A Reversible Data Hiding Scheme Based on Two Dimensional Difference-Histogram Modification to Embed Binary Data

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Abstract— **In this paper, a reversible data hiding scheme based on two dimensional difference histogram modification is proposed. We adopted difference-pair-mapping (DPM) strategy. A sequence of pairs of difference values is calculated by taking each pixel-pair and its surroundings. Then, a two-dimensional difference-histogram is produced by counting the frequency of the resulting difference pairs. Then, according to a particularly designed DPM, a reversible data embedding (RDH) is implemented. We have presented a method of data hiding in which the average embedding capacity is inceased. Experimental results have been compared with Li et al. method and found significant increase in embedding capacity of the algorithm.**

Keywords—**Difference pair mapping (DPM), embedding capacity (E.C.), Peak signal to noise ratio (PSNR), reversible data hiding (RDH).**

I. INTRODUCTION

Data hiding is a process to hide data into host image. In majority of cases of data hiding, the host image will encounter inconsiderable distortion due to data hiding and the original image cannot be recovered. Some permanent distortion has happened to the host image even after the embedded image has been extracted out [1]. Any prevailing digital media, like, audios, videos, and digital images can be used as carriers. The digital image is used as a carrier since it is mostly forwarded over the internet. The image for carrying data is called a host image and the image carrying embedded data is called a stego image. When the data is embedded into images, the pixels of an image are modified, and hence the quality of image is degraded. Since, the modified pixels cannot be returned into their original state after the secret messages has been extracted out, permanent distortion will exist. Distortion for some applications is undesirable for example, a distorted leg X-ray image could result in an incorrect medical analysis. In these applications , technique for Reversible data hiding are mandatory[2].The aim of Reversible data hiding is to embed secret message into a host image by altering its pixel value and at the end, host image as well as embedded message should be completely recovered.[3].

II. RECENT WORKS

Recently, some reversible data hiding techniques have been recorded in literature. The first histogram-based RDH method is the one proposed by Ni *et al.* in [4]. In this method, peak and minimum points of the pixel-intensity-histogram to embed data were used. Each pixel value is modified at most by 1, and thus a better marked image quality can be obtained. Embedding capacity of this method is low and it does not work when cover image has a flat histogram.

Tai *et al.* [5], proposed efficient extension of the histogram modification technique by considering differences between adjacent pixels rather than simple pixel value. They exploited binary tree structure to terminate the requirement to communicate pairs of peak and zero points to the recipient and to prevent overflow and underflow, histogram shifting technique was used. Since image neighbor pixels are strongly correlated so the difference was expected to be very close to zero. Hence, using this method, they achieved large hiding capacity while preserving embedding distortion low. Zhincheng Ni *et al.* [6] proposed reversible data hiding technique which was able to embed about 5-80 kb into a 512×512×8 grayscale image and PSNR of marked image versus original image reported to be above 48dB. In this proposed method, they exploited the zero or the minimum points of the histogram of an image and slightly changed the pixel grayscale values to embed data into an image. Even, the computational complexity of their proposed scheme

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was low because in this method, they didn't use discrete cosine transform, discrete wavelet transform and fast fourier transform, which requires more time. All the processing was in spatial domain. Hence, the execution time was short. Many applications need high quality images, such as medical, law forensics or military images. The reversible data hiding method proposed by Ni *et al.* can produce high quality stego image (less than or equal to 48.13 dB), but the embedding capacity is low and is limited by the distribution of image histogram. Wein Hong *et al.* [7] proposed a novel reversible data hiding technique based on modification of prediction errors. In this scheme, pixel values are first predicted, and then error values are obtained. The PSNR of the stego image produced by MPE is guaranteed to be above 48 dB. Thodi *et al.* [8] described two new reversible watermarking algorithms, which combines histogram shifting and difference expansion technique. And second one using flag bits. Then, a new reversible data embedding technique called prediction-error expansion was then introduced and watermarking algorithms based on the prediction-error expansion technique were presented.

Wein Hong [9], proposed an improved reversible data hiding technique which includes three schemes, dual binary tree (DBT), median edge detection (MED) and expansion embedding capacity (EEC). The embedding performance was good in terms of image quality and payload. Krishna *et al.* [10] proposed an efficient extension of the histogram modification technique by considering the differences between adjacent pixels instead of using simple pixel value. They used binary tree that predetermines the multiple peak points used to embed messages. Their proposed method achieved large hiding capacity while keeping distortion low.

This paper presents system for embedding binary data using modified reversible data hiding in MATLAB. The paper is organized as follows. The proposed Modified Reversible data hiding is presented in Section III. The results are presented in section IV. Finally, the conclusion is given in section V.

III. MODIFIED RDH SCHEME

Following are the two processes:
Embedding Procedure: Brief description for our embedding procedure is as follows:

1) Read the image into MATLAB and transform it to gray scale if it is in RGB form. Then split the test image into non-overlapped pixel-pairs.

