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A METHOD TO REDUCE CHANGES IN PHOTOGRAPHIC IMAGES WITH EMBEDDED IMAGES

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Abstract. *We propose a new method for embedding another photographic image (image B) in a photographic image (image A). An image (image A') is generated by embedding information of image B in image A, and then an image (image B') is restored by extracting information from image A'. A method similar to our method has been proposed, but our method reduces changes between image A and image A' compared to the conventional method. The conventional method changed the pixel values of image A within plus or minus 2 and generated image A', but our method changes the pixel values of image A within plus or minus 1 and generates image A'. The performance improvement of our method is achieved by embedding the information of one pixel of image B in 3 ∗ 3 pixels of image A, while the conventional method embeds the information of one pixel of image B in 2 ∗ 2 pixels of image A. To verify the effectiveness of our method, experiments using various photographic images were performed.*
Keywords: Photographic image, Embedding, Digital watermark, High quality

1. **Introduction.** A technique called digital watermark for embedding information in images has been widely used [1, 2]. Digital watermark can embed information in images in a way that is almost imperceptible to humans, and is mainly used to protect copyrights and detect unauthorized copying. Studies that embed digital watermark in images can be broadly divided into methods that use luminance information of images [3, 4, 5] and frequency information [6, 7, 8]. Chen et al. [3] proposed a reversible high capacity information hiding method based on predicted difference, Huang [4] proposed a reversible visible watermarking technique for block-truncation-coding-compressed images, Hiraoka [5] proposed a method for embedding another photographic image in a photographic image using the luminance information of the photographic images, Fan et al. [6] proposed a histogram based non-blind watermarking scheme with high robustness, Hu et al. [7] proposed a method for directly hiding the pixel values of a small color watermark in a carrier color image, and Wang et al. [8] proposed a blind image watermarking method for color images based on 2D-DCT. We focus on the conventional method [5] in digital watermark that uses luminance information of images. The conventional method [5] is simpler than the conventional methods [3, 4, 6, 7, 8]. The conventional method [5] embeds another photographic image (image B) in a photographic image (image A). An image (image A') is generated by embedding information of image B in image A, and then an image (image B') is restored by extracting information from image A'. Images A and A' are similar, and images B and B' are similar. In order to make people unaware that image B is embedded

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in image A', the difference between images A and A' must be visually unrecognizable. The conventional method [5] changed the pixel values of image A within plus or minus 2, and then generated image A'.

We propose a new method to make the difference between images A and A' less recognizable than the conventional method [5]. Our method changes the pixel values of image A within plus or minus 1, and then generates image A'. The performance improvement of our method is achieved by embedding the information of one pixel of image B in $3*3$ pixels of image A, while the conventional method embeds the information of one pixel of image B in $2*2$ pixels of image A. To verify the effectiveness of our method, we conducted experiments comparing the performances of our method and the conventional method [5] using various photographic images. In the experiments, we quantitatively compared image A' with image A. The experimental results showed that our method has smaller changes between images A and A' than the conventional method [5].

This paper is organized as follows: the second section describes our method for embedding image B in image A and restoring image B' from image A', 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 Embedding and Restoring Methods.** Our method generates image A' by embedding image B in image A, and then image B' is restored from image A'. A conceptual diagram of our method is shown in Figure 1. The pixel values for spatial coordinates (i, j) $(i = 1, 2, 3, \ldots, I;\ j = 1, 2, 3, \ldots, J)$ of images A, B, A' and B' are defined as $f_{A,i,j}$, $f_{B,i,j}$, $f_{A',i,j}$ and $f_{B',i,j}$, respectively. Images A, B, A' and B' are the same size and have 256 gradations from 0 to 255. The methods for embedding image B in image A and restoring image B' from image A' are described below.

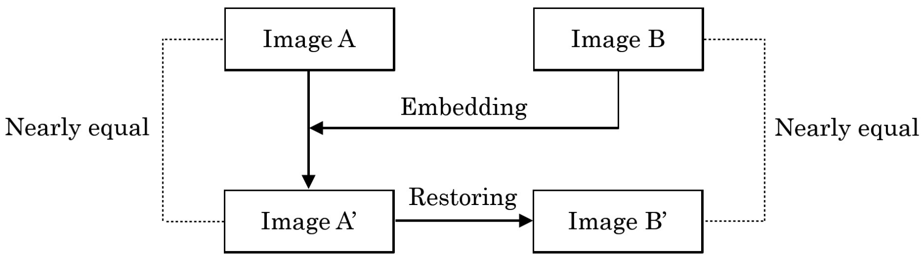


FIGURE 1. Conceptual diagram of our method

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 $(= 2, 5, 8, 11, \ldots)$ and l $(= 2, 5, 8, 11, \ldots)$ are the values of the tolerance sequence with first term 2 and tolerance 3.

