Improved Data Hiding Method Based on Use of Edge Line Distortion Score

Reza DAVARZANI and Khashayar YAGHMAIE

University of Semnan, Semnan, Iran
reza.davarzaniii@gmail.com
khashayar.yaghmaie@gmail.com

Abstract: This paper by considering objective distortion measure into a data hiding method makes a little improvement to it. The distortion measure considers not only how many pixels are changed but also where the pixels are changed and how the flipping affects the overall shape formed by the edge line. The data hiding method uses a secret key and a weight matrix to protect the hidden data and ensures that in each \( m \times n \) image block of the host image as many as \( \log_2(mn+1) - 1 \) bits can be hidden in the block by changing at most 2 bits in the block. In this paper we propose a revised scheme that by using of edge line distortion score can maintain a little higher quality of the host image without any reduction in capacity. Experimental results and Comparisons show increasing quality of the image.

Key words: Binary text images, Data hiding, Distortion measure, Security

INTRODUCTION

Computer networks and the internet have enabled fast and economic distribution of multimedia such as image, video, audio and text documents. Data hiding and authentication of digital documents have aroused great interest due to their wide application areas such as legal documents, certificates, digital books and engineering drawings. There are a few of important methods for data hiding in binary images in references [WU 04], [PAN 00], [TSE 01], [YAN 07], and [CHE 07].

[WU 04] referred a predefined flippability lookup table and flipped some number most flippable pixels to embed one bit in one block. Wu’s scheme took watermarked image quality in to account while the capacity is limited for only one hidden bit for one block. In order to enhance the capacity, another method based on using secret keys and weight matrix has also been suggested [PAN 00]. This method succeeds in increasing the capacity but the penalty is poor quality of the watermarked image especially when it tries to achieve high capacities. Further improvements on visual quality are obtained by using the edge pixels [TSE 01]. Choosing suitable pixels to carry watermark data in a blind data hiding method based on preserving the connectivity of pixels in a local neighborhood is proposed in [YAN 07]. The “flippability” of a pixel is determined by imposing three transition criteria in a 3×3 moving window centered at the pixel. Recently a new objective distortion measure is proposed which evaluates the distortion introduced by changing individual edge pixels based on edge line segment for binary text images [CHE 07].

By combining two methods that are presented in [TSE 01] and [CHE 07], this paper will make a little improvement in quality of the binary text images after data hiding without any reduction in capacity.

1. Reviews

1.1. Data hiding in binary images

In Tseng scheme [TSE 01], we are given a host binary image \( F \). \( F \) will be partitioned into blocks \( F_i \) of fixed size \( m \times n \). There are some symbols should be depicted.

1. \( F_i \) : a host block bitmap of size \( m \times n \), which is to be modified to embed data.
2. \( K \) : a secret key shared by the sender and the receiver. It is a randomly selected matrix with elements \( \{0,1\} \) of size \( m \times n \).
3. \( r \) : the number of bits to be embedded into each \( F_i \). The value of \( r \) satisfies \( r \leq \lfloor \log_2(mn+1) \rfloor - 1 \).
4. \( W \) : a secret weight matrix shared by the sender and the receiver. It is an integer matrix of size \( m \times n \) which is randomly arranged with elements \( \{W_{ij} \mid i = 1,...,m; j = 1,...,n\} = \{1,2,...,2^{r+1} - 1\} \). Each element will appear at least once in \( W \) and for
each 2×2 sub-block of \( W \), the sub-block contains at least one odd element.

5. \( B \): information consisting of \( Lr \) bits to be embedded in \( F \), where \( L \) is the number of \( m \times n \) blocks in the host image.

6. \( dist(F) \): an integer matrix of the same size as \( F \) such that:

\[
[dist(F)]_{ij} = \min \left\{ \sqrt{(x-x')^2 + (y-y')^2} \left| \left[ F \right]_{ij} \neq \left[ F \right]_{x',y'} \right. \right\}.
\] (1)

That is, \( [dist(F)]_{ij} \) is the distance from \( [F]_{ij} \) to the closest element \( [F]_{x',y'} \) such that the complement of \( [F]_{x',y'} \) is equal to \( [F]_{ij} \).

The detailed data hiding steps are as follows.

\textit{Step 1.} If \( F_i \) is completely black or blank, simply keep \( F_i \) intact (no hidden with data) and skip the following steps. Otherwise, perform the following.

