Reversible Data Hiding Based on Generalized Equalization Model

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Abstract— **Reversible data hiding is one of the data hiding technique, where the host image can be recovered exactly. This is lossless data hiding technique, suitable for medical and satellite applications. In this abstract the reversible data hiding based on generalized equalization model is proposed. It is the robust algorithm to achieve image contrast enhancement. The generalized equalization performs contrast enhancement and data embedding with RDH. The main advantage of this technique is to improve the image contrast, i.e., image quality is improved. Relative Contrast Error (RCE), Relative Mean Brightness Error (RMBE), Pack Signal-to-Noise Ratio (PSNR in dB), Payload (bits per pixels bpp), these parameters are used to evaluate the visual quality, contrast enhancement and how much amount of message bits have been embedded in to marked image.**

Keywords: ***Contrast Enhancement, Histogram Modification, White Balancing, Location Map, Reversible Data Hiding, Visual Quality, Generalized Equalization Model***

I. INTRODUCTION

Reversible Data Hiding (RDH) has been thoroughly studied in the signal processing community. It is also called as invertible or lossless data hiding, RDH is to embed the data into an input signal to generate the marked signal, from which the host signal can be precisely recovered after extracting the embedded information. The RDH technique is useful in some fragile applications where no enduring change is allowed on the given input signal. The technique of RDH is proposed for digital images to embed invisible data hiding. The hiding rate and the marked image quality are major parameters to evaluate the performance of a RDH algorithm, because of the hiding rate and the marked image quality are inversely proportion so that the hiding rate is increasing than more distortion occurred in image information. The distortion of image information is measured in terms of peak signal-to-noise ratio (PSNR).

The direct modification of image histogram gives less amount of embedding capacity. Some of the recent algorithms [1]-[5] are handles with centrally distributed prediction error by utilizing the correlation between neighboring pixels, so that distortion is less in the data hiding. Prediction error based algorithms produces the high PSNR value for marked image and the visual quality can improved hardly because of the embedding operations has been introduced more or less distortion. Increasing the visual quality is more important for the poor illumination image. The contrast enhancement of image is desired to show the details for visual quality. The RDH technique is produces the PSNR value is high to the enhanced image and the visibility of image information has been improved. So in this study, we have a tendency to aim at inventing a new RDH algorithm to attain the property of contrast enhancement. In this RDH algorithm, contrast enhancement of image can be achieved by generalized equalization model. Image enhancement is changing the original image into a better understandable level in spectral quality for feature extraction. The generalized equalization model [6], [11] is proposed for image enhancement based on the relationships between the image histogram and tone mapping. Generally, tone mapping algorithms can be classified into two categories.

I) White balancing: The poor visibility in an image is occurred by the undesirable illuminance or the physical limitations of inexpensive imaging sensors. The white balancing performs the whit correction in generalized version than the overall gray values of the image are changed so the image quality is increased.
II) Contrast enhancement: Contrast enhancement algorithms are generally used for the restoration of degraded image. The contrast of the image is enhanced globally or locally by the different contrast enhancement techniques

Based on these two things we can de design the system for Generalized Equalization Model.

The proposed algorithm is performed by changing the histogram of pixel values. Firstly, find out the two highest histogram peaks from the image histogram. The histogram bins between the two peaks are not modified while the outer histogram bins are shifted out ward, it can increase the embedding capacity. This process is going on until the good PSNR and contrast enhancement are achieved. The pre-processing is avoided the overflows and underflows due to histogram modification at bounding pixel values and a location map is generated to remember their locations. The data is embedded into the highest two peaks of image histogram. The data extraction and complete recovery of the host image is depending on two histogram peaks and location map values. The proposed algorithm was applied to Harvard medical, Getty satellite and USC-SIPI images to indicate its efficiency.

II. RDH BASED ON GENERALIZED EQUALIZATION MODEL

A. Generalized Equalization Model

This model unifies spatial filtering based enhancement methods, which has potential applications in enhancement of image. The block diagram of generalized equalization model is shown in Fig. 1.

