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Capacity Enhancement of Reversible Data Hiding Technique Using Adaptive Embedding

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ABSTRACT:
Reversible data hiding is current research area in field of data hiding. Reversible data hiding is defined as the process of hiding secret data in such a way that at receiver side both secret message and cover image can be recovered. This kind of reversibility is required in some areas such as medical and military applications. One most important characteristic of proposed hiding scheme is to use adaptive embedding means hiding two bits together in one pixel pair depending upon the complexity of image. This scheme also utilizes the histogram shifting and prediction error expansion scheme. It means two dimensional histogram scheme is used. Another advantage of proposed scheme is that no location map is required for this scheme hence overhead information reduces. Main focus of this paper is on enhancing the capacity of RDH (Reversible data hiding scheme).

keywords- Data hiding; Histogram Shifting; differential pair mapping; Adaptive embedding; Payload; Two dimensional Histogram.

I. INTRODUCTION

A large amount of data is transferred these days using internet. Due to this rapid development, data is generally transferred in digital form. Digital data can be easily tampered hence for the security purposes, Data hiding is very necessary. Data hiding is a scheme in which the secret data is hidden in some cover media like image, audio, video etc. the image formed after hiding the secret message is called marked image. The marked image should look almost similar to the original cover image so that no one else can get idea of secret data communication. Thus Steganography is a technique in which the hidden communication takes place and no one other than intended recipient can get idea of communication. Generally the images are preferred as a cover media because the images are usually sent in large amount through internet. Two main types of data hiding techniques exist: Irreversible data hiding and Reversible data hiding .In case of irreversible data hiding at the extraction side only secret message is recovered but in reversible data hiding both secret message and cover media is recovered without any distortion. Thus data hiding is necessary for protection and authentication of data. When only protection of data is required, it is called Steganography but when authentication of data is required, it is called watermarking. In some domains such as medical and military, even a slightest distortion is not acceptable so reversible data hiding (RDH) is required.

The block diagram for Reversible data hiding can be shown as in Fig 1.

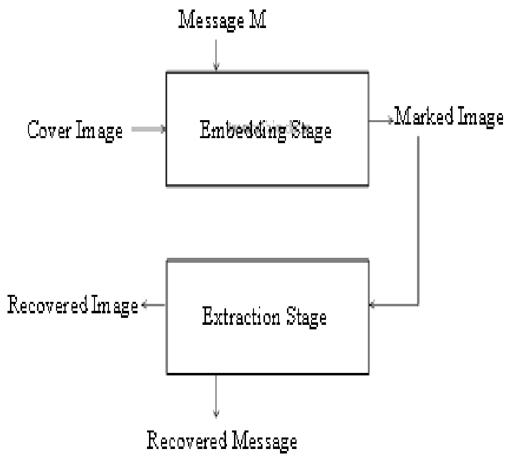

Fig .1 Data Hiding Block diagram

The Data hiding schemes need to fulfill certain conditions. These conditions can be described as:

- *Marked image quality*: Marked image formed after hiding the secret data should be good. It means there should be minimum variation between original and modified image so that no one can get the idea of communication.
- *Payload*: It is the number of bits that can be hidden in the cover image. The Payload should be high.
- *Overhead Information*: The amount of data that is required at the output to decode the hidden secret should be less.
- *Complexity*: The algorithm should be simple. So that it is easy to implement and understand.
- *Visual quality*: The marked image should look similar to the original image. There should be no degradation in image quality.

Various types of hiding schemes have been proposed in the literature. Some important techniques include difference expansion scheme,Histogram technique which is and prediction error expansion based schemes. These schemes give good results both in terms of marked image quality and hiding capacity.

