Analysis of Reversible Watermarking using Image Compression and Histogram Shifting

Meghana Daware¹, Navnath Chine², Babasaheb Thombare³
megh296daware@gmail.com¹, navanath.chine@gmail.com², Babasaheb.114@gmail.com³
Department of Computer Engineering ¹, ², ³
SND College of Engineering and Research Centre, Yeola, India ¹, ², ³

Abstract— In this paper, we propose new reversible watermarking technique which is for data hiding. This data hiding enables embedding of messages in a host image without any loss of host content, which is proposed for image authentication that if the watermarked image is deemed authentic, we can revert it to the exact copy of the original image before the embedding occurred. Our first contribution is towards the modulation of the Histogram Shifting on image contents with compression of image. we present an improved histogram-based reversible data hiding technique based on pixel prediction and sorting. A rhombus pixel prediction is employed to explore the prediction for histogram-based embedding. Sorting the prediction has a good effect on increasing the embedding capacity. The second contribution is to hide data into textured area of the image. To achieve large hiding capacity we used characteristics of the pixel difference by keeping low distortion. The proposed scheme which derives a two-stage embedding strategy to solve the problem about communicating peak points. We also present a histogram shifting technique to prevent overflow and underflow. In this way, the watermark embedder and extractor synchronized for message extraction and image reconstruction.

Keywords— Reversible data hiding, image authentication, Reversible/lossless watermarking, data hiding.

I. INTRODUCTION

Since from last twelve years many reversible watermarking schemes have been proposed for protecting images of sensitive content, like medical or military images, for which any modification may affect their interpretation. These techniques allow the user to restore exactly the original image from its watermarked image by removing the watermark. Thus it becomes possible to update the watermark content, as for example security attributes (e.g., one digital signature or some authenticity codes), at any time without adding new image distortions. However, if the reversibility property releases constraints of invisibility, it may also introduce discontinuity in data protection.

Also, there are some sensitive images where any embedding distortion made to the image is intolerable, such as military images, medical images or artwork preservation. For example, even slight changes are not accepted in medical images due to a potential risk of a physician giving a wrong explanation of the image.

This is the reason why, there is still a need for reversible techniques that introduce the lowest distortion possible with high embedding capacity.

So, reversible data hiding techniques give a solution to the problem of how to embed a large message in digital images in a lossless manner so that the image can be completely restored to its original state before the embedding occurred. From the application point of view, reversible data hiding technique can be used as a fragile invertible authentication watermarking that embeds an authentication code in a digital image way.

II. HISTORY AND BACKGROUND

Reversible data hiding techniques is proposed for various fields such as audio [2], MPEG-2 video [3], 3D-meshes [4], visible watermarking [5], SMVQ-based compressed domain [6]. For lossless compression, Fridrich et al. [1] devised an invertible watermarking method by using a lossless compression algorithm to make space in which to embed data.

In 2003, Tian [9] devised a high capacity reversible data hiding scheme that is called difference expansion (DE), where the message is embedded based on the 1-D Haar wavelet transform.
Table I

