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IMPROVING THE ACCURACY OF EMBEDDING ANOTHER PHOTOGRAPHIC IMAGE IN A PHOTOGRAPHIC IMAGE

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Abstract. *A method for embedding another photographic image B in a photographic image A has been proposed by changing the pixel values of the photographic image A within plus or minus 2. In this paper, we propose a method for improving the accuracy of the error of the photographic image B' restored from the photographic image A' in the conventional method, where the photographic image A' is generated by embedding the photographic image B in the photographic image A. The proposed method is executed by changing the pixel value of the photographic image B as preprocessing for executing the conventional method. The preprocessing has two ideas: the first idea is to reduce the restoration error of the photographic image B' when applying the conventional interpolation, and the second idea is to increase the number of interpolation methods to two so that the interpolation method can be selected. To verify the effectiveness of the proposed method, experiments using various photographic images were performed.*

Keywords: Photographic image, Embedding, High quality, Change of pixel value, Interpolation

1. **Introduction.** A technique called "digital watermark" for embedding information in contents such as images, videos, and audio has been widely used [1]. Digital watermark is mainly used for copyright protection such as detecting illegal copy and falsification of data. This paper focuses on digital watermark of images. In recent years, it has become possible to take pictures from the camera mounted on smartphones and tablet terminals and easily upload the pictures to SNS (Social Networking Service) and websites, but there are many cases of fraudulent and secondary uses of the pictures. Therefore, many researches on digital watermark of images have been conducted [2-11]. Ahmad and Mirza [2] proposed an image adaptive perceptual shaping technique using genetic programming for creating robust and imperceptible watermark for any digital image. Chen [3] proposed a reversible image watermarking scheme based on the proposed block centering difference method and the absolute histogram modulation method. He et al. [4] proposed a robust digital watermarking algorithm based on DWT (Discrete Wavelet Transform), SVD (Singular Value Decomposition), and Arnold scrambling. Kaur et al. [5] proposed an algorithm for image watermark using visual cryptography that generates two shares with DWT and SVD. Jan et al. [6] proposed an algorithm based on DWT and RT (Ranklets Transform) domain in which the mid-rank coefficients in low frequency sub-band (LL3) of DWT are selected for random number watermark embedding. Fita and Endebu [7] proposed an algorithm for colored digital image watermarking technique based on SVD. Hsu and Tu [8] proposed a dual function watermarking scheme: one is copyright verification, and the other is tampering detection. Huang [9] proposed a reversible visible watermarking technique for BTC (Block Truncation Coding)-compressed images. Fan et al. [10] proposed

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a histogram based non-blind watermarking scheme with high robustness. Hiraoka [11] proposed a method for embedding another photographic image in a photographic image using the luminance information of the photographic images. This paper focuses on the conventional method [11]. The conventional method [11] is simpler than the conventional methods [2-10].

We in this paper propose a method for improving the accuracy of the error of image B' restored from image A' in the conventional method [11], where image A' is generated by embedding image B in image A. Strictly speaking, the proposed method creates image B1 by changing the pixel values of image B as preprocessing, and then embeds image B1 in image A. In the proposed method, an interpolation method of the pixel values for restoring image B' from image A' in the conventional method [11] can be selected from two methods. To verify the effectiveness of the proposed method, we conducted experiments comparing the performance of the proposed method and the conventional method [11] using various photographic images. The experimental results show that the proposed method has better accuracy of the restoration error of image B' than the conventional method [11].

This paper is organized as follows: the second section describes the proposed method for improving the accuracy of the error of image B', the third section shows experimental results and reveals the effectiveness of the proposed method, and the conclusion of this paper is given in the fourth section.

2. **Proposed Method.** As shown in Figure 1, the proposed method generates image A' by embedding image B1 in image A, and then image B' is restored from image A', where image B1 is created by converting image B. The proposed method incorporates the following two ideas into the conventional method [11].

