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Data Hiding Method with Quality Control for Binary Images

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ABSTRACT

Secret data hiding in binary images is more difficult than other formats since binary images require only one bit representation to indicate black and white. This study proposes a new method for data hiding in binary images using optimized bit position to replace a secret bit. This method manipulates blocks, which are sub-divided. The parity bit for a specified block decides whether to change or not, to embed a secret bit. By finding the best position to insert a secret bit for each divided block, the image quality of the resulting stego-image can be improved, while maintaining low computational complexity. The experimental results show that the proposed method has an improvement with respect to a previous work.

Keywords: *Data Hiding, Quality Control, Binary Images*

1. Introduction

Data hiding involves concealing information in a host signal, such as text, image, audio, or video. Binary images are two-color images, with a 0 or 1 value for each pixel, in which each pixel requires only one bit representation, to indicate black and white. The difficulty lies in the fact that changing pixel values in a binary image can cause irregularities that are visually very noticeable. Hiding data in binary images is therefore more challenging than hiding it in other formats [1].

There are two primary methods of data hiding in these images: sub-block modification and single pixel manipulation. The first modifies the sub-block, which is divided into a group of pixels. Matsui and Tanaka embedded secret data in 'dithered' images by manipulating the dithering patterns; they also embedded in fax images, by manipulating the run lengths [2]. Low *et al.* changed line spacing and character spacing to embed secret data in textual images, for bulk electronic publications [3,4]. These methods are used for some special types of binary images. The second approach modifies single pixel from black to white or vice versa: some special single pixels in the image are changed to embed the secret data. Koch and Zhao proposed a data hiding method by forcing the ratio of black and white pixels in a block to be larger or smaller than one [5]. However, there is a difficulty with this. Only a limited number of bits can be embedded, since the enforcing method has trouble dealing with blocks that have a significantly low or high percentage of black pixels. Wu *et al*. embedded bits in image blocks, selected by calculating a characteristic value and finding a pattern [6]. Lie *et al*. partitioned the binary image into blocks of 2x2 pixels and embedded a bit 0 or 1 in the block. This method can hide one bit per block by modifying 0.5 pixels on average [7]. Wu and Liu manipulated flappable pixels to enforce a specific block-based relationship in order to embed a significant amount of data without causing noticeable visual effects [8]. Venkatesan et al. proposed using the parity of blocks. The cover image is partitioned into small blocks, in which one bit information is stored. Unfortunately, if all of the pixel values belong to 0 or 1, a secret bit cannot be hidden [9].

This paper proposes a new data hiding method for binary images, using optimized bit position and parity bit check with adopted block parity. This method manipulates sub-divided blocks. The parity bit for a specified block decides whether to change or not, to embed a secret bit. By finding the best position to insert a secret bit for each divided block, the image quality of the stego-image can be maintained with relatively low computational complexity.

This paper is organized as follows. In Section 2, data hiding scheme using block parity proposed by Venkatesan *et al*. is reviewed. In Section 3, our proposed data hiding method is described in more detail. In Section 4, our experimental results are presented and discussed. Our conclusions are presented in Section 5.

2. Related Work

Venkatesan *et al*. proposed data hiding method for binary images to maintain the quality of cover image. To change a bit close to the position which has the same value,

neighbor matrix was adopted. For 3x3 sub-block B_m, the resulted sub-block B''_m is more difficult to be detected than B'_m. To find the location, Venkatesan *et al*. defined a neighbor matrix.

$$B_m = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \quad B'_m = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & \mathbf{1} \end{bmatrix} \quad B''_m = \begin{bmatrix} 1 & 1 & 0 \\ 1 & \mathbf{1} & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

Figure 1. Sub-block matrix of cover image

But there is a room to improve the capacity with less distortion to the human visual system. This paper proposes a new data hiding method for binary images using optimized bit position and parity bit check.

3. Proposed Method

In this section, we consider the position of data embedding, and how the secret data is embedded and extracted. The binary image is made up of black and white. There is only one bit representation for each pixel, say 0 or 1.

