Digital Image Watermarking Framework Using LWT and DCT

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Abstract

As a protection against unauthorized copying of digital multimedia objects, digital watermarking technology is now attracting substantial attention. In this paper, an image watermarking algorithm is presented by utilizing a cascade of two powerful mathematical transforms; the Lifting Wavelet Transform (LWT) and the Discrete Cosine Transform (DCT). The lifting wavelet transform is applied to decompose the original image into four sub-band images. Then the discrete cosine transform is computed on the selected sub-band of the LWT coefficients. The watermark is embedded in the DCT transformed the selected LWT sub-band of the cover image. The proposed system focuses on an invisible watermark embedding and quality factors such as imperceptibility to degradation of watermarked image and performance evaluation metrics. This presented algorithm is realized in MATLAB.

1. Introduction

The need for watermarking of multimedia contents has gained significance in the past few years, due to the rapid growth of such digitized media over the internet. There are two ways to provide copyright protection to image: encryption and watermarking. Encryption protects information but once the multimedia has been decrypted, it can be repeatedly copied and distributed without any difficulties. Therefore, digital watermarking techniques are needed in order to serve as standalone or complementary copyright protection systems.

Digital watermarking is defined like an embedding of additional information, which is called watermark, into the multimedia data. Digital image watermarking schemes can be placed under two categories based on whether or not they use the original image for extraction of watermark from watermarked image such as blind watermarking techniques which do not require original image and non-blind watermarking that requires original image to exist for detection.

Moreover, there are two main directions for embedding, namely the spatial and the frequency domain. Watermark information is directly embedded into image pixels by the spatial domain methods. The frequency domain approaches are the most successful and popular for image watermarking. The main development of digital watermarking is like this: copyright protection, pirate tracking, copying protection, image authentication, cover-up communication, classification control of digital watermarking video and so on. Two major applications of digital watermarking are copyright protection and data authentication. The quality of watermarked image is measured by Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Root Mean Square Error (RMSE).

In this paper, a digital image watermarking algorithm is described based on combining two transforms; LWT and DCT. Watermarking is done by altering the wavelets coefficients of carefully selected LWT sub-bands (HH), followed by the application of the DCT transform on the selected sub-bands. The rest of the paper is organized as follows: A brief review of some of the works available in the literature that utilizes watermarking for copyright protection in frequency domain is given in Section 2. The proposed blind watermarking approach is presented in section 3. Finally, the conclusions are summed up in section 4.

2. Related Work

A number of earlier works related to digital image watermarking inspired us to do this research. Some of such recent researches are briefly described in this section.

G. Gupta and H.Aggarwal [7] have presented a digital image watermarking based on DCT, DWT and FFT. The proposed algorithm has been observed that DCT gives the better results than other transforms. B. L. Gunjal and R.R Manthalkar [3] have introduced generalized algorithms to present DWT, CDMA based, DCT-DWT combined approach. The presented paper showed that the transform domain watermarking techniques have been recommended to achieve robustness.

P. Lam, O. Winkelmeyer, S. Abbas Mehdi and N. kamoosi [10] have described a technique of using perceptual masking in conjuction with DCT. They concluded that the method of DCT with perceptual masking is better than DCT and DWT. M. Jiansheng, L. Sukang and T. Xiaomei [9] have proposed an algorithm of digital watermarking based on DCT and DWT. The system showed that the algorithm has strong capability of embedding signal and anti-attack.

R. Hovancak and D. Levicky [12] evaluated two different watermarking methods using DCT. Original image is needed for extraction of watermark in first method and the one is not needed in second method. The proposed method showed that the first method has better robustness. A. Al-Haj [1] has described a combination method of DWT and DCT. The proposed system showed that combining the two transforms improved the performance of the watermarking algorithm.

