DOI: 10.21917/ijivp.2018.0266

PERFORMANCE EVALUATION AND COMPARATIVE ANALYSIS OF WATERMARKING ALGORITHM BASED ON ADAPTIVE PREDICTION METHOD

Chetna Sharma and Neeraj Jain
Department of Electronics and Communication Engineering, Modern Institute of Technology & Research Centre, Alwar, India

Abstract
Now a days digital watermarking appeared as a solution for copyright detection, protection and maintenance of important data. This paper deals with a new reversible watermarking algorithm based on adaptive prediction error expansion, which can recover original image after extracting the hidden data. Embedding capacity of such algorithm depend on the prediction accuracy of the predictor. The method can embed secret data into 3×3 image block order by exploiting the pixel redundancy within each block. It has been observed that proposed method of reversible watermarking provide much better results in terms of Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) in comparison to existing literature.

Keywords:
Reversible Image Watermarking, Adaptive Prediction, Peak Signal to Noise Ratio (PSNR)

1. INTRODUCTION

Watermarking is a key process for the protection of copyright ownership of electronic data. Digital watermarking is used to hide the information inside a signal which cannot be easily extracted by the third party [1]. Digital watermarking is highly trending act of hiding information in multimedia data (audio, video or images), for the purpose of protecting or authenticating of content. A digital watermark of the authorized distributor is added into the image. The watermark can be anything, such as any text, logo or image of the distributor which acts as the information of the ownership of the authentic or authorized distributor. The watermark in the host image is embedded into it such that it does not distort the host image and also not be visible for the observer.

Digital watermarking can be classified into two types as spatial domain watermarking and frequency domain watermarking. Watermarks can be embedded into images through the spatial domain or the frequency domain. The spatial domain usually uses simple algorithms to embed the watermark by modifying the pixel values of the original image. In the frequency domain, pixel values are transformed to the coefficients. These coefficients are modified to embed watermarks in the original images. Hence, watermarks embedded by the technique of the transform domain are more robust than watermarks which are embedded by spatial domain. Some important features of digital watermarking are robustness, imperceptibility, security, transparency, capacity [2].

Reversible watermarking means embedding specific information into the cover media in such a way that it can recover the original cover media at the decoder. Reversible watermarking is useful for important media purposes, such as medical and military images, because it need to recover completely without any loss. Reversible watermarking is also useful in other applications such as image and video coding [3].

Reversible watermarking is an original category of watermarking schemes. It not only can strengthen the ownership of the original media but also can completely recover the original media from the watermarked media. This characteristic is suitable for some important media, such as medical and military images, because these kinds of media do not allow any losses [4].

Reversible watermarking is also used for color images by way of analyzing the correlation of different color components in color image and expanding prediction pixels by adaptive prediction operator, the embedding of watermark data and the retrieving of the original image had been realized. Experiments showed that the given algorithm achieves better effect compared with other traditional algorithms for color image, and it can retrieve the original image lossless [5]. Pawar et al. [6] have also proposed a method for watermarking. This method used conditional local prediction and give better results. Mehta et al. [7] presents a comparison between classical Prediction error expansion based reversible watermarking and proposed prediction error expansion scheme considering region of interest for gray scale medical images. In classical prediction error expansion, the augmentation of the predicted error values is used for data embedding. In the proposed scheme, prediction error expansion by preserving the Region of Interest is used. Both the schemes focus on Reversible data hiding where the original primary image can be remodeled listlessly after extracting the payload. A performance evaluation based on Peak Signal to Noise ratio (PSNR), total payload capacity is carried out. Additional capacity and less distortion of the primary image in comparison to the basic method is obtained through the results.

Yi et al. [8] proposed a reversible data hiding method for natural images using the block-level prediction-error expansion. The method can embed secret data into 2×2 image blocks by exploiting the pixel redundancy within each block. Extending this concept to the encrypted domain, the authors proposed a reversible data hiding method in encrypted images using adaptive block-level prediction-error expansion. Due to the adaptive pixel selection and iterative embedding processes, the proposed method can achieve a high embedding rate and pleasing visual quality of the marked decrypted images.

