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A Novel DWT-CT approach in Digital Watermarking using PSO

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Abstract---The importance of watermarking is dramatically enhanced due to the promising technologies like Internet of Things (IoT), Data analysis, and automation of identification in many sectors. Due to these reasons, systems are inter-connected through networking and internet and huge amounts of information is generated, distributed and transmitted over the World Wide Web. Thus authentication of the information is a challenging task. The algorithm developed for the watermarking needs to be robust against various attack such as salt & peppers, filtering, compression and cropping etc. This paper focuses on the robustness of the algorithm by using a hybrid approach of two transforms such as Contourlet, Discrete Wavelet Transform (DWT). Also, the Particle Swarm Optimization (PSO) is used to optimize the embedding strength factor. The proposed digital watermarking algorithm has been tested against common types of image attacks. Experiment results for the proposed algorithm gives better performance by using similarity metrics such as NCC (Normalized Cross Correlation value) and PSNR (Peak Signal to Noise Ratio).

Keywords*—watermarking, particle swarm optimization, discrete wavelet transfrom, contourlet transformation, PSNR, NCC.*

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I. INTRODUCTION

In today's era, the development of the internet has introduced many new opportunities for the creation and delivery of information in digitized form including text, images, audio, and video. Copyright protection of digital information became essential due to the exponential growth of the digital media access and editing over networks [1][2]. An important issue that arises is the protection of rights of all participants. One of the protection mechanisms that attract many researchers is based on digital watermarking techniques. Digital watermarking is a process of information hiding which is used to hide secret information in multimedia data like digital images, text documents, audios, or video clips. In specific, it acts as a digital signature, giving the image a sense of ownership or authenticity.

In general, a digital watermarking scheme should be imperceptible and robust to attacks such as cropping, rotation, filtering, compression, and others [3] which may cause the removal or substitution of the original watermark with another watermark by the intruders. Commonly used image watermarking algorithms are spatial domain based schemes like Least Significant Bits (LSB) [4] and frequency domain transformation schemes like Discrete Fourier Transform (DFT) [5], Discrete Cosine Transform (DCT) [6], Discrete Wavelet Transform (DWT) [7] , and Discrete Contourlet Transform (CT) [8][9][10].

A brief review to understand the background of the problem is discussed in section 1 and a quick overview about DWT, CLT and PSO is presented in Section 2. The related work is discussed in Section 3. The proposed watermarking technique is discussed in Section 4. The experimental results are presented in Section 5 followed by comparison results in section 6. Finally Section 7 concluded the proposed research work.

II. PRELIMINARIES

A. *Discrete Wavelet Transformation*

Wavelet transforms are based on small waves, called wavelet, of varying frequency and limited duration. The wavelet transform decomposes the image into four spatial sub-bands, i.e. approximation, horizontal, vertical and diagonal. Hence wavelets reflect the anisotropic properties of HVS more precisely. Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH, and HL) [7]. One of the main challenges of the watermarking problem is to achieve a better tradeoff between robustness and perceptivity. Robustness can be achieved by increasing the strength of the embedded watermark, but the visible distortion would be increased as well [11].

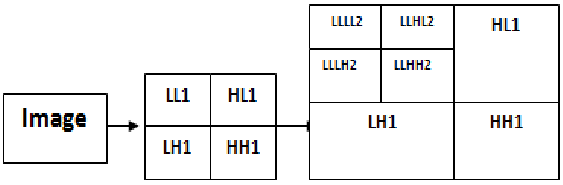

Figure 1 Two Level Pyramid of DWT

B. Contourlet Transformation

Although wavelets are good at representing discontinuities in one dimension or point singularities, it fails to represent singularities in higher dimensions. The Discrete Contourlet Transform is a relatively new transform defined in the discrete form by Do et al. [8] to capture the edge information in all directions. The main feature of this transform is the potential to efficiently handle 2-D singularities, i.e. edges. The CT can be divided into two main steps: Laplacian Pyramid (LP) decomposition [9] and Directional Filter Banks (DFB) decomposition [10]. An image is first decomposed into low pass image and band pass image by LP decomposition. Each band pass image is further decomposed by DFB step. A DFB is designed to capture the high frequency content like smooth contours and directional edges. Multi-resolution and multi-direction decomposition can be obtained by repeating the same steps mentioned above for the low pass image.

In Contourlet, the number of directional sub bands at each level is set to 2^n where n is a positive integer number. For example, if we choose to decompose an image into four levels using n= (1, 2, 3, 4) then we get 2, 4, 8, and 16 sub bands as shown in Figure 2.