Y. Jie [16] has proposed an algorithm of image information hiding based on the combination of image blending, DCT and new anti-Arnold transform. The proposed system showed that the algorithm has good imperceptibility, validity and certain degree of robustness under some common noise. V.Venkata Rama Prasad and R. Kurupati [14] have described a digital image watermarking algorithm based on DWT and DCT with scrambling and filtering. The proposed method showed that the combination of the two transforms improved the imperceptibility of the watermarked image by maintaining the robustness to attacks.

S. Hajjara, M. Abdallah and A. Hudaib [13] have presented a method for digital image watermarking using the biorthogonal wavelet transform. The proposed method showed that biorthogonal wavelets have the property of perfect reconstruction and smoothness.

3. Watermarking Approach in Frequency Domain

This section details the proposed blind watermarking scheme for copyright protection of digital images. The following subsections present the steps involved in the watermark embedding and extraction processes along with a brief description about the lifting wavelet transform (LWT) and discrete cosine transform (DCT).

3.1. Lifting Wavelet Transform (LWT)

Lifting Wavelet Transform based on the traditional wavelet is introduced by Wim Sweldens, using a simple relationship among all multi-resolution analyses with the same scaling function. The lifting scheme has several virtues compared with the traditional wavelet such as LWT can compute more effectively and needs smaller memory space and the transform coefficients from LWT are integers, overcoming the weakness of quantizing errors from the traditional wavelet transform. As the basic idea of integer wavelet transform, lifting wavelet transform consists of the following steps: split, predict and update [2].

(1) **Split**: The original data set $x[n]$ is divided into two disjoint subsets including odd subset $\mathbf{x_o[n] = x\ [2n+1]}$ and even subset $\mathbf{x_e\ [n] = x\ [2n]}$.

(2) **Predict**: The error in predicting $x_o[n]$ from $x_e\ [n]$ using prediction operator P is generated as the wavelet coefficients $d\ [n]$ as in (1).

$$\mathbf{d\ [n] = x_o[n] - P\ (\ x_e\ [n])} \quad (1)$$

(3) **Update**: Scaling coefficients c[n] that represent a coarse approximation to the original signal x_e [n] are obtained by combining x_e[n] and d[n]. This is accomplished by applying an update operator U to the wavelet coefficients and adding the result to x_e [n] as in (2).

$$\mathbf{c\,[n] = x_e\,[n] + U\,(d[n])} \qquad (2)$$

The lifting stage is formed by these three steps. As long as the same P and U are chosen for the forward and inverse transforms, the construction of the original signal will be perfect [4].

In lifting wavelet transform, original image decomposition produces four bands of data, such as approximation coefficients matrix (LL) and detail coefficients matrices HL, LH, HH. Host image Lena as shown in Figure.1 is decomposed into four bands as shown in Figure.2. Figure.3 depicts the perfect reconstruction using the approximation coefficients and detail coefficients, obtained by lifting wavelet decomposition.

Figure.1. Original image

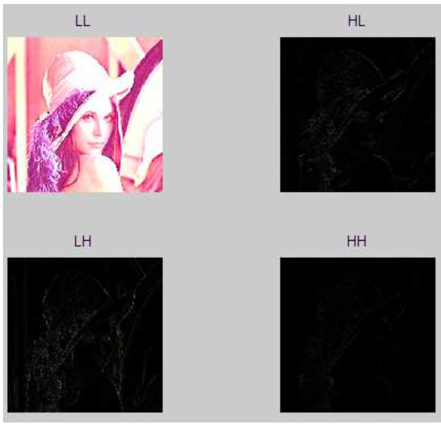

Figure.2. Decomposition of original image

Figure.3. Original image reconstruction

3.2. Discrete Cosine Transform (DCT)

A technique for converting a signal into elementary frequency components is the discrete cosine transform. It represents an image as a sum of sinusoids of varying magnitudes and frequencies. With an input image, x, the DCT coefficients for the transformed output image, y, are computed according to (3) shown below. In the equation, x is the input image having M x N pixels, x (m, n) is the intensity of the pixel in row m and column n of the image and y (u, v) is the DCT coefficient in row u and column v of the DCT matrix [11].

$$y(u,v) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\,\alpha_u\,\alpha_v \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} x(m,n)\,\cos\frac{(2m+1)u\pi}{2M}\cos\frac{(2n+1)v\pi}{2N} \qquad (3)$$

Where

$\alpha_u = \frac{1}{\sqrt{2}}$ if u=0 or $\alpha_u = 1$ if u=1,2,…,N-1.

