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An Efficient Two Pass Lossless Invisible Watermarking Algorithm for Natural Images

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***Abstract*—In this paper, we propose a novel method for image watermarking which can recover the original image after extracting the embedded data without effecting the original cover image. The proposed embedding algorithm runs in two pass. The watermarked image after first pass works as a cover image for second pass. In each pass, embedded data utilizes different prediction algorithm. First pass uses a highly effective method for prediction whether in second pass a simpler and less complex method is used in our work. Moreover, the proposed algorithm has simple decoder complexity. Our algorithm gives better embedding capacity and Peak Signal to Noise Ratio (PSNR) than various One Pass algorithms. We also modified our two pass algorithm which increases PSNR value by sacrificing payload capacity.**

***Index Terms*—Image Watermarking, Lossless Invisible Watermarking, Two Pass, Prediction, Embedding.**

I. Introduction

Image watermarking refer to embed data or watermark inside the cover image. In today's world the copyright protection of data has become an important topic. One way of protecting data is digital watermarking. It means embedding a specific information (like logo, secret code, etc.) inside the cover media. When the cover medium is image, then it is called image watermarking.

In Invisible Image Watermarking, the watermark is not visible after the watermarking process. The watermarked image is different or distorted from the cover image. If this distortion can be removed and original image can be recovered, then the scheme is called lossless watermarking. Many invisible watermarking algorithms have been proposed in literature. Ni [1] has used histogram shifting methods for embedding data stream on the cover image. This approach has been extended by Hwang [2] by using one peak point and two zero points of the histogram for embedding. Tian [3] has used difference expansion technique for embedding and Coltuc [4] used Reversible Contrast Mapping for reversible data embedding. Recently a lot of researchers have used prediction based image coding, in which a pixel is predicted with the help of neighboring causal pixels. This results into a lesser variance error histogram where more number of error samples occur at and around zero values.

Hong [5] uses Median Edge Detector (MED) as prediction algorithm whereas Gradient Adjusted Predictor (GAP) is used by Fallahpour [6]. Also Muzzarelli [7] had used Least Square (LS) based error minimization technique for prediction and then Histogram shifting method is used. These histogram shifting methods used in literature are one pass algorithm.

Thus the main contribution of this paper is to propose an efficient Two Pass embedding algorithm which produces better PSNR of watermarked image and more payload capacity for higher degree of embedding. The pay load capacity of image is highly dependent on the error histogram peaking at and around zero values. Based on this, the proposed algorithm has efficiently modified a prediction scheme [8] that uses Least Square (LS) error minimization technique. Moreover the complexity involved at decoder is very simpler than encoder.

II. Proposed Two Pass Invisible Watermarking

The proposed algorithm at the encoder side can be divided into five steps as shown in Fig. 2 and they are as follows :-

A. Under/Over flow control:-

Embedding of data bit is done by shifting prediction error which may results under/over flow. To avoid it, we modify the values of extreme pixels by (1). Thus the new modified image (8 bit) has the pixel range from $[Q, 255-Q]$, where Q is a constant which depends on the degree of embedding. The modification is recorded in overhead information [9].

$$I(i,j) = \begin{cases} Q & \text{if } I(i.j) \leq Q \\ I(i,j) & \text{if } Q < I(i,j) < 255-Q \\ 255-Q & \text{otherwise} \end{cases} \quad (1)$$

B. Proposed Prediction scheme and Error estimation :-

Our algorithm modifies the prediction scheme used in [8]. The proposed prediction scheme has divided input image into non-overlapping blocks. For each blocks, we classify the pixels into 7 sets depending on the activity of pixels. Classification of pixels and its prediction for each set is as follows :

1) We estimated slope value slp, ($slp = d_{45} - d_{135}$) using causal neighboring pixels where $d_{45} = |A-C| + |B-F| + |C-H|$ and $d_{135} = |I-A| + |J-B| + |G-C|$.
2) The slope 'slp' determines the characteristics of the pixel and then classify it into a particular set depending on slp value. The 7 set using slp are : $slp > 80$, $slp < -80$, $32 < slp \leq 80$, $-32 > slp \geq -80$, $-32 \leq slp < -8$, $-8 \leq slp \leq 8$ and $8 < slp \leq 32$.

