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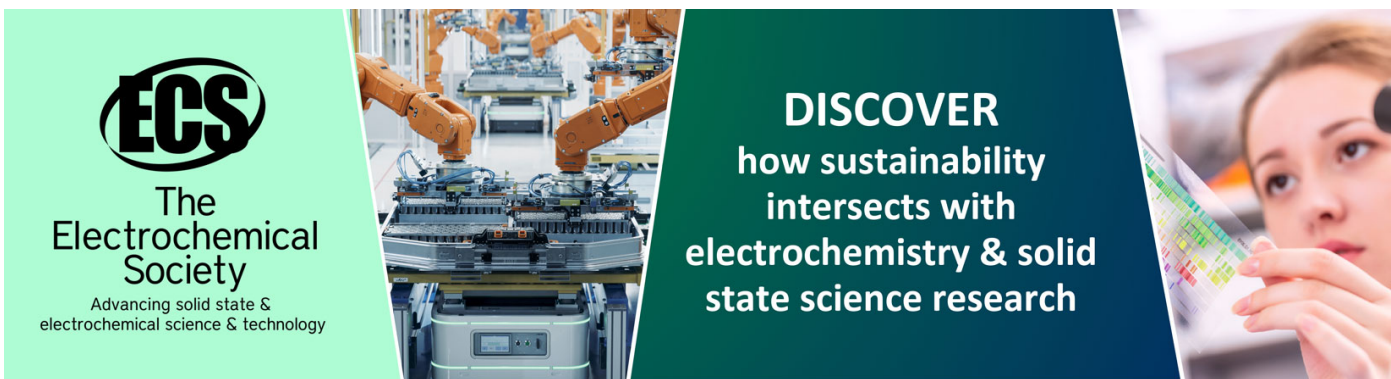
New education system for construction of optical holography setup – Tangible learning with Augmented Reality

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New education system for construction of optical holography setup - Tangible learning with Augmented Reality -

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Abstract. In case of teaching optical system construction, it is difficult to prepare the optical components for the attendance student. However the tangible learning is very important to master the optical system construction. It helps learners understand easily to use an inexpensive learning system that provides optical experiments experiences. Therefore, we propose the new education system for construction of optical setup with the augmented reality. To use the augmented reality, the proposed system can simulate the optical system construction by the direct hand control. Also, this system only requires an inexpensive web camera, printed markers and a personal computer. Since this system does not require the darkroom and the expensive optical equipments, the learners can study anytime, anywhere when they want to do.

In this paper, we developed the system that can teach the optical system construction of the Denisyuk hologram and 2-step transmission type hologram. For the tangible learning and the easy understanding, the proposed system displays the CG objects of the optical components on the markers which are controlled by the learner's hands. The proposed system does not only display the CG object, but also display the light beam which is controlled by the optical components. To display the light beam that is hard to be seen directly, the learners can confirm about what is happening by the own manipulation. For the construction of optical holography setup, we arrange a laser, mirrors, a PBS (polarizing beam splitter), lenses, a polarizer, half-wave plates, spatial filters, an optical power meter and a recording plate. After the construction, proposed system can check optical setup correctly. In comparison with the learners who only read a book, the learners who use the system can construct the optical holography setup more quickly and correctly.

1. Introduction

Holography is well known as the technique which can record the 3D image information. By using the optical setup, the 3D image information is recorded to the recording material as the fringe pattern. For the construction of the optical setup, a user is required the precise knowledge of optical elements and the technique. However, since the beginner usually does not have the basic knowledge and the experience, it is difficult to teach the optical system construction of the hologram only with a textbook. As the education system, there are e-learning systems. Since most e-learning systems only show texts, figures and movies, it is not suitable for learning of the technique such as optical system construction.

In this paper, we proposed the new education system for the optical system construction of the hologram recording. To employ the augmented reality (AR), proposed system can provide the tangible learning[1, 2, 3]. When the user controls markers, the proposed system can make the user feel controlling virtual optical components with the direct hand. As the optical components, the proposed system has a laser, mirrors, a PBS (polarizing beam splitter), lenses, a polarizer, half-wave plates, spatial filters, an optical power meter and a recording plate. To control the virtual optical components, the user can learn not only the role of the optical components but also the setup of the Denisyuk hologram and 2-step reflection type hologram.