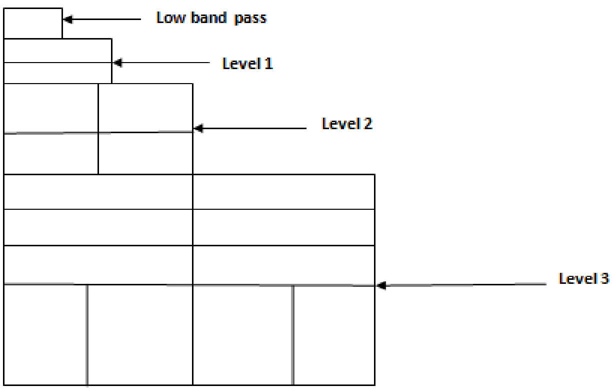

Figure 2 Contourlet Decomposition

C. Particle Swarm Optimization

It is a population based stochastic optimization model which is generated after the social behavior of bird flocks or fish schooling developed by Kennedy and Elberhart [12]. The real particle swarm optimization method shows every particle like a potential solution of a problem in n – dimensional space. The modification in particle local best and global best can be defined as the velocity value. Velocity of each particle is upgraded by using the following equation (1) and the every particle updated its position by equation (2)

$$Vi\ (t+1) = a\ Vi + const1 * random * (pbest(t) – Xi(t)) + const2 * random * (gbest(t) – X_i(t)) \quad (1)$$

$$Xi(t+1) = Xi(t) + Vi\ (t+1) \quad (2)$$

Steps Used PSO Algorithm

- Each particle initial position and initial velocity is generated randomly.
- The velocity of all particles is updated according to equation (1) and the position of all particles is updated according to equation (2).
- If the fitness of the current particle is smaller than its previous best (pbest) fitness, replace pbest by the update pbest.
  $pbest = p(t) \quad \text{if} \quad f(p(t)) > pbest \quad (3)$
- For each particle, if its fitness is smaller than the best one (gbest) of all the particles, update gbest.
  $gbest = g(t) \quad \text{if} \quad f(g(t)) > gbest \quad (4)$
  Where, f (t) is the objective function to be optimized.
- The process is update till the certain termination conditions are not founded. When the process terminates the pbest and gbest is determined.

III. RELATED WORK

The author [13] proposes the application of Discrete Wavelet Transform (DWT) into image watermarking by using Particle Swarm Optimization (PSO) which is an evolutionary technique with the stochastic, population-based algorithm for solving problem. To protect copyright information of digital images, the original image is decomposed according to two-dimensional discrete wavelet transform. Subsequently the preprocessed watermark with an affined scrambling transform is optimal embedded into the vertical sub-band (HL_m) coefficients in wavelet domain without compromising the quality of the image. The scaling factors are trained with the assistance of PSO.

The author [14] proposed a blind image watermarking scheme based on wavelet tree quantization. Two largest coefficients are selected as significant coefficients and the difference between them is taken as significant difference. The significant difference with an average significant difference value and maximum difference coefficients are quantized for embedding watermark bit.

In the work [15], an image-adaptive watermarking algorithm based on wavelet transform was proposed. At first, a digital image used as watermarking was scrambled. Next, the original image was decomposed by discrete wavelet transform and in accordance with the characteristics of human visual system, wavelet decomposition in the low-frequency domain, Methods which average of adjacent domain instead of single wavelet decomposition coefficients was used to estimate and quantitative, watermarking was adaptively embedded in wavelet coefficients of low-frequency domain.

The author [16] have presented blind digital watermarking algorithm in which genetic algorithm is combined with discrete cosine transform domain. In the proposed algorithm, firstly the image is divided into 8 x 8 blocks and each block is transformed to DCT domain. Now apply GA in each 8 x 8 DCT block to find the best coefficients for insertion of a watermark. For embedding the watermark, two DCT coefficients, whose difference is large enough and they must be in the low frequencies are chosen. If the distance is greater, robustness increases.

IV. THE COMBINED OPTIMIZED DWT-CT DIGITAL WATERMARKING ALGORITHM

In our performance evaluation, we used the combined DWT-CT transform in which gain factor is optimized by the PSO. It comprises of two units; embedding algorithm and extraction algorithm.

I. Watermark Embedding Unit

Before embedding the watermark into the original image it will be transformed into coefficients by applying DWT and CT. Original image also transformed into coefficients then both are applied to the embedding algorithm which is known as watermarked image, now inverse transforms are applied to obtain the watermarked image. Selection of the embedding factor is optimized by PSO. Fig. 3 shows the block diagram of the watermark embedding algorithm.