2) For every pixel-pair (x, y), compute prediction of y to get z using GAP predictor given below:

$$z = \begin{cases} v_1, & if\ d_v - d_h > 80 \\ \frac{(v_1+u)}{2}, & if\ d_v - d_h \in (32,80] \\ \frac{(v_1+3u)}{4}, & if d_v - d_h \in (8,32] \\ u, & if\ d_v - d_h \in [-8,8] \\ \frac{(v_4+3u)}{4}, & if d_v - d_h \in [-32,8) \\ \frac{(v_4+u)}{2}, & if\ d_v - d_h \in [-80,-32) \\ v_4, & if\ d_v - d_h < -80 \end{cases} \quad (1)$$

v1 to v10 are adjoining pixels taken from surrounding window described below

	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}

Fig.1 Adjoining pixels from surrounding window for calculation of z and threshold value t.

where $\{v_1, \ldots, v_6, v_7, v_8\}$ are surrounding pixels of (x,y) (see Fig. 1), $d_v = |v_1-v_5| + |v_3-v_7| + |v_4-v_8|$ and $d_h = |v_1-v_2| + |v_3-v_4| + |v_4-v_5|$ represent the vertical and horizontal gradients, and $u = (v_1+v_4)/2 + (v_3 - v_5)/4$, Where i represent the row and j represents the column co-ordinate of the host image. In this, ceil function in MATLAB is used to round off z to its nearest integer.

3) Then the noisy-level is calculated by summing both horizontal and vertical pixel differences of each two consecutive pixels in pixel window, and it is less than or equal to 13×255.

3) For each pixel-pair with noisy-level less than T (threshold), compute the difference-pair ($variable_1$,$variable_2$) and implement data embedding according to the DPM defined below.

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I. Look up table for embedding procedure

Conditions on variable$_1$ and variable$_2$	Operation in data embedding	Modification movement to pixel-pair	Marked value
variable$_1$= 0 & variable$_2$<= -2	Expansion embedding	down	(x, y-b)
variable$_1$= 0 & variable$_2$= -1			
variable$_1$=1 & variable$_2$= -1			
variable$_1$>=1 & variable$_2$=0			
variable$_1$= -1 &variable$_2$<=-2	Expansion embedding	left	(x-b, y)
variable$_1$=-1 &variable$_2$= -1			
variable$_1$>= 1 &variable$_2$<= -2	Shifting	down	(x, y-3)
variable$_1$>=2& variable$_2$=-1			
variable$_1$<= -2& variable$_2$<=-2	Shifting	left	(x-3, y)
variable$_1$=0& variable$_2$= -1			
variable$_1$= 0 & variable$_2$= 0	Expansion embedding	up	(x, y+b)
variable$_1$= 0 & variable$_2$>= 1			
variable$_1$>=2 & variable$_2$>=1	Shifting	right	(x+3, y)
variable$_1$=1 & variable$_2$>= 1	Expansion embedding	right	(x+b, y)
variable$_1$<= -1& variable$_2$>= 0	shifting	up	(x, y+3)

5) Some pixels are chosen for embedding process and changed in order to do embedding of bits and some are shifted without any embedding in order to make the algorithm reversible.

Table I gives details about shifted and embedded pixels which are chosen according to look up table.

6) Keep all the modified values of pixel pairs in a matrix and save the watermarked image to the folder when embedding has been done on all image.

These are the steps for embedding two bit binary data.

Extraction Procedure

The extraction procedure consists of several basic steps. The corresponding data extraction and image restoration procedure are summarized as follows.

Below are the steps for extraction process.

1) Load watermarked image in MATLAB workspace.

2) Then, start extraction process from last pixel-pair except the last two columns and last two rows, divide the marked image into k non overlapped pixel-pairs .

3) Evaluate the z (gap predictor) and t (threshold) .

4) Find direction variables, variable$_1$ and variable$_2$ using formula variable$_1$=x-y andvariable$_2$=y-z where x is first pixel and y is second pixel of pixel pair.

5) Apply the extraction of embedded bits and shifted bits according to the look up table described below.

6) Store the extracted bits found in reverse order in an array and also store newly generated values of x and y in a matrix.

Step 7) Store the newly generated matrix in the form of image and compare with the original to check the performance of the algorithm.

Step 8) Store the extracted bits in an array and reverse the order.

Step 9) Compare the embedded and extracted bits for checking the accuracy and performance of the algorithm.

Finally, the embedded bits are extracted and the original image is recovered.