2. Tangible education system

Figure 1 shows the proposed education system with the augmented reality (AR). AR is a live, direct or indirect, real-world environment whose elements are augmented by the computer-generated sensory input such as the sound, the video or the graphics data. By using this technique, in this paper, we added CG object to the captured image by the camera. For the development of this system, ARToolKit[4, 5], which is a computer tracking library for creation of AR applications, is employed. ARToolKit helps to get the coordinate of the marker captured by the camera. On the basis of this coordinate information, the proposed system augments the 3D CG object and displays. As a result, the learner controls the markers, and can practice the tangible learning.

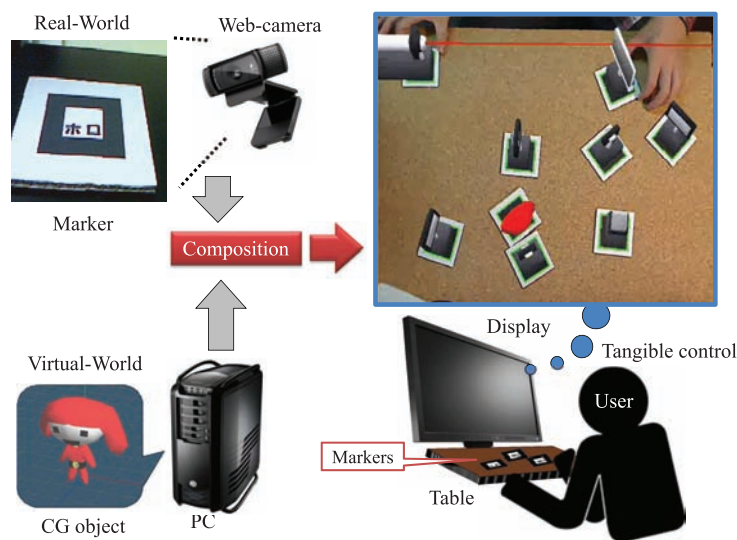


Figure 1. Proposed tangible education system.

2.1. ARToolKit

ARToolKit is a library to make vision-based AR applications[4, 5]. By using ARToolKit, the creator can make AR applications easily without the expensive sensor or the high spec computer. Also, since the application with ARToolKit can employ the direct hand action, the user can easily understand how to arrange optical components.

The application with ARToolKit consists of the camera, markers, the personal computer and the monitor. Since the system is necessary to make the superimposed CG objects seem to be in real-world, the added CG objects are required the geometrical consistency with the real-world. Figure 2 shows the calculation model of the coordinate. Each marker has a black square with a unique pattern in it. To calculate the distortion from the captured marker image, the system can obtain the pose and position of the marker. The transform matrix T_{cm} from the marker coordinate system P_m to the camera coordinate system P_c is determined by

$$P_c = \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} r_1 & r_2 & r_3 & t_x \\ r_4 & r_5 & r_6 & t_y \\ r_7 & r_8 & r_9 & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} = T_{cm} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} = T_{cm}P_m, \quad (1)$$

where t is the translation component, r is the rotation component. To compare the size of the captured marker image to the registered line length of the marker, the system can display the CG object naturally.

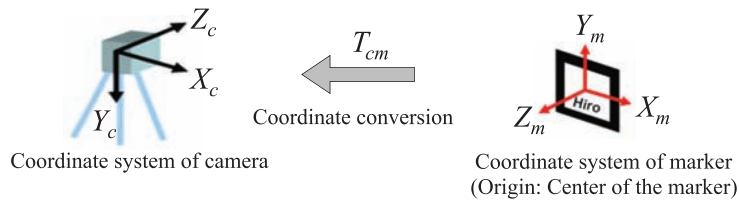


Figure 2. Coordinate conversion between the camera and the marker.

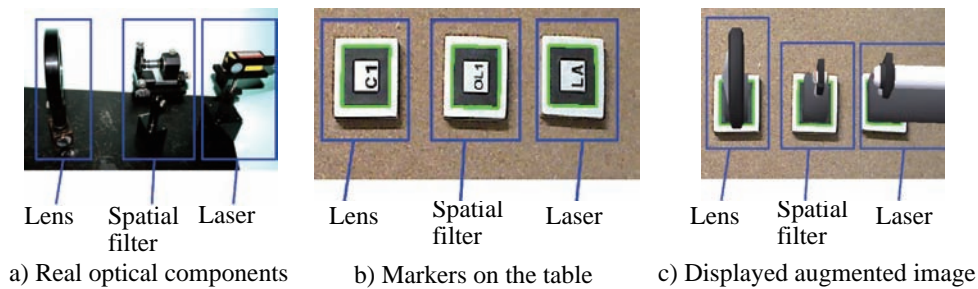


Figure 3. Real optical components and the displayed augmented images.

