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Reversible Data Hiding in Images with Improved Data Capacity by Duplicating Peak Pair Values

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***Abstract*— Data hiding is hiding the confidential information into the digital medium like image, audio, video etc. Data hidden in these mediums cannot be determined by human visual perception. To retrieve back this confidential information and cover image used, we have to do Reversible Data Hiding (RDH). The qualities of Reversible Data Hiding are measured by Peak Signal to Noise Ratio (PSNR), image quality, reversibility of both image and data, and data embedding capacity. Our proposed method improves all the quality measurements. The ultimate aim of our proposed method is to enhance the data embedding capacity and to keep the PSNR value above 48 dB. It works with peak pairs; select 2 pairs of the peak values from the histogram generated from the cover image and hide our data in the peak pairs. The data capacity of our method is enhanced by performing XOR operation. This embedding process is repeated number of times in order to improve the data capacity. The contrast enhancement is obtained by performing histogram equalization along with data hiding. The experiment shows the proposed method worked well in all the measures. This method is tested with normal, aerial and medical images and we obtained good result in all these different image sets.**

Index terms – Reversible Data Hiding, Histogram Equalization, Cover Image Recovery, Contrast Enhancement, Data Capacity.

I. INTRODUCTION

The great need of exchange of data or information has led to the rise of internet. With the growth of internet more importance has been given to the security and confidentiality of data or information which is much sensitive in nature. The reason is communication being performed is in an unsecure network. Various vulnerabilities exist in the network and it is prone to attacks. Anyone with the right knowledge can interrupt the data transfer and can perceive the sensitive data. So the primary concern is given to security. The data has to be kept safe without changing its quality. For this various techniques are developed.

Data Hiding is an invisible communication between sender and receiver. The Reversible Data Hiding gives importance to both cover medium and information. These reasons made Reversible Data Hiding [2] technique popular now. The areas where these techniques used are more sensitive in both data and cover image. The application areas of Reversible Data hiding are large; they are copy right protection, feature tagging, highly secret communications, digital watermark, medical, military, cloud, and etc.

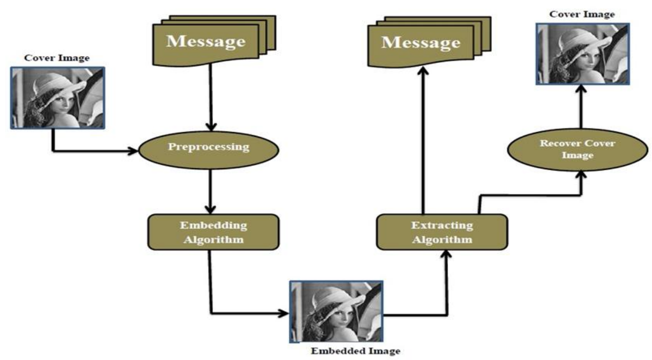

Figure 1: General block diagram of Reversible Data Hiding

Figure 1 shows the basic block diagram of Reversible Data Hiding. First phase is embedding, we give confidential message that we want to communicate and cover image, which is used to hide our confidential message as the input to the embedding algorithm. Embedding algorithm working on the cover image embeds complete information into the cover image and the output of embedding algorithm we get is embedded cover image. This embedded cover image is given as input to extracting algorithm which separates both confidential message and cover image. Both cover image and message must be same as the original so that it can be called as Reversible Data Hiding. Otherwise it is not Reversible Data Hiding.

In the Reversible data hiding, both image and data are equally important so that the original cover object without losing has recovered after the message is extracted. This vital technique is referred as "Reversible Data Hiding (RDH)", which is widely used in the areas of medical, military and law forensics, here no distortion of the original object is allowed.

Yun [3] proposed a new method proposed for cover image recovery namely Reversible Data Hiding (RDH). In this paper the author describes the main problems of 2 methods: LSB method and Quantization Index Modulation (QIM) method. In LSB method, we replace LSB bits of a pixel with the data. This replaced LSB values are not memorized further. In Quantization Index Modulation (QIM) method, normally the quantization error occurs. Due to these reasons complete cover image recovery gets impossible in effect.

Wen [4] introduced a method for Reversible Data Hiding for complete cover image recovery. The method keeps a separate record for change of the selected minimum points. This method improves the data capacity and reached the goal of data and cover image recovery. Yongjian [5] introduced a new method, even and odd number based embedding method. The method satisfies good embedding capacity and image quality. The 2 methods newly proposed by Ho [6] are: difference image histogram and the transform coefficient histogram.

