RESEARCH ARTICLE OPEN ACCESS

Data Hiding Using Reversibly Designed Difference-Pair Method

Er. Ranjeet Kaur*, Er. Hitesh Pahuja**
*(Department of Electronics and Communication Engineering, RIMT-IET, Mandi Gobindgarh)
** (Department of Electronics and Communication Engineering, RIMT-IET, Mandi Gobindgarh)

ABSTRACT
There is no question that data hiding has increasingly drawn extensive attention recently. This report presents a data hiding technique based on the modification of image histogram. It is fully reversible, that means, the original cover image can be recovered from the marked image, after the hidden data has been extracted. In this work, a data hiding scheme using reversibly designed difference-pair method is presented. In comparison to the previous work, since only one pixel of a pixel-pair was allowed to be modified by 1 bit in value, their embedding capacity was low. The embedding algorithm should have higher embedding capacity as this was the major drawback. Therefore it was decided to work on an algorithm which can increase embedding capacity in reversible domain. Results achieved after the execution of algorithms were compared with the existed work to draw result oriented conclusion.
Keywords – Difference Pair Mapping, Embedding Capacity, Pixel Pair Mapping, Reversible Data Hiding

I. INTRODUCTION

Data hiding also referred as information hiding has been recently considered as a most promising technique for data or information security. According to studies by Li et al [15] reversible data hiding (RDH) is an information hiding technique that aims to embed secret information or message into a cover image by slight variation or modification in the pixel values They also concluded that, many methods of reversible data hiding have been presented so far which are based on histogram modification, difference expansion, prediction error expansion and integer transform. Among all above mentioned RDH methods histogram modification based one is of most attention recently due to its control over embedding distortion and increased embedding capacity.

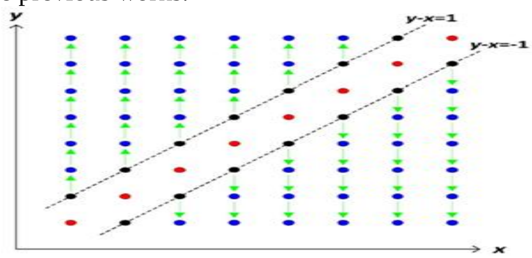
Hong [14] demonstrated that during data embedding the pixel values are modified thereby resulting with distortion between the cover (original) image and marked image. To ensure good data embedding capacity and quality of image a distortion is often required. Data hiding can be classified into two types; namely, reversible and non-reversible. Among these better image quality and higher payload are associated with non-reversible methods in comparison to reversible methods.

This paper presents a data hiding technique based on the modification of image histogram. It is fully reversible, that means, the original cover image can be recovered from the marked image, after the hidden data has been extracted. In this work, we will present a data hiding scheme using reversibly designed difference-pair method. Some papers constituting the base of this study are summarized below-Tian [1] presented a novel reversible data embedding method for digital images that was based on difference expansion. Pixel differences were used to embed data due to high redundancies amid the neighboring pixel values in natural images. Xuan et al [2] also proposed a RDH method for digital images having high embedding capacity and high visual quality of marked images. The spread-spectrum technique was used to embed in the wavelet coefficients and histogram modification to prevent the overflow and the under flow. The experimental results showed that the purposed method posses' superior performance in terms of high data embedding capacity and high visual quality of marked images compared to the existing RDH scheme. Ni et al [3] submitted a novel reversible data hiding scheme which can recover the real image without any distortion from the marked image after the hidden data have been extracted. The proposed algorithm utilized the zero or minimum points of the histogram of an image and slightly altered the pixel gray scale values to embed data into the image. The peak signal-to-noise ratio (PSNR) of the marked image versus the original image generated by this method was guaranteed to be above 48 dB. Lee et al [4] suggested a difference histogram method. The paper involved modifying the two dimensional pixel-intensity-histogram by designing pixel-pair-mapping (PPM) which is an injective mapping defined on pixel-pairs. This method manipulates the correlation among neighboring pixels and can embed larger payload with reduced distortion. Furthermore Ni et al [3] and Yaqub et al [5] achieved a high hiding capacity in a reversible domain by using difference-expansion technique. He modified the technique of difference-expansion by hiding the data in the difference in each acceptable expandable vector with in an image, which was obtained by subtracting the median pixel in that vector with other pixels. Varsaki et al [6] proposed that reversible data hiding technique can be able to embed about 5-80kb into a 512x512x8 gray scale image while guaranteeing the PSNR of the marked image versus the original image to be above 48dB. Puech et al [7] established that the reversible data hiding (RDH) method for encrypted images can be used to embed data in encrypted images and then to decrypt the image and to rebuild the original image by removing the hidden data. In the suggested method, the embedding factor was 1 bit for 16 pixels. Hu et al [8] observed that in order to increase embedding capacity, the compressibility of the overflow location map is improved by designing a new embedding scheme. Chrysochos et al [9] also established a new difference expansion (DE) based scheme that utilized consecutive overlapping pairs instead of non-overlapping pairs used as in case of traditional DE derivatives. This technique was based on the well known difference expansion family of technique. The embedding capacity and peak signal to noise ratio (PSNR) value were improved. Nafari and Jahromi [10] also showed a new RDH scheme which was based on statistical correlation of sub-sampled image. Here the data was embedded by modifying the pixel values. This method achieved higher embedding capacity with higher PSNR. Jung et al [11] proposed a new histogram modification based data hiding algorithm, wherein unlike conventional reversible data hiding techniques, the level of data embedding can be adjusted adaptively for each pixel while considering (HVS) human visual characteristics. Zhao et al [12] proposed a RDH scheme in which data embedding was done using multilevel histogram modification. In the proposed technique secret data can be embedded in differences of adjacent pixel values. In this method a histogram was erected based on these difference statistics. A multilevel histogram modification mechanism was retained. The hiding capacity was increased as compared with those traditional methods based on one or two level histogram modification. Ramaswamy and Arumugam [13] presented a novel data hiding scheme based on histogram modification. This technique was based on differences of adjacent pixels for embedding data. The number of data bits that can be embedded into an image equals the number of pixels associated with the peak point. Hence this technique can be applied to obstruct overflow and underflow problems of the pixels. Li et al [15] proposed a RDH based method to embed data in natural images. The techniques was very efficient than existed methods but with main drawback of less embedding capacity. Palshikar and Jadhav [16] presented a paper in which lossless data recovery was achieved by using histogram shifting and encryption method. In this method, the sub image information was replaced by the watermark image which is the hidden information by dividing image in 3 planes of R,G,B layer, then the three tier image after hiding information recorded as R’,G’,B’. Sridhar and Moorthi [17] also suggested a novel scheme for separable reversible data hiding in encrypted images, which included image encryption, data embedding and data recovery phases. Chaturvedi and Bairwa [18] showed that the hiding capacity of the system can be increased by using an integer wavelet transform based steganography technique. This technique hides data into the integer wavelet coefficients of an image. To increase the hiding capacity of the system, the proposed scheme combines a data hiding technique and the optimum pixel adjustment algorithm.

