Very High Embedding Capacity Algorithm for Reversible Image Watermarking

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Abstract— Reversible image watermarking enables the embedding of copyright or useful information in a host image without any loss of information. Here a novel technique to improve the embedding capacity i.e. reversible watermarking using an adaptive prediction error expansion & pixel selection is proposed. This work is an improvement in conventional Prediction Error Expansion by adding two new techniques adaptive embedding & pixel selection.

Instead of uniform embedding, here one or two bits of watermark are adaptively embed into the expandable pixels as per the regional complexity. Adaptive Prediction Error Expansion can obtain the embedded rate upto 1.3 bits per pixel as compared to the 1 BPP of conventional Prediction Error Expansion. Also an intermediate step of prediction error expansion is proposed to select relatively smooth pixels and ignore the rough ones. In other words, the rough pixels may remain unchanged, and only smooth pixels are expanded or shifted. Therefore compared with conventional Prediction Error Expansion, a more sharply distributed prediction error histogram is obtained i.e. , and a larger proportion of prediction-errors in the histogram are expanded to carry hidden data. So the amount of shifted pixels is diminished, which leads to a better image quality. With these improvements, this method performs better than conventional Prediction Error Expansion. It can embed larger payloads with less distortion (almost 30% greater than the conventional method).

Keywords- Reversible image watermarking, Adaptive prediction error expansion, Gradient adjusted prediction, Pixel Selection (PS).

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I. INTRODUCTION

Among different kinds of digital watermarking schemes, reversible watermarking has become a research hotspot recently. Compared with traditional watermarking, it can restore the original cover media through the watermark extracting process; thus, reversible watermarking is very useful, especially in applications dictating high Fidelity of multimedia content, such as military aerial intelligence gathering, medical records, and management of multimedia information.

Visible watermarks are routinely added to digital images as a form of copy protection, but their presence essentially destroys the picture, obliterating information within altered pixels in a way that cannot be reversed. The system could be used for the authentication of military images. Inexpensive image editing software is now available that can be used to make essentially undetectable "photo realistic" changes to almost any photograph. In a military setting it is important to prevent unauthorized manipulation of digital images and to be able to demonstrate credibility and provenance.

Digital watermarking has been widely used to protect the copyright of digital images. In order to strengthen the intellectual property right of a digital image, a trademark of the owner could be selected as a watermark and embedded into the protected image. The image that embedded the watermark is called a watermarked image. Then the watermarked image could be published, and the owner can prove the ownership of a suspected image by retrieving the watermark from the watermarked image. we can determine the ownership of the suspected image.

The earliest reversible watermarking scheme was invented by Barton in 1997 in his paper 'Method and Apparatus for Embedding Authentication Information within Digital Data', after that no. of reversible watermarking methods have been reported in the literature.

The Reversible watermarking algorithms are generally classified into following categories:
1) Reversible watermarking using data compression,
2) Reversible watermarking using difference expansion [4].
3) Reversible watermarking using histogram operation.
4) Reversible watermarking using integer transform [7].
5) Reversible watermarking using Prediction Error Expansion Method [5]

In the above techniques PEE becomes very much popular due to its potential to well exploit the spatial redundancy in natural images.

Prediction Error expansion is an improved version of Tian's Difference Expansion PEE algorithm is developed by Thodi & Rodriguez [5] in 2007 in their paper of Expansion embedding techniques for reversible watermarking, where they propose prediction-error expansion, a new method for expansion embedding reversible watermarking. Prediction-error expansion combines the advantages of expansion embedding with the superior de correlating abilities of a predictor, resulting in a higher data-embedding capacity than with difference Expansion (DE).After that no. of PEE methods developed using different prediction algorithm.

