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Dynamic Prediction Error Integrated Reversible Image Watermarking

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Abstract: With an eye on affording much-needed copyright and safety to multimedia data, a number of methods have been put forward by experts in the field of digital image watermarking. Among them, digital watermarking using wavelet transform has gained supreme significance, keen enthusiasm due to its perceptual visibility and robustness among different attacks. In this study, dynamic prediction error integrated reversible image watermarking is proposed. The technique consists of four modules, namely pre-processing module, pixel prediction module, embedding module and extraction module. Watermark embedding is carried out by calculation of prediction error. The evaluation metric used are Peak Signal to Noise Ratio (PSNR) and Normalised Correlation (NC). We can see high NC and PSNR obtained for the technique with an average NC of 0.996 and PSNR of 51.8. Highest PSNR obtained was 54.05. Robustness analysis for various attacks such as filter, noise, cropping and blurring were also carried out. Comparative analysis is also carried out with respect to our earlier work, base paper and conventional method. From the evaluation metric values, we can infer that the proposed technique has obtained good results.

Key words: Reversible watermarking, prediction error, watermark embedding, biorthogonal DWT, entropy, robustness, PSNR, NC

INTRODUCTION

The rapid growth of digital media like internet and compact discs has ushered in a wonderful era where the flow, duplication and modification of digital images have become all the more easier and simpler. And, this phenomenon has unfortunately resulted in tremendous threats to multimedia safety and copyright security. This has motivated many an investigator to devise alternate methods, one of which is known by the term ‘digital watermarking’ which is nothing but the art of concealing data in a healthy way and without being noticed by pirates or others of the sort (Zaboli *et al*., 2005; Doerr and Dugelay, 2003; Vijaya *et al*., 2013). Of late, watermarking is employed extensively for rights safety, endorsement and content reliability authentication of intellectual property in digital (Maity and Kundu, 2004). This embedded data such as images, audios and videos can be mined and located from the multimedia at a later stage when needed and can be effectively used as a testimony to the proof of rights correlated purposes. Broadly, digital watermarking is carried out with the aim of frustrating illicit reproduction or utilization of digital images (Memon and Wong, 1998; Voyatzis and Pitas, 1999; Kahng *et al*., 2001; Fernando and Hernandez, 1999.).

Digital watermarking (Voyatzis and Pitas, 1999) technology is swiftly spreading its wings in computer science, cryptography, signal processing, Image Processing and communications. It is designed by the architects of this technology as the solution to provide high quality security on top of data encryption and dishevelled rush for safety of digital data (Mohanty, 1999). A simple model of a digital watermark would be a noticeable “seal” placed over an image to distinguish the patent (Kahng *et al*., 2001).

The fundamental benefit of watermarking is the indivisibility of the content from the watermark. This enables the watermarks appropriate for various programs such as signatures, fingerprinting, authentication, copy control and secret communication. As a rule, watermarking systems fine-tune an image by implanting client data and once an adaption is made, it cannot be revoked (Chen and Tsai, 2011). This technique for revertible watermarking required two indispensable stipulations, i.e., after entrenching the watermark into the

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cover image, the specified image should be defaced to the least after taking out the watermark; the cover image is capable of being re-established entirely (Kahng *et al*., 2001; Mohanty,, 1999). They comprise sturdiness against solidity, such as JPEG, dimension and feature ratio alterations, alternation, trimming, deletion of rows and columns, accumulation of sound, sifting, assaults on cryptography and data and inclusion of different watermarks.

In this study, dynamic prediction error integrated reversible image watermarking is proposed. The technique consists of four modules, namely pre-processing module, pixel prediction module, embedding module and extraction module. In pre-processing module, image scaling and transformation is carried out and subsequently, band selection is carried out. In pixel prediction module, the pixels values are predicted based on the position and making use of mathematical operations. In watermarking embedding module, the watermark is embedded into the image to form the watermarked image. Initially the prediction error is found out by comparing the predicted image to that of the original value and embedding is carried out based on the error value. The watermark is extracted from the watermarked image in watermark extraction module.

