NON-BLIND IMAGE WATERMARKING USING CONTOURLET TRANSFORM

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Abstract

This paper presents a novel non-blind watermarking algorithm using contourlet transform. The contourlet transform is preferred for watermarking because of its ability to capture the directional edges and contours superior to other transforms such as cosine transform, wavelet transform, etc. Watermark is encrypted and embedded into high frequency directional subband, which is obtained by performing contourlet decomposition on the host image. The watermarked image has very good perceptual transparency. Watermark extraction algorithm is a non-blind process, which makes use of original image as reference for retrieving the watermark. This algorithm is robust against cropping attacks and geometric attacks and also has superior Peak Signal to Noise Ratio (PSNR) for the watermarked image.

***Keywords*:** Non-blind watermarking, encryption, decryption and contourlet transform.

1. Introduction

Digital watermarking is the process of embedding information into the digital image in a way that is difficult to modify or remove. Digital watermarking is considered as an efficient tool to prove the ownership of digital data. Any watermarking system consists of two steps; (1) Watermark embedding (2) Watermark extraction. Watermark embedding is the process in which the secret image is hidden inside the cover image without modifying the visibility of the cover image. The hidden image is retrieved at the receiver by watermark extraction process. Watermarking can be classified depending on the data type that is being used. They are image watermarking, video watermarking, audio watermarking and text watermarking. According to human perception the digital watermarks are classified as visible watermark and Invisible watermark. Visible watermarking systems are those in which watermark embedded is visible to the human visual system (HVS) when image is viewed [10]. Visible watermarking is normally used to prevent unauthorized access to the data. In invisible watermarking, watermark embedded is perceptually invisible to the HVS [6]. The major requirements of watermarking system are perceptual transparency, payload of the watermark, robustness, security and efficiency [12]. Robustness of the watermarking system is its ability to resist various signal processing attacks. Some of the common signals processing attacks are JPEG compression, filtering, cropping, geometric distortions and additive noise. The digital watermarking has been used in a wide variety of applications such as copyright protection, owner identification, transaction tracking, medical applications and covert communications [13]. Depending on the method used for watermark extraction digital watermarking is divided into blind watermarking and non-blind watermarking. Blind watermarking [18] method does not require original image to extract the watermark from the watermarked image, whereas the non-blind watermarking [2] method extracts the watermark by comparing the watermarked image with the original image. The Contourlet transform (CT) is a two dimensional multiresolutional and multidirectional image representation method. It effectively expresses smooth contour and edges, which is considered as an important feature of this method. Contourlet transform is widely used in image analysis and image processing.

2. Literature Review

Watermarking in the early stages were done using spatial domain techniques like LSB. In the spatial domain method, the watermark is added by just modifying pixel values of host images. The most common spatial domain method is the least significant bit (LSB) modification. This watermarking approach modifies least significant bits of images based on assumption that the LSB bits are insignificant [17]. Spatial domain watermarking methods are easy to implement. The watermarked images have a good perceptual transparency, but these techniques are vulnerable to attacks that can destroy the watermark. The other techniques work in the transform domain, where images are represented in terms of frequencies. Reversible transforms are used to transfer an image to its frequency representation. Watermark can be embedded by modifying values of transform domain coefficients. Inverse transforms are used to obtain the watermarked image. The discrete cosine transform (DCT) developed by Piva *et al* is one of the reversible transform domain technique [14], [7]. In DCT domain watermarking image is first divided into non overlapping blocks and DCT is performed on each of those blocks. The watermark is embedded by modifying the selected coefficients by block and coefficient selection criteria. Inverse DCT is performed on each block to obtain watermarked image. Discrete Fourier Transform (DFT) is another transform domain technique which improves robustness to the watermark [3], [4]. Embedding watermark in the DFT magnitude or phase coefficients does not introduce perceptible distortions, hence all major compression schemes preserves the DFT coefficients. DFT domain watermarking is also used for its translation or shift invariant property. Discrete Wavelet transform (DWT), proposed by Boncelet *et al*. [20] is the most popular transform domain technique since DWT has numerous advantages including space-frequency localization, multiresolution representation and superior HVS modeling. In the DWT domain watermarking [9], [15] image is decomposed into four subbands and embedding of the watermark is done in the finest scale wavelet coefficients to have better robustness and transparency. As human visual system is less sensitive to the changes made in the high frequency coefficients finest scale coefficients is chosen compared to coarse level coefficients. Wavelet transform has been accepted as right tool for one dimensional piecewise smooth images. Wavelets when extended to two dimensions are good at isolating discontinuities at edge points but failed to capture smoothness along the contours. Moreover directionality property of wavelet is also limited. As an improvement on wavelet transform Minh Do and Martin Vetterli proposed contourlet transform (CT) [8]. The contourlets possess multiscale and time frequency localization properties of wavelets in addition to directionality and anisotropy [21]. Hence contourlets are considered as an improvement over wavelets in terms of efficiency. Some algorithms of watermarking based on contourlet transform have also been proposed so far. Khalighi *et al* [11] proposed a non blind watermarking scheme based on the multiresolution property of CT, where watermark is embedded into the selected subbands providing robustness against common watermarking attacks. Akhaee *et al* presented an improved multiplicative image watermarking system where watermark data is embedded in the directional subband with highest energy. By modeling the contourlet coefficients with General Gaussian Distribution, the distribution of watermarked noisy coefficients were calculated analytically in [1]. At the receiver based on maximum likely decision rule, an optimum detector is designed.

