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Research Paper

A ROBUST ALGORITHM FOR DIGITAL IMAGE COPYRIGHT PROTECTION

A Sai Kumar[1]*, K Nishanth Rao[2] and S Narasimha Rao[2]

*Corresponding Author: A Sai Kumar, ✉ saikumar.vit@gmail.com

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 this paper, a new robust digital image watermarking algorithm based on Joint DWT-DCT Transformation is proposed. The imperceptibility is provided as well as higher robustness against common signal processing attacks. The watermarked image is embedded in certain sub-bands of a 3-level DWT transformed of a host image. Then, DCT transform of each selected DWT sub-band is computed and the PN-sequences of the watermark bits are embedded in the coefficients of corresponding DCT middle frequencies. Then, the same approach as the embedding process is used to extract the DCT middle frequencies of each sub-band. Finally, correlation between mid-band coefficients and PN-sequences is calculated to determine watermarked bits.

Keywords: Digital image watermarking, Image copyright protection, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Robustness

INTRODUCTION

The fast development of the Internet in recent years has made it possible to easily create copy, transmit, and distribute digital data. Consequently, this has led to a strong demand for reliable and secure copyright protection techniques for digital data. Digital watermarking has been proposed as valid solution for this problem. The purpose of the watermark is to embed some additional information about the digital data without visibly modifying it.

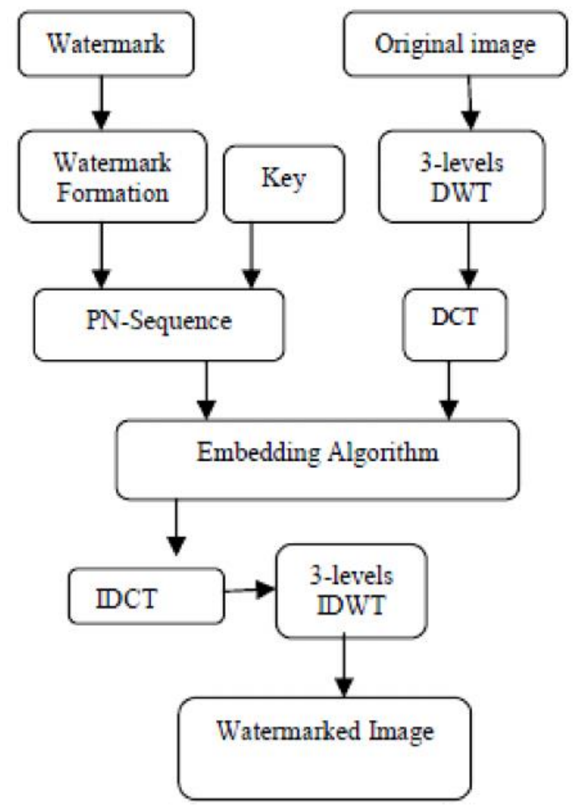
In order to be successful, the watermark should be invisible and robust to modification of the image. It should be robust against common image processing operations such as filtering, additive noise, resizing, cropping, etc., and common image compression

[1] VIT University, Vellore, India.
[2] CMR Institute of Technology, Hyderabad, India.

techniques. Thus, two essential prerequisites for an powerful watermarking scheme, robustness and invisibility conflict with each other (Lin and Chin, 2000).

The classification of watermarking techniques was based on domain which the watermark is applied, i.e., the spatial or the transform domain. Spatial domain techniques are not resistant enough to image compression and other image processing. Transform domain watermarking schemes like those based on DCT (Lin and Chin, 2000; and Deng, 2003), DWT (Tay and Havlicek, 2002) typically provide higher image imperceptibility and are much more robust to image manipulations. However, DWT (Tay and Havlicek, 2002) has been used more frequently in digital image watermarking due to its time/frequency decomposition characteristics.In order to further performance improvements in DWT based digital image watermarking algorithms could be obtained by jointing DWT with DCT (Ali Al-Haj, 2007).

