REVERSIBLE DATA HIDING BASED ON INVARIANT IMAGE CLASSIFICATION AND EXPANSION EMBEDDING IN MEDICAL IMAGES

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Abstract—In this paper, an improved reversible data hiding scheme is proposed. In the method proposed by us, it apply expansion embedding, which will adaptively takes care of local specilities of image content. In our method, it classify pixels based on their predicted value and pixels prediction errors. By applying expansion embedding to the pixels prediction errors and by considering their immediate neighbourhood, the scheme we propose inserts data. The method proposed by us uses expansion embedding rather than histogram shifting used in existing system. The method proposed by us improves the performance by minimizing image distortion.

Keywords— HS (Histogram Shifting), DE (Difference Expansion), EE (Expansion Embedding), PHS (Pixel Histogram Shifting)

I. INTRODUCTION

Reversible watermarking was a milestone in the development of secure data hiding and digital watermarking. Several methods have been proposed to protect highly sensitive images like military images and medical images.

The main feature of reversible data hiding is that both the hidden data as well as the original medium before hiding is recoverable correctly. There are mainly three classification for reversible data hiding: Expansion embedding, Histogram shifting, a combination of both.

The basis for expansion embedding was first proposed by Tian et al in [1], which was further generalised by [2]. Expansion embedding can also be applied to pixel prediction errors. In [3] Sachnev et al proposed one.

In [4] Ni et al introduced a famous HS, which was related to single histogram maxima and minimum, and shifting of all pixels between that range. Overhead data, also need to be embedded along with original data. In [5], Neela et al proposed a good HS based watermarking.

The problem of overflows and underflows also need to be considered while embedding. In some methods, algorithms contain measures to avoid overflows and underflows. But in some, overhead data, that contain information about overflows and underflows need to be embedded along with original data.

In this paper we propose a combination of expansion embedding along with invariant image classification. The invariant image classification was proposed by Gouenou Coatrieux et al in [6], along with histogram shifting. The method proposed by us improves the PSNR value by minimising the image distortion.

This paper is organised as follows: Section II contain motivation, section III describes about system model and experimental set up, section IV contain a brief explanation about existing system, section V explain the proposed method, section VI contain experimental results, section VII is conclusion of the paper.

II. MOTIVATION

The existing system that we referred to improve performance is one proposed by Gouenou Coatrieux et al [6] in 2013. In the method proposed by them, they mainly apply the method to medical images. They first classify the image pixel as background pixel and textured area pixels. In background area they apply pixel histogram shifting and in textured area, they apply dynamic prediction error histogram shifting.

They classify this based on pixel’s prediction errors and pixels predicted value. In order to embed a bit 1, they shift the pixels by +/- ∆ and in order to embed a bit 0, they make no change. They apply this technique of histogram shifting, only to pixels, whose prediction error value fall in a particular area (Carriers).

In the paper, proposed by Gouenou Coatrieux et al [6], they suggest to minimizing the image distortion. They suggest it by using their classification method and a good expansion embedding technique instead of using histogram shifting.

In the method proposed by us, we use the classification method proposed by Gouenou Coatrieux et al [6] and the difference expansion method proposed by Sachnev et al in [3]. The method proposed by us would improve the PSNR value and thus minimize the image distortion.
III. SYSTEM MODEL AND EXPERIMENTAL SETUP

The aim is to minimize image distortion, the existing system referred here is one proposed Gouenou Coatrieux et al in [6]. In their method, they mainly suggest the technique to medical images. We also use the medical images used in the standard [7]. The software we used for implementing is matlab of version 2010a.

