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Copyright Protection of Digital Images Using Robust Watermarking Based on Joint DLT and DWT

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Abstract — Digital watermarking is a new method of protecting multimedia content from unauthorized copying. A digital multimedia technology has offered many facilities in the transmission, reproduction and manipulation of data. However, this advance has also brought the problem such as copyright protection for content providers. Copyright protection of images has become a major concern with the rapid expansion of the Internet, which contains millions of freely available images. Digital watermarking is one of the proposed solutions for copyright protection of multimedia and is becoming a major player not only for use in images but also in the latest technology such as audio, image and video. In this paper robustness of digital image watermarking algorithm based on transforming domain. We are proposing a robust combined Discrete Laguerre Transform (DLT) and Discrete Wavelet Transform (DWT) watermark transformation algorithm. Experimental results show that the higher robustness against common signal processing attacks. The combined of DLT and DWT, the proposed system achieves significantly higher robustness of the method against some common image processing operations such as Salt and Pepper noise addition , Gaussian noise addition, Speckle Noise addition, Cropping, JPEG compression.

Index Terms — Copyright Protection, Data Hiding, JPEG, Normalized Cross Correlation (NC), Peak Signal to Noise (PSNR), Steganography, Watermarking.

1. INTRODUCTION

In recent years it has been seen a rapid growth of network multimedia systems. This has led to an increasing awareness of how easy it is becoming to reproduce the data. The ease with which perfect copies can be made may lead to large-scale unauthorized copying, which is a great concern to the image, music, film, and book. A digital data can be easily transmitted, received, duplicated or modified by using the Internet. So that the copyright protection of digital data is an important legal issue [1]. There are various processes are used for copyright protection of digital data. The Digital watermarking is new and most popular technique for copyright protection and considered as a possible solution. Watermarking is very similar to steganography in a number of respects. Both seek to embed information inside a cover message with little to no degradation of the cover-object. Steganography differs from cryptography in the sense that where cryptography focuses on keeping the contents of a message secret, steganography focuses on keeping the existence of a message secret [2].

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Steganography and cryptography are both ways to protect information from unwanted parties but neither technology alone is perfect and can be compromised. In watermarking all of the instances of an object are marked in the same way. The kind of information hidden in the object when using watermarking is usually a signature to signify origin or ownership for the purpose of copyright watermarking all of the instances of an object are marked in the same way. The kind of information hidden in the object when using watermarking is usually a signature to signify origin or ownership for the purpose of copyright protection [3]. Many watermarking techniques do exist. These can be divided into two broad categories, those working in the spatial and time domain and those working in the transform (frequency) domain [4].Watermarking algorithms can also be classified based on the domain used for watermark embedding [5]. Spatial domain watermarking directly embeds the watermark into the object [6] while frequency domain watermarking embeds the watermark by changing frequency component values by an orthogonal transformation [7]. To obtain better imperceptibility as well as robustness, the addition of the watermark is done in a transformed domain [8]. Discrete Laguerre Transform (DLT) and Discrete Wavelet Transform (DWT) are two such popular transforms, operating in the frequency domain [9].

Watermarking techniques can be classified according to the type of watermark being used, i.e., The watermark may be a visually recognizable logo or a sequence of random numbers. Another classification is based on the domain which the watermark is applied i.e., The spatial domain or the transform

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domain. The earlier watermarking techniques were almost in spatial domain. Spatial domain techniques are not resistant enough to image compression and other image processing [10]. Transform domain watermarking schemes like those

based on the Discrete Laguerre Transform (DLT) [11] the Discrete Wavelet Transform (DWT) typically provide higher image imperceptibility and are much [12] more robust to image manipulations. The wavelet transform is widely applied to different tasks in image processing. Since wavelet transform coefficients are highly de-correlated having compact energy concentration, and are consistent with the feature of the human visual system. DWT based watermarking is a widely used technique to embed a spread spectrum watermark into DWT coefficients [13]. Further performance improvements in the DWT-based digital image watermarking algorithms could be obtained by combining Discrete Laguerre Transform (DLT) with Discrete Wavelet Transform (DWT). However, robustness of common DLT and DWT [12] transform methods is increased by previous hybrid method despite their robustness against noise and blurring attack is not acceptable. In order to solve this problem, in this paper a new image watermarking algorithm based on jointed Discrete Laguerre Transform (DLT) [11] and Discrete Wavelet Transform (DWT) method is presented.

