Digital Watermarking for Color Image Using DHWT and LSB

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Abstract*—Copyright infringement is a serious problem in the creative industry especially with the massive growth of digital content creations. Digital watermarking is a method that could be used for protecting copyright infringement. The aim is to embed a digital watermark secretly into the digital content (image). This paper proposes Discrete-Haar Wavelet Transform (DHWT) method and (LSB) steganography method for digital watermarking. As a demonstration of concept, an application is developed for watermarking color images. The testing and evaluation results show that the average PSNR for images with 512x512 pixels resolution is 76.918 dB, for images with 1024x1024 pixels resolution is 85.065 dB, and for images with 2048x2048 pixels resolution is 85.15 dB.

***Keywords*—DHWT, digital watermarking, LSB, steganography**

I. INTRODUCTION

Copyright Infringement is a serious problem in the digital era today. According to the United States Trade Representative, there are eleven countries included in the priority watch list and twenty-three country are included in the watch list in terms of copyright infringement [1]. The protection of digital intellectual properties such as images, videos, and audios (music) is essential to address this problem.

One solution that could be used to handle copyright protection is by using a Digital Right Management (DRM) technology. The purpose of DRM is to regulate access, tracking, and limit the use of digital creation [2]. One of the DRM technics is digital watermarking. Digital Watermarking is a method to hide message about images, audios, and other media inside another media [3].

Related studies on digital watermarking using discrete wavelet transform (DWT) in [4], least significant bit (LSB) in [5], and discrete cosine transform (DCT) in [6] show that the implementation of digital watermarking for color images is feasible. This paper proposes DHWT (Discrete-Haar Wavelet Transform) due to its low computing requirements and it is highly suitable for two-dimensional signal processing applications.

The DHWT method is combined with LSB (least significant bit) to add more security to the digital contents. Here, color images are chosen as the media for inserting the digital watermark. LSB is a famous tool for doing steganography. Thus, by combining the two methods, the color image is protected by a digital watermark that is hidden from the human's eyes.

II. LITERATURE REVIEW

A. Digital Watermarking

Watermarking is a technic for inserting or hiding a piece of secret information inside a host without changing the host so that there is no difference in the host before and after the watermarking process. Watermark can be a text, image, audio, or random bit with no meaning. Watermark is inserted on digital data without damaging the data. The watermark that has been inserted cannot be erased from the host and will be carried away when the host is copied or spread.

Watermarking technique divided into two, embedding watermark inside the host (embedding watermark) and extract the watermark from the host (extraction watermark). Terms on the good watermarking process are [7].

a. Fidelity: Quality of the host do not change too far after the watermarking process.
b. Imperceptibility: watermark cannot be seen by the eyes
c. Key uniqueness: unique key required to extract the watermark.
d. Non-invertibility: need original data to get back the watermark
e. Recovery: watermark must be retrieved from the host.
f. Robustness: watermark must be robust from an attack that can happen on the host towards the watermark.
g. Tamper resistance: watermarking must persist toward attack for change, erase, or add false watermark to the host.

B. Discrete Haar Wavelet Transform (DHWT)

Discrete wavelet transform (DWT) founded in 1976. DWT does digital imaging with a digital filter or changes the signal to different frequency or scale [7]. DHWT is the first DWT method and becomes the basis of DWT. DHWT founded by Hungarian mathematician Alfred Haar. DHWT have two processes forward and inverse. The forward process is a process of changing the image to frequency. Result of the forward process is an image with four-part that is a low-frequency image (LL), medium frequency image (LH & HL), and high-frequency image (HH). Division of the image can be seen in Fig. 1.

Discrete Wavelet Transform (DWT) founded on 1976. DWT performs a digital imaging using digital filtering techniques or in other words separate the signal into different frequencies and scales [7]. DHWT was one of the first DWT techniques to be discovered and became the theoretical basis in the DWT technique.