Literature review: With an eye on affording much-needed copyright and safety to multimedia data, a number of methods have been put forward by experts in the field. Among them, digital watermarking has gained supreme significance, keen enthusiasm being invested on watermarking of digital images and some of them are given in this section. Naskar and Chakraborty (2012) proposed a reversible digital image watermarking algorithm that predicted a pixel greyscale value exploiting its correlation with its neighboring pixels and embeds watermark bits into the prediction errors. Their algorithm succeeded in providing high embedding capacity with very low distortion, without 'multilayer embedding', hence reducing the computational burden compared with existing state-of-the-art algorithms. Zhang *et al.* (2011) introduced the spread spectrum watermarking as an optimization technique with wonderful qualities of easy deprival of the invisibility and the robustness. In addition, quality metric recommended was effortless and surpassed the high-tech metrics to the core and documented watermarking problem as a logical solution. Li *et al.* (2011), on the other hand, have devised a reversible watermarking system based on Prediction-Error Expansion (PEE), flexible implanting and pixel choice. In their technique, the spotlight was vastly linked regions and pixels and it was able to take maximum advantage of the spatial surplus snatching a higher level accomplishment over the competing conservative PEE.

Coltuc (2012) has taken pains to develop a low-deformation transform for forecast-error growth reversible watermarking. The transform recommended produced a reduced amount of deformation than the traditional forecast-error growth for composite predictors like the median edge detector or the gradient-adapted predictor. Chen and Tsai (2011) have given expression to a novel flexible block sized revertible image watermarking scheme. The main feature of the technique was that it was capable of restoring the original image from a watermarked image after extraction of the implanted watermarks. The measure of embedded quantity was calculated by the biggest variance in a block and watermarks implanted into LSB bits of the same variance. From the outcomes of investigation, it was evidenced the new adaptive block size scheme possessed superior competence levels than those of conservative fixed block sized techniques. Chung *et al.* (2012) were instrumental in devising a distortion decline method for histogram adaptation-based reversible data concealment. They gave shape to a watermark supplement method which could decrease the deformation arising in HM-based RDH technique. Subsequently, co-ordinated scrutiny for standard deformation ratio of the scheme suggested was made available. The swap between the deformation and the number of detached blocks was also experimented. The outcome of investigation was a pointer to the decreased degree of deformation and higher PSNR lower bound advantages of the recommended block-based watermark supplement method. Huang *et al.* (2010) have come out with a histogram-based reversible data hiding with quadtree perception. They advocated a revertible data concealing algorithm that showed supreme strength than traditional algorithm, having identical output image quality after embedding and analog usancillary data made available.

Naskar and Chakraborty (2011) have gifted a novel method of revertible image watermarking by synchronising logic function based forecast. Their method was a reversible digital image watermarking algorithm which was capable of forecasting a pixel greyscale value taking due advantage of its link with pixels in the vicinity, employing coordinate logic operations and implanting watermark morsels into the forecasting faults. They weighed its performance against other identical programs. Outcomes of the investigation reveal that the cover image deformation caused by the algorithm was lower than that of other high-tech reversible watermarking algorithms. Tang (2011) has offered a superior reversible watermarking algorithm based on arbitrary series. Their contribution was an improved digital watermarking algorithm based on arbitrary series into reversible watermarking algorithm. The algorithm made use of the forceful watermarking algorithm of the popular arbitrary series as implanting method. Sobel's edge recognition algorithm used digout the pixel value of edges from the watermarked image.

MATERIALS AND METHODS

Proposed dynamic prediction error integrated reversible image watermarking: In this study, dynamic prediction error integrated reversible image watermarking is proposed. The technique consists of four modules, namely pre-processing module, pixel prediction module, embedding module and extraction module. The block diagram of the proposed technique is given in Fig. 1.

Pre-processing and band selection module: Initially, image scaling and transformation is carried out in the pre-processing module. Subsequently, band selection is carried out.