In 2003, Tian [1] first proposed high capacity reversible data hiding scheme, in which the Haar wavelet transform was used to generate high pass and low pass bands in which information is embedded into difference of pixel values. The difference is expanded. So this is names as difference expansion. This scheme possesses high hiding capacity but the marked image quality is not so good. Secondly the content of image is not taken into account so distortion is always present. In 2006, Ni [2] proposed a high quality reversible data hiding scheme using the histogram of the image so it is named as histogram shifting technique. In this peak points and zero points are calculated depending upon the occurrence of the intensity values in an image. The bits are hidden in the peak point pixels and other values are shifted by1. The hiding capacity is limited to peak point pixels. So many schemes were proposed to increase the hiding capacity. In 2007, Thodi [3] extended the difference expansion to prediction error expansion scheme in which instead of expanding the difference between two pixel values, the prediction error between the pixel value and its predicted value is expanded. This scheme has good hiding as well as marked image quality.

The proposed work is based on combination of both prediction error expansion and histogram shifting techniques. It mainly focuses on increasing the hiding capacity while maintaining the marked image quality. Proposed work also uses Adaptive Embedding [4]. The image is first divided into flat and rough regions based on adaptive embedding threshold and flat regions are used for embedding two bits simultaneously in a pixel and rough regions are used for hiding only one bit. As adaptive embedding threshold is less, the marked image quality is good but if adaptive embedding threshold is increased then embedding capacity rises but the marked image quality distorts. Hence the value of adaptive embedding threshold must be selected optimally as required in application. Differential Pair mapping (DPM) technique has been used for embedding the data.DPM is an injective mapping defined on the difference pairs [5]. It is an extension to expansion embedding and shifting techniques used in the histogram based approach [5].It has been found that proposed scheme works better than some techniques.

The rest of paper is organized as follows: The related work is briefly discussed in section II. Section III discusses the proposed scheme in detail. Section IV shows the experimental results and Section V illustrates the conclusion.

II. RELATED WORK

Various techniques for reversible data hiding have been proposed based on prediction error expansion and difference expansion. Proposed scheme works both on difference expansion and prediction error expansion hence both can be described as:

A. Histogram approach:

In histogram approach [3], the histogram of image is drawn. From histogram the peak and zero point are calculated. The text data bits are hidden in the peak point values and rest of values between the range of peak and zero point are shifted by1. Thus embedding capacity is limited to value of peak point. Lee [4] introduced histogram of difference values rather than original pixel values for data embedding. Zhao [7] proposed a strategy of sequential recovery in which the pixel is recovered by using the previous recovered pixels. X. Li [10] gave a general framework that histogram technique can be designed by designing shifting and embedding functions only. Compression algorithm also combined with data hiding to increase capacity [12].

B. Two Dimensional Histogram Approach:

In the proposed scheme Two dimensional histogram[5] is used in which both difference values[4] and prediction error values[5]] are used to design the histogram .The predictor used is PDE (partial differential equation predictor).It iteratively keep on updating weights until its predicted value gets stable. This predictor is basically an effective mathematical tool proposed by Perona and Malik [9]. It is effective predictor as compared to the MED and mean value predictors since it automatically keep on updating its weights according to the content of image. Thus prediction is more accurate as it considers the content of particular image. 2-D Histogram considers correlations between image pixels and also the correlations between pixel value and its predicted values. Thus instead of one dimensional histogram, spatial redundancy can be better exploited in this case. Hence 2-D Histogram is preferred for data hiding.

C. Differential Pair Mapping:

For a particular pixel pair, difference value (x - y) and prediction error value like(y - z) is taken and histogram is made for all pixels of image, where x and y is a pixel pair and z is prediction of y. Injective mapping is defined on the pixel pairs according to some specified conditions, which will be discussed later in this paper. Mapping decides the modification direction of pixel pair. One more important thing about the DPM (differential pair mapping) is that four modification directions can be used for data embedding like in a particular pixel pair the pixel first pixel can be shifted in left and right direction similarly second pixel can also be shifted upwards and downwards.

