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A Location Map-Free Reversible Data Hiding Method Inserting Data to Image Edges

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Abstract: This paper proposes a reversible data hiding method that embeds data to image edges. The proposed method once distorts an original image to embed data, it restores the original image as well as extracts hidden data from the image conveying hidden data. To extract data and to recover the original image, this method memorizes only one parameter and does not require any location map that records the positions conveying hidden data. Differing from the conventional method having these features, the proposed method is able to hide data to only image edges. Simulation results show the effectiveness of the proposed method.

1. Introduction

A data hiding method distorts an image imperceptively to embed data into an image [1–4]. Though a reversible data hiding method once distorts an original image to embed data, the method restores the original image as well as extracts hidden data from a stego image which is the image conveying hidden data [5–8]. Reversible data hiding methods, thus, are applicable to medical and military images [5, 6].

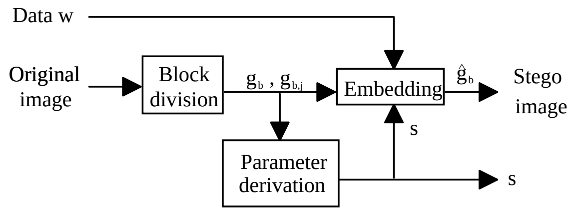
A reversible data hiding method that embeds data in the spatial domain using simple statistics has been proposed [7, 8]. This conventional method controls data embedding and extraction by block-based single parameter, and it does not require any location map that records the pixels conveying hidden data. It, however, does not take account into human visual system such that distortion in image edges is difficult to notice [2].

This paper proposes an extended reversible data hiding method based on the conventional method [7, 8]. Though the proposed method holds all the advantages of the conventional method, it is able to hide data to only image edges. The proposed method uses the statistics and the criteria for edge watermarking rather than detects image edges.

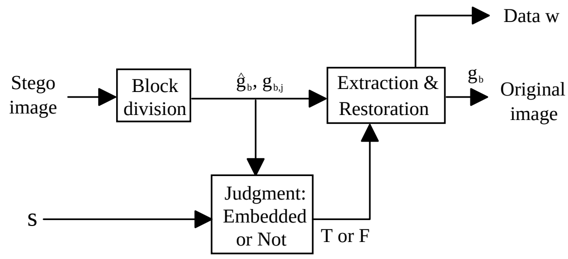
2. Conventional Method

This section describes the conventional method [8] briefly. The block diagram of the conventional method is shown in Fig. 1. This conventional method divides an image into overlapped blocks consisting of 3 × 3 pixels, as shown in Fig. 2 (a). A data bit, w_n, is hidden into g_b which is the central pixel of the b-th block, as shown in Fig. 2 (b).

Firstly, the conventional method derives parameter s that is one and only one parameter. Then, the method reversibly embeds data to an original image using s. This parameter, s, is also used in the extraction of hidden data and the restoration of the original image.

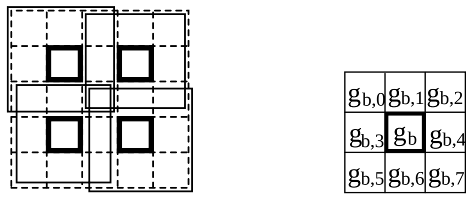


(a) Embedding.



(b) Extraction and restoration

Figure 1. Block diagram of the conventional method.



(a) Placement of blocks. (b) b-th block.

Figure 2. Divided block and its placement.

2.1. Parameter Derivation

For derivation of only one parameter s, the following six steps are applied to all overlapped blocks.

1. From the surrounding pixels $g_{b,j}$, obtain the average value $\bar{g}_b$ by Eq. (1).

$$\bar{g}_b = \left\lfloor \frac{1}{8} \sum_{j=0}^{7} g_{b,j} \right\rfloor \tag{1}$$

2. Obtain D_b that is given as

$$D_b = g_{\max,b} - g_{\min,b}, \tag{2}$$

where $g_{\max,b}$ and $g_{\min,b}$ are the maximum and the minimum of $g_{b,j}$'s, respectively. That is

$$g_{\max,b} = \max_j g_{b,j}, \tag{3}$$

$$g_{\min,b} = \min_j g_{b,j}. \tag{4}$$

3. By Eq. (5), $\tilde{g}_b$, that is adaptively changed from $\bar{g}_b$, is obtained.

$$\tilde{g}_b = \bar{g}_b - \mathrm{round}\left((2+D_b)\cos\left(\frac{\bar{g}_b}{2^K-1}\pi\right)\right), \tag{5}$$

where K represents the bit depth of the image.

