A Method for Embedding Multiple Photographic Images in a Photographic Image

Naoki Kouno
Department of Information Systems, University of Nagasaki, Japan

Kanya Goto
Graduate School of Regional Design and Creation, University of Nagasaki, Japan

Toru Hiraoka
Department of Information Systems, University of Nagasaki, Japan
E-mail: hiraoka@sun.ac.jp

Abstract

A method has been proposed 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'. The conventional methods can only embed one photographic image in one photographic image. Therefore, we extend the conventional method and propose a method for embedding multiple photographic images in one photographic image. In our method, as more images B are embedding in image A, the image quality of image A' deteriorates, but the image quality of images B' dose not deteriorate. To verify the effectiveness of our method, experiments using various photographic images were performed. As a result of the experiments, the relationship between the number of images B and the image quality of image A' was clarified.

Keywords: Multiple photographic images, Embedding, Restoring, Digital watermark

1. Introduction

Digital watermarking [1] methods have been proposed that uses two photographic images of the same size with 256 gradations and embed another photographic image in one of the photographic images [2], [3]. The conventional methods [2], [3] embed one photographic image (image B) in one 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. To make people unaware that image B is embedded in image A', the difference between images A and A' must be visually unrecognizable. In the conventional method [2], each pixel value of pixels in image B whose horizontal and vertical positions are odd numbers is embedded in 4 pixels in image A. At that time, the pixel values in image A are changed within ± 2, and then image A' is generated. In the conventional method [3], each pixel value of pixels in image B whose horizontal and vertical positions are the values of the tolerance sequence with first term 2 and tolerance 3 is embedded in 8 pixels in image A. At that time, the pixel values in image A are changed within ± 1, and then image A' is generated. It is known through experiments that the conventional method [3] reduces the difference between images A and A' about 60% compared to the conventional method [2]. On the other hand, the conventional method [3] is known to have a larger difference between images B and B' than the conventional method [2]. In the conventional methods [2], [3], it is important not to be aware that image B is embedded in image A', so we focus on the conventional method [3].

Since the conventional method [3] can only embed one photographic image in one photographic image, we extend the conventional method [3] and propose a method for embedding multiple photographic images in one photographic image. In our method, as more images B are embedding in image A, the image quality of image A' deteriorates, but the image quality of images B' dose not deteriorate. To verify the effectiveness of our method, experiments using various photographic images were performed. As a result of the experiments, the relationship between the number of images B and the image quality of image A' was clarified.

2. Our Method

Our method generates image A' by embedding images B_o $(o = 1,2,\cdots,O)$ in image A, where O is the number of images B_o to be embedded in image A, and then images $\mathrm{B'}_o$ are restored from image A'. A conceptual diagram of our method is shown in Fig. 1. The pixel values for spatial coordinates (i,j) $(i = 1,2,\cdots,I; j = 1,2,\cdots,J)$ of images A, B, A' and B' are defined as $f_{\mathrm{A},i,j}$, $f_{\mathrm{B}_o,i,j}$, $f_{\mathrm{A'},i,j}$ and $f_{\mathrm{B'}_o,i,j}$, respectively. Images A, B_o, A' and $\mathrm{B'}_o$ are the same size and have 256 gradations from 0 to 255. The methods for embedding images B_o in image A and restoring images $\mathrm{B'}_o$ from image A' are described below.

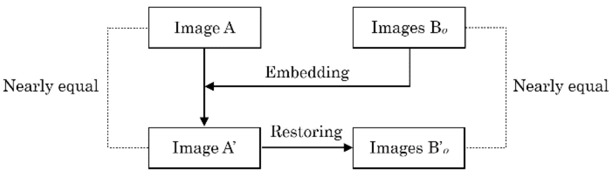

Fig. 1. Conceptual diagram of our method

2.1. *Embedding method*

Let the binary representations of $f_{\mathrm{B}_o,k,l}$ be $b_{\mathrm{B}_o,p,k,l}$ ($p = 1,2,\cdots,8$), and the following relationship (Eq. (1)) is established, where k ($= 2,5,8,\cdots$) and l ($= 2,5,8,\cdots$) are the values of the tolerance sequence with first term 2 and tolerance 3.