\textit{Step 2.} Compute \( SUM((F_i \oplus K) \otimes W) \), where \( \oplus \) and \( \otimes \) are bitwise exclusive-OR and pair-wise multiplication operator on two equal-size integer matrices, respectively.

\textit{Step 3.} From the matrix \( F_i \oplus K \), compute for each \( w = 1, \ldots, 2^{r+1} - 1 \) the following set:

\[
S_w = \left\{\{j,k\} \mid \left[ W \right]_{j,k} = w, \left[ F_i \oplus K \right]_{j,k} = 0, \left[ dist(F) \right]_{j,k} \leq \sqrt{2} \right\},
\] (2)

Intuitively, \( S_w \) is the set containing every matrix index \( (j,k) \) such that a pixel with its complement value exists in its 8-connected neighbors and if we complement the \( [F_i]_{j,k} \), we can increase the sum in step 2 by \( w \). Also, define \( S_w = S_w' \) for any \( w = w' \mod 2^{r+1} \).

\textit{Step 4.} Define a weight difference

\[ d = (h_0b_2 \ldots b_{r+1}) - SUM((F_i \oplus K) \otimes W) \mod 2^{r+1} \] (3)

if \( d = 0 \), there is no need to change \( F_i \). Otherwise, we run the following program to transform \( F_i \) to \( F_i' \).

If possible randomly pick an \( h \) from \( \{1,2,\ldots,2^{r+1} - 1\} \) such that \( S_{hd} \neq \phi \) and \( S_{-(h-1)d} \neq \phi \).

a) Randomly pick a point \((j,k)\) \in \( S_{hd} \) and complement the bit \( [F_i]_{j,k} \).

b) Randomly pick a point \((p,q)\) \in \( S_{-(h-1)d} \) and complement the bit \( [F_i]_{j,k} \).

By changing these two points \( hd \) and \( -(h-1)d \) will be added to \( SUM((F_i \oplus K) \otimes W) \). So in total the sum will be increased by \( d \), as it was required.

If it is not possible to find such an \( h \), no data will be hidden. We compute \( SUM((F_i \oplus K) \otimes W) \mod 2 \). if it is equal to 1 then \( F_i \) will be kept intact. Otherwise, we select a point \((j,k)\) \in \( S_w \) where \( w \) is an odd number and complement the bit \( [F_i]_{j,k} \). Therefore, an odd sum determines that no data is hidden. However, note that if the resultant block is completely black or blank, we will regard the data hiding as invalid. That is, we will hide the same bit stream again in the next host block.

\textit{Step 5.} Upon receiving the block \( F_i' \), the receiver computes \( SUM((F_i' \oplus K) \otimes W) / 2 \). This is the hidden data if the block is not completely black or white and \( SUM((F_i' \oplus K) \otimes W) \) is even.

Here undefined \( S_0 \) could be regarded as non-empty set although nothing is changed to achieve an increase of weight by 0, the same with multiples of \( 2^r \).

1.2. Objective distortion measure for binary text image

Objective distortion measure based on edge line segment proposed in [CHE 07] which calculates the edge line segment similarity for binary text images. This measure is proposed based on how the overall shape of edges are affected by the flipping some of the pixels.

An edge line is defined as the common sharing ‘line’ between two neighboring pixels where the pixel values for the two pixels are different. The edge pixel refers to pixels (either white or black) on the edge. When the edge line changes its direction by 90 degrees, it forms a sharp “corner.” For a 2×2 block, if any two pixels in the same row or column have different colors, the four pixels form a cross at the center point of the block. Each edge line segment starts from one corner or cross and ends at another corner or cross without any corner or cross in between. These corners or crosses define the two ends of the ends of the edge line segment. An edge line segment is associated with a pixel if flipping the pixel changes the edge line segment.

The edge line segments associated with an individually flipped pixel and the length of each line segment play an important role in distortion measure. For the two edge line segments whose length are \( l_1 \) and \( l_2 \), their edge line segment similarity are defined as:

\[
ELSS = \frac{\min(l_1,l_2)}{\max(l_1,l_2)}
\] (4)

Larger ELSS corresponds to less distortion to the edge line segment pair and we use \((1-ELSS)\) as the distortion for a given pair of edge line segments. The edge line distortion score \( EDSS \) calculated based on the edge line segments for the \( k \)th flipped pixel is
given by:
\[
ELDS_k = \sum_i \left(1 - \frac{\min\{l_{i1}, l_{i2}\}}{\max\{l_{i1}, l_{i2}\}}\right)
\]  

where \(l_{i1}\) and \(l_{i2}\) are the edge line segment lengths of the \(i\)th pair of edge line segments that are associated with the \(k\) th pixel before and after flipping.