2. DIGITAL WATERMARKING

Watermarking of papers was first done in Fabriano, Italy in 1292 [14]. During manufacturing a water coated stamp was impressed on the still not dry paper pulp. The watermark in the paper was visible as a lighter pattern when the paper was viewed by transmitted light. The watermark was used by paper makers to identify their products. Also referred to as simply watermarking a pattern of bits inserted into a digital image, audio or video file that identifies the file's copyright information. The name comes from the faintly visible watermarks imprinted on stationery that identify the manufacturer of the stationery. The purpose of digital watermarks is to provide copyright protection for intellectual property that's in digital format. Digital watermarking embeds identifying information in an image, which is not always hidden, in such a manner that it cannot easily be removed. It can also contain device control code that prevents illegal recording. An application of watermarking is copyright control, in which an image owner seeks to prevent illegal copying of the image. Watermarking has been considered to be a promising solution to protect the copyright of multimedia data through transcoding, because the embedded message is always included in the data. There is no evidence that watermarking techniques can achieve the ultimate goal to retrieve [15] the right owner information from the received data after all kinds of content-preserving manipulations. Because of the fidelity constraint, watermarks can only be embedded in a limited space in the multimedia data. There is always a biased advantage for the attacker whose target is only to get rid of the watermarks by exploiting various manipulations in the finite watermarking embedding space [16]. A more

reasonable expectation of applying watermarks techniques for copyright protection may be to consider specific application scenarios.

3. METHODOLOGIES

The DLT and DWT transforms have been extensively used in many digital signal processing applications [17]. In this paper we are proposing Discrete Laguerre Transform (DLT) because the quality of the Discrete Laguerre Transform (DLT) domain watermarked images are higher than the corresponding Discrete Cosine Transform (DCT) domain watermarked images. We introduce the two transforms briefly, and outline their relevance to the implementation of digital watermarking.

3. 1 Discrete Laguerre Transform (DLT)

The Mandyam and Ahmed introduced the Discrete Laguerre Transform (DLT) in since 1996. The Discrete Laguerre Transform (DLT) is based on the Laguerre functions, which constitute an orthonormal set of basis functions in the interval (0, ∞). The n^{th} Laguerre function starting from n = 0 is defined as

$$l_n(p,x) = (-1)^n \sqrt{2p}\,\phi_n(2px)$$

Where

$$\phi_n(x) = e^{-x/2} L_n(x)$$

and

$$L_n(x) = \frac{e^x}{n!}\frac{d^n}{dx^n}(x^n e^{-x})^1$$

and p is a nonzero constant. Due to the exponential term e^{-px}, the Laguerre functions are not polynomials. By some minor modifications to the Gauss and Jacobi orthogonalisation procedure one gets the desired DLT transform matrix. We use the following representation for Laguerre functions

$$l_n(p,x) = e^{-px} G_n(p,x)$$

Where G_n (x) is an n^{th} order polynomial . Therefore , we can modify the Lagrangian interpolation formula as

$$l_n(p,x) = e^{-px} \sum_{k=1}^{n} \frac{\omega(x)}{(x-x_k)\omega'(x_k)} l_n(p,x_k) e^{px_k}$$

As an example, the 4x4 DLT transforms matrix is as follows

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$$L_{4x4}=\begin{bmatrix}0.7766 & 0.5978 & 0.1972 & 0.0232\\ -0.5261 & 0.4458 & 0.6974 & 0.1950\\ 0.3160 & -0.5785 & 0.4372 & 0.6118\\ -0.1420 & 0.3303 & -0.5325 & 0.7663\end{bmatrix}$$

