shutters.

System Structure

The system configuration of the Invisible Light Projection System is shown in Fig. 3. A newly developed high-speed liquid crystal shutter (LC shutter) is placed in front of the projector lens. The projector displays the virtual subject. As shown in Fig. 4, the LC shutter can be adjusted to become transparent, and it controls the projected light to make it invisible to the camera. The "invisible" projected image can be adjusted so that it will match the size and position of the virtual subject or the composite image. By watching this projected image, performers can orient themselves with the virtual subject.

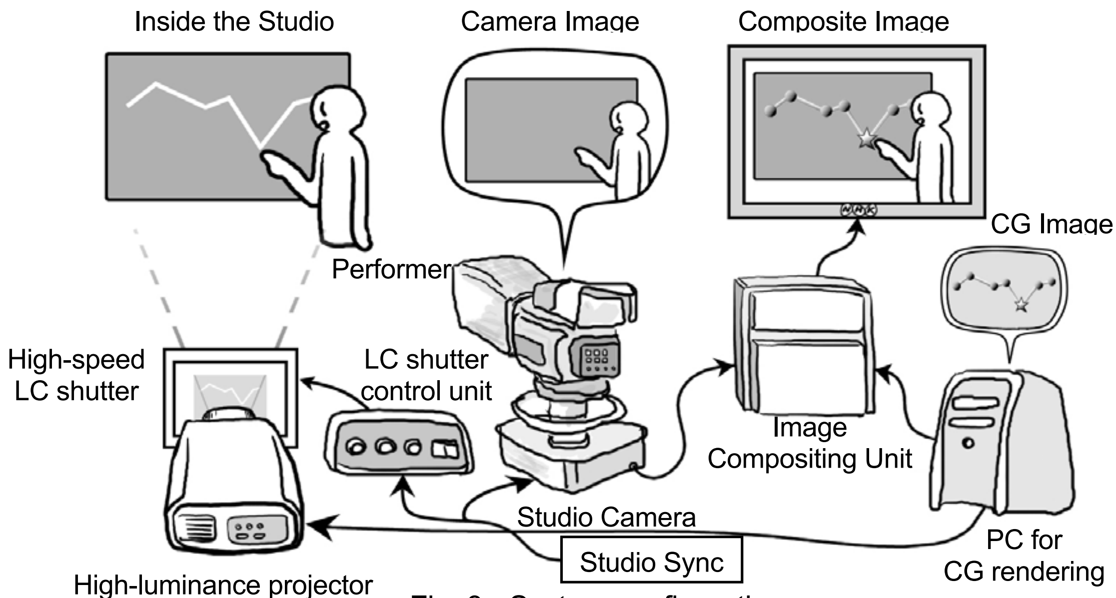

Fig. 3 - System configuration

Development of the High-Speed LC Shutter

Initially, we considered a control method that would use a mechanical shutter. However, the equipment would be bulky, and shutter noise would be a problem. We also required a steady operation system that could be synchronized with the non-exposure time of the camera, and realized that a mechanical shutter would not be suitable for studio production.

We then developed an electronically controlled LC shutter (Fig. 4) that can be synchronized with a CCD camera shutter. The shutter, made of a composite film of nematic LC and polymer, can modulate incident light at a very high speed – within the time of one field. This high-speed LC shutter has a higher maximum transmittance than that of conventional LC shutters with polarizing plates. Through high voltage control, we achieved a high-speed response with rise and decay times of under 2 ms. By installing this high-speed LC shutter in front of the projector lens, we can display projector images in Invisible Light.

Figure 4 - High-speed LC shutter

Measures to enable studio use

Certain issues had to be resolved before we could apply the Invisible Light Projection System in studio production.