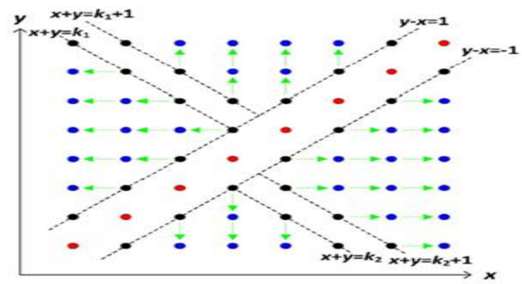
II. EXPERIMENTAL ANALYSIS

2.1 Related and Proposed Work

The proposed scheme performs in spatial domain and is based on DPM principle. Traditional DPM methods apply DE on non-overlapping pixel pairs [15] with embedding 1bpp.The proposed method may perform up to 2bpp, outperforming the aforementioned techniques, in terms of capacity versus PSNR values, while preserving reversibility. Before decrypting the embedding procedure, few terms need to be understood that has been used from the previous works.



(a) Lee et al.’s method



(b) Its improvement

Figure 1: PPM for illustrating the data embedding procedure [15]

We point out that, in an equivalent way, Lee et al.’s [4] embedding procedure can be demonstrated by a PPM shown in Fig. 1(a), in which a subset Z^2 is divided into two disjointed parts as black points and blue points, each black point is mapped to a blue one (indicated by a green arrow) and each blue point is mapped to another blue point. Here, each point represents the value of a pixel-pair and the black points are used for expansion embedding while the blue ones for shifting.

According to this PPM, for a cover pixel-pair (x, y), its marked value can be determined in the following way:

1) If y-x=0 (i.e., (x, y) is a red point), the marked pixel-pair is taken as (x, y) itself.

2) If y-x =1 or y-x= -1 (i.e., (x, y) is a black point)

a) If the to-be-embedded data bit b=0, the marked pixel-pair (x, y) is taken as itself.

b) If the to-be-embedded data bit b=1, the marked pixel-pair (x, y) is taken as its associate blue point.

3) If y-x >1or y-x< -1 (i.e.,(x, y) is a blue point), the marked pixel-pair is taken as its associate blue point.

The corresponding data extraction and image restoration process can also be demonstrated according to the PPM since it is an injection, i.e., each point has at most one inverse. The trivial description is omitted. From the PPM viewpoint, Lee et al.'s [4] difference-histogram based method is actually implemented by modifying the two dimensional pixel-intensity-histogram. Lee et al.'s [4] method only modifies the second pixel of the pair. Thus two modification directions, up and down, are allowed in data embedding. This is to say, in PPM, a point (x, y) can be either mapped to its upper neighbour (x, y+1) or lower neighbour (x, y-1). Actually, one can also modify the first pixel without introducing additional distortion resulting in modification directions left and right. In this way, the associate mapped point of (x, y) has four choices: (x-1, y), (x+1, y), (x, y+1) or (x, y-1) (see Fig. 2(a). Based on these four modification directions, this method can be improved by designing a new PPM shown in Fig. 1(b). According to this figure, one can see that more pixel-pairs (black points) are utilized for expansion embedding, and the number of shifted pixel-pairs (blue ones) is reduced as well. Here in Fig. 1(b), the parameters k1 and k2 can be adaptively selected by maximizing EC.