Pre-processing: Image scaling and transformation is carried out in the pre-processing module. The Image scaling relates to image resizing where image is resized to a standard size of 512× 512 pixels. Converting the image to standard size makes it easy for the subsequent operation. Subsequently, the image is Discrete Wavelet Transformed (DWT) transformed using Bi-orthogonal based transformation.

The DWT (Discrete Wavelet Transform) transforms distinct time domain signal to frequency domain by employing filter banks. Use of synthesis filters in the filter bank of the wavelet transformation results in bi-orthogonal transformation. Biorthogonal Wavelets are relations of closely united symmetric wavelets. Biorthogonal transformation employs two scaling functions which can cause several multi-resolutions inspect and henceforth two varied wavelet functions. These factors makes the employment of biorthogonal wavelets is apt for watermarking domain.

Band selection module: After pre-processing, the band with maximum entropy is found out. Entropy is a measure of the improbability in a random variable. It is often

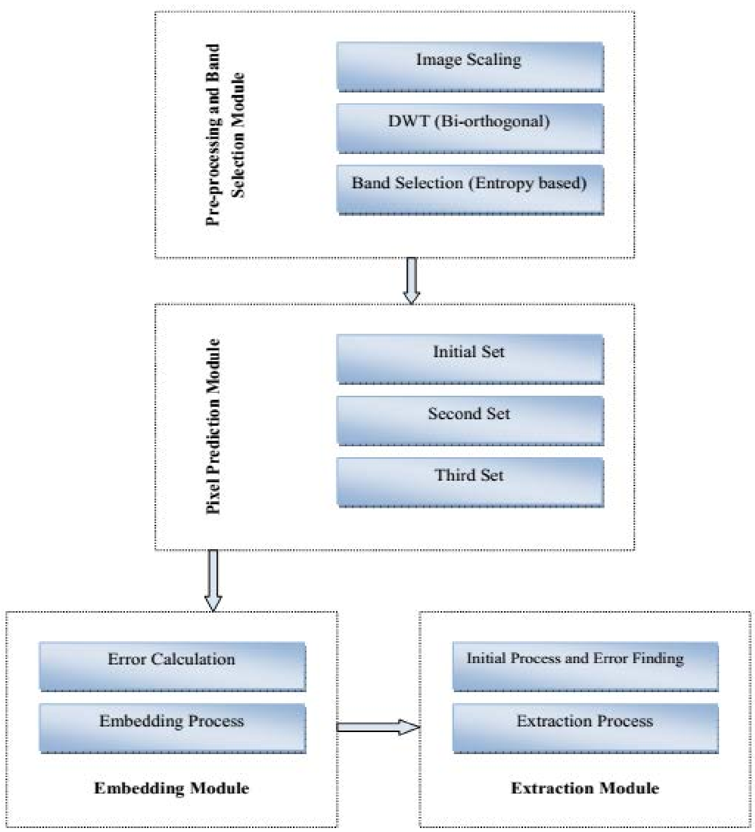

Fig. 1: The block diagram of the proposed technique

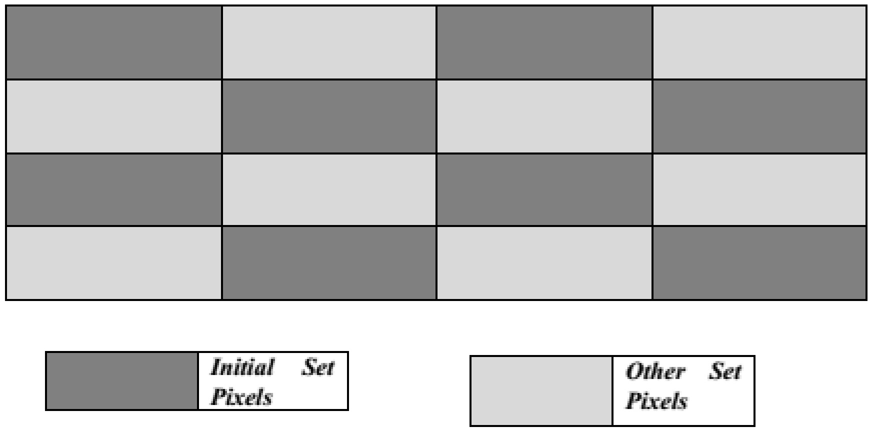

Fig. 2: Initial Set pixels in the image

described in terms of Shannon entropy which is the predictable value of the information comprised in a message. It gives auseful standard for estimating and comparing probability distribution and delivers a directory of the data of any array. The entropy represented by $\Im$ can be described in mathematical terms as:

