A Unique Method Reversible Data Hiding Method with Image Contrast Enhancement

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Abstract : Recently, several image contrast enhancement methods have been proposed such that the original image can be recovered from its contrast-enhanced version. Hence a flexibility in changing image contrast can be provided when needed. However, the artificial distortions may be introduced into the image content after adopting these methods. Meanwhile, there is lack of using the adequate image quality metrics for performance evaluation. In this paper, a novel reversible data hiding method is proposed for image contrast enhancement. To better preserve image quality, it is restricted that only the adjacent bins in the original image histogram may be merged in the pre-processing. 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**.**

***Index Terms* - Contrast enhancement, reversible data hiding, image quality, histograms, adjacent bin.**

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 inappropriate 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 [3]. Although image content should be preserved in some particular applications such as steganography (e.g., [4]), many image enhancement methods have been proposed to improve the visual effects, such as in [3, 5, 6, 7, 8, 9, 10]. 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 Most of the RDH algorithms are proposed for digital images (e.g. [11,12, 13, 14, 15, 16,] trying to keep the peak signal-to-noise ratio PSNR) as high as possible for a given data hiding rate. Besides correctly extracting the hidden data from the host signal, the original signal should be exactly recovered after data extraction. In this sense, RDH can be used to make the process of contrast enhancement reversible by hiding the changes that have been made to the original image. Alternatively, the process can be simplified by achieving the contrast enhancement effect through the process of RDH. The first attempt to accomplish image contrast enhancement with RDH was made in the scheme proposed in where each of the highest two bins in the image histogram are split into two adjacent bins for data embedding, respectively. By repeatedly splitting the highest two bins in the modified histogram to reduce their heights, the effect of histogram equalization may be obtained. As both RDH and contrast enhancement can be fulfilled with the method in there are two drawbacks in applying it. Firstly, the artificial distortions may be introduced into the image content by pre-processing, which is conducted to avoid the overflows or underflows of pixel values. Secondly, the region of interest (ROI) cannot be brought out when the expanded bins are mostly from the image background. To cope with these issues, an improved method is proposed in for medical images. Instead of directly modifying those pixel values that may be overflowed or under flowed, the interval containing the minimum number of pixels is adaptively chosen on each side of the histogram..

II. Reversible Data Hiding with Contrast Enhancement

To perform reversible data hiding and contrast enhancement simultaneously, the process named histogram bin expansion has been proposed in . Firstly, a image histogram is calculated by counting the number of every pixel value in a gray-level image. Among all non-empty bins in the obtained histogram, the two peaks (i.e., the highest two bins) are chosen, and the corresponding values are denoted as fL and fR (fL < fR). By keeping the bins between the two peaks unchanged and shifting the other bins outwards, each of the two peaks can be expanded. More specifically, a pixel value f in the image is modified to f ′ by conducting the following operation

$$f' = \begin{cases} f-1, & \text{if } f < f_L \\ f-b_i, & \text{if } f = f_L \\ f, & \text{if } f_L < f < f_R \\ f+b_i, & \text{if } f = f_R \\ f+1, & \text{if } f > f_R \end{cases} . \quad (1)$$