Let C be the cover image of WxH pixels and S be the n-bit secret data. For $p(i,j)$ pixel value belonging to C image, a new pixel value is defined as $p'(i,j)$.

3.1 Embedding Scheme

The following steps are executed to embed secret data.

Step 1: For a given cover image, calculate the matrix which stores the position of the isolated pixel. Given a specified pixel value $p(i,j)$, the value of the neighboring four pixels for the row and column direction is compared, and the difference value is calculated for each 0 or 1. Next, the difference of the neighboring eight pixels which are surrounding the specified pixel is compared and calculated. These are defined as $NB_4(i,j)$ and $NB_8(i,j)$ separately, where $\Gamma(\cdot)$ is an indicator function which is taking value from {0,1}.

$$NB_4(i,j) = \sum_{k=-1}^{1} \Gamma(\{p(i+k,j) \neq p(i,j)\}) + \sum_{l=-1}^{1} \Gamma(\{p(i,j+l) \neq p(i,j)\})$$
$$NB_8(i,j) = \sum_{k=-1}^{1} \sum_{l=-1}^{1} \Gamma(\{p(i+k,j+l) \neq p(i,j)\}) \quad (1)$$

For example, when a cover image is given as Figure 2, the difference of the neighboring pixels for $p(2,1)$ are calculated as $NB_4(2,1) = 2$ and $NB_8(2,1) = 4$ respectively.

Step 2: The cover image is partitioned into MxN-size blocks. For a specified sub-block B_m, calculate the sum of the block which is given by

$$S(B_m) = \sum_{k=C}^{M-1} \sum_{l=C}^{N-1} p(k,l) \quad (2)$$

Step 3: If $S(B_m)$ is not equal to 0 or MxN, embed 1-bit of secret data into B_m to the following three cases:

Case 1: If $S(B_m)$ mod 2 is equal to 0 and the embedding bit is 1, then change the isolated pixel $p(i,j)$ where $NB_4(i,j)$ value is larger than any other pixel for $p(i,j) = 0$ pixel. When there exists another pixel which the value of the neighboring four pixels is equal, select a pixel that $NB_8(i,j)$ value is larger.

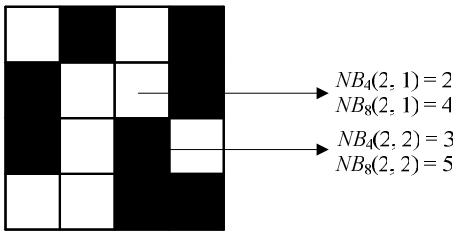


Figure 2. Difference of the neighboring pixels

Case 2: If $S(B_m)$ mod 2 is equal to 1 and the embedding bit is 0, then change the isolated pixel $p(i,j)$ where $NB_4(i,j)$ value is larger than any other pixel for $p(i,j) = 1$ pixel. When there exists another pixel, for which the value of the neighboring four pixels is equal, select a pixel that $NB_8(i,j)$ value is larger than.

Case 3: If it does not belong to Case 1 and Case 2, any other pixel values for the block remain unchanged.

Step 4: For the embedded block B'_m which is a new block for B_m after embedding, calculate the sum of the block. When the value belongs to 0 or MxN, discard this block for embedding a secret bit.

For example, $NB_4(i,j)$ and $NB_8(i,j)$ values are calculated for the 4x4 sub-block shown in Figure 3. As a result, $NB_4(0,3) = 3$ and $NB_8(i,j) = 7$ are largest value for a sub-block, so pixel $p(0,3)$ is selected to embed a secret bit.

3.2 Extracting Scheme

The following steps are executed to recover the secret data. It can be directly extracted from the stego-image only.

Step 1: For a given stego-image, partition into MxN-size blocks. For each block B'_m, calculate the sum of the block which is given by

$$S(B'_m) = \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} p'(k,l) \quad (3)$$

Step 2: If $S(B'_m)$ is not equal to 0 or MxN, extract 1-bit from B'_m to the following two cases:

Case 1: If $S(B'_m)$ mod 2 is equal to 0, the extracted bit is 0.

Case 2: If $S(B'_m)$ mod 2 is equal to 1, the extracted bit is 1.