2. ADAPTIVE PREDICTION ERROR

2.1 EXPANSION METHOD

In this method, watermarked information bit (0 or 1) is embedded into original image using additive predictor error expansion method. Firstly, predicted value $p(n)$ of original pixel $a(n)$ is estimated by a prediction technique and then prediction error $c(n)$ is obtained as, $c(n) = a(n)-p(n)$. The watermark is then embedded into the residual/error pixel $c(n)$ by traditional additive Predictor Error Expansion method as given by Eq.(1).

$$c_w(n) = \begin{cases} c(n) + sign(c(n)) \times Q & -Q \le c(n) < Q \\ c(n) + b \times Q & if\ c(n) = 0 \\ c(n) + sign(c(n)) \times Q & otherwise \end{cases} \tag{1}$$

Here b is to be embedded bit (0 or 1), sign($c(n)$) implies +1 if $c(n)$ is positive and -1 if negative. Q is embedding rate i.e. Q=1 implies single layer embedding and Q>1 means multilayer embedding.

Thus, after predictor error expansion, watermarked pixels can be given by Eq.(2):

$$a_w(n) = c_w(n) + p(n) \tag{2}$$

At the retrieval side, the original image and the watermarked can be restored. First, prediction value is estimated (similar to what is done at embedding side) and thus $c_w(n)$ can be calculated as Eq.(3):

$$c_w(n) = a_w(n) – p(n) \tag{3}$$

Once, c_w is obtained, the residual image (c) and hidden bit (b) can be obtained using the Eq.(4):

$$c(n) = \begin{cases} c(n)\, and\, b = 0 & if -Q \le c_w(n) < Q \\ c(n) - sign(c_w(n)) \times Q\, and\, b = 0 & if -2Q \le c_w(n) < -Q \\ & or\, Q \le c_w(n) < -Q \\ c_w(n) = sign(c_w(n)) \times Q & otherwise \end{cases}$$

(4)

The original pixel is estimated by Eq.(5):

$$a(n) = p(n) + c(n) \tag{5}$$

Thus, original image and watermark information can be recovered completely using adaptive Predictor Error Expansion.

3. PROPOSED METHOD

Goal of the proposed watermarking scheme is to increase the prediction accuracy so as to achieve higher embedding capacity. For this, a symmetrical predictor structure is proposed [9]. Based on the coordinate position of the pixels of given image (*IM*), label its pixels by four symbols position.

Let $R(n)$, $S(n)$, $T(n)$ and $U(n)$ are symbols representing pixels of *IM* at even-even positions, even-odd positions, odd-even positions and odd-odd positions respectively with the first pixel of the image considered to be at (1,1) i.e. odd-odd. Motivation behind classifying the pixels into four parts as per the coordinate positions is to make use of a symmetrical predictor structure.

U	*T*	*U*	*T*	*U*	*T*	*U*	*T*
S	*R*	*S*	*R*	*S*	*R*	*S*	*R*
U	*T*	*U*	*T*	*U*	*T*	*U*	*T*
S	*R*	*S*	*R*	*S*	*R*	*S*	*R*
U	*T*	*U*	*T*	*U*	*T*	*U*	*T*
S	*R*	*S*	*R*	*S*	*R*	*S*	*R*
U	*T*	*U*	*T*	*U*	*T*	*U*	*T*
S	*R*	*S*	*R*	*S*	*R*	*S*	*R*

Fig.1. Labeling of Image (*IM*) based on spatial coordinates

3.1 PREDICTION AND WATERMARKING OF EVEN-EVEN POSITIONED PIXEL

In first stage, only pixels denoted by *R* shown in Fig.1 are predicted (i.e. pixels at even-even positions) and then watermarked by predictor error expansion method. Prediction method proposed by [9] is 4th order predictor and is given as Eq.(6):

$$\hat{R} = (T(n\text{-}3)+T(n+3)+S(n\text{-}1)S(n+1))/4 \tag{6}$$

Here, $\hat{R}(n)$ is the predicted value of $R(n)$ shown in Fig.2.