3. Contourlet Transform

Contourlet Transform proposed by Minh N. Do and Vetterli [8] is a true two dimensional image representation and decomposition scheme. Contourlet transform efficiently represent images containing contours and textures since it is a geometrical image based transform. The multiresolution, localization and critical sampling properties of wavelets are also possessed by contourlets, but the two properties that make contourlets superior than other transforms are directionality and anisotropy. The Contourlet expansion is composed of basis function oriented at various directions in multiple scales with flexible aspect ratios (anisotropy).The main feature of this transform is its potential to capture the geometric smoothness of the contours. The contourlet transform performs decomposition in two stages namely the Laplacian pyramid (LP), Directional Filter Bank (DFB) respectively. In the first stage of decomposition LP is used to capture point discontinuities, followed by DFB in the second stage to link point discontinuities into linear structure. Laplacian pyramid introduced by Burt and Adelson [2] is a method for achieving multiscale decomposition. The function of LP at each step is to decompose the image to generate a sampled low pass version of the original image where the difference between the original image and the prediction giving a bandpass image. One of the distinguishing features of LP is that each pyramid level generates only one bandpass image which does not have scrambled frequencies. The analysis and reconstruction scheme of the Laplacian pyramid is shown in figure 1.

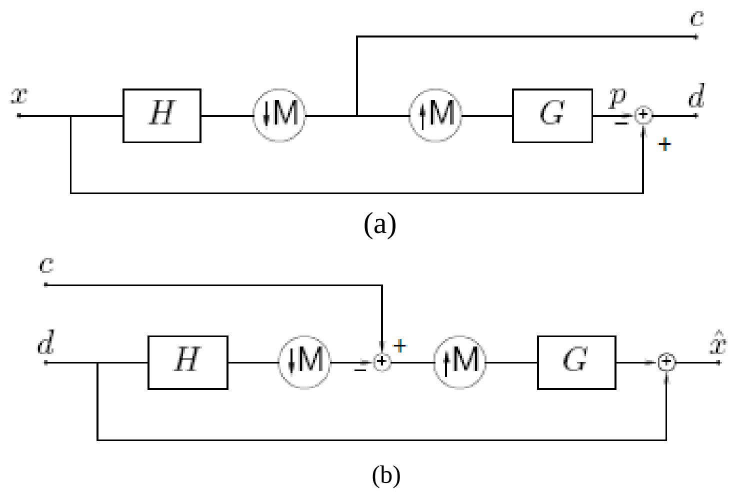


Fig. 1 Laplacian pyramid scheme (a) Analysis (b) Reconstruction [8]

Directional filter bank (DFB) is used to process the bandpass image obtained from LP decomposition. DFB construction involves decomposing the input image and using diamond shaped filters. DFB effectively represents high frequency components of images, whereas low frequency components are handled poorly. DFB is implemented via a n-level tree structured decomposition that leads to 2n subbands with wedge shaped frequency partitioning as shown in figure 2.

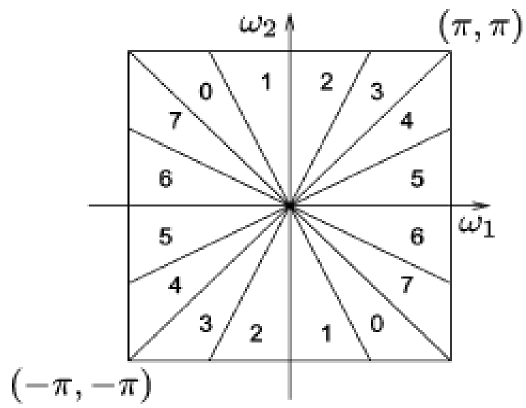


Fig. 2 DFB Frequency partitioning where n=3 and 2^3=8 wedge shaped frequency subband [8]

4. Proposed Method

4.1. *Watermark Embedding*

In the embedding process the watermark image is encrypted using Knapsack Algorithm [5]. Knapsack Algorithm makes use of super increasing order in combination, denoted as private key. Public key is extracted from this private key. Public key is used for encryption purpose, while private key is used for decryption purpose. The encrypted watermark is embedded into the directional subbands of the host image. Contourlet decomposition is performed on the host image to obtain the subbands. The steps involved in watermark embedding are as follows.

