Protection Method from Secret Photography

Ippei Suzuki*, Shinnosuke Ando, Yoichi Ochiai*

University of Tsukuba, Japan.
* Pixie Dust Technologies, Inc., Japan.
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ABSTRACT

We present a method to protect contents from secret photography by using high-speed projection. We divide an image into parts and project them in succession at a high frame rate in order to make the image visible to human eyes. By contrast, cameras can only capture an incomplete frame.

1 INTRODUCTION

1.1 Background and Objectives

Protecting contents from secret photography is a serious problem for contents providers. Some solutions already exist to prevent such recordable copies. One solution is to overlay something that appears to the human eye (e.g., visible watermarks, stickers of credit) on contents. This is a very simple and effective solution, as a camera cannot capture the content as it is. However, in this case, people similarly cannot see the content as it is. Therefore, this method worsens the experience of viewers. Another solution involves inspection and security. For example, an organizer of an event can confiscate camera devices before visitors enter an area in which that content can be captured. Even if the inspection overlooks some cameras, warnings might be issued not to use cameras. However, event visitors secretly taking pictures is still possible. Ill-intentioned visitors (e.g., ranging from those who wish to infringe on the privacy of others to those who violate copyright protections) can use small cameras (e.g., pen-shaped secret cameras, a smartphone hidden in a breast pocket, wearable eyeglass-like devices) to take photographs secretly. How can we against these types of cameras? The difficult point is that contents are not only visible to the humans but can also be captured by cameras. Therefore, we try to make the contents that humans can see but cannot be captured by such cameras.

1.2 Overview

Our approach presents images to human eyes by using the afterimage effect caused in the human visual system. We divide the image into smaller parts and project each part in succession over the same projection periods. By contrast to human eyes, cameras must synchronize the frame period and the shutter timing to capture photos, as shown in Fig. 1. However, it is extremely difficult to capture an image with a camera that does not synchronize with a projector. Our system does not consider long exposure in photographs because a small camera, which is the focus of our system, tends to have an insufficient adjustable diaphragm as shown in Fig. 2. When people try to take a beautiful photo using a small camera and without blowing up highlights, they have to increase the shutter speed. However, when they increase the shutter speed, they can capture only incomplete flames. Therefore, our system works well in this type of situation.

2 RELATED WORK

Researchers have tried to use the afterimage effect of human eyes to develop methods that embed invisible information in the environment. Grundhofer et al. presented a method to detect invisible markers by using a synchronized camera [1]. VRCodes [2] uses a built-in

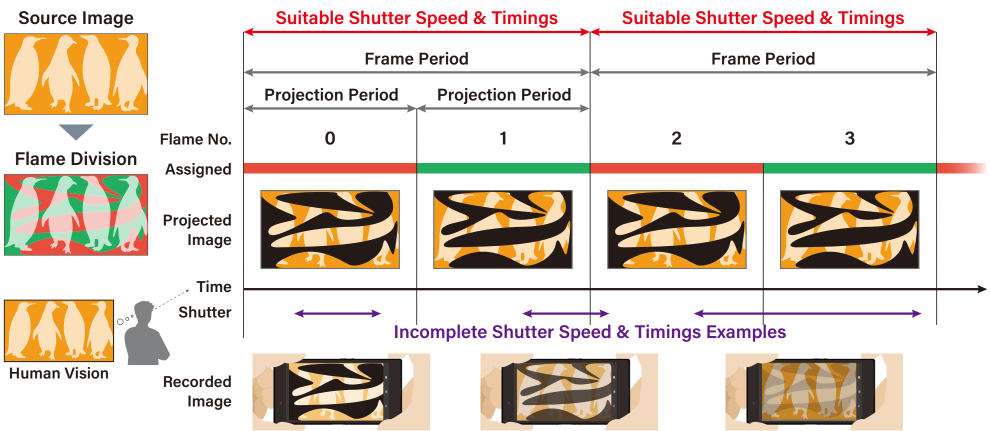

Fig. 1 Theory and effect of the method described in this paper.