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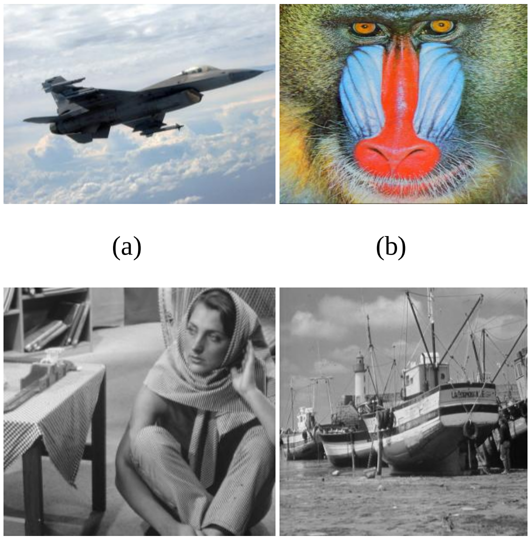
II. Look up table for extraction process

Conditions on variable$_1$ and variable$_2$	Extracted data bit	Recovered value of pixels
(variable$_1$= 3or variable$_1$=2) &(variable$_2$<= -2)	variable$_1$ -1	(x, y+b)
(variable$_1$= 3or variable$_1$=2) & (variable$_2$<= -4) or ((variable$_1$= 0or variable$_1$=1) &(variable$_2$<= -2))	variable$_1$	(x, y+b)
(variable$_1$= -4 or variable$_1$=-3 or variable$_1$=-2 or variable$_1$=-1) & variable$_2$<= -2	1 – variable$_1$	(x+b, y)
(variable$_1$ >=4 & variable$_2$<= -5) or (variable$_1$>= 5 & variable$_2$= -4)	No change	(x, y+3)
variable$_1$<=-5 & variable$_2$<= -2	No change	(x+3, y)
(variable$_1$= 1 & variable$_2$= -1) or (variable$_1$= 2 &(variable$_2$= -2)	variable$_1$-1	(x, y+b)
(variable$_1$= 3& variable$_2$=-4) or (variable$_1$= 2 & variable$_2$=-3) or (variable$_1$= 1& variable$_2$=-1) or (variable$_1$= 4 & variable$_2$=-4) or (variable$_1$=3 & variable$_2$= -3) or (variable$_1$=2 &variable$_2$=-2) or (variable$_1$=1 &variable$_2$=-1)	-1 - variable$_2$	(x, y+b)
variable$_1$= -4 or variable$_1$=-3 or variable$_1$=-2 or variable$_1$=-1) & variable$_2$= -1)	-1 – variable$_1$	(x, y+b)
(variable$_1$= 7& variable$_2$=-2) or (variable$_1$= 8 & variable$_2$=-3) or (variable$_1$>= 1& variable$_2$=-1) or (variable$_1$= 4 & variable$_2$=-0) or (variable$_2$= 0 or variable$_2$= -1 or variable$_2$= -2 or variable$_2$= -3)	-variable$_2$	(x, y+ b)

variable$_1$<=-5 & variable$_2$= -1	No change	(x+3, y)
variable$_1$<=0 & variable$_1$>=-3) & (variable$_2$= 0 or variable$_2$=1) or (variable$_2$= 2 or variable$_2$=3) or (variable$_1$= 0 or variable$_1$=-1) or (variable$_1$=-2 or variable$_1$= -3) &variable$_2$>=1)	- variable$_1$	(x, y-b)
variable$_1$>=5 & variable$_2$>=1	No change	(x- 3,y)
variable$_1$= 1or variable$_1$=2 or variable$_1$=3 or variable$_1$=4)&(variable$_2$>=1or variable$_2$>=1)	variable$_1$ -1	(x-b, y)
variable$_1$<=-4 & variable$_2$>=3	No change	(x, y-3)

IV. Results and Discussions

Four 256×256 sized gray scale images are used in our experiment. Fig. 3 shows the histograms of original image and watermarked image and Fig. 4 shows the comparison between the proposed method and Li *et al* method [3]. Tables 3, 4, 5 and 6 represents the PSNR and Embedding capacity of proposed method and Li *et al*. method [3].



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

Fig.2 Test images (a) Airplane (F-16) (b) Baboon

(c) Barbara (d) Fishing Boat

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Table 3. Peak Signal to Noise ratio (PSNR in dB) and Embedding Capacity (E.C. in bits) for Airplane (F-16)

Threshold values	Proposed Method		Li *et al.* [3]	
	PSNR	E.C.	PSNR	E.C.
0	48.7285	3380	58.2209	1964
20	46.6810	6228	56.1926	3651
40	44.1497	16156	53.6373	9439
Max.	42.9005	27410	52.3760	16060

Table 4. Peak Signal to Noise ratio (PSNR in dB) and Embedding Capacity (E.C. in bits) for Baboon

Threshold values	Proposed Method		Li *et al.* [3]	
	PSNR	E.C.	PSNR	E.C.
0	45.1776	1408	54.7353	875
20	44.6387	1708	54.1799	1054
40	44.1520	2012	53.6980	1227
60	43.7310	2336	53.2753	1427
70	43.5372	2478	53.0798	1513
Max.	41.8732	5778	51.3855	3594

