An Invertible Image Data Hiding Based On Contrast Enhancement

Renji Elsa Jacob, Gopika Krishnan

Abstract— Data hiding is the art and science of communicating secret data in an appropriate multimedia carrier, e.g., image, audio, and video files. Reversible Data Hiding (RDH) is usually used to hide a piece of data into an image to produce a marked image. RDH is used widely in the field of signal processing to provide security to these images from the intruders. In addition, to evaluate the performance of RDH with PSNR, here the focus is on the contrast enhancement of the image. The data is embedded in the image, such that the data and image are completely recoverable. The highlight of RDH is that it gives back the original image after the data is being extracted from the marked image. It has been found that, by embedding considerable amount of data into the image, the contrast of the image is being enhanced. Many RDH techniques have been developed. Different RDH algorithms have their own merits and no single approach is optimal and applicable to all cases. To increase the embedding capacity, the equalization process is repeated. Along with the message bits, the side information is also embedded in the host image for the complete recovery. By adding the considerable amount of data into the image, the brightness of the image is increased. Improving the algorithm on the color and video will be the future work.

Index Terms— Contrast enhancement, Data embedding, Embedding capacity, Histogram modification, Pixels, Peak signal-to-noise ratio, Reversible Data Hiding

1. INTRODUCTION

Data Hiding is a term including a wide range of applications for embedding messages in content. Hiding information destroys the host image even though the distortion introduced by hiding is imperceptible to the human visual system. Consequently, reversible data hiding techniques are designed to solve the problem of lossless embedding of large messages in digital images so that after the embedded message is extracted, the image can be completely restored to its original state before embedding occurred.

In most applications, small distortions due to data embedding are allowed whereas in applications like medical, law forensics and military imagery, no distortions are allowed. For these cases, we require a special kind of data hiding method, which is called as reversible data hiding (RDH). Reversible Data Hiding (RDH) is used to embed a piece of data into an image to generate a marked image and after extracting process the original image can be recovered from the marked image. It is also called as invertible or lossless data hiding[10].

The traditional methods [2]-[5] has many drawbacks like degradation of hidden data as well as original image and computational maybe costly. The conventional methods of RDH algorithm does not perform the task of contrast enhancement to improve the visual quality of the host image.

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So by using this RDH algorithm, the contrast enhancement is achieved instead of keeping the PSNR high. The hiding rate and quality of the marked image are important parameters for the measurement of the performance of the RDH algorithm as the increase in the hiding rate causes more distortion in the image content. The peak signal-to-noise ratio (PSNR) value of the marked image is calculated to measure the distortion. The PSNR of a marked image generated is usually kept high but the visual quality will be low. For the images obtained in poor illumination, the visual quality is more important than keeping the PSNR value high.

Contrast enhancement of images can be obtained through histogram equalization [6]. The data embedding and contrast enhancement can be done simultaneously in this algorithm by modifying the histogram of the pixel values. At first, the highest two bins are found and the bins between the peaks are unchanged. Each of the two peaks split into the adjacent bins by shifting outward the outer bins. The highest bins in the modified histogram can be further split until the sufficient contrast enhancement is obtained, which can also increase the embedding capacity.

The boundary pixel values are pre-processed to avoid the overflows and underflows because of the histogram modification and a location map is generated to remember their locations. The location map is hidden into the host image along with the message bits and other side information for the recovery of the original image. So that a complete data extraction and original image recovery is possible.

2 PROPOSED METHOD

ISSN 2229-5518

In this section the various steps in data embedding and recovery process are described. The data embedding is done by the histogram modification technique. Consider an 8-bit gray-level image I, by counting the pixels with a gray-level value j for j∈{0,1,....,254,255} the image histogram can be calculated. Let h_I denotes the image histogram then h_I(j) represent the number of pixels with a value j.

