Reversible Data Hiding with Contrast Enhancement by Histogram Shifting

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***Abstract*—In this paper, a new reversible Data Hiding algorithm (RDH) is presented for the images with poor visual quality .The proposed method can do the data hiding and improves the visual quality of the host image at the same time. The visual quality of the host image improved by enhancing the contrast. In this algorithm the highest two peaks in the histogram are chosen for data embedding, peaks before and after those two peaks are shifted repeatedly to achieve the contrast enhancement. Some side data also embedded along with the intended data into the host image, for the complete recovery. The proposed algorithm was tested on two images, the evaluated results shown that the contrast of the images was improved after data embedding .Hence this algorithm achieves the data hiding and contrast enhancement simultaneously.**

Index Terms*—Reversible data hiding, histogram shifting, contrast enhancement, image quality, Location map.

I. INTRODUCTION

Data hiding is a process of hiding some useful information in to the host data (e.g. audio, image, video). In the digital world the digital content can be easily manipulated, so the authentication is necessary to check the integrity of the data. Data hiding is the optimum technique to provide authentication. Apart from authentication data hiding also used for the copy control and distribution tracking etc. In the data hiding process some portions of the host data is modified permanently according to the hidden data. But for some applications like military and medical no permanent change in the host data is allowed. For those applications Reversible Data Hiding (RDH) [2] is needed, in which host data is completely recovered after the extraction of hidden data.

Previously proposed methods for reversible data hiding [3]-[8] for invisible and [9] visible are concentrated on keeping the Peak Signal-to-Noise Ratio (PSNR) value high. However for the images with poor illumination the visual quality need to be improved. There is always a trade-off between these two, if one is improved then the other one will be degraded. So more hiding rates leads to more distortion. Generally algorithms based on Histogram shifting will give low hiding capacity. The other methods [5], [6], [8] manipulate the correlation between the neighboring pixels to achieve more hiding rates. However with the multi-level histogram shifting [7] more hiding rates is possible.

Even though all the previous methods trying to keep the PSNR value high for the Stego images, the visual quality hardly preserved and the extra distortion had been introduced by the hiding process. However for the images which are taken in the poor lightning conditions the quality is needed to be improved, rather than keeping the PSNR value high. The images with poor illumination, which need authentication is generally observed in the applications like medical and military. For exactly like these applications we aim at the new RDH algorithm which will give data hiding and contrast enhancement simultaneously.

Generally for the low contrasted images the histogram is concentrated only in one area. Histogram is needed to be spreaded all over the gray levels to achieve the contrast enhancement. So this algorithm incorporated with the multi-level histogram shifting which can lead to histogram spreading, consequently contrast enhancement. In the first step the histogram of the image is computed and from that the highest two bins are evaluated. Then the bins after and before the highest bins are shifted outwards by keeping the bins between them as it is. Then the highest two bins and the emptied bins are modified according to the given data. This process is repeated for more hiding rates and for better contrast enhancement. The results shown that in this algorithm also have some distortion in the host image, but unlike the other methods the change in the host image is in the positive way, i.e. the contrast of host image get enhanced.

The rest of the paper as organized as follows, Section II contains the detailed explanation of proposed RDH algorithm, Section III contains the implementation steps. The experimental results are given in Section V, and finally conclusion in Section VI.

II. PROPOSED ALGORITHM

In this paper, the process of proposed algorithm is explained by choosing the images as 8-bit grayscale images. However this method can be applicable for color images by manipulating each plane at a time. The images with both dimensions equal were chosen for simplicity in calculations. Here f is the 8-bit grayscale host image, with dimensions $M \times M$, g is the gray values in f, $g \in \{0,1 \ldots .254,255\}$ Histogram of host image is $h_f, h_f(g)$ denotes the number of pixels in f which are having the gray value as g. h_l and h_h denotes lower gray level and higher gray level in the highest two bins respectively. f' is the marked image. The information which is to be hidden is denoted by b. L is the number of the pairs chosen.

A. Pre-Processing

The algorithm presented in this paper uses the concept of histogram shifting. In histogram shifting the highest two bins are chosen in each level, the bins which are in left and right sides of these two bins are shifted outwards, while remaining in between them kept unchanged. So if the original histogram contains *N* bins then the shifted version will have *N+2* bins. The permitted gray values of $g \in \{0,1,2 \ldots .255\}$.When the bins in 0 & 255 are shifted, the underflow and overflow errors will occur. To avoid these errors pre-processing is needed. For one level histogram shifting the pixels which are having gray levels 0 & 255 needed to be pre-processed. And for *L* levels the pixels in between [0, *L-1*] and [256-*L*, 255] are needed to be pre-processed. The algorithm presented here is reversible in nature, so we need to remember all these pre-processed pixels for the recovery process. So one two dimensional array with the dimensions same as the image is composed. The array will have 1 as the value in corresponding pre-processed location of the image, so that the image can be recovered in the extraction process. The pre-processing involves adding of +*L* and –*L* for the pixels in between [0, *L-1*] and [256-*L*, 255] respectively.