Step 1: The host image of size MxN is decomposed into number of subbands using contourlet transform. At each level of decomposition, there are 2^n directional subbands, where n=1, 2, 3, 4. Four level of contourlet decomposition is performed on the host image to produce 16 directional subbands.

Step 2: Watermark Image is encrypted using Knapsack Algorithm. For every bit position the weight is taken in the super increasing order in combination, denoted as private key. Public key is extracted from this private key. Watermark is encrypted with the public key.

Step 3: The coefficients of selected directional subband i.e. 15th subband is modified as per the following equation

$$f'(i,j) = f(i,j) + \alpha A_k \qquad 0 \le i \le (M/2) - 1, 0 \le j \le (M/8) - 1 \tag{1}$$

Where $f'(i,j)$ represents the pixels in the watermarked image and f(i,j) represent the pixels in subband selected for embedding. The multiplication factor is selected such that the watermarked image looks similar to the original image and A_k represents the encrypted watermark bit.

Step 4: Inverse contourlet transform (ICT) is performed to obtain the watermarked image. Then Peak Signal to Noise Ratio (PSNR) is calculated to measure the watermarked image quality with that of the original image.

$$PSNR = 10\log_{10}\left[\frac{255^2}{MSE}\right](dB) \tag{2}$$

$$MSE = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}\left[I(i,j) - k(i,j)\right]^2 (dB) \tag{3}$$

Where MSE is the mean square error, M and N is the rows and columns of host image, $I(i,j)$ represent the original image and $k(i,j)$ represents the watermarked image.

The flow diagram of embedding algorithm & extraction algorithm used for watermarking is shown in figure 3 and figure 4 respectively.

