Reversible Data Hiding with Image Contrast Enhancement Using Histogram Modification

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Abstract- **In this paper, reversible data hiding algorithm is proposed for digital images. In addition to that contrast enhancements of images are also performed to improve its visual quality. This technique ensures security and provides mechanism to protect the integrity of the message from any modification by preventing planned and accidental changes. Our method is based on 2D histogram modification to exploit the redundancy in digital images and to produce extra space for embedding to achieve very high embedding capacity. A preprocessing strategy is established to combine the neighboring bins in 2D histogram. By histogram equalization, overflow and underflow of the pixel values can be prevented. The lowest bins are used for reducing the changes made and the highest bins are effectively used for data embedding. By embedding in highest bins, contrast enhanced image can be achieved. The experimental results clearly establish that in comparison with the other reversible data hiding algorithm, the proposed algorithm achieves better performance in terms of contrast enhancement there by preserving image quality. The proposed technique achieves satisfactory and stable performance both on embedding capacity and visual quality.**

Index terms- **Reversible data hiding, 2D histogram, contrast enhancement, embedding capacity, image quality.**

I.INTRODUCTION

The demand of internet has made the transmission of digital media faster in the digital era. The availability of internet everywhere and the risks of illegal accessing of transmitted data is increasing day by day. Therefore, there is a need for protection of secret data from unauthorized users in a public network. This has become an important issue. Data hiding is one of the most important techniques to protect the security of digital media. Data hiding is used in a wide range of applications for embedding confidential messages. Sometimes hiding the information demolishes the host image even though the distortion is not visible to human eyes. In applications such as medical imagery and military imagery, no degradation of the original cover is allowed. In these cases, we need an important data hiding method known as Reversible Data Hiding or lossless data hiding. Reversible data hiding techniques are devised to solve the problems of lossless embedding of larger messages. The image can be restored completely without any loss. Contrast enhancement is executed to bring out unclear details and is widely used in medical images.

II. RELATED WORK

A brief survey of the early proposed methods are detailed as follows. In [1] ordered histogram shifting is used to improve the contrast in images .But the disadvantage of this method is that when pixels have identical values, data extraction and image recovery may fail. In [2] histogram shifting and controlled contrast enhancement (CCE) technique is proposed to efficiently remove the various attacks on watermark image. The drawback of this paper is that it has low payload capacity. In [3] bit plane slicing and histogram shifting based embedding is proposed to detect the distortion introduced by preprocessing. It has higher embedding rate but the disadvantage is that it is not accurate to measure the quality of images with PSNR. In [4] histogram shifting with the base line embedding and extensive embedding technique is used to generate marked images with good quality and better embedding payload. But the drawback is that artificial distortions are caused after conducting the preprocessing step. In [5] histogram equalization and image contrast enhancement by reversible data hiding technique is proposed to utilize contextual information around each pixel to enhance the contrast of an input image. The advantage of this technique is that the visual quality can be preserved. The disadvantage is that it does not produce better enhanced images. In [6] Global histogram equalization is a technique used to increase image brightness by making use of the histogram information of the cover image to make its transformation function. Additional storage requirements can be removed in this method. The drawback is that it fails to adapt with the local image brightness features and sometimes image recovery may fail. In [7] Encryption is done using cryptographic algorithm to improve the payload and image quality. The drawback is that it does not give conditional security. In [8] Encryption is done using ciphers and non-overlapping blocks. The advantage of this technique is that we can obtain satisfactory quality of decrypted images and also higher embedding rate. The disadvantage is that it may be subjected to some errors on data extraction and image restoration. In [9] Reversible data hiding using interpolation technique is used, which features minimum distortion and relatively very huge embedding capacity. The drawback is that auxiliary information needs to be separately provided for data extraction. In [10] High capacity reversible data hiding enhanced image algorithm based on multi MSB production is used to embed additional data by multi MSB substitution. This method achieved higher embedding capacity. The drawback is that it is very difficult to distinguish the prediction errors. In[11] Reversible data hiding based on reference pixel and block selection is used to adaptively embed data in the smooth blocks and thus improve the marked image quality with the comparable embedding capacity. This technique may be subjected to high distortion with image recovery being failed. In [12] Adaptive bin selection process and brightness preservation technique is used to achieve highest visual quality. This method can control the embedding distortion in provide sufficient embedding capacity. The disadvantage is that the constraint on choosing the bins to be expanded for data embedding is not relaxed. In [13] Reversible data hiding using control contrast enhancement and Haar integer wavelet transform is used to achieve large embedding capacity. However when a large number of bits is embedded, it can introduce over-enhanced images with obvious distortion for human visual perception. In [14] The contrast of region of interest (ROI) in medical images can be enhanced to get the foreground contour. This technique is less robust as the hidden data can be lost with image manipulation. In [15] Spatial steganography scheme is proposed in which four least significant bits of the cover image are used to hide secret information and a logistic mapping is employed to scramble cover image before embedding operation. This technique has very less security.

