# Slanting Shadow: Changing Invisible Shadow Shapes by Rotation for Expanding Shadowgraph Experience

Saki Sakaguchi, Hikari Tono and Mitsunori Matsushita*
Kansai University

## Abstract

This paper proposes a method for hiding information inside an actual object and viewing the hidden information as shadows selectively by rotating the object. Our proposed system creates shadows using the properties of polarizing plates and 1/2 wavelength boards. The goal of our research is to develop a novel method for creating extended shadows.

**CR Categories:** H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities;

## 1 Introduction

The goal of our research is to develop a novel method for creating extended shadows. One method allows adding invisible information to an object and then visualizing by performing a specific action (e.g., sympathetic paper). The Restive Shadow system hides information within an object, and different shadows are cast from the object when it is placed under light of different wavelengths. This system uses an object comprising an infrared (IR) pass filter. The user can create the shadow selectively by irradiating the object with light of specific wavelengths. The shape of the shadow depends on the IR light wavelength. This paper proposes a method for hiding information inside an actual object and viewing the hidden information as shadows selectively by rotating the object. This method allows the user to change the shape of the shadow.

## 2 System

Our proposed system creates shadows using the properties of polarizing plates and 1/2 wavelength boards. The 1/2 wavelength boards are fixed between two polarizing plates with the same polarization direction. The resulting angle between the optical axis of the boards and the polarization direction is assumed to be $\theta$ (Fig. 1). Figure 2 shows the mechanism of blocking lights with two pieces of polarizing plate and a 1/2 wavelength board. If $\theta$ is $45^\circ$, the direction of the light rotates by $90^\circ$. The second polarizing plate blocks the light by rotating the light direction by $90^\circ$ through the 1/2 wavelength board. This system creates invisible shadows caused by the IR light. The shadow may not be created even if $\theta = 45^\circ$, depending on the wavelength of the IR light. Therefore, a user can control the creation of shadows by changing the wavelength of the IR light. We created two different objects for an application. Object-1 is shown in Fig. 3. The inside of the object comprises a plastic board and two pieces of 1/2 wavelength boards. Each 1/2 wavelength board has a different shape and optical axis and, hence, rotation of the irradiated object changes the shape of the shadow cast. SC-74 filters attached to both sides of the object prevent the user from viewing the internal structure of the object. Object-2 is shown in Fig. 4. The inside of the object comprises a plastic board and a number of pieces of 1/2 wavelength boards with the same shape but two different optical axes. IR-80 filters attached to specific places change the light permeability according to varying IR light wavelengths. Figure 5 shows an outline of the proposed system. The system comprises an IR light source, two polarizing plates, an IR camera, a projector, and a screen. When the objects are placed on a table illuminated by IR light, the system creates shadows that are invisible to the human eye. An SC-74 filter is attached to the CCD camera to transmit the IR light. The screen is suitable for back-projection, that it enables projection of the invisible shadows cast by the IR light and images produced by a projector. Placing the projector underneath the screen inhibits the interference of the image from the projector and the invisible shadow. The IR light source can be adjusted to produce one of two wavelengths: 770 and 940 nm. The polarizing plate for the IR light is attached to the light source, and that for the visible light is attached to the screen.