Figure 1: Joint DCT-DWT Watermark Embedding Procedure



WATERMARK EMBEDDING

We start the watermarking process by applying DWT to the host image, and afterwards performing the DCT to the selected DWT sub-bands. The agreement adopted by many DWT-based watermarking methods, is to embed the watermark in the middle frequency sub-bands HLX and LHX is better in perspective of imperceptibility and robustness. Consequently, HLX sub-bands in level three is chosen for Performing DCT on them. The watermark embedding procedure is represented in Figure 1. Followed by a detailed explanation.

Step 1: Perform DWT on the host image to decompose it into four non-overlapping multiresolution coefficient sets: LL_1, HL_1, LH_1 and HH_1.

Step 2: Perform DWT again on two HL_1 and LH_1 sub-bands to get eight smaller sub-bands and choose four coefficient sets: HL_{12}, LH_{12}, HL_{22} and LH_{22} as shown in Figure 2a.

Step 3: Perform DWT again on four sub-bands: HL_{12}, LH_{12}, HL_{22} and LH_{22} to get sixteen smaller Sub bands and choose four coefficient sets: HL_{13}, LH_{13}, HL_{23} and LH_{23} as shown in Figure 2b.

Step 4: Divide four coefficient sets: HL_{13}, LH_{13}, HL_{23} and LH_{23} into 4 x 4 blocks.

Step 5: Perform DCT to each block in the chosen coefficient sets (HL_{13}, LH_{13}, HL_{23} and LH_{23}).

Figure 2: (a) Four Multi-Resolution DWT Subbands of the Original Image in Level 2 to Apply DWT to Another Level; (b) Four Selected Multiresolution DWT Coefficient Sets of the Host Image in Level 3

Step 6: Re-formulate the grey-scale watermark image into a vector of zeros and ones.

Step 7: Generate two uncorrelated pseudorandom sequences by a key. One sequence is used to embed the watermark bit 0 (PN_0) and the other sequence is used to embed the other sequence is used 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 coefficient sets.

Step 8: Embed the two pseudorandom sequencesPN_0 and PN_1, with a gain factor á in the DCT transformed 4 x 4 blocks of the selected DWT coefficient sets of the host image. Instead of embedding in all coefficients of the DCT block, it applied only to the of the DCT block, it applied 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 Equation (1):

$$X' = \begin{cases} X + \sim * PN0 & watermark\_bit = 0 \\ X + \sim * PN1 & watermark\_bit = 1 \end{cases} \quad ...(1)$$

Step 9: Perform inverse DCT (IDCT) on each block after its mid-band coefficients have been modified to embed the watermark bits as described in the previous step.

Step 10: Perform the inverse DWT (IDWT) on the DWT transformed image, including the modified coefficient sets, to produce the watermarked host image.

WATERMARK EXTRACTION

The watermark extraction procedure is shown in Figure 3. The joint DWT-DCT algorithm is a blind watermarking algorithm, and thus the original host image is not required to extract the watermark.

Step 1: perform combination of two filters as prefiltering operation. This filter enhances contrast of watermarked image.

Step 2: Perform DWT on the pre-filtered watermarked image to decompose it into four no overlapping multi-resolution coefficient sets: LL_1, HL_1, LH_1 and HH_1.

Step 3: Perform DWT again on two sub-bands HL1and LH1 to get eight smaller sub-bands and choose four coefficient sets: HL_{12}, LH_{12}, HL_{22} and LH_{22} as shown in Figure 2a.

Step 4: Perform DWT again on four sub-bands: HL_{12}, LH_{12}, HL_{22} and LH_{22} to get sixteen smaller subbandsand choose four coefficient sets: HL_{13}, LH_{13}, HL_{23} and LH_{23} as shown in Figure 2b.

Step 5: Divide four coefficient sets: HL_{13}, LH_{13}, HL_{23} and LH_{23} into 4 x 4 blocks.

