Comparisons between 2D Discrete Cosine Transforms (2D DCT), 2D Discrete Fourier Transforms (2D DFT), and 2D Discrete Wavelet Transforms (2D DWT) in Digital Image Watermarking

Rosa Andrie Asmara, Reza Agustina, Hidayatulloh
Information Technology Department
State Polytechnics of Malang
Indonesia
rosaandrie@gmail.com

Abstract— **Digital Image Watermarking is used recently to secure the image by embedding another digital image. It is typically used to identify ownership of the copyright of the signal. Frequency domain transformation methods used widely in Digital Image Compression and Digital Image Watermarking. They reduce the weakness of classics digital image watermarking such as Least Significant Bit (LSB) methods which is more noise-tolerant. Popular transformation method used are Two Dimensional Discrete Cosine Transform (2D DCT), Two Dimensional Discrete Fourier Transforms (2D DFT), and Two Dimensional Discrete Wavelet Transform (2D DWT). This paper will show the comparison result of those three transformation method. The experiments are comparison analysis of image watermark quality using Peak Signal to Noise Ratio (PSNR), color converting, image resizing, image optical scanning and the noise-tolerant of the image watermarked by giving Gaussian noise.**

Keywords—Digital Image Watermarking, 2D Discrete Cosine Transform (2D DCT), 2D Discrete Fourier Transform (2D DFT), 2D Discrete Wavelet Transform (2D DWT), Least Significant Bit method (LSB), Digital Signal Processing

I. Introduction

Digital Image Watermarking is used recently to secure the image by embedding another digital image. Komatsu and Tominagaare the first person using the term Digital Watermarking [1]. It is typically used to identify ownership of the copyright of the signal. The information are embedded in image is called a "digital image watermark". The information where the watermark is to be embedded is called a "host image" [2,3]. Traditional method for Digital Image Watermarking used Least Significant Bit (LSB). Many researcher proposed the LSB method with some improvement and analysis to create better digital image watermark results [4,5,6]. The method for LSB will be explained detail in the Section 2.

LSB method for digital image watermarking have a weakness which is cannot handle simple noise. Image watermarked also will loss the watermark information if some image processing is implemented such as Image Resizing and Image Cropping. Some Frequency Domain Transformations method is implemented to handle such weakness in traditional method. It is also proved that even the image is printed and scanned to return the format in digital, the watermark image can also be extracted smoothly.

Discrete Cosine Transform (DCT) are popular among science and engineering application, from image watermarking, steganography, and lossy compression for audio and image. Cosine function is used rather than sine function due to the critical for compression, fewer cosine function are needed to approximate the typical signal. Cosine function also express a particular choice of boundary condition in differential equations. DCT is similar to the Discrete Fourier Transform (DFT), but using only real numbers. DCT are equivalent of DFT of roughly twice the length, operating on real data with even symmetry and in some variants the input or output data are shifted by half a sample.

The remainder of this paper is organized as follows: Section 2 explained the 2D DCT, 2D DFT, and an effective method of skeleton extraction. Section 3 describes the two-round hierarchical matching for Chinese calligraphic retrieval. Section 4 presents the experiments and evaluation. Conclusion and future work are given in the final section.

II. Proposed Method

A. Digital Image Watermarking

Digital image watermarking is one of the steganography branch, which is a technic to hide information in a digital

media. The purpose is to protect important information [8]. The information inserted in digital image watermarking can be in text, image, or audio format file. There are some criteria to create good image watermarking:

- *Imperceptibility:* Good *Watermark* is invisible by human eye. One cannot distinguished well between original and watermarked image.

- *Robustness* : Good Watermark have to be resists with file manipulation such as file compression, image noising, color converting, image resizing.

- *Security* : watermarked file can only detected by the file owner or authorized ones.

- *Recovery* : Watermarked file must be converted back to original file. Main purpose of watermarking is for copyrighting file owner, which can be used for file authorization.

