Digital Image Watermarking Scheme based on LWT Domain

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Abstract

Digital watermarking technology is now attracting considerable attention as one of the potential solutions for protecting copyrights of digital images. In this paper, digital color image watermarking scheme based on Lifting Wavelet Transform (LWT) is proposed. The RGB color space is converted into YCbCr color space and Y component is selected for watermark embedding. The Y channel is transformed into frequency domain using Lifting Wavelet Transform (LWT). LWT decomposition is done with 'Harr' which is simple and symmetric wavelet. The proposed system focuses on an invisible and blind watermarking. The system will be tested on quality factors such as imperceptibility and performance evaluation metrics. The presented algorithm is implemented in Matlab.

1. Introduction

As the field of multimedia security protection, digital watermarking technology for digital images is becoming a useful way to solve the problem of intellectual property protection, due to the rapid evolution of the internet.

Digital image watermarking is a technique for inserting information into an image to make assertion about the image. The embedded information is called watermark which is, in general, a visible or invisible identification code that may contain owner's information. The visible watermark can be easily removed from the digital cover image. Unlike visible watermarks, the invisible watermarks could be very difficult to remove from the media because they became an integral component of the cover image after being embedded. This embedded data can later be extracted from, or detected in, the multimedia for security purposes. A watermarking method consists of the watermark structure, an embedding process, and an extraction or a detection process.

There are two main classes in watermarking techniques, namely the spatial and transform domain. In transform domain, the data is embedded by modulating the transform domain signal coefficients. The spatial domain techniques embed the watermark by directly modifying the pixel values of the original image. The transform domain techniques are most successful and popular for image watermarking. In all transform domain watermarking schemes, there is a conflict between robustness and transparency. If the watermark is embedded in perceptually most significant components, the scheme would be robust to attacks but the watermark may not be meeting imperceptibility criterion. On the other hand, if the watermark is embedded in perceptually insignificant components, it would be easier to hide the watermark but the scheme may be less resilient to attacks. An effective watermarking scheme should meet certain requirements including imperceptibility, robustness, security, and low-computational complexity.

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. Two major applications of digital watermarking are copyright protection (proving ownership of data) and data authentication. The quality of watermarked image is measured by Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE).The process of watermarking in the simplest form is shown in Figure 1.

The main objective of this paper is to present a watermarking technique that uses the Lifting Wavelet Transform (LWT) over selected Y channel. The important goal for the system is to keep the imperceptibility and transparency of watermarked image. Watermarking is done by inserting an amount of information to the lifting wavelet coefficients of Y component.

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 background theory of the proposed scheme is described in Section 3 and Section 4.The proposed blind watermarking approach is presented in section 5. Experimental results are described in section 6. Finally, the conclusions are summed up in section 7.

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. S. Shahraeini and M. Yaghoobi [10] have proposed a blind watermarking algorithm based on fractal model in discrete wavelet domain for copyright protection. The experimental results of the system showed that the algorithm is robust against JPEG compression attacks. S. K. Jinna, and Dr. L. Ganesan [7] have presented a reversible image watermarking using histogram shifting method. They showed that more image quality is achieved for the same payload compared to other reversible watermarking methods.

G. Gupta and H.Aggarwal [3] 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 [2] 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 [8] 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. R. Hovancak and D. Levicky [5] 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.

Y. Jie [6] 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. S. Hajjara, M. Abdallah and A. Hudaib [4] 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.

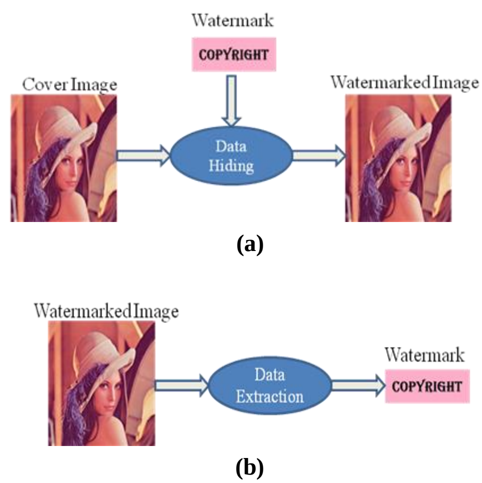

Figure.1. Process of Watermarking: (a) Embedding and (b) Extraction

3. RGB and YCbCr Color Spaces

The RGB color space is converted into YCbCr color space and then watermark is embedded into Y component of YCbCr color space. Firstly, the color image is read. Then R, G, and B components of original cover image are separated. After that, they are converted into YCbCr color space using following equation (1), equation (2) and equation (3) [1].

$$\mathbf{Y = 0.257\ R + 0.504\ G + 0.098\ B + 16} \quad (1)$$

$$\mathbf{Cb = -0.148\ R - 0.291\ G + 0.439\ B + 128} \quad (2)$$

$$\mathbf{Cr = 0.439\ R - 0.368\ G - 0.071\ B + 128} \quad (3)$$

After embedding the watermark using LWT, YCbCr color space is converted back into RGB color space.