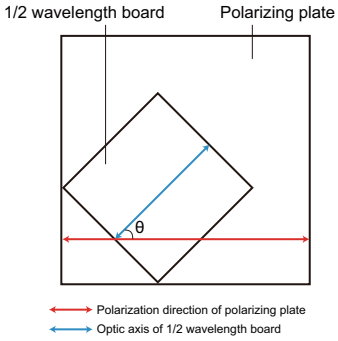


**Figure 1:** *Polarizing plate and 1/2 wavelength board*

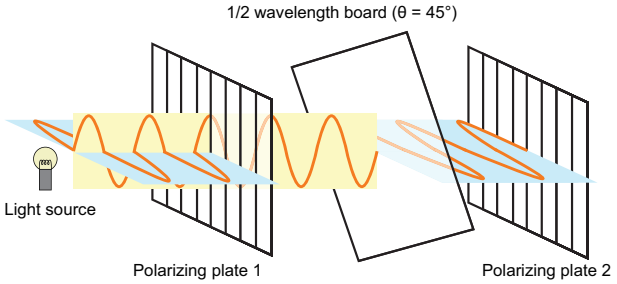


**Figure 2:** *Blocking lights with polarizers and 1/2 wavelength board*

*e-mail:mat@res.kutc.kansai-u.ac.jp


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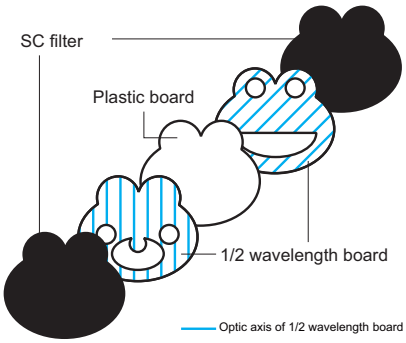


**Figure 3:** *Object-1*

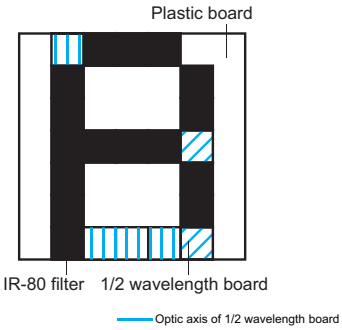


**Figure 4:** *Object-2*

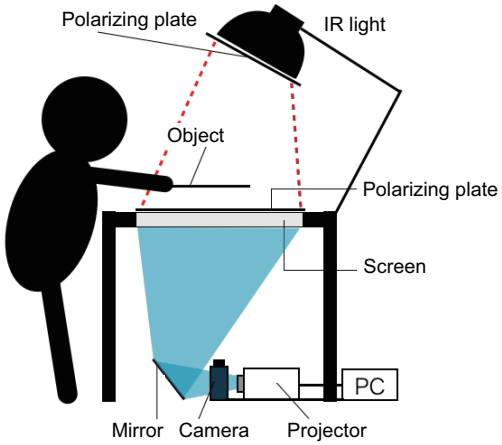


**Figure 5:** *System*

## 3 Applications

We created an application to cast shadows of different shapes from an original object. A user can see the shadow shapes by placing the object over a screen and change the shadow shapes by tilting the object. When the light wavelength is 770 nm, two different shadows appear, depending on the object angle, and when the light wavelength is 940 nm, the shadows become unclear. Figure 6 shows the shadows created using Object-1 (shown in Fig. 3). If the user creates a shadow using the 770 nm light, a picture appears that can be changed from a bear shape to a frog shape by tilting the object. Figure 7 shows the shadows created using Object-2 (shown in Fig.