IV. EXISTING SCHEME

In the existing system, proposed by Gouenou Coatrieux et at [6], they mainly use medical images. They does the water marking in two steps,
1. Invariant image classification
2. Data embedding by either PHS/DPEHS

A. Invariant Image Classification

In this phase, the pixels are classified as background area and textured area. They do this so by, evaluating the predicted value of a pixel. The predicted value $p_{i,j}$ of a pixel $P_{i,j}$ is derived from its four nearest neighbour pixels, by

$$\hat{p}_{i,j} = \frac{P_{i-1,j} + P_{i+1,j} + P_{i,j-1} + P_{i,j+1}}{4}$$

(1) [6]

If the predicted value $p_{i,j}$ falls in the range identified by $(p_{i,j} < \Delta)$ or $(p_{i,j} > (2^d - 1 - \Delta))$, then the pixels is identified as a background pixels. Otherwise the pixels are identified as textured area.

B. Data Embedding By PHS / DPEHS

All pixels in background area or in textured area are not used for embedding. They does this classification by evaluating the prediction error of pixels. The prediction error $e_{i,j}$ of a pixel $P_{i,j}$ is given by

$$e_{i,j} = P_{i,j} - \hat{p}_{i,j}$$

(2) [6]

In background area, if the prediction error $e_{i,j}$ of a pixel $P_{i,j}$ fall in the range $[-\Delta, +\Delta]$, then, the pixels are used for embedding [Carriers], and all other pixels are considered as non carriers.

In textured area, if the prediction error $e_{i,j}$ of a pixel $P_{i,j}$ fall in the range,

$$[-m_e - \Delta/2, -m_e + \Delta/2] \cup [m_e - \Delta/2, m_e + \Delta/2]$$

Where $m_e$ is the mean value of $\{e_{i-k,j-l} | k, l = -2, 0, 2 \}$ are considered as carriers. All other pixels are identified as non-carriers.

In order to embed a bit 0, either in background area or in textured area, no change is made either to prediction errors or pixel value. But, in order to embed a bit 1, the pixels/prediction errors are shifted by +/- $\Delta$, of the prediction errors are +/- negative respectively.

All the non carrier pixels are shifted by +/- $\Delta$, in order to avoid contradiction.

C. Overflows And Underflows

Overflows occur when the new pixel value fall above the maximum possible value and Underflows occur, when the new value fall below the minimum possible value.

Background Area: In background area, overflows and underflows are handled by overhead data. Overhead data is, that is to be embedded along with the original data other that it. It would minimize the data embedding capacity.

If overflow/underflow occur in background area, then that corresponding pixels is identified flag bits, row and column number etc in the overhead data.

If the predicted value fall in low part ie: $p_{i,j} < \Delta$, then there is no problem of Overflow, but there may be underflows. Similarly if the predicted value fall in the range $(p_{i,j} > (2^d - 1 - \Delta))$ there is no problem of underflow, but there may be overflows.

Textured Area: In textured area, in order to discriminate water markable pixels, that don’t introduce overflows/underflows, it uses a different approach. They use two characteristics defined as $\bar{m}_e_{min}$ and $\bar{m}_e_{max}$. The value $\bar{m}_e_{min}$ corresponds to the minimum value of a block $B_k$ and $\bar{m}_e_{max}$ corresponds to maximum values of $B_k$.

D. Overall Scheme

The overall procedure is given below,

1. Calculate the value of $\bar{m}_e_{min}$ and $\bar{m}_e_{max}$ for the image
2. Consider the pixels one by one in row and column wise order.
3. For each pixels, the pixels predicted value $\hat{p}_{i,j}$, prediction error $e_{i,j}$, mean value $m_e$, $\bar{m}_e_{min}$, $\bar{m}_e_{max}$ are calculated.
4. If the pixels predicted value $\hat{p}_{i,j}$, fall in the case of background area,
   a. The prediction error $e_{i,j}$ fall in the range $[-\Delta, +\Delta]$, then take as carrier pixel and embed the bit.
   b. Otherwise, non carriers shift it by +/- $\Delta$.
5. If the prediction error $e_{i,j}$, fall in the case of textured area,
V. PROPOSED SCHEME

In the method proposed by us, instead of using histogram shifting with invariant image classification, we use difference expansion embedding with invariant image classification.

We use the same method as in existing scheme to identify the carriers and non carriers (that is watermarkable pixels and non watermarkable pixels). We apply expansion embedding to pixels prediction errors for embedding, instead of shifting it by +/- Δ. The expansion embedding we use is one proposed by Sachnev et al in [3].