2.2. Education system for construction of optical holography setup

To master the optical system construction of the hologram, it is important to understand the role of the optical components and how to use it. Therefore, the proposed system makes the tangible learning possible by the control of the markers with hands. Also, to help the intuitively understanding for the role of the optical components, the proposed system displays the light path and shape formed by the optical components.

2.3. Display of the virtual optical components on the markers

Figure 3 shows the photographed real optical components, the markers on the table and the displayed augmented images. In the case of constructing the optical system shown in Fig. 3 (a), the learner arranges markers as shown in Fig. 3 (b) on the table. On the display, the captured image is augmented by the proposed system as shown in Fig. 3 (c). The augmented CG optical components can be controlled freely by the pose of the markers.

2.4. Unified coordinate system

ARToolKit only obtains the relation between the camera coordinate system and each marker coordinate system. To achieve the simulation of the optical system construction on the proposed system, each coordinate system needs to be the unified coordinate system based on the one marker. In this paper, we configure a laser marker to the base marker. The location of other markers are calculated as bellow. Figure 4 shows the conceptual diagram of the coordinate

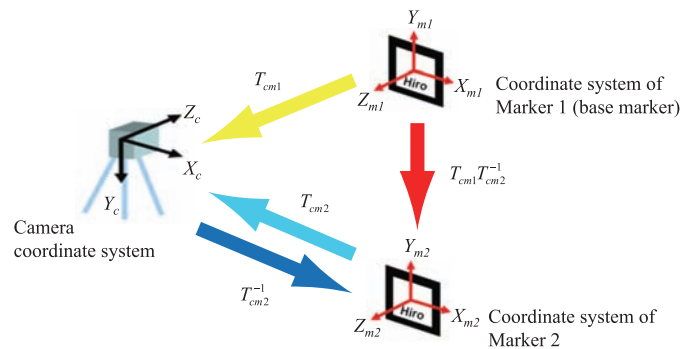


Figure 4. Real optical components and the displayed augmented images.

conversion. The relation between the camera coordinate system P_c and the marker 1 (base marker) coordinate system P_{m1} is defined as

$$P_c = T_{cm1}P_{m1}. \quad (2)$$

Also, the relation between the camera coordinate system P_c and the marker 2 coordinate system P_{m2} is defined as

$$P_{m2} = T_{cm2}^{-1}P_c. \quad (3)$$

P_{m2} can be transformed by using P_{m1} as bellow

$$P_{m2} = T_{cm2}^{-1}T_{cm1}P_{m1}. \quad (4)$$

By using Eq. (4), the proposed system calculates each marker coordinate based on the marker 1. The proposed system create the virtual optical components on the display from the calculated marker coordinates.

3. Light control with the virtual optical components

For understanding of the optical system construction to the user, it is effective to reflect changes of the light beam shape and the light path by the optical components on the display. In the case of using of the real optical components, it is difficult to see changes of the light beam by the optical components. On the other hands, since the proposed system can display the condition of the light beam, user can understand the role of the optical components in an intuitive way. Also, since the adjustment to the light intensity has the important role in the recording of the hologram, the proposed system implements the adjustment to the light intensity.

3.1. Calculation of the light path

Fist of all, to employ the calculation method described in 2.4, the proposed system obtains the coordinate of the all markers based on the laser marker as shown in Fig. 5. Then, the proposed system displays changes of the light beam by the virtual optical components which is placed on the light path of the laser beam as shown in Fig. 6. Also, the proposed system obtains the parameter of the light beam such as the light path length, the angle of deflection, the light diameter and the light power. Through this information, the user can control the light path by just using the markers.

3.2. Light path operation with laser, mirror and PBS

Figure 7 shows the laser marker, the augmented laser marker and the real laser. The CG laser and the direction of the light beam can be operated by the laser marker. Also, the light beam has the light power and the angle of deflection as the parameter.

