

# Evaluation of Histogram Equalisation and Reversible Data Hiding Method with Image Contrast Improvement

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**Abstract**— Reversible data hiding (RDH) is a special kind of data hiding technique which can exactly recover the cover image from the stego image after extracting the hidden data. Recently, Wu et al. proposed a novel RDH method with contrast enhancement (RDH-CE). RDH-CE achieved a good effect in improving visual quality especially for poorly illustrated images. In Wu 's method, however, the PSNR of stego image is relatively low and embedding performance is largely influenced by the histogram distribution of cover image. Since PSNR is still considered as one of the most important metrics for evaluating the RDH performance, this paper presents a reliable RDH method based on adaptive histogram shifting for gray-scale images to improve the PSNR of stego image while maintaining the good effect of the contrast enhancement obtained by RDH-CE. The proposed method has been applied to two image sets and compared with the previous methods. For image quality assessment, the PSNR, SSIM and three no-reference metrics have been adopted in performance evaluation. The experimental results have clearly shown that better visual quality can be achieved with the proposed method. Besides recovering the original images, extra data can be hidden into the contrast-enhanced images and correctly extracted.

**Key words:** Reversible Data Hiding, Histogram Modification, Location Map, Contrast Enhancement, PSNR

## I. INTRODUCTION

Contrast enhancement is a kind of image processing technique to improve visibility of image or video details [1, 2]. Due to the limitations in the image acquisition systems such as poor illumination, low quality imaging sensors and nappropriate setting, the contrast of the acquired images may be far from ideal. For a better human understanding and interpretation, the quality of the captured images often needs to be improved. To generate the “useful” images, contrast enhancement is usually performed on those images with low dynamic range to bring out the interested details. It has been an active research topic for more than half a century in the field of image processing.

Although image content should be preserved in some particular applications such as steganography many image enhancement methods have been proposed to improve the visual effects. With these methods, image visual effects can be improved by performing contrast enhancement, but more or less information will be lost because the permanent changes are made. Although the image contrast can be enhanced with different algorithms and parameters, the original image is not always available due to the limited storage space or the spread of the enhanced images. Therefore, it is desirable to make the process of contrast enhancement reversible so that the original images can be recovered from their contrast-enhanced versions.

Since no information is lost by making the process of contrast enhancement reversible, the technique can provide a flexibility in changing image contrast. For instance, if a contrast-enhanced image is not suitable for an application, the original image can be firstly recovered for further processing. Since storing a huge number of the original and contrast-enhanced images is time-costing, reversible image contrast enhancement (RICE) becomes attractive to alleviate the problem. Besides the information used to recover the original image, extra data can be also hidden into the contrast-enhanced image to facilitate more functionality. For instance, a digital signature of the original image can be included in the embedded data so that the recovery process can be verified. The hidden data may also contain other image processing codes so that the recovered image can be further processed. Thus it is beneficial to combine data hiding with image contrast enhancement to achieve the reversibility. Generally speaking, reversible image contrast enhancement is technically based on reversible data hiding (RDH), which is also referred as lossless data hiding or reversible watermarking. In the past two decades, the topic of RDH has been extensively studied to hide data into a host signal in a lossless manner. Generally speaking, reversible image contrast enhancement is technically based on reversible data hiding (RDH), which is also referred as lossless data hiding or reversible watermarking. In the past two decades, the topic of RDH has been extensively studied to hide data into a host signal in a lossless manner

## II. DETAILS OF RDCHE METHODS

Selecting two highest peaks to be split in histogram of the image and shifting histogram bins for peak split, which is the core technique of RDH-CE Consider a gray scale-image C consisting of  $j$  ( $j \in [0, 255]$ ) different pixel values. Then the image histogram, denoting  $G$ , contains  $i$  ( $i < j$ ) nonempty bins, in which the two bins with the highest frequency values are chosen in each time for data embedding. We use  $G_a$ , and  $G_b$  to denote the smaller and bigger bin values corresponding to the two highest peaks in the histogram, respectively. At this step, the embedding procedure is performed in the way that the binary bits are either added to or subtracted from the pixel values  $i$  according to Eq. 1,

$$i' = \begin{cases} i - 1 & \text{for } i < G_a \\ G_a - m_k & \text{for } i = G_a \\ i & \text{for } G_a < i < G_b \\ G_b + m_k & \text{for } i = G_b \\ i + 1 & \text{for } i > G_b \end{cases}$$

where  $i'$  and  $m_k$  are the modified pixel value and the  $k$ -th binary bit of the data to be embedded, respectively. The left bins of  $G_a$  and the right bins of  $G_b$  are shifted to the locations of the next adjacent bins toward the left and right

ends (0 and 255) in G, respectively. A location map is generated to record the locations of the pre-shifted (pre-modified) pixels for preventing overflow or underflow. The location map is compressed by JBIG2 ] to increase the embedding efficiency. A final data to be embedded consists of 3 parts: a location map, a secret data and two peak bin values. Let PCE denotes the amount of peak pairs selected by embedding capacity. The above embedding procedure repeats PCE - 1 times. At the PCE-1 times embedding, the binary values of the last two peak bins are kept in LSBs of the first 16 pixels in the last row of the image C by LSB replacement, and the stego image C' is produced.