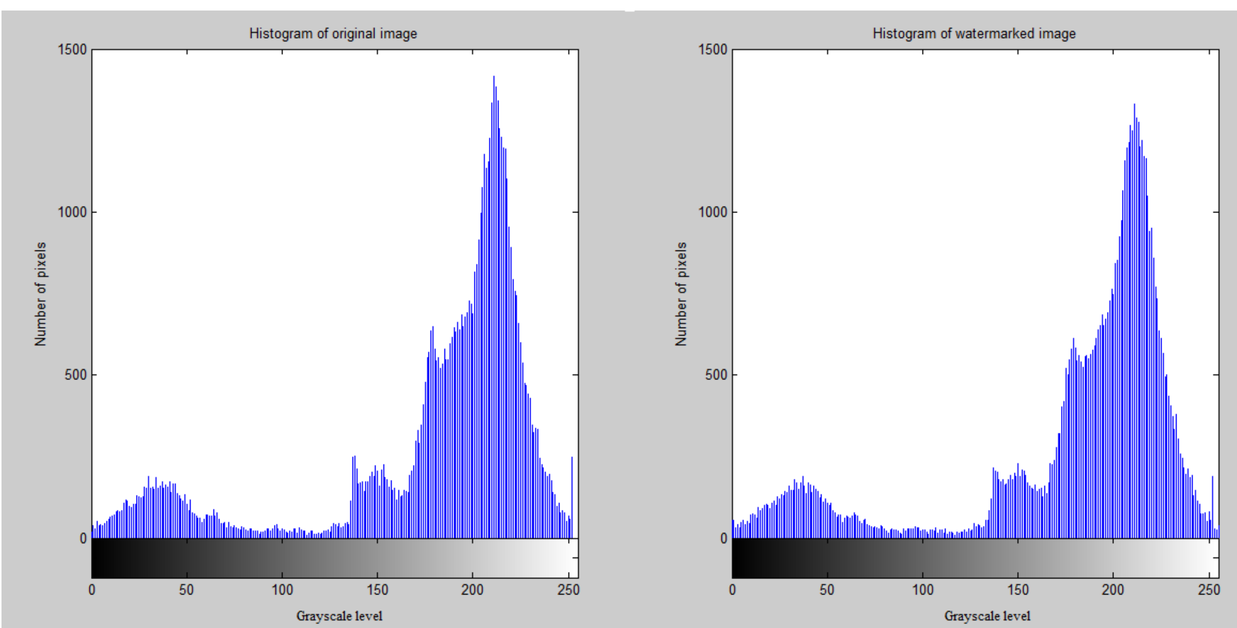
Table 5 Peak Signal to Noise ratio (PSNR in dB) and Embedding Capacity (E.C. in bits) for Barbara

Threshold values	Proposed Method		Li *et al.* [3]	
	PSNR	E.C.	PSNR	E.C.
0	45.7569	1802	55.2953	1126
20	45.1798	2194	54.7328	1374
40	44.6495	2778	54.1943	1719
60	44.1358	3426	53.6761	2116
70	43.8764	3824	53.4283	2388
Max.	42.1547	12744	51.6893	7939

Table 6 Peak Signal to Noise ratio (PSNR in dB) and Embedding Capacity (E.C. in bits) for Fishing Boat

Threshold values	Proposed Method		Li *et al.*[3]	
	PSNR	E.C.	PSNR	E.C.
0	46.6057	2266	56.1466	1376
20	45.8397	2914	55.3719	1759
40	45.0344	3834	54.5637	2308
60	44.2312	5086	53.7814	3050
70	43.8840	5844	53.4017	3516
Max.	42.2399	14806	51.7911	9096

(a) Airplane (F-16)