4. By Eq. (6), d_b, that is difference between center pixel g_b and $\tilde{g}_b$, is obtained.

$$d_b = g_b - \tilde{g}_b \tag{6}$$

5. Obtain Δ_b that is given as

$$\Delta_b = \begin{cases} g_{\max,b} - \bar{g}_b, & d_b \geq 0 \\ g_{\min,b} - \bar{g}_b, & d_b < 0 \end{cases}. \tag{7}$$

6. By Eq. (8), s_b that is a candidate of parameter s is obtained.

$$s_b = \begin{cases} |\Delta_b|, & \tilde{g}_b + 2d_b < 0 \text{ or } 2^K - 2 < \tilde{g}_b + 2d_b \\ \infty, & \text{others} \end{cases} \tag{8}$$

Then, only one parameter s is chosen as among s_b's that are obtained from all blocks.

$$s = \min_b s_b. \tag{9}$$

2.2. Embedding

By using above obtained s, this method hides data into the image reversibly by Eq. (10).

$$\hat{g}_b = \begin{cases} \tilde{g}_b + 2d_b + w_n, & |\Delta_b| < s, \\ g_b, & \text{others} \end{cases} \tag{10}$$

In Eq. (10), this method distinguishes usable and unusable blocks by s, where this method can hide a data bit into a usable block reversibly. It is noted that a stego image consists of watermarked and unwatermarked blocks in this method.

2.3. Hidden Data Extraction and Original Image Restoration

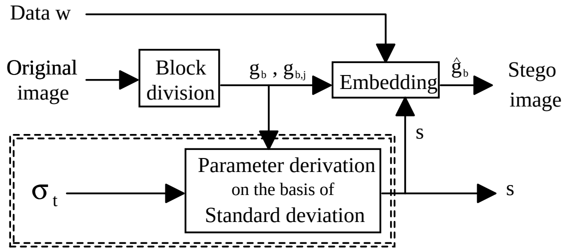
To extract hidden data and restore the original image, the following three steps are applied to all blocks in a stego image.

1. Obtain Δ_b in each block by

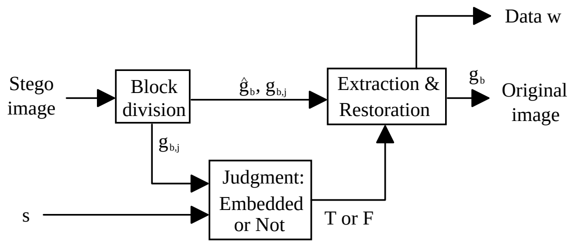
$$\Delta_b = \begin{cases} g_{\max,b} - \bar{g}_b, & \hat{g}_b - \tilde{g}_b \geq 0 \\ g_{\min,b} - \bar{g}_b, & \hat{g}_b - \tilde{g}_b < 0 \end{cases}. \tag{11}$$

2. If $|\Delta_b| < s$, embedded binary data bit w_n is extracted by Eq. (12). That is,

$$w_n = (\hat{g}_b - \tilde{g}_b) \bmod 2, |\Delta_b| < s \tag{12}$$



(a) Embedding (Dashed square indicates the major difference between the proposed and conventional [8] methods).



(b) Extraction and restoration.

Figure 3. Block diagram of the proposed method.

3. Original pixel g_b is restored by Eq. (13).

$$g_b = \begin{cases} \frac{\hat{g}_b + \tilde{g}_b - w_n}{2}, & |\Delta_b| < s \\ \hat{g}_b, & \text{others} \end{cases} \tag{13}$$

This method distinguishes the watermarked and the unwatermarked blocks using comparison between s and Δ_b. That is, this method never requires a location map that indicates the watermarked blocks.

The conventional method, however, embeds data to all the usable blocks. That is, no user can control location of blocks to be marked among usable blocks. In the next section, a reversible data hiding method embedding data to image edges is proposed.

3. Proposed Method

This section proposes a reversible data hiding method that inserts data into image edges. Though the proposed method uses block-based statistics and one parameter as well as the conventional method does, it hides data to only image edges.

3.1. Algorithms

The block diagram of the proposed method is shown in Fig. 3. The proposed method also divides an image into overlapped blocks, as shown in Fig. 2. In the method, firstly, a user-defined parameter σ_t is given that is used in the derivation process of parameter s only. That is, either hiding data, extracting hidden data, or restoring the original image does not require σ_t in the proposed method. Using user-defined parameter σ_t, the method derives s which is based on standard deviation. Then, the method reversibly embeds data into image edges by using s. The extraction of embedded data and the restoration of an original image also use parameter s. These three algorithms, i.e., derivation of s, embedding, and extraction and restoration are subsequently described from the next section.

3.1.1. Parameter derivation

Firstly, user-defined parameter σ_t is given. Then, For derivation of only one parameter s, the following five steps are applied to all overlapped blocks of an original image.

