A Blind Watermarking Algorithm Based On DCT-DWT and ARNOLD Transform

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***Abstract*— With the rapid development of information technology piracy is more prominent. Digital watermarking is a new technology to protect the legal owner's copyrights. In this paper, we introduce a blind watermarking algorithm based on DCT and DWT. Using middle frequency band of DCT and 2-levels DWT provides better imperceptibility. Furthermore by using ARNOLD transformation the robustness and security of watermark image is increased. The results show that the proposed method have better performance with respect to DWT-Only method. Therefore, the proposed method has enhanced imperceptibility of watermarked image and robustness of watermark image against image processing attacks.**

Keywords - Digital Watermarking, DCT, DWT, ARNOLD Transform, Blind Extracting.

I. INTRODUCTION

In recent years, with the speedy development of information technology, multimedia such as digital video, audio and image are widely used, so because of easy access to digital contents, copy control of digital data became an important issue.

There is a strong demand for secure copyright protection techniques in multimedia applications. As a new technology to protect intellectual property right and the legitimate use of digital media information, the digital watermarking has drawn more attention. Digital watermarking has been advocated by many specialists as the best method to such multimedia copyright protection problem that can embed some information in digital images in order to achieve copyright protection, tracking and prevent illegal copying.

Depending on the application, the original host image is or is not available to the watermark recovery system. While most watermarking techniques require the original picture, there is a great interest in techniques that do not require the original data for recovering, i.e. blind watermarking techniques. That is because of the larger applications of such techniques.

There are three kinds of digital watermarking techniques according to their embedding purpose:robust [1], fragile [2] and semi-fragile [3].

Watermarking algorithms can be divided into two major categories of spatial [4] and transform domain [5]. Spatial methods usually alter the gray value of some pixels of an image directly. Transform techniques such as DFT, DCT [6] and DWT [7] are used to incorporate the watermark into the transform coefficients of an image. Compared to spatial domain techniques, transform domain techniques proved to be more effective and achieve higher imperceptibility and robustness for digital watermarking algorithms.

DCT and DWT are useful transforms in transform domain technique. DWT has features in local time-frequency and multi scale transformation. DCT provides important information about the image concentration in a small part of the DCT-coefficient.

In this paper, we propose a blind watermarking scheme based on combination of DCT and DWT transformation. The proposed method combines the advantages of multi resolution and energy compression properties of DWT and DCT. We also use ARNOLD transform to increase security of watermark image. Therefore, the proposed method have advantages of methods that used these transformation separately [8] [9].

The rest of the paper is organized as follows: In section Ⅱ we review DCT, DWT and ARNOLD transforms. The proposed method is described in section Ⅲ. After that simulations and experimental results are analyzed in section Ⅳ. Section Ⅴ conclude the paper.

II. RELATED BACKGROUND INFORMATION

A. Discrete Cosine Transform

The discrete cosine transforms (DCT) is a technique for converting a signal into elementary frequency components [10]. It represents an image as a sum of sinusoids of varying magnitudes and frequencies. Suppose input image x, output image y and image size N×M, the DCT coefficients can be achieved according to E.q.1 shown below:

$$y(u,v) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\,\alpha \quad \alpha \quad \sum_{=0}^{-1}\sum_{=0}^{-1} x(m,n)\times$$

$$\cos\frac{(2m+1)u\pi}{2M}\cos\frac{(2n+1)u\pi}{2N} \qquad (1)$$

Where

$$\alpha = \begin{cases} \frac{1}{\sqrt{2}} & u = 0 \\ 1 & u = 1,2,\dots,M-1 \end{cases}$$

$$\alpha = \begin{cases} \frac{1}{\sqrt{2}} & v = 0 \\ 1 & v = 1,2,\dots,N-1 \end{cases}$$

The corresponding inverse transformation is defined as:

$$x(m,n)=\sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\sum_{=0}^{-1}\sum_{=0}^{-1}\alpha\alpha y(u,v)\times$$

$$\cos\frac{(2m+1)u\pi}{2M}\cos\frac{(2n+1)v\pi}{2N} \qquad (2)$$

The popular block-based DCT transform segments an image to non-overlapping blocks and applies DCT to each block. DCT transformation breaks up an image into different frequency bands: low frequency band, middle frequency band and high frequency band. The low frequency band is sensitive to HVS (Human Vision System). On the other hand the high frequency band is subjected to removal through compression. The watermark is therefore embedded by modifying the coefficients of the middle frequency sub-band so that the visibility of the image will not be affected and the watermark will not be removed by compression [11] [12].

B. Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) is an efficient technique for multi-resolution sub-band decomposition of signals useful in many signal and image processing applications. It has good local frequency feature and transformation mechanism according to characteristics of HVS. For two dimensional images, applying DWT divide the input image into four non-overlapping multi-resolution sub-bands LL, LH, HL and HH. 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. The information of low frequency sub-band is an image close to the original image. Most signal information of original image is stored in this frequency sub-band. The frequency sub-bands of LH, HL and HH represents the level detail, the upright detail and the diagonal detail of the original image respectively. In general most of the image energy is concentrated at the lower frequency sub-band LL and therefore embedding watermarks in these sub-bands may degrade quality of the image significantly. On the other hand, the higher frequency sub-band HH consists of negligible details. This allows the watermark to be embedded without being perceived by the human eye but may be removed by compression. In general, the watermark is embedded into sub-bands HL,LH because of acceptable performance of imperceptibility and robustness could be achieved [13] [14].

C. ARNOLD Transform

In this paper, ARNOLD transformation is chosen as pretreatment method to watermark [15]. ARNOLD transformation algorithm is simple, periodic and can recover watermark from image after scramble easily, therefore it gets a good application in the information hidden of image.

For digital square image (N×N), discrete ARNOLD mapping can be done as follow:

$$\begin{pmatrix} x' \\ y' \end{pmatrix}=\begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix}(\text{mod } N) \qquad (3)$$

Where N represents the height or width of the original image; $(x, y) \in [0, N-1] \times [0, N-1]$ is the original image's pixel coordinate; $(x', y') \in [0, N-1] \times [0, N-1]$ represents the scrambled image's pixel coordinate. ARNOLD transform changes the position of pixels. After several transformations in the image, disordered image is generated. Because of the periodicity of ARNOLD, the original image can be recovered. Transformation times can be used as the key, so that the security of watermark algorithm is enhanced.

III. PROPOSED METHOD

A. Watermark Embedding

Watermark embedding algorithm is explained as follow:

1. 2-level DWT applied to original image and choose sub-band LH_2 (or HL_2) as shown in Fig. 1.
2. Sub-band LH_2 (or HL_2) divided into 4×4 blocks and apply DCT to each block.
3. Scramble the watermark image with ARNOLD transform for K1 times and gain the scrambled watermark. The times of ARNOLD transform is used as the key. Then, scrambled watermark change into a vector of zeros and ones.
4. Generate two uncorrelated pseudorandom sequences. 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 pseudorandom sequence is equal to middle frequency band of 4×4 blocks.
5. Two pseudorandom sequences are embed into middle frequency band of each 4×4 block with gain factor α. If **X** refers to matrix of middle frequency coefficients of DCT transformed block, then embedding will be done as follows:

   If the watermark bit is 0 then,

   $$X' = X + \alpha \times PN\text{-}0 \qquad (4)$$

   Otherwise,

   If the watermark bit is 1 then,

   $$X' = X + \alpha \times PN\text{-}1 \qquad (5)$$

   Where X' is matrix of middle frequency coefficients of DCT transformed block after watermark embedding.
6. Apply inverse DCT (IDCT) to each block after embedding procedure.
7. At the end, apply 2-level inverse DWT (IDWT) into sub-band LH_2 (HL_2), therefore watermarked image has been achieved.