III. REVERSIBLE IMAGE CONTRAST ENHANCEMENT WITH A 2D HISTOGRAM

A. Generating 2D Histogram from Image

By scanning the image, the occurrences of every possible pixel value are counted to find the 1D histogram from a gray scale image. The occurrences of two adjacent pixel values are counted to calculate 2D histogram. A pair is formed by taking the pixel and the one to the right of that pixel and the non-overlapping pixel pairs in the image are scanned one by one. After counting the number of each pair of pixel values, a 2D histogram $H = \{h(0, 0), \cdots, h(255, 255)\}$ is calculated ,where $h(i, j)$ represents the number of pixel sets with value (i, j) in which $i \in \{0, \cdots, 255\}$, $j \in \{0, \cdots, 255\}$. The 2D histogram is illustrated in two different ways. The non-empty bins are visualized, when illustrated as a mesh and the bin heights are plotted in the 2D plane. A bin in 1dimensional histogram is similar to a row and column of bins in two dimensional histogram with the same pixel value on the right or left of a pixel set, respectively. The non-empty histogram bins are roughly distributed along the diagonal.

B. Preprocessing

Preprocessing is done to prevent the overflow and underflow of pixel values due to histogram shifting. By embedding a pixel, we can get a watermarked pixel with overflow and underflow values resulting in 256 and -1.To solve this, we can preprocess the pixel values 0 and 255 to 1 and 254.The steps followed here consist of modifying the image before embedding and embed the location map to the payload. The location map is generated and original pixel po is preprocessed to preprocessing pixel in the following ways:

Scan the image and set the value to avoid overflow and underflow of pixel values.

$$M_i = \begin{cases} 0 & \text{if } p_o = 1 \text{ or } 254 \\ 1 & \text{if } p_o = 0 \text{ or } 255 \end{cases} \quad (1)$$

$$p = \begin{cases} 254 & \text{if } p_o = 255 \\ 1 & \text{if } p_o = 0 \\ p_0 & \text{else} \end{cases} \quad (2)$$

Repeat the top mentioned steps until the image is scanned. During the extraction stage, recovery of pixel values 0 and 255 using M is insignificant:

i. Scan the image and set the values.

$$p_o = \begin{cases} 0 & \text{if } p = 1 \text{ and } M_i = 1 \\ 255 & \text{if } p = 254 \text{ and } M_i = 1 \end{cases} \quad (3)$$

ii. Repeat the top mentioned steps until the whole image is scanned.

The location map is compressed losslessly using arithmetic coding and is added to the payload.

C. *Data Embedding with 2D Histogram*

Even sets are embedded first and then the odd sets. If the sum of the horizontal and vertical position is even, then the pixel is considered to be even, likewise odd if the sum is odd.

Each pixel is embedded twice in the same row, using two estimates namely, the high estimate (p_h) and low estimate (p_l).

The first prediction error histogram is p-p_h. One bit is embedded in p using Positive Histogram Shifting:

$$p' = \begin{cases} p + b_1 & \text{if } p - p_h = 0 \\ p + 1 & \text{if } p - p_h > 0 \\ p & \text{else} \end{cases} \quad (4)$$

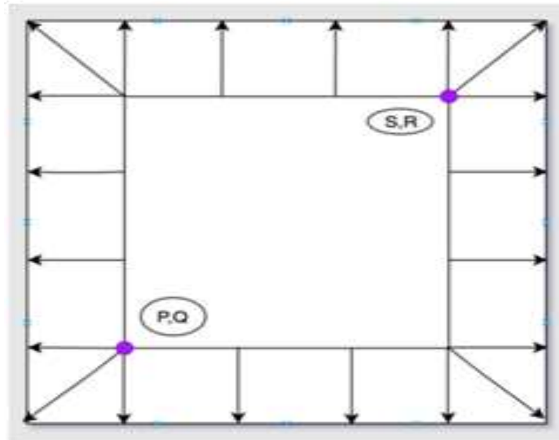
where $b_1 \varepsilon$ {0,1} is the first message bit and p' is the embedded pixel. If the prediction error is 0, only one bit is embedded and the rest of the pixels are shifted by 1 if prediction error is strictly positive.