$U(n$-4)	$T(n$-3)	$U(n$-2)
$S(n$-1)	$R(n)$	$S(n$+1)
$U(n$+2)	$T(n$+3)	$U(n$+4)

Fig.2. Prediction analysis of $R(n)$

In an image, generally a pixel has a value close to its neighbors and it depends on the local structure (edge direction etc.) of the image. Thus, we propose an adaptive prediction method of 8th order predictor. Initially, neighboring pixels of all R are divided into four sets, denoted by set_1, set_2, set_3, set_4. These sets are describes by Eq.(7):

$$\begin{aligned} set_1(n) &= \{S(n\text{-}1), S(n+1), m_1\}, \\ set_2(n) &= \{U(n\text{-}2), U(n+2), m_2\}, \\ set_3(n) &= \{T(n\text{-}3), T(n+3), m_3\}, \\ set_4(n) &= \{U(n\text{-}4), U(n+4), m_4\}, \end{aligned} \tag{7}$$

Here,

$$\begin{aligned} m_1 &= (S(n\text{-}1) + S(n+1))/2, \\ m_2 &= (U(n\text{-}2) + U(n+2))/2, \\ m_3 &= (T(n\text{-}3) + T(n+3))/2, \\ m_4 &= (U(n\text{-}4) + U(n+4))/2 \end{aligned} \tag{8}$$

In order to estimate the strength of edges at $R(n)$, we estimate four parameters that give intensity variations of pixels in four directions. These parameters are proposed to be estimated as given Eq.(9):

$$\begin{aligned} \sigma^2_{set_1} &= \frac{1}{3} X \sum_{n=1}^{3} \left(set_1(n) - m\right)^2 \\ \sigma^2_{set_2} &= \frac{1}{3} X \sum_{n=1}^{3} \left(set_2(n) - m\right)^2 \\ \sigma^2_{set_3} &= \frac{1}{3} X \sum_{n=1}^{3} \left(set_3(n) - m\right)^2 \\ \sigma^2_{set_4} &= \frac{1}{3} X \sum_{n=1}^{3} \left(set_4(n) - m\right)^2 \end{aligned} \tag{9}$$

where, m is given by Eq.(10):

$$m = (m_1 + m_2 + m_3 + m_4)/4 \tag{10}$$

Here, Eq.(8) gives estimate of edges of $R(n)$ at horizontal (00), vertical (900), in 450 and 1350 directions respectively. Then predicted value of $R(n)$ is considered to be the estimated sum of m_1, m_2, m_3 and m_4.

$$R(n) = w_1 m_1 + w_2 m_2 + w_3 m_3 + w_4 m_4 \tag{11}$$

where, w_1, w_2, w_3 and w_4 are the prediction coefficients used with m_1, m_2, m_3 and m_4 respectively. Normalizing it to find prediction coefficients as given by Eq.(12).

$$\begin{aligned} w_1 &= \frac{\left(\sigma^2_{set_1}\right)^{-1}}{N} \\ w_2 &= \frac{\left(\sigma^2_{set_2}\right)^{-1}}{N} \\ w_3 &= \frac{\left(\sigma^2_{set_3}\right)^{-1}}{N} \\ w_4 &= \frac{\left(\sigma^2_{set_4}\right)^{-1}}{N} \end{aligned} \tag{12}$$

where n_{ji} is the normalization factor given by equation,

$$N = \left(\sigma^2_{set_1}\right)^{-1} + \left(\sigma^2_{set_2}\right)^{-1} + \left(\sigma^2_{set_3}\right)^{-1} + \left(\sigma^2_{set_4}\right)^{-1} \tag{13}$$

In case, if any of the parameter is zero, that means there is no intensity variation of pixels in that direction, then corresponding prediction coefficient is made 1 and the rest are made 0. If more than one parameter is zero, the weights are equally divided among the corresponding coefficients. Thus by combining Eq.(11) and Eq.(12), $R(n)$ can be predicted efficiently.