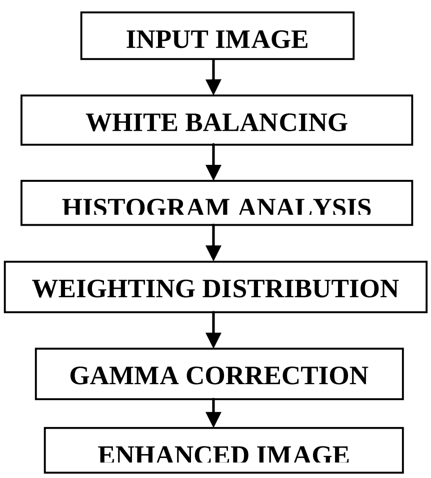


Figure1. Block diagram of generalized equalization model

Whitening Balance: White balance is the global adjustment of the intensities of the gray images. White balance changes the overall gray values of white in an image and is used for white correction; generalized versions of white balance are used to get white other than neutrals to also appear correct or pleasing.

Histogram Analysis: Histogram-based algorithm has been widely used in contrast enhancement. Histogram equalization is a method in image processing of contrast adjustment using the image histogram. This method usually increases the global contrast of images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

Weighting Distribution: The Gaussian filter is a one type of image filter, which uses a Gaussian function for calculating the transform the weight to each pixel in the image. It is depending on size of the filter.

Gamma Correction: Gamma correction, gamma nonlinearity, gamma encoding, or often simply gamma, is the name of a nonlinear operation used to code and decode tristimulus values in still images. Gamma correction is, in the simplest cases, defined by the power-law expression. Gamma refers to the brightness. By applying gamma correction, the brightness and contrast of the image is enhanced.

B. Data Embedding by Histogram Modification

The proposed algorithm is applied for gray scale images. Given an 8-bit gray-level image M, the image histogram can be calculated by counting the pixels with a gray-level value k for $k \in \{0, 1, 2, \ldots 254, 255\}$. The h_M is denoting the image histogram so that $h_M(k)$ shows the number of pixels with a value k, suppose M consists of n number of different pixel values. Then M having n number of histogram bins in h_M, from which highest two peaks or bins are chosen and the corresponding smaller (M_S) and bigger (M_H) values. For a pixel computed in h_M with value m, data embedding is performed by equation (1)

$$m' = \begin{cases} m-1, & for\ m < M_S \\ M_S - b_r, & for\ m = M_S \\ m, & for\ M_S < m < M_H \\ M_H - b_r, & for\ m = M_H \\ m+1, & for\ m > M_H \end{cases} \quad (1)$$

Where m' is the changed pixel value, and b_r is the r-th message bit (0 or 1) to be embedded. Finally $h_M(M_S) + h_M(M_H)$ binary bits are hided. There is no bounding value (0 or 255), because of pre-processing. That is, the bins between the two peaks are unchanged while the outer ones are shifted outward so that each of the peaks can be split into two adjacent bins, there are M_S-1 and M_S, M_H and M_H+1 respectively.

The two peak values M_S and M_H want to be provided to extract the embedded message and recover the host image. One way to keep them is to exclude the bottom row of first 16 pixels in M from image histogram. The least significant bits (LSB) of those pixels are collected and the binary values of two peaks are incorporated in those places. After applying Eq.(1) to each pixel counted in h_M for data embedding, the values of M_H and M_S are used to replace the LSBs of the 16 excluded pixels by bitwise operation. Then the following equation is performed on any pixel counted in the histogram and with the value of M_S-1, M_S, M_H or M_H+1.

The r-th binary value is the extracted from the marked image. The extraction operations and embedding operations are performed in the same order. According to Eq.(3), the every pixel counted in the histogram to recover its original image by the following operation:

$$b'_r = \begin{cases} 1, & if\ m' = M_S - 1 \\ 0, & if\ m' = M_S \\ 0, & if\ m' = M_H \\ 1, & if\ m' = M_H - 1 \end{cases} \qquad (2)$$

$$m = \begin{cases} m' + 1, & for\ i' < M_S - 1 \\ M_S, & for\ i' = M_S \\ M_H, & for\ i' = M_H \\ m' - 1, & for\ i' > M_H + 1 \end{cases} \qquad (3)$$