3) Then it find fourth order LS based parameter for pixels belonging to each set. And quantized all the estimated LS based parameters (α_1, α_2, α_3, α_4) to predict the pixels belonging to each set by (2), where A, B, C, D are the nearest neighboring pixel shown in Fig. 1.

$$\hat{x}(n) = \alpha_1 A + \alpha_2 B + \alpha_3 C + \alpha_4 D \quad (2)$$

Thus a total of 7 LS based predictor of order 4 is estimated to predict the pixels for each block. Finally error image (E) can be generated by subtracting predicted image (P) with original image (I) and it act as an input to embedding system.

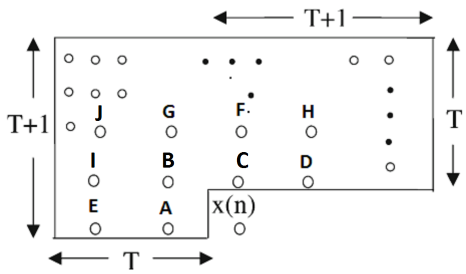

Fig. 1. Pixel structure used in Proposed Algorithm

C. Embedding Algorithm

After achieving prediction error image (E), the embedding scheme is based on shifting of prediction errors [9]. Let I be original Image and I^w be output watermarked image.

1) Review of existing One Pass Embedding scheme (OP) :
Input - Error Image (E), Data stream
Output - Invisible watermarked Image (I^w)

The given data stream is embedded into error Image (E) depending on it's error sample value. For embedding the prediction error can be modified as shown in (3).

$$E'(i,j) = \begin{cases} E(i,j) + b \times sign \times Q & -Q \leq E(i,j) < \text{Q} \\ E(i,j) + b \times Q & \text{if } E(i,j) = 0 \\ E(i,j) + sign \times Q & \text{otherwise} \end{cases} \quad (3)$$

Here b is to-be-embedded bit (0 or 1), Q represents degree or order of embedding and sign represents $sign(E(i,j))$. The watermarked output is given by (4).

$$I^w(i,j) = P(i,j) + E'(i,j) \quad (4)$$

Let suppose the predicted error image is of dimension 512×512 and $n(i)$ is number of error samples at i^{th} value. Then following analysis can be drawn:

The total payload of OP algorithm using (3) will be $\sum_{i=-Q}^{Q-1} n(i)$. Distribution of error samples are dependent on the data stream and follows (3). After embedding data stream into error image, minimum Square Error (SE_{min}) achieved by OP algorithm is shown in (5) and is obtained when all the data stream has 0 bit in it. Similarly maximum Square Error (SE_{max}) can be achieved when all the data stream has 1 bit in it and is shown in (6).

$$SE_{Best} = [512 \times 512 - \sum_{i=-Q}^{Q-1} n(i)] \times Q^2 \quad (5)$$

$$SE_{Worst} = [512 \times 512] \times Q^2 \quad (6)$$

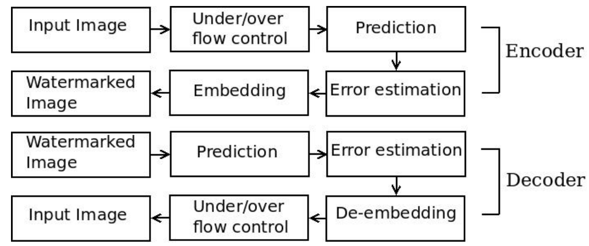

Fig. 2. Overview of Embedding and De-embedding for One Pass Algorithm

From experimental results, we observed that proposed prediction algorithm has more number ($n(i)$) of error samples at and around zero value as compared to other prediction algorithm. Thus using proposed prediction scheme in OP embedding algorithm results into more payload capacity and have lesser SE_{min} which leads to more PSNR in Best case.

$$PSNR = 10 \times (log_{10} \frac{255^2}{MSE}), MSE = SE/(512 \times 512) \quad (7)$$

We proposed a Two Pass (TP) embedding algorithm which has more PSNR and payload capacity as compared to OP.

2) Proposed Two Pass Embedding Algorithm (TP): The proposed Two Pass embedding algorithm has a different scheme for higher degree of embedding ($Q \geq 2$) and it works in two pass as shown in Fig. 3(c). For $Q = 1$, it follows the same procedure as it was done for OP algorithm. Working of TP for $Q = 2$ is as follows:
Input - Original Image (I), Data stream
Output - Watermarked Image (I^w)

1) In first pass, the cover image (input image) is sent to encoder system of $Q = 1$ as shown in Fig 3(c).
2) Let suppose the output watermarked image after first pass is I^{w1}. Then in second pass, I^{w1} will act as an input to the encoder system of $Q = 1$.
3) But the prediction scheme used in second pass will be different from the prediction method in the first pass.