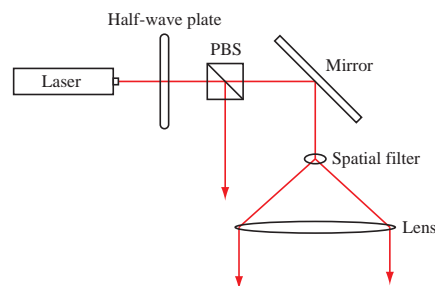
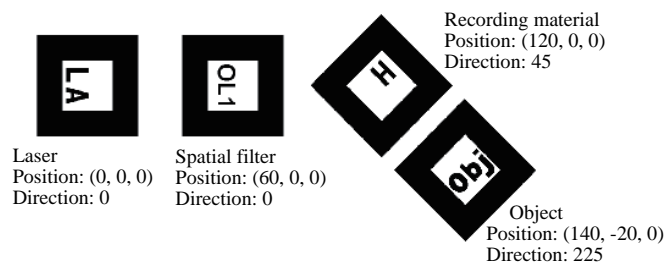


Figure 5. Acquisition of coordinate of all markers. **Figure 6.** Drawing of the light path.

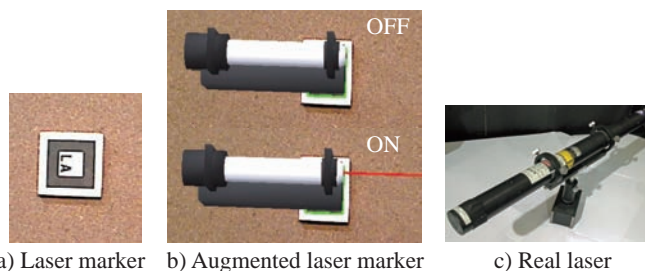


Figure 7. Laser marker and augmented laser marker.

Figure 8 shows the mirror marker, the augmented mirror markers and the real mirror. Figure 9 shows the PBS marker, the augmented PBS marker and real PBS. Mirrors can control the direction of the light beam as shown in Fig. 8 (b). The user can operate the light beam from the CG laser object by adjusting the direction of the mirror marker. The PBS can divide the laser beam depending on the deflection angle of the light beam. Therefore, user can learn to divide the reference beam and object beam.



Figure 8. Mirror markers and augmented mirror markers. **Figure 9.** PBS marker and augmented PBS marker.

3.3. Light beam diameter operation with spatial filter and lens

Figure 10 shows the spatial filter marker, the augmented spatial filter markers and the real spatial filter. The displayed color of the expanded light beam by the spatial filter fades as the light beam expands. Also, the virtual spatial filter has the parameter of NA, and user can configure the number of spatial filter's NA according to the intended optical setup.

Figure 11 shows the lens marker, the augmented lens markers and the real lens. The CG lens objects have the parameter of the focal length. Therefore, user can control the light diameter by the position of the lens marker as shown in Fig. 11 (b).

3.4. Light power operation with power meter, half-wave plate and polarizer

Figure 12 shows the power meter marker, the augmented power meter marker and the real power meter. To set the power meter marker on the light path, the proposed system display the light power of the position where the power meter marker is put as shown in Fig. 12 (b).

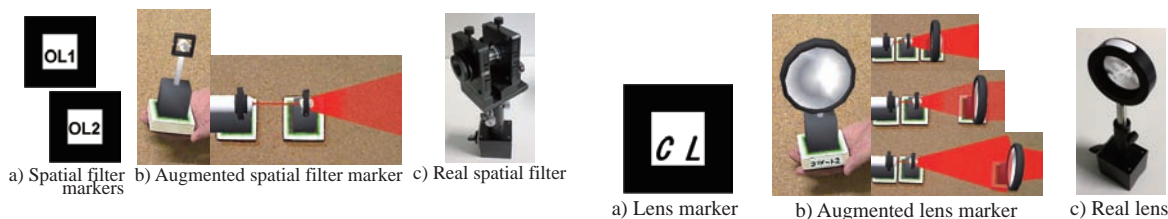


Figure 10. Spatial filter markers and **Figure 11.** Lens markers and augmented lens markers.

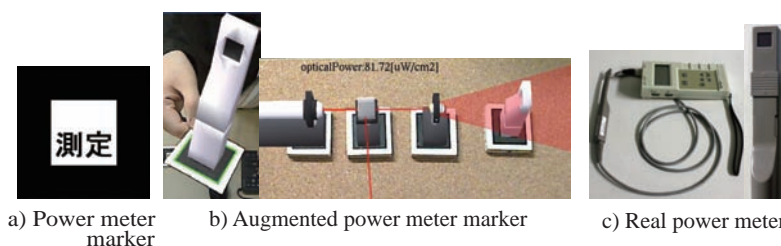


Figure 12. Power meter marker and augmented power meter markers.