$$f_{\mathrm{B}_o,k,l} = \sum_{p=1}^{8} 2^{8-p}\, b_{\mathrm{B}_o,p,k,l} \quad (1)$$

Information is respectively embedded in $f_{\mathrm{A},k-1,l-1}$, $f_{\mathrm{A},k,l-1}$, $f_{\mathrm{A},k+1,l-1}$, $f_{\mathrm{A},k-1,l}$, $f_{\mathrm{A},k+1,l}$, $f_{\mathrm{A},k-1,l+1}$, $f_{\mathrm{A},k,l+1}$ and $f_{\mathrm{A},k+1,l+1}$ using the values $b_{\mathrm{B}_o,1,k,l}$, $b_{\mathrm{B}_o,2,k,l}$, $b_{\mathrm{B}_o,3,k,l}$, $b_{\mathrm{B}_o,4,k,l}$, $b_{\mathrm{B}_o,5,k,l}$, $b_{\mathrm{B}_o,6,k,l}$, $b_{\mathrm{B}_o,7,k,l}$ and $b_{\mathrm{B}_o,8,k,l}$, and then $f_{\mathrm{A'},k-1,l-1}$, $f_{\mathrm{A'},k,l-1}$, $f_{\mathrm{A'},k+1,l-1}$, $f_{\mathrm{A'},k-1,l}$, $f_{\mathrm{A'},k+1,l}$, $f_{\mathrm{A'},k-1,l+1}$, $f_{\mathrm{A'},k,l+1}$ and $f_{\mathrm{A'},k+1,l+1}$ are generated. Note that $f_{\mathrm{A'},k,l}$ is the same value as $f_{\mathrm{A},k,l}$. Since $f_{\mathrm{A'},k-1,l-1}$, $f_{\mathrm{A'},k,l-1}$, $f_{\mathrm{A'},k+1,l-1}$, $f_{\mathrm{A'},k-1,l}$, $f_{\mathrm{A'},k+1,l}$, $f_{\mathrm{A'},k-1,l+1}$, $f_{\mathrm{A'},k,l+1}$ and $f_{\mathrm{A'},k+1,l+1}$ are calculated in the same procedure, only the case of $f_{\mathrm{A'},k-1,l-1}$ is described below. The values $c_{\mathrm{A},k-1,l-1}$, which are integers greater than or equal to 0 and less than 2^O, are calculated from the pixel values $f_{\mathrm{A},k-1,l-1}$ by the following Eq. (2).

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

where % represents a remainder operation. The values $c_{\mathrm{B},k-1,l-1}$, which are integers greater than or equal to 0 and less than 2^O, are calculated from the values $b_{\mathrm{B}_o,1,k,l}$ by the following Eq. (3).

$$c_{\mathrm{B},k-1,l-1} = \sum_{o=1}^{O} 2^{O-o}\, b_{\mathrm{B}_o,1,k,l} \quad (3)$$

The values $f_{\mathrm{A'},k-1,l-1}$ are calculated by the following Eq. (4).

$$f_{\mathrm{A'},k-1,l-1} = f_{\mathrm{A},k-1,l-1} - c_{\mathrm{A},k-1,l-1} + c_{\mathrm{B},k-1,l-1} \quad (4)$$

If $f_{\mathrm{A'},k-1,l-1}$ is smaller than 0, we must add 2^O to $f_{\mathrm{A'},k-1,l-1}$. If $f_{\mathrm{A'},k-1,l-1}$ is greater than 255, we must subtract 2^O from $f_{\mathrm{A'},k-1,l-1}$.

When embedding images B_o in image A, our method changes the pixel values of image A within plus or minus $2^O - 1$, and then generates image A'. As more images B_o are embedding in image A, the image quality of image A' deteriorates.