$\alpha_v = \frac{1}{\sqrt{2}}$ if u=0 or $\alpha_v = 1$ if v=1,2,…,N-1.

The image is reconstructed by applying inverse DCT operation according to (4).

$$x(m,n) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} \alpha_u\,\alpha_v\,y(u,v)\cos\frac{(2m+1)u\pi}{2M}\cos\frac{(2n+1)v\pi}{2N} \qquad (4)$$

The popular block-based DCT transform segments an image on non-overlapping blocks and applies DCT to each block. These results in giving three frequency sub-bands: low frequency sub-band, mid-frequency sub-band and high frequency sub-band. DCT-based watermarking is based on two facts. The first fact is that much of the signal energy lies at low-frequencies sub-band which contains the most important visual parts of the image. The second fact is that high frequency components of the image are usually removed through compression and noise attacks. 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 [5,8,6,15].

In discrete cosine transform, the host image Cameraman as shown in Figure.4 is divided into 8 by 8 blocks and the DCT coefficients are computed for each block. Then, the reconstruction of original image as shown in Figure.5 is done by using the inverse DCT of each block. Discrete cosine transform can be used to reconstruct a sequence very accurately from only a few DCT coefficients. It is a useful property for applications requiring data reduction.

Figure.4. Original image

Figure.5. Reconstruction of original image

3.3. Watermark Embedding Process

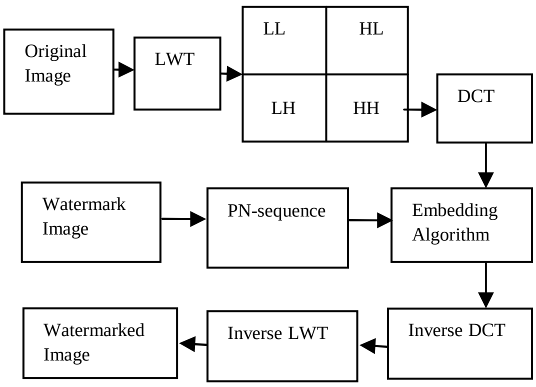

Figure.6. Watermark embedding procedure using combined LWT-DCT method

The watermark embedding procedure is depicted in Figure.6 followed by a detailed explanation.

Step 1**:** Read in the cover image f(x, y).

Step 2**:** Apply LWT to decompose the cover image "f" into four non-overlapping multi-resolution sub-bands: LL, HL, LH, and HH. From the four sub-bands, choose HH sub-band (f_{HH}) for embedding the watermark image.

Step 3**:** Divide the sub band HH into 4x4 blocks.

Step 4**:** Apply DCT to each 4x4 block in the chosen sub-band (HH).

Step 5**:** Read in the binary watermark image.

Step 6**:** Generate two uncorrelated pseudorandom (PN) sequences. One sequence is used to embed the watermark bit 0 (PN0) and the other sequence is used to embed the watermark bit 1 (PN1). The number of elements in each of the two pseudorandom sequences must be equal to the number of mid-band elements of the DCT transformed LWT sub bands.

Step 7**:** Embed the two pseudorandom sequences, PN0 and PN1, with a gain factor, in the DCT transformed 4x4 blocks of the selected LWT sub-bands of the host image. Embedding is not applied to all coefficients of the DCT block, but only to the mid-band DCT coefficients. If we donate X as the matrix of the mid-band coefficients of the DCT transformed block, then embedding is done as follows:

If the watermark bit is 0 then

$$X' = X + k * PN0$$

Otherwise,

If the watermark bit is 1 then,

$$X' = X + k * PN1$$

Where X ' is watermarked DCT block.