We can see that the Laguerre basis polynomials are all subject to an exponential decay, and therefore, for x

sufficiently large, $l_n(x)$ approaches zero for all possible n. One can therefore conclude that signals that can be best represented by DLT are those that have some sort of exponential decay. The DLT differs than other transforms such as DCT. It can be observed that the DLT has no "DC basis vector," as is the case with the DCT and DFT. So, signals with a DC offset are not suitable for efficient representation by the DLT.

3. 2 Discrete Wavelet Transform (DWT)

A wavelet transform in which the wavelets are discretely sampled are known as the discrete wavelet transform. The DWT gives a multi-resolution description of a signal which is very useful in analyzing real world signals. The Discrete Wavelet Transform (DWT) [18] of image signals produces a non-redundant image representation, which provides better spatial and spectral localization of image formation compared with other multi scale representations such as Gaussian and Laplacian pyramid. Recently, Discrete Wavelet Transform has attracted more and more interest in image de-noising. The DWT can be interpreted as signal decomposition in a set of independent, spatially oriented frequency channels. The signal S is passed through two complementary filters and emerges as two signals, approximation and Details. This is called decomposition or analysis. The components can be assembled back into the original signal without loss of information. This process is called reconstruction or synthesis. The mathematical manipulation, which implies analysis and synthesis is called discrete wavelet transform and inverse discrete wavelet transform. An image can be decomposed into a sequence of different spatial resolution images using DWT [19]. In case of a 2D image, an N level decomposition can be performed resulting in 3N+1 different frequency bands namely, LL, LH, HL and HH as shown in figure 1.

After the original image has been DWT transformed, it is decomposed into 4 frequency districts which is one low frequency district (LL) and three high-frequency districts (LH,HL,HH). A 2D image after three-times DWT decomposed can be shown as figure 1. Where L represents a low - pass filter, H represents a high - pass filter. An original image can be decomposed of frequency districts of HL1, LH1, and HH1. The low frequency district information also can be decomposed into sub-level frequency district information of LL2, HL2, LH2 and HH2. By doing this the original image can be decomposed for n level wavelet transformation [20].These are also known by other names, the sub-bands may be respectively called a1 or the first average image, h1 called horizontal fluctuation, v1 called vertical fluctuation and d1 called the first diagonal fluctuation. The sub-image a1 is formed by computing the trends along the rows of the image followed by computing trends along its columns. In the same manner , fluctuations are also created by

computing trends along rows followed by trends along columns. The next level of wavelet transform is applied to the low frequency sub band image LL only. The Gaussian noise will nearly be averaged out in low frequency wavelet coefficients. Therefore, only the wavelet coefficients in the higher frequency levels need to be threshold.

H - High Frequency Bands
L - Low Frequency Bands
1, 2, 3 - Decomposition Levels

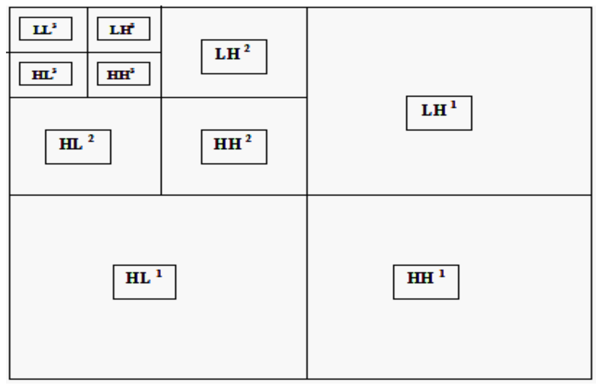

Figure - 1 The 2D Discrete Wavelet Transform (DWT) with 3-Level Decomposition

The Discrete Wavelet Transform (DWT) is a special case of the WT that provides a compact representation of a signal in time and frequency that can be computed efficiently [21]. The DWT is defined by the following equation