Hence, the proposed Adaptive Prediction Error Expansion method is adaptive to edge characteristics of neighboring pixels. After predicting each pixel of R and finding corresponding $c(n)$, we can apply Adaptive Prediction Error Expansion method to get watermarked pixels of R and is denoted by R_w.

3.2 PREDICTION AND WATERMARKING OF REMAINING PIXELS

In second stage, pixels denoted by S are predicted and undergoes watermarking process. Same procedure is followed to predict the values of S as explained in previous section. However, pixels available for proposed method are 6 original and 2 watermarked pixels shown in Fig.3. Once predicted value of S is obtained, adaptive Predictor Error Expansion method is used to get watermarked pixels S_w. Similarly, in the third Stage, the prediction of T type pixel is done in the same way as done for type R and S pixels with the only difference that pixels available for prediction are 2 original and 6 watermarked pixels shown in Fig.4. Similarly, in the fourth stage, the prediction of U type pixel is done in the same way as done for type R, S and T pixels with the only difference that pixels available for prediction are 8 watermarked pixels.

$T(n\text{-}4)$	$U(n\text{-}3)$	$T(n\text{-}2)$
$R_w(n\text{-}1)$	$S(n)$	$R_w(n+1)$
$T(n+2)$	$U(n+3)$	$T(n+4)$

Fig.3. Neighborhood of S type pixels

$S_w(n\text{-}4)$	$R_w(n\text{-}3)$	$S_w(n\text{-}2)$
$U(n\text{-}1)$	$T(n)$	$U(n+1)$
$S_w(n+2)$	$R_w(n+3)$	$S_w(n+4)$

Fig.4. Neighborhood of T type pixels

$R_w(n\text{-}4)$	$S_w(n\text{-}3)$	$R_w(n\text{-}2)$
$T_w(n\text{-}1)$	$U(n)$	$T_w(n+1)$
$R_w(n+2)$	$S_w(n+3)$	$R_w(n+4)$

Fig.5. Neighborhood of U type pixels

Thus, proposed Adaptive Prediction Error Expansion method exploits neighborhood pixels efficiently and estimates the prediction coefficients adaptively based on the similarity of pixels in different directions.

3.3 WATERMARKING EMBEDDING AND EXTRACTION PROCESS

The input image, which is typically of 8 bit resolution, is modified in such a way that the pixel values of the modified image will be in the range [Q, 255-Q], where Q is the embedding rate. The truncation information is send as an overhead to decoder.

$$c(n) = \begin{cases} Q & \text{if } I(i,j) < Q \\ I(i,j) & \text{if } Q < I(i,j) < 255 - Q \\ 255 - Q & \text{otherwise} \end{cases} \tag{14}$$

Once we get the preprocessed image (I_q), classify its pixels into four groups based on their coordinate positions. Then the proposed algorithm can be used to get watermarked image (I_w). At the decoder side, watermarked image (I_w) is present. In a reverse order of watermark embedding, the preprocessed image (I_q) is recover and watermark data easily.

3.3.1 Embedding Algorithm:

The proposed algorithm has following steps:

Step 1: Apply proposed prediction error expansion algorithm for pixels of type R using 8 neighborhood original pixels and calculate the value of prediction coefficients.

Step 2: Apply the calculated value of prediction coefficients to embed the information in the image pixels and get watermarked pixel.

Step 3: Apply proposed prediction error expansion algorithm for pixels of type S using 6 original and 2 watermarked pixels and calculate the value of prediction coefficients.

Step 4: Apply the calculated value of prediction coefficients to embed the information in the image pixels and get watermarked pixel.

Step 5: Repeat the same procedure for type T and type U pixels.

3.3.2 Retrieval Algorithm:

The proposed algorithm has following steps:

Step 1: Apply proposed prediction error expansion algorithm for pixels of type U using 8 neighborhood watermarked pixels. Use inverse prediction error expansion method to get secret bits and original pixels. Recover the original pixels of type U and hidden bits.

Step 2: Apply proposed algorithm for pixels of type T using 2 original pixels and 6 watermarked pixels. Recover the original pixels of type T and hidden bits.