2.2. *Restoring method*

Let the binary representations of $f_{\mathrm{A'},i,j}\%2^O$ be $b_{\mathrm{A'},o,i,j}$, and the following relationship (Eq. (5)) is established.

$$f_{\mathrm{A'},i,j}\%2^O = \sum_{o=1}^{O} 2^{O-o}\, b_{\mathrm{A'},o,i,j} \quad (5)$$

The pixel values $f_{\mathrm{B'}_o,k,l}$ for spatial coordinates (k,l) are restored by the following Eq. (6).

$$f_{\mathrm{B'}_o,k,l} = 128 b_{\mathrm{A'},o,k-1,l-1} + 64 b_{\mathrm{A'},o,k,l-1} + 32 b_{\mathrm{A'},o,k+1,l-1} + 16 b_{\mathrm{A'},o,k-1,l} + 8 b_{\mathrm{A'},o,k+1,l} + 4 b_{\mathrm{A'},o,k-1,l+1} + 2 b_{\mathrm{A'},o,k,l+1} + b_{\mathrm{A'},o,k+1,l+1} \quad (6)$$

The pixel values $f_{\mathrm{B'}_o,k',l'}$ for spatial coordinates (k',l') other than (k,l) are restored by the following Eq. (7) and Eq. (8).

$$f_{\mathrm{B'}_o,k',l'} = \frac{\sum_{m=-2}^{2}\sum_{n=-2}^{2} f_{\mathrm{B'}_o,k'+m,l'+n}\, d_{m,n}}{d_{m,n}} \quad (7)$$

$$d_{m,n} = \frac{1}{\sqrt{m^2+n^2}} \quad (8)$$

where m and n are the relative positions from the target pixel. Note that Eq. (7) is calculated using only the pixel values $f_{\mathrm{B'}_o,k,l}$ obtained in Eq. (6).

3. Experiments

In this experiment, Lena image shown in Fig. 2 was used as image A, and 4 photographic images shown in Fig. 3 were used as images B_o. The size of all image A and images B_o was 256 * 256 pixels. Visual and quantitative evaluations were performed to verify the effectiveness of our method.

Fig. 2. Lena image (image A)

(a) Airplane (b) Barbara (c) Boat (d)Cameraman

Fig. 3. Various photographic images (images B_o)

3.1. *Evaluation of embedded images*

Averages of absolute values of the differences between the pixel values of image A and images A' were calculated. Hereinafter, the averages are referred to as difference averages. The difference averages for 4 cases of embedding one image B_o are shown in Table 1. The difference averages for 6 cases of embedding 2 images B_o are shown in Table 2. For example, "(a)+(b)" in Table 1 means that 2 images B_o (a) and (b) of Fig. 3 are embedded. The difference averages for 4 cases of embedding 3 images B_o are shown in Table 3. The difference average for one case of embedding 4 images B_o is shown in Table 4. From Table 1 to 4, it was found that the larger the number of images B_o to be embedded in image A, the larger the difference averFiage.

Table 1. Difference averages between image A and images A' for 4 cases of embedding one image B_o

Symbols of images B_o	Difference averages
(a)	0.443
(b)	0.442
(c)	0.443
(d)	0.442

Table 2. Difference averages between image A and images A' for 6 cases of embedding 2 images B_o

Symbols of images B_o	Difference averages
(a) + (b)	1.093
(a) + (c)	1.100
(a) + (d)	1.092
(b) + (c)	1.099
(b) + (d)	1.096
(c) + (d)	1.127

Table 3. Difference averages between image A and images A' for 4 cases of embedding 3 images B_o

Symbols of images B_o	Difference averages
(a) + (b) + (c)	2.302
(a) + (b) + (d)	2.291
(a) + (c) + (d)	2.320
(b) + (c) + (d)	2.316

Table 4. Difference averages between image A and images A' for one case of embedding 4 images B_o