$$W(j,k)=\sum_{j}\sum_{k}x(k)2^{-j/2}\psi(2^{-j}n-k)$$

Where $\psi(t)$ is a time function with finite energy and fast decay called the mother wavelet. The DWT analysis can be performed using a fast, pyramidal algorithm related to multirate filter banks [22]. A multirate filter bank the DWT can be viewed as a constant Q filter bank with octave spacing between the centers of the filters. Each subband contains half the samples of the neighboring higher frequency subband.

4. THE FLOWCHARTS OF WATERMARKING EMBEDDING AND DETECTION PROCEDURE

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The watermark embedding flowcharts for all the proposed algorithms figure 2 shows. We are ensuring that the watermark size is less than that of the image and then we resize both the image and the watermark to ensure that both of them have an integer number of separate 4x4 blocks. We compute the frequency domain coefficients for each block of both image and watermark using the proper polynomial depending on the used algorithm. The

frequency domain coefficients of the watermarked image are obtained by adding the coefficients of both image and watermark in the mid band frequency only. After embedding the watermark, the inverse transform is applied to each block of the watermarked image to reconstruct the watermarked image. In order to detect the watermark, both the original image and the watermarked
image is needed. First, frequency domain coefficients of the entire watermarked images are computed to obtain the image spectrum. Then DLT of the original image is
computed. Next, the difference between the frequency

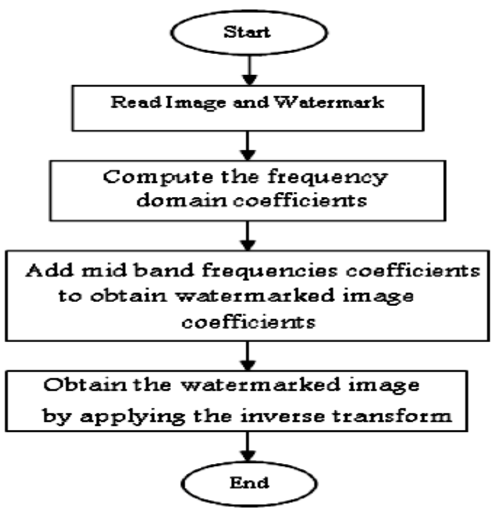

Figure - 2 The Watermark Embedding Flowcharts

domain coefficients of both image and watermark in the mid band frequency is computed to obtain the watermark coefficients. Finally, the watermark is obtained by applying the inverse transform to the watermark coefficients; the extraction procedure flow chart is shown in figure 3.

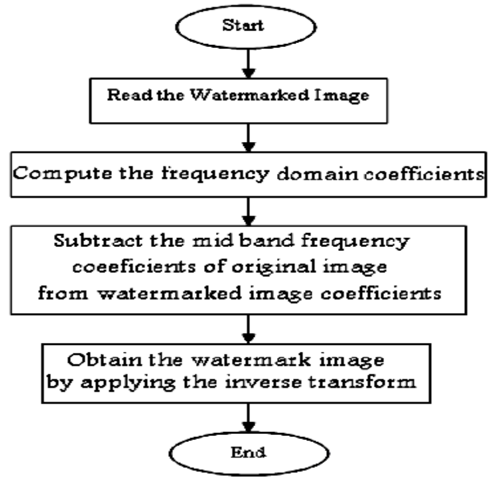

Figure - 3 The Watermark Detection Flowcharts

5. THE COMBINED DWT AND DLT EMBEDDING ALGORITHEM

The watermarking process is started by applying three levels DWT on the host image. The agreement adopted by many DWT based watermarking methods is to embed the watermark in the middle frequency sub bands HL_x and LH_x is better in perspective of imperceptibility and robustness. The HL_x coefficient sets in level three are chosen to make to increase the robustness of our watermark against common watermarking attack specially adding noise and blurring attacks, at little to no additional impact on image quality. Then, the block base DLT is performed on these selected DWT coefficient sets and embed pseudorandom sequences in the middle frequencies. The watermark embedding procedure is represented in figure 4 followed by a detailed explanation.