Step 3: Repeat the same process for pixels of type S. Recover the original pixels of type S and hidden bits.

Step 4: Repeat the same process for pixels of type *R*. Recover the original pixels of type *R* and hidden bits.

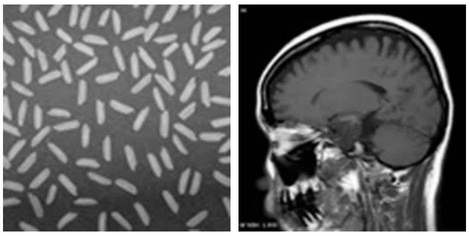
4. SIMULATION AND RESULTS

This section deals the simulation results of proposed method. For testing the algorithm several host images are used as shown in Fig.6.

Baboon Lena

Pepper Barbara

Cameraman Parrot



Rice Skull

Duck Building

Fig.6. Host images

The host images are used to embed the watermark bits into its pixels. The size of each of the host image is 512×512 i.e. each of the host image has 262144 number of pixels. Each of the host images is a gray scale 8-bit image. The simulation was done in MATLAB 2014 to test the validity of the proposed algorithm.

Fig.7. Watermarked image

The value of PSNR is satisfactorily good (above 40dB) in all cases which implies the validity of the proposed algorithm. The value of PSNR demonstrates the ability of the watermarking algorithm to efficiently embed more number of watermarking bits efficiently into the host image. Higher the PSNR better will be the quality of the Watermarked image. Lesser PSNR indicates a more distorted watermarked image.

The formula for measuring PSNR and MSE are given in Eq.(15) and Eq.(16).

$$PSNR = 10\log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \tag{15}$$

$$MSE = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}\left[I(i,j) - I'(i,j)\right]^2 \tag{16}$$

Table.1. Simulation results for different host images at *Q*=1

Image	PSNR(dB)	Embedding Capacity	MSE
Baboon	51.2125	155061	0.7013
Lena	52.3358	200263	0.6162
Cameraman	52.7836	216717	0.5853
Peppers	51.6166	172245	0.6694
Barbara	52.3863	201124	0.6127
Duck	52.4975	205118	0.6049
Parrot	53.4402	238366	0.5427
Building	51.3897	163368	0.6872
Rice	52.2202	195080	0.6245
Skull	52.7190	213358	0.5896

It is observed during the experiment that the Peak Signal to Noise Ratio (PSNR) and embedding capacity between the host image and the watermarked image are depend on the embedding rate (*Q*). It is clear from the simulation results in Fig.11 that embedding capacity increases with the increase in embedding rate (*Q*).

It gives embedding capacity for different stages of Peppers image:

- First stage = 31718
- Second stage = 30413
- Third stage = 29968
- Fourth stage = 29102

Table.2. Embedding capacity with respect to embedding rate

Embedding rate	Embedding Capacity
1	172245
2	230401
3	245351
4	250883
5	253475
6	255008
7	256068
8	256843
9	257426
10	257878

Table.3. PSNR, MSE, Embedding capacity for different embedding rate (Q)

Embedding Rate (Q)	PSNR (dB)	MSE	Embedding Capacity
0.3	71.2772	0.0696	118393
0.4	66.2148	0.1247	115405
0.6	59.0734	0.2837	110726
0.8	53.9894	0.5094	106751
1	51.6166	0.6694	172245
1.2	49.6442	0.8401	217076
1.4	46.9022	1.1519	214428
1.6	44.4824	1.5220	211638
1.8	42.3408	1.9476	208886
2	41.1762	2.2271	230401

T.P.C. = (1st stage + 2nd stage + 3rd stage + 4th stage) = 121201

where, T.P.C. is the total payload capacity (Embedding capacity is the maximum number of bits which can be embedded into the host image).

It is observed from the Table.4 that the proposed algorithm works better that existing literature [8] in terms of PSNR for a given embedding rate of Q = 0.2.