A. Prediction Error Expansion Embedding

The expansion embedding proposed by Sachnev et al in [3] is as shown below:

For Pixel \( R_{i,j} \), its predicted value \( \hat{R}_{i,j} \) is calculated as in equation (1). Then find its prediction error \( \varepsilon_{i,j} \) by (2). The prediction error can be expanded to embed a bit b, using

\[
\varepsilon_{i,j} = 2 \times \varepsilon_{i,j} + b
\]

After data embedding the original value \( R_{i,j} \) is modified to \( P_{new_{i,j}} \) as follows:

\[
P_{new_{i,j}} = E_{i,j} + P_{i,j}
\]

In the image, the \( R_{i,j} \) is replaced by the value of \( P_{new_{i,j}} \) if it does not cause any overflows and underflows.

B. Prediction Error Expansion Decoding

The decoding procedure is as shown below:

The predicted value \( \hat{R}_{i,j} \) is calculated first by using equation (1). The modified prediction error is computed as follows.

\[
E_{i,j} = P_{new_{i,j}} - \hat{R}_{i,j}
\]

The embedded bit can be extracted as follows.

\[
\hat{R}_{i,j} = E_{i,j} \mod 2
\]

The original prediction error is computed as follows.

\[
\varepsilon_{i,j} = \left\lfloor \frac{E_{i,j}}{2} \right\rfloor
\]

The original pixel value in the position \((i,j)\) is recovered as follows.

\[
P_{i,j} = \varepsilon_{i,j} + \hat{R}_{i,j}
\]

In our method, we use invariant image classification to classify background pixels and textured area pixels [6] (section 4 a). In background area and textured area in order to distinguish watermark able pixels and non watermarkable pixels we use the method described in section 4 B.

But for embedding, instead of embedding a bit we use expansion embedding instead of histogram shifting by +/- Δ.

In the existing scheme the non carrier (non watermarkable) pixels are also shifted by +/- Δ. In the method proposed by us, the non carrier pixels are not changed. Hence we can minimize the image distortion and thus improve performance.

C. Embedding Procedure

The overall procedure for data embedding is as below:

1. Read the image and consider it as a matrix of pixels.
2. Calculate the value of \( R_{min} \) and \( R_{max} \) of the image.
3. Consider the pixels one by one in a predefined sequence.
4. Calculate the value for pixels predicted value \( P_{i,j} \), prediction error \( E_{i,j} \), mean value \( m_e \), block minimum \( m_{min} \), block maximum \( m_{max} \) etc.
5. If the pixels predicted value fall in the range by \( p_{i,j} \) (background pixel)

\[
\frac{\Delta}{2} \leq p_{i,j} < \frac{\Delta}{2}
\]

\[
(2^d - 1 - \Delta)
\]

The new pixel value,

\[
P_{new_{i,j}} = E_{i,j} + P_{i,j} #
\]

b. Else the pixels are not used for embedding (ie. Non-Carriers)

\[
P_{new_{i,j}} = P_{i,j}
\]

6. If the prediction error \( \varepsilon_{i,j} \) fall in the range of

\[
[-m_e, m_e + \frac{\Delta}{2}] \cup [m_e + \frac{\Delta}{2}, m_e + \frac{\Delta}{2}]
\]
a. If , $\bar{e}_{\text{max}} > T_{\text{min}}$ and $\bar{e}_{\text{max}} < T_{\text{max}}$ (Carriers) , then embed the bit as

\[ E_{i,j} = 2 \times e_{i,j} + \text{bit} \]

The new pixel value, 

\[ P_{\text{new}}_{i,j} = E_{i,j} + P_{i,j} \]

b. Else the pixels are not used for embedding (ie. Non-Carriers)

\[ P_{\text{new}}_{i,j} = P_{i,j} \]

7. Else the pixels are not used for embedding

The new pixel value,

\[ P_{\text{new}}_{i,j} = P_{i,j} \]