Step 1: Apply DWT on the host image to decompose it into four non-overlapping multi-resolution coefficient sets: LL1, HL1, LH1 and HH1.

Step 2: Apply DWT again on two HL1 and LH1 coefficient sets to get eight smaller coefficient sets and
choose four coefficient sets: HL12, LH12, HL22 and
LH22 as shown in figure 5.

Step 3: Apply DWT again on four coefficient sets: HL12, LH12, HL22 and LH22 to get sixteen smaller coefficient sets and choose four coefficient sets: HL13, LH13, HL23 and LH23as shown in figure 6.

Step 4: Divide four coefficient sets: HL13, LH13, HL23 and LH23 into 4 x 4 blocks.

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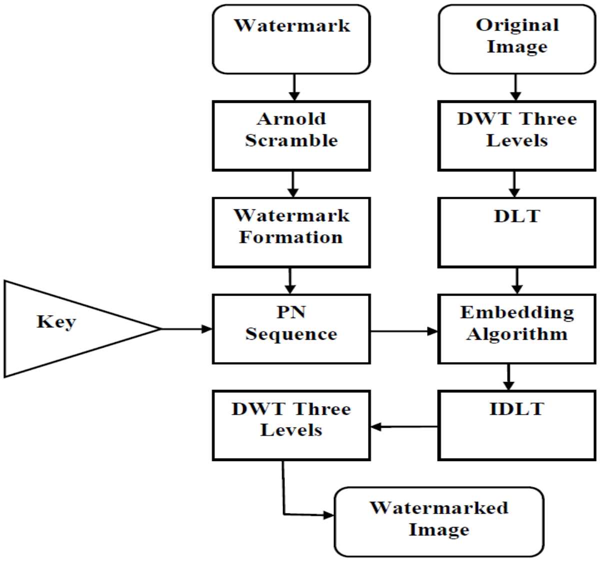

Figure - 4 The Combined DWT and DLT Embedding Algorithm

Step 5: Apply DLT to each block in the chosen coefficient sets (HL13, LH13, HL23 and LH23). These coefficients sets are chosen to inquire both of imperceptibility and robustness of algorithms equally.

Step 6: scramble the watermark signal with an Arnold algorithm for key times and gain the scrambled watermark Ws(i , j) key times can be seen as the secret key

Step 7: Re-formulate the scramble watermark image into a vector of zeros and ones.

Step 8: Generate two uncorrelated pseudorandom sequences by a key . One sequence is used to embed the watermark bit 0 (PN_0) and the other sequence is used to embed the watermark bit 1 (PN_1). Number of elements in each of the two pseudorandom sequences must be equal to the number of mid-band elements of the DLT transformed DWT coefficient sets.

Step 9: Embed the two pseudorandom sequences, PN_0 and P N_1, with a gain factor α i n t he DLT transformed 4x4 blocks of the selected, DWT coefficient sets of the host image. Instead of embedding in all coefficients of the DLT block, it applied only to the mid-band DLT coefficients. If we donate X as the matrix of the mid-band coefficients of the DLT transformed block, then embedding is done as follows

If the watermark bit is 0 then

$$X' = X + \alpha * PN\_0$$

Otherwise, if the watermark bit is 1 then

$$X' = X + \alpha * PN\_1$$

Step 10: Apply inverse DLT (IDLT) on each block after its mid-band coefficients have been modified to embed the watermark bits as described in the previous step.

