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A location map-free reversible data hiding method for specific area embedding

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Abstract: This paper proposes a reversible data hiding method that embeds data into specific areas such as image edges. Though a reversible data hiding method distorts an original image to hide data, it not only extracts hidden data but also restores the original image from the distorted image. The proposed method memorizes only one parameter for data extraction and image restoration, and no location map recording watermarked positions is required. By simple modification to the conventional method that has the above mentioned features, the proposed method has a new function; hiding data to only specific areas.

Keywords: lossless watermarking, edge, smooth areas, spatial domain

Classification: Science and engineering for electronics

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1 Introduction

A data hiding method imperceptively distorts an image to embed data into the image, and it extracts hidden data from a *stego* image that conveys hidden data [1, 2, 3, 4, 5, 6, 7, 8]. A *reversible* data hiding method further restores the original image from a stego image [4, 5, 6, 7, 8], thus it is applicable to medical and military images [5]. The conventional reversible data hiding method [7, 8] controls data embedding and extraction by only one parameter, and it requires no *location map* that records the watermarked pixel positions. This method, however, cannot control data hiding positions.

This paper proposes an extended method based on the conventional method [8]. A simple modification on statistics, the proposed method provides a new function, i.e., the method not only holds all the advantages of the conventional method [7, 8] but also hides data to specific areas such as edge areas of images. This feature makes the proposed method possible to take account into that distortion is more imperceptible in edge ares than smooth areas [2, 3].

2 Conventional method

This section briefly describes the conventional method [8]. This method divides a $X \times Y$-sized image into B of 3×3-sized overlapping blocks, as shown in Fig. 1 (a), where $B = \lfloor (X-1)/2 \rfloor \lfloor (Y-1)/2 \rfloor$. A data bit, w_n, is hidden into t_b that is the central pixel of the b-th block, as shown in Fig. 1 (b), where $n = 0, 1, \ldots, N-1$, $b = 0, 1, \ldots, B-1$, and $N \leq B$.

Firstly, the following two steps are applied to all overlapping blocks to derive only one parameter p that is used for data hiding, extraction, and image restoration.

1. Calculate μ_b, the average of surrounding pixels in the b-th block, and

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

Fig. 1. Divided block and its placement.

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obtain $\tilde{\mu}_b$, adaptively transformed version of μ_b, as

$$\mu_b = \left\lfloor \frac{1}{8} \sum_{j=0}^{7} s_{b,j} \right\rfloor, \tag{1}$$

$$\tilde{\mu}_b = \mu_b - \text{round}\left((2 + D_b) \cos\left(\frac{\mu_b}{2^K - 1}\pi \right) \right), \tag{2}$$

where $D_b = \max_j s_{b,j} - \min_j s_{b,j}$, and K is the bit depth of the image.

2. Calculate d_b and obtain Δ_b and p_b as,

$$d_b = t_b - \tilde{\mu}_b, \tag{3}$$

$$\Delta_b = \begin{cases} \max_j s_{b,j} - \mu_b, & d_b \geq 0 \\ \min_j s_{b,j} - \mu_b, & d_b < 0 \end{cases}, \tag{4}$$

$$p_b = \begin{cases} |\Delta_b|, & \tilde{\mu}_b + 2d_b < 0 \text{ or } 2^K - 2 < \tilde{\mu}_b + 2d_b \\ \infty, & \text{others} \end{cases}. \tag{5}$$

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

$$p = \min_b p_b. \tag{6}$$

By using p, this method hides data into the image reversibly by Eq. (7).

$$\hat{t}_b = \begin{cases} \tilde{\mu}_b + 2d_b + w_n, & |\Delta_b| < p \\ t_b, & \text{others} \end{cases} \tag{7}$$

This method embeds data to all *usable* blocks in which complete data extraction and image restoration are guaranteed, thus no user can select blocks to be watermarked among usable blocks. In the next section, an extended method that can control areas to be watermarked is proposed.

3 Proposed method

This section proposes a reversible data hiding method that a user can control embedding areas. Simply by modifying statistics that are used in the parameter derivation process, the proposed method hides data to only edge or only smooth areas without losing advantages of the conventional method [8]. As an example, the algorithm that embeds data into only edge areas is focused in this section.