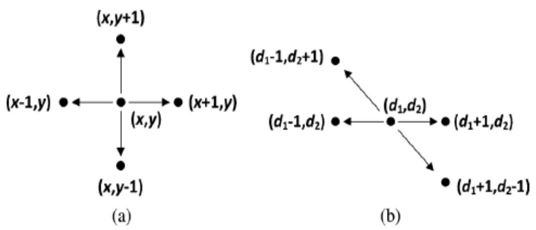


Figure 2: (a) By modifying either x or y by 1 has four modification directions (b) The corresponding difference-pair (d1, d2) also has four modification directions, where d1=x-y, d2=y-z and z is a prediction of y [15]

2.1.1 Embedding procedure: Modified DPM

For a pixel-pair, [15] proposes to compute two difference values d1 =x-y and d2=y-z to form a two-dimensional difference-histogram of (d1, d2) where z is a prediction of y which will be clarified later.

Inspired by the aforementioned new PPM, we will modify either x or y by 1 to 3. In this situation, since it has four modification directions, the difference-pair also has four modification directions, or (see Fig. 2(b)). For example, by modifying y to y+1,y+2 Or y+3, the modification direction to (x,y) is "up" and the corresponding modification direction to (d1,d2) is "upper-left", since d1 changes to d1-1, d1-2 and d1-3 and d2 changes to d2+1, d2+2 and d2+3. Similarly by modifying x to x+1, x+2 Or x+3, the modification direction to (x, y) is "right" and the corresponding modification direction to (d1, d2) is "right", since d1 changes to d1+1, d1+2 and d1+3 and d2 changes to d2.Based on these modification directions, we will introduce a new RDH scheme by designing a DPM.

The ideas of related works play an important role in our scheme. We extend the idea of two-dimensional pixel-intensity- histogram (or, in an equivalent sense, one-dimensional difference-histogram) of Lee et al. [4] to two-dimensional difference-histogram as shown in fig. 3.

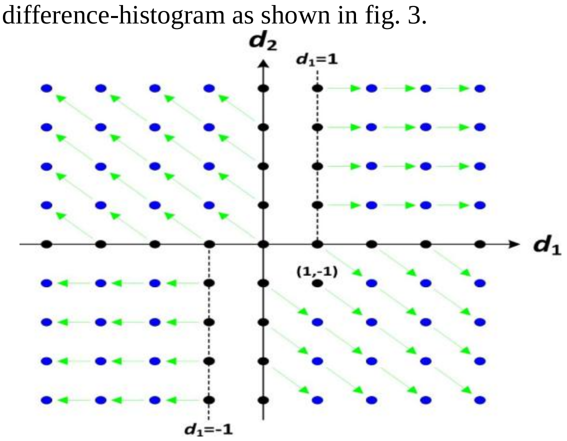


Figure 3: DPM for illustrating the data embedding procedure in [15].

Besides, for each (x, y), we compute the predication of y based on the context of (x, y) for an accurate estimation. Here, the gradient-adjusted-prediction (GAP) will be used in our scheme [15]. Moreover, to further improve the marked image quality, we adopt a strategy to select smooth pixel-pairs for data embedding. The main idea of this strategy is similar to those of pixel selection of their previous work [4] and error energy estimation of Hong [14]. By pixel-pair-selection, a noisy-level is computed for each pixel-pair, and only the pixel-pairs with relatively small noisy-levels will be embedded.

We now briefly introduce our embedding procedure:

Step1) Divide the test image into non-overlapped pixel-pairs.

Step2) For each pixel-pair (x, y), compute the prediction of y to get z using GAP predictor as shown in Figure 4.

$$z = \begin{cases} v1, & \text{if } dv - dh > 80 \\ \dfrac{(v1 + u)}{2}, & \text{if } dv - dh \in (32, 80] \\ \dfrac{(v1 + 3u)}{4}, & \text{if } dv - dh \in (8, 32] \\ u, & \text{if } dv - dh \in (-8, 8] \\ \dfrac{(v4 + 3u)}{4}, & \text{if } dv - dh \in (-32, -8] \\ \dfrac{(v4 + u)}{2}, & \text{if } dv - dh \in (-80, -32] \\ v4, & \text{if } dv - dh < -80 \end{cases}$$

Figure 4: Gap predictor for calculating z [15]

Where v1 to v10 are neighbouring pixels taken from surrounding window as described below in Figure 5.

	j	j+1	j+2	j+3
i	X	Y	v_1	v_2
i+1	v_3	v_4	v_5	v_6
i+2	v_7	v_8	v_9	v_{10}

Figure 5: Pixel window for calculation of z and threshold t. [15]

Here i represent the row and j represents the column co-ordinate of the test image
In this z has been rounded to its nearest integer by using ceil function in Matlab.
Horizontal and vertical gradients dv and dh has been calculated using formula below:
dv=|v3-v7|+|v4-v8|+|v1-v5|...........(2.1)
dh=|v3-v4|+|v1-v2|+|v4-v5|……...(2.2)
and u=(v1+v4)/2+(v3-v5)/4……...(2.3)
Step 3): Here, for discrete image, the noisy-level is computed by summing both vertical and horizontal differences of every two consecutive pixels in pixel window, and it is less than or equal to 13*255. Clearly a pixel-pair located in smooth regions may have a small noisy-level.
Step 4): Finally, for each pixel-pair with noisy-level less than a threshold T, compute the difference-pair (d1, d2) and implement data embedding according to the DPM defined below.