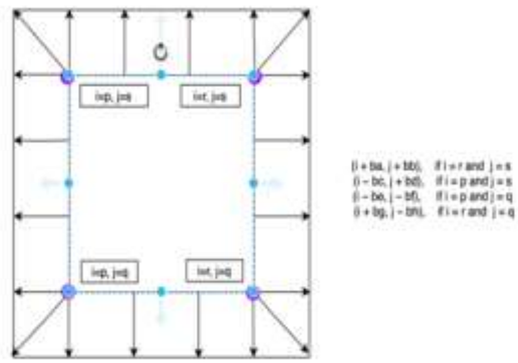
The second prediction error histogram is p'-p_l. One bit is embedded in p' using

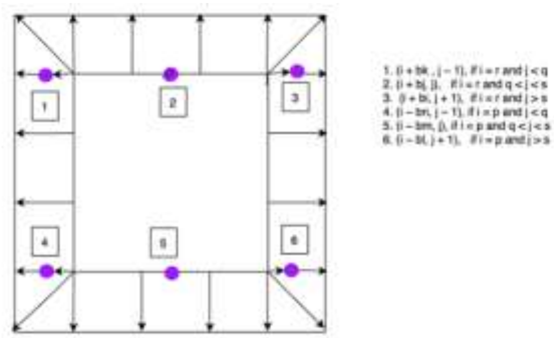
Negative Histogram Shifting:

$$p'' = \begin{cases} p' - b_2 & \text{if } p' - p_l = 0 \\ p' - 1 & \text{if } p' - p_l < 0 \\ p' & \text{else} \end{cases} \quad (5)$$

where $b_2 \varepsilon$ {0,1} is the second message bit and p'' is the embedded pixel. If the prediction error is 0, only one bit is embedded and the rest of the pixels are shifted if prediction error is strictly negative.







For eg:

p=50, q=50, r=200, s=200

(i,j) = (50,250)

i=50 => 10001100

j=250 => 11111010

Matched => i =p, j>s => (i-b,j+1)

Message bit (b) => 1

i-b=> 00110010

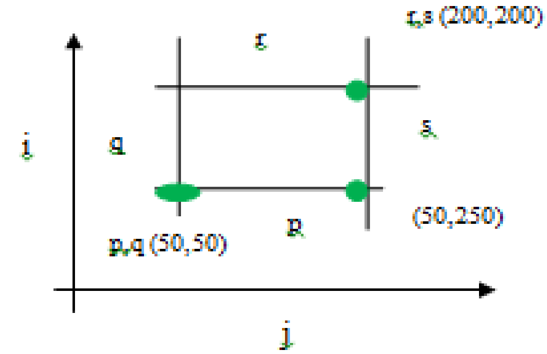
00000001

00110001

j+1 => 11111010

00000001

11111011



D. Data Extraction and Image Recovery

The steps used in embedding are performed in reverse order for extraction and recovery, odd pixels are recovered first before even pixels. Message bits are extracted using following equation:

$$b = \begin{cases} 0 & \text{if } p'' - p_l = 0 \\ 1 & \text{if } p'' - p_l = -1 \end{cases} \quad (6)$$

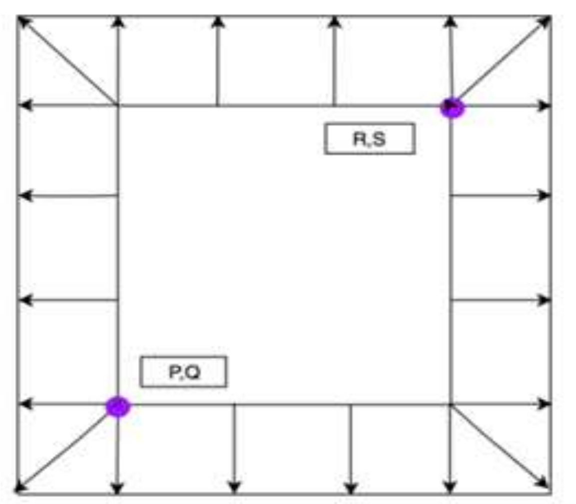
$$b = \begin{cases} 0 & \text{if } p' - p_h = 0 \\ 1 & \text{if } p' - p_h = 1 \end{cases} \quad (7)$$

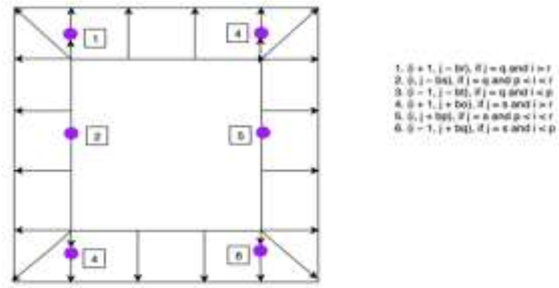
Pixels are recovered using the given equations:

$$p' = \begin{cases} p'' + 1 & \text{if } p'' - p_l < 0 \\ p'' & \text{else} \end{cases} \quad (8)$$

$$p = \begin{cases} p' - 1 & \text{if } p' - p_h > 0 \\ p' & \text{else} \end{cases} \quad (9)$$

The above mentioned steps are repeated for even set. The embedding capacity and the distortion will vary depending on different predictions.