3.1 Algorithms for edge-watermarking

The block diagram of the proposed method for edge-watermarking is shown in Fig. 2. The proposed method also divides a $X \times Y$-sized image into B of 3×3-sized overlapping blocks as shown in Fig. 1. Then, in this method, a user-defined parameter σ_u that is used in only the derivation process of parameter q is given. Using σ_u, the method derives only one parameter q based on the standard deviation of blocks. Then, the method reversibly

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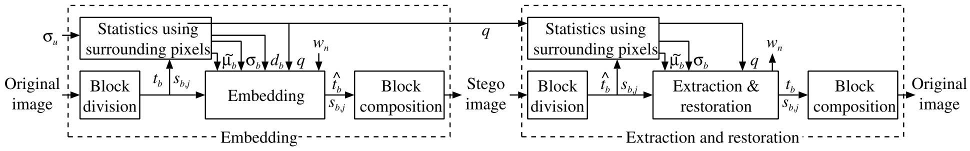

Fig. 2. Block diagram of the proposed method.

embeds data into image edges by using q. The extraction of embedded data and the restoration of the original image also use parameter q. From the next section, each of above processes is subsequently described.

3.1.1 Parameter derivation

1. User-defined parameter σ_u is given, and $b := 0$.
2. μ_b, $\tilde{\mu}_b$, and d_b are obtained by Eqs. (1), (2), and (3), respectively.
3. From surrounding pixels in the b-th block, standard deviation σ_b is obtained as

$$\sigma_b = \left\lfloor \sqrt{\frac{1}{8}\sum_{j=0}^{7}(s_{b,j}-\mu_b)^2} \right\rfloor . \tag{8}$$

4. Obtain q_b, that is a candidate of parameter q as

$$q_b = \begin{cases} -1, & \sigma_b \geq \sigma_u \text{ and } 0 \leq \tilde{\mu}_b + 2d_b \leq 2^K - 2, \\ \sigma_b, & \text{others} \end{cases} . \tag{9}$$

5. $b := b + 1$. Continue to Step 2 unless $b = B$.
6. The maximum of q_b's becomes q as

$$q = \max_b q_b. \tag{10}$$

For data extraction and image restoration, the proposed method memorizes only q and user-defined parameter σ_u is no longer required.

3.1.2 Embedding

By using above obtained q, the proposed method inserts data into image edges reversibly.

1. $b := 0$ and $n := 0$.
2. Obtain σ_b by Eq. (8).
3. Stego pixel $\hat{t}_b$ is obtained by

$$\hat{t}_b = \begin{cases} \tilde{\mu}_b + 2d_b + w_n, & \sigma_b > q \\ t_b, & \text{others} \end{cases} . \tag{11}$$

4. If $\sigma_b > q$, $n := n + 1$.

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5. $b := b + 1$. Continue to Step 2 unless $b = B$.

6. $N := n$, and a stego image with N-bits hidden data is generated.

In Eq. (11), the proposed method distinguishes usable and unusable blocks, and it further distinguishes edge blocks and smooth blocks among usable blocks, by only one parameter q.

3.1.3 Hidden data extraction and original image restoration

Parameter q is transmitted from the embedding side to this side in the proposed method, but no location map is required.

1. $b := 0$ and $n := 0$.

2. Obtain σ_b by Eq. (8).

3. If $\sigma_b > q$, hidden data bit w_n is extracted and original pixel t_b is restored as

$$w_n = \left(\hat{t}_b - \tilde{\mu}_b\right) \bmod 2, \quad \sigma_b > q, \tag{12}$$

$$t_b = \begin{cases} \left(\hat{t}_b + \tilde{\mu}_b - w_n\right)/2, & \sigma_b > q \\ \hat{t}_b, & \text{others} \end{cases}, \tag{13}$$

$$n := n + 1, \quad \sigma_b > q. \tag{14}$$

4. $b := b + 1$. Continue to Step 2 unless $b = B$.

5. N-bits data and the original image are obtained.

The proposed method distinguishes the watermarked and the unwatermarked blocks by using q, so it does not require any location map.

3.2 Features

In addition to the reversible data hiding, location map-free, only one parameter memorization as well as the conventional method [8], the proposed method hides data into only specific areas, and Sect. 3.1 describes the algorithms for edge-embedding.

For this additional feature, the proposed method simply derives parameter q based on the standard deviation of surrounding pixels of t_b, whereas the conventional method uses the average of surrounding pixels. The condition $\sigma_b \geq \sigma_u$ in Eq. (9) distinguishes whether t_b is at an edge. That is, the used statistics are simply modified to serve this extra feature rather than introducing an edge detection process.