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II. PREVIOUS WORK

Brief Details of Existing System i.e. Reversible Watermarking By Prediction Error Expansion

This technique was introduce by Thodi & Rodriguez in 2008 [9]. In which using the capacity parameter first capacity was find out. The capacity parameter will divide the image into two parts

1) Inner Region
2) Outer Region

Then the prediction image of the original image is found out using any prediction algorithm, such as Median edge detector. Consider the the original image I(i,j)

Then prediction image is

$$I^\wedge(i,j) = \begin{cases} \min(v1,v3) & \text{if } v4 \geq \max(v1, v3) \\ \max(v1,v3) & \text{if } v4 \leq \min(v1,v3) \\ v1+v3-v4 & \text{otherwise} \end{cases}$$

Where v1,v3 and are v4 the right, lower and diagonal neighbors of current pixel.

find the prediction error = original image – prediction image.

a) Then if the Prediction error of current pixel is a part of inner region then embed one bit into that particular pixel.i.e. Add 1 bit into the prediction error then the whole thing can be add with prediction pixel.

b) But if the prediction error of current pixel is a part of outer region, then simply shift the original pixel by the capacity parameter to avoid any ambiguity or to nullify the effect of embedding.

Here take the sufficient precautions to handle the overflow pixels by using the location map.

Problems with Predicton Error Expansion method

1) The Embedding capacity is less. i.e. the maximum capacity will be 1 BPP.(As in the prediction error expansion method, the 1 bit of watermark is uniformly embedded into the image pixels whose prediction error comes into the inner region.). This problem can be solve by using adaptive data embedding.

2) After embedding, the quality of image degrades. The degradation in the quality of image degrades due to large amount of shiftable pixels; this problem can be solve by using pixel selection.

Remedy to the Problems of Prediction Error Expansion Method

To avoid the above two drawbacks incorporate two new algorithms in this method.

a) Adaptive Data Embedding
b) Pixel Selection

Adaptive Data Embedding

In conventional Prediction Error Expansion, uniformly embed 1 bit data into the prediction error of flat region pixel & shift pixels from the rough region to avoid ambiguity. But in case of adaptive embedding embed 2 bits adaptively into the expandable pixels of flat region& 1 bit into the rough region pixels. When the capacity is high, this avoids expanding pixels with large prediction-errors and reduces embedding impact by decreasing the maximum modification to pixel values. For that pixel selection threshold is required which can be find out using the forward variance.

E.g.Consider for a particular pixel, the prediction error is 'e'. Then the average distortion is

$$D(e)= e2 + e+0.5$$

Now if 1 more bit is added into the same prediction error then the additional distortion due to double embedding is

$$AD(e) = 8e2 + 8e +3$$

So for two prediction-errors e1 and e2,

$$D(e1) > AD(e2) \text{ if e1 is large enough with respect}$$

to e2. This means that instead of embedding 1 bit into a pixel with large prediction-error, it is better to embed additionally 1 bit into an already embedded pixel whose original prediction error is sufficiently small. So the pixels with relatively small prediction-errors are well exploited.

Pixel Selection

First defined a pixel selection threshold then select the smooth pixels from the flat region & rough region for either embedding process or shifting, & the rough pixels remain unchanged. Soa more sharply distributed prediction error histogram will be obtained.& due to this a large amount of prediction errors will be available for expansion to carry data.

e.g. Consider a pixel having prediction error e may be either in rough region or flat region, is going to be expanded or shifted, hence its expected value of Mean square(MSE) is,

$$\frac{\sum \mathbb{E}(|x^w - x|^2)}{N} = \frac{0.5 \times N_c + N_s}{N}$$

Where Nc= capacity
Ns= No. of shiftable pixels
N= Total No. of Pixels.

From the formula for a fixed capacity the MSE is depends on the No. of shiftable pixels.

So to reduce the MSE minimize the no. of shiftable pixels in a way to minimize the embedding impact .Hence using pixel selection only smooth pixels are expanded, and rough ones are unchanged.