Table 1: Represents the data embedding procedure in x and y using difference pairs d1 and d2 and z predictor.

Conditions on d1 and d2	Operation in data embedding	Modification direction to pixel pair	Modification direction to(d1,d2)	Marked value
d1==0 & d2<=-2	Expansion embedding	Down	Lower-right	(x, y-b)
d1==-1 & d2<=-2;	Expansion embedding	Left	Left	(x-b, y)
d1>=1 & d2<=-2	Shifting	Down	Lower-right	(x, y-bmax)
d1<=-2 & d2<=-2	Shifting	Left	Left	(x-bmax,y)
d1==0 & d2==-1	Expansion embedding	Down	Lower-right	(x, y-b)
d1==-1 & d2==-1	Expansion embedding	Left	Left	(x-b, y)
d1==1 & d2==-1	Expansion embedding	Down	Lower-right	(x, y-b)
d1<=-2 & d2==-1	Shifting	Left	Left	(x-bmax,y)
d1>=2 & d2==-1	Shifting	Down	Lower-right	(x, y-bmax)
d1==0 & d2==0	Expansion embedding	Up	Upper-left	(x,y+b)
d1>=1 & d2==0	Expansion embedding	Down	Lower-right	(x, y-b)
d1>=2 & d2>=1	Shifting	Right	Right	(x+bmax, y)
d1==1 & d2>=1	Expansion embedding	Right	Right	(x+b, y)
d1==0 & d2>=1	Expansion embedding	Up	Upper-left	(x,y+b)
d1<=-1 & d2>=0	Shifting	Up	Upper-left	(x,y+bmax)

In order to achieve reversible data hiding, some pixels are embedded and modified in order to done embedding necessity and some pixels are shifted by an exact value in order to make the algorithm reversible. Table 1 gives all information about the pixels which are embedded or shifted.
Step 5): All the modified pixel pairs are kept in a matrix and corresponding record of embedded bits has been done. In the end the watermarked image has been saved to the folder along with the matrix containing embedding bits.

2.1.2 Extraction Process

The following extraction procedure was adopted during the experimental;
Step1) Load watermarked image in MATLAB workspace. The difference between reversible and non-reversible techniques is that reversible techniques only need the watermarked image at extraction process where as non-reversible techniques need secret keys as well which is the drawback of non-reversible techniques.
Step 2) Divide the whole image into non-overlapped pixel pairs and start for extraction from the pixels which are embedded in last in embedded algorithm.
Step 3) compute the gap predictor variable z and threshold t using the same gap predictor values described in figure 4 and 5 in the embedded algorithm.
Step 4) Evaluate modification direction variables d1 and d2 using formula d1=x-y and d2=y-z where x is first pixel of pixel pair and y is second pixel of pixel pair.
Step 5) Apply the embedded extraction and shifting according to the table listed below in Table 2.

Table 2: Table showing conditions on parameters d1 and d2 in order to do extraction

Conditions on d1 and d2	Extracted data bit	Recovered value
(d1==3 | d1==2) & d2==-2	d1-1	(x,y+b)
(d1==3 | d1==2) & d2<=-4	d1	(x,y+b)
(d1==0 | d1==1) & d2<=-2	d1	(x,y+b)
d1>=4 & d2<=-5	None	(x,y+bmax)
d1<=-5 & d2<=-2	None	(x+bmax,y)
(d1==1 & d2==-1) or (d1==2 & d2==-2)	d1-1	(x,y+b)
(d1==3 & d2==-4) | (d1==2 & d2==-3)| (d1==1 & d2==-2)| (d1==0 & d2==-1)	-1-d2	(x,y+b)
(d1==-4 | d1==-3 | d1==-2 | d1==-1) & d2==-1	-1-d1	(x+b,y)
(d1==4 & d2==-4) | (d1==3 & d2==-3)| (d1==2 & d2==-2)| (d1==1 & d2==-1)	-1-d2	(x,y+b)
(d1==7 & d2==-2) | (d1==8 & d2==-3)	-d2	(x,y+b)
d1<=-5 & d2==-1	None	(x+bmax,y)
d1>=5 & d2==-4	None	(x,y+bmax)
(d1<=0 & d1>=-3) & (d2==0 | d2==1 | d2==2 | d2==3)	-d1	(x,y-b)
(d1>=1) & (d2==0 | d2==-1 | d2==-2 | d2==-3)	-d2	(x,y+b)
d1>=5 & d2>=1	None	(x-bmax,y)
(d1==1 | d1==2 | d1==3 | d1==4) & d2>=1	d1-1	(x-b,y)
(d1==0 | d1==-1 | d1==-2 | d1==-3) & d2>=1	-d1	(x,y-b)
d1<=-4 & d2>=3	None	(x,y-bmax)

Step 6) Put the extracted bits in an array and modified values of x and y in a matrix.
Step 7) Repeat the steps from step 3 and find the extracted bits and modified pixels for all overlapped pair by choosing the pairs in recursive order to embedded process.
Step 8) Store the modified matrix of image and extracted bit array in the folder and compare with image taken in embedded process.

