A Study on the Image Steganographic method using Multi-pixel Differencing and LSB Substitution Methods

(다중 픽셀 차이값과 LSB 교체 기법을 이용한 이미지 스테가노그래픽 기법 연구)

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Abstract A data hiding method based on least significant bit (LSB) substitution and multi-pixel differencing (MPD) is presented on the proposed method to improve the capacity of the hidden secret data and to provide an imperceptible visual quality. First, a sum of different values for four-pixel sub-block is calculated. The low value of the sum can be located on a smooth block and the high value is located on an edged block. The secret data are hidden into the cover image by LSB method in the smooth block, while MPD method in the edged block. The experimental results show that the proposed method has a higher capacity and maintains a good visual quality.

Key Words : Data Hiding, Information Hiding, MPD, LSB

1. Introduction

Data or information hiding methods which hide secret data into digital data has much interest by growing the internet and developing of compression techniques.

The most important requirement in data hiding is that the detector could not detect the presence of the hidden message for the cover data. Secret data can be hidden many different ways in cover data. Generally common approaches are categorized as least significant bit substitution and pixel-value differencing [1-3]. LSB substitution is a common method that replaces two or more of the least significant bits of each pixel with secret bits. LSB matching modifies the least significant bits of the cover image, but does not simply replace as does LSB substitution method. If the secret bit does not match that of the cover data, then one is randomly added or subtracted from the cover bit [4-5]. Pixel-value differencing method offers a high imperceptibility by calculating the difference of two consecutive pixels to decide the length of the embedding bits. To provide a

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better stego-image quality than PVD, it was proposed based on pixel-value differencing and modulus function by adjusting the remainder of the two consecutive pixels instead of the difference value. Other methods based on PVD and LSB substitution were proposed to improve the capacity and provide an imperceptible visual quality [6-8]. Another data hiding method using multi-pixel differencing was presented by neighboring pixels correlation to estimate the degree of smoothness or contrast of pixels [9].

The measurement of stego-image is a large amount of data and visual quality as well as transparency and robustness. The peak signal-to-noise ratio (PSNR) and quality index are used to judge the quality of the embedded image. In general, if the PSNR value is higher than the standard measurement of 30 dB, then the secret data which is embedded in the cover data is imperceptible to human vision [10].

This paper proposes a method that yields a high capacity by improving the multi-pixel differencing method, which adopts LSB substitution method in the smooth blocks.

This paper is organized as follows. Section 2 describes our proposed method. In Section 3, the experimental results are presented and discussed. Finally, the conclusions are presented in Section 4

2. The Proposed Method

In this Section, the embedding and extracting algorithm are described. To increase capacity, the proposed algorithm is divided into two parts: smooth block and edge block for four-pixel sub-block and then LSB and MPD methods are applied. The division of the smoothness and edge is controlled by the sender and receiver, which threshold value can be used as a key.

2.1. The Embedding Algorithm

For a given 256 gray-valued cover image, a difference value is computed from every non-overlapping block of four consecutive pixels, say p_i, p_{i+1}, p_{i+2} and p_{i+3}. Assume that the four gray values are ordered from lower to higher value, g_0, g_1, g_2 and g_3 respectively. The detailed embedding algorithm is given as follows.

Step 1: Calculate the difference value d_i for each pixel-pair of four consecutive pixels, which is given by

$$d_i = | g_i - g_0 |, 1 \leq i \leq 3. \quad (1)$$

Step 2: Let T be threshold value. For each d_1, d_2 and d_3, compute the sum of differences, $D = d_1 + d_2 + d_3$. Next, we divide into two areas, if $D < T$, a given four-pixel block B belongs to smooth block, otherwise it counts to edge block.

Step 3: Embed n bits of secret data into g_i ($1 \leq i \leq 3$) to the following two cases.

Case 1: If B belongs to a smooth block, read 9 bits from secret data stream, and calculate new pixel g_i by replacing 3-bit LSB for each g_i.

Case 2: If B belongs to an edge block, the number of bits can be embedded for each g_i in this block is calculated by $n = \log_2 (u_i - l_i + 1)$ for each difference value, where the lower and upper bound values of the range R_i ($i = 1, 2, \cdots, w$) are defined already.