$$\Im = -\sum_{j} \rho_j \log_2 \rho_j \tag{1}$$

In the Eq. 1, ρ_i is the probability that the difference between two neighbouring wavelet pixels is equal to j. Maximum entropy is found out after following a process which is explained in this sub-module. The bands available are approximation (CA) and detailed (CH, CV, CD) coefficient bands. But as CA band coefficients cannot be taken for watermark embedding process, we neglect CA band. Hence, we have to find out highest entropy among CH, CV and CD.

Let the original image be represented by I and after pre-processing let the image be represented Ψas having dimensions x×y. Initially, the corresponding entropy values of the three bands in consideration (CH, CV and CD) are found out. Let the entropies of the bands be represented as $\eta_{a\text{-}c}$ for CH, CV and CD, respectively. Comparison is carried out among the found out entropies to obtain the best band represented B which is the band having maximum entropy value. The equations are given by:

$$\text{if}\,(\eta_i \geq \eta_j \text{ and } \eta_i \geq \eta_k),\ \eta_{max} = \eta_i \tag{2}$$

$$\begin{aligned} &\text{if}\,(\eta_{max} = \eta_a) \text{ Then } B = CH;\\ &\text{if}\,(\eta_{max} = \eta_b) \text{ Then } B = CV;\\ &\text{if}\,(\eta_{max} = \eta_c) \text{ Then } B = CD \end{aligned} \tag{3}$$

Hence, the band with maximum entropy is selected as the best band and taken for further processing.

Pixel prediction module: In this module, the pixels values are predicted based on the position and making use of mathematical operations. The prediction is carried out based on the neighbouring pixel values and finding the median. The process of prediction depends on the position of the pixel and is classified accordingly. The classes includes four kinds of pixels based on the position termed as initial set, first derived set, second derived set and third derived set.

Initial set: Those pixels which have the same the value during the watermarking procedure contributes to the initial set. Here in our case, the pixels which have the row and column odd values odd and also those pixels having row and column values even is taken as initial set.

Here, in Fig. 2 initial set pixels are given in dark grey colour and other set pixels are given in light grey colour. Let the image be represented as $_{k\times m}$ where k is the number of rows and m is the number of column. Then, the first sets of pixels (FI) are defined as:

$$FI_{ij} = I_{ij} \text{ where } i = j = i\%\,2 = 0 \text{ or } i = j = i\%\,2 = 1 \tag{4}$$

Hence, the initial set is found out and is left unchanged. From these initial set, other predictions would be carried out.

Second set and third set: The second set is predicted by finding the median of the adjacent initial set pixel values based on certain constraints.

Initially, the image is split into groups of four pixels. Considering every four pixel as 2×2 matrixes, then the diagonal elements would be the initial pixels, top right pixel would form the second set and bottom left pixel

