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A METHOD FOR EMBEDDING ANOTHER PHOTOGRAPHIC IMAGE IN A PHOTOGRAPHIC IMAGE

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Abstract. *We propose a hight-quality method for embedding another photographic image in a photographic image. Our method prepares two photographic images (image A and image B) of the same size with 256 gradation, and embeds information of image B in image A. Embedding is executed by changing the pixel value of image A within plus or minus 2. An image (image A') created by embedding image B in image A is difficult to recognize the difference from image A. In restoration, the pixel value of a quarter of image B is reproduced without change. An image (image B') restored from image A' is almost the same as image B. Since it cannot be recognized that image B is embedded in image A' and image B' can be restored from image A', our method can be used as a digital watermark. In addition, since image A and image B can be represented by image A', our method can be used as image compression. We verify the effectiveness of our method visually and quantitatively through experiments using various photographic images.*

Keywords: Photographic image, Embedding, Digital watermark, High quality

1. **Introduction.** There have been many studies to embed another information in an image, a video or an audio, and the technologies in those studies have been called digital watermarks [1]. Although the embedded information with digital watermarks cannot be perceived, the embedded information can be extracted by using detection software. Digital watermarks are assumed to be used mainly for copyright protection such as detection of unauthorized copying and data tampering. Studies that embed digital watermarks in images can be broadly divided into methods that use luminance information of images [2, 3, 4, 5] and methods that use frequency information [6, 7, 8]. In SVD-based watermarking scheme, Chang et al. [2] embedded the extra information required for later restoration into the least important non-zero coefficients of the S matrices in the image. Latif and Naghsh-Nilchi [3] proposed a watermarking method using genetic algorithm-based parameter amelioration of parametric Slant-Hadamard transform. Emami et al. [4] proposed an approximation approach using histogram intersection for identification of the rightful owner utilizing the remaining information of the attacked watermarks regardless of the attack behavior. Chen et al. [5] proposed a reversible high capacity information hiding method based on predicted difference. Tang et al. [6] proposed a robust images hashing based on DCT and DWT for copy detection. Kaur et al. [7] proposed a watermarking method using $(2, 2)$ visual cryptography with DWT-SVD. In watermarking scheme based on DWT and ranklets transform domain, Jan et al. [8] selected the mid-rank coefficients in low frequency sub-band of DWT for random number watermark embedding.

We in this paper propose a new method for embedding another photographic image in a photographic image. Our method uses the luminance information of the photographic images, and it is simpler than the conventional method [2, 3, 4, 6, 7, 8]. In addition, since

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our method can embed another photographic image of the same size as the photographic image, it can embed more information than the conventional method [5]. Our method prepares two photographic images (image A and image B) of the same size with 256 gradation and an even number of vertical and horizontal sizes, and embeds information of image B in image A. An image (image A') is generated by embedding information of image B, then an image (image B') is restored by extracting information from image A'. Image A' and image B' are the same size as image A and image B. It is difficult to visually recognize the difference between image A and image A', and image B and image B' are almost the same. Since it is impossible to perceive that image B is embedded in image A', our method can be used as a digital watermark. In addition, since image A and image B can be expressed only by image A', our method can be used as image compression. To verify the effectiveness of our method, we conducted experiments using various photographic images. In the experiments, we visually and quantitatively compared image A' and image B' with image A and image B. As a result of the experiments, we clarified that our method is effective for embedding image B in image A.

This paper is organized as follows: the second section describes our method for embedding another photographic image in the photographic image, the third section shows experimental results and reveals the effectiveness of our method, and the conclusion of this paper is given in the fourth section.

2. **Our Method.** As shown in Figure 1, our method generates image A' by embedding image B in image A, then image B' is restored from image A'. The sizes of image A, image B, image A' and image B' are the same with the even number of vertical and horizontal pixels. The pixel values of image A, image B, image A' and image B' have value of 256 gradation from 0 to 255. The pixel values for spatial coordinates (i, j) $(i = 1, 2, \ldots, I;$ $j = 1, 2, \ldots, J)$ of image A, image B, image A' and image B' are defined as $f_{A,i,j}$, $f_{B,i,j}$, $f_{A',i,j}$ and $f_{B',i,j}$, respectively. The method for embedding image B in image A and the method for restoring image B' from image A' are described below.

