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Research paper

Digital Watermarking Based on DWT (Discrete Wavelet Transform) and DCT (Discrete Cosine Transform)

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Abstract

Digital watermarking is a technique to secure privacy of digital information and it's an important research area. There is a high risk in piracy with technology developments. Therefore, digital watermarking methods are necessary to solve the problem of content authentication and copyright protection. Digital data is available such as images and videos. The increased value of digital content makes new challenges to secure the digital media. Several digital watermarking methods are actually proposed in special domain and transforms domain. Spatial domain methods still have relatively low-bit capacity. Frequency domain-based methods are more robust and can embed more bits for watermark. watermarking in the frequency domain includes: Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). In this work, digital watermarking method for embedding and extraction copyright protection based on DWT and DCT is proposed. The two methods taking benefit from the advantages of both techniques and make one hybrid method. The combined method is applied on two-dimensional images (original cover image and watermark image). This watermarking method provides good performance and strong robustness.

Keywords: *Digital Watermarking; Frequency Domain; Video Tampering; and Temporal Attacks.*

1. Introduction

Digital watermarking is the technique of embedding secret data into a multimedia which include: video, image, song, and documentation. This information embedded in a way to extract and detect even when the image is modified. Watermarking methods are used to secure digital information [1]. Cover image must be inserted to hidden image then watermarking image can be extracted. In Digital watermarking method, host image is embedding with information which is called watermark, and then transmit the watermark image which later can be extracted by the receiver [2]. Digit watermarks must match the following requirements: Imperceptible, Reliable, Secure, Robust, and Unambiguous.

Currently, digital watermarking is very important activity in research are as a result of the quick development of digital multimedia and information, Watermarking methods are actually used to secure the information and is commonly used to steady the ownership of image, video, audio, and text [3]. Digital watermarking methods can be divided into two domains which are: spatial domain watermarking and frequency domain watermarking [1].

Spatial domain watermarking methods modify the pixel values of the mask image, based watermarking deals with modifying the pixels of one or two randomly selected subsets of image. Method implementation computation is very fast and simple but is not strong against attacks [3][4].

Frequency domain watermarking methods embed the watermark in the coefficients of transformed image, frequency domain is commonly used in current watermarking methods which include: Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Discrete Fourier Transform (DFT) and Singular Valued Decomposition (SVD). Watermarking methods in frequency domain comes with some advantages include: better robustness and the ability to represent information with small number of coefficients [5].

DCT is similar to Fourier Transform which represents data in terms of frequency space rather than an amplitude space and this is valuable simply because it corresponds more to the way humans perceive light [3]. Therefore, the part that are not considered can be identified and rejected. DCT based watermarking methods are robust compared to spatial domain methods [4].

DWT is actually used in several signal processing applications include: video and audio compression, removal of noise in audio, and the simulation of wireless antenna distribution. One of the biggest challenges of digital watermarking is to reach an improved trade-off between robustness and perceptivity [2]. Robustness can be accomplished by increasing the strength of the embedded watermark, but visible distortion should be also increased [6].

DWT is preferred simply because it provides both simultaneous spatial localization and frequency spread of the watermark within the host image. The main idea of DWT in image process is to multi differentiated decompose the image into sub-image of different spatial domain and independent frequencies [6][7].

A watermarking method is a procedure to embeds data or image into a digital object. This data or image can be later extracted or detected by reversing the same watermarking method used in the embedding process. The host image is used to handle this data or image which is called original image or cover image. A watermarking method is a process used to put a data inside a cover image in order to protect image copyright ownership [5][7].

Image watermarking methods are classified based on five perspectives including: Visibility, Application, Fragility, Extraction, and Domain of Transformation [5][6]. In this paper, we focus on domain of transformation classification which consist of spatial domain and frequency domain. In spatial domain methods, watermark information is embedded straight into image pixels. The images are manipulated by changing bits value. In frequency domain methods, watermark information is embedded in the transform domain [4][8]. The methods used in frequency domain have their own advantages. The Classification of image watermarking diagram is shown in Figure 1.