<table>
<thead>
<tr>
<th>Paper</th>
<th>Authors, year</th>
<th>Technique Used</th>
<th>Advantages</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving various reversible data hiding schemes via optimal codes for binary covers</td>
<td>W. Zhang, B. Chen, and N. Yu 2012</td>
<td>Used a decompression algorithm as the coding scheme for embedding data.</td>
<td>The proposed code construction is proved to be optimal when the compression algorithm reaches entropy.</td>
<td>It only use two simple methods to modify HS, and therefore, the problem is whether there exists other more effective modifying methods or not. Another problem is how to design recursive codes for gray scale covers.</td>
</tr>
<tr>
<td>Reversible Data Hiding: Principles, Techniques, and Recent Studies</td>
<td>Nosrati, Ronak Karimi Mehdi Hariri 2011</td>
<td>primary techniques as the principles of RHD are talked.</td>
<td>Here investigated some RDH techniques. Also discussed their advantages and disadvantages.</td>
<td>There will be no idea about which is suitable in which domain.</td>
</tr>
<tr>
<td>Reversible image watermarking using interpolation technique</td>
<td>Lixin Luo, Zheyong Chen, Ming Chen, Xiao Zeng, and Zhang Xiong 2010</td>
<td>It utilize the interpolation-error, the difference between interpolation value and corresponding pixel value, to embed bit “1” or “0” by expanding it additively or leaving it unchanged.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Reversible watermarking algorithm using sorting and prediction.”</td>
<td>V. Sachnev, H. J. Kim, I. Nam, S. Suresh, and Y.-Q. Shi 2009</td>
<td>Sorting technique is used to record the prediction errors based on magnitude of its local variance.</td>
<td>The proposed scheme can embed more data with less distortion.</td>
<td>More calculations are needed. Size of location map affects the efficiency of the system.</td>
</tr>
<tr>
<td>An Effective Algorithm of Encryption and Decryption of Images Using Random Number Generation Technique and Huffman coding</td>
<td>, T. Bhaskara Reddy, Miss. Hema Suresh Yaragunti, Mr. T. Sri Harish Reddy, S. Kiran 2013</td>
<td>This algorithm is based on Caesar Cipher algorithm, random generation technique, concept of shuffling the rows i.e. rows transposition and Huffman Encoding.</td>
<td>Provides high security to an image and occupies minimum memory space.</td>
<td>Some problems in the decoding section such that, here Huffman coding is used.</td>
</tr>
<tr>
<td>“Reversible Data Hiding With Optimal Value Transfer”</td>
<td>Xinpeng Zhang, 2013</td>
<td>The optimal rule of value modification under a payload-distortion criterion is found by using an iterative procedure, and practical reversible data hiding scheme is proposed.</td>
<td>The optimal transfer mechanism gives a new rule of value modification and can be used on various cover values.</td>
<td>Computation complexity due to the prediction will be higher.</td>
</tr>
<tr>
<td>Difference Expansion Reversible Image Watermarking Schemes Using Integer Wavelet Transform Based Approach</td>
<td>Subhanya R.J (1) , Anjani Dayanandh N (2) 2014</td>
<td>Uses the watermarking algorithm that embeds image/text data invisibly into a video based on Integer Wavelet Transform and minimize the mean square distortion between the original and watermarked image and also to increase PSNR.</td>
<td>Can improve the quality of the watermarked image and give more robustness of the watermark and also increasing PSNR.</td>
<td>Low hiding capacity and complex computations.</td>
</tr>
<tr>
<td>“Separable reversible data hiding in encrypted image.”</td>
<td>X. Zhang 2012</td>
<td>A novel scheme for separable reversible data hiding, which consists of image encryption, data embedding and data-extraction/image-recovery phases.</td>
<td>Simple Less computation</td>
<td>Data compression is not efficient.</td>
</tr>
</tbody>
</table>

The DE scheme is able to embedding as high as 0.15 to 1.97 bpp, which is significantly larger than other schemes proposed previously. Kamstra et al. [11] improved the DE scheme by using the low-pass image to find suitable expandable differences in the high-pass band. Thodi and Rodriguez [12] proposed an improved version of the DE. In 2011, Ni DE-based schemes can achieve high embedding capacity, where the correlation inherent in the neighborhood of a pixel is better exploited than the DE scheme. Hu et al. [13] construct a payload dependent location map, where the compressibility of location map is further improved. Besides, several DE-based schemes [14][15][16] are also proposed recently in which they in differ in the employed prediction algorithm, capacity but low image quality. Histogram-based reversible data hiding scheme was first proposed by Ni et al. [17] in 2006, where the message is embedded into the histogram bin. They used pairs of peak points and zero points to achieve low.
embedding distortion but low hiding capacity. et al. [18][19] increased the hiding by extending the histogram modification technique for integer wavelet transform. Jun In 2009, Tsai et al. [20] used a residue image indicating a difference between a basic pixel and each pixel in a non-overlapping block to increase the embedding capacity. Tai et al. [21] designed a synchronization mechanism by selecting fixed peak bins in histogram of pixel differences. et al. [22] proposed an improved histogram modification based reversible data hiding technique with a consideration of the human visual system (HVS) characteristics. Yang and Tsai [23] used an interleaving prediction to improve histogram-based reversible data hiding. In 2013, Al-Qershi and Khoo [24] adopt a two-dimensional difference expansion technique (2D-DE) to increase the hiding capacity. Huang and Chang [25] employed modification of difference values between pixels by using histogram-based scheme with extensions to pyramidal structure by utilizing inherent characteristics of original images. Besides, Lou et al. [26][27] presented an innovative active steganalysis algorithm for reversible data hiding schemes based on histogram shifting. Their proposed active steganalysis algorithm can effectively detect stego images at low bit rates and estimate the hidden messages locations. Note that histogram-based reversible data hiding schemes can achieve high embedding capacity and high image quality. However, those techniques all suffer from the unresolved issue represented by the need to communicate pairs of peak and zero points to recipients.