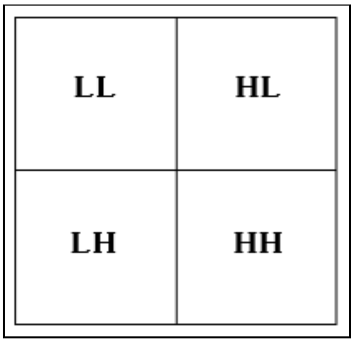


Fig. 1. DHWT forward process.

The image that will be used for the watermarking process is the low-frequency image because its more robust in terms of compression file attack [8]. In this research, the value of the watermark will be inserted inside the blue value because blue is a color that has the highest frequency range so the changes are not visible to the eyes.

Watermark insertion process with DHWT is as follows [4].

1. Get RGB value from each pixel image.
2. Do forward process on the RGB value. Calculation of the frequency on DHWT can be written down as.

$$a = \frac{(x_i + x_{i+1})}{2} \quad (1)$$

$$d = \frac{(x_i - x_{i+1})}{2} \quad (2)$$

   Where:

   a, d = value of the frequency and will be used in the inverse process; and

   x_i , x_{i+1} = pixel coordinates

3. Inserting watermark using LSB method.
4. Changing back the frequency to the image. The changing process with the inverse process can be written down as.

$$x_i = a + d \quad (3)$$

$$x_{i+1} = a - d \quad (4)$$

   Where:

   a, d = value of frequency from forward process

   x_i , x_{i+1} = pixel coordinates

The extraction process on DHWT is as follows.

a. Get RGB value from each pixel image.
b. Do forward process on the RGB value.
c. Extract watermark using LSB method.
d. Change back into image using the inverse transform.

C. Least Significant Bit (LSB)

Least Significant Bit (LSB) method is one of the watermarking methods that use Spatial method. Every byte contains an 8-bit value. LSB is using the smallest value so the changes are not seen by eyes. LSB method will change the smallest value of the frequency value from the forward process into watermark value [9]. Thus, the least significant bit for little endian system is 1 for 10001001. Embedding “1010” to “00011010 10001101 01101100 01010101” will become “00011011 10001100 01101101 01010100”.

D. Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) is a parameter to measure the quality of the image that has already been inserted the watermark. PSNR shows the comparison between the maximum value of the signal that been measure from the noise affecting the signal. Before calculating the PSNR, it needs to calculate the average error (Mean Square Error – MSE) first. Formula to calculate MSE can be written down as [6].

$$MSE = \frac{1}{n}\sum\left(I_{x,y} - I^*_{x,y}\right)^2 \quad (5)$$

Where:

$I_{x,y}$ = pixel value of the original image on the coordinate (x,y)

$I^*_{x,y}$ = pixel value of the watermarked image on the coordinate (x,y)

n = number of pixel from the image

The formula of PSNR can be written down as.

$$PSNR = 10log_{10}\frac{E^2_{max}}{MSE} \quad (6)$$

Where:

E_{max} = maximum value of the pixel

The higher the value of PSNR, the more likely the image with the original. If the original image is compared with the same image, the PSNR value will be infinite because of division by zero. PSNR value is appropriate to compare the difference between the original image and the edited image, but it cannot be used to compare between image. Image with PSNR value of 20 dB can be seen as more decent compared to image with PSNR value of 30dB. Comparison of PSNR ratio can be seen in Fig. 2.

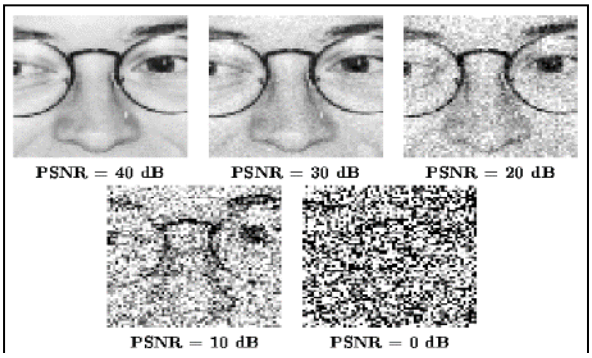


Fig. 2. Illustration of PSNR measurement [10]

III. IMPLEMENTATION

The implementation process of digital watermarking using DHWT and LSB method are as follows.

a. Application Homepage

In the homepage, user can choose which process to use. Embedding Watermark button will open an embedding page and extracting watermark button will open an extraction page. Image of application homepage can be seen in Fig. 3.