The procedure of data extracting and image recovery starts with extracting the PCE-1 peaks, and continues by inverting the procedure of embedding process

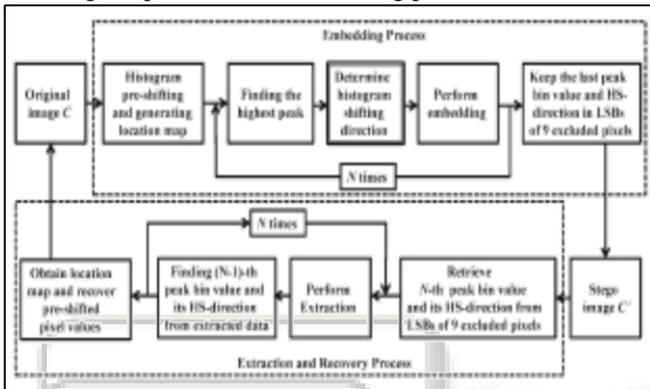


Fig. 1: Block diagram of proposed RDH algorithm

The proposed method can be considered as a improved version of RDH-CE. Suppose that N (N = 2PCE) peaks are selected for a given 8-bit gray-level image C. To avoid the possible changes of the bounding pixels caused by overflow or underflow, as doing in RDH-CE, N/2 histogram bins at the right and left ends in G are pre-shifted simultaneously, and locations of pre-shifted pixels are recorded within a location map. The proposed embedding procedure is performed similar to RDH-CE in which peaks are split for data embedding. In our method, only one highest peak is chosen for data embedding in each time instead of utilizing the two highest peaks, and each of peaks can be split in any direction (right or left). Each time a peak is selected for embedding, its histogram shifting direction (HS-direction) is determined based on the PSNR value of the image to be modified prior to the histogram shifting. The PSNR expresses the visual quality of the modified image as well as the difference between the original image and the modified image. Therefore, each HS-direction is selected adaptively so that the modification of the image caused by data embedding is as minimal as possible in each step. Bin values and HS-directions of previous N-1 peaks are kept together with the location map as side information, meanwhile the value and HS-direction of the last N-th peak are saved in LSBs of the excluded 9 pixels using LSB replacement. The data extracting process and image recovery process are performed by reverse process of the data embedding.

A. The procedure of the proposed algorithm is illustrated in Fig. 1. The embedding process is performed as follows:

- Step 1. Pixels which belong to histogram bins in the range of [0, N/2-1] are added by N/2 and pixels in the range of [256-N/2, 255] are subtracted by N/2 excluding the first 9 pixels in the bottom row. Positions of those pixels are recorded in the location map.
- Step 2. The image histogram is calculated excluding the first 9 pixels in the bottom row.
- Step 3. One highest peak is selected in the histogram, and its HS-direction is calculated as follows:
- Step 3.1. Shift histogram bins in the right side of the selected peak toward the right end by one, and the peak is split with binary bits of data.
- Step 3.2. Calculate the PSNR value (R-PSNR) of the right shifted image by Eq. 2.

$$PSNR(C, C_p) = 10 \log_{10} \frac{MAX_C^2}{(1/mn) \sum_{s,t} \|C(s,t) - C'(s,t)\|}$$

Here, C is the original image; C<sub>p</sub>) is the modified image using p(0 < p < N) peaks; MAX<sub>C</sub> is the maximum possible pixel value of the original image C. Step 3.3. Return back the right shifted image into the previous state.

- Step 3.4. Shift histogram bins in the left side of the selected peak toward the left end by one, and the peak is split with binary bits of data again.
- Step 3.5. Calculate the PSNR value (L-PSNR) of the left shifted image.
- Step 3.6. If the R-PSNR is higher than the L-PSNR, then the HS-direction will be set as 1 (right side). Otherwise, it will be set as 0 (left side).
- Step 4. To embed data, Eq. 3 is applied to all pixels in the whole image in sequential order excluding those 9 pixels

$$i' = \begin{cases} i - 1 & \text{if } direction = 0(\text{left}) \\ G_s - m_k & \text{if } i = G_s \text{ and } direction = 0 \\ G_s + m_k & \text{if } i = G_s \text{ and } direction = 1 \\ i + 1 & \text{if } direction = 1(\text{right}) \end{cases}$$

Here, G<sub>s</sub> indicates the bin value of the selected peak.

- Step 5. The value of the peak and its HS-direction are kept as the side information.
- Step 6. Then another one peak and its HS-direction in the histogram of the modified image are determined.
- Step 7. Step 2 - Step 6 are repeated until all data are embedded.
- Step 8. The location map (binary values) is embedded before message bits. The amount of peaks, the length of bitstream in the location map, LSBs of excluded 9 pixels, previous peak values and its HS-directions are embedded when the last peak is split.
- Step 9. The last N-th peak value and its HS-direction are embedded into LSBs of excluded 9 pixels of the stego image by LSB replacement.