1. By Eq. (1), the average of surrounding pixels, $\bar{g}_b$, is obtained.
2. Obtain $\tilde{g}_b$, that is adaptively changed value from $\bar{g}_b$, by Eqs. (5).
3. Using Eq. (6), d_b, that is difference between center pixel g_b and $\tilde{g}_b$, is obtained.
4. Obtain the standard deviation of the surrounding pixels by Eq. (14).

$$\sigma_b = \left\lfloor \sqrt{\frac{1}{8}\sum_{j=0}^{7}\left(g_{b,j} - \bar{g}_b\right)^2} \right\rfloor \tag{14}$$

5. Obtain s_b, that is a candidate of parameter s, by Eq. (15).

$$s_b = \begin{cases} 0, & \sigma_b \geq \sigma_t \text{ and } 0 \leq \tilde{g}_b + 2d_b \leq 2^K - 2 \\ \sigma_b, & \text{others} \end{cases} \tag{15}$$

Among s_b's obtained from all blocks, only one parameter s is chosen as

$$s = \max_b s_b. \tag{16}$$

For embedding, extraction, and restoration, the proposed method memorizes only s, and user-defined parameter σ_t is no longer required.

3.1.2. Embedding

By using above obtained s, the proposed method inserts data into image edges reversibly. To embed data reversibly into image edges, the following three steps are applied to all blocks in the original image.

1. Obtain the standard deviation of surrounding pixels σ_b by Eq. (14).
2. From the comparison between σ_b and parameter s, obtain stego pixel $\hat{g}_b$ by Eq. (17).

$$\hat{g}_b = \begin{cases} \tilde{g}_b + 2d_b + w_n, & \sigma_b > s \\ g_b, & \text{others} \end{cases}. \tag{17}$$

In Eq. (17), the proposed method distinguishes usable and unusable blocks, and further distinguishes edge blocks and plane blocks among usable blocks, by only one parameter s.

3.1.3. Hidden Data Extraction and Original Image Restoration

Comparing the standard deviation of surrounding pixels, σ_b, with memorized parameter s, the proposed method extracts hidden data and restores the original image. The following three steps are applied to all blocks in a stego image.

1. Obtain the standard deviation of surrounding pixels, σ_b, by Eq. (14).
2. If $\sigma_b > s$, embedded binary data bit w_n is extract by Eq. (18).

$$w_n = (\hat{g}_b - \tilde{g}_b) \bmod 2, \sigma_b > s \tag{18}$$

3. Original pixel g_b is restored by Eq. (19).

$$g_b = \begin{cases} \frac{\hat{g}_b + \tilde{g}_b - w_n}{2}, & \sigma_b > s \\ \hat{g}_b, & \text{others} \end{cases} \tag{19}$$

The proposed method distinguishes the watermarked and the unwatermarked blocks using s as well as the conventional method [8].

3.2. Features

3.2.1. Edge Watermarking

The proposed method hides data into image edges. For this additional feature, the proposed method derives parameter s simply based on the standard deviation of surrounding pixels of g_b, whereas the conventional method uses the average of surrounding pixels. That is, the used statistics and criteria are modified rather than introducing a edge detection process. In Eq. (15), term $\sigma_b \geq \sigma_t$ distinguishes whether g_b is at an image edge or not. The effectiveness of introduction the standard deviation to the parameter is shown in Sect. 4.

3.2.2. Location Map-Free

From Eq. (17), the proposed method embeds data into blocks in which $\sigma_b > s$ is satisfied. Since σ_b is obtained from surrounding pixels that are not modified by any embedding process, σ_b does not change by data hiding. In the extraction and restoration process, thus, the method can detect watermarked blocks by comparing σ_b and memorized parameter s. Consequently, The proposed method require no location map.

3.2.3. Reversibility

For that the proposed method have reversibility, all stego pixels must be in the dynamic range of pixels, that is,

$$0 \leq \hat{g}_b \leq 2^K - 1, \quad \forall b. \tag{20}$$

From Eq. (17) and $w_n \in \{0, 1\}$, the method require that the following equation must be satisfied in embedding process.

$$0 \leq \tilde{g}_b + 2d_b \leq 2^K - 2 \tag{21}$$

In Eq. (15), term $0 \leq \tilde{g}_b + 2d_b \leq 2^K - 2$ distinguishes whether stego pixel $\hat{g}_b$ will be in the dynamic range of pixels or not. The method leaves blocks which do not satisfy this term.