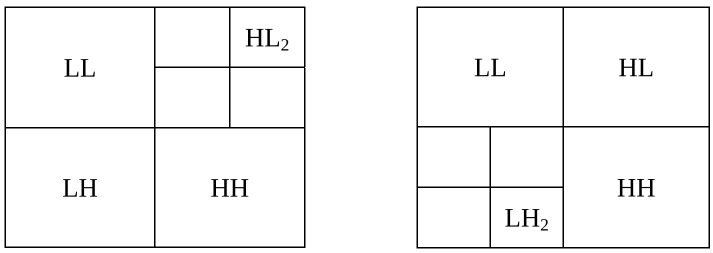

Fig. 1. Multi-resolution DWT Sub-bands

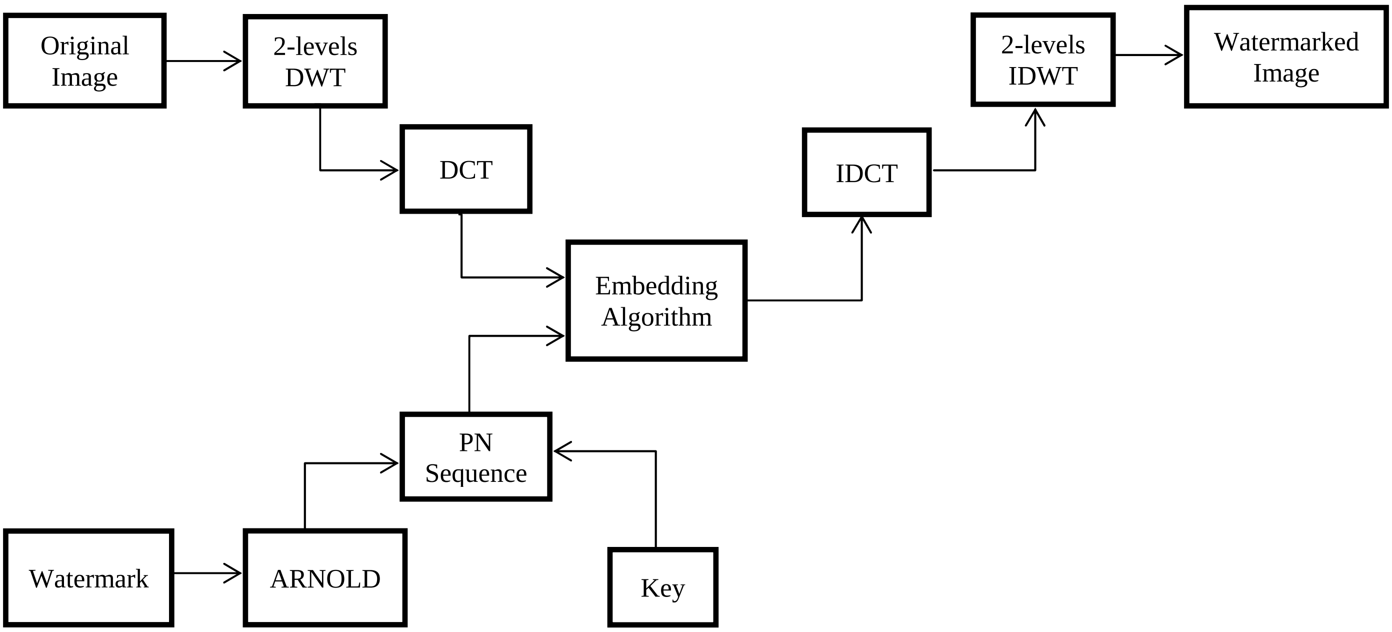

Fig2. Watermark Embedding Algorithm

B. Watermark Exracting

Watermark extracting algorithm is explained as follow:

1. Apply 2-level DWT to watermarked image and choose sub-band LH_2 (HL_2).
2. Divide the sub-band LH_2 (or HL_2) into 4×4 blocks and apply DCT to each block.
3. Regenerate two pseudorandom sequence PN-0 and PN-1 using the same method used in watermark embedding algorithm.
4. Calculate correlation between matrix of middle frequency coefficients of DCT transformed block and two pseudorandom sequence (PN-0 , PN-1) . If correlation with PN-0 was higher than PN-1, so watermark bit is assumed 0, otherwise watermark bit is assumed 1.
5. Reconstruct watermark image with the extracted watermark bit and apply N-K1 (N is peiod of ARNOLD transform) times.