At first the pre-processing is performed. In pre-processing, the pixels in the range of [0, L-1] and [256-L, 255] are processed. The pixel values in the range 0 to L-1 are added by L while the pixels in the range 256 –L to 255 are subtracted by L, excluding the first 16 pixels in the bottom row. Consider N different pixel values are present in I, hence there are N nonempty bins in h_I, from which the two peaks(i.e. the highest two bins) are selected. I_S and I_H represents the corresponding smaller and bigger values respectively. The data embedding is performed for a pixel counted in h_I with value i, by

$$i' = \begin{cases} i-1, & for \quad i < I_S \\ I_S - b_k, & for \quad i = I_S \\ i, & for \quad I_S < i < I_H \\ I_H + b_k, & for \quad i = I_H \\ i+1, & for \quad i > I_H \end{cases} \qquad (1)$$

where i' is the modified pixel value, and b_k is the k-th message bit(0 or 1) to be hidden. By using the Eq.(1) to all the pixel counted in h_I, totally $h_I(I_S) + h_I(I_H)$ binary values can be embedded. The bins between the two peaks remain unchanged and the outer bins are moved outward. So each of the peaks can be divided into two adjacent bins, $I_S - 1$ and I_S, I_H and $I_H - 1$ respectively.

For extracting the embedded data, the peak values I_S and I_H are needed. So to keep these values, first exclude 16 pixels in I from the histogram calculation. The least significant bits (LSB) of those pixels are collected and included in the binary message to be hidden. The bit- wise operation is performed for substituting the LSBs of the16 excluded pixels by values of the I_S and I_H.

In the extraction part, the peak values need to be recovered and the histogram is found excluding the 16 pixels. To extract data, the following operation is performed on any pixel counted with values of $I_S - 1$, I_S, I_H or $I_H - 1$ in the histogram:

$$b'_k = \begin{cases} 1, & if \ i' = I_S - 1 \\ 0, & if \quad i' = I_S \\ 0, & if \quad i' = I_H \\ 1, & if \ i' = I_H + 1 \end{cases} \qquad (2)$$

where b'_k is the k-th binary value extracted from the marked image I'. To recover the original image, the following operation is performed on every pixel counted in the histogram:

$$i = \begin{cases} i' + 1, & for \ i' < I_S - 1 \\ I_S, & for \ i' = I_S - 1 \ or \ i' = I_S \\ I_H, & for \ i' = I_H \ or \ i' = I_S + 1 \\ i' - 1, \ , & for \ i' > I_H + 1 \end{cases} \qquad (3)$$

The original LSBs of 16 excluded pixels are obtained from the extracted data. The excluded pixels can be restored back to recover the original image.

Each of the two peaks in the histogram is split into two adjacent bins with the same heights because the numbers of 0s and 1s must be equal in the message bits. The hiding rate can be increased by further splitting the highest bins in the modified histogram [7] and the process repeats to achieve histogram equalization effect. So by this way, the data embedding and contrast enhancement are simultaneously performed [8]. The value of L, the previous peak values are embedded with the last two peaks to be split. In the extraction process, the last split peak values are regained and the data embedded are obtained using Eq.(2) and the original image is recovered using Eq.(3).

2.1 Procedure of the Proposed Algorithm

The steps of the proposed algorithm are shown in the Fig. 1. Let the total number of pairs of histogram bins to be split for data embedding is L.

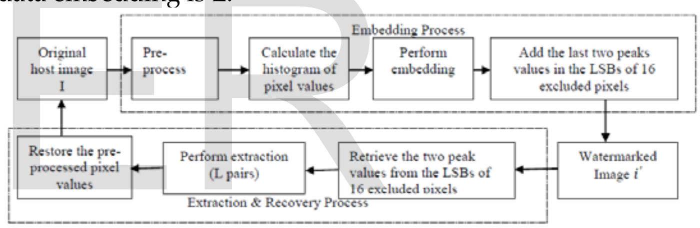

Fig.1 Block Diagram of the proposed algorithm

Embedding process includes the following steps:

1. Pre-Process: The pixels in the range of [0, L-1] and [256-L, 255] are processed. The pixel values in the range 0 to L-1 are added by L while the pixels in the range 256 –L to 255 are subtracted by L, excluding the first 16 pixels in the bottom row.