III. Experimental Results

Proposed method has been tried on many images taken from the internet. But here we will show results for six images which are taken from different perspectives as shown in figure 6.

Figure 6: Images used in experimental results

Here, for discrete image, the noisy-level is computed by summing both vertical and horizontal differences of every two consecutive pixels in region window taken for gap predictor z, and it is less than or equal to 255*13.Clearly, a pixel-pair located in smooth regions may have a small noisy-level. Finally, for each pixel-pair with noisy-level less than a threshold, difference-pair has been computed and data embedding has been implemented according to the DPM Table 1.

The criteria we adopted for choosing threshold are different from Li et al [15]. We use formula for obtaining maximum threshold which is the average of all the noise levels in the image as illustrated below.

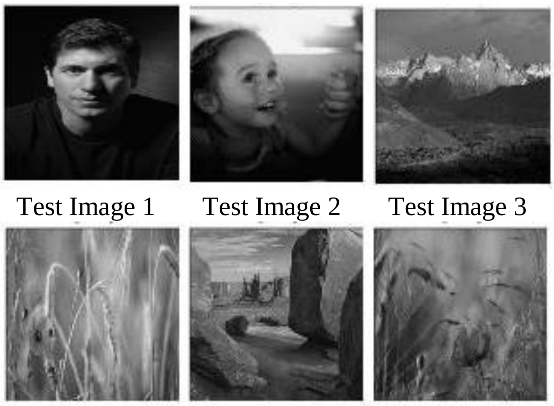
Sum (Noise level)/ ((r*c)/2) ………………… (1)

where r and c are rows and columns in the image.

Threshold values are chosen by noisy-level which is computed by summing both vertical and horizontal differences of every two consecutive pixels in gap generator window space V.

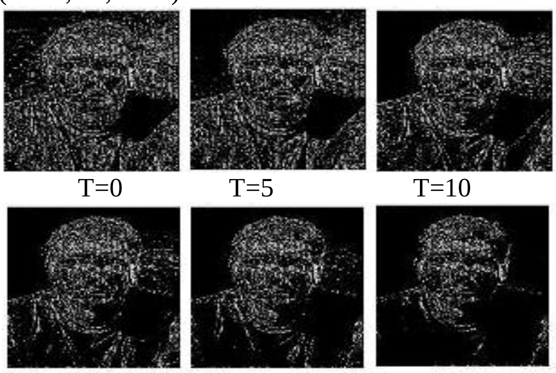
Results have been shown for threshold values 0, 5, 10, 15, 20 and tmax which is the average noise level in the image.

Below we have shown results for taken images at different threshold levels.



Test Image 4 Test Image 5 Test Image 6

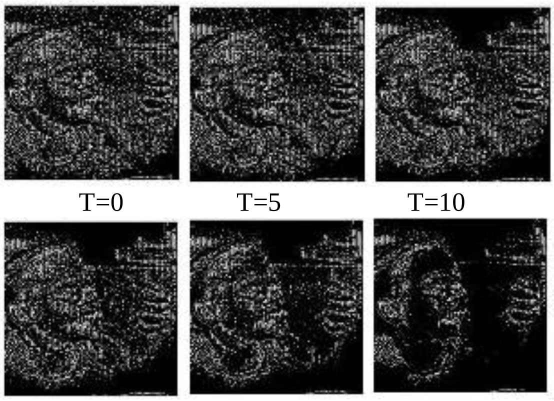
For Test Image1: Row 1 (T=0, 5, 10) and Row 2 (T=15, 20, tmax).



T=15 T=20 T= tmax

Figure 7: White portion showing embedding at T=0, 5, 10, 15, 20 and tmax respectively.

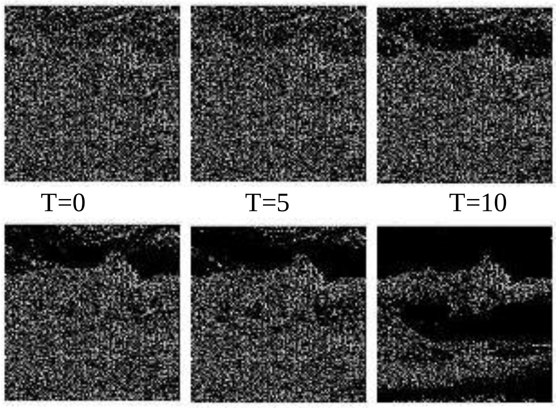
For Test Image 2: Row 1 (T=0, 5, 10) and Row2 (T=15, 20, tmax)



T=15 T=20 T=tmax

Figure 8: White portion showing embedding at T=0, 5, 10, 15, 20 and tmax respectively.

