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# JOINT DWT-DCT BASED BLIND AND ROBUST DIGITAL WATERMARKING APPROACH FOR COPYRIGHT PROTECTION

**SUKANTI B. MARDOLKAR, NAYANA SHENVI**

Dept. of ETC Engineering, Goa College of Engineering, Farmagudi-Goa

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**Abstract**: In this paper, a robust and blind digital watermarking algorithm based on Joint DWT-DCT transformation, with low frequency embedding and weighted correction is proposed. Binary watermark is scrambled using Arnold transform before embedding to improve security. The watermark embedding is done in low frequency coefficients of each 4×4 DCT block of selected DWT sub-band. The experimental results show that the proposed algorithm achieves both imperceptibility and robustness.

**Key Words:** Digital image watermarking, Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT).

**Corresponding Author: MS. SUKANTI B. MARDOLKAR**

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## INTRODUCTION

In this present era of information technology, it is extremely easy to create, copy, transmit, and distribute digital data. This poses a threat of possession and usage of digital data by unauthorized person**.** Digital watermarking has been proposed as a viable solution to the ever-increasing demand for copyright protection.

Watermarking is a process that embeds data called a watermark or digital signature or tag or label into a multimedia object such that watermark can be detected or extracted later to make an assertion about the object [1]. In order to be successful, the watermark should be imperceptible and robust to premeditated or spontaneous modification of the image. It should be robust against common image processing operations such as filtering, additive noise, resizing, cropping etc and common image compression techniques [2].

Watermarking can be classified as non-blind and blind watermarking. In non-blind watermarking technique, detector requires the original host image for extracting the watermark, while the blind technique does not require the original image. Another classification is based on domain of watermarking that is spatial-domain and frequency-domain techniques. Compared to spatial domain techniques, frequency-domain techniques based on Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking algorithms. In these domains watermark is placed in perceptually significant coefficients of the image. However, DWT has been used more frequently in digital image watermarking due to its time/frequency decomposition characteristics, which resemble to the theoretical models of the human visual system [2]. Further performance improvements in DWT-based digital image watermarking algorithms could be obtained by combining DWT with DCT [2-5]. The idea of applying two transform is based on the fact that combined transforms could compensate for the drawbacks of each other, resulting in effective watermarking [3].

## THE DCT AND DWT TRANSFORMS

### Discrete Cosine Transform

The discrete cosine transforms (DCT) is a technique that is very commonly used for converting a signal into elementary frequency components. It represents an image as a sum of sinusoids of varying magnitudes and frequencies. Application of DCT to an image gives a matrix of coefficients that can be divided into three frequency sub-bands: low frequency sub-band (FL), mid-frequency sub- band (FM), and high frequency sub-band (FH).

The signal energy lies at low-frequencies sub-band which contains the most significant visual parts of the image. The high frequency components of the image are usually removed through compression and noise attacks. Frequency bands of 8x8 DCT block [6] are shown Fig 1.

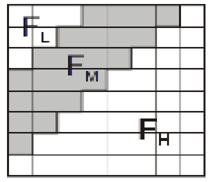



**Fig.1 Definition of DCT region.**

**Discrete Wavelet Transform**

Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image. It is useful for processing of non-stationary signals [7]. The transform is based on small waves, called wavelets, of varying frequency and limited duration. Wavelet transform provides both frequency and spatial description of an image. For 2-D images, applying DWT corresponds to processing the image by 2-D filters in each dimension. The filters divide the input image into four non-overlapping multi-resolution sub-bands LL (approximate), LH (Vertical), HL (Horizontal) and HH (Diagonal). The sub-band LL represents the coarse-scale DWT coefficients while the sub-bands LH, HL and HH represent the fine-scale of DWT coefficients.

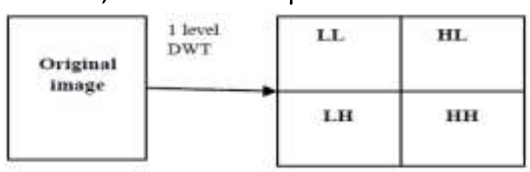



**Fig. 2. Single Level DWT Decomposition of Image.**

Due to its excellent spatio frequency localization properties, the DWT are very suitable to identify the areas in the host image where a watermark can be embedded effectively [7]. In general most of the image energy is concentrated at the lower frequency sub-bands LLx and therefore embedding watermarks in these sub-bands may degrade the image significantly. Embedding in the low frequency sub-bands, however, could increase robustness significantly. On the other hand, the high frequency sub-bands HHx include the edges and textures of the image and the human eye is not generally sensitive to changes in such sub-bands. This allows the watermark to be embedded without being perceived by the human eye.