III. DESIGN ISSUES

A. EMBEDDING

Embedding Algorithm

1) The image is divided into \( N_b \) non-overlapping blocks.

2) Let \( n \) be the number of (peak, zero). The more the number of pairs, the worse the image quality is. Then, the following iterations are executed \( n \) times for \( i = 1:n \).

3) For pair \( (p_i, z_i) \) the image block will be scanned. There are two kinds of conditions for different peak and zero points. The details are described as follows.

(a) \( p_i > z_i \)

For all intensity values of pixels located between \( z_i + 1 \) and \( p_i \), \( [z_i + 1, p_i] \) histogram shifts leftward by reducing intensity value to one. Therefore, a gap will be created at grey level \( p_i \). If embedding bits are ‘1’, \( p_i \) pixels value will increase by 1. Otherwise, the \( p_i \) pixels value will not be modified.

(b) \( p_i < z_i \)

For all intensity values of pixels located between \( p_i + 1 \) and \( z_i - 1 \), \( [p_i + 1, z_i - 1] \), histogram shifts rightward by increase intensity value by one. Thus, a gap at grey level \( p_i + 1 \) will be created. embedding bits are ‘1’, then the \( p_i \) is increased by 1. Otherwise, the intensity will not be changed.

A. Extraction

Data Extraction Process is a Reverse Process of Data Embedding

B. HISTOGRAM CREATION AND MODIFICATION

For a host image, we first generate its histogram and find a peak point and a zero point. A peak point corresponds to the grayscale value which is the maximum number of pixels in a given image assumes. On the contrary, a zero point corresponds to the grayscale value which no pixel in a given image assumes. For example, the histogram of the grayscale Lena image (512×512×8) is illustrated in Fig. 4, in which the peak point is at 154 and the zero point is at 255. Let \( P \) be the value of peak point and \( Z \) be the value of zero point. The range of the histogram, \( [P+1, Z-1] \), is shifted to the right-hand side by 1 to leave the zero point at \( P+1 \). Once a pixel with value \( P \) is encountered, if the message bit is “1,” increase the pixel value by 1. Otherwise, no modification is needed. We note that the number of message bits that can be embedded into an image equals to the number of pixels which are associated with the peak point.
C. RHOMBUS PREDICTION AND SORTING

To improve our previous work, we present the prediction sorting to generate the correlation of neighboring pixels. In order to predict the pixel value of position \( u_{i,j} \) in Fig. 5, we use a rhombus prediction by considering four neighboring pixels \( v_{i-1,j}, v_{i-1,j+1}, v_{i+1,j}, v_{i+1,j+1} \). All pixels of the image are divided into two sets: the “White” set and “Gray” set. The pixel value \( u \) of the White set is predicted by using the four neighboring pixel values of the Gray set and to hide data. Note that the two sets are independent, which means changes in one set do not affect the other set, and vice versa. The center pixel \( u_{i,j} \) can be predicted from the four neighboring pixels \( v_{i-1,j}, v_{i-1,j+1}, v_{i+1,j}, v_{i+1,j+1} \). The predicted value \( u'_{i,j} \) is computed as follows:

\[
\begin{align*}
\setlength{
\abovedisplayskip}{2pt}
\setlength{
\abovedisplayshortskip}{2pt}
\setlength{
\belowdisplayskip}{2pt}
\setlength{
\belowdisplayshortskip}{2pt}
\end{align*}
\]

In order to hide more data with less visual degradation the pixel difference needs to be changed. Thus, the cover pixels can be rearranged by sorting according to the prediction of neighboring pixels. To ensure the reversibility, we use a stable sorting algorithm to sort the prediction values. Sorting cover pixels according to the prediction values enables hiding data in pixel difference with high embedding capacity. As a result, this observation leads us toward designs in which the embedding is done in pixel differences according to the prediction sorting. Hiding data according to the sorting adapted to the rhombus prediction will be presented in more detail in Section

D. HISTOGRAM MODIFICATION ON PIXEL DIFFERENCES

The reversible data hiding scheme for White set is designed as follows.