Fig. 3. Home menu

b. Embedding Page

On the embedding page, the user is asked to choose a host image and a watermark image. Host image must have a resolution of multiple by 2 and watermark image must have resolution sized of 1/32 from the host image. After both images selected click the embed watermark button to start the process. After the process finished, it will automatically open a save dialog to save the watermarked image to the device. Image of embedding page can be seen in Fig. 4.

Fig. 4. Embedding tab

c. Extracting Page

On extraction page, the user is asked to choose a watermarked image that has been saved from the embedding process. Host image must have a resolution of multiple by 2. After the image selected, click the extract watermark button to start the extraction process. The watermark that has been extracted is shown on the application and can be saved if the save watermark button clicked. Image of extraction page can be seen in Fig. 5.

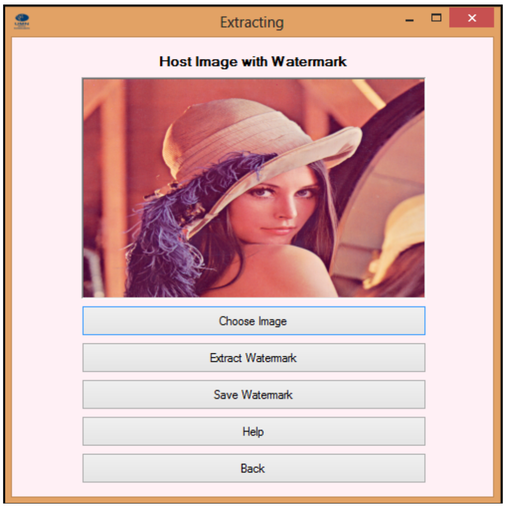


Fig. 5. Extraction tab

IV. RESULT AND ANALYSIS

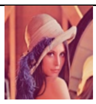
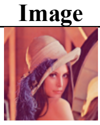
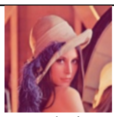
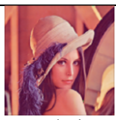
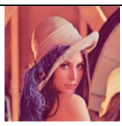
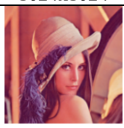
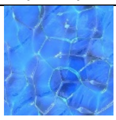
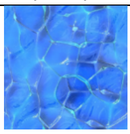
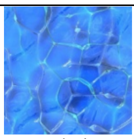
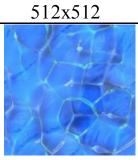
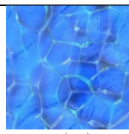
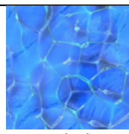
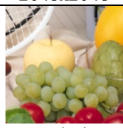
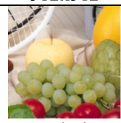
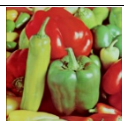
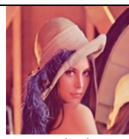
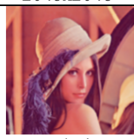
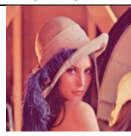
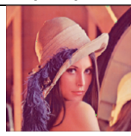
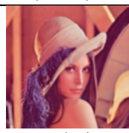
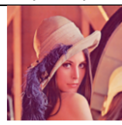
Application testing is done using images with resolutions of multiple of 2. This is due to DHWT process that uses values from a pair of two neighboring pixels. The watermark resolution is 1/32 of the host image resolution, since the watermark is inserted on the LL frequency part of the image only. It is equivalent to the ¼ resolution of the host image. Inside the ¼ resolution of the host image, it takes 8-bits to store 1-bit of the watermark.