B. Least Significant Bit Method

Least significant bit (LSB) is very simple and less computation cost compare to the other method of transformations. Figure 1 shows the insertion method in LSB. For every bit starting from MSB of watermark image pixel is inserted to the LSB of some image source pixel. The results will be the addition of 1 if the watermark bit is 1 and same as previous value if the watermark bit is 0. Human eyes will be difficult to distinguishing the image source before and after watermarking. However this method face some image processing implementations such as Image Resizing and Image Cropping due to the pixel value modification. The PSNR of the LSB 1 bit substitution is 55.8784 [4].
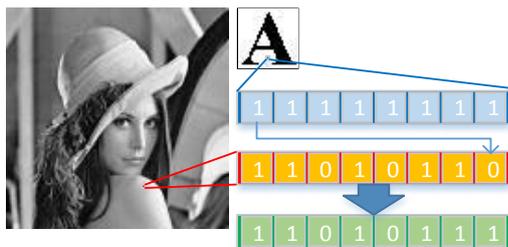

Fig. 1. LSB method of Digital Image Watermarking

C. 2D Discrete Cosine Transform (2D DCT)

DCT in image processing is first introduced by Ahmed, Natarajan and Rao [7]. DCT is similar to DFT, but using only real numbers. DCT turn over the image edge to make the image transformed into other form of even function. This is one of linear transformations in digital signal processing. 2D DCT is defined as:

$$F(jk) = a(j)a(k)\sum_{m=0}^{N-1}\sum_{n=0}^{N-1} f(mn)\cos\left[\frac{(2m+1)j\pi}{2N}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (1)$$

The corresponding inverse discrete cosine transformation (2D-IDCT) is defined as:

$$f(mn) = \sum_{m=0}^{N-1}\sum_{n=0}^{N-1} a(j)a(k)F(jk)\cos\left[\frac{(2m+1)j\pi}{2N}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (2)$$

The 2D-DCT can not only focusing on transform the main information of original image into the smallest low-frequency component, but also it can cause the image blocking effect being the smallest, which can realize the good compromise between the information centralizing and the computing complication, thus it obtains the wide spreading application.

D. 2D Discrete Fourier Transform (2D DFT)

Consider one N1 x N2 image, f(n1,n2), where we assume that the index range are n_1 = -M_1,…,M_1 and n_2 = -M_2,…,M_2, for mathematical simplicity, and hence N_1 = 2M_1 + 1 and N_2 = 2M_1 + 1. Let $F(k_1,k_2)$ denote the 2D discrete Fourier Transform (2D DFT) of the image. $F(k_1,k_2)$ are given by

$$F(k_1, k_2) = \sum_{n_1 n_2} f(n_1, n_2) W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2} = A_F(k_1, k_2) e^{j\theta_F(k_1, k_2)} \quad (3)$$

Where k_1 = -M_1,…,M_1, k_2 = -M_2,…,M_2, , , and the operator denotes $\sum_{n_1=-M_1}^{M_1}\sum_{n_2}^{M_2}$ is an amplitude component, and is a phase component.

The 2D Inverse Discrete Fourier (2D IDFT) of is given by

$$f(k_1, k_2) = \frac{1}{N_1 N_2} \sum_{k_1 k_2} F(k_1, k_2) W_{N_1}^{-k_1 n_1} W_{N_2}^{-k_2 n_2}$$

Where denotes

E. 2D Discrete Wavelet Transform (2D DWT)

Discrete wavelet transform (DWT) represents an image as a subset of wavelet functions using different locations and scales. It makes some decomposition images. Any decomposition of an image into wavelet involves a pair of waveforms: the high frequencies corresponding to the detailed parts of an image and the low frequencies corresponding to the smooth parts of an image. DWT for an image as a 2-D signal can be derived from a 1-D DWT. According to the characteristic of the DW decomposition, an image can be decomposed to four sub-band images through a 1-level 2-D DWT, as shown in **Error! Reference source not found.**. These four sub-band images in Fig. 4 can be mapped to four sub-band elements representing LL (Approximation), HL (Vertical), LH (Horizontal), and HH (Diagonal) respectively.