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

Information is respectively embedded in $f_{A,k-1,l-1}$, $f_{A,k,l-1}$, $f_{A,k+1,l-1}$, $f_{A,k-1,l}$, $f_{A,k+1,l}$, $f_{A,k-1,l+1}$, $f_{A,k,l+1}$ and $f_{A,k+1,l+1}$ using the values $b_{B,1,k,l}$, $b_{B,2,k,l}$, $b_{B,3,k,l}$, $b_{B,4,k,l}$, $b_{B,5,k,l}$, $b_{B,6,k,l}$, $b_{B,7,k,l}$ and $b_{B,8,k,l}$, and then $f_{A',k-1,l-1}$, $f_{A',k,l-1}$, $f_{A',k+1,l-1}$, $f_{A',k-1,l}$, $f_{A',k+1,l}$, $f_{A',k-1,l+1}$, $f_{A',k,l+1}$ and $f_{A',k+1,l+1}$ are generated. Note that $f_{A',k,l}$ is the same value as $f_{A,k,l}$. Since $f_{A',k-1,l-1}$, $f_{A',k,l-1}$, $f_{A',k+1,l-1}$, $f_{A',k-1,l}$, $f_{A',k+1,l}$, $f_{A',k-1,l+1}$, $f_{A',k,l+1}$ and $f_{A',k+1,l+1}$ are calculated in the same procedure, only the case of $f_{A',k-1,l-1}$ is described below. The values $c_{A,k-1,l-1}$ with 0 or 1 are calculated from the pixel values $f_{A,k-1,l-1}$ by the following equation.

$$c_{A,k-1,l-1} = f_{A,k-1,l-1} \,\%\, 2 \quad (2)$$

where % represents a remainder operation.

When $c_{A,k-1,l-1}$ is 0, $f_{A',k-1,l-1}$ must be calculated by the following equations.

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

$$g_{A,k-1,l-1} = \begin{cases} f_{A,k-1,l-1} - 1 & (f_{A,k-1,l-1} \geq a_{A,k-1,l-1}) \\ f_{A,k-1,l-1} + 1 & (f_{A,k-1,l-1} < a_{A,k-1,l-1}) \end{cases} \tag{4}$$

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

where m and n are the relative positions from the target pixel. If $f_{A',k-1,l-1}$ is smaller than 0, we must add 2 to $f_{A',k-1,l-1}$. If $f_{A',k-1,l-1}$ is greater than 255, we must subtract 2 from $f_{A',k-1,l-1}$. Equation (5) computes the eight-neighbor average $a_{A,k-1,l-1}$ of the target pixel. Equation (4) subtracts 1 from the pixel value $f_{A,k-1,l-1}$ if the pixel value $f_{A,k-1,l-1}$ is equal to or greater than the eight-neighbor average $a_{A,k-1,l-1}$, and adds 1 to the pixel value $f_{A,k-1,l-1}$ if the pixel value $f_{A,k-1,l-1}$ is greater than the eight-neighbor average $a_{A,k-1,l-1}$.

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

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

When embedding image B in image A, our method changes the pixel values of image A within plus or minus 1, and then generates image A'. On the other hand, the conventional method [5] changes the pixel values of image A within plus or minus 2. Thus, the maximum of absolute values of the differences between images A and A' is 1 for our method and 2 for the conventional method [5].

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

$$\begin{aligned} f_{B',k,l} = {} & 128(f_{A,k-1,l-1} \,\%\, 2) + 64(f_{A,k,l-1} \,\%\, 2) + 32(f_{A,k+1,l-1} \,\%\, 2) + 16(f_{A,k-1,l} \,\%\, 2) \\ & + 8(f_{A,k,l+1} \,\%\, 2) + 4(f_{A,k-1,l+1} \,\%\, 2) + 2(f_{A,k,l+1} \,\%\, 2) + (f_{A,k+1,l+1} \,\%\, 2) \end{aligned} \tag{7}$$