Capacity Parameter: (T)

The capacity parameter is used to form the inner region & outer region of original image based on the capacity. Finally, each pixel of inner region is expanded to carry 1 bit, and pixels of outer region are shifted to eliminate ambiguity. Here, expanding or shifting a pixel means to expand or shift its prediction-error in the prediction-error histogram.

First, image pixels are predicted to get the prediction-error histogram which is a Laplacian like distribution centered at 0.

3.5 Methods to Find the Prediction Error

1) Median edge detector
   - This algorithm was used in the previous method.

2) Gradient Adjusted prediction algorithm.(GAP) [ ]

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Here the GAP algorithms is used, as it more accurate than MED because it finds the prediction error by using more neighboring pixels.

Here the terms u1,u2,u3,u4,v1,v2,v3,v4,x,y & z are in context with the current pixel I(i,j).

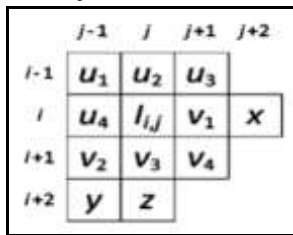|	j-1	j	j+1	j+2
i-1	u_1	u_2	u_3	
i	u_4	$I_{i,j}$	v_1	x
i+1	v_2	v_3	v_4	
i+2	y	z		

Fig. 3.5.1 Terms in Context with the Current Pixel I(i,j)

The Prediction image can be find out using GAP as follows:

$$\hat{I}_{i,j} = \begin{cases} v_1 & \text{if } d_v - d_h > 80 \\ \frac{(v_1 + I'_{i,j})}{2} & \text{if } d_v - d_h \in (32, 80] \\ \frac{(v_1 + 3I'_{i,j})}{4} & \text{if } d_v - d_h \in (8, 32] \\ I'_{i,j} & \text{if } d_v - d_h \in [-8, 8] \\ \frac{(v_3 + 3I'_{i,j})}{4} & \text{if } d_v - d_h \in [-32, -8) \\ \frac{(v_3 + I'_{i,j})}{2} & \text{if } d_v - d_h \in [-80, -32) \\ v_3 & \text{if } d_v - d_h < -80 \end{cases}$$

Fig. 3.5.2 Gradient Adjusted Prediction Method

Then find out the prediction error

Pi,j = Ii,j -I^i,j

III. PROPOSED METHOD

The project concept is divided into 4 parts or modules as follows:

1) Image partition
2) Pixel Selection
3) Adaptive Data embedding
4) Data Extraction

1 Image partition

First divide image pixels into two parts to get "flat regions" and "rough regions" according to local complexity; then adaptively embed 2 bits into each expandable pixel of flat regions and 1 bit into that of rough regions. When the capacity is high, this avoids expanding pixels with large prediction-errors and reduces embedding impact by decreasing the maximum modification to pixel values. Image partition is done by using a threshold called as adaptive embedding threshold and forward variance.The adaptive embedding threshold can be found out iteratively, the threshold being based on PSNR.

Image Partition
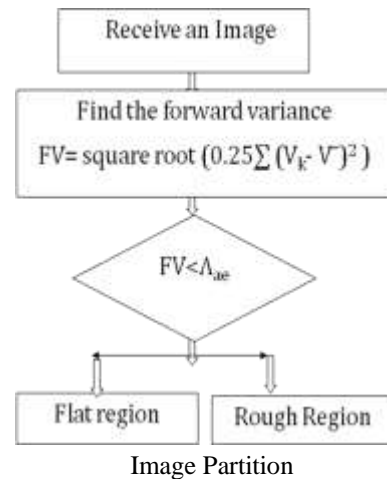
2 Pixel Selection

According to the capacity, the capacity-parameter and threshold (pixel selection threshold) are determined which will be used to select pixels.

Select relatively smooth pixels (i.e., pixels located in smooth area) and ignore the rough ones. In other words, the rough pixels may remain unchanged, and only smooth pixels are expanded or shifted. In this way, compared with conventional PEE, a more sharply distributed prediction-error histogram is obtained, and a larger proportion of prediction-errors in the histogram are expanded to carry hidden data. So the amount of shifted pixels is diminished, which leads to a better image quality.