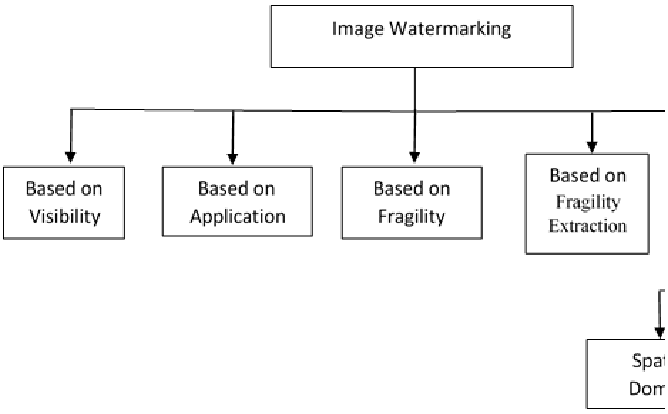

Fig. 1: Digital watermarking classification.

2. Digital Watermarking Applications

Digital image watermarking can be used in several applications. In this section, we focus on several main areas that cause the development watermarking methods [9]. This set of applications does not include all the possible areas of application in digital watermarking, which are actually include several other applications, but it includes the majority of applications that we have found valuable. Table 1 show several digital watermarking application areas [10][11].

Table 1: Digital Watermarking Applications.

AREA	DESCRIPTION
Copyright Protection and Owner identification	Watermarking is commonly used for copyright protection. The watermark information belongs to the owner of the original image.
Broadcast monitoring	Watermarking are useful to help automate the identification of broadcast programs. A watermark is placed into the data broadcasted over the network.
Data Hiding	Watermarking is the carrier of an important message, which is embedded and for some reason coded to be able to transmit it in such a way that it would not be detected by the unauthorized person.
Data Authentication	Watermarking allows detection of modifies or processing released into the image. Fragile watermark is used, that would not be extracted if the data is corrupted.
Medical Safety	Watermarking means that patient's name and some other data about patient is embedded into medical images, that is going to make simpler medial information search and increase security.
Indexing	Watermarking is widely used in several multimedia applications to insert indexing and protect information.

3. The Proposed System

In this work, digital watermarking technique for embedding and extraction copyright protection based on DWT and DCT is proposed. These techniques are frequency domain methods and is used in this work because it is more robust than spatial domain methods. DWT and DCT methods are applied on two-dimensional images and can be also applied on digital video sequence. The combined digital watermarking method which include embedded and extraction is explained.

Watermark Embedding Process:
In this process, the watermark is selected upon your choice. And then, this watermark is embedded on the digital data. The selection of watermark is depending on data type whether it is original or compressed data and whether the watermark is visible or invisible. Figure 2 show digital watermarking embedding process diagram.

Watermark Extraction Process:
In this process, the watermark is extracted from the watermarked digital data which is used in the embedding process. This actually done to make sure that the watermarking technique reason is achieved. Figure 3 show digital watermarking extraction process diagram.

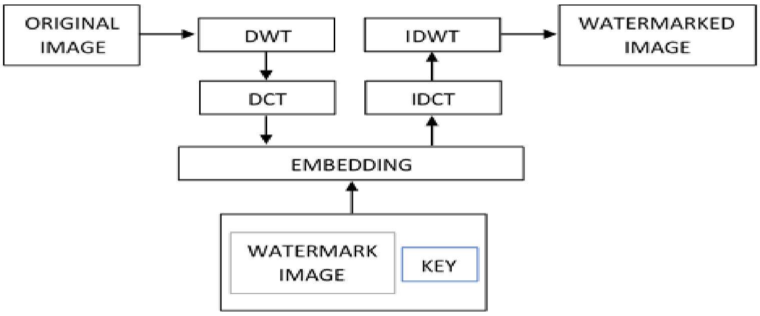

Fig. 2: Digital Watermarking Embedding Process.

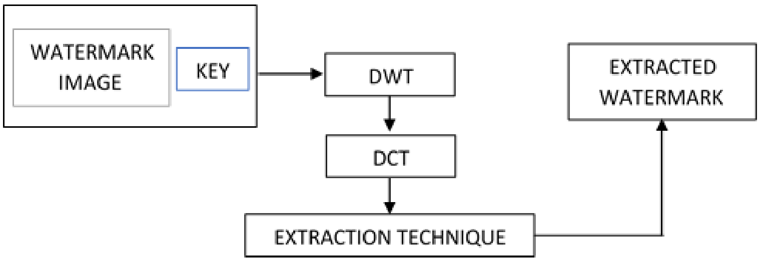

Fig. 3: Digital Watermarking Extracted Process.