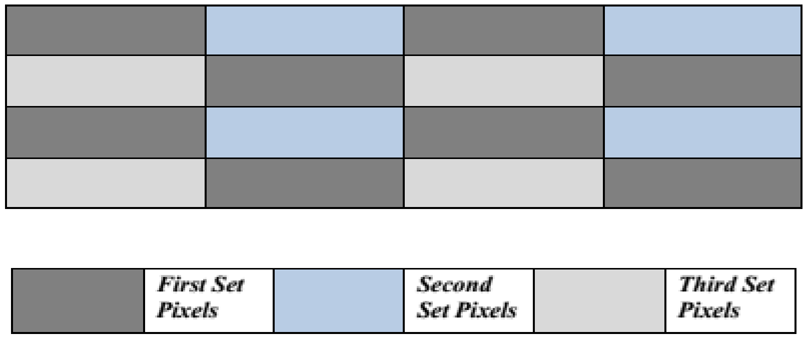

Fig. 3: Second and third set pixels in the image

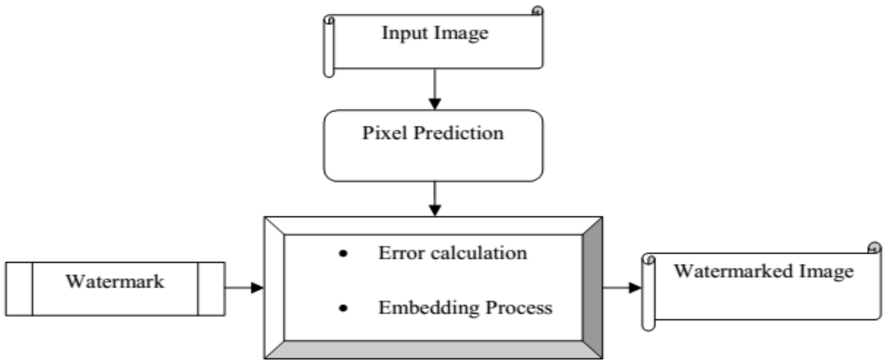

Fig. 4: The block diagram of the embedding module

would form the third set. Second set pixels are calculated as the median of the diagonal initial values and the third set is calculated as the median of diagonal initial values and the second set value (Fig. 3). Consider the four positional matrix values as $I_{(i,j)}$, $I_{(i+j,j)}$, $I_{(i+1,j+1}$ and $I_{i,j}$. Here, $I_{(i,j)}$and $I_{(i+1,j+1)}$ forms the initial values (already known), $I_{(i+j+1)}$ forms the second set and $I_{i+1,j}$forms the third set. Hence, the second set is given by:

$$I_{(i,\,j+1)} = \frac{I_{(i,\,j)} + I_{(i+1,\,j+1)}}{2} \tag{5}$$

And the third set is given by:

$$I_{(i+1,\,j)} = \frac{I_{(i,\,j)} + I_{(i+1,\,j+1)} + I_{(i,\,j+1)}}{3} \tag{6}$$

Similarly, the second and third sets are computed for the all groups to form the predicted image.

Embedding module: In this module, the watermark is embedded into the image to form the watermarked image. Initially the prediction error is found out by comparing the predicted image to that of the original value and embedding is carried out based on the error value. The block diagram of the embedding module is given in Fig. 4.

Prediction module is the difference between the original image value and the predicted image value using initial set, second set and third set predicted pixels. Suppose the predicted image be represented as $PI_{k\times m}$ and the original image value is represented as $G_{k\times m}$. Then, the error is given by:

$$E_{ij} = | G_{ij} - P_{ij} | \tag{7}$$

Owing to high correlation between the adjacent pixels, error would be small and pixels having lower errors are preferred for embedding process. If the watermark bit is be one, then the predicted pixel value is replaced with the original image value. In other case, when watermark bit is zero, the predicted value is added with a threshold value to make it close to the original image value. In both cases, watermark bit is embedded into the error by adding the error to the watermark bit.

$$\text{if}(W_{ij} = 1),\; P_{ij} = G_{ij} \tag{8}$$

$$\text{if}(W_{ij} = 0),\; P_{ij} = P_{ij} + th \tag{9}$$

In both cases, watermark bit is embedded into the error by adding the error to the watermark bit to form the watermarked image (S_{ij}):