1. Multiple cameras operation.
   Even if there are several cameras used in the studio, they are all operated in synchronization with the studio system. Therefore, we confirmed that as long as each camera has its shutter turned on, none of the cameras would detect the Invisible Light Projection image.
2. Flickering images due to the use of cameras in the 1/100 shutter mode.
   As long as the performer made no sudden movements (such as thrusting out an arm or jumping sideways), this was not a significant problem.
3. Visibility under the bright studio lighting.
   With a large 5800 ANSI lumen LC projector and our newly developed high-transmittance, high-speed LC shutter, the Invisible Light Projection image remained visible under actual production lighting.
4. Noise produced by the projector fan.
   By covering the entire projector while ensuring adequate airflow, we were able to keep the fan noise under 40 dBA. To further reduce noise, the projector can be placed far from the performer's microphone without affecting the projector image.

Hardware Integration

In order to solve problems 3 and 4 mentioned above, we developed the Invisible Light Projection System (Fig.5). This system consists of a large high luminance projector stored in a special soundproof case. A high-speed LC shutter and a LC shutter drive unit are also integrated inside this soundproof case. By supplying the Invisible Light Projection system with a studio sync input and a virtual subject image input, Invisible Light Projection images can be displayed in the studio without changing the present virtual studio system. We brought the Invisible Light Projection System into the studio and applied it in an actual program production.

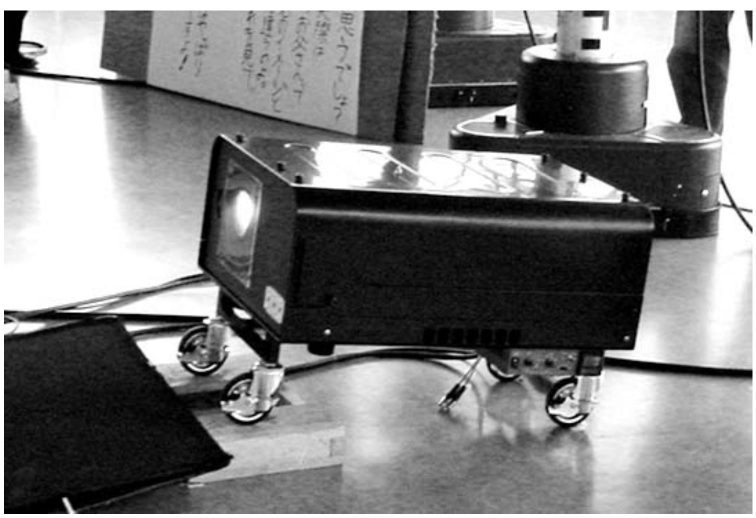

Figure 5 - Projector for the Invisible Light Projection System

Specification

Size and Weight	515mm(W) * 470mm (H) * 720mm (D), about 50Kg
Video input	Analog Composite (NTSC), HD SDI, Analog Component
Sync input	NTSC or HD
Pixels	1280 * 1024 (SXGA)
Screen Size	150 – 200 inch for screen distance 8.0m
Light output	5800 ANSI Lumen

APPLICATIONS IN PROGRAM PRODUCTION

The Invisible Light Projection System has been used for several programs, such as a lecture program discussing educational issues, a live program covering information on the latest technology, and an entertainment program in which the cast had an interactive conversation with a group previously recorded by VTR. In each case, the performers could establish proper eye contact with the Invisible Light Projection image, and real-time interaction with the virtual subjects was achieved. Here, as an example, we describe the production of "NHK Ningen Kouza" (Human Lecture).

The professor, who was the program lecturer, had no previous experience in a virtual studio. To assist the professor and help the studio shooting go more smoothly, we used our system. In this program, issues regarding the Japanese educational system and its recent changes were discussed with keywords and illustrations shown as discussion aids. Instead of using board diagrams, as would be used in a normal studio shooting, we used Invisible Light Projection diagrams as a commentary guide. The studio set-up consisted of the Invisible Light Projection system combined with an actual classroom set. Our system was especially effective for displaying CG diagrams and text on a blank blackboard.

During the program, the professor could identify the position of the Invisible Light Projection images displayed on the blackboard (Fig. 6). At the same time, the images taken by the studio camera did not show the Invisible Light Projection images (Fig. 7). The camera only recorded a blank blackboard. Figure 8 shows the final composite of the camera image and the virtual CG image. The professor was able to maintain proper eye contact and give a natural performance. Invisible Light Projection images can also be displayed on cue, so that a performer can recognize his cue without looking at the floor monitor.