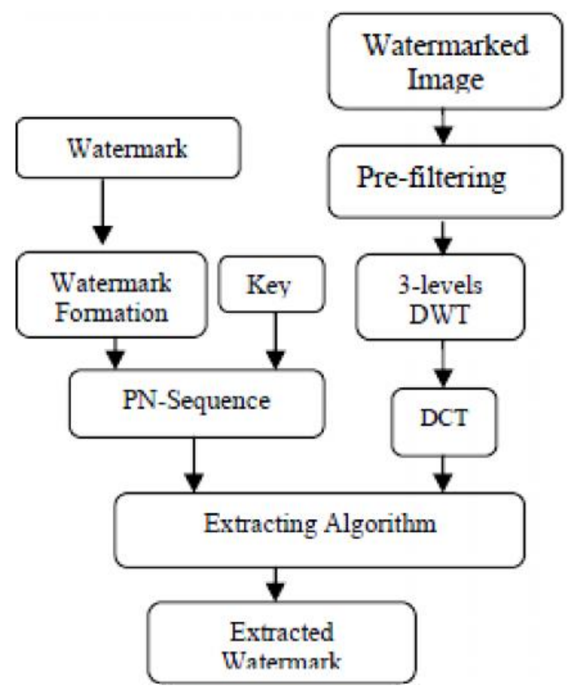
Step 6: Perform DCT on each block in the chosen coefficient sets (HL_{13}, LH_{13}, HL_{23}, LH_{23}).

Step 7: Regenerate the two pseudorandom sequences (PN_0 and PN_1) using the same key which used in the watermark embedding procedure.

Step 8: For each block in the coefficient sets: HL_{13}, LH_{13}, HL_{23} and LH_{23}. Calculate the correlation between the mid-band coefficients and the two generated Pseudo-random 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.

Figure 3: Joint DWT-DCT Watermark Extraction Procedure



Step 9: The watermark is reconstructed using the extracted watermark bits, and compute the similarity between the original and extracted watermarks.

PERFORMANCE EVALUATION

The Peak Signal Noise Ratio (PSNR) is used to evaluate the fidelity of the watermarked image, and PSNR in decibels (dB) is given below in equation:

$$PSNR_{dB} = 10 \times \log_{10}^{\frac{255^2}{MSE}}$$

The Normalized Hamming Similarity (NHS) is used to measure the similarity between the original (*W*) and extracted watermarks (*W**), and it can be calculated as equation.

$$NHS = 1 - \frac{HD(W, W^*)}{32 \times 32}$$

where *HD*(*W*, *W**) is the Hamming distance between two binary sequences, and it can be calculated as follow:

$$HD = \sum_i \sum_j x\ or\ (W(i, j), W^*(i, j))$$

In general, a correlation coefficient of about 0.7 or above is considered acceptable.

The Figures 4a and 4b show original image and watermark image which are used in this experiment, respectively. The Figures 5a and 5b depict watermarked image and watermark which extracted after no attack, respectively.

In order to get the measure of the robustness of the presented algorithm, several image processing attacks are implemented

Figure 4: (a) Host Image; (b) Watermark Used in the Experiments

(a)

(b)

Figure 5: (a) Watermarked Image; (b) Watermark Which Extracted After No Attack

(a)

(b)

on the watermarked image. The presented method and experiments are implemented using MATLAB. The performance analysis results are cited in Table 1.

Table 1: Results of the Experiments Using PSNR and NHS for Testing Robustness

Attack	PSNR	NHS
No Attack	48.42	0.9343
Guassian Noise (10%)	25.75	0.9172
Salt and Pepper Noise (10%)	20.94	0.8895
Average-Filtering (hsize = 3)	31.81	0.8674
Cropping	24.86	0.8343
Rotation (45° in Clockwise)	31.79	0.6254
Scaling (S = 50%)	30.22	0.8213
JPEG (QF = 50)	31.73	0.8912

CONCLUSION

A DWT-DCT digital image watermarking algorithm for image copyright protection is presented in this paper. Watermarking is done with embedding the watermark in the special middle frequency sub-bands of 3-levels DWT transformed of a host image, followed by computing DCT on the selected DWT sub-bands. Implementation results show that the imperceptibility of the watermarked image is acceptable. The watermarks can be extracted from the most of the common image processing attacks with high NHS values except for image rotation attack.

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