Step 4: Calculate the difference value $d_i = d_i + b_i$ for each g_i ($1 \leq i \leq 3$), which b_i is a decimal value for the embedded secret bits.

Step 5: For edge blocks, optimize by rearranging of the new pixel values. Let P be the sum of pixel for a given sub-block, new pixel value can be obtained by

$$g_0 = (P - D) / 4, \quad g_i = g_0 + d_i, \ 1 \le i \le 3. \tag{2}$$

In here, g_i is matched for each stego-image, p_i.

2.2. The Extracting Algorithm

The following steps are executed to recover the original secret data.

Step 1: Partition the stego-image into blocks of four consecutive pixels, and the partition procedure is identical with embedding.

Step 2: Calculate the difference value d_i for each block of four consecutive pixels g_i of the stego-image which is given by Eq. (3). This equation can be deduced from Eq. (2) directly.

$$d_i = g_i - g_0, \ 1 \le i \le 3. \tag{3}$$

Step 3: For three d_i values, the embedded bits, b_i can extract by calculating as

$$b_i = d_i - l_i, \ 1 \le i \le 3. \tag{4}$$

3. Experimental Results

In our experiments, six 512x512 gray images shown in Fig. 1 were used as cover images and randomized data was used as secret data for each. The secret data is generated by pseudo-random numbers and assigned a range table R_1=[0, 7], R_2=[8, 15], R_3=[16, 31], R_4=[32, 63], R_5=[64, 127] and R_6=[128, 255]. Also the threshold T is given to 2^4x3. This paper adopts the peak signal-to-noise ratio (PSNR) and a universal image quality index, Q [11] to measure the imperceptibility and capacity for the amount of embedded data.

Our experiments used an eight-bit grayscale image, so the PSNR is utilized as an objective distortion measurement and calculated. Let the width of image be W and height be H.

$$PSNR = 10 \times \log_{10} 255^2 / MSE, \tag{5}$$

where MSE is the mean square error and g_{ij} and g'_{ij} are pixel values of the cover and stego image, which is defined as

$$MSE = \sum_{i=0}^{W-1} \sum_{j=0}^{H-1} (g_{ij} - g'_{ij})^2 / W \cdot H \tag{6}$$

A universal image quality index is provided to demonstrate the quality of stego-images. This quality index is based on statistical measurements, and its definition is as follows

$$Q = \frac{4\,\theta_{xy} M_x M_{x'}}{(\theta_x^2 + \theta_y^2)\,[M_x^2 + M_{x'}^2]} \tag{7}$$

where each factor is given in Eq. (8).

$$M_{x'} = \frac{1}{W \cdot H} \sum_{i=0}^{W-1} \sum_{j=0}^{H-1} g_{ij}, \quad M_{x'} = \frac{1}{W \cdot H} \sum_{i=0}^{W-1} \sum_{j=0}^{H-1} g'_{ij},$$
$$\theta_x^2 = \frac{1}{W \cdot H-1} \sum_{i=0}^{W-1} \sum_{j=0}^{H-1} (g_{ij} - M_x)^2, \quad \theta_y^2 = \frac{1}{W \cdot H-1} \sum_{i=0}^{W-1} \sum_{j=0}^{H-1} (g'_{ij} - M_{x'})^2, \tag{8}$$
$$\theta_{xy} = \frac{1}{W \cdot H-1} \sum_{i=0}^{W-1} \sum_{j=0}^{H-1} (g_{ij} - M_x)(g'_{ij} - M_{x'})$$

Q's dynamic range is [-1, 1]. Value 1 means that the two images are exactly the same, and -1 means that the two images are unrelated.

<Table 1> The results of the proposed method.