The discrete Wavelet Transform will decompose a given signal into other signal known as the approximation and detail coefficients. A given function f(t) can be expressed through the following representation:

$$f(t) = \sum_{j=1}^{L}\sum_{K=-\infty}^{\infty} d(j,K)\varphi(2^{-j}t - K) + \sum_{K=-\infty}^{\infty} a(L,K)\theta(2^{-L}t - K) \quad (4)$$
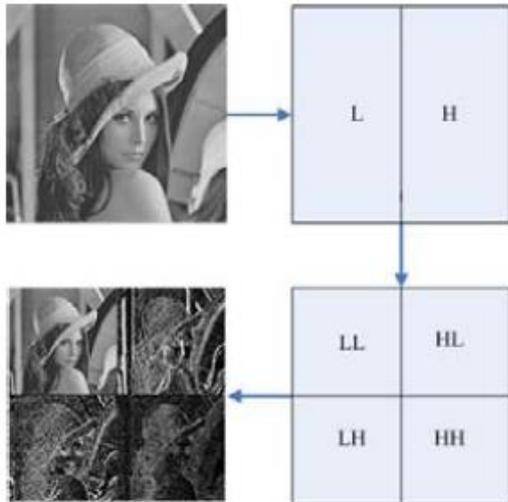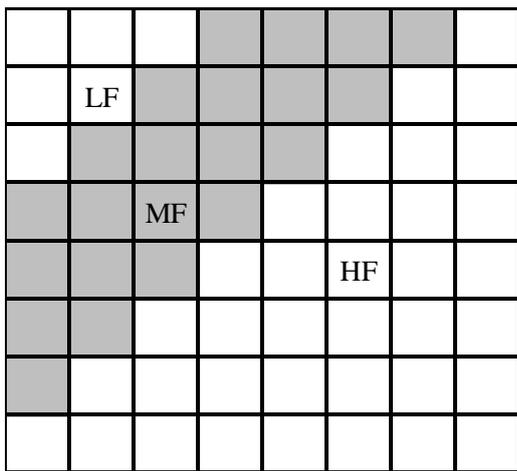

Fig. 2. 1-Level Decomposition 2D DWT

Fig. 3. DCT Frequency components

Fig. 4. Watermark image steps in frequency domain transform

Where: is the mother wavelet and   is the scaling function. *a*(L,K) is called the approximation coefficient at scale L and d(j,K) is called the detail coefficients at scale j. The approximation and detail coefficients can be expressed as:

$$a(L,K) = \frac{1}{\sqrt{2^L}}\int_{-\infty}^{\infty} f(t)\theta(\quad (5)$$

$$d(j,K) = \frac{1}{\sqrt{2^j}}\int_{-\infty}^{\infty} f(t)\varphi(\quad (6)$$

Based on the choice of the mother wavelet $\varphi(t)$ and scaling function $\theta(t)$, different families of wavelets can be constructed.

F. Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR)

Peak signal-to-noise ratio (PSNR) is a ratio between maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR is usually expressed in terms of the logarithmic decibel scale. The signal is an original data, and the noise is the error from watermark system.

PSNR usually defined via the mean squared error (MSE). Given a noise-free m x n image I and noisy approximation K, MSE is defined as:

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(I(i,j) - \quad (7)$$

The PSNR (in dB) is defined as:

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$
$$= 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$
$$= 20\log_{10}(MAX_I) - 10\log_{10}(MSE) \quad (8)$$

Where, MAX_I is the maximum possible pixel value of the image. When the pixels are represented using 8 bits per sample, this is 255.

III.   EXPERIMENTS

Figure below shows the general watermark image steps in frequency domain transforms.