Idea 1: The pixel values of image B are changed so that the restoration error of image B' is reduced.

Idea 2: An interpolation method for restoring image B' is selected from two interpolation methods. At this time, the method that the restoration error of each pixel of image B' is smaller is selected. The information of which the two interpolation methods are selected is embedded in image B1 by changing the pixel values of image B.

The method for changing image B to image B1 as the preprocessing, the method for embedding image B1 in image A, and the method for restoring image B' from image A' are described below. To make the proposed method easier to understand, the embedding

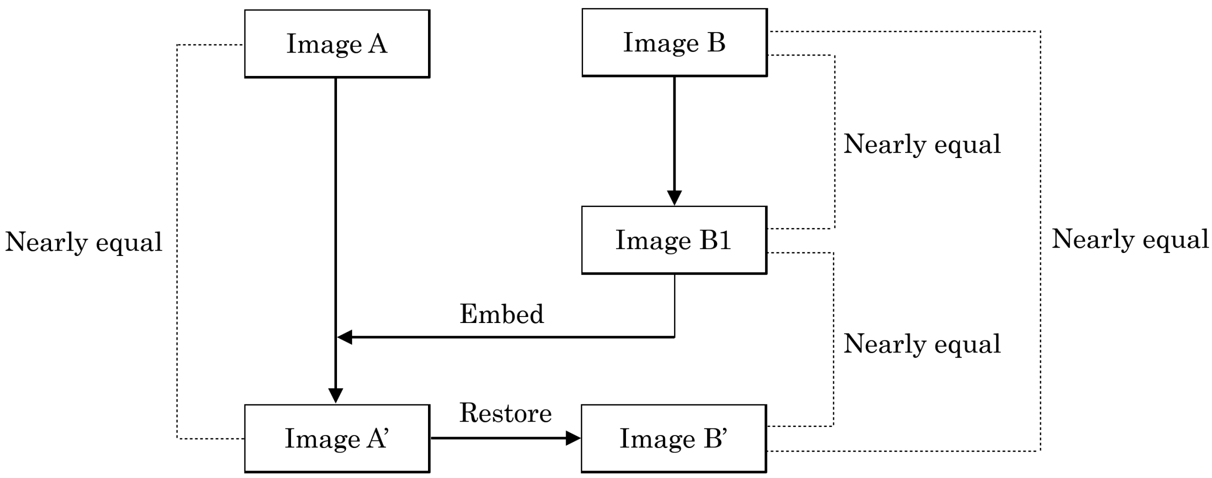


FIGURE 1. Conceptual diagram of the proposed method

method, the restoring method, and the preprocessing are described in this order. Hereinafter, the sizes of image A, image B, image B1, image A' and image B' are the same as the even number of vertical and horizontal pixels. The pixel values of image A, image B, image B1, image A' and image B' have value of 256 gradation from 0 to 255. The pixel values for spatial coordinates (i, j) $(i = 1, 2, \dots, I;\ j = 1, 2, \dots, J)$ of image A, image B, image B1, image A' and image B' are defined as $f_{A,i,j}$, $f_{B,i,j}$, $f_{B1,i,j}$, $f_{A',i,j}$ and $f_{B',i,j}$, respectively.

2.1. **Embedding method.** Let the binary representations of $f_{B1,k,l}$ be $b_{B1,1,k,l}$, $b_{B1,2,k,l}$, $b_{B1,3,k,l}$, $b_{B1,4,k,l}$, $b_{B1,5,k,l}$, $b_{B1,6,k,l}$, $b_{B1,7,k,l}$ and $b_{B1,8,k,l}$, and the following relationship (Equation (1)) is established, where k and l are odd numbers.

$$\begin{aligned} f_{B1,k,l} = {} & 128b_{B1,1,k,l} + 64b_{B1,2,k,l} + 32b_{B1,3,k,l} + 16b_{B1,4,k,l} \\ & + 8b_{B1,5,k,l} + 4b_{B1,6,k,l} + 2b_{B1,7,k,l} + b_{B1,8,k,l} \end{aligned} \tag{1}$$