2. The histogram of the image is calculated excluding the first 16 pixels in the bottom row.

3. Embedding: The highest two bins in the image histogram are split for data embedding by using the eq.(1). Again the two peaks in the modified histogram are taken to be split and continue until L pairs are split. The value of L, LSBs of the 16 excluded pixels and the previous peak values are embedded along with the last two peaks to be split.

4. The LSBs of the 16 excluded pixels are replaced by last two peak values to form the marked image.

ISSN 2229-5518

Extraction and recovery process includes:

1. The LSBs of the 16 excluded pixels are recovered to know the last two peak values.

2. The data embedded with the last two pixels are extracted by using the eq.(2) and by using the eq.(3) the recovery operations can be done on all the pixels except the 16 excluded ones. The process repeats until all the data are extracted.

3. The original image is recovered by updating back the original LSBs of 16 excluded pixels

3 RESULTS AND DISCUSSION

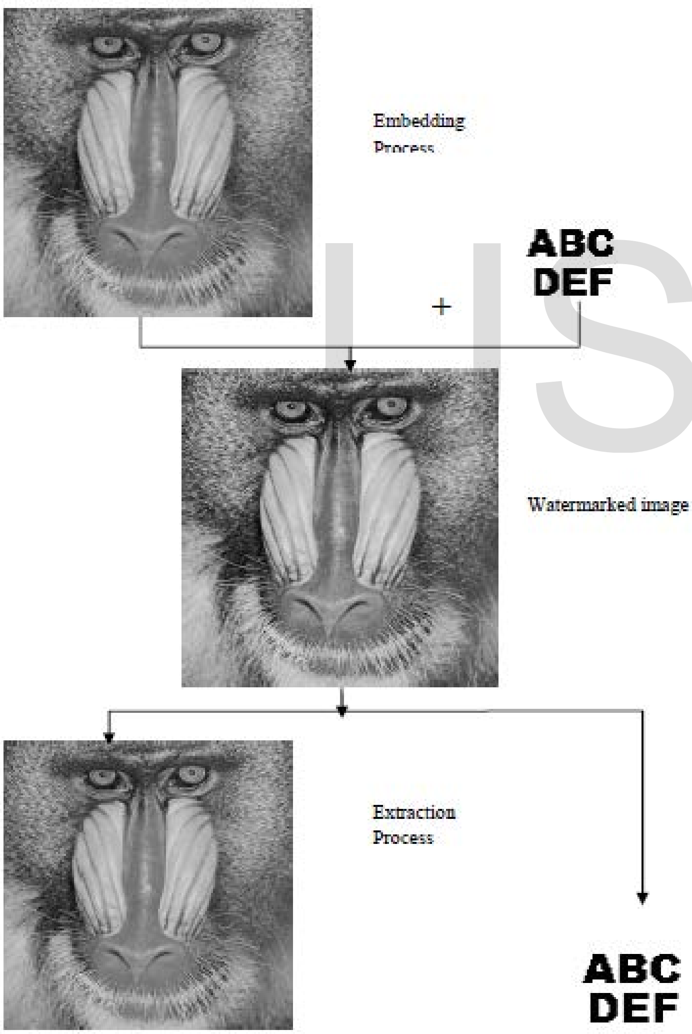

Fig.2 Graphical representation of the proposed method

In the proposed method steps, the data to be hidden are embedded into the host image and we obtain a watermarked image, whose contrast has enhanced than the host image. During the extraction process, the data hidden is extracted and the original host image is recovered. Figure 2 shows the graphical representation of the proposed method for the grayscale images.

The only parameter in the parameter algorithm is L (the pair number of the histogram peaks to be split). The data bits to be hidden can be any string of binary values where the number of 0s and 1s are almost equal, or some extra bits can be added to make so [9]. In this experiment the hiding rate generally increases by using more histogram peaks for data embedding.