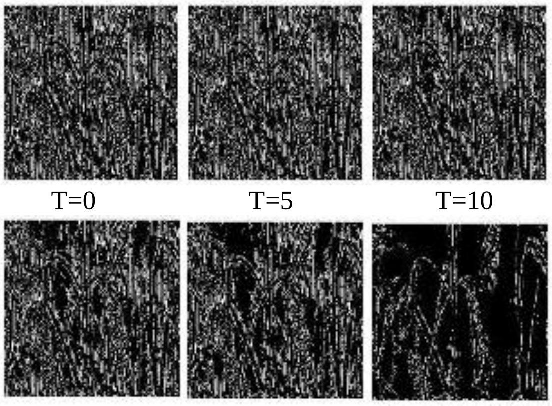
For Test Image 3: Row 1 (T=0, 5, 10) and Row 2 (T=15, 20, tmax)



T=15 T=20 T=tmax

Figure 9: White portion showing embedding at T=0, 5, 10, 15, 20 and tmax respectively

For Test Image 4: Row 1 (T=0, 5, 10) and Row 2 (T=15, 20, tmax)

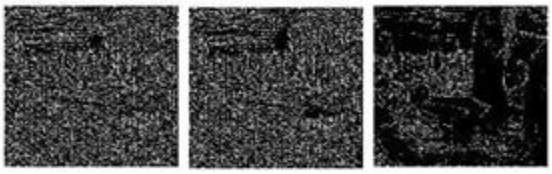


T=15 T=20 T=tmax

Figure 10: White portion showing embedding at T=0, 5, 10, 15, 20 and tmax respectively.

For Test Image 5: Row 1 (T=0, 5, 10) and Row 2 (T=15, 20, tmax

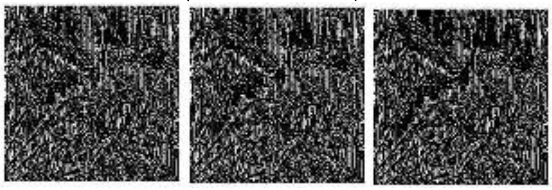
T=0 T=5 T=10



T=15 T=20 T=tmax

Figure 11: White portion showing embedding at T=0, 5, 10, 15, 20 and tmax respectively.

For Test Image 6: Row 1 (T=0, 5, 10) and Row 2 (T=15, 20, tmax)



T=0 T=5 T=10

T=15 T=20 T=tmax

Figure 12: White portion showing embedding at T=0, 5, 10, 15, 20 and tmax respectively

Table3: BPP, PSNR and MSE values for Li et al. [15] and presented Scheme for image1

Image1	BPP	PSNR	MSE	Tmax	BPP	PSNR	MSE
Proposed technique				Li et al. [15]			
T=0	0.6179	43.6667	2.7952	34.6957	0.3512	53.0183	0.3245
T=5	0.3304	44.7241	2.1911		0.1989	54.2190	0.2461
T=10	0.2040	45.5252	1.8221		0.1245	55.0905	0.2014
T=15	0.1292	46.3425	1.5095		0.0788	55.8840	0.1678
T=20	0.0934	46.9069	1.3255		0.0569	56.4391	0.1476
T=Tmax	0.0505	48.1598	0.9933		0.0305	57.7012	0.1104

Table 4: BPP, PSNR and MSE values for Li et al. [15] and presented Scheme for image2

Image2	BPP	PSNR	MSE	Tmax	BPP	PSNR	MSE
Proposed technique				Li et al. [15]			
T=0	0.5013	43.1849	3.1232	34.6724	0.2847	52.5842	0.3586
T=5	0.3598	43.6228	2.8236		0.2107	53.1108	0.3177
T=10	0.2895	43.9525	2.6172		0.1712	53.4760	0.2921
T=15	0.2271	44.4755	2.3203		0.1352	54.0042	0.2586
T=20	0.1630	45.1528	1.9852		0.0980	54.6786	0.2214
T=Tmax	0.0683	47.1630	1.2496		0.0420	56.7272	0.1382

Table 5: BPP, PSNR and MSE values for Li et al. [15] and presented Scheme for image3

Image3	BPP	PSNR	MSE	Tmax	BPP	PSNR	MSE
Proposed technique				Li et al. [15]			
T=0	0.3130	42.5487	3.6159	86.1668	0.1882	52.0736	0.4034
T=5	0.2945	42.6259	3.5521		0.1774	52.1435	0.3969
T=10	0.2201	42.9379	3.3059		0.1323	52.4664	0.3685
T=15	0.1671	43.2509	3.0760		0.1000	52.7730	0.3434
T=20	0.1345	43.5172	2.8931		0.0805	53.0460	0.3225
T=Tmax	0.0323	46.4834	1.4613		0.0193	56.0254	0.1624