2. Propose a simple scheme for improving quality of the image after data hiding

Since in Tseng Scheme [TSE 01] each bit being modified is neighboring to a bit that is equal to its new value, thus we can use objective distortion measure [CHE 07] to select the most flippable pixel when hiding information. For each host image block \(F_i\), we store all \(h \in \{0,1,...,2^{r+1} - 1\}\) such that \(S_{hd} \neq \emptyset\) and \(S_{d, (h-1)d} \neq \emptyset\) and also store pairs of coordinates \((j,k) \in S_{hd}\) and \((p,q) \in S_{(h-1)d}\). In the selection process of flipping pixels, select one pair of pixels which have smallest sum of edge line distortion score (ELDS). In other words, Step 4 in section 1.1 changes as follows:

Step 4. Define a weight difference
\[
d = (h, b_2...b_0) - \text{SUM}(\{F_i \oplus K\} \oplus W) \mod 2^{r+1}
\]  

if \(d = 0\), there is no need to change \(F_i\). Otherwise, we run the following program to transform \(F_i\) to \(F_i’\).

a) Store all \(h \in \{0,1,...,2^{r+1} - 1\}\) such that \(S_{hd} \neq \emptyset\) and \(S_{d, (h-1)d} \neq \emptyset\).

b) Store pairs of coordinates \((j,k) \in S_{hd}\) and \((p,q) \in S_{(h-1)d}\) into \(SS_d\).

c) Select one pair of coordinates in \(SS_d\), the pixels on which have smallest sum of edge line distortion score (ELDS).

3. Experimental results and analysis

Due to flippability analysis for each pixel, our scheme improves the image quality after data hiding. The watermark extraction process is a simple reverse process of watermark embedding.

We used the visual distortion table proposed by [WU 04] to evaluate improving of quality image in the data hiding method, which is defined in [YAN 07]. The flippability score (FC) is obtained by matching the 3×3 pattern centered at the flipped pixel in the look up table. The complement of flippability score with reference to value “1” is used, namely “distortion score (DS)” and given by:

\[
DS(i) = 1 - FC(i)
\]  

where \(i\) represents the \(i\)th flipped pixel. The total distortion (TD) and the average per pixel distortion (APPD) introduced by flipping pixels in binary images are defined as

\[
TD = \sum_{i=1}^{n} DS(i) \Rightarrow APPD = TD/n
\]  

where \(n\) denotes the total number of pixels being flipped to embed the data.

Herein, Tseng scheme [TSE 01] and the proposed scheme are implemented on two types of binary images, i.e. English and Chinese documents of size 337×337. The results of experiments are shown in Figure 1, Figure 2 and Table 1. It can be observed that the visual quality of the image watermarked obtained by using our proposed method is a little better than Tseng scheme.

4. Conclusion

In this paper we revised the data hiding method is proposed in [TSE 01] and we could improve the quality of watermarked image by using of edge line distortion score, without any reduction in capacity. In theory, our scheme has high capacity of \(M = \lceil \log_2((mn+1)-1) \rceil\) bits per block and taking image quality into account we always choose \(r\) as half of \(M\). we utilize edge line distortion score (ELDS) of every pixel to control image quality after watermarking. Therefore when the same watermark capacity is demanded our scheme achieves a little better performance in aspect of image quality. The improved scheme can be applied to a wide variety of binary text images authentication and data secret transmission.

<table>
<thead>
<tr>
<th>Method</th>
<th>Text</th>
<th>Capacity (bit)</th>
<th>TD</th>
<th>APPD</th>
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<td>Proposed</td>
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<td>405</td>
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<tr>
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<td></td>
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</tbody>
</table>
Figure 1. Comparison of hiding effect. (a) the original English text image of size 337×337. (b) and (c) After embedding 405 and 243 bits by the proposed scheme, respectively. (d) and (e) After embedding 405 and 243 bits by Tseng scheme, respectively.

Figure 2. Comparison of hiding effect. (a) the original Chinese text image of size 337×337. (b) and (c) After embedding 500 and 300 bits by the proposed scheme, respectively. (d) and (e) After embedding 500 and 300 bits by Tseng scheme, respectively.

REFERENCES