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 $b_{B1,1,k,l}$ and $b_{B1,2,k,l}$, $b_{B1,3,k,l}$ and $b_{B1,4,k,l}$, $b_{B1,5,k,l}$ and $b_{B1,6,k,l}$, and $b_{B1,7,k,l}$ and $b_{B1,8,k,l}$, and 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.

$$c_{A,k,l} = f_{A,k,l} \% 4 \tag{2}$$

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.

$$f_{A',k,l} = \begin{cases} f_{A,k,l} & (b_{B1,1,k,l} = 0 \wedge b_{B1,2,k,l} = 0) \\ f_{A,k,l} + 1 & (b_{B1,1,k,l} = 0 \wedge b_{B1,2,k,l} = 1) \\ g_{A,k,l} & (b_{B1,1,k,l} = 1 \wedge b_{B1,2,k,l} = 0) \\ f_{A,k,l} - 1 & (b_{B1,1,k,l} = 1 \wedge b_{B1,2,k,l} = 1) \end{cases} \tag{3}$$

where

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

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

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.

$$f_{A',k,l} = \begin{cases} f_{A,k,l} - 1 & (b_{B1,1,k,l} = 0 \wedge b_{B1,2,k,l} = 0) \\ f_{A,k,l} & (b_{B1,1,k,l} = 0 \wedge b_{B1,2,k,l} = 1) \\ f_{A,k,l} + 1 & (b_{B1,1,k,l} = 1 \wedge b_{B1,2,k,l} = 0) \\ g_{A,k,l} & (b_{B1,1,k,l} = 1 \wedge b_{B1,2,k,l} = 1) \end{cases} \tag{6}$$

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

$$f_{A',k,l} = \begin{cases} g_{A,k,l} & (b_{B1,1,k,l} = 0 \wedge b_{B1,2,k,l} = 0) \\ f_{A,k,l} - 1 & (b_{B1,1,k,l} = 0 \wedge b_{B1,2,k,l} = 1) \\ f_{A,k,l} & (b_{B1,1,k,l} = 1 \wedge b_{B1,2,k,l} = 0) \\ f_{A,k,l} + 1 & (b_{B1,1,k,l} = 1 \wedge b_{B1,2,k,l} = 1) \end{cases} \tag{7}$$

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

$$f_{A',k,l} = \begin{cases} f_{A,k,l}+1 & (b_{B1,1,k,l}=0 \wedge b_{B1,2,k,l}=0) \\ g_{A,k,l} & (b_{B1,1,k,l}=0 \wedge b_{B1,2,k,l}=1) \\ f_{A,k,l}-1 & (b_{B1,1,k,l}=1 \wedge b_{B1,2,k,l}=0) \\ f_{A,k,l} & (b_{B1,1,k,l}=1 \wedge b_{B1,2,k,l}=1) \end{cases} \tag{8}$$

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

$$c_{A',k,l} = \begin{cases} 0 & (f_{A',k,l}\,\%\,4=0) \\ 64 & (f_{A',k,l}\,\%\,4=1) \\ 128 & (f_{A',k,l}\,\%\,4=2) \\ 192 & (f_{A',k,l}\,\%\,4=3) \end{cases} \tag{10}$$

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

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

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

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

$$f_{B',k',l'} = \begin{cases} f_{B',k'',l''} & (\text{Case 1: } f_{B',k'',l''}\,\%\,2=0) \\ \frac{\sum_{m'=k'-1}^{k'+1}\sum_{n'=l'-1}^{l'+1} f_{B',m',n'}}{M} & (\text{Case 2: } f_{B',k'',l''}\,\%\,2=1) \end{cases} \tag{14}$$

where

$$k'' = \begin{cases} k'-1 & (k'\,\%\,2=0) \\ k' & (k'\,\%\,2=1) \end{cases} \tag{15}$$

$$l'' = \begin{cases} l'-1 & (l'\,\%\,2=0) \\ l' & (l'\,\%\,2=1) \end{cases} \tag{16}$$

and 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).