4. 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 [9].Lifting wavelet transform requires three phases for its implementation, namely: split, predict and update.

Split: The original data set **x[n]** is divided into two subsets with no common elements, whose length are the half of original data. Generally speaking, the original signal is divided into odd subset $\mathbf{x_o[n] = x[2n+1]}$ and even subset $\mathbf{x_e[n] = x[2n]}$.

Predict: Odd series $\mathbf{x_o[n]}$ is predicted according to even series $\mathbf{x_e[n]}$ by the predict operator **P**, and the errors are called wavelet coefficients **d [n]** as in equation (4).

$$\mathbf{d[n] = x_o[n] - P(x_e[n])} \quad (4)$$

Update: Update operators **U** are put on wavelet coefficients **d[n]**, and then the results add the odd series $\mathbf{x_e[n]}$, which are called scale coefficients **c [n]** as in equation (5).

$$\mathbf{c[n] = x_e[n] + U(d[n])} \quad (5)$$

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. Figure.2 is the process of the lifting wavelet algorithm.

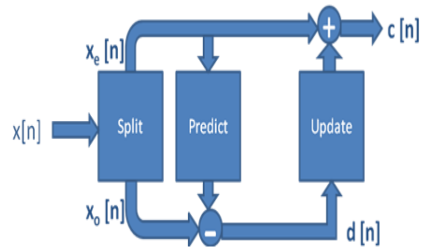

Figure.2. Lifting Wavelet Algorithm

5. Proposed Watermarking Technique

In this section, a description about the proposed technique including the embedding and extraction process is given. The proposed technique uses Lifting Wavelet Transform (LWT) for watermarking. The original image is converted into YCbCr color space and Y channel is chosen for transformation. The Y channel is decomposed into four sub-bands by using LWT. The watermark is embedded in the detail wavelet coefficients in order to make the technique robust against attack, and to preserve imperceptibility. The proposed technique for embedding and extraction is described in the following subsections.

5.1. Watermark Embedding Process

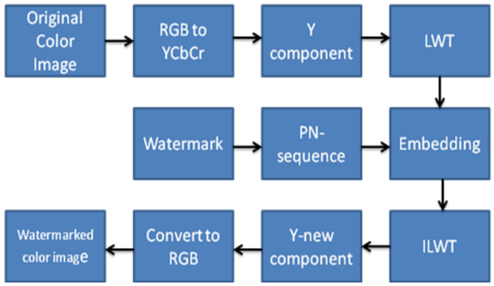

Figure.3. Watermark embedding procedure

The watermark embedding procedure is depicted in Figure.3 followed by a detailed explanation.

Step1: Read in the original color image f(x, y).

Step2: Convert the original color image into YCbCr color space and take Y component for embedding watermark.

Step3: Apply LWT to decompose the Y component using simple 'haar' wavelet into four non-overlapping sub-bands: LL, HL, LH, and HH. From the four sub-bands, choose HH sub-band (f_{HH}) for embedding the watermark image.

Step4: Read in the binary watermark image.

Step5: 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 elements of the HH sub-band.

Step 6: Embed the two pseudorandom sequences, PN0 and PN1, with a gain factor, in the selected LWT sub-band of the Y color space. If X is denoted as the matrix of LWT coefficients of the Y channel, then embedding is done as follows:

If the watermark bit is 0 then

$$\mathbf{X' = X + k * PN0}$$

Otherwise,

If the watermark bit is 1 then,

$$\mathbf{X' = X + k * PN1}$$

Where X ' is watermarked matrix.

Step7: Apply the inverse LWT (ILWT) on the LWT transformed image, including the modified sub-band.

Step 8:Convert from YCbCr color space using Y new component to RGB to produce the watermarked image.

5.2. Watermark Extraction Process

The extraction process is shown in Figure.4. 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. The extraction process is described in the steps.