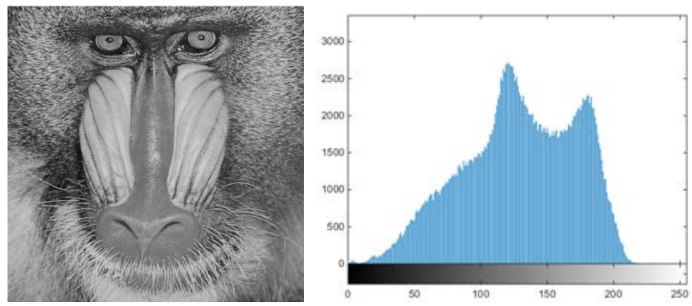

Fig 3 (a) Original image 'Baboon' (b) corresponding histogram

The hidden data is invisible in the contrast enhanced images. The more contrast enhancement is obtained, the more histogram peaks were split for data embedding. Also the PSNR values decreases with data hiding rate while the visual quality is maintained.

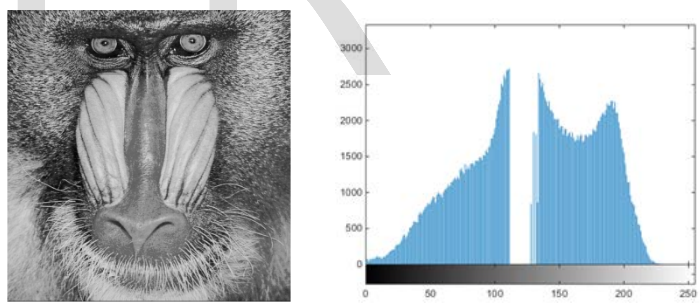

Fig 4 Contrast enhanced image by splitting 10 pairs of histogram peaks & corresponding histogram

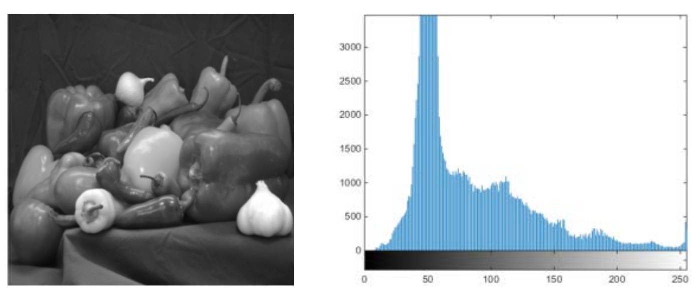

Fig 5 (a) Original image 'Pepper' (b) corresponding histogram

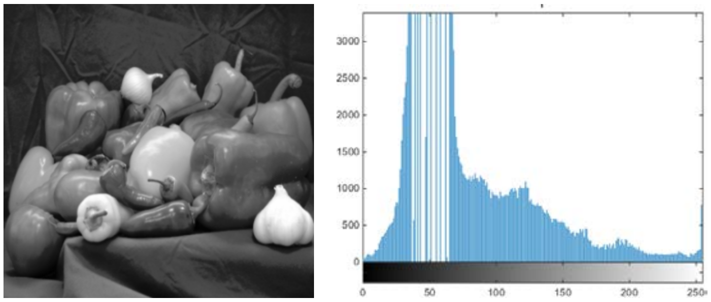

Fig 6 Contrast enhanced image by splitting 10 pairs of histogram peaks & corresponding histogram

Figure 3 and 4 shows the original image and contrast enhanced images of 'Baboon' with their corresponding histogram for value of L, i.e, 10 pairs. Figure 5 and 6 shows the original image and contrast enhanced images of 'Pepper' with their corresponding histogram for value of L, i.e, 10 pairs. It is seen from the figure that the contrast of the image is increased from the original image and also the contrast increases as the L value increases.

The figure also shows comparison of the histograms of the input image and the image with secret data. It is seen that the histogram after embedding the data is equalized, which is the major cause for the contrast enhancement of the image.