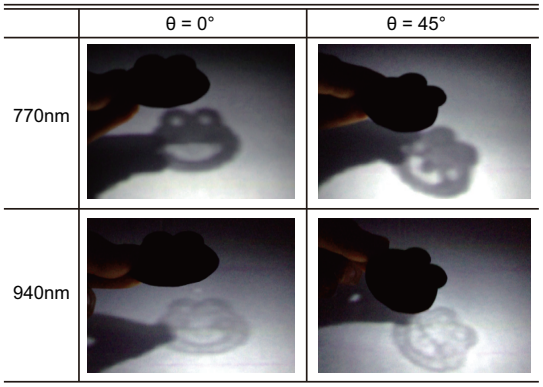


**Figure 6:** *Shadows with Object-1*

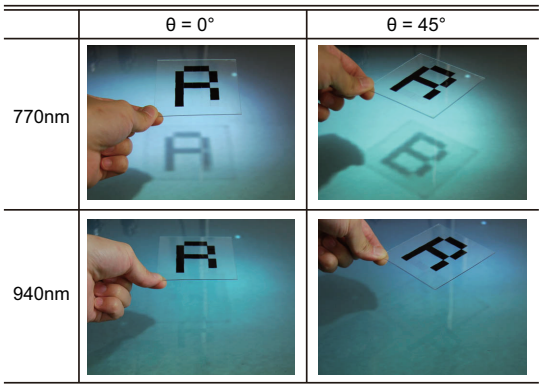


**Figure 7:** *Shadows with Object-2*

4). If the user creates a shadow using the 770 nm light, a letter “A” appears; the shadow can be changed from “A” to “B” by tilting the object.

## 4 Related Work

Several researchers have attempted to extend shadows to applications in the media arts. Some developed systems use artificial shadows[Chikamori and Kunoh][Worthington. 2004], but our proposed system uses natural shadows created by shining infrared lights. The Restive Shadow system[Sakaguchi et al. 2013] allows extending shadows using infrared lights and IR filters that enable the transmission of infrared lights. Directing the light toward the object causes the object’s shadow to appear; the shape of the object then appears to change according to the wavelength of the radiated infrared light because the object is attached different types of IR filters. Our proposed system is similar to this system in using shadows created by shining infrared lights, but it differs in changing shadow shapes using polarizing plates and 1/2 wavelength boards. Some studies have reported the use of polarizing plates to obtain selective visualizing information[Fujimura et al. 2012][Sakurai et al. 2009]. These systems display different information to each user using polarizing plates that have different polarization directions. Studies using polarizing plates and 1/2 wavelength boards for visualizing information have also been performed[Simazaki][Koike et al. 2009]. These systems allow visualizing and hiding information by rotating polarizing plates or 1/2 wavelength boards. Our proposed system is similar to these systems in that information is visualized selectively using the properties of polarizers, but it differs in using invisible

shadows generated by shining infrared lights.

## 5 Concluding Remarks

This paper proposed a method for hiding information inside an actual object and viewing the hidden information as shadows selectively by rotating the object. We plan to add various information by combining the capture of markers and develop more novel method for creating extended shadows.

## Acknowledgements

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## References

TONO, H., SAKAGUCHI, S., AND MATSUSHITA, M. Basic Study on Creation of Invisible Shadows by Using Infrared Lights and Polarizers. In *ACM SIGGRAPH 2014 Posters*. pp.27:1–27:1. 2014.

CHIKAMORI, M., AND KUNOH, K. Kage. http://www.plaplax.com/legacy/artwork/minim++/artwork/kage.htm.

FUJIMURA, W., KOIDE, Y., SONGER, R., HAYAKAWA, T., SHIRAI, A., AND YANAKA, K. 2x3d: Real time shader for simultaneous 2d/3d hybrid theater. In *SIGGRAPH Asia 2012 Emerging Technologies*. pp.1:1-1:2. 2012.

KOIKE, H., NISHIKAWA, W., AND FUKUCHI, K. A study on polarization on an lcd tabletop system: Development of a transparent marker using optical films. *Transactions of the Virtual Reality Society of Japan*. Vol.14. No.1. pp.111-119. 2009.

SAKAGUCHI, S., TONO, H., TANAKA, T., AND MATSUSHITA, M. Restive shadow: Animating invisible shadows for expanding shadowgraph experience. In *SIGGRAPH Asia 2013 Emerging Technologies*. pp.16:1-16:2. 2013.

SAKURAI, S., KITAMURA, Y., SUBRAMANIAN, S., AND KISHINO, F. A visibility control system for collaborative digital table. *Personal Ubiquitous Comput.*. Vol.13. No.8. pp.619-632. 2009.

SIMAZAKI, K. Polarization plate art. http://www.print-art.co.jp/henkoban.html.

WORTHINGTON, P. Shadow monsters. http://www.moma.org/visit/calendar/exhibitions/1346.