Step 3: For all the embedded block B'_m, stack an extracted bit.

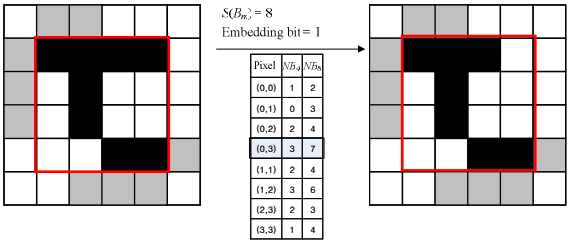


Figure 3. Example of data embedding process

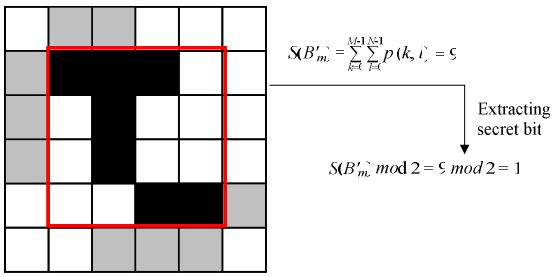


Figure 4. Example of data extracting process

For a sub-block B'_m, the sum of block $S(B'_m)$ is equal to 9 and finally the value of $S(B'_m)$ *mod* 2 = 9 *mod* 2 = 1. So the embedded bit is 1.

4. Experimental Results

In our experiments, four 512x512 binary images shown in Figure 5 were used as cover images. The secret data was generated by pseudo-random numbers. This study adopts the peak signal-to-noise ratio (PSNR) as extending 1-bit binary value to 8-bit, and calculates capacity for the amount of embedded data. Our experiments used an extended eight-bit value, in which white value is extended to 0xFF and black to 0x00.

Figure 6 shows the stego-images and embedded blocks for the Baboon image, where these compare with for various *M*x*N* block sizes. As the results, there are not any visual artifacts present.

We found that these distortions do happen, to the edge areas of the image. This means that such distortions will be less noticeable, because changes to edge areas of binary image are generally less conspicuous to human eyes.

(a) Baboon **(b) Airplane**

(c) Lena **(d) Boat**

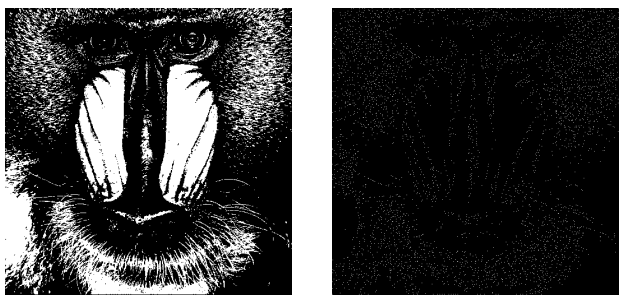
Figure 5. Four cover images

Figure 6(a) illustrates a Baboon image, size 512x512 and it takes 13,415 bits embedded blocks, which are divided into 2x2 sub-blocks. Figure 6(c) and 6(e) show the stego-images after embedding 11,960 bits and 8,301 bits respectively. Figure 6(b), 6(d) and 6(f) display the embedded pixels for 2x2, 3x3 and 4x4 sub-block respectively.

Table 1 shows the capacity of the proposed method on the different sub-block sizes. The table shows that the proposed method can hide more secret data when a cover image changes its pixel value rapidly. For example, the Baboon has a higher capacity than the other images, which contain many blocks so that all of the sub-block's values are scattered uniformly and randomly. As sub-block size is larger, the capacity is low and the PSNR value is high. This means that there is a trade-off between capacity and invisibility. Each sub-block can embed a secret bit, except a full black or white block.

(a) 2x2 block **(b) Difference**

(c) 3x3 block **(d) Difference**



(e) 4x4 block **(f) Difference**

Figure 6. Embedding results: (a) (c) (e) stego-images; (b) (d) (f) difference images

Table 1 shows the comparison with other method. The proposed method can hide more secret data than other method although the PSNR value is similar for each image. In here, the PSNR value is adopted for comparison with other method.