B. Data embedding by histogram shifting

Histogram $h(g)$ is calculated for the pre-processed host image *f.* In the histogram $h(g)$ the highest two bins h_l and h_h are evaluated by sorting histogram $h(g)$. By taking these two bins h_l and h_h as reference bins, the bins which are in left and right sides of these two shifted to left and right by one position. Consequently two bins are emptied on both sides of h_l and h_h respectively. Then the highest two bins are splitted in to four bins according to the data to be hidden. The histogram shifting is achieved by applying Eq. (1) on every pixel in the host image.

$$f' = \begin{cases} f-1, & \forall\, f < h_l \\ f, & \forall\, h_l < f < h_h \\ f+1, & \forall\, f > h_h \end{cases} \quad (1)$$

The splitting of highest two bins is performed by applying Eq. (2) on the host image.

$$f' = \begin{cases} h_l - b_k, & if\ f = h_l \\ h_h + b_k, & if\ f = h_h \end{cases} \quad (2)$$

The Eq. (1) and Eq. (2) is applied on the host image repeatedly *L* times. The last pair of bin values are stored in the LSBs of 16 excluded pixels from the bottom row of the host image.

C. Data Extraction

Extraction begin from the last pair of bin values which are extracted from the 16 excluded pixels from the bottom row of the image. Then the following operation mentioned in Eq. (3) is performed repeatedly *L* times for the pixels which are having gray values as $h_l - 1, h_l, h_h, h_h + 1$.

$$b'_k = \begin{cases} 1, & if\ f' = h_l - 1 \\ 0, & if\ f' = h_l\ or\ h_h \\ 1, & if\ f' = h_h + 1 \end{cases} \quad (3)$$

Where b'_k is the k-th binary bit of the extracted data from the marked image f'.

After the data have been extracted out, the original histogram is needed to for the further processing. So to recover the original histogram from the shifted version of it, the bins which are left and right sides of the highest two bins h_l and h_h are shifted inwards by one position, while the bins between h_l and h_h kept unchanged.

D. Post-processing

In embedding process pre-processing and data embedding are the two consecutive steps. As extraction process is reverse process of embedding process, in extraction process data extraction and post-processing have to be done consecutively to recover the pre-processed pixels. In post-processing by using the extracted location map the corresponding pixels in the recovered image are added by *L* subtracted by *L* to get the original host image.

III. IMPLEMENTATION

Embedding Process:

The complete embedding process is explained in Fig. 1. In pre-processing the location map is calculated. Since the location map is having same size as the image and it is added to the payload. So JBIG compression [10] is needed to compress the location map. Along with data side information such as compressed location map, size of it and LSBs of 16 excluded pixels are embedded to ensure the recovery of the host image at the extraction. After data embedding finally the last pair of bin values are stored in the LSBs of 16 excluded pixels from the bottom row of the host image.

Extraction Process:

The Extraction process is reverse process of the extraction process as shown in Fig. 2. It start from the extraction of LSBs from the 16 excluded pixels. After data has been extracted out the compressed location map and other side information is separated and the location map is decompressed by using same JBIG standard. By using the recovered location map the post-processing done to the recovered image to get back the original host image. Finally the LSBs of 16 excluded pixels are recovered and returned back in the image to get the original host image.

IV. CONTRAST ENHANCEMENT

As mentioned in section II-B the histogram is shifted in the data embedding process *L* times. Consequently the resulted histogram is more spreaded than the original histogram. The spreaded histogram indicates the increased contrast of the image. Larger *L* values gives the better contrast enhancement and more hiding rates.

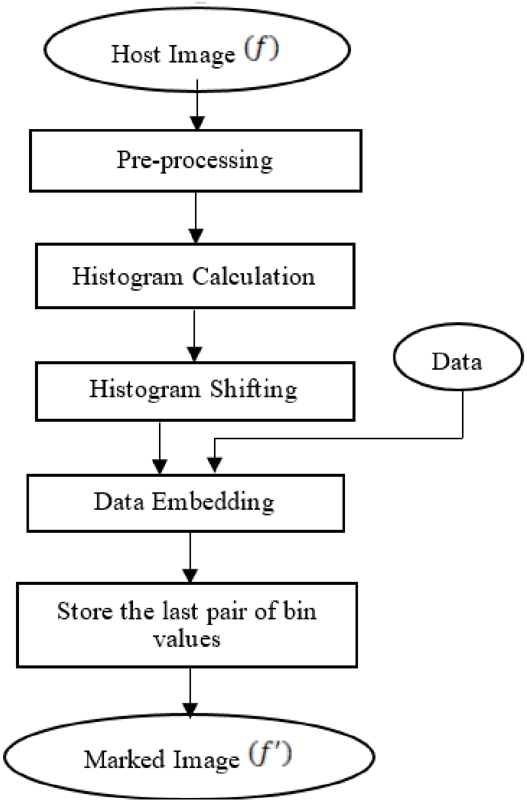


Fig. 1. Embedding Process.