(a) Histogram of Airplane image

(b) Histogram of marked Airplane image

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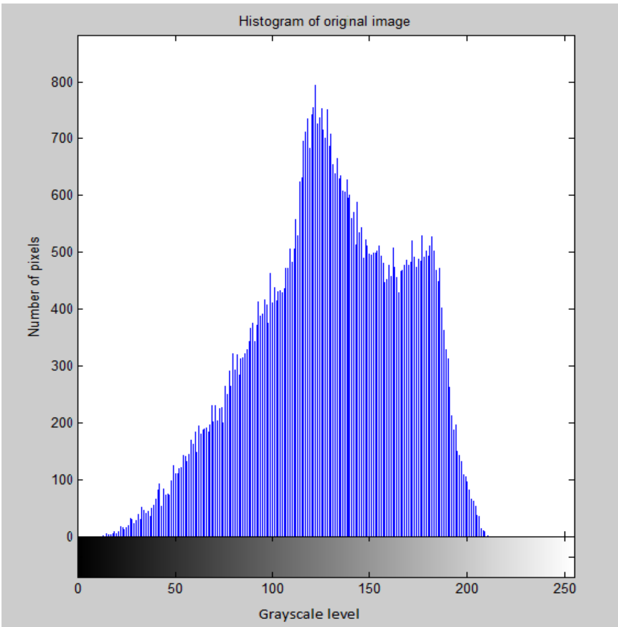
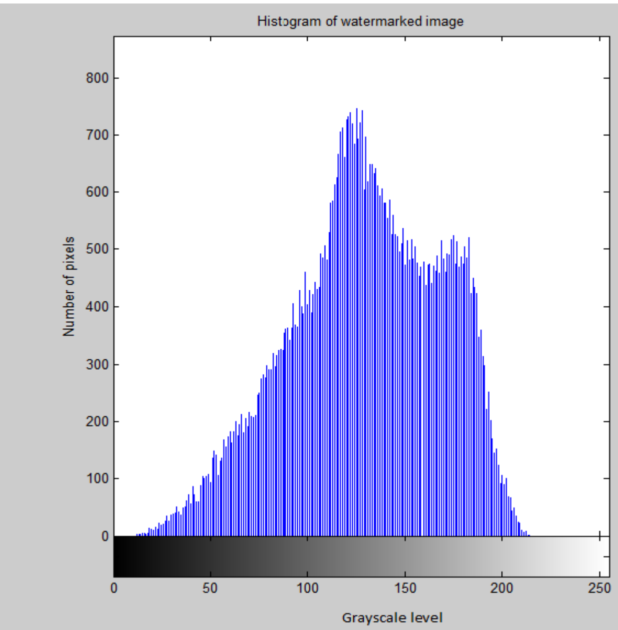
(b) Baboon