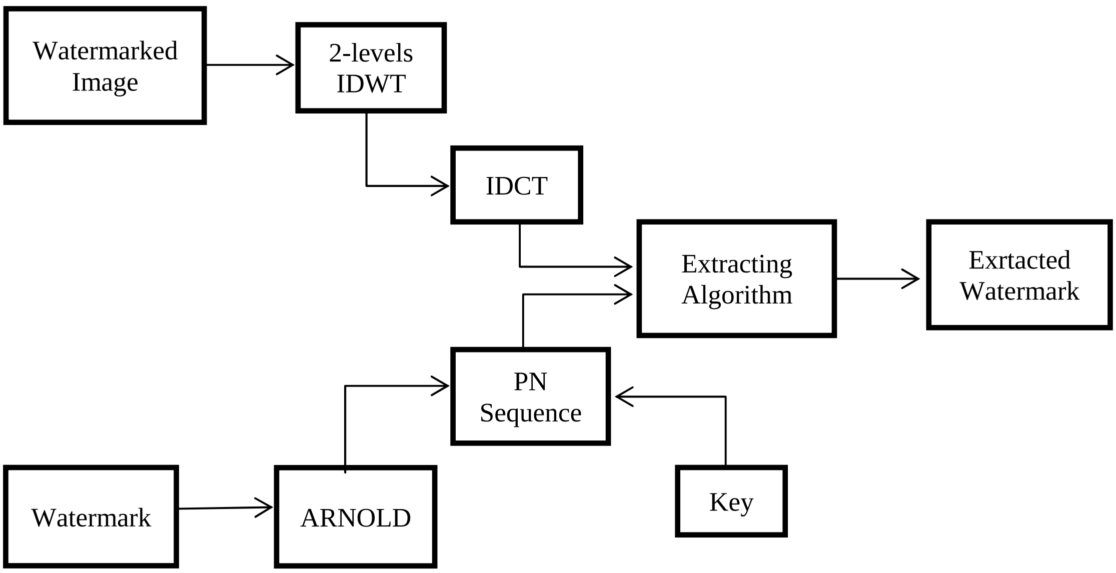

Fig. 3. Watermark Extracting Algorithm

IV. EXPERIMENTAL RESULTS:

In our experiment, we used two test images “mandi” with size of 1024×1024 as original image and a binary image with size of 64×64 as watermark image that shown in Fig. 4,5.

Fig. 4. Original Image

Fig. 5 .Watermark Image

For performance evaluation of watermarking algorithm we use two metrics: imperceptibility and robustness. The two metrics are described below.

1) Imperceptibility: Imperceptibility refers to quality of image after embed watermark. As a measure of the quality of a watermarked image, the peak signal to noise ratio (PSNR) is typically used. PSNR in decibels (dB) is given as follow:

$$\text{PSNR}=10.\log_{10}\left(\frac{\text{MAX}^2}{\text{MSE}}\right)=20.\log_{10}\left(\frac{\text{MAX}}{\sqrt{\text{MSE}}}\right) \qquad (6)$$

2) Robustness: Robustness is measure of the immunity of the watermark against attempts to remove or degrade it by different types of digital signal processing attacks. Normalized Correlation (NC) is used to calculate similarity between original watermark and extracted watermarked Therefore, robustness of extracted watermark against different attacks has been shown. NC may take values between 0 to 1. The bigger this NC value is, the better the similarity between original watermark and extracted watermark is. The definition of NC is as follow:

$$\text{NC}=\frac{\sum_{=1} ww'}{\sqrt{\sum_{=1} w^2}\sqrt{\sum_{=1} w'^2}} \qquad (7)$$

Where N is dimension of watermark (N×N), Wi is original watermark and W'i is extracted watermark.

