Optical Watermark Pattern Technique using Color–Difference Modulation

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***Abstract*— We propose a new optically written watermarking technique that produces a watermark pattern by modulating color difference. The illumination that contains such a watermark is projected onto an object. An image of the object taken by the camera contains the same watermark, which can be extracted by image processing. Therefore, this technique can protect portrait rights of real objects. We conducted a simulation where one-bit binary data were embedded in blocks that consisted of 8 x 8 pixels using the phase of the highest-frequency component. The simulation results revealed that a watermark pattern produced by modulating color difference could be accurately read out.**

Keywords-Watermark pattern, information embedding, portrait right.

I. INTRODUCTION

Digital watermarking has been widely used to protect the copyright of digital content, which includes images printed from digital data. This is to prevent the illegal use of images copied by digital cameras or scanners. However, printed images or other real objects that have a high value, such as paintings in museums, do not contain watermarks in themselves, and images taken of these with cameras can easily be utilized without copyright.

We developed a technique that can prevent the illegal use of images of real objects that do not have watermarks [1] [2] by using illumination that contains an embedded watermark pattern invisible to the naked eye. An image taken of an object illuminated with the watermark pattern by a camera would also contain the pattern.

We embedded the watermark pattern in the illumination by modulating its brightness, as documented in our previous study. In this current study, we produced a watermark pattern by modulating color differences and evaluated its readability from the captured image by comparing it with the previous method that modulates brightness.

II. EMBEDDING WATERMARK PATTERN IN THE ILLUMINATION

Figure 1 outlines the basic concept underlying our watermarking technique using light to embed a watermark. An object is illuminated by a projected light that contains an invisible watermark. A photograph taken of the object illuminated this way would also contain the watermark. The watermark can be extracted in the same way as that in conventional watermarking techniques for digital content.

Figure 2 illustrates the procedure for applying a watermark and reading it from a captured image.

The color difference signal Cb of Luminance, Chroma-blue and Chroma-red (YCbCr) signal was used to produce the watermark. Figure 2 (a) shows the original data of Cb as a frequency domain. The original data is divided into numerous blocks, each of which consists of 8 x 8 pixels. Each block has only the highest frequency component (HC)