Table 6: BPP, PSNR and MSE values for Li et al. [15] and presented Scheme for image4

Image4	BPP	PSNR	MSE	Tmax	BPP	PSNR	MSE
Proposed technique				Li et al. [15]			
T=0	0.2477	42.3103	3.8199	86.7166	0.1752	51.9812	0.4121
T=5	0.2435	42.3209	3.8106		0.1726	51.9976	0.4105
T=10	0.2119	42.4676	3.6840		0.1525	52.1330	0.3979
T=15	0.1661	42.7805	3.4279		0.1216	52.4301	0.3716
T=20	0.1330	43.1293	3.1633		0.0971	52.7643	0.3441
T=Tmax	0.0325	46.3880	1.4638		0.0221	55.9702	0.1645

Table 7: BPP, PSNR and MSE values for Li et al. [15] and presented Scheme for image5

Image5	BPP	PSNR	MSE	Tmax	BPP	PSNR	MSE
Proposed technique				Li et al. [15]			
T=0	0.1934	42.1557	3.9583	100.6118	0.1155	51.6754	0.4121
T=5	0.1929	42.1405	3.9722		0.1152	51.6641	0.4433
T=10	0.1889	42.1573	3.9569		0.1131	51.6847	0.4412
T=15	0.1791	42.2103	3.9089		0.1073	51.7353	0.4361
T=20	0.1657	42.3094	3.8207		0.0992	51.8509	0.4246
T=Tmax	0.0337	46.3704	1.4998		0.0199	55.9158	0.1665

Table 8: BPP, PSNR and MSE values for Li et al. [15] and presented Scheme for image6

Image6	BPP	PSNR	MSE	Tmax	BPP	PSNR	MSE
Proposed technique				Li et al. [15]			
T=0	0.2811	42.4191	3.7254	67.2209	0.1902	52.0599	0.4047
T=5	0.2598	42.4787	3.6746		0.1780	52.1457	0.3967
T=10	0.2214	42.6566	3.5272		0.1529	52.2928	0.3835
T=15	0.1730	42.9823	3.2723		0.1201	52.6010	0.3573
T=20	0.1374	43.3403	3.0134		0.0947	52.9625	0.3287
T=Tmax	0.0407	46.2094	1.5565		0.0267	55.7556	0.1728