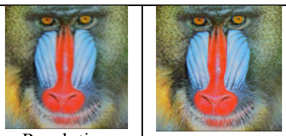
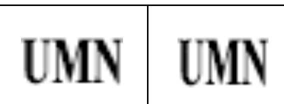
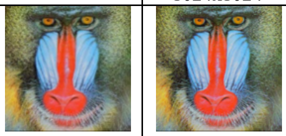
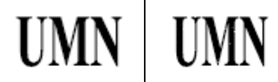
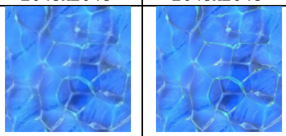
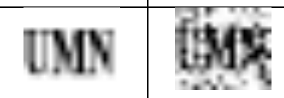
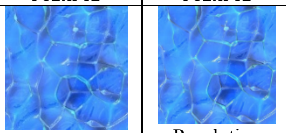
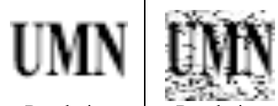
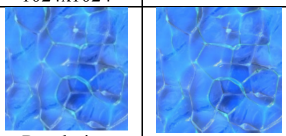
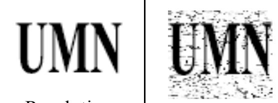
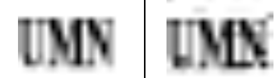
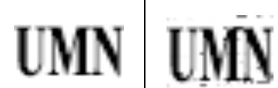
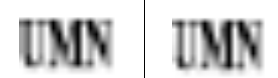
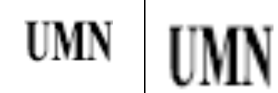
Application testing uses five host images and two watermark images. Each image has three resolutions: 512x512 pixels (host) and 16x16 pixels (watermark), 1024x1024 pixels (host) with 32x32 pixels (watermark), and

2048x2048 pixels (host) with 64x64 pixels (watermark). The five pictures are "line.png", "baboon.png", "fruit.png", "pepper.png" from [11], and "cell.png" from [12]. Watermark images are created using Adobe Photoshop.

On some cases, there are some value of the blue color is 255 and after the forward process, the value is even. The even value after LSB process become an odd value. After the inverse transform, this value is 256 or exceed the maximum value color. The same case happens with the value of 0 that after LSB and inverse transform become -1. In the process value, 256 is changed to 254 and value -1 is changed to 1 without erasing the watermark value inside it. Result of the testing can be seen in Table 1.

TABLE I. TEST RESULTS

No.	Host Image	Watermark Image	Original Watermark	Extracted Watermark
1	 Resolution 512x512	 Resolution 512x512	Resolution 16x16	Resolution 16x16
2	 Resolution 1024x1024	 Resolution 1024x1024	Resolution 32x32	Resolution 32x32
3	 Resolution 2048x2048	 Resolution 2048x2048	Resolution 64x64	Resolution 64x64
4	 Resolution 512x512	 Resolution 512x512	Resolution 16x16	Resolution 16x16
5	 Resolution 1024x1024	 Resolution 1024x1024	Resolution 32x32	Resolution 32x32
6	 Resolution 1024x1024	 Resolution 1024x1024	Resolution 64x64	Resolution 64x64
7	 Resolution 512x512	 Resolution 512x512	Resolution 16x16	Resolution 16x16
8	 Resolution 1024x1024	 Resolution 1024x1024	Resolution 32x32	Resolution 32x32
9	 Resolution 2048x2048	 Resolution 2048x2048	Resolution 64x64	Resolution 64x64
10	 Resolution 512x512	 Resolution 512x512	Resolution 16x16	Resolution 16x16
11	 Resolution 1024x1024	 Resolution 1024x1024	Resolution 32x32	Resolution 32x32
12	 Resolution 2048x2048	 Resolution 2048x2048	Resolution 64x64	Resolution 64x64
13	 Resolution 512x512	 Resolution 512x512	Resolution 16x16	Resolution 16x16
14	 Resolution 1024x1024	 Resolution 1024x1024	Resolution 32x32	Resolution 32x32
15	 Resolution 2048x2048	 Resolution 2048x2048	Resolution 64x64	Resolution 64x64
16	 Resolution 512x512	 Resolution 512x512	Resolution 16x16	Resolution 16x16
17	 Resolution 1024x1024	 Resolution 1024x1024	Resolution 32x32	Resolution 32x32
18	 Resolution 2048x2048	 Resolution 2048x2048	Resolution 64x64	Resolution 64x64
19	 Resolution 512x512	 Resolution 512x512	Resolution 16x16	Resolution 16x16

