Performance Analysis of Digital Image Watermarking Technique–Combined DWT – DCT over individual DWT

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ABSTRACT - **The proliferation of digitized media due to the rapid growth of networked multimedia systems, has created an urgent need for copyright enforcement technologies that can protect copyright ownership of multimedia objects. Digital image watermarking is one such technology that has been developed to protect digital images from illegal manipulations. In particular, digital image watermarking algorithms which are based on the discrete wavelet transform have been widely recognized to be more prevalent than others. This is due to the wavelets' excellent spatial localization, frequency spread, and multi-resolution characteristics, which are similar to the theoretical models of the human visual system. In this paper, we describe an imperceptible and a robust combined DWT-DCT digital image watermarking algorithm. The algorithm watermarks a given digital image using a combination of the Discrete Wavelet Transform (DWT) and the Discrete Cosine Transform (DCT). Performance evaluation results show that combining the two transforms improved the performance of the watermarking algorithms that are based solely on the DWT transform.**

Keywords- Digital image watermarking, image copyright protection, frequency-domain watermarking, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT)

INTRODUCTION

The development of effective digital image copyright protection methods have recently become an urgent and necessary requirement in the multimedia industry due to the ever-increasing unauthorized manipulation and reproduction of original digital objects. The new technology of digital watermarking has been advocated by many specialists as the best method to such multimedia copyright protection problem[1,2]. Its expected that digital watermarking will have a wide-span of practical applications such as digital cameras, medical imaging, image databases, and video-on-demand systems, among many others.

In order for a digital watermarking method to be effective it should be imperceptible, and robust to common image manipulations like compression, filtering, rotation, scaling cropping, collusion attacks among many other digital signal processing operations. Current digital image watermarking techniques can be grouped into two major classes:

1. Spatial Domain Watermarking
2. Frequency Domain Watermarking

Compared to spatial domain techniques, frequency-domain watermarking techniques proved to be more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking algorithms.

Commonly used frequency-domain transforms include the Discrete Wavelet Transform (DWT), the Discrete Cosine Transform (DCT) and Discrete Fourier Transform (DFT). However, DWT has been used in digital image watermarking more frequently due to its excellent spatial localization and multi-resolution characteristics, which are similar to the theoretical models of the human visual system. Further performance improvements in DWT-based digital image watermarking algorithms could be obtained by combining DWT with DCT. 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.

In this paper, we will describe a digital image watermarking algorithm based on combining two transforms; DWT and DCT. Watermarking is done by altering the wavelets coefficients of carefully selected DWT sub-bands, followed by the application of the DCT transform on the selected sub-bands.

THE DCT AND DWT TRANSFORMS

The DCT and DWT transforms have been extensively used in many digital signal processing applications. In this section, we introduce the two transforms briefly, and outline their relevance to the implementation of digital watermarking.

The DCT transform: The discrete cosine transforms is a technique for converting a signal into elementary frequency components. 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 Eq. shown below. In the equation, x, is the input imagehaving N x M 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.

$$C(u,v)=\alpha_u\alpha_v\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}I(x,y)\cos\frac{\pi(2x+1)u}{2M}\cos\frac{\pi(2y+1)v}{2N},$$

for $0\le u\le M-1$, $0\le v\le N-1$ and

$$\alpha_u=\begin{cases}1/\sqrt{M}, & u=0\\ \sqrt{2/M}, & 1\le u\le M-1\end{cases}$$

$$\alpha_v=\begin{cases}1/\sqrt{N}, & v=0\\ \sqrt{2/N}, & 1\le v\le N-1\end{cases}$$

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

The image is reconstructed by applying inverse DCT operation according to Eq. shown below:

$$f(x,y)=\sum_{u=0}^{M-1}\sum_{v=0}^{N-1}\alpha_u\alpha_v C(u,v)\cos\frac{\pi(2x+1)u}{2M}\cos\frac{\pi(2y+1)v}{2N},$$

for $0\le x\le M-1$, $0\le y\le N-1$ and α_u, α_v as defined above.

The popular block-based DCT transform segments an image non-overlapping blocks and applies DCT to each block. This results in giving three frequency sub-bands: low frequency sub-band, mid-frequency-sub-ban 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.