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where bi is the i-th bit value (0 or 1) to be hidden. Note that only the expanded bins contain the embedded bits therefore bi is embedded in the i-th pixel scanned with value fL or fR. After applying Eq. (1) to all pixels in the image, heights of the two expanded bins are reduced. By updating the values of fL and fR, each of the two peaks in the modified histogram can be further expanded after applying Eq. (1). Therefore, the effect of histogram equalization can be achieved by repeatedly applying the histogram bin expansion to reduce heights of the highest two bins in the modified histogram. One side effect of applying Eq. (1) is that the bounding pixel values may be overflowed or underflowed. The pre-processing is therefore needed to avoid the possible overflows and underflows. Suppose that S pairs of the highest histogram bins are expanded in total. Then S is added to the pixel values from 0 to S − 1, while the pixels from 256 − S to 255 are subtracted by S. To memorize the locations, a binary location map with the same size as the image is generated by using 1s to mark those pixels modified, while 0s are set to the unchanged pixels. The binary location map can be previously generated and losslessly compressed. Note that the compressed location map and its length, the value of S, the least significant bits (LSB) of the last 16 pixels in the image before the last histogram bin expansion and the previously expanded bin valuesare all embedded by applying Eq. (1) for S times in total. Finally, the last To recover the original image, the two expanded bin values are used to replace the LSBs of the last 16 pixels to generate the contrast-enhanced image. values of the last two expanded bin values are firstly extracted from the LSBs of the last 16 pixels. By denoting the extracted bin values as fLL and fLR, the bits embedded within the last two expanded bins can be sequentially extracted by

$$b_i' = \begin{cases} 1, & \text{if } f' = f_{LL}-1 \text{ or } f' = f_{LR}+1 \\ 0, & \text{if } f' = f_{LL} \text{ or } f' = f_{LR} \\ null, & otherwise \end{cases} , \quad (2)$$

where f ′ is a pixel value scanned in the image and b′ i is the bit value extracted from the i-th pixel whose value falls into {fLL−1, fLL, fLR, fLR+1}. Meanwhile, histogram shrinkage is performed to reverse the histogram bin expansion. More specifically, a pixel value f ′ scanned in the image is modified to f ′ ′ by

$$f'' = \begin{cases} f'+1, & \text{if } f' < f_{LL} \\ f', & \text{if } f_{LL}-1 < f' < f_{LR}+1 \\ f'-1, & \text{if } f' > f_{LR} \end{cases} . \quad (3)$$

$$\begin{cases} f+b_i, & \text{if } f = f_R \\ f+1, & \text{if } f > f_R \end{cases}$$

By knowing the other expanded bins from the extracted data, data extraction and histogram shrinkage can be continued for the other S − 1 times. Note that the values of fLL and fLR in Eq. (2) and Eq. (3) need to be updated at each time so that the image after pre-processing can be eventually obtained.

By separating the compressed location map from the other extracted data, it can be decompressed and used to change the pixels modified in pre-processing. Since S is added to the pixel values originally in [0, S − 1] in pre-processing, a pixel value within [S, 2S − 1] is subtracted by S if the corresponding bit value in the decompressed location map is 1. Similarly, S is added to a pixel within[256 − 2S, 255 − S] if the corresponding bit is 1

III. Proposed Methodology

Currently available data hiding techniques do not pay much attention on stego-object (hidden information in original object) with respect to its originality of cover (original) object. Both cover-objects and stego-objects are drifted in context of (quality measure in image) peak signal to noise ratio (PSNR) and mean square error (MSE) aspects. This paper proposed a data hiding method around the edge boundary of an object with high PSNR. The experimental results show very high rate of PSNR. Proposed scheme is targeted for low rate of hidden data but with high PSNR. We have proposed an edge boundary based information hiding method with high PSNR and with high perceptual transparency as well as comparison with original cover image. Through experimental results proposed technique has high perceptual transparency with low computational complexity. Stego-image can further be used as an original image for application (segmentation of objects, feature extraction of objects). Its information hiding capacity can easily be increased depending on computed threshold. Thresholds may vary depending on the image visual characteristics to consider its high PSNR. Moreover, extraction of the secret information is independent of original cover image.