The method introduced by Masoumeh [7] utilizes the difference of the pixel values of the host image and the zero or the minimum points of the histogram of the difference image. It then modifies the pixel gray scale value slightly to embed secret data into image. Qiminget [8] proposed a method that uses JPEG images as cover image. Data are embedded on the compressed data of the image. Such that it does not require decompression of the JPEG cover images.

A new method proposed by Hsiang [9] uses hierarchical relationships of original cover images. The result shows that better performance can be obtained in enhanced image quality and embedding capacity.

Different Reversible Data Hiding methods [10] – [16] are analyzed. Each method achieves its own advantages. They are based on histogram shifting, LSB method, non-overlapping, overlapping, pixel value difference, transformation domain and etc.

III. Overview Of The Proposed Method

This is new Reversible Data Hiding Method which meets all the measurements like improved security, data embedding capacity, contrast of the embedded image, PSNR value and also keeps the file size same as original.

A. Pre-Processing and Location Map

Before data embedding, first a preprocessing of the cover image is performed. Then adjust the gray scale value {0 – 255} into {1 – 254} and memorize this operation and create a binary image which is called as Location Map. For the original image I, if I (i, j) value is 0 or 255 change the value 0 to 1 and 255 to 254 and change i^{th} and j^{th} position value to 1. Otherwise set to 0. This operation is performed to avoid underflow and overflow. One more value 128 is also added in the location map.

B. Duplicating Pixel Values

All pixel values are in the range of 1 to 254 of the image after complete preprocessing. All pixels contain original values of cover image. Our aim is to increase the data capacity of the image. For increasing data capacity, we need to increase the frequency of the peak pairs. To increase the peak pairs duplicate the original pixel values into peak pair values. This is the core idea of the proposed method. We are duplicating the original pixel values into the peak pair values. By duplicating pixels we get increased frequency of the peak pairs. So our data capacity is increased. Duplicating peak values by equation (1) is applied in the original image.

If Pixel value < 128 then

New Pixel value = Pixel value Ɵ 255;

else (1)

New Pixel value = Pixel value;

end

Duplicated pixel values are restored after each pair of data embedding has completed. This restoration will keep the property of the image.

B. Data Embedding, Extracting and Recovery by Histogram Modification

In embedding process, generate a histogram from cover image and find highest 2 peak values I_S and I_R ($I_S < I_R$). Then perform actual data embedding algorithm by using equation (2):

If Pixel value < I_S, set Pixel -1;

If Pixel value = I_S, set $I_S - b_k$;

If $I_S <$ Pixel value $< I_R$, no change pixel value; (2)

If Pixel value = I_R, set $I_R + b_k$;

If Pixel value > I_R, set Pixel +1;

Finally embedding the two peak values into excluded last 16 pixel's LSB. Then perform the checking of data which are not completely embedded. If not, repeatedly do the above operations number of rounds. After the data embedding phase the output will be embed cover image.

The data extraction phase is actually the reverse process of data embedding. First extract two peak values from the last 16 bit LSBs and perform the number of round data extraction

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using equation (3).

If Pixel value= $I_S - 1$, b_k *is 1;*

If Pixel value= I_S, b_k *is 0;* (3)

If Pixel value= I_R, b_k *is 0;*

If Pixel value= $I_R + 1$, b_k *is 1;*

Finally perform the cover image recovery phase, because in RDH both cover image and data are equally important. Cover image recovery, completely recovers the cover image that as same as original cover input image. The recovery of cover image operation is performed using equation (4).

If Pixel value < $I_S - 1$, *set pixel value + 1.*

If Pixel value = I_S *- 1 or* I_S, *set pixel value is* I_S*;* (4)

If Pixel value = I_R *or* $I_R + 1$, *set pixel value is* I_R.

If Pixel value > $I_R + 1$, *set pixel value – 1.*

Finally, compare both original image and recovered image, if the result is same, it means that reversible data hiding (RDH) is successful. We tested all the images in the test set and we got a completely recovered image, which means recovered image is same as original image before embedding.

B. Contrast Enhancement

The advantage of proposed method is test images are achieved better visibility. The contrast enhancement is achieved by applying histogram equalization method. Histogram equalization is one of the best methods for contrast enhancement. Here is our proposed algorithm; cover image corresponding histogram is generated. This histogram is split by peak pairs and creates 3 regions. Region 1 is 0 to I_S, Region 2 is I_S to I_R and Region 3 is I_R to 255. Then we perform data embedding with histogram equalization. The peak pairs I_S and I_R hold the data bits, region 1 is shifted left by 1 (-1), region 2 not changed, and region 3 is shifted right by 1 (+1). This method is repeatedly performed with 10, 15, 20 pairs and in 20 pair we can see the better contrast enhanced data embedded image.