## THE PROPOSED ALGORITHM

### Watermark Embedding Approach

Fig. 4. shows the image embedding flowchart and its various operational steps are described as follows:

**Step1:** Apply DWT to the host image to decompose it into four non-overlapping multi-resolution sub-bands: $LL_1$ , $HL_1$, $LH_1$, and $HH_1$.

**Step2:** Apply DWT again to sub-band $HL_1$ to get four smaller sub-bands and choose the $HL_2$ sub-band for embedding watermark bits as shown in Fig.3.

**Step3:** Divide sub-band HL2 into 4x4 blocks.

**Step4:** Apply DCT to each block in the sub-band HL2.

**Step5:** Scramble the watermark using Arnold Transform to increase the watermark secrecy and security. Arnold transform is given as:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} mod\ N \ ;\ x, y \in \{0,1,2,\dots,N-1\} \quad (1)$$

Where, x and y denote the coordinate of pixels of the original watermark, x' and y' denote the coordinate of pixels of the transformed watermark.

**Step6:** Generate two uncorrelated pseudorandom sequences by using a seed. One sequence is used to embed the watermark bit 0(PNseq_0) and the other sequence is used to embed the watermark bit 1(PNseq_1).

**Step7:** Embed the two pseudorandom sequences with a gain factor α in the DCT transformed 4×4 blocks of the selected DWT sub-bands of the host image.

Instead of embedding in all the coefficients of the DCT block, it embeds only to the low frequency DCT coefficients.

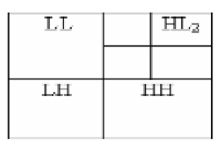



**Fig. 3. Two Level DWT Decomposition of an Image.**

If we denote P as the matrix of the low frequency coefficients of the DCT transformed block, then embedding is done as following equation.

If watermark bit is 0, then

$$P' = P + \alpha \times (PNseq\_0) \quad (2)$$

If watermark bit is 1, then

$$P' = P + \alpha \times (PNseq\_1) \quad (3)$$

**Step7:** Perform the inverse DCT on each block after its low-band coefficients have been modified to embed the watermark bits.

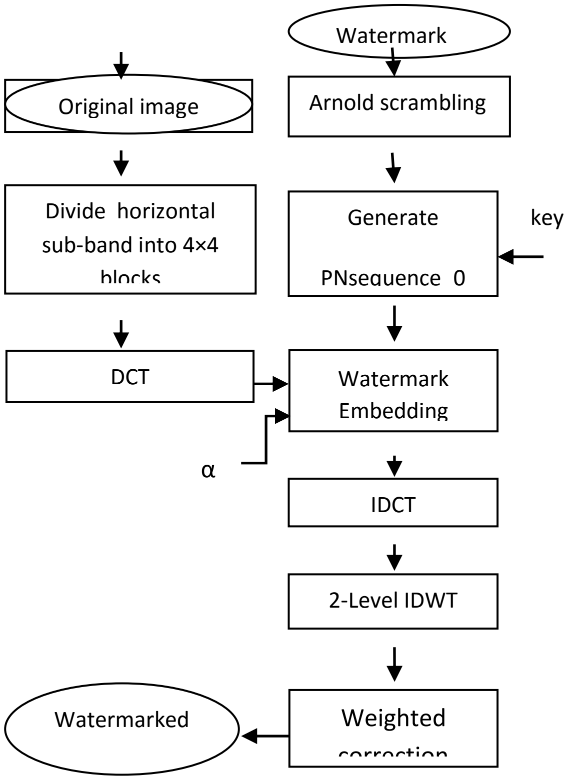



**Fig. 4. Embedding of watermark bits into the host image.**

**Step8:** Perform the inverse DWT on the DCT transformed image, including the modified coefficient set, to produce the watermarked host image.
**Step9:** Justify the watermarked image using weighted correction in spatial domain.

**Watermark Extracting Approach**

Fig.5. shows the watermark extracting flowchart and its various operational steps are described as follows:
**Step1:** Apply DWT to watermarked image to decompose it into four non-overlapping multi-resolution sub-bands: $LL_1$, $HL_1$, $LH_1$, and $HH_1$.
**Step2:** Apply DWT to sub-band $HL_1$ to get four smaller sub-bands and choose the $HL_2$ sub-band.
**Step3:** Divide the chosen sub-band HL2 into 4 x 4 blocks.
**Step4:** Apply DCT to each block in the chosen sub-band.

**Step5:** Regenerate the two pseudorandom sequences PNseq_0 and PNseq_1 using the same seed (key) that was used in the watermark embedding procedure.