3 Adaptive Data Embedding

Image pixels from left to right and top to bottom are scanned, and watermark message is embedded. The embedding contains two stages. One is Expansion embedding and another one is Histogram shifting. In Expansion embedding: If the prediction-error belongs to the inner region, is expanded, and the watermarked value is computed. Data bit is embedded into the pixel. In Histogram shifting: If, the prediction error of a particular pixel comes into the outer region then that pixel is shifted by the capacity parameter to maintain the quality of image. In the above embedding procedure, the maximum modification to pixel values is the capacity-parameter, is an important factor to the embedding performance. So, to minimize the distortion in PEE, the capacity-parameter is taken as the smallest integer such that the inner region can provide sufficient expandable pixels to embed the payload.

Data Extraction

The Extraction procedure is exactly reverse of embedding procedure & it is relatively simple. We require to store the auxiliary information whichis required at a time of extraction, into the first few rows of watermarked image. The auxiliary information consists of adaptive ebbedding threshold, pixel selection threshold, capacity parameter, end locations & count of the overflow pixels.

IV. RESULTS

1 Determination of optimum adaptive embedding threshold

Using iterative approach it is possible to obtain optimum adaptive embedding threshold. Here the Maximum PSNR for optimum adaptive embedding threshold is determined for a particular capacity say 0.3 BPP for different images.

The selected T_aet is represented by red color.

Sr. No.	Host image	capacity	T_aet	T_aet
1	Lena	0.3	0	55.94
			2	55.94
			5	55.94
			7	55.94
			8	55.94
			12	-

Table 7.1.1 Adapive Embedding Threshold for Lena Image

Sr.No.	Host image	Capacity	T_aet	T_aet
2	Barbara	0.3	0	55.96
			2	55.96
			5	55.96
			7	55.96
			8	55.97
			12	-

Table 7.1.2 Adapive Embedding Threshold for Barbara Image

Sr.No.	Host image	Capacity	T_aet	T_aet
3	Ann	0.3	0	-
			2	-
			5	56.25
			7	56.25
			9	56.25
			12	56.25
			15	56.25
			18	56.25

Table 7.1.3 Adapive Embedding Threshold for Ann Image

Sr.No.	Host image	Capacity	T_aet	T_aet
4	Man	0.3	0	55.96
			2	55.96
			5	55.96
			7	55.96
			8	55.97
			12	-

Table 7.1.4 Adapive Embedding Threshold forMan Image

Sr.No.	Host image	Capacity	T_aet	T_aet
5	Boat	0.3	0	55.96
			2	55.96
			5	55.96
			7	55.96
			8	55.97
			12	-

V. EXPERIMENTAL RESULTS

Original Image   Image Partition

Prediction Image   Watermarked image

Restored image   Extracted watermark

Fig.1 Image Partition, Prediction image, Watermarked image, Restored Image & Extracted Image for Casablanca