1) Predict the pixel value \( u_{i,j} \) in White set using Eq. 1

2) Sort the host pixel \( u_{i,j} \) according to the prediction value \( u'_{i,j} \) and produce the sorted pixels \( \{x_0, x_1, ..., x_i\} \) for \( 0 \leq i \leq N-1 \) where \( N \) is the pixel number of White set.

3) Calculate the pixel difference \( d_i \) between pixels \( x_{i-1} \) and \( x_i \) by

\[
\begin{align*}
\setlength{
\abovedisplayskip}{2pt}
\setlength{
\abovedisplayshortskip}{2pt}
\setlength{
\belowdisplayskip}{2pt}
\setlength{
\belowdisplayshortskip}{2pt}
\end{align*}
\]

4) Determine the peak point \( P \) from the pixel differences.

5) If \( d_i > P \), shift \( x_i \) by 1 unit:

\[
\begin{align*}
\setlength{
\abovedisplayskip}{2pt}
\setlength{
\abovedisplayshortskip}{2pt}
\setlength{
\belowdisplayskip}{2pt}
\setlength{
\belowdisplayshortskip}{2pt}
\end{align*}
\]

6) If \( d_i = P \), modify \( x_i \) according to the message bit:

\[
\begin{align*}
\setlength{
\abovedisplayskip}{2pt}
\setlength{
\abovedisplayshortskip}{2pt}
\setlength{
\belowdisplayskip}{2pt}
\setlength{
\belowdisplayshortskip}{2pt}
\end{align*}
\]

7) Construct the watermarked White set according to the sorted pixels \( \{y_0, y_1, ..., y_i\} \) for \( 0 \leq i \leq N-1 \) where \( N \) is the pixel number of White set.

The embedding scheme for White set computes predicted values using the Gray set and embeds data using the White set. Thus, the output of the embedding scheme for White set is the unchanged pixels from the Gray set and the watermarked pixels from the White set. Similarly, we can embed data in Gray set by considering the predicted values using the watermarked White set. The White and Gray embedding schemes are similar in nature. As a result, the consecutive usage of the White embedding scheme and the Gray embedding scheme results in nearly double the embedding capacity. At the receiving end, the recipient
extracts message bits from the watermarked image by scanning the image in the same order as during the embedding. The recipient sorts the watermarked pixel $u'_{i,j}$ in White set according to the prediction value $u'_i$, and produces the sorted pixels $\{y_0, y_1, \ldots, y_L\}$. The message bit $b$ can be extracted by,

$$b = \begin{cases} 0, & \text{if } |y_i - x_{i-1}| = P, \\ 1, & \text{if } |y_i - x_{i-1}| = P + 1, \end{cases}$$

... (5)

where $x_{i-1}$ denotes the restored value of $y_{i-1}$. Then the original pixel value of $x_i$ can be restored by

$$x_i = \begin{cases} y_i + 1, & \text{if } |y_i - x_{i-1}| > P \text{ and } y_i < x_{i-1}, \\ y_i - 1, & \text{if } |y_i - x_{i-1}| > P \text{ and } y_i > x_{i-1}, \\ y_i, & \text{otherwise}. \end{cases}$$

... (6)

Thus, the exact copy of the original host image is obtained.