III. PROPOSED SCHEME

Basically the proposed scheme considers all the factors for data embedding in a clear and precise way thus embedding procedure is discussed.

A. Embedding Procedure:

Step1: Except the last two rows and columns divide the cover image into pixel pairs.

Step2: Check for the pixel pair having value (0-3) or (252-255).if any then shrink the pixel values in the range (3-252).

Step 3: Note the Locations of these problematic pixels and embed into last two rows and columns.

Step 4: Now for pixel selection, calculate the value of forward variance as in Eq. 4

$$FV= \sqrt{1/4\sum (VK - V')^2} \qquad (4)$$

$V' = 1/4\sum VK$

Where VK = surrounding 4 pixels. K varies from 1 to 4.

Calculate the value of backward variance as in eq.5 as

$$BV= \sqrt{1/4\sum (UK - U')^2} \qquad (5)$$

$U' = 1/4\sum UK$

Where UK = surrounding 4 pixels. K varies from 1 to 4.

U1	U2	U3	
U4	Ii,j	V1	X
V2	V3	V4	
Y	Z		

Calculate gap between forward variance and backward variance as in eq. 6.

$$G = FV - BV \qquad (6)$$

Then threshold s is selected from the maximum value of these FV, BV, Gap in such a way that it is capable to embed the payload.

Step 5: Select an appropriate adaptive embedding threshold Δ_{ae}. Select regions as in Eq. 5.

$$\text{If } FV > \Delta_{ae}. \quad \text{Rough region} \qquad (7)$$
$$FV < \Delta_{ae}. \quad \text{Smooth region.}$$

Smooth regions can be used for adaptive embedding means for hiding 2 bits together like 00,01,10,11. Rough regions can be used for single bit embedding like 0, 1.

Step 6: Now for every pixel pair like(x, y) using adaptive embedding threshold and 's',Calculate the difference value d1 = x - y and d2 = y - z where z is the prediction of pixel element y. Partial differential equation predictor is used to predict the pixel values.

Step 7: Perform the same operation for every pixel pair.

Step 8: Calculate the prediction error for the image and limit the value of error to value of 2 so that marked image quality can be improved.

Step 9: Apply the differential pair mapping technique for embedding the data bits as shown in Fig 2.

Thus data embedding is done according to above designed differential pair mapping as shown in table 1. For rough regions single bit is hidden into one pixel pair at a time using similar procedure as in double bit embedding.

B. ***Extraction Procedure****:*

During the extraction phase, only the value of last embedded pixel needs to be sent as overhead. Thus for extraction same procedure is done in inverse order to recover the image.

Step 1: From the marked image calculate the value of forward variance, backward variance and gap.

Step 2: calculate the prediction of the image by using PDE as predictor.

Step 3: Calculate the prediction error between marked image and its predicted image.

Step 4: By limiting the values of forward variance value and threshold s then compute the value of hidden bits and the original image by using the Table III.

Step 5: The cover image and secret data can be perfectly recovered.

C. Overflow/Underflow problem:

For the proposed scheme Overflow and underflow problem occur in data hiding when the pixel lies in the range {253-255} and {0-2} respectively. Hence these pixels are called as saturated pixels .To prevent Overflow and underflow to occur the cover image is narrowed between (3-252) ranges before data embedding procedure. For data extraction these problematic locations can be saved.

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TABLE-I

DATA EMBEDDING AND FORMATION OF MARKED IMAGE WHEN ADAPTIVE EMBEDDING IS DONE FOR HIDING BITS (0, 1, 2, 3) FOR SMOOTH REGIONS