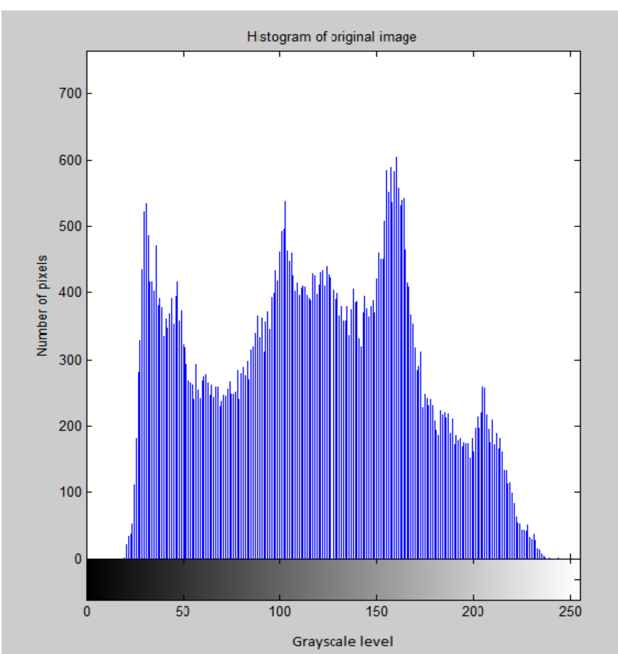


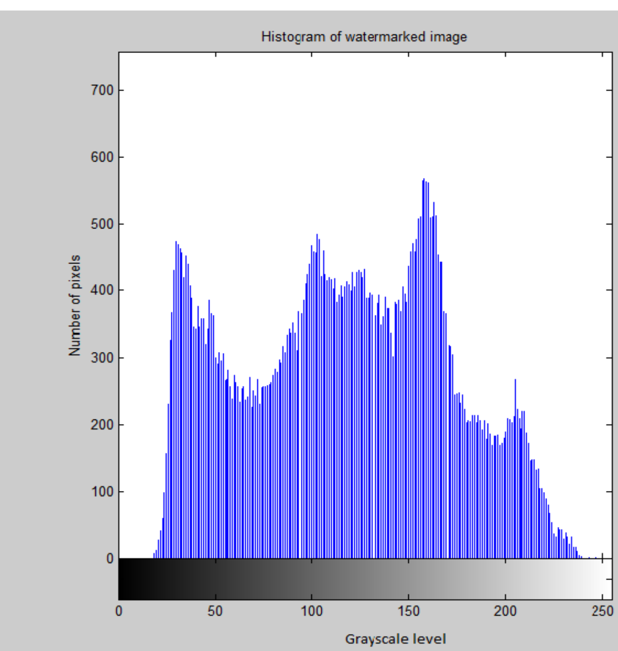


(a) Histogram of Baboon image

(b) Histogram of marked Baboon mage

(c) Barbara





(a) Histogram of Barbara image

(b) Histogram of marked Barbara image

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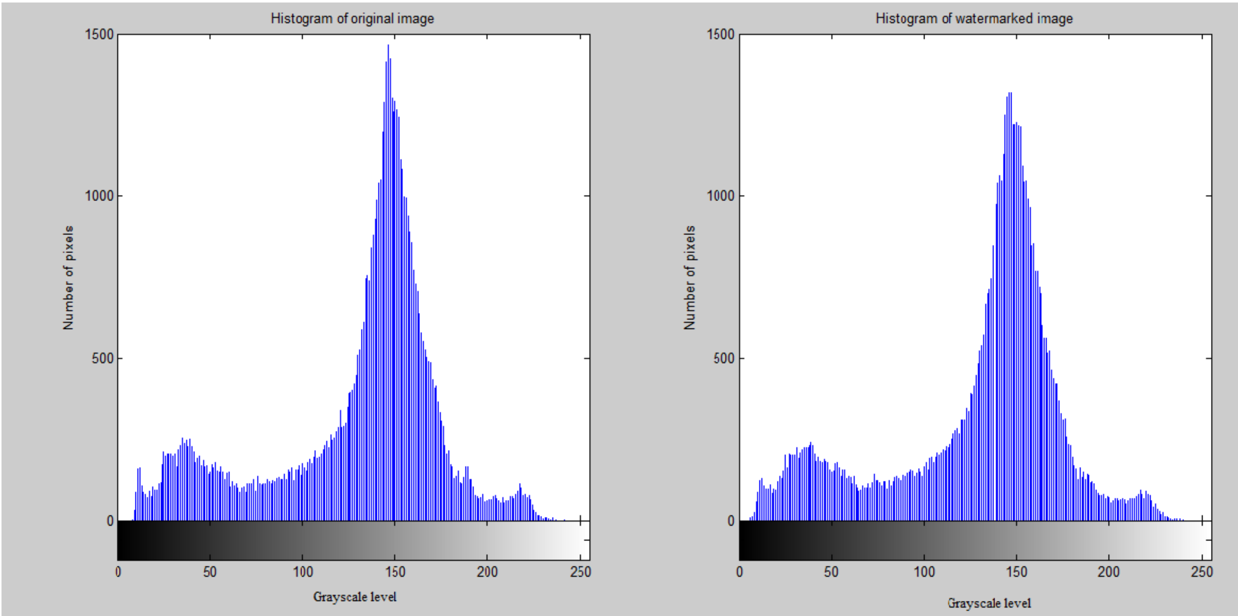
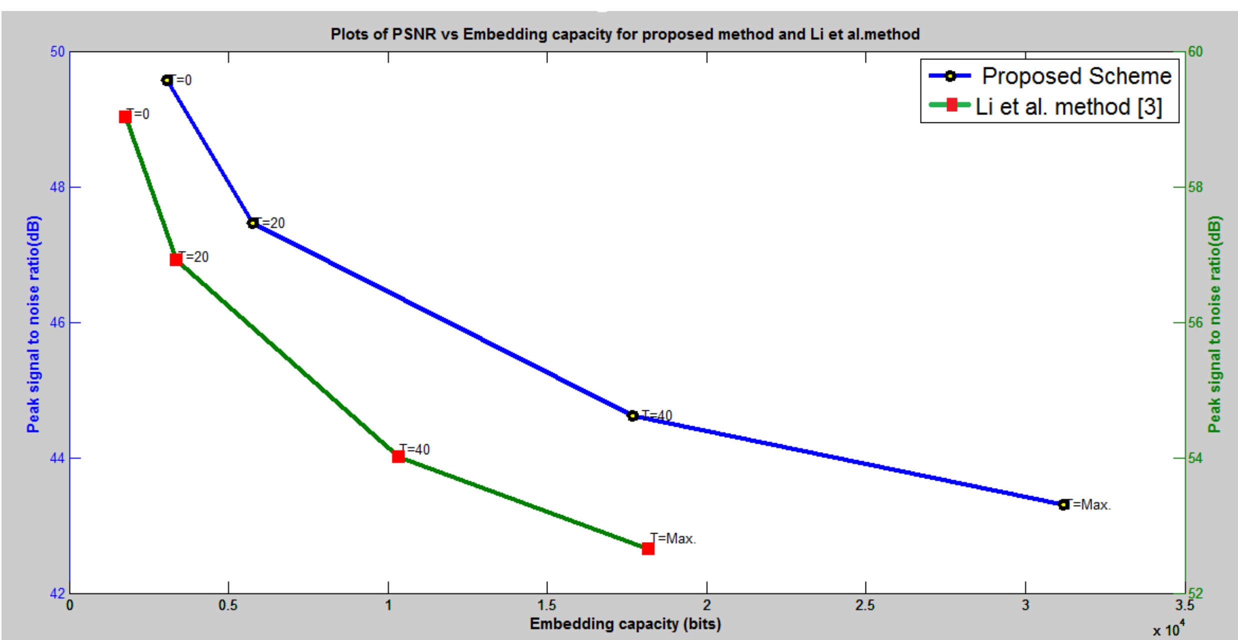
(d) Fishing Boat



(a) Histogram of Fishing Boat image (b) Histogram of marked Fishing Boat image

Fig. 3 Histograms of original and marked images (a) Air plane (F-16) (b) Baboon (c) Barbara (d) Fishing Boat

(a) Airplane (F-16)