2.3. **Preprocessing.** Idea 1 and Idea 2 in the preprocessing are described in detail below. In the proposed method, the processing of Idea 2 is performed after the processing of Idea 1. Although the restoration error of image B' can be reduced by using only Idea 1 or Idea 2, the restoration error can be reduced by using both ideas as compared with the case of using individual ideas.

2.3.1. *Idea 1.* When one of i and j is an even number in the spatial coordinates (i,j), the pixel values $f_{B1,i,j}$ are set to the pixel values $f_{B,i,j}$. When both i and j are odd numbers in the spatial coordinates (i,j), the pixel values $f_{B1,i,j}$ are set to the values $f'_{B1,i,j}$ that minimize the following equation. Let i and j when both are the odd numbers be k and l ($k = 1, 3, \ldots, I-1$; $l = 1, 3, \ldots, J-1$). The notation $\wedge$ means that it is true only when both events are true, and the notation $\vee$ means that it is true that either event is true.

$$\min_{f'_{B1,k,l}} \sum_{i=1}^{I} \sum_{j=1}^{J} \left| f''_{B1,i,j} - f_{B,i,j} \right| \tag{17}$$

where

$$f''_{B1,i,j} = f'_{B1,i,j} \qquad (i \text{ is odd } \wedge j \text{ is odd}) \tag{18}$$

$$f''_{B1,i,j} = f_{B1',i',j'} \qquad (i \text{ is even } \vee j \text{ is even}) \tag{19}$$

and $f'_{B1',i',j'}$ are values interpolated by Case 2 of Equation (14).

Although the optimal solution cannot be obtained for the solution of Equation (17), it is solved as follows. Let the pixel values of the image B1 at the t-th iteration number be $f^{(t)}_{B1,i,j}$, where $f^{(t)}_{B1,i,j}$ have value of 256 gradation from 0 to 255 and $f^{(0)}_{B1,i,j} = f_{B,i,j}$. In spatial coordinates (k,l), while changing each pixel value $f^{(t)}_{B1,k,l}$ to $f^{(t)}_{B1,k,l} - 1$, $f^{(t)}_{B1,k,l}$ and $f^{(t)}_{B1,k,l} + 1$, the case that the sum of the absolute values of difference between the value obtained by interpolating the peripheral coordinates by Case 2 of Equation (14) and $f_{B,m',n'}$ and the absolute values of difference between $f^{(t)}_{B1,k,l}$ after the change and $f^{(t)}_{B,k,l}$ is minimum is selected, and then $f^{(t)}_{B1,k,l}$ are updated in the selected case. All pixel values $f^{(t)}_{B1,k,l}$ are updated to $f^{(t+1)}_{B1,k,l}$. This processing is repeated T times.