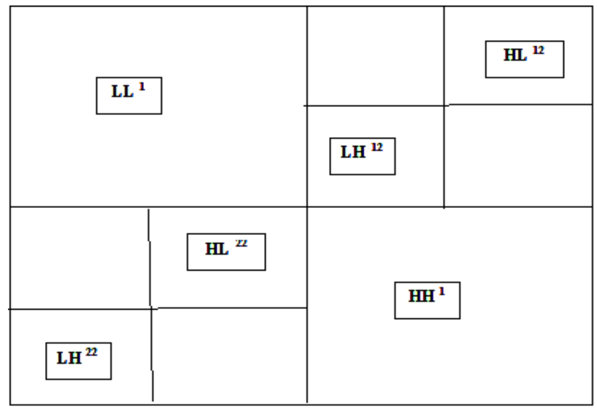

Figure - 5 The 2nd Level Original Image Sets of the four Multi Resolution DWT Coefficients

Step 11: Apply the inverse DWT (IDWT) on the DWT transformed image, including the modified coefficient sets, to produce the watermarked host image.

6. THE COMBINED DWT AND DLT EXTRACTING ALGORITHEM

The watermark extraction algorithm is depicted in figure 7 and described in details in the following steps. The combined DWT and DLT algorithm is a blind watermarking algorithm, and thus the original host image is not required to extract the watermark. Execration algorithm is the same as embedding one, and pre-filtering is used before applying DWT transform to better separate watermark information from host image.

Step 1: Apply DWT on the pre-filtered watermarked image to decompose it into four non overlapping multi-resolution coefficient sets: LL1, HL1, LH1 and HH1.

Step 2: Apply DWT again on two coefficient sets HL1 and LH1 to get eight smaller coefficient sets and choose four coefficient sets: HL12, LH12, HL22 and LH22 as shown in figure 5.

Step 3: Apply DWT again on four coefficient sets HL12, LH12, HL22 and LH22 to get sixteen smaller coefficient sets and choose four coefficient sets HL13, LH13, HL23 and LH23 as shown in figure 6

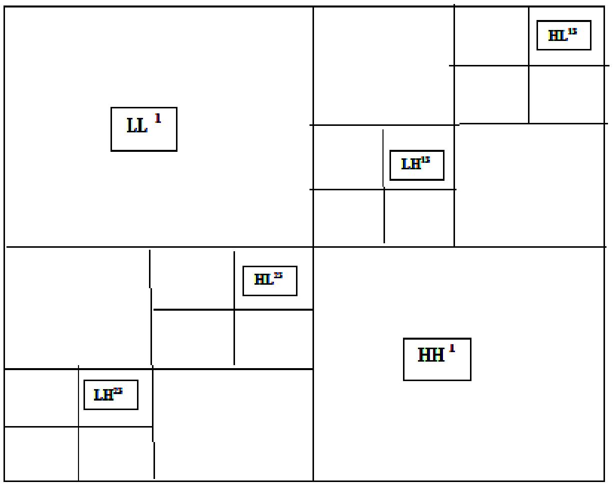

Figure - 6 The 3rd Level Host Image Sets of the four Selected Multi Resolution DWT Coefficients

Step 4: Divide four coefficient sets: HL13, LH13, HL23 and LH23 into 4 x 4 blocks.

Step 5: Apply DLT on each block in the chosen coefficient sets (HL13, LH13, HL23 and LH23).

Step 6: Regenerate the two pseudorandom sequences (PN_0 and PN_1) using the same key which used in the watermark embedding procedure