V. PERFORMANCE EVALUATION

This is a new proposed method of reversible data hiding. Proposed method's advantages are improved data capacity and enhanced contrast of the host image. We tested this proposed algorithm with 3 data sets they are normal, aerial and medical images. Each test sets shown high difference in the data capacity and other parameters like PSNR (Peak Signal to noise Ratio), contrast and also in improved security. The file size is preserved same as original image. Because we don't try to increase the gray level of the image but we perform histogram equalization together with data embedding.

A. Contrast Enhancement by Visual inspection

Figure 2: The original and contrast enhanced images of "Lena" by splitting 10, 15 and 20 pairs of histogram peak in the proposed algorithm. (a) Original cover image of "Lena". (b) 10 peak pair. (c) 15 peak pair. (d) 20 peak pair.

Figure 3: The original and contrast enhanced images of "Ship" by splitting 10, 15 and 20 pairs of histogram peak in the proposed algorithm. (a) Original cover image of "Ship". (b) 10 peak pair. (c) 15 peak pair. (d) 20 peak pair

In Figure 2 and 3, (a) original input image (b) 10 peak pair embedded image (c) 20 peak pair embedded image. We compare with the image (a), (b), (c) and (d) we can see that contrast enhancement of the cover image. When we compared with original image and 10 peak pair, 10 peak pair compared with 15 peak pair and 15 peak pair compared with 20 peak pair we can see that dynamically increase in the contrast by each peak pair by peak pair. From these we can definitely say that embedded image achieve contrast enhancement. Figure 1 and 2 represent the original, 10, 15 and 20 pair of cover image of lena and ship respectively. Increasing peak pairs we get the advantage not only in contrast enhancement but also in high data embedding capacity.

B. 1-Peak Pair Comparison

Table 1 show the proposed system in which how much bit per pixel is improved compared to old method [1]. Each image achieves maximum data capacity by duplicating peak pairs. In the table, we analysis one peak pair data embedding in both old and proposed XOR method. In one peak pair data embedding we embed our data into high frequency of two peak values. Our proposed method duplicates the normal pixel into peak values, so the frequency is improved by nearly double of the old method. If we increase the peak pairs we would get high data capacity. Figure 4 shows how much data capacity is increased with compared to old method [1].

Table 1: 1-Peak Pair Data Embedding Comparison.

Test Image	bpp of XOR method	bpp of old method[1]	PSNR of XOR method(dB)	PSNR of old method(dB)[1]
Lena	.0388	.0214	48.3347	48.2376
Bridge	.1071	.0747	50.5390	48.3523
Pair	.0541	.0283	48.4214	48.3038
Elaine	.0360	.0109	48.5384	48.2980
Ship	.0510	.0438	48.3347	48.2448

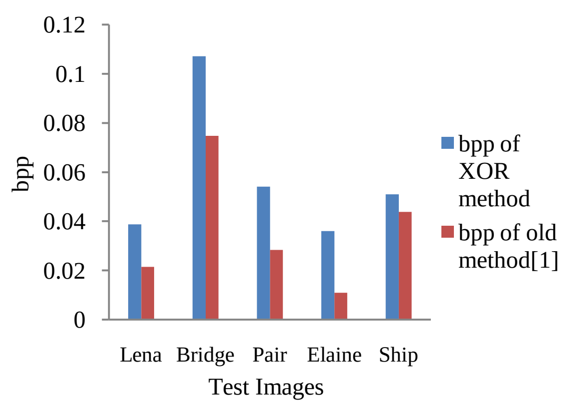

Figure 4:1-Peak Pair Data Embedding Comparison

C. 10, 15 and 20 Peak Pair Comparison

Next is comparative analysis of images in the dataset. We take 3 image sets are normal, medical and aerial dataset images. In each dataset application is different from one another. Normal image dataset are random images, aerial images are the images taken from high altitude and medical images are the image used in the medical areas. Comparative analysis is focused on how much proposed method improves all the parameters like PSNR and data capacity. Table 2 and 3 shows the comparison result with 10, 15 and 20 pair of different 3 set of datasets. Table 2 shows the analysis result of PSNR (dB) value in 10, 15 and 20 pairs in 3 dataset images.