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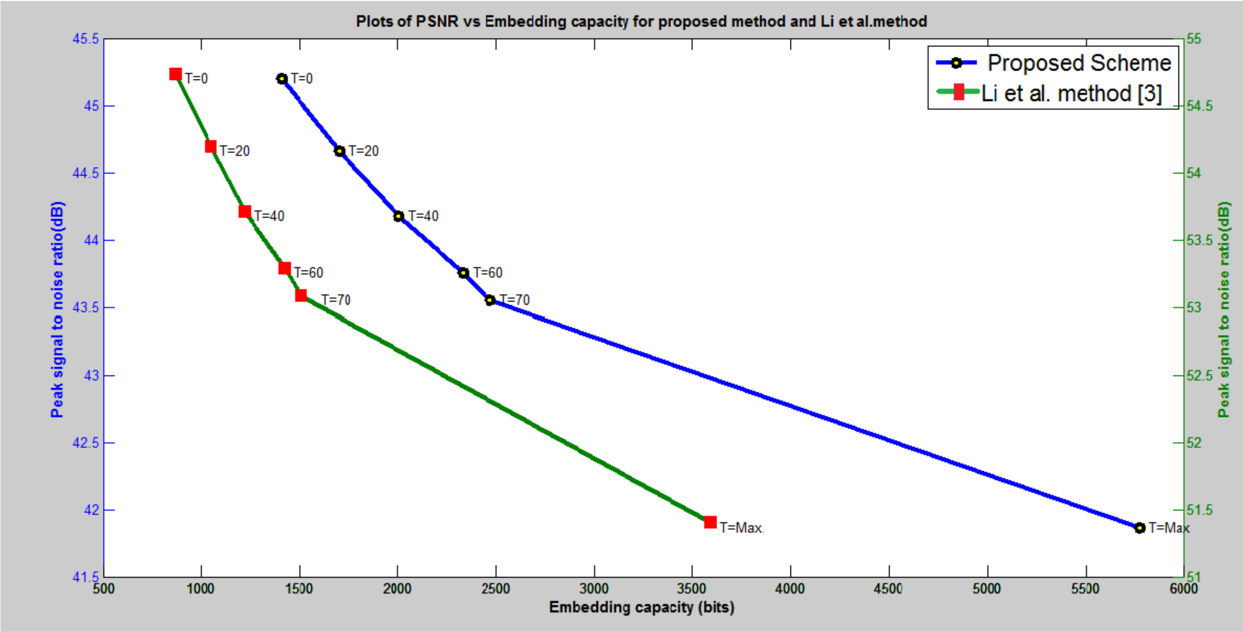
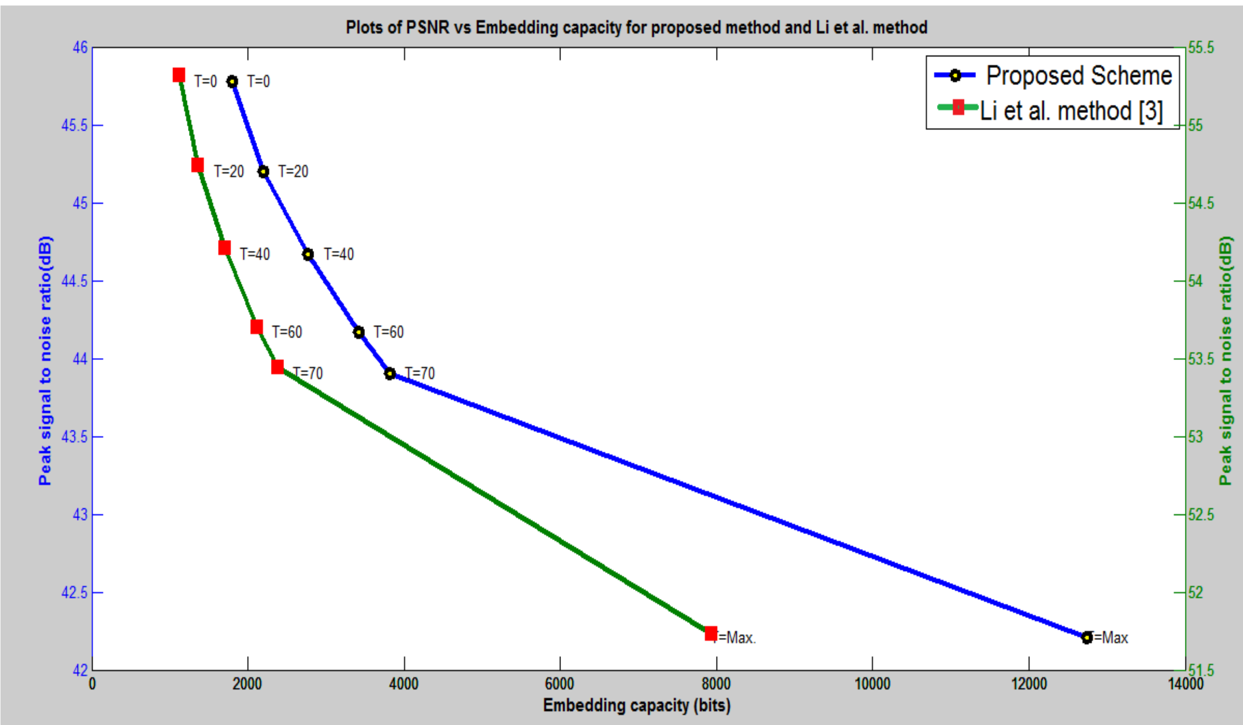
(b) Baboon