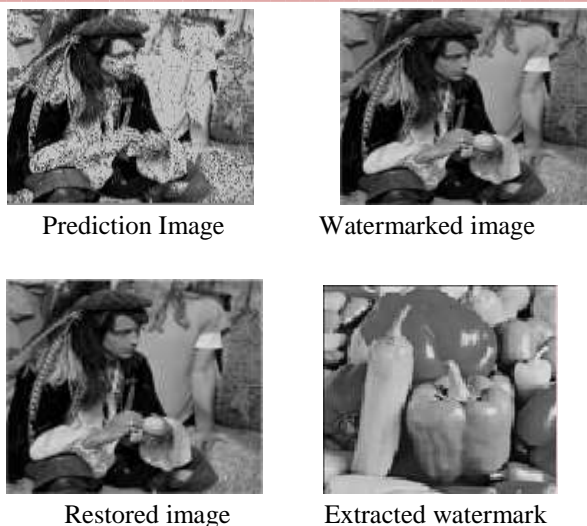Original Image- Man   Image Partition

Prediction Image   Watermarked image

Restored image   Extracted watermark

Fig.2 Image Partition, Prediction image, Watermarked

image, Restored Image & Extracted Image for Man

Original Image   Image partition

Prediction Image   Watermarked image
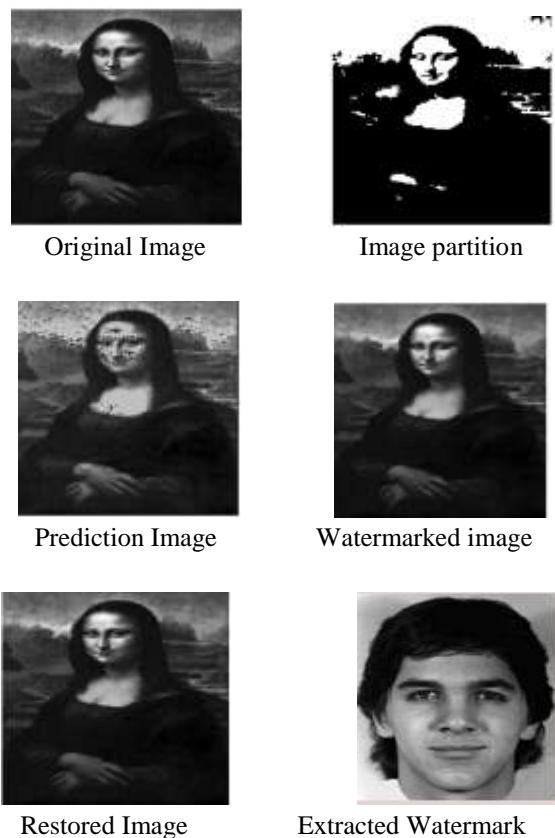

Restored Image   Extracted Watermark

Fig. 3 Image Partition, Prediction image, Watermarked image, Restored image & Extracted Image for Monalisa

VI. Comparison Between Various Methods

Sr.No	Method/Capacity	0.07	0.14	0.3	0.7	1
1	Proposed Method	61.94	59.04	55.94	52.42	50.84
2	Conventional PEE Method	49.80	47.50	46.20	39.9	32.5
3	Hu's Method	55.1	54.5	49.60	39.5	37.5
4	Wang's Method	-	53.2	49.0	40.00	36.75
5	Luo's Method	-	-	49.5	40.1	34.90

The table shows that even for the high embedding value i.e. 1 BPP the PSNR is more than 50.

We have taken different images & tried to find their maximum embedding capacity we got following results.

Sr.No	Image / Capacity	0.3	0.7	1	1.2	1.35	1.5	1.6
1	Ann	56.2	48.6	42.0	42.02	41.69	41.44	-
2	Man	55.93	52.42	50.85	50.81	-	-	-
3	Boat	56.30	52.73	44.06	43.14	-	-	-
4	Monalisa	56.2	45.6	43.84	51.20	51.20	51.20	51.19
5	Airplane	53.5	47.2	43.55	41.32	40.56	40.57	48.35
6	Airport	55.7	52.2	50.70	50.70			
7	Casablanca	56.28	44.37	42.93	42.31	42.01	41.71	

The images like Monalisa & Airplane like carries the embedding capacity upto 1.6 Bits per pixel while carrying the better PSNR.

VII. CONCLUSION

1) The capacity goes beyond 1.5BPP for most of the Images.

2) The spatial redundancy plays a very important role in the capacity.

3) When we convert colour images into gray scale image it shows very good redundancy & such images can be used for watermarking.

4) Practically the max capacity with reversibility for natural images is very useful.

5) There is no need to obtain the optimum adaptive embedding threshold.

6) We can directly assume that threshold 8, as it works for most the images, as capacity parameter adjusted himself according to capacity.

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