D. Extracting Procedure

The overall procedure for data extracting is as below:

1. Read the image and consider it as a matrix of pixels.

2. Calculate the value of $T_{\text{min}}$ and $T_{\text{max}}$ of the image.

3. Consider the pixels one by one in a predefined sequence as $P_{i,j}$

4. Calculate the value for pixels predicted value $\hat{P}_{i,j}$ , modified prediction error $\hat{e}_{i,j}$ , as described in section 5A

\[ E_{i,j} = P_{\text{new}}_{i,j} - \hat{P}_{i,j} \]

The expected embedded bit as

\[ e_{i,j} = \left\lfloor \frac{E_{i,j}}{2} \right\rfloor \]

The original pixel value,

\[ P_{\text{new}} = e_{i,j} + \hat{P}_{i,j} \]

5. Set the new pixel value $P_{\text{new}}$ as the value of pixel in location (i,j)

\[ \text{Ie: Temp}= Image (i,j) \]

And Image (i,j) = $P_{\text{new}}$

Then find the value of predicted value $\hat{P}_{i,j}$ , prediction error $\hat{e}_{i,j}$ , mean value $m_e$ , block minimum $\bar{e}_{\text{max}}$ , block maximum $\bar{e}_{\text{max}}$ .

6. If the pixels predicted value fall in the range by (p$_{i,j} < \Delta$ ) or (p$_{i,j} > (2^d-1 - \Delta)$ ) . ie. Background area pixel

a. If the prediction error $\hat{e}_{i,j}$ fall in (-$\Delta$ ,+$\Delta$) (Carrier pixel) , then take the embedded bit as $b$ , set original pixel value at location (i,j) as $P_{\text{new}}$

b. Else the pixels were not used for embedding (ie. Non-Carriers) , set original pixel value at location (i,j) as temp and discard the extracted bit $b$ .

7. If the prediction error $\hat{e}_{i,j}$ fall in the range of

\[ \left[ -m_e - \Delta/2, -m_e + \Delta/2 \right) \cup \left[ m_e - \Delta/2, m_e + \Delta/2 \right]. \]

a. If , $\bar{e}_{\text{max}} > T_{\text{min}}$ and $\bar{e}_{\text{max}} < T_{\text{max}}$ (Carriers) , then take the embedded bit as $b$ , set original pixel value at location (i,j) as $P_{\text{new}}$

b. Else the pixels were not used for embedding (ie. Non-Carriers) , set original pixel value at location (i,j) as temp and discard the extracted bit $b$ .

8. Else the pixels were not used for embedding (ie. Non-Carriers) , set original pixel value at location (i,j) as temp and discard the extracted bit $b$ .

V. EXPERIMENTAL RESULTS

A. Image Database

Image data selected for comparing the existing system and proposed system is form the image in the standard text book of Digital Image Processing by Gonzalves.

The comparison was done based on the value of image distortion using PSNR.

\[ \text{PSNR} = 10 \cdot \log_{10} \left( \frac{N M \cdot (2^d - 2)}{\left( \frac{1}{L} \sum_{i=j}^{L} |(K(i,j) - (\hat{K}(i,j)))|^2 \right)^{1/2}} \right) \]

Where d corresponds to image depth , N & M are image dimensions.

B. Experimental Results

Table I shown below summarises the experimental results conducted on standard images . It shows the result of it with existing system and proposed system.

<table>
<thead>
<tr>
<th>Images</th>
<th>PSNR (Peak Signal to Noise Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head CT</td>
<td>25.51</td>
</tr>
<tr>
<td>Proposed</td>
<td>26.01</td>
</tr>
</tbody>
</table>
VI. CONCLUSION

This paper proposed a secure data embedding method. In this paper we proposed a new reversible data hiding scheme which uses a combination of invariant image classification and expansion embedding. It would minimize the image distortion than the one in existing systems. The method can be improved by better pixel prediction. The robustness of water marking should also be considered.

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REFERENCES


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Vandy | PET | 31.28 | 32.06
---|---|---|---
Blurred Heart | 21.5 | 20.87