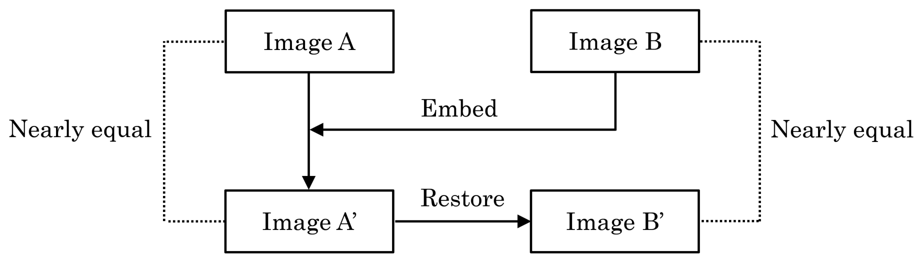


FIGURE 1. Conceptual diagram of our method

2.1. **Embedding method.** Let the binary representations of $f_{B,k,l}$ be $b_{B,1,k,l}$, $b_{B,2,k,l}$, $b_{B,3,k,l}$, $b_{B,4,k,l}$, $b_{B,5,k,l}$, $b_{B,6,k,l}$, $b_{B,7,k,l}$ and $b_{B,8,k,l}$, and the following relationship (Equation (1)) is established, where k and l are odd numbers.

$$f_{B,k,l} = 128b_{B,1,k,l} + 64b_{B,2,k,l} + 32b_{B,3,k,l} + 16b_{B,4,k,l} + 8b_{B,5,k,l} + 4b_{B,6,k,l} + 2b_{B,7,k,l} + b_{B,8,k,l} \quad (1)$$

Information is respectively embedded in $f_{A,k,l}$, $f_{A,k+1,l}$, $f_{A,k,l+1}$, and $f_{A,k+1,l+1}$ using the values $b_{B,1,k,l}$ and $b_{B,2,k,l}$, $b_{B,3,k,l}$ and $b_{B,4,k,l}$, $b_{B,5,k,l}$ and $b_{B,6,k,l}$, and $b_{B,7,k,l}$ and $b_{B,8,k,l}$, then $f_{A',k,l}$, $f_{A',k+1,l}$, $f_{A',k,l+1}$ and $f_{A',k+1,l+1}$ are generated. Since $f_{A',k,l}$, $f_{A',k+1,l}$, $f_{A',k,l+1}$ and $f_{A',k+1,l+1}$ are computed in the same procedure, only the case of $f_{A',k,l}$ is described below. The values $c_{A,k,l}$ with 0, 1, 2 and 3 are calculated from the pixel values $f_{A,k,l}$ by the following equation. The notation % represents a remainder operation.

$$c_{A,k,l} = f_{A,k,l} \% 4 \quad (2)$$

When $c_{A,k,l}$ is 0, $f_{A',k,l}$ must be calculated by the following equation. The notation $\wedge$ means that it is true only when both events are true.

$$f_{A',k,l} = \begin{cases} f_{A,k,l} & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 0) \\ f_{A,k,l} + 1 & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 1) \\ g_{A,k,l} & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 0) \\ f_{A,k,l} - 1 & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 1) \end{cases} \tag{3}$$

where

$$g_{A,k,l} = \begin{cases} f_{A,k,l} + 2 & (|f_{A,k,l} + 2 - a_{A,k,l}| \leq |f_{A,k,l} - 2 - a_{A,k,l}|) \\ f_{A,k,l} - 2 & (|f_{A,k,l} + 2 - a_{A,k,l}| > |f_{A,k,l} - 2 - a_{A,k,l}|) \end{cases} \tag{4}$$

$$a_{A,k,l} = \frac{\sum_{m=k-1}^{k+1} \sum_{n=l-1}^{l+1} f_{A,m,n}}{9} \tag{5}$$

where m and n are the positions of neighboring pixels. In case $f_{A',k,l}$ is smaller than 0, we must add 4 to $f_{A',k,l}$. In case $f_{A',k,l}$ is greater than 255, we must subtract 4 from $f_{A',k,l}$.

When $c_{A,k,l}$ is 1, $f_{A',k,l}$ must be calculated by the following equation.

$$f_{A',k,l} = \begin{cases} f_{A,k,l} - 1 & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 0) \\ f_{A,k,l} & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 1) \\ f_{A,k,l} + 1 & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 0) \\ g_{A,k,l} & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 1) \end{cases} \tag{6}$$

When $c_{A,k,l}$ is 2, $f_{A',k,l}$ must be calculated by the following equation.

$$f_{A',k,l} = \begin{cases} g_{A,k,l} & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 0) \\ f_{A,k,l} - 1 & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 1) \\ f_{A,k,l} & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 0) \\ f_{A,k,l} + 1 & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 1) \end{cases} \tag{7}$$

When $c_{A,k,l}$ is 3, $f_{A',k,l}$ must be calculated by the following equation.