It is generally recognized that if PSNR value is greater than 35 decibels (dB) the watermark is not within the scope of human visual system and NC of about 0.7 or above is considered acceptable. In the proposed method the PSNR is 53.29 without any attacks and PSNR values of DWT-Only is 38.51, so the imperceptibility of watermarked image is maintained. The watermarked image is shown in Fig. 6.

Fig. 6 .Watermarked Image

The values of NC after different image processing attacks for the combined DWT-DCT algorithm and DWT-Only algorithm are shown in table 1. As table 1 shows that NC values of extracted watermark in the proposed method after applying JPEG (Q=100,80,40) , Gaussian noise (mean=0.005), Salt&Pepper noise (noise density=0.005) and Cropping (block size = 64×64,128×128,256×256), are significantly more than NC values of extracted watermark in DWT-Only after applying these attacks, therefore, the proposed method is more robust against many common different types of attacks such as image compression, noise and cropping because of applying combined of DWT-DCT and ARNOLD transform. The extracted watermarks of the proposed method after these attacks are shown in Fig. 7.

TABLE I
THE PARAMETER VALUES OF ATTACKED WATERMARKED IMAGE

Attack		**NC**	
		DCT&DWT	**DWT**
JPEG(Q)	100	1	0.991
	80	0.983	0.861
	40	0.846	0.701
NOISE	GUASSIAN (0.005)	0.860	0.694
	SALT&PEPPER (0.005)	0.853	0.660
CROPPING (Block Size)	64	0.977	0.875
	128	0.918	0.748
	256	0.757	0.561

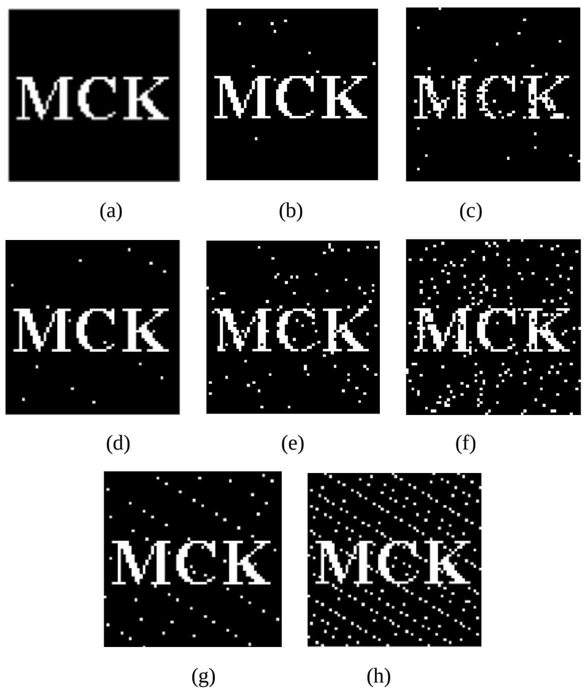

Fig. 7 .Extracted Watermark From Attacks Such As (a) JPEG (Q=100) , (b) JPEG (Q=80) , (c) JPEG (Q=40) , (d) Gaussian noise (0.005) , (e) Salt&pepper (0.005) , (f) Cropping (64×64) , (g) Cropping (128×128) , (h) Cropping (256×256)

V. CONCLUTION:

In this paper, we proposed a new watermarking algorithm based on DWT and DCT transformations. As a result, applying two mentioned transformations can compensate the drawbacks of each one to achieve an effective watermarking. Considering the imperceptibility, increasing the level of DWT can improve the performance of watermarking. However, increasing the level of DWT causes some limitations in watermarking algorithms such as restrictions on the size of the watermark image. Using 2-level DWT can increase the imperceptibility of watermarking without limitations. Furthermore, the watermark is scrambled and embedded in a spread spectrum pattern by ARNOLD transform to improve the security and robustness.

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