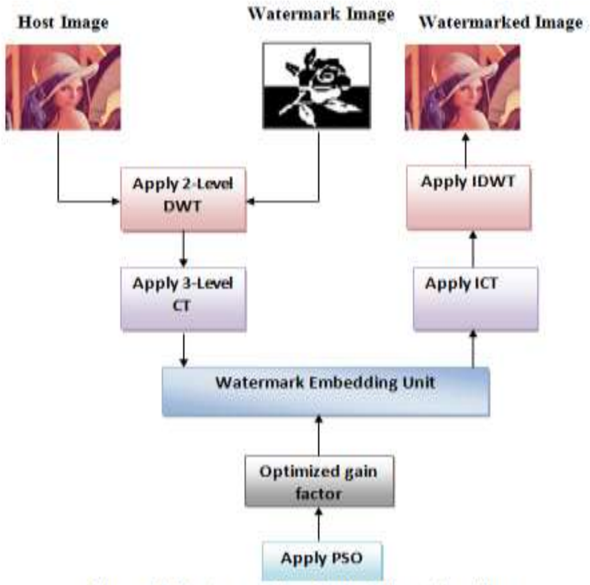

Figure 3 Watermarking Embedding Algorithm

II. Watermark Extraction Unit

Watermark extraction process deals with the retrieval of the watermark in the presence of the original image. The objective of the watermark extraction algorithm is to obtain the reliable an estimate of the original watermark from the watermarked image. The extraction process is opposite of the watermark embedding process. Fig. 4 shows the block diagram of the watermark extraction algorithm.

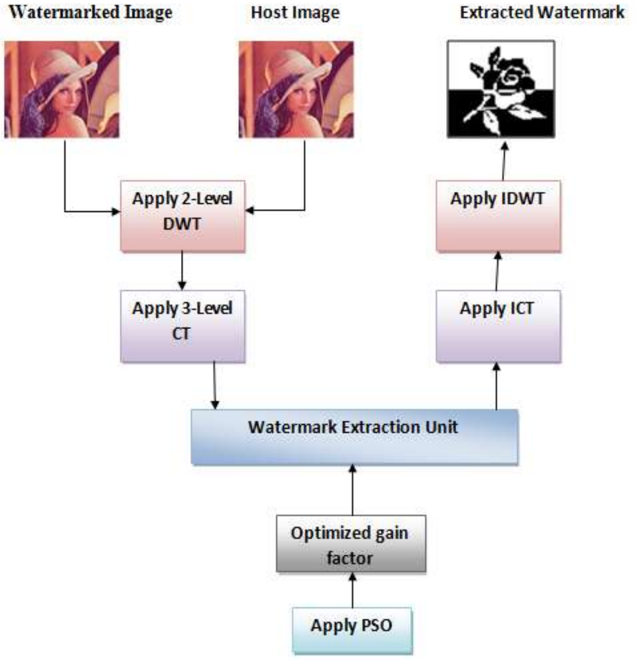

Figure 4 Watermarking Extraction Algorithm

V. EXPERIMENTAL RESULTS

In order to easily compare with other watermarking techniques in the literature, a standard 256 x 256 grey scale Lena image is used as the host image. The watermark image is made from a binary loge image of size 128 x 128 pixels. In contourlet decomposition, both LP decomposition and DFB decomposition with 'pkva' filters is used. The first two pyramidal levels are chosen and the number of directional sub bands for each level is set to 2, 4 and 8. In wavelet decomposition, 'haar' filters are used because of their high efficiency. Testing the robustness is done by applying a number of different attacks which are JPEG, median filtering, average filtering, salt & pepper noise, cropping, image sharpening, and histogram equalization.

Types of attacks	Lena Image	
	Watermarked Image	Extracted Logo
Cropping		
JPEG		
Sharpening		
Rotation		

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137 – 141

Average Filtering		
Median Filtering		
Gaussian		
Salt & Pepper		

Figure 5. Several attacks on "Lena" image and their corresponding extracted watermarks

VI. COMPARISON RESULT

Here the results of the proposed method are compared with Sonam et al. [16] method for Lena image. As it is shown in the table, when the image has been corrupted by JPEG compression, the proposed method provides more robust watermark extraction when the quality factor is low. The proposed method shows that the image remains imperceptible (because PSNR> 30 dB) while the watermark survives from attacks. The comparison is given in the table below:

Table I Parameter values without attacks

Error Metrics	Existing Method [16]		Proposed Method	
	Mandrill	Leena	Mandrill	Leena
NCC	0.998	0.998	1.0000	1
PSNR	29.220	36.301	40.4277	40.0398