$$f_{A',k,l} = \begin{cases} f_{A,k,l} + 1 & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 0) \\ g_{A,k,l} & (b_{B,1,k,l} = 0 \wedge b_{B,2,k,l} = 1) \\ f_{A,k,l} - 1 & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 0) \\ f_{A,k,l} & (b_{B,1,k,l} = 1 \wedge b_{B,2,k,l} = 1) \end{cases} \tag{8}$$

2.2. **Restoring method.** The pixel values $f_{B',k,l}$ for spatial coordinates (k, l) are restored by the following equation.

$$f_{B',k,l} = c_{A',k,l} + c_{A',k+1,l} + c_{A',k,l+1} + c_{A',k+1,l+1} \tag{9}$$

where

$$c_{A',k,l} = \begin{cases} 0 & (f_{A',k,l}\%4 = 0) \\ 64 & (f_{A',k,l}\%4 = 1) \\ 128 & (f_{A',k,l}\%4 = 2) \\ 194 & (f_{A',k,l}\%4 = 3) \end{cases} \tag{10}$$

$$c_{A',k+1,l} = \begin{cases} 0 & (f_{A',k+1,l}\%4 = 0) \\ 16 & (f_{A',k+1,l}\%4 = 1) \\ 32 & (f_{A',k+1,l}\%4 = 2) \\ 48 & (f_{A',k+1,l}\%4 = 3) \end{cases} \tag{11}$$

$$c_{A',k,l+1} = \begin{cases} 0 & (f_{A',k,l+1}\%4 = 0) \\ 4 & (f_{A',k,l+1}\%4 = 1) \\ 8 & (f_{A',k,l+1}\%4 = 2) \\ 12 & (f_{A',k,l+1}\%4 = 3) \end{cases} \tag{12}$$

$$c_{A',k+1,l+1} = \begin{cases} 0 & (f_{A',k+1,l+1}\%4 = 0) \\ 1 & (f_{A',k+1,l+1}\%4 = 1) \\ 2 & (f_{A',k+1,l+1}\%4 = 2) \\ 3 & (f_{A',k+1,l+1}\%4 = 3) \end{cases} \tag{13}$$

The pixel values $f_{B',k',l'}$ for spatial coordinates (k', l') other than (k, l) are restored by the following equation.

$$f_{B',k',l'} = \frac{\sum_{m'=k'-1}^{k'+1} \sum_{n'=l'-1}^{l'+1} f_{B',m',n'}}{M} \tag{14}$$

where m' and n' are the positions of neighboring pixels. Equation (14) is calculated using only the pixel values $f_{B',k,l}$ obtained in Equation (9), and M is the number of pixels used in the calculation of Equation (14).

3. **Experiments.** Experiments were conducted that ten photographic images in Figure 3 were each embedded in Lenna image in Figure 2. Lenna image corresponds to image A, and ten photographic images correspond to image B. The size of all photographic images was 256×256 pixels. Visual and quantitative evaluations were performed to verify the effectiveness of our method.

FIGURE 2. Lenna image (image A)