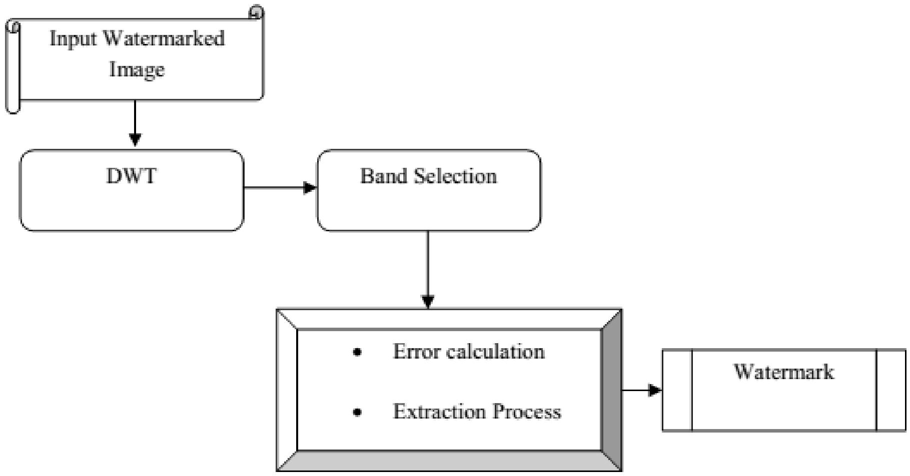

Fig. 5: The block diagram of the embedding procedure

$$S_{ij} = W_{ij} + E_{ij} \tag{10}$$

After the embedding procedure, the Inverse DWT is applied to form the watermarked image. The flow of process is given in Algorithm 1:

Algorithm A: Watermarked inverse DWT

Input: Image and watermark
Output: Watermarked image
Start
Performed image scaling and apply DWT
Select best band from CH, CV and CD based on entropy:
If ($\eta_i \geq \eta_j$ and $\eta_i \geq \eta_k$), $\eta_{max} = \eta_i$
If ($\eta_{max} = \eta_a$) Then B = CH; if ($\eta_{max} = \eta_b$), Then B = CV; if ($\eta_{max} = \eta_i$) Then B = CD
Find the initial set using formula: $Fi_{ij} = I_{ij}$ where I = j = i%2 = 0 or i = j = i %2 = 1
Find the second and third set using formulas:
$I(i,j+1) = \frac{I(i,j) + I(i+1,j+1)}{2}$;
$I(i,j+1) = \frac{I(i,j) + I(i+1,j+1) + I(i,j+1)}{3}$
Find out the error given by $E_{ij} = |G_{ij}-P_{ij}|$
Check for the conditions and update
if (W = 1), $P_{ij} = G_{ij}$; if if (W = 0), $P_{ij} = G_{ij}$+th
Get the watermarked omage and apply IDWT:
$S_{ij} = W_{ij}+E_{ij}$

Extraction module: The watermark is extracted from the watermarked image in this module. The block diagram of the embedding procedure is given in Fig. 5.

The watermarked image S_{ij} is initially applied DWT and the band (CH, CV and CD) having maximum entropy (η_{max} = max {η_a, η_b, η_c} is found out as in the initial section. Band selected is processed for subsequent operations and the respective error is found out. Here, the error is the difference between the predicted pixel value and the watermarked pixel value. Suppose the predicted pixel is given by P_{ij} and that of watermarked pixel is given by S_{ij} then error is defined as:

$$Er_{ij} = | S_{ij} - P_{ij} \tag{11}$$

This error value is compared with a set threshold (represented by Thr) to extract the watermark. Suppose the error value is less than threshold, then the recovered watermark bit is taken as one else the watermark bit is taken as zero. This can be represented by:

$$\text{if}(Er_{ij} < \text{Thr}),\ \text{THEN}\ \hat{W}_{ij} = 1 \tag{12}$$

$$\text{if}(Er_{ij} \geq \text{Thr}),\ \text{THEN}\ \hat{W}_{ij} = 0 \tag{13}$$

Hence, we have obtained back the watermark image from the watermarked image (Algorithm B).