Table.4. Comparison of the proposed method with existing literature

Image	PSNR (dB)	
	Proposed algorithm	Existing literature [8]
Lena	79.89	48.45
Peppers	78.38	46.26
Baboon	78.54	38.75
Barbara	79.83	46.32

5. CONCLUSIONS

Performance of proposed watermarking algorithm based on adaptive prediction method has been shown in Table.1 in terms of PSNR, embedding capacity and MSE. In Table.4 comparison of proposed method has also been shown with other existing technique in the literature. The simulation result reveals that proposed scheme gives high value of PSNR compare to existing technique in the literature.

REFERENCES

[1] S. Kumar and T.P. Singh, "A Review of Digital Watermarking, Applications and its Techniques", *International Journal of Computer and Organization Trends*, Vol. 4, No. 4, pp. 19-22, 2014.

[2] M. Durvey and D. Satyarthi, "A Review Paper on Digital Watermarking", *International Journal of Emerging Trends and Technology in Computer Science*, Vol. 3, No. 4, pp. 99-105, 2014.

[3] R. Li, O. Au, C. Yuk and S. Yip, "Enhanced Image Transcoding using Reversible Data Hiding", *Proceedings of IEEE International Symposium on Circuits and Systems*, pp. 1273-1276, 2007.

[4] J. Feng, I. Lin, C. Tsai and Y. Chu, "Reversible Watermarking: Current Status and Key Issues", *International Journal of Network Security*, Vol. 2, No. 3, pp. 161-171, 2006.

[5] Y. Qi and L. Liu, "Reversible Watermarking Algorithm based on Prediction Error Expansion for Color Image", *Proceedings of International Conference on Image Processing*, pp. 102-106, 2017.

[6] K. Pawar, B. Pillai and S.K. Mishra, "Conditional Local Prediction Based Image Watermarking", *International Journal of Engineering Technology and Applied Science*, Vol. 2, No. 3, pp. 1-8, 2016.

[7] Jinal H. Mehta and Vishakha Kelkar, "Comparison of Reversible Watermarking using Prediction Error Expansion and Prediction Error Expansion Considering Region of Interest for Medical Images", *Proceedings of IEEE 2nd International Conference for Convergence in Technology*, 2017.

[8] S. Yi, Y. Zhou and Z. Hua, "Reversible Data Hiding in Encrypted Images using Adaptive Block-Level Prediction-Error Expansion", *Signal Processing: Image Communication*, Vol. 64, pp. 78-88, 2018.

[9] M. Chen, Z. Chen, X. Zeng and Z. Xiong "Reversible Image Watermarking based on Full Context Prediction", *Proceedings of International Conference on Image Processing*, pp. 4253-4256, 2009.

[10] W. Zhang, K. Ma and N. Yu, "Reversibility Improved Data Hiding in Encrypted Images", *Signal Processing*, Vol. 94, pp. 118-127, 2014

[11] Mahsa Afsharizadeh and Majid Mohammadi,"Prediction-based Reversible Image Watermarking using Artificial Neural Networks", *Turkish Journal of Electrical Engineering and Computer Sciences*, Vol. 24, pp. 896-910, 2016.

[12] C. Vinoth Kumar and V. Natarajan, "Hybrid Local Prediction Error Based Difference Expansion Reversible

Watermarking for Medical Images", *Computers and Electrical Engineering*, Vol. 53, pp. 333-345, 2015.

[13] Xinlu Gui, Xiaolong Li and Bin Yang, "A High Capacity Reversible Data Hiding Scheme Based on generalized Prediction Error Expansion and Adaptive Embedding", *Signal Processing*, Vol. 98, pp. 370-380, 2014.

[14] Raheleh Khorsand Movaghar and Hossein Khaleghi Bizaki, "A New Approach for Digital Image Watermarking to Predict Optimal Blocks using Artificial Neural Networks", *Turkish Journal of Electrical Engineering and Computer Science*, Vol. 25, pp. 644-654,2017.

[15] Zahra Pakdaman, Saeid Saryazdi and Hossein Nezamabadi-Pour, "A Prediction based Reversible Image Watermarking in Hadamard Domain", *Multimedia Tools and Application*, Vol. 76, No. 6, pp. 1-29, 2016.