Symbols of images B_o	Difference averages
(a) + (b) + (c) + (d)	4.711

Next, the differences between image A and images A' were visually evaluated. Images A' for 4 cases of embedding one image B_o are shown in Fig. 4, Images A' for 6 cases of embedding 2 images B_o are shown in Fig. 5. Images A' for 4 cases of embedding 3 images B_o are shown in Fig. 6. Image A' for one case of embedding 4 images B_o is shown in Fig. 7. From Fig. 2 and 4 to 7, it was found that images A', in which one and 2 images B_o were embedded, were visually unrecognizable as different from image A. It was also found that images A', in which one or 3 images B_o were embedded, were slightly recognizable as different from image A, and image A', in which one or 4 images B_o were embedded, were clearly recognizable as different from image A.

(a) (b) (c) (d)

Fig. 4. Images A' for 4 cases of embedding one image B_o

(a) + (b) (a) + (c) (a) + (d) (b) + (c)

(b) + (d) (c) + (d)

Fig. 5. Images A' for 6 cases of embedding 2 images B_o

(a) + (b) + (c) (a) + (b) + (d) (a) + (c) + (d) (b) + (c) + (d)

Fig. 6. Images A' for 4 cases of embedding 3 images B_o

(a) + (b) + (c) + (d)

Fig. 7. Images A' for one case of embedding 4 images B_o

3.2. *Evaluation of restored images*

Difference averages between images B_o and images B'_o restored from images A' were calculated. The difference averages in this case are the same value no matter how many images B_o are embedded. The difference averages are shown in Table 5. Additionally, images B'_o are shown in Fig. 8. Images B'_o do not change no matter how many images B_o are embedded. From Table 5, it was found that the difference averages were somewhat larger, ranging from 6 to 13 values. However, from Fig. 3 and 8, it was found that images B'_o are fully recognizable as same as images B_o, although images B'_o were disturbed at the edges.

Table 5. Difference averages between images B_o and images B'_o

Symbols of images B_o	Difference averages
(a)	8.265
(b)	12.717
(c)	6.642
(d)	8.191

Fig. 8. Images B'_o

4. Conclusion

We proposed a method for embedding multiple photographic images (images B_o) in one photographic image (image A). An image (image A') was generated by embedding information of images B_o in image A, and then an image (images B'_o) was restored by extracting information from image A'. In our method, as more images B were embedding in image A, the image quality of image A' deteriorated, but the image quality of images images B'_o did not deteriorate. To verify the effectiveness of our method, experiments using various photographic images were performed. As a result of the experiments, it was found that images A', in which one and 2 images B_o were embedded, were visually unrecognizable as different from image A. Additionally, it was found that images A', in which one or 3 images B_o were embedded, were slightly recognizable as different from image A, and image A', in which one or 4 images B_o were embedded, were clearly recognizable as different from image A.

A future task is to be able to apply our method to photographic images of different sizes.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number JP23K11727 and The Telecommunications Advancement Foundation Grant.

References

1. A. C. Pavan and M. T. Somashekara, An overview on research trends, challenges, applications and future direction in digital image watermarking, International Research Journal on Advanced Science Hub 5(1), 2023, pp. 2582-4376.
2. T. Hiraoka, A method for embedding another photographic image in a photographic image, ICIC Express Letter 14(4), 2020, pp. 311-317.
3. T. Hiraoka and K. Goto, A method to reduce changes in photographic images with embedded images, ICIC Express Letter.

Authors Introduction

Mr. Naoki Kouno

He is a student in the Department of Information Systems, University of Nagasaki. His research interests inculede image processing and data analysis.

Mr. Kanya Goto

He received B.Eco. degree from Keio University in 2006. He is currently a CEO in Movenext Corporation. His research interests include non-photorealistic rendering and electronic watermark.

Dr. Toru Hiraoka

He received B.Des., M.Des. and D.Eng. degrees from Kyushu Institute of Design in 1995, 1997 and 2005, respectively. He is currently a Professor in University of Nagasaki. His research interests include non-photorealistic rendering and disaster prevention.