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

$$f_{B',k',l'} = \frac{\sum_{m'=-2}^{2} \sum_{n'=-2}^{2} f_{B',k'+m',l'+n'} d_{m',n'}}{d_{m',n'}} \tag{8}$$

$$d_{m',n'} = \frac{1}{\sqrt{m'^2 + n'^2}} \tag{9}$$

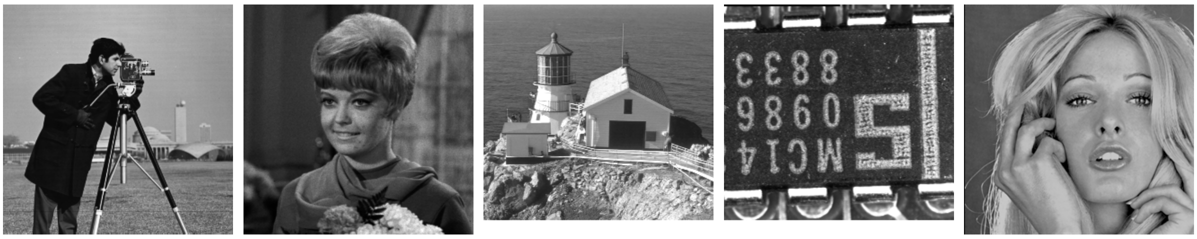
where m' and n' are the relative positions from the target pixel. Note that Equation (8) is calculated using only the pixel values $f_{B',k,l}$ obtained in Equation (7).

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

Averages of absolute values of the differences between the pixel values of image A and images A' embedded images B by our method are shown in Table 1. Hereinafter, the averages are referred to as difference averages. For comparison, the difference averages between image A and images A' of the conventional method [5] are also shown in Table 1. Table 1 shows that the difference averages of our method are about 0.4 and those of the conventional method [5] about 1.0, indicating that our method can improve the

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 (images B)

Table 1. Difference averages between image A and images A'

	Our method	Conventional method [5]
(a) Airplane	0.443	0.999
(b) Barbara	0.442	1.003
(c) Boat	0.443	1.002
(d) Bridge	0.442	1.001
(e) Building	0.442	1.001
(f) Cameraman	0.442	0.996
(g) Girl	0.440	1.004
(h) Lighthouse	0.439	0.999
(i) Text	0.442	1.001
(j) Woman	0.440	1.000

accuracy more than twice as much as the conventional method [5]. In actual research, the maximum absolute values of the differences between the pixel values of images A and A' were 1 in our method and 2 in the conventional method [5]. Thus, it could be concluded that our method was able to generate image A' by changing the pixel values of image A within a narrower range than the conventional method [5]. For reference, images A' of our method are shown in Figure 4. Comparing Figures 2 and 4, no difference could be recognized. Therefore, it is not known that images B are embedded in images A'.

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

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

Figure 4. Image A' of our method

The difference averages between image B and images B' restored from images A' by our method and the conventional method [5] are shown in Table 2, respectively. Additionally, images B' of our method are shown in Figure 5. Table 2 shows that the difference averages of our method are larger than those of the conventional method [5]. However, Figures 3 and 5 show that images B' are fully recognizable as same as images B, although images B' were disturbed at the edges.

Table 2. Difference averages between image B and images B'

	Our method	Conventional method [5]
(a) Airplane	8.265	5.388
(b) Barbara	12.717	7.893
(c) Boat	6.642	4.087
(d) Bridge	15.956	11.632
(e) Building	9.286	5.363
(f) Cameraman	8.191	5.356
(g) Girl	5.249	3.437
(h) Lighthouse	11.732	8.102
(i) Text	11.829	7.280
(j) Woman	6.861	4.257

4. **Conclusions.** We proposed a new method for embedding another photographic image (image B) in a photographic image (image A). An image (image A') was generated by embedding information of image B in image A, and then an image (image B') was restored by extracting information from image A'. Our method reduced changes in image A' compared to the conventional method [5]. To verify the effectiveness of our method, we conducted experiments comparing the performances of our method and the conventional method [5] using various photographic images. The experimental results showed that our method has smaller changes between image A and image A' than the conventional method [5].

(a) Airplane

(b) Barbara

(c) Boat

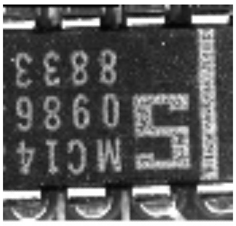
(d) Bridge

(e) Building

(f) Cameraman

(g) Girl

(h) Lighthouse



(i) Text

(j) Woman

Figure 5. Image B' of our method

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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