Figure 7 shows the stego-images after embedding secret data for each 3x3 sub-blcok. In these experiments, the proposed method produces less distortion to the cover image, in spite of its higher capacity. For the stego- images shown in Figure 7(a), 7(b), 7(c) and 7(d), it can be embedded less than other two images since many sub-blocks in these images have a full 0 or 1 value, where discarded for embedding.

Figure 8 shows the detailed image for result. The stego-images are shown in Figure 8(b), 8(c), 8(e) and 8(f) for 170x170 cover images. As shown in Figure 8, the proposed method has less distortion than the previous method.

5. Conclusions

We have proposed a data hiding method using optimized bit position and parity bit check for binary images. No reference to the original cover image was required when extracting the embedded secret data from the stego-image.

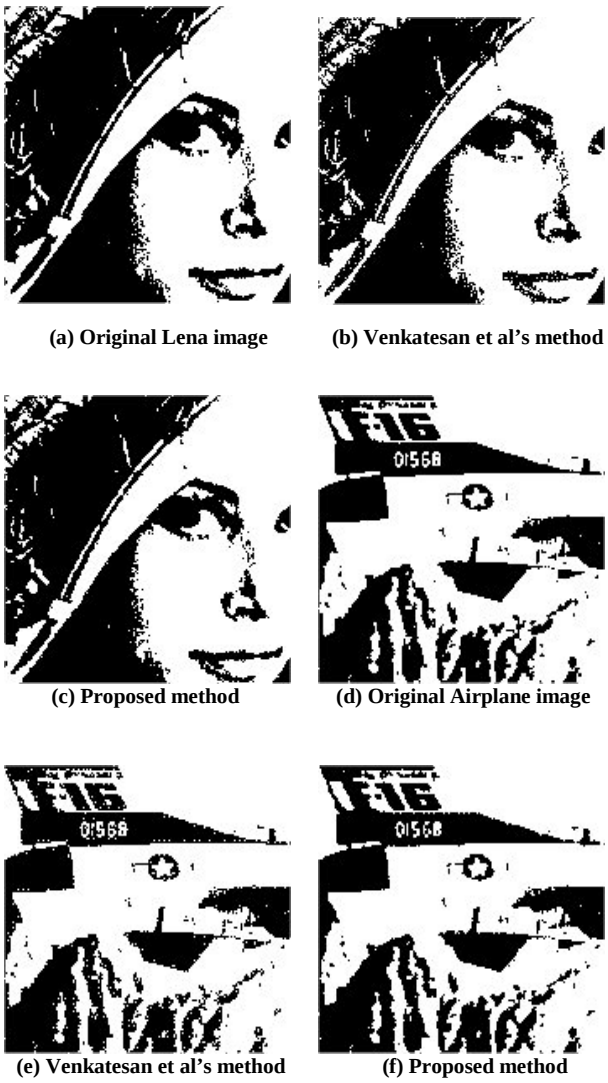
Table 1. Comparison of embedding for 3x3 block size

Cover Image	Venkatesan et al.'s		The proposed method	
	Capacity (bits)	PSNR (dB)	Capacity (bits)	PSNR (dB)
Baboon	9,441	16.36	11,960	16.32
Airplane	3,293	21.25	3,587	21.50
Lena	3,657	20.45	4,433	20.51
Boat	3,714	20.56	4,429	20.45

(a) capacity=11,960bits **(b) capacity=3,587bits**

(c) capacity=4,433bits **(d) capacity=4,429bits**

Figure 7. Stego-images of the proposed method



(a) Original Lena image **(b) Venkatesan et al's method**

(c) Proposed method **(d) Original Airplane image**

(e) Venkatesan et al's method **(f) Proposed method**

Figure 8. Detailed comparison for stego-images.

This method manipulated blocks which were sub-divided into a small *M*x*N*-size block. The parity bit for a specified block decided whether to change or not, to embed a secret bit. By finding the best position to insert a secret bit for each divided block, the image quality of the stego-image could be improved, while retaining a low computational complexity. Our experimental results have shown that the proposed method provided a better way to hide more secret data compared with other method without making noticeable distortions.

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