Using these three steps, the proposed embedding algorithm has produced better PSNR and more payload capacity as compared to OP algorithm. This can be explained as follows :

3) Better PSNR of Proposed Embedding (TP) Algorithm : Diagrammatically, the proposed two pass embedding scheme can be shown in Fig 3(a) in which we have cited a particular example and it can be described as follows:

1) In first Pass, let suppose an original pixel value (210) is sent to the encoder of $Q = 1$.
2) Then predicted value can have three possible case, i.e. greater than, equal to or less than original value.
3) Thus output of encoder ($Q = 1$) is I^{w1}, can have four cases including all case of data embedded (0 and 1).
4) In second pass, I^{w1} will act as an input to the encoder system of $Q = 1$. But prediction scheme will be different from previous pass (first Pass).
5) Thus following all the steps can lead to 16 possible cases at the output (I^w) of second pass.

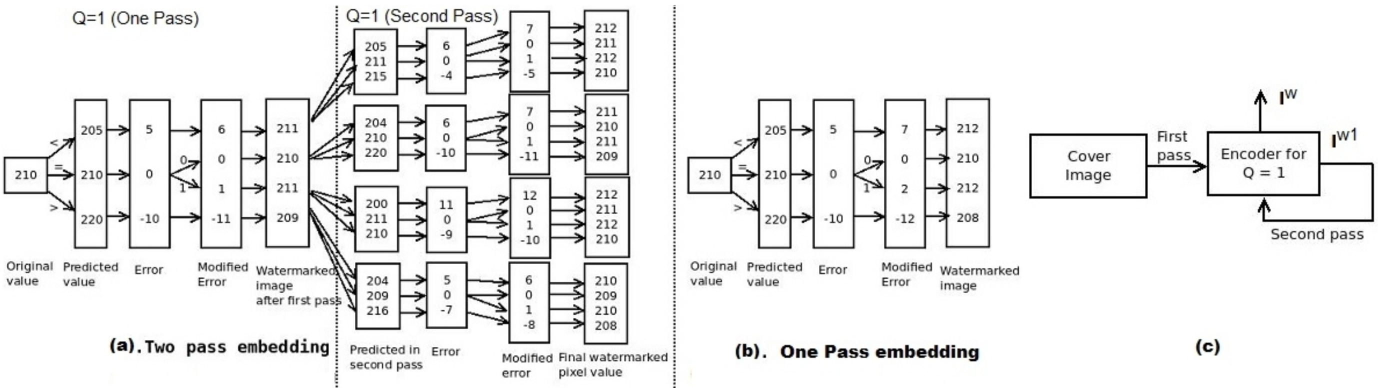

Fig. 3. (a) Benefit of Two Pass (Q = 2) over One pass embedding Algorithm (b) Working of One Pass algorithm (c) Encoder of Two Pass Algorithm

TABLE I
EMBEDDING AND DE-EMBEDDING OF PROPOSED TWO PASS ALGORITHM. HERE FP AND SP REFERS FIRST PASS AND SECOND PASS.

Q	Embedding	De-embedding
$Q = 1$	OP	OP
$Q(even)$	$Q/2$ FP, $Q/2$ SP	$Q/2$ FP , $Q/2$ SP
$Q(odd)$	(Q+1)/2 FP, (Q-1)/2 SP	(Q+1)/2 FP,(Q-1)/2 SP

Let suppose the error obtained between original pixel value i.e, I = 200 (after Overflow/Underflow) and final watermarked value (I^w) is E_{TP} (error two pass), i.e, $E_{TP} = I$ -I^w .
Now we can observe that out of 16 cases, there exist 5 cases where absolute value of E_{TP} is 2 else it is 0 or 1. This happens because, the prediction algorithm used in second pass is different from prediction algorithm in first pass. Thus if error after first pass (Q=1) is positive (I - $I^{w1} > 0$) and if error after second pass is negative ($I^{w1} - I^w < 0$) or vice -versa, then final error (E_{TP}) observed is -1,1 or 0. Whereas in OP, the change in error is 2 in every case as shown in Fig.3(b). Thus in proposed TP embedding algorithm, cancellation of error samples occurs from first pass to second pass which decreases mean square error (MSE) of final error image and thus PSNR increases.