C. Pre-Process for Complete Recovery

In the proposed algorithm, it is need that all pixels counted in h_M are within range of {*L*-2, ... , 255-*L*}. There L is pair number of the histogram peaks to be split (L is the positive integer). If there is any bounding pixels like [0 to *L*-1] or [256-*L* to 255], on that case overflow or underflow will be occurred by histogram shifting. To eliminate it, the pre-processing is performed on image histogram for the histogram shifting operations. If pixel value is below the *L* than subtract the *L* from the pixel value else pixel value is above the [255-*L*] than add the *L* to the pixel value. Therefore, no overflow or underflow will be occurred because of each bounding pixel values are possible to change. To identify the pre-processed pixels, a location map with the same size as the original image is generated by assigning 1 to the location of a modified pixel, and 0 to that of an unchanged one (excluded the first 16 pixels of bottom row). Based on location map values the host image is recovered.

D. Step by Step Process of the Proposed Algorithm

The procedure of the proposed algorithm is illustrated in Fig. 2. For the data embedding process the pairs of histogram bins are to be splits.

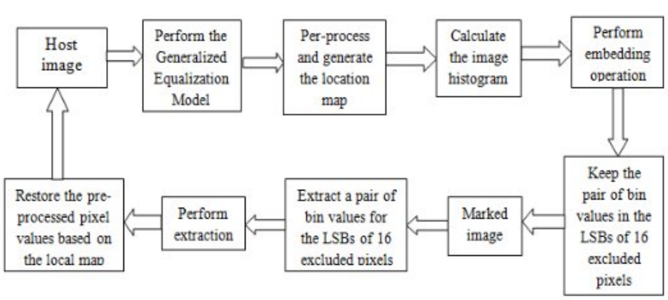


Figure 2. Block diagram of the proposed RDH algorithm

The step by step process of data embedding:

1) Generalized Equalization Model: The generalized equalization model follows the histogram equalization and white balancing, It is discussed in Section II-A.
2) Pre-process: By the pre-processing step change the boundary pixel values in the range of [0, *L*-1] and [256-*L*, 255] excluding the bottom row of first 16 pixels based on the pre-processing the modified pixel locations are denoted in the location map as mentioned in Section II-C.
3) Without consider the first 16 pixels of bottom row to calculate the image histogram.
4) Embedding Process: To find out the highest two histogram peaks and split those peaks for data embedding by using the Eq. (1), so each pixel in the histogram achieves the modified histogram. The histograms two peaks are converted into binary form. Now, the bottom row of first 16 pixels LSBs are replaced by the binary values of the two highest histogram peaks.
5) The step 2, 3, 4, and 5 are repeats *L* number of times, to achieve the marked image.

The step by step process of data extraction and recovery of original image:

1) The highest two histogram peaks are recovered form LSBs of bottom first 16 pixels.
2) By using the histogram two peaks extract the data bits form marked image by the Eq. (2).
3) The image recovery is followed by the Eq. (3) and it is depend on histogram two peaks.
4) The modified pixel values in the pre-processing are to be recovered by the location map values, if pixel values are [*L* to *L*+*L*-1] and related location map locations are 1 then add L to the pixels, if pixel values are [255-*L* to 255-2*L*-1] and related location map locations are 1 then subtract *L* from the pixels, if location map values are 0 than no modification required in the pixel values.
5) The step 1, 2, 3 and 4 are repeats *L* number of times to retrieve the host image.

III. EXPERIMENTAL RESULTS

In the paper 8 USC-SIPI test images [7] and their size is 512 ×512, 10 Harvard medical images [8] and their size is 256× 256 and 8 Getty satellite images [9] and their size is 256 ×256. This algorithm is performed on the grey-level images. The important parameter in the aforementioned algorithm is *L* (the pair number of histogram peaks to be split). As shown in Fig. 3, Fig. 4 and Fig. 5, the hiding rates were generally increased by *L* value. In this algorithm takes the maximum value of L is 32 to eliminate the ambivalence. For all test images, visually impaired complete recovery and extraction were achieved for any $L \in [1, 32]$. At *L* is 32, the pure data hiding rate was 2.0189 bit per pixel (bpp) for F-16 image, 0.6545 bpp for Baboon, and averagely 1.1490 bpp of the 8 USC-SIPI images, the average of the 10 Harvard images was 14.1821 bpp and the average of the 8 Getty satellite images was 0.0446 bpp. The data hiding rate was calculated by how many number of hiding bits extracted from the marked image. The host and marked images of "F-16", "Brain CT scan" and "India map" images, at different *L* values like 10, 15 and 20 peaks for embedding of data are shown in Fig. 5, Fig. 6, and Fig. 7, respectively. The embedded data was invisible in marked image. The contrast enhancement effect was improved based on the number of histogram peaks are split for data embedding. The PSNR value of contrast enhanced images was decreased and visual quality of image improved with the data hiding capacity.