B. The extraction process and recovery process are performed as follows:

- Step 1. The N-th peak value and its HS-direction are obtained from LSBs of excluded 9 pixels. The amount of peaks, the length of bitstream in the location map, LSBs

of excluded 9 pixels are known by using the N-th peak and its HS-direction.

- Step 2. The extraction is performed by using Eq. 4.

$$m'_k = \begin{cases} 1 & \text{if } i' = G_s - 1 \text{ and } direction = 0 \\ 0 & \text{if } i' = G_s \\ 1 & \text{if } i' = G_s + 1 \text{ and } direction = 1 \end{cases}$$

where,  $m'_k$  is the the k-th binary bit of the data extracted from the stego image.

- Step 3. The recovery process is performed by applying Eq. 5 to all pixels excluding the first 9 pixels in the bottom row

$$i = \begin{cases} i' + 1 & \text{for } i' < G_s - 1 \text{ and } direction = 0 \\ G_s & \text{for } i' = G_s - 1 \text{ or } i' = G_s \text{ (direction} = 0) \\ G_s & \text{for } i' = G_s \text{ or } i' = G_s + 1 \text{ (direction} = 1) \\ i' - 1 & \text{for } i' > G_s + 1 \text{ and } direction = 1 \end{cases}$$

- Step 4. Data are extracted by using the (N — 1)-th peak value and its HS-direction, and the previous peak value and its HS-direction are determined from the extracted data.
- Step 5. Step 2 — Step 5 are repeated until N equals to 1.
- Step 6: The location map is reconstructed from extracted data bits, and pre-shifted pixels are retrieved.
- Step 7: LSBs of the first 9 pixels in the bottom row are written back, and the original image is fully recovered.

### III. SIMULATION RESULTS & DISCUSSION

In the Simulation results the original images with the size of 512x512 with the different standard images were employed, and converted into gray level images. Basically, the two peaks in the histogram are selected for data embedding so that histogram equalization. can be simultaneously performed by repeating the process. Then the image contrast can be enhanced by splitting a number of histogram peaks pair by pair. The PSNR value of the contrast-enhanced images decrease with the data hiding rate and the visual quality has been preserved. Moreover, the original image can be exactly recovered without any additional information.

Hence the proposed algorithm has made the image contrast enhancement reversible. The visual quality for all six images has been preserved, Figure 2 and Figure 3 Shows the visual quality and histogram of Lena image

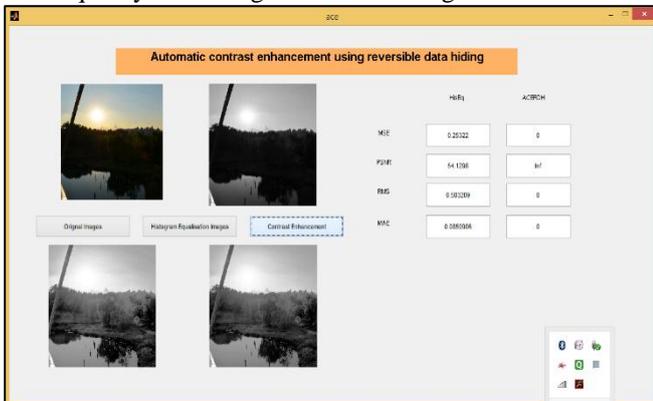


Figure 2: Input image with and without hidden data.

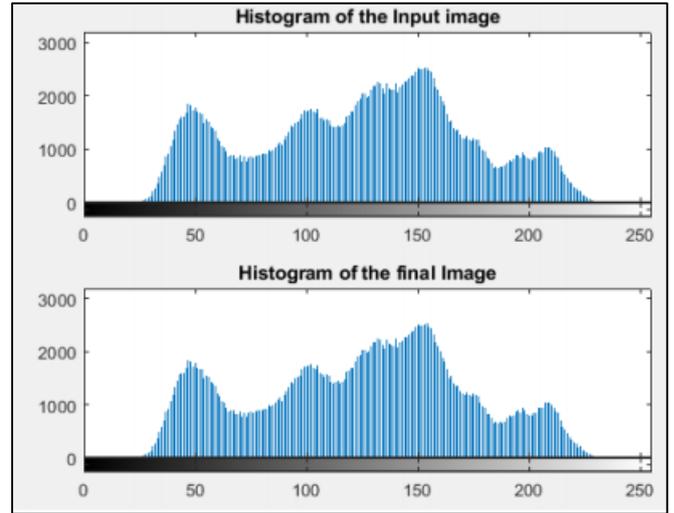


Fig. 3: Histogram of Input and Final image

### IV. CONCLUSION

In this paper, we introduced an adaptive histogram shifting method to Wu's RDH-CE method to improve the PSNR of stego image. One highest peak is selected in each step for data embedding and its histogram shifting direction is determined adaptively based on PSNR of image to be modified. The proposed method can improve efficiently the PSNR of stego image keeping the degree of the contrast enhancement provided by RDH-CE. From the experimental results, it is noted that determining adaptively HS-direction based on distance metrics between original image and the modified image in each step of the embedding process will result in improving PSNR of stego image efficiently.

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