Cover Image	Our Method			Our Optimized Method		
	Capacity	PSNR	Q	Capacity	PSNR	Q
Airplane	627,390	33.56	0.8151	627,390	34.46	0.8159
Man	651,406	32.61	0.9214	651,406	33.11	0.9215
Peppers	619,002	33.71	0.9214	619,002	33.91	0.8767
Boat	651,551	32.51	0.9063	651,551	32.40	0.9061
House	650,744	32.02	0.8187	650,744	32.47	0.8201
Lena	619,084	35.33	0.8628	619,084	35.95	0.8632

Table 1 shows the results of the proposed method in the terms of capacity, PSNR and quality index. Our method can hide 636,530 bits on average for the six cover images and sustains 33.29 dB. After optimizing the four-pixel sub-block, PSNR improves by 0.43 dB. Table 2 results the detailed comparisons of the three methods with PSNR value and capacity for different cover images. According to the table, the proposed method has a higher capacity. Although PSNR is low by 1.12 dB compared with MPD method, the proposed method can embed 33,137 bits on average, where the PSNR of the proposed method higher than 30 dB, it is difficult to detect by human eyes.

The resulting images after embedding secret data generated by randomization are shown in Fig. 2. Since the average PSNR value is 33.72 dB, the secret data does not impinge on the human eye.

4. Conclusions

We have proposed a data hiding method that improves on the method of embedding by multi-pixel differencing. The proposed method divided the four-pixel sub-block into a smooth block or an edge block. For a smooth block, secret data are hidden into the cover image by LSB substitution method, while the MPD method is used for an edge block. And for an edge block, pixel values are optimized for minimizing of the distance between pixel-pair for each sub-block. Our experimental results have shown that the proposed method could embed more than the multi-pixel differencing method sustaining a good visual quality.

<Table 2> Comparisons of other methods for capacity and visual quality.

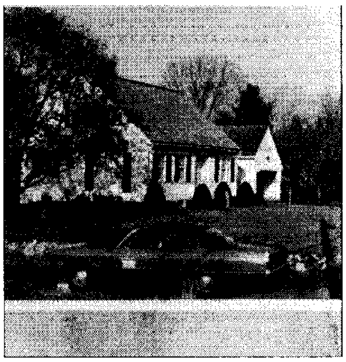
Cover Image	2-bit LSB		PVD		MPD		Our Method	
	Capacity (bit)	PSNR (dB)	Capacity (bit)	PSNR (dB)	Capacity (bit)	PSNR (dB)	Capacity (bit)	PSNR (dB)
Airplane	524,288	43.99	409,778	46.19	584,008	35.05	627,390	34.46
Man	524,288	44.33	424,585	39.09	620,729	33.73	651,406	33.11
Peppers	524,288	44.40	407,479	40.86	594,241	35.90	619,002	33.91
Boat	524,288	44.25	421,965	39.56	631,433	33.91	651,551	32.40
House	524,288	44.18	420,386	39.51	599,424	33.52	650,744	32.47
Lena	524,288	44.34	409,807	41.18	590,518	36.92	619,084	35.95

(a) Airplane

(b) Man

(c) Peppers

(d) Boat



(e) House

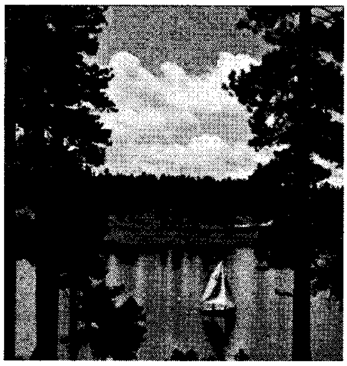
(f) Lena

(Fig. 1) Six cover images

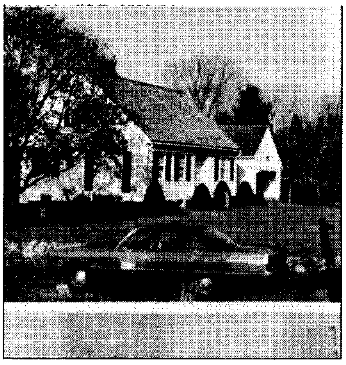
(a) Airplane, PSNR=34.46dB

(b) Man, PSNR=33.11dB

(c) Peppers, PSNR=33.91dB



(d) Boat, PSNR=32.40dB



(e) House, PSNR=32.47dB

(f) Lena, PSNR=33.95dB

(Fig. 2) Six stego-images

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