To hide data to only smooth areas, replace Eqs. (9) and (10) with Eqs. (15) and (16), respectively, and the condition $\sigma_b > q$ in every steps and equations is replaced with $\sigma_b < q$.

$$q_b = \begin{cases} \infty, & \sigma_b \leq \sigma_u \text{ and } 0 \leq \tilde{\mu}_b + 2d_b \leq 2^K - 2 \\ \sigma_b, & \text{others} \end{cases} \tag{15}$$

$$q = \min_b q_b \tag{16}$$

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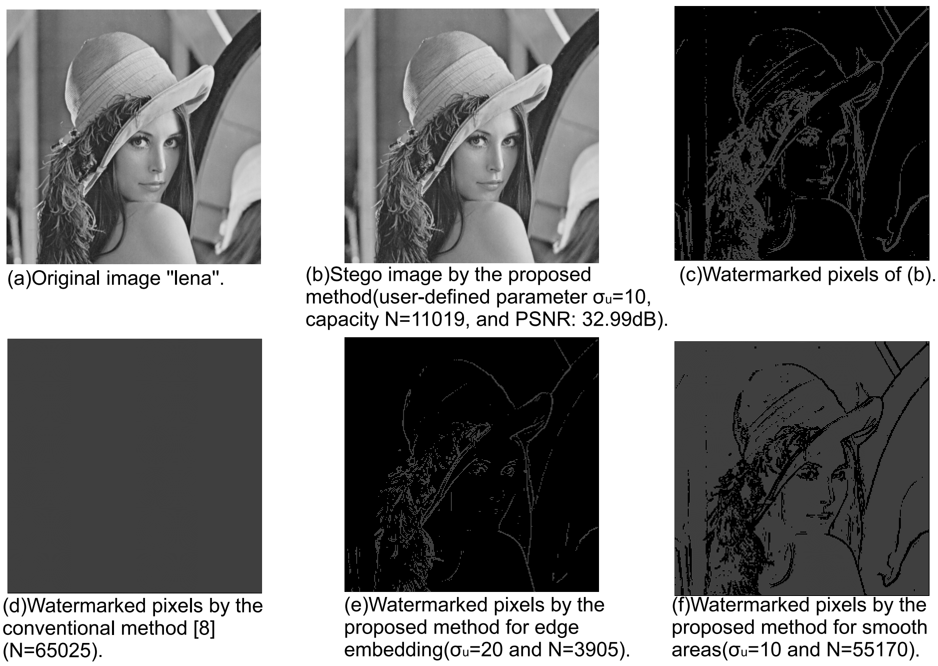
4 Experimental results

The proposed method is evaluated by using image “lena” (Fig. 3 (a), 8-bits grayscale, 512 × 512 pixels). Data to be hidden, **w**, consists of equiprobable zero and one.

Fig. 3 (b) shows the stego image generated by the algorithms described in Sect. 3.1 with $\sigma_u = 10$, and its corresponding watermarked pixels are shown in Fig. 3 (c). Fig. 3 (d) shows watermarked pixels by the conventional [8]. In Figs. 3 (c) and (d), bright pixels are watermarked pixels, whereas dark pixels are unwatermarked pixels or surrounding pixels. From Figs. 3 (c) and (d), the proposed method is dedicated to image edges, whereas the conventional method scatters data over the whole image.

Fig. 3 (e) shows watermarked pixels by the proposed method with $\sigma_u = 20$. In this condition, data are hidden to the ridge lines of image edges, in comparison with Fig. 3 (c). Namely, the proposed method is capable to control the embedding area along image edges by changing σ_u.

Meanwhile, Fig. 3 (f) shows watermarked pixels by the proposed method for embedding to only smooth areas that is described in Sect. 3.2. Comparing this figure with Fig. 3 (b), it is found that the method hide data within smooth areas in contrast with edge-embedding.



(a)Original image "lena".

(b)Stego image by the proposed method(user-defined parameter σ_u=10, capacity N=11019, and PSNR: 32.99dB).

(c)Watermarked pixels of (b).

(d)Watermarked pixels by the conventional method [8] (N=65025).

(e)Watermarked pixels by the proposed method for edge embedding(σ_u=20 and N=3905).

(f)Watermarked pixels by the proposed method for smooth areas(σ_u=10 and N=55170).

Fig. 3. Location of watermarked pixels.

5 Conclusions

A location map-free reversible data hiding method inserting data into specific areas has been proposed in this paper. In addition to features of the conventional method [7, 8] such as reversible, location map-free, and one parameter-based, the proposed method has a new function, i.e., the method

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embeds into only edge or only smooth areas. Though the proposed method introduces a new functionality, it does not introduce an extra edge detection process and only statistics in algorithms are changed.

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

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