In extraction process, Eq. (17) is transformed as,

$$\hat{g}_b - \tilde{g}_b = 2d_b + w_n. \tag{22}$$

Here, $\hat{g}_b$ and $\tilde{g}_b$ can be obtained from stego blocks. Since $w_n \in \{0, 1\}$,

$$(\hat{g}_b - \tilde{g}_b) \bmod 2 = (2d_b + w_n) \bmod 2 = w_n. \tag{23}$$

In restoration process, similarly, Eq. (17) is transformed as,

$$g_b = \frac{\hat{g}_b + \tilde{g}_b - w_n}{2}. \tag{24}$$

Consequently, the proposed method is reversible.

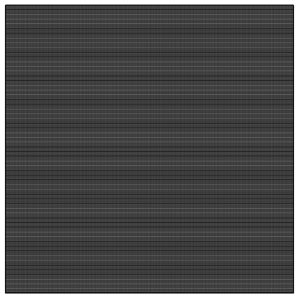
4. Experimental Results

The proposed method is evaluated by using image "lena" (Fig. 4 (a), 8-bits grayscale, 512×512 pixels). Data to be hidden, **w**, consists of equiprobable zero and one.

Figs. 4 (b) and (c) show watermarked pixels by the conventional [8] and proposed method, respectively. White pixels are watermarked pixels, whereas black pixels are unwatermarked pixels or surrounding pixels. Fig. 4 (d) shows image edges of the original image obtained by using sobel filter, in which white dots represent detected edge pixels. From these figures, it is found that the proposed method is dedicated to image edges, whereas the conventional method scatters data over the whole image.

Figs. 4 (e) and (f) show watermarked pixels by the proposed method under the conditions that $\sigma_t = 5$ and 20, respectively. In Fig. 4 (e), i.e., $\sigma_t = 5$, the proposed method embeds data to and around image edges. By contrast, as shown in Fig. 4 (f), data is hidden to edges under the condition $\sigma_t = 20$. That is, the proposed method can control width of embedding area along image edges by changing user-defined parameter σ_t. In other words, σ_t controls the capacity for hidden data. Small σ_t is suitable for large payload data, whereas a user want to set σ_t to large value for small payload data.

(a) Original image "lena".



(b) Watermarked pixels by the conventional method [8].

(c) Watermarked pixels by the proposed method ($\sigma_t = 10$).

(d) Image edges detected by sobel filter.

(e) Watermarked pixels by the proposed method ($\sigma_t = 5$).

(f) Watermarked pixels by the proposed method ($\sigma_t = 20$).

Figure 4. Watermarked pixels by the conventional and proposed method.

5. Conclusions

A location map-free reversible data hiding method inserting data to image edges has been proposed. In addition to features of conventional method [8] such as reversible data hiding, spatial domain-based, location map-free, one parameter-based, the proposed method has a new function, i.e., the method embeds data to image edges. Though the proposed method introduces a new functionality, it still uses only one parameter based on block-based simple statistics as well as the conventional method does.

An investigation of statistics and criteria for other functionalities is a further work.

References

[1] I.J. Cox, J. Kilian, F.T. Leighton, and T. Shamoon, "Secure spread spectrum watermarking for multimedia," IEEE Trans. Image Process., vol.6, no.12, pp.1673–1687, Dec. 1997.

[2] G.C. Langelaar, I. Setyawan, and R.L. Lagendijk, "Watermarking digital image and video data," IEEE Signal Process. Mag., vol.17, no.5, pp.20–46, Sept. 2000.

[3] H.S. Malvar and D.A.F. Florencio, "Improved spread spectrum: A new modulation technique for robust watermarking," IEEE Trans. Signal Process., vol.51, no.4, pp.898–905, Apr. 2003.

[4] M. Fujiyoshi, O. Watanabe, and H. Kiya, "A method of guaranteeing image-quality for quantization-based watermarking using a nonorthogonal transformation," IEICE Trans. Fundamentals, vol.E88-A, no.6, pp.1434–1442, Jun. 2005.

[5] J. Fridrich, M. Goljan, and R. Du, "Lossless data embedding — New paradigm in digital watermarking," EURASIP J. Appl. Signal Process., vol.2002, no.2, pp.185–196, Feb. 2002.

[6] J. Tian, "Reversible data embedding using a difference expansion," IEEE Trans. Circuits Syst. Video Technol., vol.13, no.8, pp.890–896, Aug. 2003.

[7] H.L. Jin, M. Masaaki, and H. Kiya, "Lossless data hiding in the spatial domain for high quality images," IEICE Trans. Fundamentals, vol.E90-A, no.4, pp.771–777, Apr. 2007.

[8] H.L. Jin, M. Masaaki, and H. Kiya, "Improvement in the image quality and the capacity of the reversible data hiding," Proc. ITC-CSCC, vol.1, pp.135–136, Jul. 2007.