Step 8**:** Apply inverse DCT (IDCT) to each block after its mid-band coefficients have been modified to embed the watermark bits as described in the previous step.

Step 9**:** Apply the inverse LWT (ILWT) on the LWT transformed image, including the modified sub-band, to produce the watermarked host image.

3.4. Watermark Extraction Process

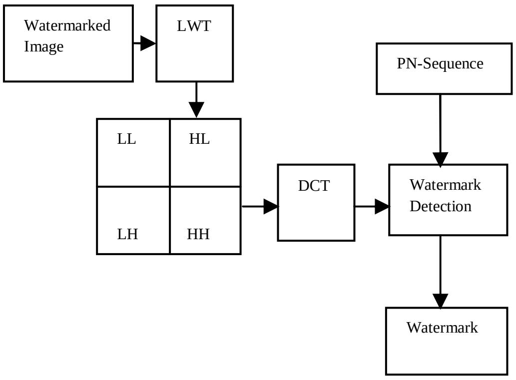

Figure.7. Watermark extraction procedure using combined LWT-DCT method

The extraction of watermark image from the watermarked image is depicted in Figure.7 and detailed in this subsection. As our watermarking approach is blind, it does not require the original image along with the watermarked image and the size of the watermark image for extraction.

Step 1: Apply LWT to decompose the watermarked image into four non-overlapping multi-resolution sub-bands: LL, HL, LH, and HH.

Step 2: Divide the sub-band HH into 4x4 blocks.

Step 3: Apply DCT to each block in the chosen sub-band HH, and extract the mid-band coefficients of each DCT transformed block.

Step 4: Regenerate the two pseudorandom sequences PN0 and PN1 using the same seed used in the watermark embedding procedure.

Step 5: For each block in the sub band HH, calculate the correlation between the mid-band coefficients and two generated pseudorandom sequences (PN0 and PN1). If the correlation with the PN0 is higher than the correlation with PN1, then the extracted watermark bit is considered 0, otherwise the extracted watermark is considered 1.

Step 6: Reconstruct the watermark using the extracted watermark bits and compute the similarity between the original and extracted watermark.

3.5. Performance Evaluations

Digital Image Watermarking algorithms are usually evaluated with respect to imperceptibility, which refers to the perceived quality of the cover image in the presence of the watermark. The peak signal to noise ratio (PSNR) is typically used as a measure of the quality of a watermarked image. PSNR in decibels (dB) is given by,

$$MSE = \frac{\sum[f(x,y) - F(x,y)]^2}{N^2}$$

$$PSNR = 20\ \log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \qquad (5)$$

The original image is f(x, y) and the watermarked image is F(x, y). N is the number of pixels. MSE means Mean Square Error. The similarity between the original watermark and watermark is measured using correlation factor C, given by,

$$C = \frac{\sum_{i=1}^{N} W_i\ W'_i}{\sqrt{\sum_{i=1}^{N} W_i^2}\ \sqrt{\sum_{i=1}^{N} W'^2_i}} \qquad (6)$$

N is the number of pixels in the watermark, W and W' are the original and extracted watermark images respectively. The correlation value C lies between 0 to 1.

4. Conclusion

In this paper, an approach for copyright protection of digital images using watermarking is presented. With the help of a combined lifting wavelet transform and discrete cosine transform, the proposed approach will be executed. Lifting wavelet transform is used to decompose the original image. Discrete cosine transform is applied on the selected LWT sub-bands. The watermark image is embedded in the DCT transformed the selected LWT sub-band of the original image. Subsequently, the watermark image is extracted from the watermarked image. The proposed system hopes to improve the watermarking performance by combining the two transforms. For the robustness experiment, the watermarked image will be tested with common image processing operations such as adding noise, image cropping and image blurring. With the help of two transforms, the presented approach hopes the watermarked image to be invisible as well as robust.

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