The DWT transform: Wavelets are special functions which, in a form analogous to sines and cosines in Fourier analysis, are used as basal functions for representing signals. 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 LL1, LH1, HL1 and HH1. The sub-band LL1 represents the coarse-scale DWT coefficients while the sub -bands LH1, HL1 and HH1 represent the fine-scale of DWT coefficients. To obtain the next coarser scale of wavelet coefficients, the sub-band LL1 is further processed until some final scale N is reached. When N is reached we will have 3N+1 sub-bands consisting of the multi-resolution sub-bands LLN and LHx, HLx and HHx where x ranges from 1 until N.

Due to its excellent spatio-frequency localization properties, the DWT is very suitable to identify the areas in the host image where a watermark can be embedded effectively. In particular, this property allows the exploitation of the masking effect of the human visual system such that if a DWT coefficient is modified, only the region corresponding to that coefficient will be modified. 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 compromise adopted by many DWT-based watermarking algorithm, is to embed the watermark in the middle frequency ub bands LHx and HLx where acceptable performance of imperceptibility and robustness could be achieved.

THE COMBINED DCT-DWT ALGORTIHM

Watermark Embedding:

The Stepwise Explanation of the watermark embedding Procedure is given below.

Step 1: Apply DWT to decompose the cover host image into four non-overlapping multi-resolution sub-bands: LL1, HL1, LH1, and HH1.
Step 2: Divide the sub-band HL1 (or HH1) into 16 x 16 blocks.
Step 3: Apply DCT watermarking to each block in the chosen sub-band (HL1 or HH1) .
Step 4: Re-formulate the grey-scale watermark image into a vector of zeros and ones.
Step 5: Generate two uncorrelated pseudorandom sequences. One sequence is used to embed the watermark bit 0 (PN_0) and the other sequence is sued to embed the watermark bit 1 (PN_1). Number of elements in each of the two pseudorandom sequences must be equal to the number of mid-band elements of the DCT-transformed DWT sub-bands.
Step 6: Embed the two pseudorandom sequences, PN_0 and PN_1, with a gain factor, in the DCT transformed 16x16 blocks of the selected DWT 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 + * PN_0

If the watermark bit is 1 then

X '= X + * PN_1

Step 7: 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 8: Apply the inverse DWT (IDWT) on the DWT transformed image, including the modified sub-band, to produce the watermarked host image.

Watermark Extraction:

The watermark extraction procedure is depicted in Figure 2, and described in details in the following steps. The combined DWT-DCT algorithm is a blind watermarking algorithm, and thus the original host image is not required to extract the watermark.
Step 1: Apply DWT to decompose the watermarked image into four non-overlapping multi-resolution subbands: LL1, HL1, LH1, and HH1.
Step 2: Divide the sub-ban HL1 (or HH1) into 16x16 blocks.
Step 3: Apply DCT to each block in the chosen sub-band (HL1 or HH1), and extract the mid-band coefficients of each DCT transformed block.
Step 4: Regenerate the two pseudorandom sequences (PN_0 and PN_1) using the same seed used in the watermark embedding procedure.
Step 5: For each block in the sub-band HL1 (or HH1), calculate the correlation between the mid-band coefficients and the two generated pseudorandom sequences (PN_0 and PN_1). If the correlation with the PN_0 was higher than the correlation with PN_1, 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 watermarks.

PERFORMANCE EVALUATION

We evaluated the performance of the combined DWT-DCT image watermarking algorithms using 512x512 size different images as the original cover host image, and a 12x20 grey-scale image of the expression **'9'** as the watermark image.

Performance Evaluation Matrix:

Watermarking algorithms are usually evaluated with respect to imperceptibility. The metrix is described below.
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. PSNR in decibels (dB) is given below in Equation.

$$\text{PSNR} = 10 \log 255^2 / \text{MSE}$$

Where

$$MSE = 1/MN \sum_{m=1}^{M} \sum_{n=1}^{N} (x(m.n) - x^\wedge(m,n))2$$

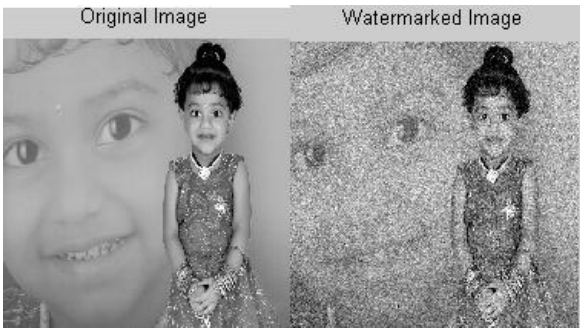
where x(m,n)=Original Image
x^(m,n)=Watermarked Image

Results:

We evaluated the PSNR and the Elapsed time on different images and observed that the visual perception of the watermarked image is far more better in the combined DWT-DCT compare to only DWT. The following table shows the difference between the two methods.

