Information Hiding in Real Object Images Captured with Video Camera Using Brightness-Modulated Light

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***Abstract*— We propose a technology that can invisibly embed information into the image of a real object captured with a video camera. It uses illumination light that illuminates the real object. The illumination light invisibly contains information. As the illumination contains information, the image of the object illuminated by such light also contains information. Information in the light is produced by modulating luminance according to the embedded pattern at half-frame frequency. Frame images over a certain period are added up after the sign of the even- or odd-numbered frames is changed. Changes in brightness by modulation in each frame are accumulated over the frames while the object image is removed because the even and odd frames are opposite in sign. This makes it possible to read out the embedded patterns. This paper demonstrates the feasibility of information hiding from our experimental results.**

Keywords-information hiding; digital watermarking; brightness-modulated light.

I. INTRODUCTION

Information hiding or data embedding technologies have recently been studied and used in various applications. Although conventional information hiding technologies hide information into digital data, we have studied a technique that does not hide information in digital data but conceals it on the surface of a real object [1]–[3]. The main purpose of this technique is to protect the portrait rights of real objects that are highly valued as portraits such as those in celebrated paintings in museums. The technique we propose uses illumination light for the real objects. This light invisibly contains certain information. Since the illumination contains information, the captured images of real objects illuminated by such light also contain information as watermarks. Although we studied this technique for still images, the need for these kinds of techniques for moving images has recently been increasing because taking moving images at any time and from anywhere has recently become easier for everyone than ever before because of the widespread use of smart phones that have video cameras built into them.

The main purpose of our study was to develop the same technique for moving pictures captured with video cameras as that for still images. We propose a technique using temporally and spatially illumination-modulated light for moving images. We demonstrated the feasibility of this technique experimentally in this study by using actual moving images captured with a video camera that solved problems that arise in practical use, such as asynchronicity between video cameras and projectors.

II. HIDING AND READING OUT INFORMATION

Figure 1 illustrates the basic configuration for the technique we present in this paper. It uses a kind of projector as a light source to illuminate the real object by projecting light whose luminance is temporally and spatially modulated. The embedded pattern is binary image and it is embedded in the projected light by increasing (decreasing) luminance in the patterned area by slight degree dB from the averaged value for odd- (even-) numbered frames. The amplitude of modulation, dB, is too small for human vision to perceive. Since the luminance of the light projected onto the object is modulated, the brightness of the captured image of the object is also modulated, although it is invisible. Because dB is so small, it is difficult to read out the embedded pattern from a single frame image. Therefore, frame images over certain periods are added up after the sign of the brightness in even- or odd-numbered frames is changed. Because the sign of every other frame is changed, the changes in brightness by modulation in each frame are accumulated over the frames. However, the background image is removed because the brightness of even and odd

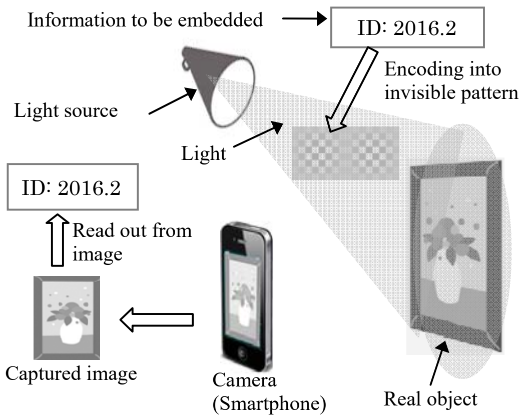

Figure 1. Basic configuration of technology.

frames cancels one another out. As a result, the embedded patterns become visible and it is then possible to read them out.

This technique presupposes that the captured image and projected image are synchronized. However, they are not actually synchronized, especially in phase. If the phase is shifted near 90 degrees in the worst case, the brightness of the modulated pattern is cancelled and cannot be added up since a frame of the image is captured across two frames of the projected moving image. To solve this problem, we propose a method where luminance is modulated at half frequency of the frame frequency of the projector that produces two groups of added up images; the first is produced by only adding up odd-numbered frames and the second is produced by only adding up even-numbered frames. The frames of captured image do not go across the two frames of projected images whose signs of dB are opposite by doing this, at least for one of these two frames. Therefore, it becomes possible to read out the embedded pattern by choosing the one with the largest contrast.

III. EXPERIMENTS

We conducted experiment to demonstrate the effectiveness of the proposed technique. We only embedded information in blue component images to enhance invisibility. We embedded simple pattern, characters, and quick response (QR) code. We used A1 size printed color images as real objects. We used a projector that had 1280 x 1024 pixels to project light that contained the invisible pattern. The brightness of the light was 200 except for the pattern embedded region where brightness was modulated with amplitude of dB, which was changed up to 20 as an experimental parameter. These figures indicate the gray scale value of which maximum is 255. The image of the object projected the light modulated with invisible pattern was captured with video camera that had 1280 x 720 pixel as a color video image.

We also evaluated the invisibility of the embedded information through subjective tests when it was in the light and captured images.

IV. RESULTS

The results from the experiments revealed that invisible patterns could be read out for dB of over four and when the number of frames (NF) added up to over 20. Figure 2(a) shows an example of the pattern to be hidden, Figure 2(b) has the brightness distribution of the projected light modulated by the pattern, Figure 2(c) has the image of the real object projected by the modulated light, and Figure 2(d) has the read out pattern. The conditions in this example were that dB was 20, NF was 30, and the size of the embedded characters in the original image was 20 pt. It can be seen in Figure 2 that the hidden pattern of the characters cannot be seen on the real object; however, it can be seen by summing up the frame images, although noise is seen in the background.

(a) Hidden pattern

(b) Projected light

(c) Image of real object projected by modulated light

(d) Read out pattern

Figure 2. Example of hidden pattern and read out pattern.

We found with regard to invisibility that for dB of under 10, the embedded pattern could not be seen either in the light or captured images and for dB of 20, we saw the flicker in the embedded pattern area although pattern could not be seen. These results indicated that there were conditions where both the invisibility and readability of the patterns were simultaneously satisfied although we have to remove the flicker in future.

V. CONCLUSION

We proposed a new technique for information hiding in real object images captured with a video camera using brightness-modulated light as illumination for the real object. Although the changes in brightness with this technique by modulation in each frame are too small to be visible, they become visible when they are accumulated over the frames.

We conducted experiments and the results from these revealed that invisible hidden patterns could be read out, as we had expected. We intend to remove the noise in background and flicker in the embedded pattern region in future work.

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