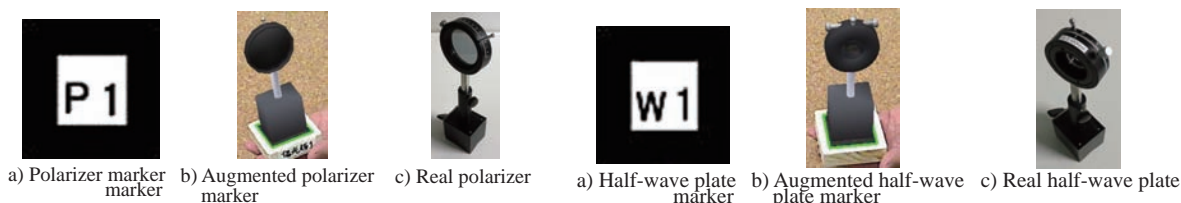


Figure 13. Polarizer marker and augmented polarizer marker. **Figure 14.** Half-wave plate marker and augmented half-wave plate marker.

Figure 13 shows the polarizer marker, the augmented polarizer marker and the real polarizer. Figure 14 shows the half-wave plate marker, the augmented half-wave plate marker and the real half-wave plate. Since the displayed object is the CG object and can not be touched, we arrange the another marker to control the polarization angle. Figure 15 shows the schematic image of the polarization angle control and its results. The proposed system calculate the angular difference between the laser marker as the base marker and the control marker.

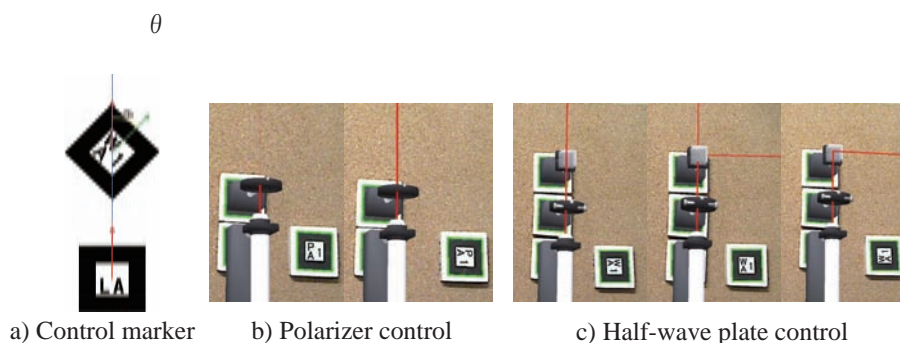


Figure 15. Operation of the half-wave plate and the polarizer.

4. Optical system construction for the hologram recording

The proposed system support the training about the optical system construction of the Denisyuk hologram and 2-step transmission type hologram as shown in Fig. 16 and 17. The user can understand the construction of the optical setup through arranging the markers. Figures 18 and 19 show the simulation outcome with the proposed system. If the user made a mistake, the proposed system shows the reason of the mistake in the message box. In the proposed system, there are some judgment conditions such as; the difference of light paths, the incident angle of the object beam and reference beam, the light power and the polarization angle.

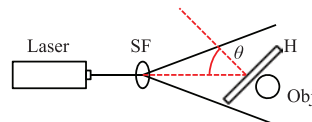


Figure 16. Schematic of the optical setup for Denisyuk hologram: SF = spatial filter, H = recording material, obj = recording object.

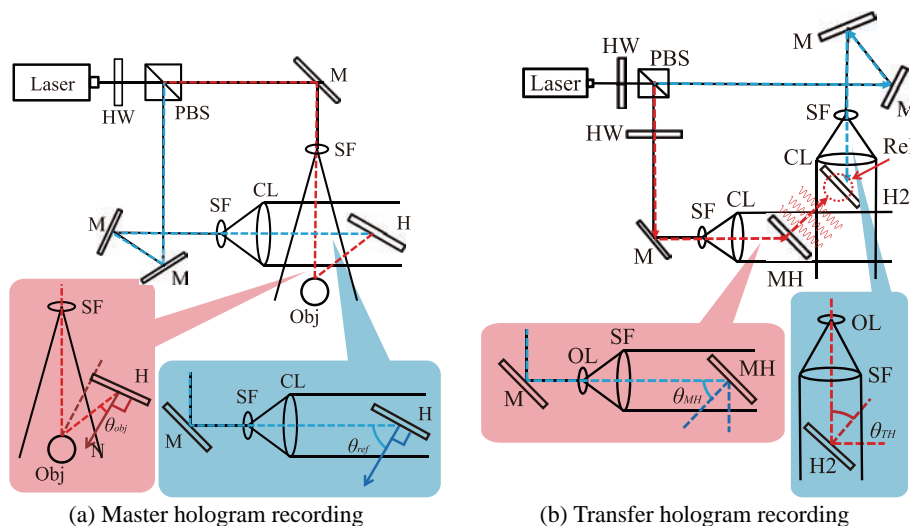


Figure 17. Schematic of the optical setup for 2-step hologram: SF = spatial filter, H, H2 = recording material, obj = recording object, PBS = polarizing beam splitter, HW = half-wave plate, MH = master hologram, CL = collimate lens, M = mirror, ReI = reconstructed image from the master hologram.