But, if same prediction algorithm is used in both the passes, then a similar predicted value can be obtained in both cases which decreases cancellation of error samples.

4) Better Pay-Load Capacity of TP Algorithm: The total payload capacity of OP algorithm will be $\sum_{i=-2}^{i=1} n(i)$ for Q = 2, where $n(i)$ is the number of error samples at i^{th} value. We expect that this frequency ($n(i)$) follows $n(0) > n(-1) > n(-2) > \cdots >$ and $n(0) > n(1) > n(2) > \cdots >$. Based on this hypothesis, we used different prediction scheme for each pass in proposed TP algorithm. In first pass, an efficient proposed prediction scheme (II B) is used which has better prediction accuracy and thus leads to more number of error samples at and around zero value.

In proposed TP algorithm, let assume the payload capacity (Q = 2) obtained in first pass is ($n_1(0)$ + $n_1(-1)$) and in second pass is ($n_2(0) + n_2(-1)$) where $n_1(i)$ and $n_2(i)$ are the number of error samples at i^{th} value by proposed prediction scheme (II B) and by other prediction scheme respectively. Thus total payload capacity of TP algorithm will be ($n_1(0)$ + $n_1(-1)$ + $n_2(0)$ + $n_2(-1)$) for Q = 2. Thus using above hypothesis, we can conclude that proposed TP algorithm has more payload capacity as compared to OP algorithm.

Table I illustrates proposed Two Pass embedding algorithm for higher degree ($Q \geq 2$). It can be explained as follows : if Degree of Embedding (DE) to be done is even, then DE in First Pass (FP) and second pass (SP) will be Q/2 and Q/2 respectively. But prediction scheme used in second pass will be different from prediction algorithm used in first pass. Similar analysis can be done in case if degree of embedding is odd.

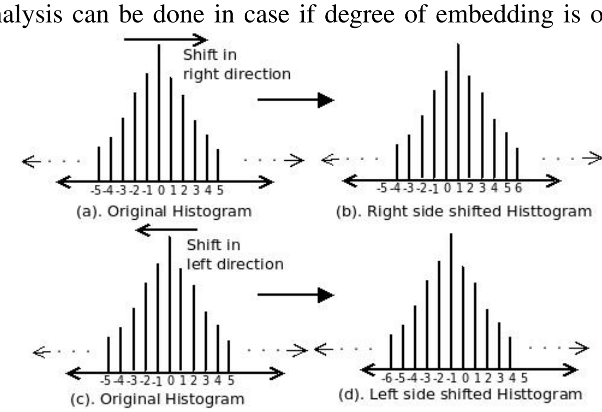

Fig. 4. Modified Two Pass Embedding algorithm by 1 unit shift

5) Modified Two Pass Embedding Algorithm(TP) for Q=2: As shown in Fig. 4, we shifted the predicted error histogram to the right side by 1 unit in first pass and then followed all the steps required at encoder for Q = 1 in One Pass algorithm, thus obtained a watermarked image (I^{w1}). We can easily get predicted error histogram for intermediate image shown in Fig. 4(c). We then shifted the intermediate histogram to left by 1 unit and then followed all the steps in second pass (for Q=1). This leads to large number of pixel cancellation which increases PSNR values. But it will decrease payload capacity as number of samples at 0 and -1 gets decreased due to shifting. It is to be noted that shifting and degree of embedding is independent from each other.

D. De-embedding

In this section, steps for extraction of hidden watermark and lossless recovery of original image are detailed.

1) Prediction and Error estimation: Prediction is done using causal pixels as it is done at encoder side. Then error

TABLE II

PERFORMANCE OF PROPOSED ALGORITHM IN TERMS OF PSNR (DB) AND PAYLOAD (PL) CAPACITY (KB). HERE PROP, PRO_OP REFERS TO ONE PASS EMBEDDING ALGORITHM FOR Q = 1 AND Q=2 RESPECTIVELY. TP_MED AND TP_GAP REFERS TO TWO PASS EMBEDDING ALGORITHM USING MED PREDICTION AND GAP PREDICTION IN SECOND PASS RESPECTIVELY. % REFERS TO PERCENTAGE OF PIXELS GET CANCELED AFTER SECOND PASS