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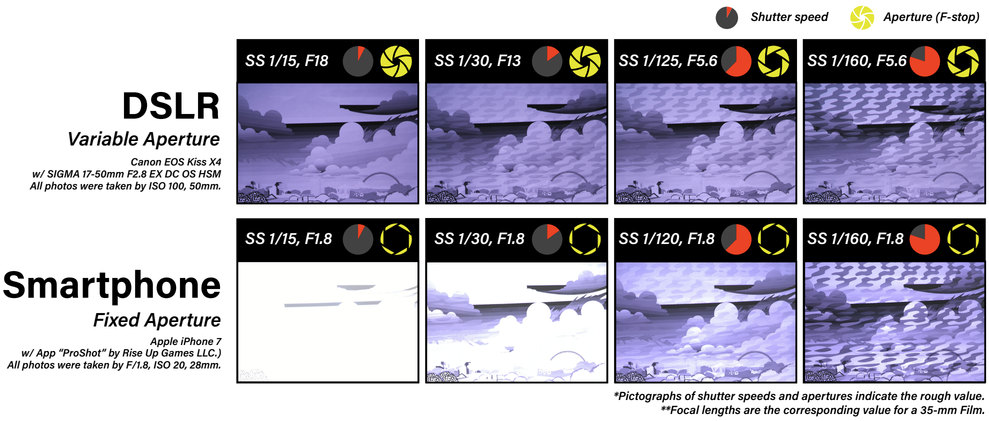

Fig. 2 Comparison of the result from DSLR and Smartphone.

rolling-shutter image sensor in pervasive cameras such as smartphones to detect binary codes embedded in displays. Sampaio et al. [3] also presented a method to detect visual codes embedded in images using an unsynchronized camera. Their system could use both rolling- and global-shutter cameras. Visual SyncAR [4] uses digital watermarks on videos to display the camera timecode and employs a system by which animations in augmented reality (AR) can be synchronized with the video. The focus of these previous studies is similar to our own. However, the previous studies mainly examined techniques for producing AR or virtual reality (VR) and not for securing and protecting recordable content.

3 IMPLEMENTATION

In this section, we describe our implementation. Our system consisted of a projector, a computer, and a screen.

Name	DLP LightCrafter 4500 EVM
Maker	Texas Instruments Inc.
DMD	912 × 1140 diamond pixel 0.45-inch WXGA DMD
Light source	RGB LED light engine with 150 lumen light output
Max pattern speed	Up to 4225 Hz binary pattern Up to 120 Hz 8-bit grayscale pattern

Table 1 Specifications of the high-speed projector.

We used one high-speed projector (DLP LightCrafter 4500 EVM; Texas Instruments Inc.). Specifications are shown in Table 1. It was controlled by GUI software provided by Texas Instruments, Inc. We set the parameters of bit plane selection, output light color, projection period, and exposure period via the GUI software. In our evaluations, the projection and exposure periods were set to the same duration. In the pattern sequence mode of GUI software, we can project 1-bit to 8-bit grayscale images by using 24-bit red-green-blue (RGB) images. Each 8-bit color (i.e., each of R, G, and B) in these images expressed different bit planes. Please see the web page of the projector (http://www.ti.com/tool/dlplcr4500evm last accessed Sep. 11, 2018) for more information about input pattern images. In this paper, we divide source images into two parts, and the parts are then projected in succession. We projected 4-bit grayscale images at 240 Hz with a white light source.

4 RESULT

We first used a digital single-lens reflex camera (DSLR) as a camera vision to explore thresholds of the effective shutter speed of our system. The DSLR can control the shutter speed finely and its f-stops can be adjusted to wide ranges. The success of our system depends on the shutter speed of the camera. Therefore, changes in the captured image must be assessed based on the shutter speed. Reducing the shutter speed darkens images, whereas a faster shutter speed makes them brighter. Thus, to investigate the effect of shutter speed while maintaining the brightness of the image, we needed to adjust the image brightness while considering other factors such as aperture and ISO speed by using DSLR. Next, a smartphone (iPhone 7; Apple Inc.) was used to verify the effects of our system in an actual situation involving secret photography. We took photos while changing the shutter speed.