Figure 6 - Invisible Light Projection image

Figure 7 – Studio camera image

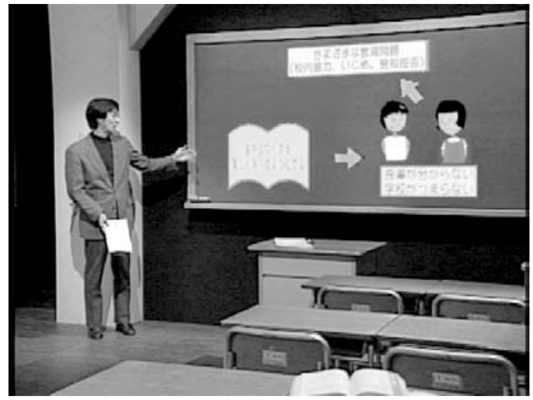

Figure 8 - Final composite image

By reading projected virtual text, the performer can also read from specified texts, without needing to memorize the text content.

The studio shooting also had a section where the professor stood in front of a blue screen, and a composite virtual background was created behind him. The professor was able to deliver his lecture while using Invisible Light Projection graphs and diagrams (Figs. 9 and 10). In the composite image, he could be seen pointing accurately at the detailed points in the graph with appropriate eye contact. Because the performer stood in front of the virtual image, the Invisible Light Projection was projected onto his face and clothing, but this was hidden in the camera image, so it posed no problem.

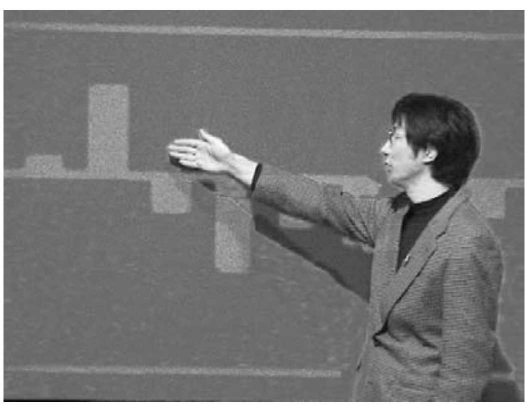

Figure 9 - The performer standing in front of the Invisible Light Projection image

Figure 10 - Final composite image

Thus, even a performer who is a first-timer in the virtual studio can perform naturally with proper eye contact. In the studio shooting for this program, over 20 scenes were shot with no re-takes.

Another feature of virtual studio production is that a gauge is used to align the position of the actual set with the virtual studio set. This adjustment is done for every studio camera before the studio shooting. However, during the shooting, this set-up tends to gradually become misaligned. When this happens, the gauge must be brought back to the studio and the shooting stopped until the positioning is realigned.

However, Invisible Light Projection images are always correctly positioned within the virtual studio set. By adjusting the camera shutter to show the protector images, the relative positions of the real- and virtual-spaces can be immediately checked and quick alignment achieved by aligning the projector images visible to the camera with the virtual image composites. Alignment of the virtual images with the studio camera images is critical for accurately pointing out details such as points on a graph. By using this method, we were able to make positioning adjustments without interrupting the studio shooting.

The Invisible Light Projection System thus enables accurate staging and cueing of virtual images, which was previously considered very difficult, and helps performers act more naturally. In these ways, the Invisible Light Projection System can make virtual studio shooting more effective.

CONCLUSIONS

The Invisible Light Projection System enables performers to see virtual subjects in a virtual studio, thus allowing natural performance with proper eye contact regarding the virtual subjects. This greatly improves the quality of virtual studio images. The system has been used in various productions, and enabled efficient video production in educational programs, entertainment programs, and live programs. This system is clearly an effective interaction support system for the virtual studio.

The benefits of using our system are especially significant in high-resolution video productions, such as those for HDTV. We hope to continue our research and development in this area by working with production staff to achieve more efficient, higher quality video production and creative video expression.

ACKNOWLEDGEMENTS

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