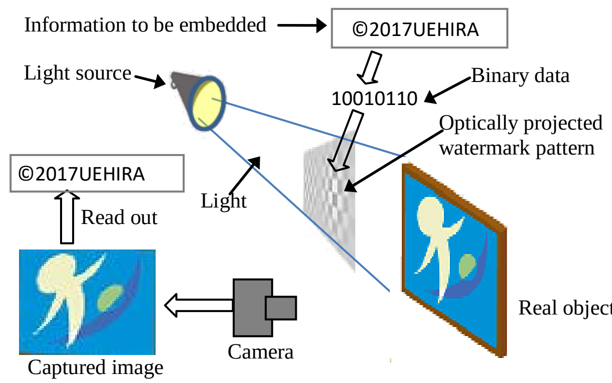

Figure 1. Basic concept underlying proposed

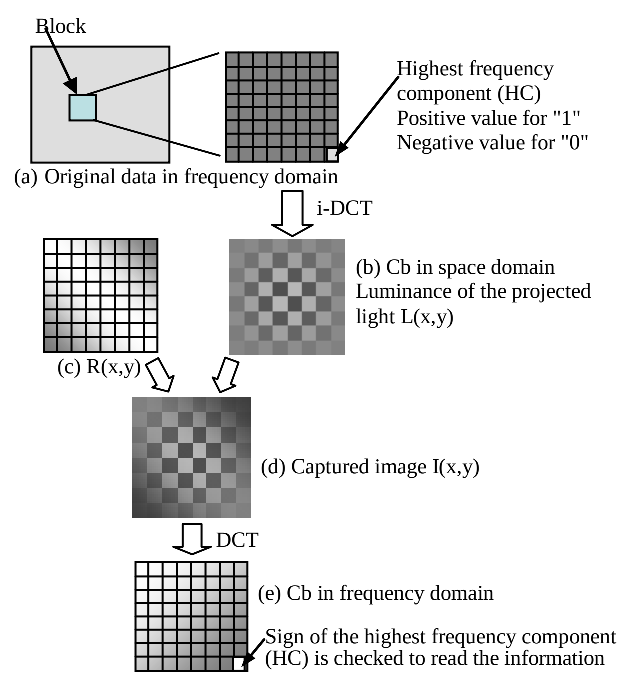

Figure 2. Procedure for watermarking

in both the x and y directions to express one-bit binary data. If the sign of the HC in a block is positive, it is expressed as "1", and if it is negative, it is expressed as "0". This original data in the frequency domain is converted into a signal in the space domain by making an inverse discreet cosine transform (i-DCT) (Fig. 2 (b)). Y and Cr signals are constant. After converting the YCbCr into an Red, Green and Blue (RGB) signal, the RGB signal is input to a projector, and the watermark pattern is projected onto the object.

The captured image of the object $I(x,y)$ is given as a product of the reflectance of the object surface $R(x,y)$ and luminance of the projected light $L(x,y)$, as shown in (1).

$$I(x,y) = R(x,y)\{L(x,y) + L_0\} \quad (1)$$

where L_0 is a bias luminance, such as one produced by room light.

A captured image is first converted into a YCbCr signal, and then Cb is converted into a signal in the frequency domain by DCT. Finally, the embedded data is read out by checking the sign of the HC of the Cb for each block.

The watermark pattern in the light and in the captured image cannot be seen by the human visual system because it is modulated at the highest frequency and the amplitude of the modulation is small.

III. Simulation

We simulated the captured images of objects using (1). We used RGB signal as $L(x,y)$, assuming that the brightness of the RGB component of the projected light was proportional to the component of the RGB signal. As for the objects $R(x,y)$, we used three standard images shown in Figure 3.

HC in the original data was changed from 1 to 20 as an experimental parameter, while Y, Cr, and L_0 were set to constant values of 200, 0, and 40, respectively. For reference, we embedded a watermark pattern by modulating Y. In this case, Cb and Cr were set to zero, and L_0 was set to 40.

(a) Image A (b) Image B (c) Image C

Figure 3. Images used as objects in the simulation.

IV. Results and Discussion

Figure 4 shows the accuracy with which the binary data was read out. The accuracy is indicated by the percentage of the data read out correctly from the entire data. The results show that the accuracy when modulating Cb is higher than that when modulating Y with values over 99% for HC values set over 2

Figure 5 shows the captured images simulated using (1)

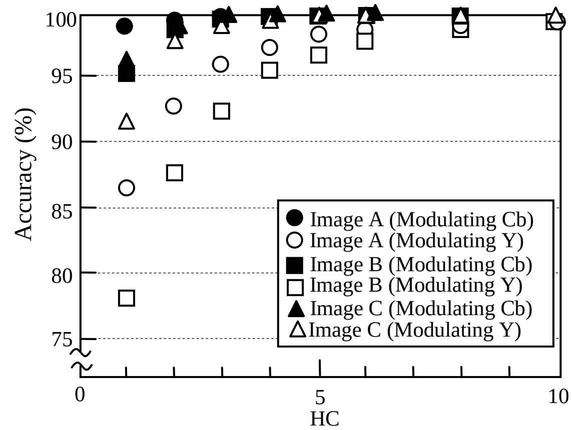

Figure 4. Accuracy in reading out binary data

Figure 5. Simulated captured images (HC=5)

when HC was set to 5. We could not see any watermark pattern in the images. These results indicate that we can satisfy both invisibility and readability of embedded data by using certain HC ranges.

V. Conclusion and Future Work

We developed a technique that can embed an invisible watermark pattern into captured images of real objects using illumination that contains the pattern. We embedded the pattern into the illumination by modulating color difference.

We demonstrated from the simulation that an accurate reading of the watermark information is possible by modulating color difference, and embedded watermarks could be invisible.

In the future, we will examine the detailed conditions for invisibility of watermarks.

References

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