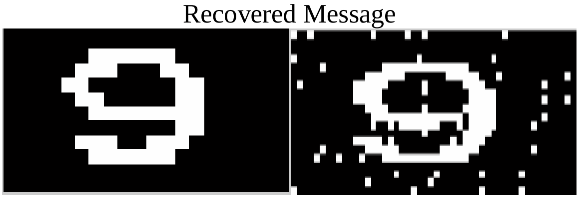
Sr. No.	Name of Image	PSNR – dB (Only DWT)	PSNR – dB (DWT-DCT)	Elapsed time – Sec (Only DWT)	Elapsed time – Sec (Only DWT)
1.	Lena	**37.0132**	**47.7707**	**59.3850**	**1.2031**
2.	Cameraman	**37.397**	**48.7107**	**25.9770**	**1.2500**
3.	Circuit	**32.5191**	**45.9555**	**26.2670**	**1.2656**
4.	Pan_card	**37.5672**	**46.8729**	**75.8390**	**1.2031**
5.	Hima	**37.5672**	**47.4048**	**64.4820**	**1.2031**

Results of combined DWT-DCT



Results of only DWT

Recovered Message



Combined DWT-DCT Only DWT

CONCLUSION

The discrete wavelet transform (DWT) and the discrete cosine transform (DCT) have been applied successfully in many in digital image watermarking. In this paper, we described a combined DWT-DCT digital image watermarking algorithm. Watermarking was done by embedding the watermark in the first and second level DWT sub-bands of the host image, followed by the application of DCT on the selected DWT sub-bands. The combination of the two transforms improved the watermarking performance considerably when compared to the DWT-Only watermarking approach. In conclusion, in DWT based digital watermarking applications, combining appropriate transforms with the DWT may have a positive impact on performance of the watermarking system.

VI. REFERENCES

[1] F. Hartung, M. Kutter, "Multimedia watermarking techniques" Proceedings of the IEEE, vol. 87, issue 7, pp. 1079-1107, Jul 1999.

[2] D. P. Mukherjee, S. Maitra, and S. T. Acton, “Spatial Domain Digital Watermarking of Multimedia Objects for Buyer Authentication” IEEE Transactions on Multimedia, vol. 6, no. 1, pp. 1-15, Feb. 2004

[3] Z. Lu,D. Xu, and S. Sun, “ Multipurpose Image Watermarking Algorithm Based on Multistage Vector Quantization” IEEE Trans Image Processing, vol. 14, no. 6, pp. 822 -831, June 2005.

[4] J-B. Zheng, D. D. Feng, and R-C. Zhao, “A Multi-Channel Framework for Image Watermarking”, Proceedings of the Fourth International Conference on Machine Learning and Cybernetics, Guangzhou, 18-21 August 2005.

[5] P. Dong, et al., “Digital Watermarking Robust to Geometric Distortions”, IEEE Transactions on Image Processing, vol. 14, no. 12, Dec. 2005.

[6] W. Xing, Z. Lu, And H. Wang, “A Digital Watermarking Method Based on Classified Labeled-Bisecting-K-Means Clustering”, Proceedings of The 2nd Inter. Conf. Machine Learning & Cybernetics, pp.2891-2895, Nov. 2003.

[7] M. A. Suhail and M. S. Obaidat, “Digital Watermarking-based DCT and jpeg Model” IEEE Trans. on Instrumentation and Measurement, vol. 52, no. 5, pp. 1640-1647, Oct. 2003.

[8] J. R. Hernández, M. Amado, and F. Pérez-González, " DCT-Domain Watermarking Techniques for Still Images: Detector Performance Analysis and a New Structure", IEEE Tran. Image Processing, vol. 9, pp. 55-68, Jan. 2000.

[9] Q. Cheng, and T. S. Huang, “Robust Optimum Detection of Transform Domain Multiplicative Watermarks” IEEE Trans. Signal Processing, vol. 51, no. 4, pp. 906-924, April 2003.