2.3.2. *Idea 2.* Let the pixel values $f^{(T)}_{B1,k,l}$ be $f_{B1,k,l}$. The following processing is performed on the pixel value $f_{B1,k,l}$ of each spatial coordinate (k,l). The values interpolated by Case 1 of Equation (14) at the spatial coordinates $(k+1,l)$, $(k,l+1)$ and $(k+1,l+1)$ are $f_{B1,1,k+1,l}$, $f_{B1,1,k,l+1}$ and $f_{B1,1,k+1,l+1}$, respectively. After adding 1 to $f_{B1,k,l}$, the values interpolated by Case 1 of Equation (14) at the spatial coordinates $(k+1,l)$, $(k,l+1)$ and $(k+1,l+1)$ are $f_{B1,1,1,k+1,l}$, $f_{B1,1,1,k,l+1}$ and $f_{B1,1,1,k+1,l+1}$, respectively. After subtracting 1 from $f_{B1,k,l}$, the values interpolated by Case 1 of Equation (14) at the spatial coordinates $(k+1,l)$, $(k,l+1)$ and $(k+1,l+1)$ are $f_{B1,1,2,k+1,l}$, $f_{B1,1,2,k,l+1}$ and $f_{B1,1,2,k+1,l+1}$, respectively. The values interpolated by Case 2 of Equation (14) at the spatial coordinates $(k+1,l)$, $(k,l+1)$ and $(k+1,l+1)$ are $f_{B1,2,k+1,l}$, $f_{B1,2,k,l+1}$ and $f_{B1,2,k+1,l+1}$, respectively. After adding 1 to $f_{B1,k,l}$, the values interpolated by Case 2 of Equation (14) at the spatial coordinates $(k+1,l)$, $(k,l+1)$ and $(k+1,l+1)$ are $f_{B1,2,1,k+1,l}$, $f_{B1,2,1,k,l+1}$ and $f_{B1,2,1,k+1,l+1}$, respectively. After subtracting 1 from $f_{B1,k,l}$, the values interpolated by Case 2 of Equation (14) at the spatial coordinates $(k+1,l)$, $(k,l+1)$ and $(k+1,l+1)$ are $f_{B1,2,2,k+1,l}$, $f_{B1,2,2,k,l+1}$ and $f_{B1,2,2,k+1,l+1}$, respectively. The values $D_{B1,1,k,l}$, $D_{B1,1,1,k,l}$, $D_{B1,1,2,k,l}$, $D_{B1,2,k,l}$, $D_{B1,2,1,k,l}$ and $D_{B1,2,2,k,l}$ are obtained by the following equations.

$$D_{B1,1,k,l} = \left| f_{B1,1,k+1,l} - f_{B,k+1,l} \right| + \left| f_{B1,1,k,l+1} - f_{B,k,l+1} \right| + \left| f_{B1,1,k+1,l+1} - f_{B,k+1,l+1} \right| \tag{20}$$

$$\begin{aligned} D_{B1,1,1,k,l} = {} & 1 + \left| f_{B1,1,1,k+1,l} - f_{B,k+1,l} \right| + \left| f_{B1,1,1,k,l+1} - f_{B,k,l+1} \right| \\ & + \left| f_{B1,1,1,k+1,l+1} - f_{B,k+1,l+1} \right| \end{aligned} \tag{21}$$

$$\begin{aligned} D_{B1,1,2,k,l} = {} & 1 + \left| f_{B1,1,2,k+1,l} - f_{B,k+1,l} \right| + \left| f_{B1,1,2,k,l+1} - f_{B,k,l+1} \right| \\ & + \left| f_{B1,1,2,k+1,l+1} - f_{B,k+1,l+1} \right| \end{aligned} \tag{22}$$

$$\begin{aligned} D_{B1,2,k,l} = {} & \left| f_{B1,2,k+1,l} - f_{B,k+1,l} \right| + \left| f_{B1,2,k,l+1} - f_{B,k,l+1} \right| \\ & + \left| f_{B1,2,k+1,l+1} - f_{B,k+1,l+1} \right| \end{aligned} \tag{23}$$

$$
\begin{aligned}
D_{B1,2,1,k,l} = 1 &+ |f_{B1,2,1,k+1,l} - f_{B,k+1,l}| + |f_{B1,2,1,k,l+1} - f_{B,k,l+1}| \\
&+ |f_{B1,2,1,k+1,l+1} - f_{B,k+1,l+1}|
\end{aligned} \tag{24}
$$