Results are shown in Figure 2. Based on the results from the smartphone, we can see our system successfully altered photos. For DSLR, when the shutter speed decreases to less than 1/30, the DSLR can capture the projected image correctly. However, photos taken by the smartphone at this shutter speed result in blown-up highlights such that people cannot see the projected image. When the shutter speed of the smartphone is increased, highlights become clear, then the effect of our system appears in the photo.

5 APPLICATIONS

5.1 Protection of Screen Content

The main purpose of this study is to develop a technique that prevents secret photographs from being captured as shown in Fig. 3 left (the text "Protection" is only shown in the captured photo). It can be applied, for example, to secret slides in a presentation, that is, for slides containing information or images that a speaker wishes to protect from being photographed. With our system, presenters do not need to warn audience members about taking photos of presented slides.

5.2 Protective Illumination

The proposed system can be used not only as an image projector but also as an illumination system. For example, the system can be installed in an art gallery as a kind of spotlight, as shown in Fig. 3 right. Our system projects a circular spotlight onto artwork when people view them. However, from the secret camera, the projected light produces a blurred image.

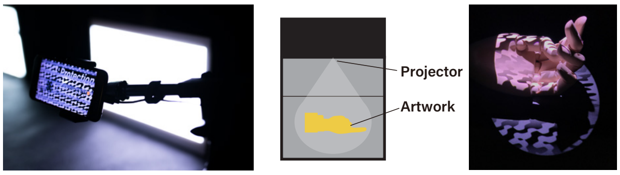

Fig. 3 Application examples.

6 DISCUSSIONS AND FUTURE WORK

6.1 Robustness of Our System

We must make a shutter speed of the secret camera faster than the threshold defined by projection speeds. If the shutter speed is slower than that threshold (e.g., when using long-term exposure), the secret camera can capture an image. Therefore, high-specification cameras such as DSLR can evade our system because they can close the f-stop to reduce the shutter speed and avoid blowing up highlights. However, because we can verbally warn people who try to use such cameras and our system can prevent them from using recordable cameras, particularly small devices that are hidden, we consider protecting content by combining warning by human with our system.

On the other hand, some of the smartphones which visitors bring to our demonstration avoided our system. Our method may not be able to prevent secret photography by 100% of the time, but it is one solution that reduces the possibilities of secret photography. For example, we might be combined with other solution that to prevent secret photography.

As another approach to achieve more robust system, we will explore to project images by changing the projection period or division pattern randomly. We will experiment whether we can ensure our system prevent reconstruction of the content which is by multiple captured photos.

Currently, our system can only show a static image. About whether our method can be applied to video, it seems to be difficult because the camera must be synchronized their every frame with the timing of video frames to capture the entire video.

6.2 Quality of the Image

The brightness of each pixel diminishes because we should project images using shorter duration than in a normal projection. When we divide images into N areas, people perceive images having 1/N of the original brightness. Employing a projector that has high brightness, high projection speed, and high resolution enhance the quality of the screen.

6.3 Flicker Perceived by the Human Vision

When a person's viewpoint of a screen was altered by eye saccade, they tended to perceive flicker. Tradeoffs exist between the strength of the system's resistance to flicker and an acceptable shutter speed in terms of slowness. When we use a low-speed projector, people also perceive flicker. Our system may not be suitable for extended viewing of media, such as of movies in cinemas. Other guests visited our demonstration reported that they could perceive division patterns when they viewed our screen through a waving hand in front of them such as via steganography as like proposed by Yamamoto et al. [5] We will explore division pattern optimization for images so that flicker can be removed.

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