(c)Barbara



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(d) Fishing Boat

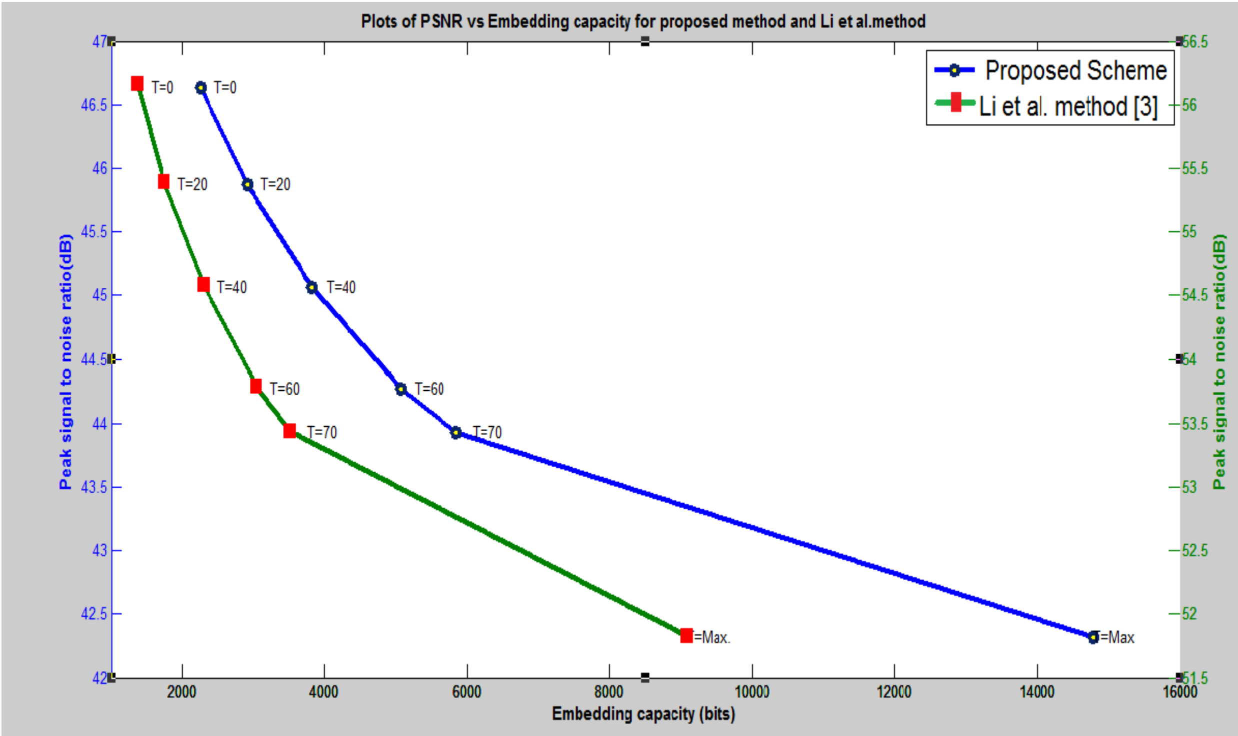

Fig.4 Performance comparisons between our scheme and Li *et al.* method [3] for (a) Airplane (F-16) (b) Baboon (c) Barbara (d) Fishing Boat

It has been observed that proposed scheme can embed two bits of data. The threshold parameter has been calculated in this algorithm which can control the embedding capacity of the RDH algorithm. Referring to Tables 3, 4, 5 and 6, one can observed that our method improves Li *et al.* [3] by increasing average embedding capacity. The binary data is used for embedding and it has been found that the presented algorithm is fully reversible and able to extract original data used in embedding process.

V. CONCLUSION

This paper covers the study of different techniques for reversible watermarking. Along with this we have modified an algorithm to make it useful for embedding binary data in the images. It has been observed that our proposed method can embed two bits of data. The threshold parameter has been calculated in this algorithm which can control the embedding capacity of the algorithm in such a way that at lower thresholds, the embedding capacity decreases as it chooses those pixel-pairs of embedding where there is difference in intensity values i.e. edges etc. Hence smooth regions and homogeneous region in the image can be eliminated while embedding hence increase impercibility of the image. We choose 6 threshold values for comparing the performance of presented method and Li *et al.* method [3]. It has been found that the presented algorithm is fully reversible and able to extract original data used in embedding process.

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