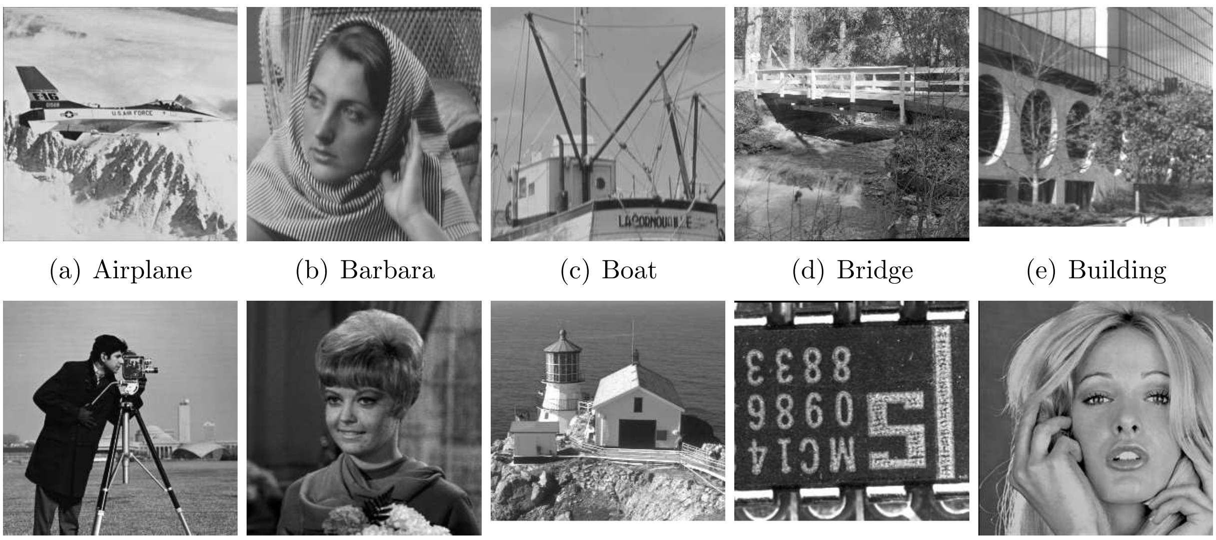
$$
\begin{aligned}
D_{B1,2,2,k,l} = 1 &+ |f_{B1,2,2,k+1,l} - f_{B,k+1,l}| + |f_{B1,2,2,k,l+1} - f_{B,k,l+1}| \\
&+ |f_{B1,2,2,k+1,l+1} - f_{B,k+1,l+1}|
\end{aligned} \tag{25}
$$

The pixel values $f_{B1,k,l}$ are updated by the following equation.

$$
f_{B1,k,l} = \begin{cases}
f_{B1,k,l} & (f_{B1,k,l} \% 2 = 0 \wedge D_{B1,1,k,l} \text{ is the smallest of } D_{B1,1,k,l}, \\
& D_{B1,1,1,k,l} \text{ and } D_{B1,1,2,k,l}) \\
f_{B1,k,l} + 1 & (f_{B1,k,l} \% 2 = 0 \wedge D_{B1,1,1,k,l} \text{ is the smallest of } D_{B1,1,k,l}, \\
& D_{B1,1,1,k,l} \text{ and } D_{B1,1,2,k,l}) \\
f_{B1,k,l} - 1 & (f_{B1,k,l} \% 2 = 0 \wedge D_{B1,1,2,k,l} \text{ is the smallest of } D_{B1,1,k,l}, \\
& D_{B1,1,1,k,l} \text{ and } D_{B1,1,2,k,l}) \\
f_{B1,k,l} & (f_{B1,k,l} \% 2 = 1 \wedge D_{B1,2,k,l} \text{ is the smallest of } D_{B1,2,k,l}, \\
& D_{B1,2,1,k,l} \text{ and } D_{B1,2,2,k,l}) \\
f_{B1,k,l} + 1 & (f_{B1,k,l} \% 2 = 1 \wedge D_{B1,2,1,k,l} \text{ is the smallest of } D_{B1,2,k,l}, \\
& D_{B1,2,1,k,l} \text{ and } D_{B1,2,2,k,l}) \\
f_{B1,k,l} - 1 & (f_{B1,k,l} \% 2 = 1 \wedge D_{B1,2,2,k,l} \text{ is the smallest of } D_{B1,2,k,l}, \\
& D_{B1,2,1,k,l} \text{ and } D_{B1,2,2,k,l})
\end{cases} \tag{26}
$$

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

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)

was $256 * 256$ pixels. In all cases, the pixel value $f_{B1,k,l}$ converged when the iteration number T of the Idea 1 was within 100. Therefore, the iteration number T was set to 100 in the following experiment.