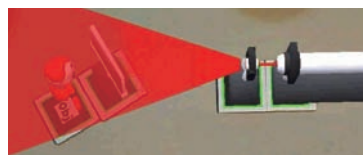


Figure 18. Simulated result about the optical setup of Denisyuk hologram.

5. Measurement of educational effect

To measure the educational effect of the proposed system, we have the proposed system used by beginners who are junior year of college and they are not familiar with the holography. The subjects were divided into 2 group which used the proposed system or only the textbook for learning. After learning, we measured the construction time of Denisyuk hologram setup for each subjects and the correctness checking. Table 1 shows the result of measurement of the educational effect. In this measurement, although there was little number of the data, but the effectiveness is confirmed.

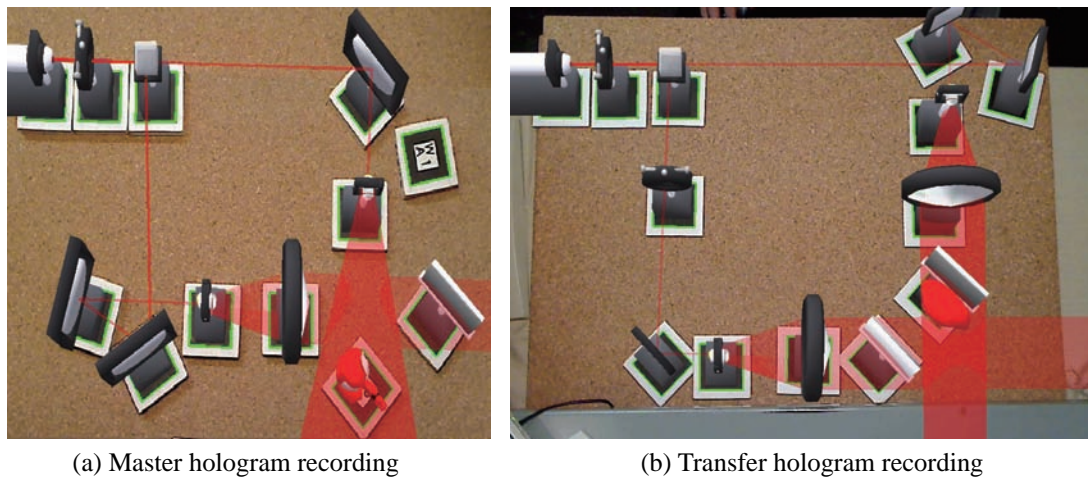


Figure 19. Simulated result about the optical setup of 2-step hologram.

Table 1. Measurement of the educational effect

With proposed system			Without proposed system		
ID	Time	Correctness checking	ID	Time	Correctness checking
a	2'03"	OK	k	3'18"	OK
b	2'18"	OK	l	8'13"	NG
c	1'54"	OK	m	3'14"	NG
d	2'11"	OK	n	3'23"	OK
e	2'18"	OK	o	4'33"	OK
f	2'27"	OK	p	8'48"	OK
g	5'35"	OK	q	6'55"	OK
h	2'41"	OK			
i	2'37"	OK			
j	3'53"	OK			
Average time		Success rate	Average time		Success rate
2'50"		100%	5'14"		71%

6. Conclusion

In this paper, we have proposed new education system for the construction of the optical setup. By using the augmented reality, the proposed system provide the tangible learning to the user. As a result, the learner can understand the role of the optical components and the maneuver of the optical setup construction intuitively.

- [1] Nagano S, Yamaguchi T and Yoshikawa H 2009 *HODIC* **29** 27–30
- [2] Shibata M, Yamaguchi T and Yoshikawa H 2010 *HODIC* **30** 17–20
- [3] Shibata M, Yamaguchi T and Yoshikawa H 2011 *HODIC* **31** 18–21
- [4] Kato H 2002 *IEIC Technical Report* **101** 222–232
- [5] Kato H and Billingham M 1999 *2nd IEEE and ACM International Workshop on Augmented Reality* 85–94