(a) Airplane

(b) Barbara

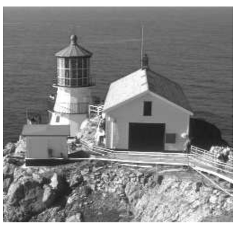
(c) Boat

(d) Bridge

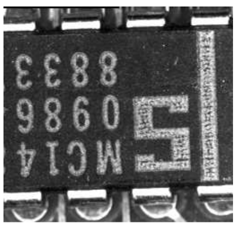
(e) Building

(f) Cameraman

(g) Girl



(h) Lighthouse



(i) Text

(j) Woman

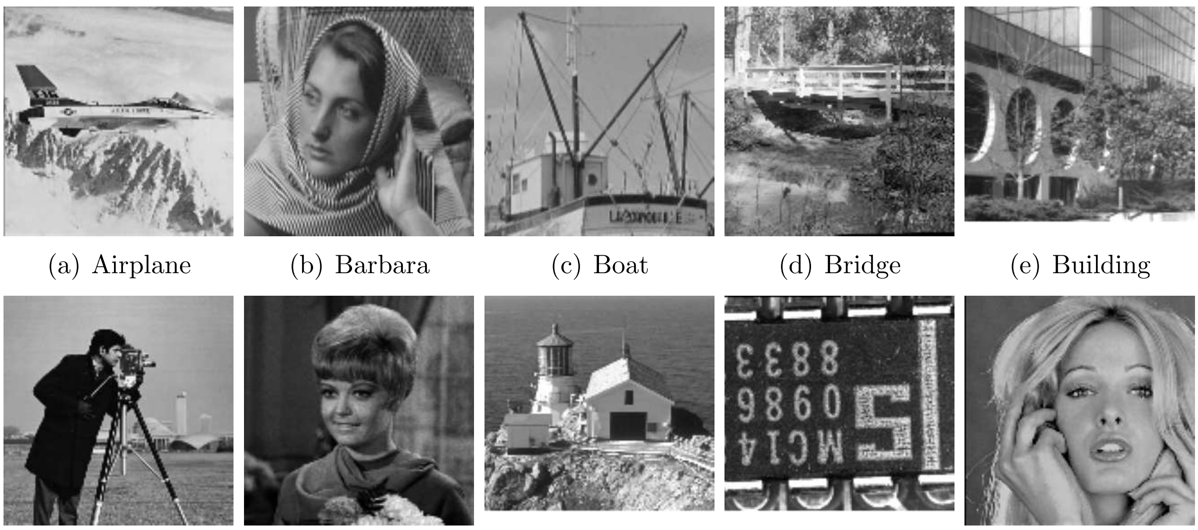
FIGURE 3. Various photographic images (image B)

3.1. **Visual evaluation.** Ten Lenna images embedded ten photographic images are shown in Figure 4, and ten photographic images restored from ten Lenna images in Figure 4 are shown in Figure 5. Ten Lenna images in Figure 4 correspond to image A', and ten photographic images in Figure 5 correspond to image B'. Comparing Figure 2 and Figure 4, no difference could be recognized. Thus, image A and image A' were the same when viewed by a person. Comparing Figure 3 and Figure 5, jaggies occurred at the edge areas in photographic images of Figure 5, but it was difficult to recognize the differences in the other areas. Thus, the contents in image B could be almost recognized from image B'. As long as the embedded images in literature [2, 3, 4, 6, 7, 8] were visually observed, our method could restore higher quality images.

(a) Airplane (b) Barbara (c) Boat (d) Bridge (e) Building

(f) Cameraman (g) Girl (h) Lighthouse (i) Text (j) Woman

FIGURE 4. Lenna images (image A') embedded ten photographic images in Figure 3



(a) Airplane (b) Barbara (c) Boat (d) Bridge (e) Building

(f) Cameraman (g) Girl (h) Lighthouse (i) Text (j) Woman

FIGURE 5. Various photographic images (image B') restored from Lenna images in Figure 4

3.2. **Quantitative evaluation.** Averages of absolute values of the differences between the pixel values of Lenna image in Figure 2 and ten Lenna images in Figure 4 are shown in Table 1. Hereinafter, the averages are referred to as difference averages. Difference averages between the pixel values of ten photographic images in Figure 3 and Figure 5 are shown in Table 2. The difference averages in Table 1 mean the difference between image A and image A', and the difference averages in Table 2 mean the difference between image B and image B'. Observing Table 1, all the difference averages were about 1.000. Thus, there were almost no difference in pixel values between image A and image A'. Observing Table 2, the difference averages were between 3.000 and 12.000, and the difference average was the largest in (d) Bridge image. The difference average of photographic image with finer textures was larger.

TABLE 1. Difference averages between Lenna image in Figure 2 and ten Lenna images in Figure 4 (image A and image A')

(a) Airplane	0.999
(b) Barbara	1.003
(c) Boat	1.002
(d) Bridge	1.001
(e) Building	1.001
(f) Cameraman	0.996
(g) Girl	1.004
(h) Lighthouse	0.999
(i) Text	1.001
(j) Woman	1.000

TABLE 2. Difference averages between ten photographic images in Figure 3 and Figure 5 (image B and image B')

(a) Airplane	5.388
(b) Barbara	7.893
(c) Boat	4.087
(d) Bridge	11.632
(e) Building	5.363
(f) Cameraman	5.356
(g) Girl	3.437
(h) Lighthouse	8.102
(i) Text	7.280
(j) Woman	4.257

4. **Conclusions.** We proposed a hight-quality method for embedding another photographic image in a photographic image using the luminance information of the photographic images. Our method prepared image A and image B of the same size with 256 gradation and an even number of vertical and horizontal sizes, and embedded information of image B in image A. Image A' was created by embedding image B in image A, then image B' was restored from image A'. By conducting visual and quantitative experiments with various photographic images, image A and image A' were nearly equal, and the contents in image B could be recognized from image B'.

A future task is to be able to apply our method to two photographic images of different sizes. In addition, it is a future task to extend our method so that a plurality of photographic images can be embedded.

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