Table 2: PSNR of 10, 15 and 20-Peak Pair Data Embedding Comparison.

Images	PSNR(dB)					
No. of Peak Pairs	10 Peak Pair		15 Peak Pair		20 Peak Pair	
Method	XOR Method	Old[1] Method	XOR Method	Old[1] Method	XOR Method	Old[1] Method
Normal Dataset	30.6658	29.3851	27.7100	26.2368	26.0318	24.5403
Aerial Dataset	31.5478	26.7983	28.7556	24.2515	26.5162	22.4494
Medical Dataset	31.5981	31.2882	28.5295	27.9261	26.3348	26.0382

Figure 5 is graphical representation of analysis result of 10, 15 and 20 peak pairs in the PSNR (dB) in 3 dataset images.

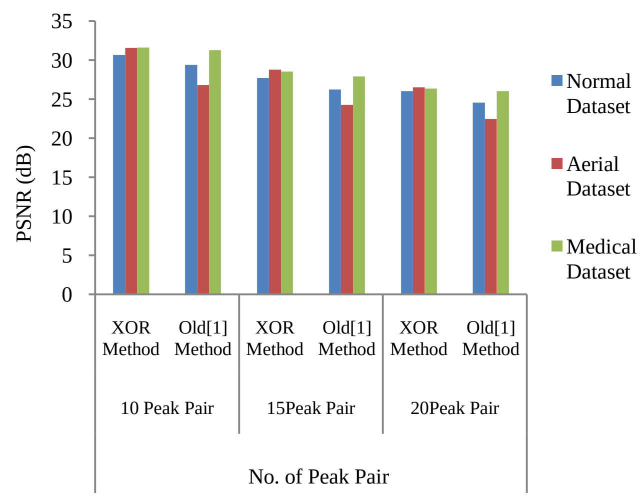

Figure 5: PSNR of 10, 15 and 20-Peak Pair Data Embedding Comparison

Table 3 shows the analysis result of data capacity (bpp) value in 10, 15 and 20 pairs in 3 dataset images. Figure 6 is graphical representation of analysis result of 10, 15 and 20 peak pairs in the data capacity (bpp) in 3 dataset images.

Table 3: bpp of 10, 15 and 20 Peak Pair Data Embedding Comparison.

Images	Bit Per Pixel					
No. of Peak Pairs	10		15		20	
Method	XOR Method	Old[1] method	XOR Method	Old[1] method	XOR Method	Old[1] method
Normal Data Set	.4672	.3223	.6296	.4526	.7679	.5714
Aerial Dataset	.3512	.2639	.5255	.3640	.7035	.4526
Medical Dataset	.4297	.4049	.5531	.5190	.6869	.5509

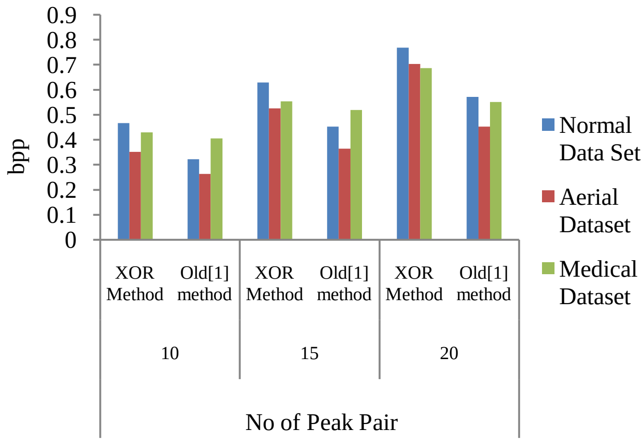

Figure 6: PSNR of 10, 15 and 20 Peak Pair Data Embedding Comparison

The comparative analysis result shows the proposed work well compare with old work [1]. So the proposed method got good result and achieved all the parameter goals.

VI. CONCLUSION

Our proposed method is the best one method in the Reversible Data Hiding methods. The main aim of our proposed method is improving data embedding capacity of the cover images. We give importance to data embedding capacity, contrast enhancement of cover image, PSNR and security. In the proposed method, we are performing contrast enhancement, improving visual quality in the cover images. The noted point is that we are strictly preserving the image file size even after performing contrast enhancement in the cover images. Our aim is to provide improved data capacity with minimum image size where the contrast enhancement is performed in images making it possible for different areas of applications like satellite, medical imaging etc.

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