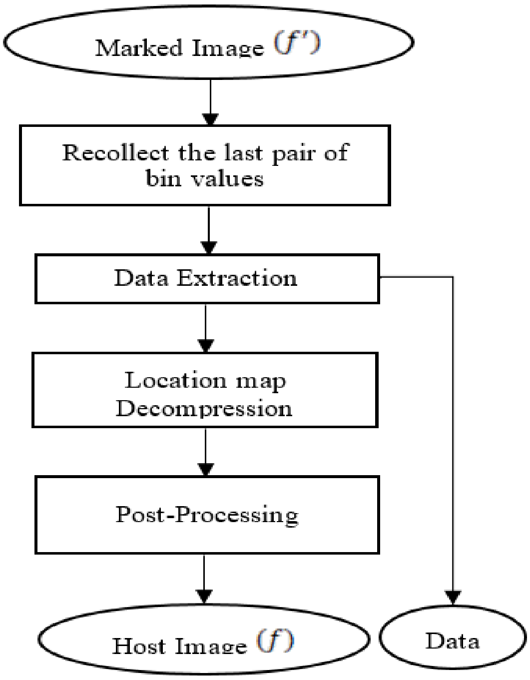


Fig. 2. Extraction Process.

V. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed algorithm 8-bit grayscale images with dimensions 512×512 were chosen.the only parameter in this algorithm is the number of pair to b chosen to split *L*. The more value of *L* gives us the more hiding rate and better contrast enhancement. However to avoid ambiguity for 8-bit images *L* value taken in [1,64]. The different hiding rates of different images are shown in the graph in Fig. 3.

The original and marked images of Lena and Hill are shown in Fig. 4. and Fig. 5. respectively, for 10,15 and 20 pairs. It can be clearly observed that the contrast of the images is increased for more values of *L*.

Table I and Table II shows the statistical results of the test images for 10, 15, 20 levels. It can be seen that for more levels the better hiding rates.

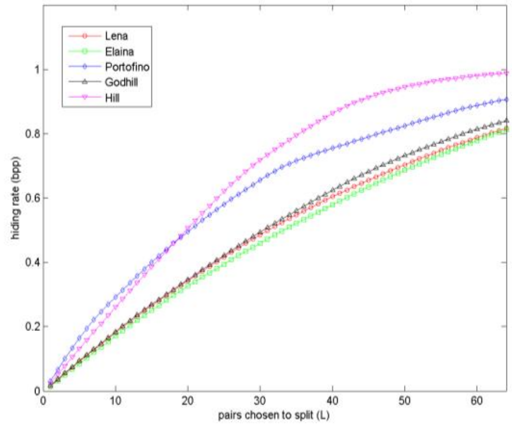
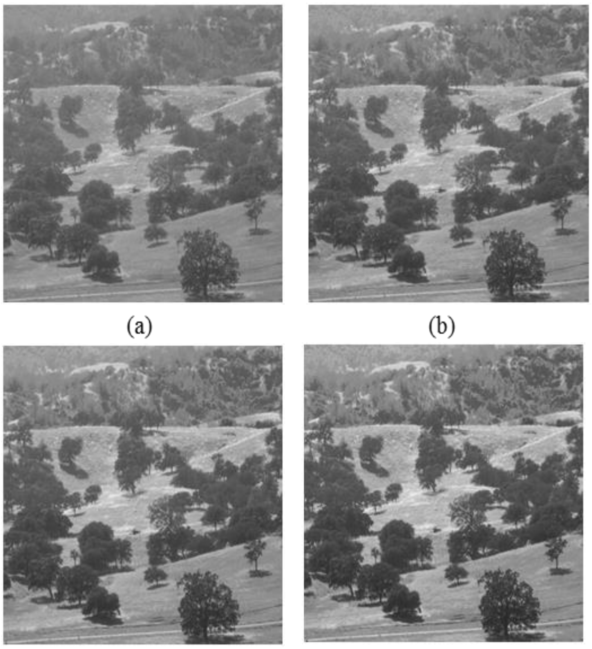


Fig.3. Hiding rate vs Pairs chosen to split *L*

(a) (b)

(c) (d)

Fig.4. Original and Stego images of Lena (a) Original image. (b) 10 levels. (c) 15 levels. (d) 20 levels.



(c) (d)

Fig.5. the Original and Stego images of Hill (a) Original image. (b) 10 levels. (c) 15 levels. (d) 20 levels.

TABLE I
Statistical evaluation Lena with 10, 15, 20 levels

Algorithm	PSNR(dB)	Hiding Rate
10 levels	30.401	0.1807
15 levels	26.887	0.2651
20 levels	26.007	0.3433

TABLE II
Statistical evaluation Hill with 10, 15, 20 levels

Algorithm	PSNR(dB)	Hiding Rate
10 levels	32.119	0.2606
15 levels	28.534	0.3862
20 levels	27.843	0.5004

VI. CONCLUSION AND FUTURE SCOPE

In this paper the Reversible data algorithm with contrast enhancement by histogram shifting was put into the practice. The results shown that the visual quality of the Stego images was improved. In the Future the same algorithm can be applicable for the color images, by incorporating the key the robustness of the algorithm can be improved, and it can be applicable to the remote sensing and medical applications.

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