Watermark Embedding Algorithm:
Step 1: Select two images: a. Cover image. b. Watermark image. Figure 4 show an example of the two images.

Fig. 4: Cover Image and Watermark Image Example.

Step 2: Cover image will be converted into gray scale image as shown in Figure 5.

Fig. 5: Convert RGB to Gray-Scale Image.

Step 3: Reading both images (cover image and watermark image) to get the two images matrices.
Step 4: Apply DWT method to divide the cover image into four sub-bands: LL1, HL1, LH1, and HH1 as shown in Figure 6.

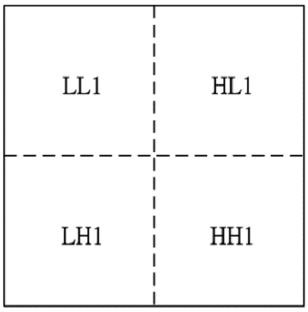

Fig. 6: Cover Image Is Divided into Four Sub-Bands.

Step 5: Divide HL1 or HH1 sub-bands into 16 x 16 blocks.
Step 6: Apply DCT watermarking to each block.
Step 7: Convert the grey-scale watermark image to a vector consist of zeros and ones.

$$\text{Watermark Image} = \begin{bmatrix} 206 & 171 & 127 & 127 \\ 207 & 170 & 131 & 125 \\ 206 & 171 & 135 & 126 \\ 207 & 169 & 119 & 129 \\ 206 & 170 & 130 & 124 \\ 206 & 171 & 132 & 121 \end{bmatrix}$$

$$\text{Watermark Vector} = [1 \;\; 0 \;\; 1 \;\; 0 \;\; 1 \;\; 1 \;\; 0 \;\; 0 \;\; 1 \;\; \ldots]$$

Step 8: Generate two sequences S1 and S2. S1 sequence is used to embed the watermark bit 0 and S2 sequence is used to embed the watermark bit 1. Elements number in S1 and S2 sequences must be equal to the number of mid-band elements of the DCT transformed DWT sub-bands.
Step 9: Embed the two sequences with a gain factor in the DCT transformed 16x16 blocks of the selected DWT sub-bands of the host image. Embedding is applied only to the mid-band DCT coefficients.

$$\text{Watermark Bit} = \begin{cases} 0 & X' = X + * S1 \\ 1 & X' = X + * S2 \end{cases}$$

Where, X is the mid-band coefficient of the DCT transformed block.
Step 10: Apply IDCT (Inverse DCT) to each block.
Step 11: Apply IDWT (Inverse DWT) on the DWT transformed image to produce the watermarked original image.

Watermark Extraction Algorithm:
Step 1: Apply DWT to divide the watermarked image into four sub bands: LL1, HL1, LH1, and HH1.
Step 2: Divide the sub-band into 16x16 blocks.
Step 3: Apply DCT to each block in the chosen sub-band and extract the mid-band coefficients of each DCT transformed block.
Step 4: Regenerate two different sequences S1 and S2 using the same seed used in the watermark embedding procedure.
Step 5: For each block in the sub-band, calculate the correlation between the mid-band coefficients and the two generated sequences S1 and S2.
If the correlation with the S1 was higher as compared to the correlation with S2, then the extracted watermark bit is considered as 0, otherwise the extracted watermark is considered as 1.
Step 6: Recover the watermark using the extracted watermark bits and compute the similarity between the original image and extracted watermarks.

3.1. Discrete Cosine Transform (DCT)

The Discrete Cosine Transform (DCT) turns a signal into the frequency domain which is effective in image processing, specifically in JPEG and MPEG compression as a result of good performance [12]. DCT is used in several fields include: pattern recognition, data compression, image processing, etc.
DCT transforms real data into real spectrum as well as reduce the problem of redundancy. The well-known block-based DCT transform segments an image non-overlapping block and applies DCT to each block [13].
DCT divide each image into parts of different frequencies where less important frequencies are rejected simply by quantization and important frequencies have been used to collect the image through decompression [14].
The DCT provides an image to be divided into different frequency bands which is much better and easier to embed watermarking information into middle frequency bands. The DCT transform and IDCT transform can be calculated as shown in the equations below:

$$F(u,v) = \frac{4C(u)C(v)}{n^2} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} f(i,j) \cos\left(\frac{(2i+1)u\pi}{2n}\right) \cos\left(\frac{(2j+1)v\pi}{2n}\right) \quad (1)$$

$$f(i,j) = \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} C(u)\, C(v)\, F(u,v) \cos\left(\frac{(2i+1)u\pi}{2n}\right) \cos\left(\frac{(2j+1)v\pi}{2n}\right) \quad (2)$$