Averages of absolute values of the differences between the pixel values $f_{A,i,j}$ and $f_{A',i,j}$ are shown in Table 1. Hereinafter, the averages are referred to as difference averages. The difference averages in Table 1 mean the difference between image A and image A'. Table 1 shows the results of the conventional method [11], the method using only Idea 1, the method using only Idea 2, and the method using Idea 1 and Idea 2. Observing Table 1, all the difference averages of all methods were about 1.000. Thus, there was almost no difference in pixel values between image A and image A', and there was no difference between the proposed method and the conventional method [11].

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

	Conventional method [11]	Idea 1	Idea 2	Idea 1 + Idea 2
(a) Airplane	0.999	1.000	0.999	1.001
(b) Barbara	1.003	1.001	1.005	1.004
(c) Boat	1.002	1.002	1.002	1.001
(d) Bridge	1.001	1.000	1.001	0.999
(e) Building	1.001	1.000	1.002	1.002
(f) Cameraman	0.996	0.996	0.999	0.998
(g) Girl	1.004	1.005	1.004	1.005
(h) Lighthouse	0.999	1.000	0.998	1.001
(i) Text	1.001	1.001	1.000	1.001
(j) Woman	1.000	1.001	0.999	1.001

The difference values between the pixel values $f_{B,k,l}$ and $f_{B',k,l}$ are shown in Table 2. The difference averages in Table 2 mean the difference between image B and image B'. Table 2 shows the results of the conventional method [11], the method using only Idea 1, the method using only Idea 2, and the method using Idea 1 and Idea 2. Observing Table 2, the difference averages were smaller in the order of the method using Idea 1 and Idea 2, the method using only Idea 2, the method using only Idea 1, and the conventional method [11]. The proposed method could restore the embedded photographic images with higher accuracy than the conventional method [11]. Using the two ideas at the same time rather than using them alone could restore the embedded photographic images with high accuracy.

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

	Conventional method [11]	Idea 1	Idea 2	Idea 1 + Idea 2
(a) Airplane	5.388	5.042	4.737	4.594
(b) Barbara	7.893	7.680	7.229	7.127
(c) Boat	4.087	3.898	3.499	3.423
(d) Bridge	11.632	10.715	10.149	9.702
(e) Building	5.363	5.137	4.598	4.530
(f) Cameraman	5.356	5.070	4.476	4.380
(g) Girl	3.437	3.180	3.107	3.000
(h) Lighthouse	8.102	7.632	6.920	6.727
(i) Text	7.280	6.882	6.095	5.943
(j) Woman	4.257	4.076	3.856	3.787

4. **Conclusions.** We proposed a method for improving the accuracy of the error of image B' restored from image A' in the conventional method [11], where image A' was generated by embedding image B in image A. Strictly speaking, the proposed method created image B1 by changing the pixel values of image B as preprocessing, and then embedded image B1 in image A. The proposed method used two ideas when converting image B to image B1. The first idea was to reduce the restoration error of the photographic image B' when applying the conventional interpolation. The second idea was to increase the number of interpolation methods to two so that the interpolation method can be selected. To verify the effectiveness of the proposed method, we conducted experiments comparing the performance of the proposed method and the conventional method [11] using various photographic images. The experimental results show that the proposed method can have better accuracy of the restoration error of image B' than the conventional method [11].

A future task is to be able to apply the proposed method to two photographic images of different sizes. In addition, it is a future task to extend the proposed method so that it can be applied to color photographic images and videos.

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