Fig. 6 shows an embedding example for White set of a grayscale image with 4×4 pixels. We first predict the pixel value $u'_{i,j}$ in White set using Eq. 1. Sort the host pixel $u_{i,j}$ according to the prediction value $u'_i$, and produce the sorted pixels $\{x_0, x_1, \ldots, x_L\}$. We then calculate the pixel difference $d_i$ between pixels $x_i$ and $x_{i-1}$. Thus, the peak point is 0 and the corresponding number is 5. Let us assume that the message bit-stream to be embedded is 01101. Since $|x_0 - x_1|=155-155|=0=P$, the first message bit 0 is embedded in $x_1$ by leaving $x_1$ unmodified. The difference between $x_1$ and $x_2$ is $|155-155|=0=P$, then the second message bit 1 is embedded in $x_2$ by setting $y_2 = x_2 + 1$ since $x_2 > x_1$. As $|x_2 - x_3|=|155-156|=2 > P$ and $x_3 > x_2$, $y_3 = x_3 + 1=157$. The embedding process continues until all of message bits are embedded, and then the resulting watermarked pixels are obtained. Finally, we construct the watermarked White set according to the sorted pixels $\{y_0, y_1, \ldots, y_L\}$.

Given $P=0$, we can completely restore the image to its original state before the embedding occurred. The recipient sorts the watermarked pixel $u_{i,j}$ in White set according to the prediction value $u'_i$, and produces the sorted pixels $\{y_0, y_1, \ldots, y_L\}$. If $|y_1 - x_0|=|155-155|=0 = 0 = P$, a message bit 0 is extracted and $x_1 = y_1$. The difference between $y_2$ and $x_1$ is $|156-156|=0=P+1$, a message bit 1 is extracted and $x_1$ is restored by setting $x_2 = y_2 = 1=155$ since $y_2 > x_1$. Thus, the extraction process continues until all of message bits are extracted. Thus, the watermarked image is reverted to the exact copy of the original host image.

E. PREVENT OVERFLOW AND UNDERFLOW

Modification to a pixel may not be allowed if the pixel is saturated (0 or 255). Pixels causing overflow or underflow errors should be excluded.

The condition,

$$0 \leq y_i \leq 255$$

is used for finding such problematic pixels. To prevent overflow and underflow, we adopt a histogram shifting technique [21] that narrows the histogram from both sides as shown in Fig.7.

Note that a single layer data hiding process consists of White and Gray data hiding. Let us assume that the number of peak points that we use to embed messages is $L$ when we adopt the proposed $L$-layer data hiding scheme. Thus, we shift the histogram from both sides by $L$ unit to prevent overflow and underflow since the pixel $x_i$ that satisfies $d_i \geq L$ will be shifted by $L$ unit after the embedding occurred.
F. LOWER BOUND OF PSNR

Obviously, the pixel $x_i$ whose difference $d_i$ is larger than peak point will be either increased or decreased by 1 in the data embedding process with one peak point. Therefore, in the worse case, all pixel values will be increased or decreased by 1 but the first pixel. That is, the resulted mean squared error (MSE) is $(N-1)/N$, which is almost equal to 1 when $N$ is large enough. Thus, the lower bound of PSNR for the watermarked image generated from the embedding process with one peak point is

$$\text{PSNR (dB)} = 10 \times \log_{10} \left( \frac{255^2}{\text{MSE}} \right) \geq 48.13 \text{ dB}.$$ 

As a result, the lower bound of PSNR for the watermarked image generated by our proposed algorithm with one peak point is theoretically proved larger than 48 dB, which is also supported by our numerous experiments.

IV. RESULT AND ANALYSIS
Fig 10. Histogram of Shifted Image

Fig 11. Histogram of Embedded Image

Fig 12. Extraction Module

Fig 13. Histogram of Un-shifted Image

Fig 14. Histogram of Recovered Image

Fig 15. Extracted Data
V. CONCLUSION

In this paper, we present an efficient method histogram modification by considering the difference between adjacent pixels instead of simple pixel value. Further, we use prediction and sorting to enhance the correlation of neighbor pixels in order to improve the embedding capacity. In addition, to solve the problem of virtually histogram-based techniques is that they have to transmit pairs of peak and minimum points to recipients,, we introduce the two-state strategy to embed the overhead information. We also use a histogram shifting technique to prevent overflow and underflow. As a result, the evaluation results show that the proposed scheme have significantly improved our previous work [21] and derived better performance. This proposed system provides high capacities at small and invertible distortion. It can easily applied for compressed image formats, such as JPEG, MPEG, and JPEG2000, since the distribution of frequency coefficients is almost Laplacian distributed due to quantization and typical characteristics of images. Thus, the proposed system is able to be easily performed in the transform domain to improve the hiding ability.

REFERENCES