		(Q = 1)				(Q = 2)							
Images		MED	GAP	LS	Prop	MED	GAP	LS	Pro_OP	TP_MED	%	TP_GAP	%
Lena	PL	51.90	55.75	60.00	**62.30**	94.76	96.00	102.40	109.38	106.63	17.91	**112.64**	25.80
	PSNR	48.61	48.65	48.71	**48.73**	43.02	43.21	43.25	**43.73**	43.30		43.24	
Baboon	PL	17.29	18.84	19.47	**19.56**	33.32	34.14	36.21	**38.74**	36.65	22.83	38.41	19.86
	PSNR	48.30	48.34	48.39	**48.41**	42.42	42.43	42.45	42.52	43.06		**43.25**	
Barbara	PL	39.30	46.29	50.29	**52.45**	71.22	73.45	74.89	87.55	83.21	23.71	**90.62**	29.06
	PSNR	48.49	48.58	48.69	**48.61**	42.78	42.80	42.85	43.00	**43.39**		43.31	

TABLE III

MODIFIED TWO PASS ALGORITHM BY SHIFTING 1 UNIT

Images		MTP_MED	%	MTP_GAP	%
Lena	PL	96.46	30.31	91.22	31.94
	PSNR	43.51		43.66	
Baboon	PL	32793	24.38	33.83	21.31
	PSNR	43.31		43.14	
Barbara	PL	75.10	31.63	72.17	32.10
	PSNR	43.64		43.70	

sample is estimated by (8), where P(i,j) is the predicted value for $I^w(i,j)$ and $E^w(i,j)$ is prediction error.

$$E^w(i,j) = I^w(i,j) - P(i,j) \tag{8}$$

2) De-embedding: The hidden bit and original error value are reversed as below

$$E(i,j) = \begin{cases} E^w(i,j) \text{ and b = 0} \\ \quad \text{if } -Q \leq E^w(i.j) < \text{Q} \\ \\ E^w(i,j) - sign(E^w(i,j)) \times Q \text{ and b=1} \\ \quad \text{if } -2 \times Q \leq E^w(i,j) < -Q \\ \quad \text{or } Q \leq E^w(i,j) < 2 \times Q \\ \\ E^w(i,j) - sign(Ew(i,j)) \times Q \\ \quad \text{otherwise} \end{cases}$$

Thus data stream is extracted while de-embedding for one pass algorithm. In the similar way using Fig. 2 and Fig. 3(c), we can extract the data for Two Pass algorithm.

$$I'(i,j) = E(i,j) + P(i,j) \tag{9}$$

3) Under/over flow recovery:- We can get $I'(i,j)$ by (9) and the original value is extracted using the under/over flow information [9]. Hence TP algorithm is reversible.

III. SIMULATION RESULTS

The test images used in our experiment is of dimension 512×512 and we used block of size 128×128 in our prediction scheme. From Table II, for $Q = 1$, we conclude that using proposed prediction scheme (II B) in OP embedding algorithm works best irrespective of input image as compared to MED, GAP and LS [7] in terms of PSNR and Payload Capacity.

While for $Q = 2$, we used our proposed prediction scheme (II B) in One pass embedding algorithm (Pro_OP) and can say that it too works best as compared to previous OP embedding algorithm using different prediction scheme reported in literature. Moreover, we have also implemented proposed TP algorithm in which we uses proposed prediction scheme (II B) in first pass and MED (TP_MED), GAP (TP_MED) prediction estimation in second pass. We have also calculated the number of pixels that get canceled in the process of Two Pass embedding algorithm. Thus proposed TP embedding algorithm (TP_MED , TP_GAP) works better than various One Pass algorithm reported in literature. Moreover the decoder of proposed algorithm is simpler than encoder as the decoder does need to estimate LS based predictor.

Table III shows results of modified TP embedding method. It illustrates that PSNR increases as number of pixels cancellation gets increased but payload capacity decreases as number of error samples at 0 and -1 gets decreased due to shifting. The proposed TP algorithm can embed any binary stream and thus independent of the given watermark (which can be converted into binary stream). Moreover, if lossy compression is used after embedding data, then we won't be able to extract the original embedded watermark and cover image at the decoder.

IV. CONCLUSIONS

We proposed a Two Pass embedding algorithm using histogram shifting which produces better PSNR of watermarked image and have more payload capacity as compared to One Pass algorithm. Both Pass uses a different predictor scheme and thus embedding is done in each Pass. We also proposed a modified version of Two Pass algorithm which increases PSNR values while sacrificing payload capacity.

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