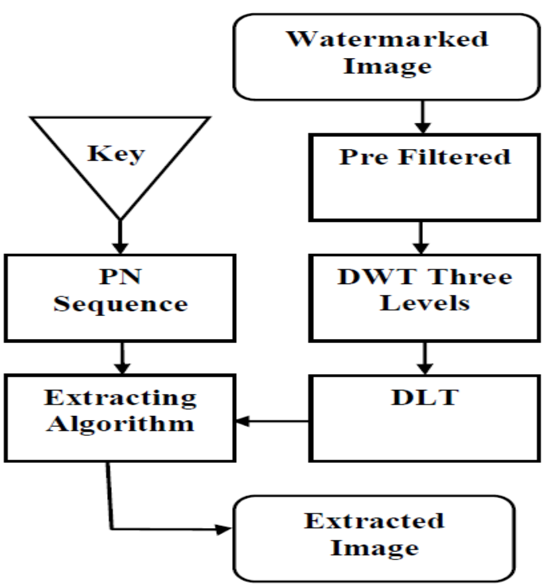

Figure - 7 The Combined DWT and DLT Extracting Algorithm

Step 7: For each block in the coefficient sets HL13, LH13, HL23 and LH23 calculate the correlation between the mid-band coefficients and the two generated pseudorandom sequences (PN_0 and PN_1). If the correlation with the PN_0 was higher than the correlation with PN_1, then the extracted watermark bit is considered 0, otherwise the extracted watermark is considered 1.

Step 8: The scrambled watermark is reconstructed using the extracted watermark bits.

Step 9: scramble the extracted watermark with Arnold algorithm with the same key time and gain the scrambled watermark W (i, j), and compute the similarity between the original and extracted watermarks.

7. EXPERIMENTAL RESULTS

In this paper the results of our study are shown. The several experiments are done to evaluate the effectiveness of the presented watermarking algorithm. The combined DLT and DWT based watermarking algorithm is applied to number of input cover images and different binary watermarks. The experiment is simulated with the software MATLAB. In this experiment, 512 x512 Lena image and 32×32 binary image is selected as the cover image i.e. original image and watermark image respectively. By using a row-major algorithm, the scrambled watermark image can be transformed into a binary sequence with a length of 1024. Note that I and J are set to 512. At this level four selected 64×64 DWT sub-band is divided into 4×4 blocks giving a total of 1024 blocks. 1024 bits of watermark vector

can be embedded in these blocks. The performance of the watermarking methods under consideration is investigated by measuring their imperceptible and robust capabilities. We are using the Normalized Cross-Correlation (NC) [23] to measure the similarity between original image and the watermarked image. Peek Signal-to-Noise Ratio (PSNR) measures the fidelity between the original image and the watermarked image. This Peak Signal to Noise (PSNR) is defined as

$$PSNR = 10\log_{10}\frac{A^2}{\frac{1}{N\times M}\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,\ j)-f'(i,\ j)]^2}$$

The Normalized Cross-Correlation (NC) is defined as A larger PSNR indicates that the watermarked image more closely resembles the original image meaning that the watermarking method makes the watermark more imperceptible. Generally, if PSNR value is greater than 36dB the watermarked image is [24] within acceptable degradation levels, i.e. The watermarked is almost invisible

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$$NC = \frac{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2} W(i,\ j)\cdot W'(i,\ j)}{\sqrt{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W(i,\ j)]^2}\sqrt{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W'(i,\ j)]^2}}$$

to human visual system. PSNR and NC values are calculated for Original watermark and extracted watermark. Robustness is a measure of the immunity of the watermark against attempts to remove or degrade it, internationally or unintentionally by different types of digital signal processing attacks [25]. In this paper, we will report on robustness results which we obtained the watermarked image was attacked by various signal processing techniques, such as Additive Gaussian noise, Additive salt noise, Median filtering, image enhancement, and cropping . After Simulation from the data in result table shows, we can see that the performance of combined DLT and DWT algorithm has great robustness against the attack from the Salt & Pepper noise addition , Gaussian noise addition, Speckle Noise addition, Cropping, JPEG compression. The combined DLT and DWT watermarking algorithm is robust to most of the image processing attacks. Thus the combined DLT and DWT watermarking algorithm can be used for protecting the copyrights of digital images.