Conditions on d1,d2	**Operation in data embedding**	**Modification direction for difference pair**	**Modification direction to pixel pair**	**Marked Value**
d1=1 and d2>0	Double bit	Right	Right	(x + bits, y)
d1=-1 and d2<0	Double bit	Left	Left	(x - bits, y)
d1=0 and d2>=0	Double bit	Upper left	Up	(x, y+ bits)
d1<0 and d2=0	Double bit	Upper left	Up	(x, y+ bits)
d1=0 and d2<0	Double bit	Lower right	Down	(x, y- bits)
d1>0 and d2=0	Double bit	Lower right	Down	(x , y- bits)
d1=1 and d2=-1	Double bit	Lower right	Down	(x, y- bits)
d1>1 and d2>0	Shifting	Right	Right	(x+3, y)
d1<-1 and d2<0	Shifting	Left	Left	(x-3, y)
d1<0 and d2>0	Shifting	Upper left	Up	(x, y + 3)
d1>1 and d2<0	Shifting	Lower right	Down	(x, y- 3)
d1=1 and d2<-1	Shifting	Lower right	Down	(x, y- 3)

TABLE-II

DATA EMBEDDING AND FORMATION OF MARKED IMAGE WHEN ADAPTIVE EMBEDDING IS DONE FOR HIDING BITS (0, 1) FOR ROUGH REGIONS

Conditions on d1,d2	**Operation in data embedding**	**Modification direction for difference pair**	**Modification direction to pixel pair**	**Marked Value**
d1=1 and d2>0	Double bit	Right	Right	(x + bits, y)
d1=-1 and d2<0	Double bit	Left	Left	(x - bits, y)
d1=0 and d2>=0	Double bit	Upper left	Up	(x, y+ bits)
d1<0 and	Double bit	Upper left	Up	(x, y+ bits)

d2=0				
d1=0 and d2<0	Double bit	Lower right	Down	(x, y-bits)
d1>0 and d2=0	Double bit	Lower right	Down	(x , y-bits)
d1=1 and d2=-1	Double bit	Lower right	Down	(x, y-bits)
d1>1 and d2>0	Shifting	Right	Right	(x+1, y)
d1<-1 and d2<0	Shifting	Left	Left	(x-1, y)
d1<0 and d2>0	Shifting	Upper left	Up	(x, y + 1)
d1>1 and d2<0	Shifting	Lower right	Down	(x, y-1)
d1=1 and d2<-1	Shifting	Lower right	Down	(x, y-1)

DATA EXTRACTION PROCEDURE
For smooth regions

Conditions on d1,d2	**Extracted data bit**	**Recovered data**
d1=1,2,3,4 and d2>=0	bit1=d1-1	(x-bit1,y)
d1=-1,-2,-3,-4 and d2<=0	bit1= -d1-1	(x+bit1,y)
d1=0 && d2>=0)or(d1=-1 && d2>=1)or (d1==-2 && d2>=1)or(d1==-3 && d2>=1	bit1=-d1	(x,y-bit1)
d1<0 && d2=0) or (d1<-1 && d2=1) or (d1<-1 && d2=2) or (d1<-1 && d2=3)	bit1=d2	(x,y-bit1)
(d1==0 && d2<0)or(d1==1 && d2<-1)or (d1=2 && d2<-1)or(d1=3 && d2<-1)	bit1=-d1	(x,y+bit1)
(d1>0 && d2=0)or(d1>1 && d2=-1)or (d1>1 && d2==-2)or(d1>1 && d2=-3	bit1=-d2	(x,y+bit1)
d1=1 && d2=-1)||(d1=2 && d2=-1)or (d1=3 && d2=-1)or(d1=4 && d2=-1	bit1=d1-1	(x,y+bit1)
(d1>4 && d2>0)	No bit	(x-3, y)
d1<-4 && d2<0	-	(x+3, y)
d1<-4 && d2>0	-	(x, y-3)
d1>4 && d2<0)	-	(x, y+3)
d1=4 && d2<-4	-	(x, y+3)

IV. EXPERIMENTAL RESULTS

Experiments have been performed on gray scale test images including Lena, baboon, pepper, Barbara etc. The proposed scheme has good hiding capacity in a single embedding pass. When a large amount of data has to be hidden then this scheme can be useful. Experiments have been performed using MATLAB 7.10. Data hiding techniques are generally evaluated by using the mean square error and peak signal to noise ratio (PSNR) as in Eq. 6 and 7.

$$PSNR= 10\log_{10}255^2/MSE \quad (dB) \qquad (6)$$

$$MSE = (1/ (M*N)) \sum_{i=1 to M} \sum_{j=1 to N} ((I'(i, j) - I(i, j))^2 \qquad (7)$$

I’ and I represent marked image and original image resp.