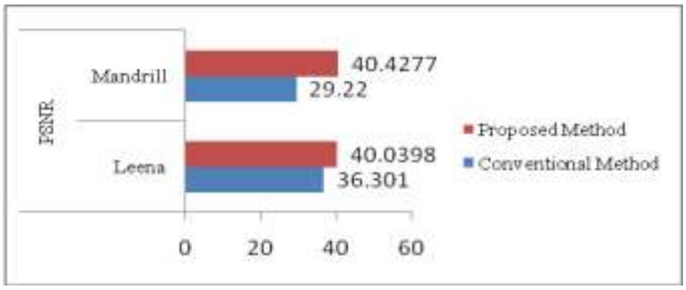

Figure 6 Comparison of PSNR values without attacks

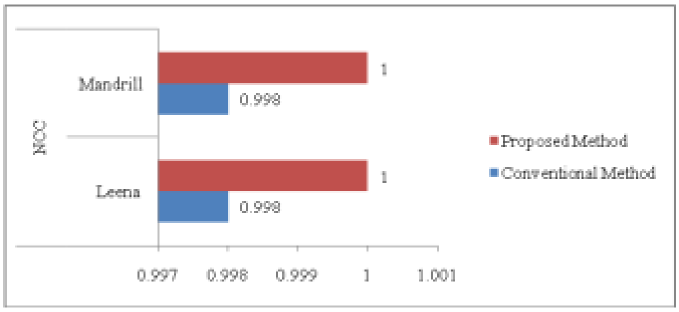

Figure 7 Comparison of NCC values without attacks

Table II PSNR Parameter values with attacks

Types of Attacks	Existing Method[16]	Proposed Method
Salt and Pepper Noise	24.868	34.3960
Gaussian Noise	19.491	40.0398
Median Filtering	28.853	33.2168
Averaging Filtering	28.229	30.9815
Sharpening	25.434	34.5457
JPEG Compression (50%)	26.579	35.1935
JPEG Compression (70%)	33.051	39.3148

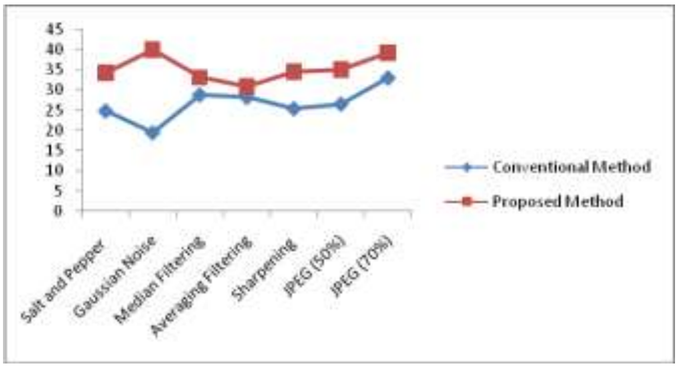

Figure 8 Comparison of PSNR values after attacks

Table III NCC Parameter values with attacks

Types of Attacks	Existing Method[16]	Proposed Method
Salt and Pepper Noise	0.987	0.9953
Gaussian Noise	0.959	1
Median Filtering	0.997	1
Averaging Filtering	0.997	1
Sharpening	0.980	0.9956
JPEG Compression (50%)	0.989	0.9949
JPEG Compression (70%)	0.996	0.9980

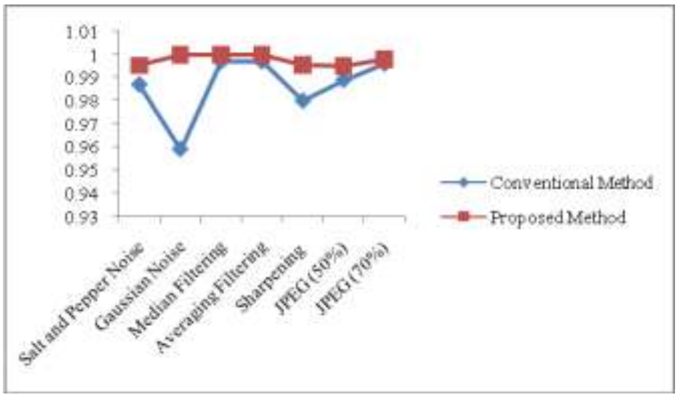

Figure 9 Comparison of NCC values after attacks

VII. CONCLUSION

In this paper, PSO based DWT-CT domain watermarking algorithm has been proposed. Numerous tests were done on watermarked image. The quality of watermarked image is good in terms of perceptibility and the proposed method is shown to be robust to all attacks which are performed. Compared to results reported at [16], proposed method gives improved NCC and show superiority over existing methods. Further work on the proposed approach is in progress to optimize parameters by using hybrid optimization technique.Further work can be extended to implement the algorithm on other formats of document rather than text.

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