20	 Resolution 1024x1024	Resolution 1024x1024	 Resolution 32x32	Resolution 32x32
21	 Resolution 2048x2048	Resolution 2048x2048	 Resolution 64x64	Resolution 64x64
22	 Resolution 512x512	Resolution 512x512	 Resolution 16x16	Resolution 16x16
23	 Resolution 1024x1024	Resolution 1024x1024	 Resolution 32x32	Resolution 32x32
24	 Resolution 2048x2048	Resolution 2048x2048	 Resolution 64x64	Resolution 64x64
25	 Resolution 512x512	Resolution 512x512	 Resolution 16x16	Resolution 16x16
26	 Resolution 1024x1024	Resolution 1024x1024	 Resolution 32x32	Resolution 32x32
27	 Resolution 2048x2048	Resolution 2048x2048	 Resolution 64x64	Resolution 64x64
28	 Resolution 512x512	Resolution 512x512	 Resolution 16x16	Resolution 16x16
29	 Resolution 1024x1024	Resolution 1024x1024	 Resolution 32x32	Resolution 32x32
30	 Resolution 2048x2048	Resolution 2048x2048	 Resolution 64x64	Resolution 64x64

The Qualities of each of the test images are evaluated using PSNR. The PSNR value for each image could be seen on Table 2.

TABLE II. PSNR VALUE

No	PSNR
1	85.06 dB
2	85.07 dB
3	85.09 dB
4	64.25 dB
5	85.04 dB
6	85.04 dB
7	65.25 dB
8	85.40 dB
9	85.78 dB
10	85.08 dB
11	85.07 dB
12	85.07 dB
13	85.14 dB
14	84.91 dB
15	84.90 dB
16	85.03 dB
17	84.95 dB
18	85.08 dB
19	64.25 dB
20	84.99 dB
21	85.01 dB
22	65.25 dB
23	85.26 dB
24	85.60 dB
25	85.03 dB
26	85.06 dB
27	85.09 dB
28	84.84 dB
29	84.90 dB
30	84.84 dB

According to Table 2, there are no obvious differences on the watermarked image compared to the host image. The bigger the host resolution, then the bigger resolution watermark can be inserted and extracted watermark will be more clear. Host image with blue dominant color produces more low-quality watermark compared to other images because the watermark is inserted on the blue color of the host. The image quality of average resolution and watermark can be seen in Table 3.

TABLE III. AVERAGE PSNR VALUE

Host and Watermark Image Resolution	Average PSNR
512 x 512 and 16 x 16	76.918 dB
1024 x 1024 and 32 x 32	85.065 dB
2048 x 2048 and 64 x 64	85.15 dB

The bigger the host resolution the larger the PSNR value. Host image with bigger resolution could produce more clear watermark and have better image quality.

V. CONCLUSION

The development of a digital watermarking application for the color image using DHWT and LSB has been completed successfully in this work. The testing and evaluation processes deliver average PSNR value for

512x512 pixels host image with 16x16 pixels watermark image of 76.918 dB, for 1024x1024 pixels host image with 32x32 pixels watermark image of 85.065 dB, and 2048x2048 pixels host image with 64x64 pixels watermark image of 85.15 dB.

It shows that the bigger resolution of host image allow larger resolution of watermark image to be embedded. The extracted watermark will also be more clear compared to the smaller host resolution. Host image with the dominant color of blue produces lower watermark quality with higher PSNR value.

Further study of digital watermarking implementation in other applications such as for face recognition as in [13] and plagiarism detection as in [14] could be conducted in the future. The purpose is to study the usage of digital watermarking for other applications and to see whether or not the digital watermarking could enhance the security features of such applications.

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