E. Detailed Procedure of the Proposed Method

The data embedding along with contrast enhancement of an image consists of the following steps:

Step 1:To generate a two dimensional histogram of image.

Step 2:To perform preprocessing by merging adjacent rows and columns on each side for S times of two dimensional histogram and generating the location map.

Step 3:To append to the payload certain information such as the location map's size, location map and Least Significant bits of t+2 border pixels.

Step 4:To perform the steps (5 - 9) repeatedly for each predictor.

Step 5:To replace the t+2 border pixel Least Significant Bits with the payload length and predictor number.

Step 6: To sort the even pixels. Use Positive Histogram Shifting and then Negative Histogram Shifting to embed the first half of payload.

Step 7: To sort the odd pixels. Use Positive Histogram Shifting and then Negative Histogram Shifting to embed the other half of payload.

Step 8: To calculate the PSNR between original and each of the embedded images.

Step 9: To generate the embedded image with the highest PSNR.

The data extraction and image recovery process of the proposed method consists of the following steps:

Step 1: To collect the t+2 border pixel least significant bits and to extract the predictor number and payload length.

Step 2: To sort the odd pixels. Use Positive Histogram Shifting and then Negative Histogram Shifting to extract the second half of payload.

Step 3: To sort the even pixels. Use Positive Histogram Shifting and then Negative Histogram Shifting to extract the first half of payload.
Step 4: To replace the t+2 border pixel Least Significant Bits with the original least significant bits.
Step 5: To reverse the pre-processing strategy by uncompressing the location map.

IV. EXPERIMENTAL SETUP

A. Hardware Requirements

- System : Pentium IV 2.4 GHz.
- Hard Disk : 1 TB
- Ram : 512 Mb.

B. Software Requirements

- Operating system : Windows 10.
- Coding Language : MATLAB
- Tool : MATLAB R 2014

C. Dataset

The USC-SIPI image dataset is a collection of digitized images. It is maintained primarily to support research in image processing, image analysis and machine vision. It contains several 512 x 512 sized color and grey-scaled images.

V. EXPERIMENTAL RESULTS

A. Test Images:

(Splash)

(Baboon)

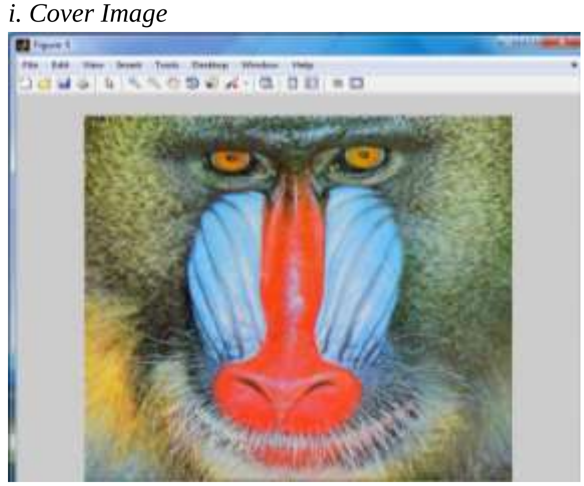
(Lena)

(F-16 Aeroplane)

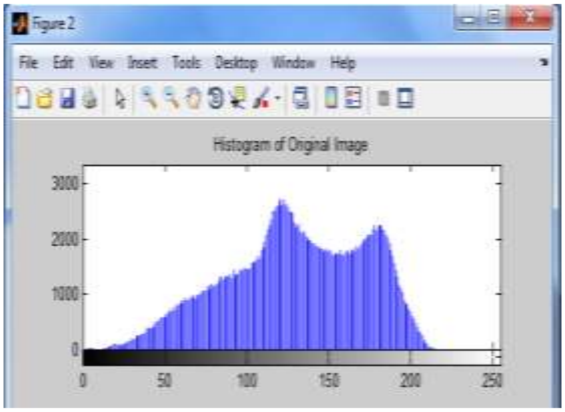
(Boat)