Where $C(w) = 1/\sqrt{2}$, When $w = 0$, $C(w) = 1$, When $w = 1,2,3,\ldots,n-1$

3.2. DWT (Discrete Wavelet Transform)

The Discrete Wavelet Transform (DWT) is a frequency domain method which is commonly used in image processing. This method in image processing includes decomposition images into frequency channels of constant bandwidth [13]. DWT offers a number of image processing algorithms including: noise edge detection, reduction, and compression.
Two-dimensional image is divided into four sub-bands, which include: LL, LH, HL and HH at level 1 DWT domain where the first letter means using low-pass or a high-pass frequency operation to the rows and second letter refers to which filter is applied to the columns [13][14]. Each sub-band can be also divided until the required number of levels is achieved. The human visual system is way more sensitive to the LL sub-band which represent low frequency component and the digital watermarking is commonly embedded in one or more of the other three sub-bands which have better image quality [15].
A two-dimensional image after one-level, two-level, and three-level DWT decomposed is shown in Figure 7.

(A) **(B)** **(C)**

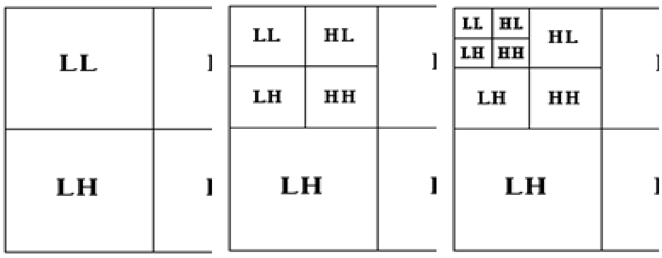

Fig. 7: DWT Decomposed (A) One Level Decomposed. (B) Two Level Decomposed. (C) Three-Level Decomposed.

4. Result and Discussion

This work is implemented using a laptop with Intel® Core™ i7-5500 CPU 2.40 GHz, 12 GB RAM. MATLAB R2015a software is used to build the application program. The program divided into two steps: Watermark Embedding step and Watermark Extraction step.

The performance evaluation of the proposed DWT-DCT image watermarking method using 512x512 'Lena' image as the original cover image as shown in Figure 8 and 256x256 gray-scale image as copyright watermark image as shown in Figure 9.

Fig. 8: Original Cover Image.

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Fig. 9: Copyright watermark Image.

The watermarking performance was evaluated using two different watermarking methods. The results from DWT and DCT methods indicated a good performance but the robustness performance was not acceptable. The embedded and extracted DCT watermarking results are shown in Figure 10 and Figure 12. The embedded and extracted DWT watermarking results are shown in Figure 11 and Figure 13.

The combined DWT+DCT watermarking method performance was better. The improvement in robustness brought by the combined DWT-DCT method was considerably high. The embedded watermarking result is shown in Table 2.

Fig. 10: DCT Watermarking Embedded Image.

Fig. 11: DWT Watermarking Embedded Image.

Fig. 12: DCT Watermarking Extracted Image.

Fig. 13: DWT Watermarking Extracted Image.

Table 2: Embedded Watermarking Results

Method	Original Image	Message Image	Watermarked Embedded Image	Time
DCT				2.9 Sec
DWT				31.5 Sec

DWT+DCT				3.4 Sec

5. Conclusion

The Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) have been applied successfully in several digital image watermarking. In this work, we proposed a combined DWT+DCT digital image watermarking method. These techniques are frequency domain methods and is used in this work because it is more robust than spatial domain methods. Embedded and extraction watermarking is tested using DWT watermarking method, DCT watermarking method and the proposed combined watermarking method. The combination of the two image watermarking methods benefits from the advantage of each method and improved the watermarking performance considerably when compared to the original DWT and DCT watermarking methods.

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