PSNR is the most important measure for calculating marked image quality. PSNR values have been calculated for various images at various embedding rate as shown in Table II.

From the table it is very clear that for large data hiding our scheme maintains good marked image quality. In a single embedding pass hiding capacity has been enhanced. Baboon.

image is containing large amount of content hence it is not possible to hide 20,000 bits using the previous scheme. But our scheme has hiding capacity 3 times to the Li's [ ] method. Adaptive embedding threshold has been taken as 5, maximum prediction error allowed for data hiding has been taken to be two and gap value for the data embedding has been taken as 5 in the experiments.

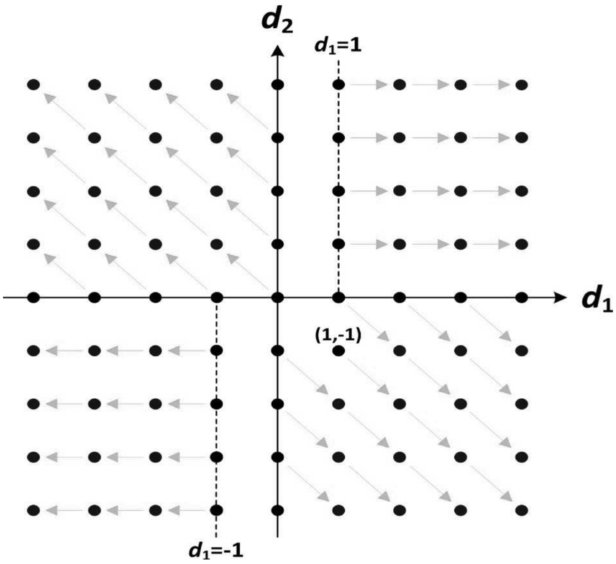

Fig 2 Differential pair mapping for proposed scheme.

TABLE-III
PSNR VALUES WHEN HIDING 10,000 BITS

IMAGE	Previous[11]	Proposed scheme
LENA	59.78	59.66
BABOON	53.96	64.01
AIRPLANE	63.18	59.39
PEPPER	57.19	59.73
AVERAGE	58.53	60.69

TABLE-IV
PSNR VALUES WHEN HIDING 20,000 BITS

IMAGE	Previous[11]	Proposed scheme
LENA	56.15	56.65
BABOON	-	60.75
AIRPLANE	59.45	56.23
PEPPER	53.39	56.61
AVERAGE	56.33	57.56

image is containing large amount of content hence it is not possible to hide 20,000 bits using the previous scheme. But our scheme has hiding capacity 3 times to the Li's [ ] method. Adaptive embedding threshold has been taken as 5, maximum prediction error allowed for data hiding has been taken to be two and gap value for the data embedding has been taken as 5 in the experiments.

V. CONCLUSION

In the proposed scheme we have used the adaptive embedding and Two Dimensional Histogram together which is a very successful approach for increasing hiding capacity in single embedding pass. This scheme is able to increase the hiding capacity for high content images without compromising with the marked image quality. Adaptive embedding increases hiding capacity and two dimensional histogram better exploits spatial redundancy. The Partial Differential Equation predictor is a content dependent predictor which maintains the marked image quality. Marked image quality can be more improved by designing a new differential pair mapping technique. For future work, security of this data can be taken into consideration by applying some encryption standards.

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