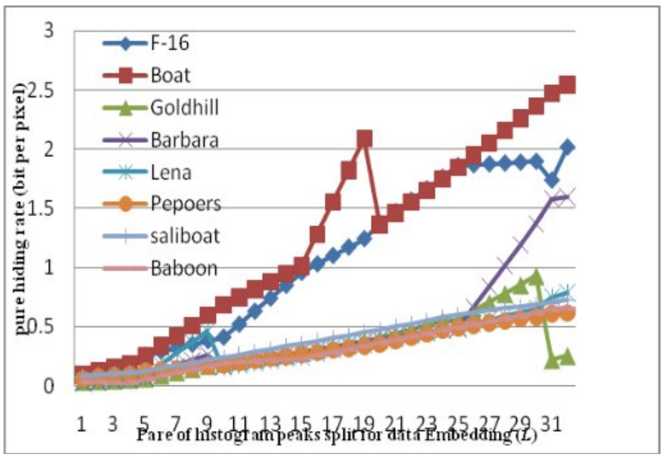


Figure 3. The data hiding rates generally increase with the number of histogram peaks used for data embedding (for 8 USC-SIPI images)

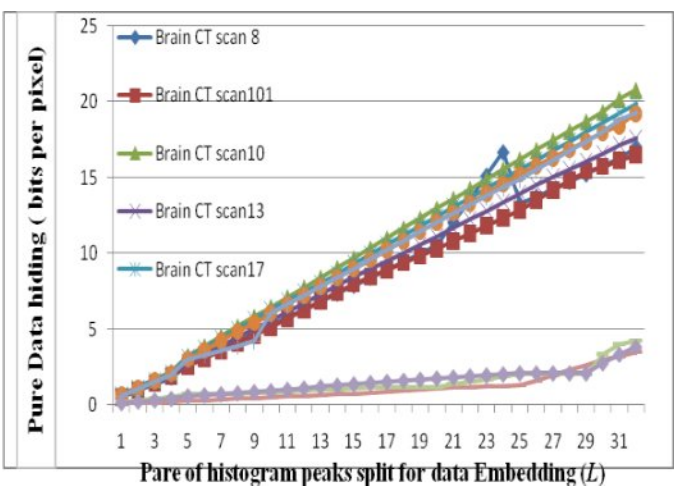


Figure 4. The data hiding rates generally increase with the number of histogram peaks used for data embedding (for 10 Harvard medical images)