Figure - 8 The Original Sunflower Image

Figure - 9 The Watermarked Sunflower Image

Figure - 10 The Original Watermarked Binary Image

Figure - 11 The Extracted Watermarked Binary Image

No Attack	Normalized Cross Correlation (NC)	Peak Signal to Noise (PSNR)
Sunflower Image	1	39.28635
Watermark	0.99831	66.48231

Table - 1 Results Shown the Table Attack free for Watermarked Image

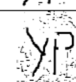
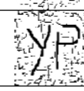
Extracted Watermark	Cropping Attack	Normalized Cross Correlation (NC)	Peak Signal to Noise (PSNR)
	10%	0.98941	66.64431
	14%	0.97564	63.57429
	21%	0.96785	60.78659

Table - 2 Results Shown the Table Cropping Attack for Watermarked Image

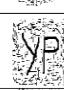
Extracted Watermark	Noise Attack	Noise Density In Parameter	Normalized Cross Correlation (NC)	Peak Signal to Noise (PSNR)
	Salt and Pepper Noise	2%	0.93456	60.14678
	Salt and Pepper Noise	4%	0.88734	58.11301
	Salt and Pepper Noise	6%	0.84978	55.67119
	Salt and Pepper Noise	9%	0.77389	54.11532
	Salt and Pepper Noise	13%	0.76831	52.71591

Table - 3 Results Shown the Table Salt and Pepper Noise Attack for Watermarked Image

Figure - 12 The Watermarked 10% Cropped Image

Figure - 13 The Watermarked 14% Cropped Image

Figure - 14 The Watermarked 21% Cropped Image

Extracted Watermark	Noise Attack	Noise Variance In Parameter	Normalized Cross Correlation (NC)	Peak Signal to Noise (PSNR)
	Gaussian Noise	0.002	0.97113	63.57281
	Gaussian Noise	0.005	0.92761	59.58104
	Gaussian Noise	0.01	0.87143	57.21749
	Gaussian Noise	0.03	0.80121	54.37826

Table - 4 Results Shown the Table Gaussian Noise Attack for Watermarked Image

Extracted Watermark	Noise Attack	Noise Variance In Parameter	Normalized Cross Correlation (NC)	Peak Signal to Noise (PSNR)
	Speckle Noise	0.03	0.89310	57.97529
	Speckle Noise	0.05	0.86179	56.65937
	Speckle Noise	0.08	0.83961	53.86490

Table - 5 Results Shown the Table Speckle Noise Attack for Watermarked Image

Extracted Watermark	JPEG Compression Attack	Normalized Cross Correlation (NC)	Peak Signal to Noise (PSNR)
	80% of Quality	0.97982	64.67893
	45% of Quality	0.96069	62.78657
	30% of Quality	0.88764	57.11478

Table - 6 Results Shown the Table JPEG Compression Attack for Watermarked Image

8. CONCLUSION

Digital watermarking is a tool that could be effectively used for multimedia copyright protection, authentication and tamper proofing. In this paper, we have presented an efficient imaging watermarking technique to protect the copyright protection of digital images with watermark embedding and watermark extraction. The Discrete Laguerre Transform (DLT) and the discrete wavelet transform (DWT) have been applied successfully in many in digital image watermarking. In this paper, we described a combined DLT and DWT digital image watermarking algorithm. Watermarking is done by embedding the watermark in the special middle frequency coefficient sets of three levels DWT transformed of a host image, followed by computing 4×4 block based Discrete Laguerre Transform (DLT) on the selected DWT coefficient sets. And before embedding this watermark image has been Discrete Laguerre Transform (DLT) in order to improve its robustness. The simulation results suggest that this watermarking system not only can keep the image quality well, but also can be the proposed algorithms are tested against image attacks and the experimental results approved that they have a good robust and they are resistant against Salt and Pepper noise addition , Gaussian noise addition, Speckle Noise addition, Cropping, JPEG compression. The robustness of the watermarking methods have been measured by computing the Peak Signal to Noise Ratio (PSNR) and Normalized cross correlation (NC) is used to measure the similarity between the original watermark and extracted watermark. In this paper Implementation results show that the imperceptibility of the watermarked image is acceptable.

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