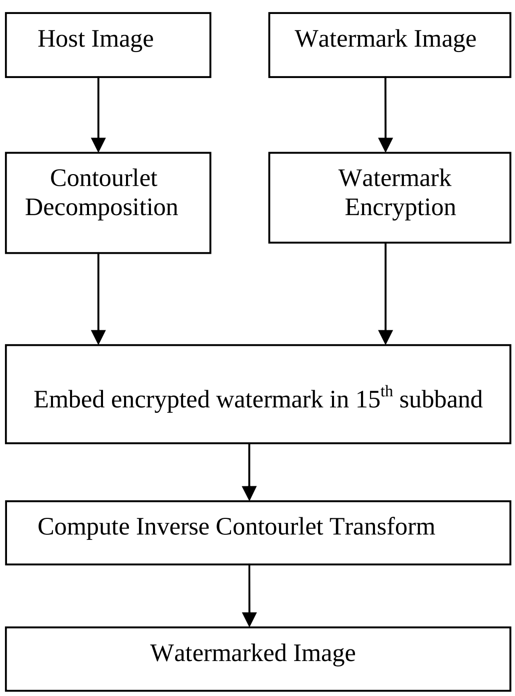


Fig. 3 Embedding Algorithm

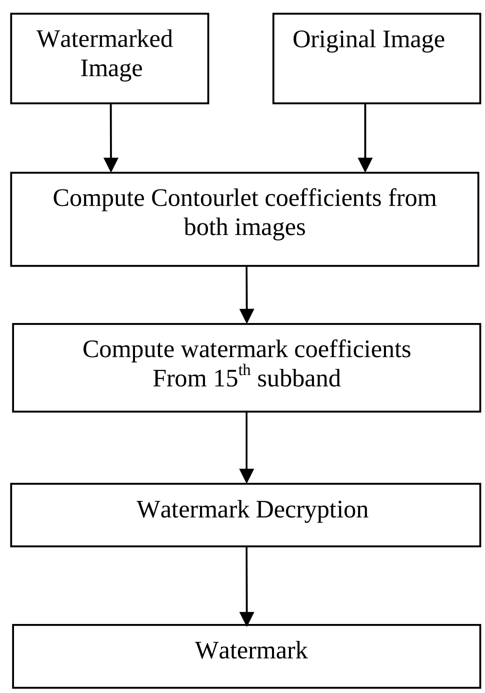


Fig. 4 Extraction Algorithm

4.2. *Watermark Detection*

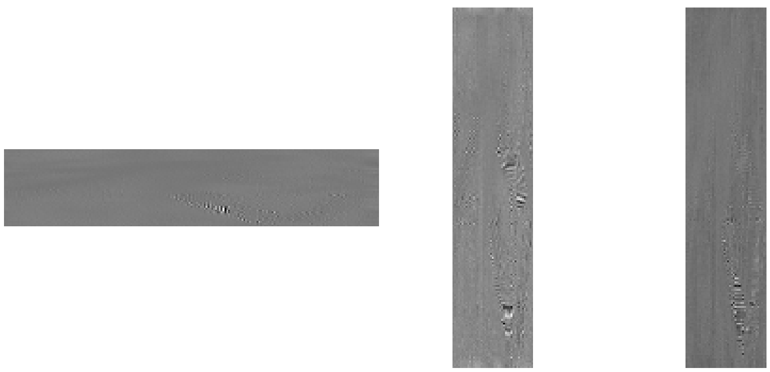
In the extraction process a copy of the original image is used as reference. The watermarked image and the original image undergo contourlet decomposition to produce directional subbands. The subband coefficients of the original image are subtracted from the modified subband coefficients of the watermarked image to obtain the encrypted watermark, which is given by the following equation.

$$A_k = \frac{f'(i,j) - f(i,j)}{\alpha} \tag{4}$$

The obtained encrypted watermark is decrypted using knapsack algorithm which makes use of private key for the decryption process.

5. Experimental Results

To evaluate performance of the proposed method number of simulations were carried out. The original image is 512x512 gray scale Lena image. The watermark image used is the logo of size 64x64. The Barbara image is transformed by contourlet transform to obtain a four level decomposition. The watermark is encrypted with the help of public key. We have chosen 15th directional subband for embedding out of the 16 subbands. Figure 5(a), 5(b) and 5(c) are the first, fifteenth and sixteenth directional subbands.



(a) (b) (c)

Fig. 5 (a) First directional subband (b) Fifteenth directional subband (c) Sixteenth directional subband

For the embedding process we make use of multiplication factor α whose value is chosen as 0.1. The original image is shown in figure 6(a), watermark image in figure 6(b), watermarked image in figure 6(c) and the extracted watermark in figure 6(d).

(a) (b)

(c) (d)

Fig. 6 (a) Original Lena image (b) Watermark image (c) Watermarked Lena image (d) Extracted watermark

The Peak Signal to Noise Ratio (PSNR) is popularly used to measure the similarity between the original image and the watermarked image, while higher PSNR usually implies higher fidelity of the watermarked image. The watermarked image obtained using proposed scheme have a PSNR value of 46.35dB which is higher than the value obtained using wavelet transform method [16], [19]. The wavelet transform method has maximum PSNR value of around 38.2 dB for the watermarked images. The extracted watermark has similarity factor of 0.85 in comparison with the original watermark. This method is found to be robust against geometric Gaussian noise attack and cropping attacks. When tested with Gaussian noise attack, the watermark extracted has similarity factor of 0.75. For cropping attack the extracted watermark achieved similarity factor value of 0.8. The cropped watermarked image and the watermark extracted from it are shown in figure 7(a) and 7(b). The proposed method is tested with only these two attacks. Embedding can also be done on the 1, 12, 14 and 16 subbands. The average PSNR of this scheme for various host images are found to be 46.23 dB.

(a) (b)

Fig. 7 (a) Watermarked image affected by cropping attack (b) watermark extracted from attacked image

Table 1 gives the Peak Signal to Noise Ratio of the proposed method tested with various host images like Lena, Baboon, Living room, Barbara, Airplane, Pirate etc. The dimensions of the various host images used and the watermark payload size are also tabulated. From the experimental results shown we conclude that the proposed method has better performance in terms of PSNR.

Table 1 PSNR results for different test images

Images	Dimension	Watermark Payload	proposed method PSNR (dB)
Lena	512x512	4KB	46.35
Barbara	512x512	4KB	46.39
Peppers	512x512	4kB	46.82
Women	512x512	4KB	46.05
Air plane	512x512	4KB	46.22
Pirate	512x512	4KB	46.31
Baboon	512x512	4KB	45.51
Living room	512x512	4KB	46.17
Mean			**46.23**

6. Conclusion

In this paper, we proposed an algorithm for watermark embedding and watermark extraction using contourlet transform. Embedding encrypted watermark to high frequency subbands allows high performance watermark extraction. The proposed method outplays the existing transform domain techniques such as Watershed, DWT Transform etc., in terms of performance and PSNR. By increasing the levels of decomposition for the watermarked image, the resistance against the attacks & the quality of extracted watermark can be improved.

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