Algoritm B: Watermarked image:

Input: Watermarked image
Output: Watermark image and recovered image
Start
Apply DWT
Select beat band from CH, CV and CD based on entropy:
If ($\eta_i \geq \eta_j$ and $\eta_i \geq \eta_k$), $\eta_{max} = \eta_i$
If ($\eta_{max} = \eta_a$) Then B = CH; if ($\eta_{max} = \eta_b$), Then B = CV; if ($\eta_{max} = \eta_i$) Then B = CD
Find out the error given by $Er_{ij} = |S_{ij}-P_{ij}|$
Compare to threshold and retrieve:
if (Er_{ij}<Thr), THEN $\hat{W}_{ij} = 1$
if ($Er_{ij} \geq$Thr), THEN $\hat{W}_{ij} = 0$
END

RESULTS AND DISCUSSION

This study gives the results and analysis made for the proposed technique. The experimental set up and evaluation metrics details are given in below study and comparative analysis (Fig. 6).

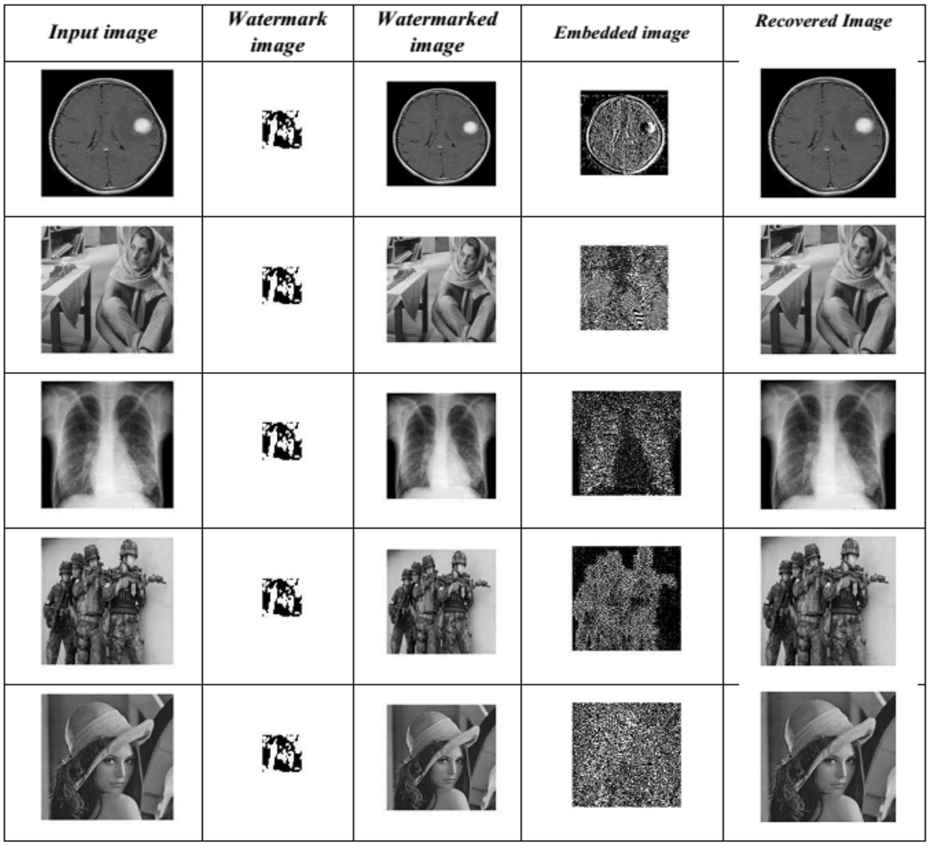

Fig. 6: Simulation results obtained of five different figure

Experimental set up and evaluation metrics: The proposed technique is implemented using MATLAB on a system having the configuration of 6 GB RAM and 3.2 GHz Intel i-7 processor. The evaluation metric used are Peak Signal to Noise Ratio (PSNR) and Normalised Correlation (NC). The quality is evaluated by the use of PSNR criterion in between the original images with the watermarked images and the extracting fidelity is compared using the NC value with original watermark and the extracted watermark. PSNR is used to measure the invisibility of the embedded watermark in carrier image. NC is used to measure the similarity between the extracted watermark and the original watermark. The definition of PSNR and NC is given in the following Equations.