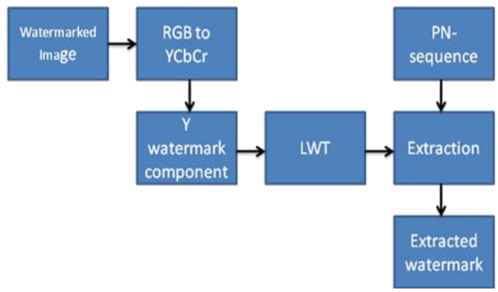

Figure.4. Watermark extraction procedure

Step1: Convert RGB of watermarked image to YCbCr color space and consider the Y watermarked component.

Step2: Apply LWT to decompose Y from watermarked image into four non-overlapping sub-bands: LL, HL, LH, and HH.

Step3: Regenerate the two pseudorandom sequences PN0 and PN1 using the same seed used in the watermark embedding procedure.

Step4: For the selected sub band HH, calculate the correlation between the LWT 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.

Step5: Reconstruct the watermark using the extracted watermark bits and compute the similarity between the original and extracted watermark.

6. **Experimental Results**

The system is implemented in Matlab. The proposed scheme is tested on standard images which are resized to 512x512 and use a 64x64 binary image as in Figure.6 as a watermark. In this section, for example, standard Lena Color image as shown in Figure.5 with 512x512 size as cover image and 64x64 size watermark image as shown in Figure.6 are used for testing. The Lena image is converted from RGB color space to YCbCr color space as shown in Figue.7. Then, Y is chosen for embedding process. The Y channel is transformed by Lifting Wavelet Transform (LWT) to obtain a four level decomposition as shown in Figure.8. The watermarked image is shown in Figure.9.

The performance Evaluation is done by performance evaluation metric such as perceptual transparency. Perceptual transparency means 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, while higher PSNR usually implies higher fidelity of the watermarked image. PSNR in decibels (dB) is given by,

$$MSE = \frac{\sum[f(x,y) - F(x,y)]^2}{N^2} \quad \textbf{(6)}$$

$$PSNR = 20 \log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \quad \textbf{(7)}$$

In equation (6), 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. In equation (7), PSNR means peak signal to noise ratio. The PSNR of host image is found 46.23 dB.

Table.1 gives the Peak Signal to Noise Ratio (PSNR) of the proposed method tested with various host images like Lena, Baboon, Peppers, etc.

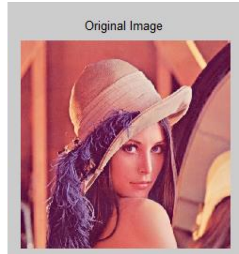

Figure.5. Original Image

Figure.6. Watermark Image

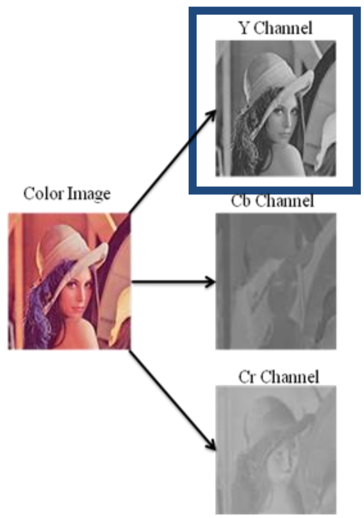

Figure.7. RGB to YCbCr Conversion

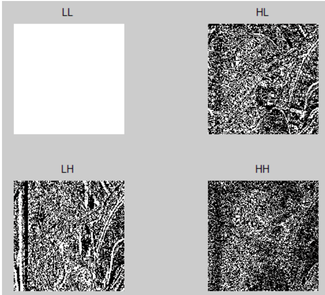

Figure.8. LWT decomposition of Y components

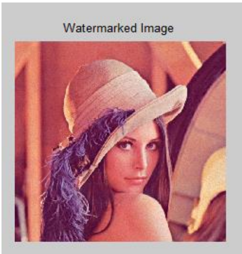

Figure.9. Watermarked Image

Table.1. PSNR results for different test images

Images	Dimension	Proposed Method PSNR (dB)
Lena	512 x 512	46.23
Baboon	512 x 512	46.31
Peppers	512 x 512	46.05
Pills	512 x 512	46.39
Flight	512 x 512	46.17
Kid	512 x 512	46.22

7. Conclusion

In this paper, an approach for copyright protection of digital images using watermarking is presented. With the aid of YCbCr color space and LWT, the proposed approach is executed. Lifting wavelet transform is used to decompose Y component. The watermark image is embedded in the LWT transformed of Y component of the original image. Subsequently, the watermark image is extracted from the watermarked image. The proposed system hopes to increase security level by generating PN sequence. The presented approach shows that the watermarked image can be embedded as invisible information. In addition, the scheme can keep imperceptibility.

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