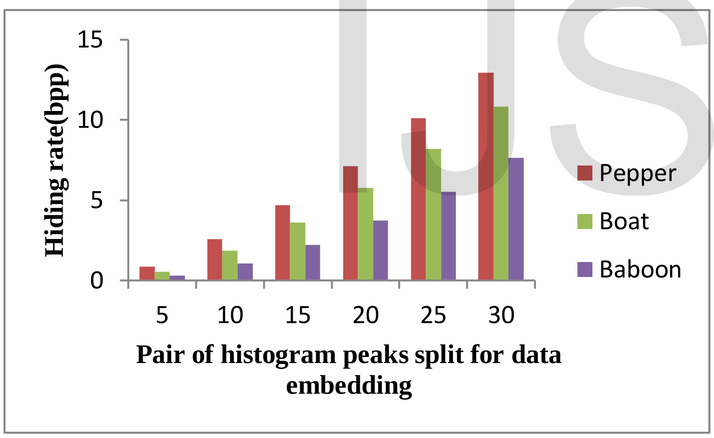

Fig 7 Data hiding rate increases as the pair of histogram peaks split increases

The data hiding capacity of the image increases as the pair of histogram peaks split increases. The experimental result show that the increased drastically. Figure 7 shows the graphical representation of the data hiding rate for three images.

Also the PSNR [12] values decreases with data hiding rate while the visual quality is maintained. Although the PSNR value of the enhanced image is often low, the visibility of image details has been improved.

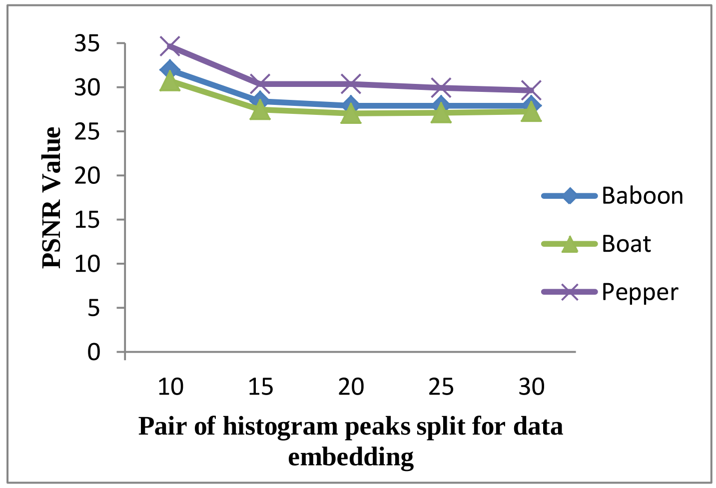

Fig 8 PSNR decreases as the number of histogram peaks split increases

Figure 8 shows that the PSNR decreases as the value of the number of histogram peaks split increases. The graph shows PSNR levels for different images and for each image the PSNR decreases with the increase in value of L.

4 CONCLUSION

As the technology has increased there is an enormous increase in multimedia and web documents and images. As large numbers of images are passed through the internet every day, there is a need to provide security to these images from the intruders. The intruders may capture the image, view the meaningful contents and after viewing modify the image and send it to destination. However, such distortion is not preferred in some applications, such as legal documentation, medical imaging[11], military reconnaissance, high-precision scientific investigation, etc., because it may lead to risks of incorrect decision making.

The proposed RDH algorithm with the contrast enhancement property improves both the data hiding and data embedding capacity. The visual quality is better using this proposed method than the traditional methods. The original image can be extracted without any distortion after extracting the embedded data. Experimental results show that the contrast enhancement of the image occurs simultaneously with the data hiding by doing histogram equalization. This algorithm can be applied to medical and satellite images as well as in color images. This method can be extended to video also.

ACKNOWLEDGEMENT

Dedicating this paper to the Almighty God, I would like to express my profound gratitude to all the people who had inspired and motivated me to take this paper. I endow my grateful thanks to Mrs. Gopika Krishnan, Assistant Professor, Department of Electronics and Communication Engineering, for her timely assistance and valuable advice throughout the paper. Finally I am grateful to my parents, who have given me all the tremendous

ISSN 2229-5518
support throughout my work. I specially thank all my dear friends, for their help and encouragement throughout the work.

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