$$PSNR = 10\log_{10}\frac{E_{max}^2 \times W_w \times W_h}{\sum_{x=0}^{W_h-1}\sum_{y=0}^{W_w-1}(W_{jk}-W_{jk}^*)^2} \tag{14}$$

Where:

W_w and W_h = The width and height of the watermarked image

W_{jk} = The original image pixel value at coordinate (j, k)

W_{jk}^* = The watermarked image pixel value at coordinate (j,k)

E_{max}^2 = Largest energy of the image pixels

$$NC = \frac{\sum_{i=0}^{W_h}\sum_{j=0}^{W_w} W(j,k)\times E_w(j,k)}{\sum_{i=0}^{W_h}\sum_{j=0}^{W_w}(W(j,k))^2} \tag{15}$$

Where, E_w (j, k) is the extracted watermark image.

Simulation results: This study gives the simulation results obtained for the proposed technique. The results obtained for five different images are given in Fig. 6. The simulation figures include input image, watermark image, watermarked image, embedded image and recovered image. NC and PSNR obtained in each case are also given. We can see high NC and PSNR obtained for the technique with an average NC of 1 and PSNR of 51.8. The highest values were obtained for chest image.

In this study the comparison is made with respect to the earlier research, base study (Naskar and Chakraborty,

Table 1: Comparative table

Parameters	NC-proposed	NC-earlier paper	NC-conventional	NC-Base paper	PSNR proposed	PSNR earlier paper	PSNR conventional	PSNR base paper
Brain MRI	0.987	1	0.35627	1	53.1919	31.6565	37.1192	41.8530
Barbara	1	1	0.53217	1	49.2935	29.7584	35.6278	38.7081
Chest	1	1	0.53605	1	54.0593	30.4016	35.7076	43.4050
Soldier Image	1	1	0.47273	1	52.8050	30.1204	35.7529	38.5477
Lena	1	1	0.48902	1	49.8573	30.0248	36.1505	40.2169

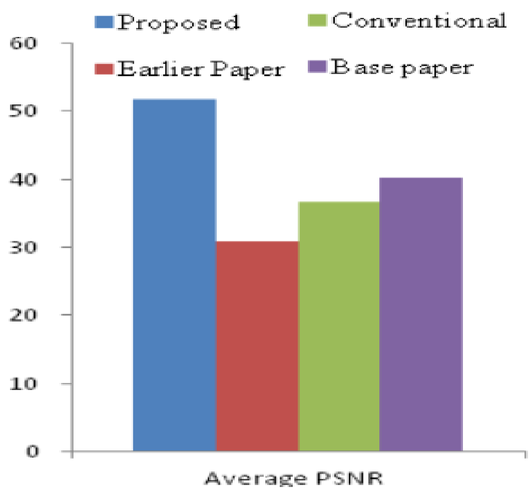

Fig. 7: Average PSNR values

2012) and conventional method. Table 1 gives the comparative PSNR and NC values for the respective technique and Fig. 7 gives the average PSNR values. PSNR taken is between the original image and the watermarked image.

From Table 1 and Fig. 7, we can see that our proposed technique has performed well by having higher PSNR and NC values in comparison to others. We can see that average PSNR value came about 51.8 and average NC stood at 1.0.

CONCLUSION

In this study, dynamic prediction error integrated reversible image watermarking is proposed. The technique consists of four modules, namely pre-processing module, pixel prediction module, embedding module and extraction module. The evaluation metric used are Peak Signal to Noise Ratio (PSNR) and Normalised Correlation (NC). The technique obtained average NC of 0.99 and average PSNR of 51.8. Highest PSNR obtained was 54.05. Robustness analysis for various attacks such as filter, noise, cropping and blurring were also carried out. Comparative analysis is also carried out with respect to our earlier work, base study (Naskar and Chakraborty, 2012) and conventional method. From the observations, we can infer that the proposed technique has obtained good results.

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