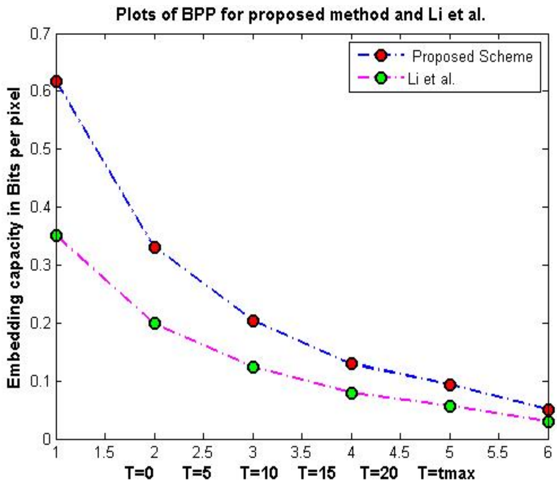


Figure 13: Plots of BPP vs. threshold for image 1

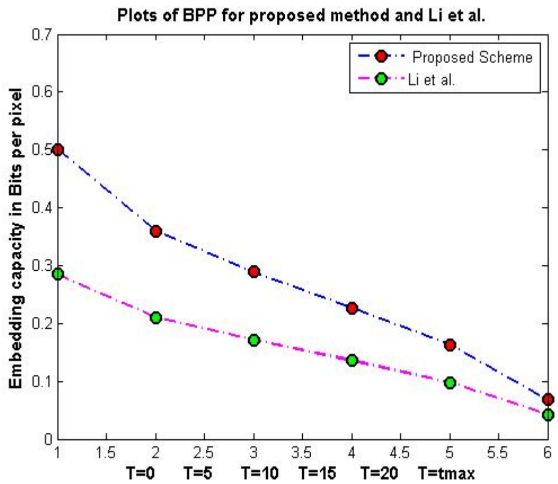


Figure 14: Plots of BPP vs. threshold level for image 2

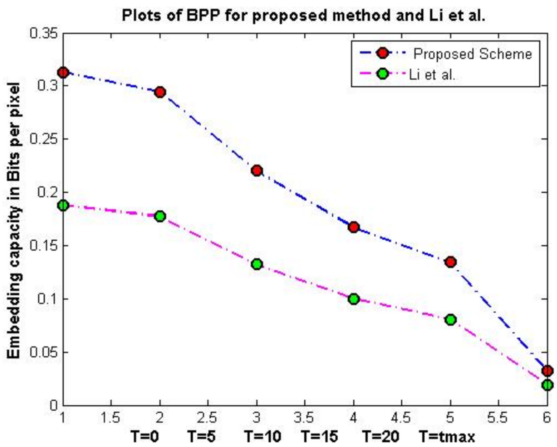


Figure 15: Plots of BPP vs. threshold level for image 3

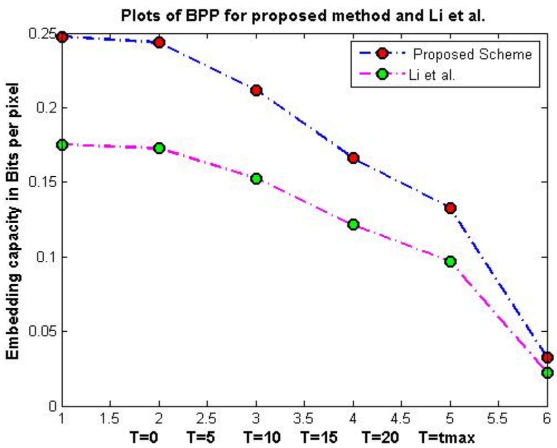


Figure 16: Plots of BPP vs. threshold level for image 4

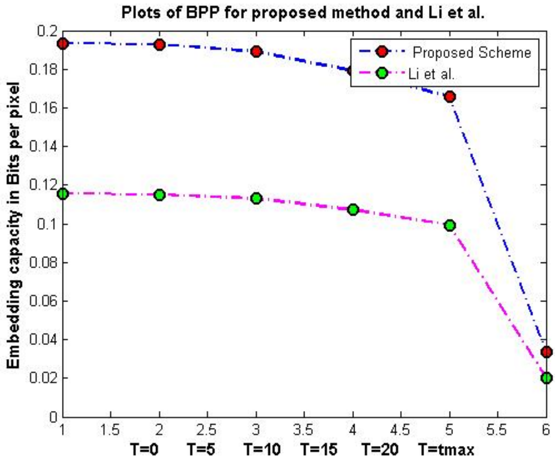


Figure 17: Plots of BPP vs. threshold level for image 5

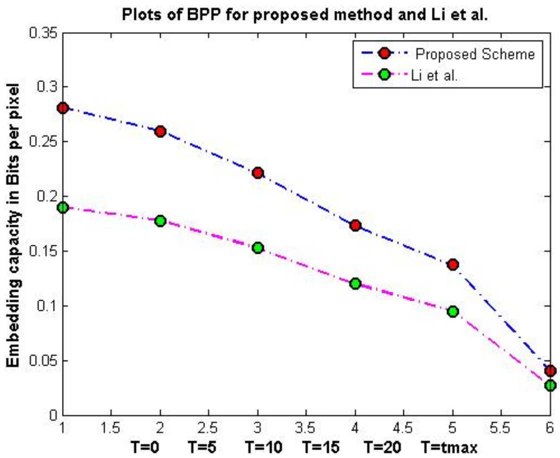


Figure 18: Plots of BPP vs. threshold level for image 6

We see that when we increase the threshold level, less pixels has been embedding as the gap generator window considers low frequency pixels in the image. As the threshold is increase algorithm picks only that pixels which are around the edges of the image as there is wide increase in intensity values around these pixels. It means that we can embed less data if we consider more and more low frequency components in the image like edges, corners, borders etc.

3.1 Performance evaluation regarding quality of the image

The ultimate objective of embedding is to produce an estimate of the unknown noise-free image, which approximates it best, under given evaluation criteria. Like in any estimation problem, an important objective goal is to minimize the error of the result as compared to the unknown, uncorrupted data. In this respect, a common criterion is minimizing the mean squared error (MSE)

$$\mathrm{MSE} = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}[f(i,j) - g(i,j)]^2.$$

……….Eq. (2)

Where f represents matrix data of our image,
g represents the matrix data of degraded image,
m represents the numbers of rows of pixels of the image and i represents the index of that row.
n represents the numbers of columns of pixels of the image and j represent the index of that column.
In image processing, another common performance measure is the peak signal to noise ratio (PSNR), which is for grey scale images defined in dB as
PSNR = 10log10 *(R^2/MSE)………….. Eq. (3)
Where R is the maximum fluctuation of intensity in the input image according to data type used. For example, if image has double precision floating point data type then R is 1 and if input image has an 8 bit unsigned integer data type R is 255.

3.2 Parameter for checking embedding capacity (BPP)

BPP (bits per pixel) has been calculated for both techniques using same thresholds. From the Table 3 and plot figure 13 of image one, it is clear that our proposed scheme embed dramatically more bits than the technique used by Li et al [15]. The decrease in PSNR values is due to more data has been embedding than the base technique which results in more number of modified pixels in the image.

IV. CONCLUSION

In this paper, a simple and efficient reversible data hiding scheme have been proposed that is based on difference pair mapping method for gray level images under the given threshold chosen according to noisy level in the image. The proposed scheme embeds secret data by modifying pixel values. Experimental results show that this method achieved higher embedding capacity with an acceptable PSNR than other reversible schemes. This algorithm has the following advantages: (1) simplicity and effectiveness, (2) adjustability of embedding capacity and quality based on threshold, (3) applicability to almost all kinds of grey images, (4) reversibility. In future works the security of the secret data can be further secured by using encryption-decryption techniques before it is embedded into the test images.

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