The usage of DCT, DFT, and DWT in image watermarking start by dividing image to 8x8 pixel sub-block.These sub-block will consist of 64 coefficient (1 DC-zero frequency coefficient and 63 AC coefficient in low frequency, middle frequency, and high frequency. Figure 4 shows the DCT frequency division.

LF represents the low frequency, MF represents middle frequency, and HF represents sub-block highest frequency. In DCT transform, LF can be found in every edge and corner of image sub-block. In DCT and DFT, watermark bit image will be put in LF. In DWT, watermark bit image will be put in LH and HL. Figure 5 shows the diagram block for DCT watermarking process. This diagram block also represents for DFT and DWT.
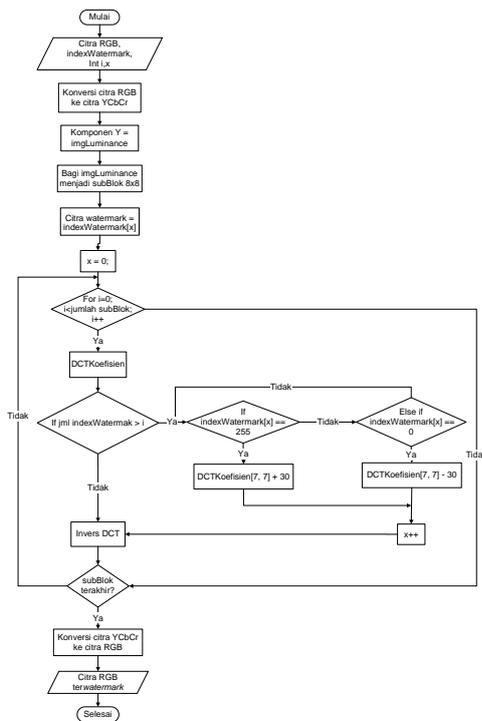

Fig. 5.   Diagram blocks of DCT image watermarking

- *User* input *host image*, RGB image in which watermark image will be inserted. Watermark image will used binary image provided.
- RGB image will be converted to YCbCr color space, Y color space (luminance) component is the only component where the watermark image will be inserted, and thus the Y-component transformed using DCT, DFT, and DWT. Y-component is used because human perception more sensitive to the light intensity, and the result for watermarked image will imperceptible. *Chrominance blue* (Cb) and *chrominance red* (Cr) component will not transform and will be used only for Inverse Transform.
- Y-component is divided into 8x8 sub-blocks.

- Each 8x8 sub-blocks then transforms using DCT, DFT, and DWT. Image watermark is a binary image with 0 and 1 pixel value. If the pixel value is 1 in the watermark image, then the sub-block host image in index [7, 7] will be add with 30, otherwise will be subtract with 30. This process is then repeated until the last watermark image pixel. The Y-component then detransformed using inverse-DCT, inverse-DFT, and inverse-DWT to get Y-component watermarked image.
- Y-component is combined again with Cb-component and Cr-component to get YCbCr watermarked image.
- Last proses is YCbCr watermarked converted again to RGB Space to get RGB watermarked.

IV.   CONCLUSION

Frequency domain transformation methods used widely in Digital Image Compression and Digital Image Watermarking. It is reduce the weakness of classics digital image watermarking such as Least Significant Bit (LSB) methods which is more noise-tolerant. Popular transformation method used are Two Dimensional Discrete Cosine Transform (2D DCT), Two Dimensional Discrete Fourier Transforms (2D DFT), and Two Dimensional Discrete Wavelet Transform (2D DWT). This paper proposed the comparison between those three transformation methods. The experiments are image watermark quality analysis using Peak Signal to Noise Ratio (PSNR), Computation cost, and the noise-tolerant of the image watermarked by giving Gaussian noise in it. The experiments will shows result of:

- Which is the best frequency in DCT-Transform, DFT-Transform, and DWT-Transform used for watermark image.

- Which is the best transform used for watermarking.

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