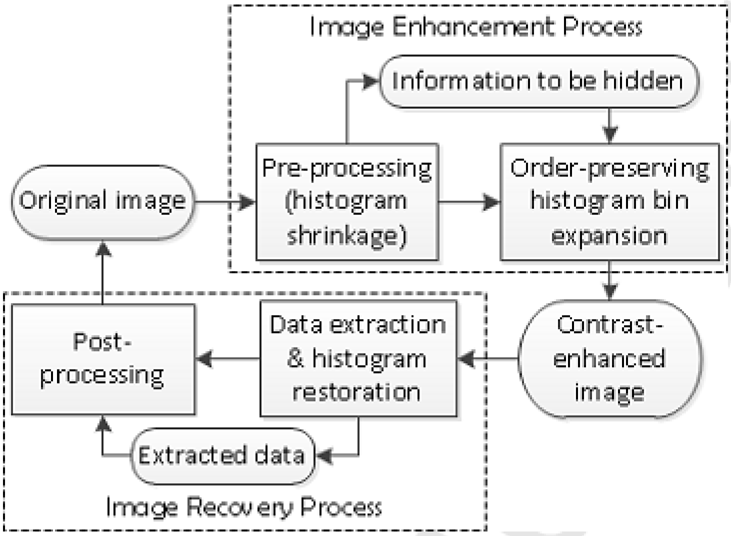

Figure 1: Flowchart of the proposed method for reversible image contrast enhancement.

Reversible Image Data Hiding with Contrast Enhancement The procedure of the proposed algorithm [is illustrated in figure 1. Given that totally pairs of histogram bins are to be split for data embedding, the embedding procedure includes the following steps:

- Pre-process: The pixels in the range of [0,L-1] and [256-L, 255] are processed excluding the first 16 pixels in the bottom row. A location map is generated to record the locations of those pixels and compressed by the JBIG2 standard to reduce its length.
- The image histogram is calculated without counting the first 16 pixels in the bottom row
- .Embedding: The two peaks (i.e. the highest two bins) in the histogram are split for data embedding by applying equation to every pixel counted in the histogram. Then the two peaks in the modified histogram are chosen to be split, and so on until pairs are split. The bit stream of the compressed location map is embedded before the message bits (binary values). The value of the length of the compressed location map, the LSBs collected from the 16 excluded pixels, and the previous peak values are embedded with the last two peaks to be split.
- The lastly split peak values are used to replace the LSBs of the 16 excluded pixels to form the markedimage

The extraction and recovery process include the following steps:

- The LSBs of the 16 excluded pixels are retrieved so that the values of the last two split peaks are known.
- The data embedded with the last two split peaks are extracted, so that the value of, the length of the compressed location map, the original LSBs of 16 excluded pixels, and the previously split peak values are known. Then the recovery operations are carried out by processing all pixels except the 16 excluded ones with the process of extraction and recovery is repeated until all of the split peaks are restored and the data embedded with them are extracted.
- The compressed location map is obtained from the extracted binary values and decompressed to the original size.
- With the decompressed map, those pixels modified in preprocess are identified. Among them, a pixel value is subtracted by if it is less than 128, or increased by otherwise. To comply with this rule, the maximum value of is 64 to avoid ambiguity. At last, the original image is recovered by writing back the original LSBs of 16 excluded pixels.

IV. CONCLUSION

In this paper, a novel reversible data hiding method has been proposed for image contrast enhancement. With the improved preprocessing, much better image quality has been achieved than the previous methods in. It has been verified that the original images can be completely recovered from the contrast-enhanced ones, while automatic implementation of the proposed method has been achieved. The experimental results have shown that both contrast enhancement and reversible data hiding can be achieved. Moreover, the statistical results obtained on two image sets and the evaluation results on each test image have validated the efficacy of the proposed method in image quality preservation. Besides the conventionally used PSNR and SSIM [29], we have adopted the no-reference metrics of] for image quality assessment. The evaluation results using the three no-reference metrics are generally consistent with the human perception. As several objective metrics have been employed in evaluating the contrast-enhanced images, an extensive subjective evaluation will be conducted in the future work.

Instead of trying to keep the PSNR value high, the proposed algorithm enhances the contrast of a host image to improve its visual quality.

The side information is embedded along with the message bits into the host image so that the original image is completely recoverable.

The visual quality can be preserved after a considerable amount of message bits have been embedded into the contrast-enhanced images.

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