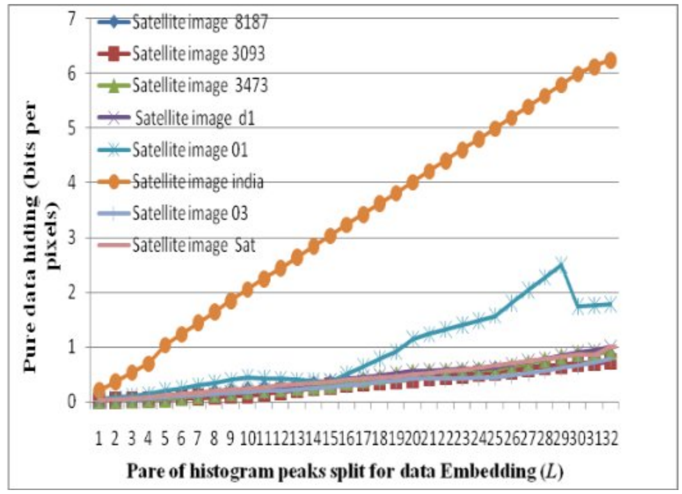
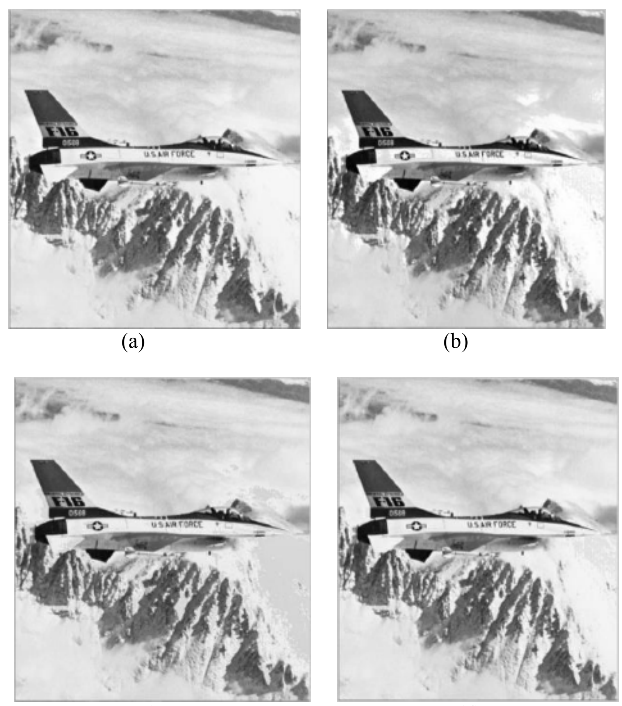
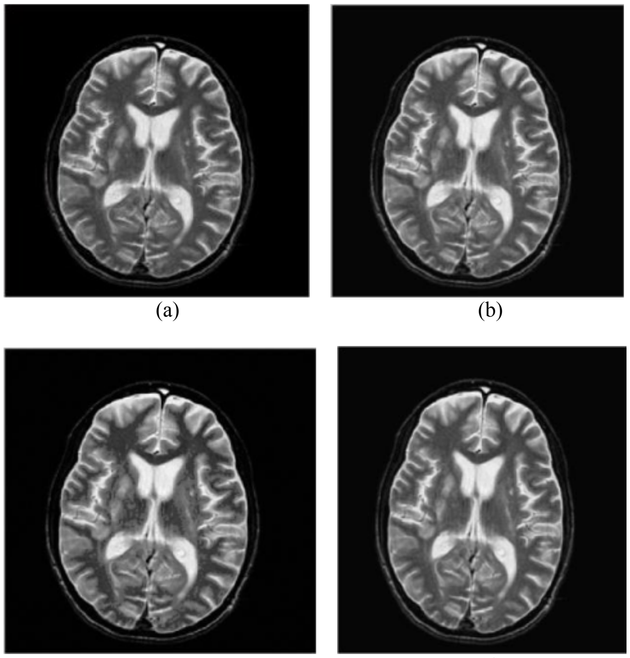


Figure 5. The data hiding rates generally increase with the number of histogram peaks used for data embedding (for 8 Getty satellite images)



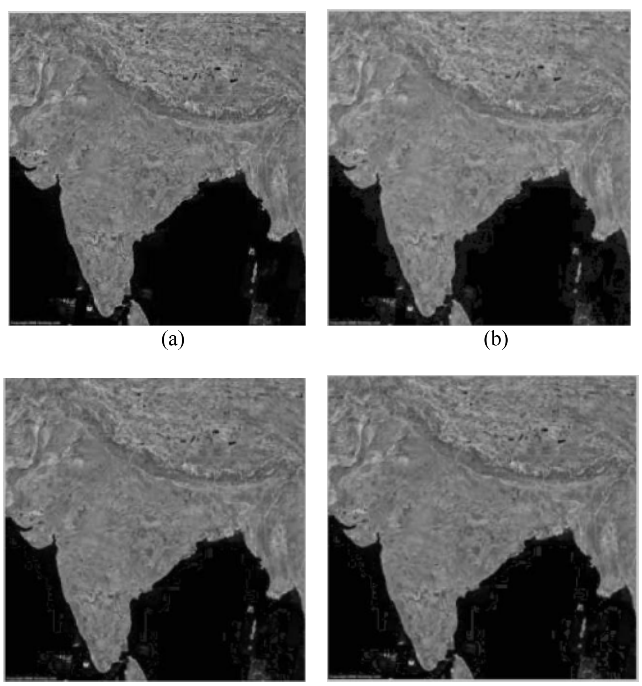
(a) (b) (c) (d)