B. Output:

i. Cover Image

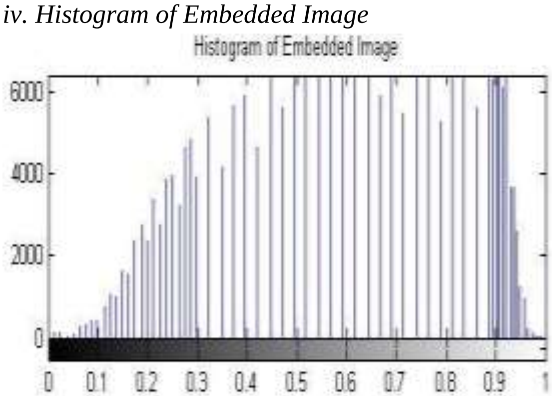


ii. Histogram of Cover Image



iii. Embedded Image

iv. Histogram of Embedded Image



C. Parameter Setting

The Mean Square Error (MSE) denotes the squared error between the embedded and the original image. Peak Signal-to-Noise Ratio (PSNR) denotes the ratio between the maximum possible power of a signal and the power of corrupting noise.

The lower the value of MSE, the lower is the error and higher is the PSNR value. The Structural Similarity Index (SSIM) is a detectable metric that quantifies image quality degradation caused by data compression or by losses in data transmission.

D. Existing Method

For 4.2.03.tiff (Baboon)

Embedding Capacity- 20,000 bits

TABLE I

METHOD	MSE	PSNR	SSIM
LSB	0.00075	80.607	0.99979
[5]	0.00958	77.859	0.92098
[6]	0.00991	79.859	0.94367

The above table shows the comparison of MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio) and SSIM (Structural Similarity Index) between three existing methods. The MSE of LSB method is lesser than other two methods and PSNR and SSIM of LSB is greater than other two methods. Since LSB value is lesser, this approach of image hiding will give less error than other two methods. The Second approach [5] gives lesser MSE, PSNR and SSIM than third method [6]. Since its MSE is lesser than the last approach, this method of hiding text will give less error than the last method. The third method [6] gives the higher MSE than other two methods; this will produce more error while the process of data hiding occurs.

E. Proposed Method

Statistical evaluation (mean) on USC-SIPI images

Embedding Capacity- 20,000 bits

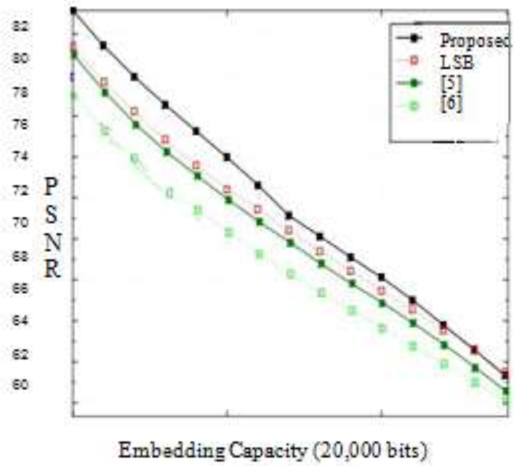
Image Dimension - 512 x 512

TABLE II

IMAGE	MSE	PSNR	SSIM
4.2.01tiff (Splash)	0.00010	81.0026	0.99932
4.2.03 tiff (Baboon)	0.00056	82.6136	0.99983
4.2.04 tiff (Lena)	0.00095	79.437	0.99973
4.2.05 tiff (F-16)	0.00095	79.569	0.99984
4.2.06 tiff (Boat)	0.00022	80.5347	0.99925

The above table describes the MSE, PSNR and SSIM values of five different input images. The images like Splash, Baboon, Lena, F-16 and Boat is taken as input and parameters like MSE, PSNR and SSIM is calculated. The MSE of the proposed method is less than the MSE of the existing methods. The PSNR of the proposed method is higher than the PSNR of the existing methods. So, this method is efficient and will give less error while data hiding when compared to the existing methods.

F. Efficiency of Proposed Method



VI. CONCLUSION

In this paper, we have proposed a new reversible data hiding method with image contrast enhancement. We have developed a preprocessing strategy by merging the adjacent rows or columns of bins in two-dimensional histogram. The changes that were made during preprocessing have been recorded. Lowest bin height is chosen to be merged with its adjacent row/column to minimize the changes made in bin merging while the highest bins can be expanded for data embedding. Thus a contrast enhanced effect can be obtained with satisfactory image quality. The process of image contrast enhancement can be performed in a lossless manner with the proposed method. The experimental results show that original image can be recovered from its contrast-enhanced versions. Also, the degree of contrast enhancement can be adjusted with respect to many parameters such as PSNR, MSE and SSIM.

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