**Step6:** For each block in the sub-band HL2 calculates the correlation between the low-band coefficients and the two generated pseudorandom sequences.

If the correlation with the PNseq_0 is higher than the correlation with PNseq_1, then the extracted watermark bit is considered 0, otherwise the extracted watermark bit is considered as 1.

**Step7:** Reconstruct the scrambled watermark using the extracted watermark bits.

**Step8:** Scramble the extracted watermark with Arnold Transform with the same key to get the extracted watermark. Compute the similarity between the original and extracted watermark.

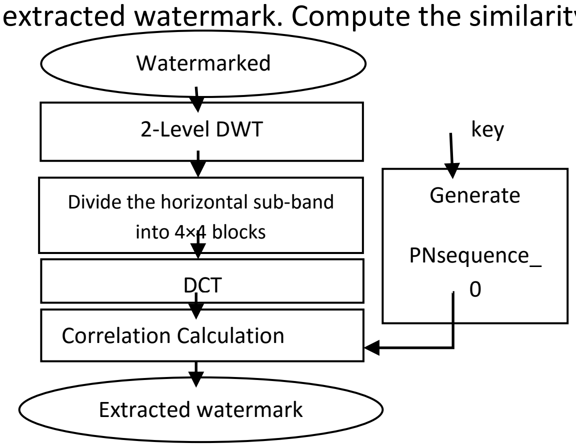



**Fig. 5. Extraction of the watermark**

**PERFORMANCE EVALUATION**

We evaluated the performance of the proposed watermarking algorithm using a 512×512 "Lena" as the original host image, and a 32×32 binary image as the watermark. Fig.6. shows the original host image and the watermark.


**Fig.6. Original 'Lena' host image and Watermark**

**Imperceptibility:** Imperceptibility means that the perceived quality of the host image should not be distorted by the presence of the watermark. As a measure of the quality of a watermarked image, the peak signal to noise ratio (PSNR) is typically used.

$$\mathbf{PSNR} = \mathbf{10}\log_{10}\left(\frac{255^2}{MSE}\right) \quad (4)$$

**where ,**

$$MSE = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}[I1(i,j)-I'2(i,j)]^2}{N \times N} \quad \textbf{(5)}$$

**Robustness:** Robustness is a measure of the immunity of the watermark against attempt to remove it by different types of attacks. Here similarity between the original watermark and the extracted watermark from the attacked image is measured by using the Normalized Correlation (NC) factor.

$$\boldsymbol{NC} = \frac{\sum_{j=0}^{J-1}\sum_{k=0}^{K-1} W_1(j,k)W_2(j,k)}{\sum_{j=0}^{J-1}\sum_{k=0}^{K-1} W_1(j,k)^2} \quad (6)$$

The presented method is implemented using MATLAB. Fig.7. shows Arnold scrambled binary watermark and the reconstructed watermark.

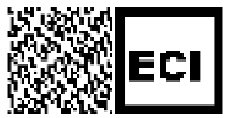


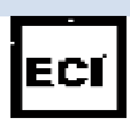

**Fig.7.Arnold scrambled and Reconstructed watermark**

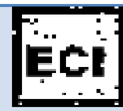
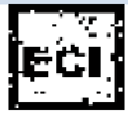
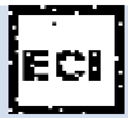
Fig.8. shows watermarked image and the watermark which extracted after no attack. The watermarked image has a PSNR of 37.8051dB. The binary watermark can be correctly extracted from the watermarked image under no attack with NC=1.


**Fig .8. Watermarked image and Extracted watermark**

In order to get the measure of the robustness of the presented algorithm, we have implemented several image processing attacks on the watermarked image. The experimental results for various attacks are given in Table 1.

**Table 1.Extracted watermarks and NC after attacks on watermarked image.**

| Attack | Parameters | Extracted watermark | NC |
|---|---|---|---|
| JPEG Compression | Q=50 |  | 0.9862 |
| Salt & pepper noise | Strength=0.01 |  | 0.9921 |

| | | | |
|---|---|---|---|
| **Gaussian Noise** | Average=0, Variance =0.002 |  | 0.9314 |
| **Speckle noise** | Variance=0.01 |  | 0.9020 |
| **Cropping** | 128×128 |  | 0.9459 |

**CONCLUSION**

A joint DWT- DCT based watermarking technique with low frequency watermarking and weighted correction has been proposed in this paper. The watermarked image is adjusted by the weighted correction in the spatial domain to increase the imperceptibility. Experimental results show that the proposed algorithm provides good perceptual transparency. The watermarks can be extracted from most of the common image processing attacks with high NC values. Therefore the proposed method is suitable candidate for copyright protection.

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