Figure 6. The original and contrast-enhanced images of "F-16" by splitting 10, 15 and 20 pairs of histogram peaks in the proposed algorithm. (a) Original image of "F-16". (b) 10 pairs: 0.586 bpp, 47.84 dB. (c) 15 pairs: 0.878 bpp, 38.564 dB. (d) 20 pairs: 1.5579 bpp, 28.502 dB.



(a) (b) (c) (d)

Figure 7. The original and contrast-enhanced images of “Brain CT scan” by splitting 10, 15 and 20 pairs of histogram peaks in the proposed algorithm. (a) Original image of “Brain CT scan”. (b) 10 pairs: 5.54 bpp, 47.473 dB. (c) 15 pairs: 8.441 bpp, 46.1841 dB. (d) 20 pairs: 11.091 bpp, 38.656 dB.



(a) (b) (c) (d)

Figure 8. The original and contrast-enhanced images of “Indian Map” by splitting 10, 15 and 20 pairs of histogram peaks in the proposed algorithm. (a) Original image of “Indian Map”. (b) 10 pairs: 2.051 bpp, 46.772 dB. (c) 15 pairs: 3.034 bpp, 43.250 dB. (d) 20 pairs: 4.013 bpp, 40.672 dB.

In addition of PSNR value, Relative Contrast Error (RCE) and Relative Mean Brightness Error (RMBE) [10] are used to evaluate the contrast enhancement effect and quality of image. For the contrast enhanced image the RCE value should be greater than 0.5. The RMBE is closer to 1 that indicates the less brightness differences between host image and enhanced image. The three evaluation values are calculated for each of the contrast enhanced images there are PSNR, RCE and RMBE.

TABLE 1: Statistical Evaluation (Mean) of 8 USC-SIPI Images

No. of times pairs to be split (L)	PSNR (dB)	Payload (bites per pixel)	RCE	RMBE
10	**47.7890**	**0.2778**	**0.6216**	**0.9333**
15	**43.7454**	**0.4543**	**0.6324**	**0.9332**
20	**37.6429**	**0.5293**	**0.6375**	**0.9319**

TABLE 2: Statistical Evaluation (Mean) of 10 harvard medical Images

No. of times pairs to be split (L)	PSNR (dB)	Payload (bites per pixel)	RCE	RMBE
10	**48.8748**	**4.2853**	**0.7096**	**0.9982**
15	**44.2389**	**6.4486**	**0.7194**	**0.9980**
20	**39.6939**	**8.6167**	**0.7202**	**0.9977**

TABLE 3: Statistical Evaluation (Mean) of 8 Getty satellite Images

No. of times pairs to be split (L)	PSNR (dB)	Payload (bites per pixel)	RCE	RMBE
10	**32.5807**	**0.4549**	**0.6629**	**0.9423**
15	**32.4466**	**0.6696**	**0.6899**	**0.9402**
20	**39.0024**	**1.0072**	**0.7035**	**0.9414**

The statistical results of three sets of test images are shown in the Table 1, Table 2 and Table 3, respectively. Each parameter shown in the three tables is the average of three sets of test images. The aforementioned algorithm utilizing the *L* at the three values, there are 10, 15 and 20, respectively. In the proposed algorithm shows the test images contrast was enhanced gradually by the splitting more histogram peaks but brightness is decreased.

IV. CONCLUSION

In this paper, a robust reversible data hiding algorithm has been proposed based on generalized equalization model for the property of contrast enhancement. Basically, the generalized equalization model shows relation between the white balancing and contrast enhancement. The highest two peaks of the histogram are selected for the data embedding. In our algorithm the image contrast and visual quality of the image can be enhanced by splitting the number of histogram peaks, it was shown in the experimental results. Furthermore, the original image can be exactly recovered. Therefore the image contrast enhancement was achieved by the proposed algorithm and it is suitable for the medical and satellite images.

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