Data Hiding Method for QR Code Based on Watermark by comparing DFT with DWT Domain

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***Abstract*—** Nowadays, commercial activities on internet and media. The 2D Barcode with a digital watermark is a widely interesting research in security field. The invisible watermark can prevent information hiding text in QR Code. This paper proposes QR Code (Quick Response Code) embedded technique for invisible watermarking by using Discrete-Fourier-Transform (DFT) compare with Discrete-Wavelet-Transform (DWT). The DFT allow a QR Code image to be broken up into different frequency bands by using blocks DFT that comparison between low-band coefficients and the DWT that use Haar Wavelet Transform method hierarchically decompose a QR Code image into a series of successively lower frequency approximation sub band and their associated detail sub bands.

***Keywords*—**2D Barcode, QR Code, Watermark, Discrete Fourier Transform (DFT), Discrete-Wavelet-Transform (DWT).

I. Introduction

BARCODE become widely known because of their accuracy, and superior functionality characteristics. QR Code is a kind of 2D (two dimensional) Barcode symbol which is categorized in matrix code. It contains *information in both the vertical and horizontal directions*, whereas a 1D (one dimensional) Barcode symbol contains data in one direction only. QR Code holds a considerably greater volume of information than a 1D Barcode. QR Code developed by Denso Wave [1] (a division of Denso Corporation) and release in 1994. QR Code can encode in many type of characters such as numeric, alphabetic character, Kanji, Kana, Hiragana, symbols, binary, and control codes. Approximate maximum capacity 7,089 characters can be encoded in one symbol and maximum version is 40. Features of QR Code are high capacity and error correction. Error correction helps to restore when symbol is dirty or damaged. The highest level can be roughly 30% of code words [2]. QR Code can decode easily by uploading picture on web providers.[3] So, everybody who has a file of QR Code image, they can decode it all. QR Code is seen as a weakness in security.[4] This paper proposes method for adding watermark that is hiding information into QR Code and compare for measure of performance in DFT and DWT domain. Digital watermarking is a kind of information security and protection technology. Mostly similar to steganography in a number of respects. The main idea of steganography is the embedding of secret information into data under assumption that others can not know the secret information in data. The main idea of watermark is to check the secret information embedded in data or not. Watermark is the embedding information in media for exchange of the information within the group. In this paper use DFT [5] and DWT [6] to embed a text inside QR Code image and then we compare them by PSNR and clock cycle. The main argument of using DFT and DWT in watermarking is to compare efficiency. To embed and extract watermark we utilize the comparison of low-band in DFT and Haar Wavelet Transform in DWT. Experimental results show the advantages in each method.

In the next section, the method description in is provided detail. Section III provide embedding and extracting algorithm. Section IV shows experimental results. In Section V involves conclusions and future work.

II. Method

A. QR Code

QR Code is a matrix symbol that consists of an array of nominally square modules arranged in an overall square pattern. QR Code includes unique finder pattern located at three corners of the symbol and intended to assist in easy location of its position, size and inclination. A wide range of sizes of symbol is provided together with four levels of error correction. Symbol structure of QR Code is as following [1].

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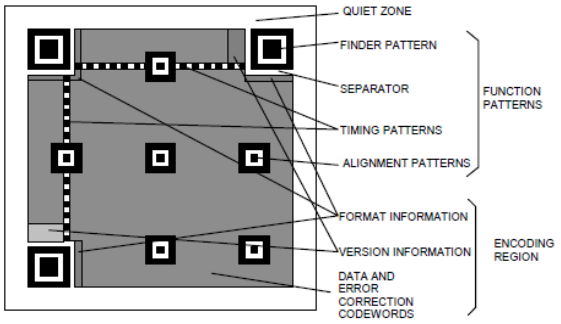

Fig.1 Symbol structure of QR Code

In version 1 measures 21 modules × 21 modules, Version 2 measures 25 modules × 25 modules and so on increasing in steps of 4 modules per side up to Version 40 which measures 177 modules × 177 modules. Four levels of Reed-Solomon error correction (referred to as L, M, Q and H in increasing order of capacity) allowing recovery for the codewords in 7%, 15%, 25% or 30% respectively.

B. Discrete Fourier Transform (DFT) based Watermarking

DFT transform is a typical scene for image processing and digital signal processing that calculate by using Log-Polar coordinate which can be defined assimilative as

$$F(u,v)=\frac{1}{XY}\sum_{x=0}^{X-1}\sum_{y=0}^{Y-1}I(x,y)\cdot e^{-j2\pi\left(\frac{ux}{X}+\frac{vy}{Y}\right)} \quad (1)$$

$$I(x,y)=\sum_{x=0}^{X-1}\sum_{y=0}^{Y-1}F(u,v)\cdot e^{j2\pi\left(\frac{ux}{X}+\frac{vy}{Y}\right)} \quad (2)$$

For $F(u, v)$ is coefficient from QR Code image that uses fourier transform by $I(x, y)$. QR Code image is hidden digital watermark in $F'(u, v)$. Fourier transform can be defined in frequency domain assimilative as

$$F'(u,v)=\left(\left|F(u,v)\right|\cdot(1+\alpha W(x,y))\right)\cdot e^{j\Phi(u,v)} \quad (3)$$

$|F(u, v)|$ and $\Phi(u, v)$ are Fourier spectrum and Phase angle in $F(u, v)$. α is an amplitude factor in QR Code image is hidden digital watermark that in $I'(x, y)$. Inverse Fourier transform can be defined assimilative as

$$I'(x,y)=\sum_{x=0}^{X-1}\sum_{y=0}^{Y-1}F'(u,v)\cdot e^{j2\pi\left(\frac{ux}{X}+\frac{vy}{Y}\right)} \quad (4)$$

C. Discrete Wavelet Transform (DWT) based Watermarking

DWT transform is a typical scene for image processing and digital signal processing that can be defined assimilative as

$$DWT(m,n)=\frac{1}{\sqrt{a_0^m}}\int_{-\infty}^{\infty}f(t)\psi\left(\frac{t-nb_0a_0^m}{a_0^m}\right)dt \quad (5)$$

For a_o^m is a scaling, $nb_oa_o^m$ is a shift position and m, n are the positive integer. In operation, the coming signal is a type of sample that can be defined assimilative as

$$DWT(m,n)=\frac{1}{\sqrt{a_0^m}}\sum_k f(k)\psi\left(\frac{n-kb_0a_0^m}{a_0^m}\right) \quad (6)$$

For m, n, k are a type of integer that n is a number of data, m is a number of scaling and k is a number of shift position. When we are considering the fineness of partition, we decreased double the scaling ($a_o=2, b_0=1$) so that we defined discrete wavelet transform as

$$DWT(m,n)=\frac{1}{\sqrt{2^m}}\sum_k f(k)\psi\left(\frac{n-k2^m}{2^m}\right) \quad (7)$$

III. Embedding and Extracting

The embedding function E for a watermarked QR Code I_W is defined as

$$I_W=E(I_o,w) \quad (8)$$

Where I_0 is the QR Code and W is the watermark of information that wishes to embed.

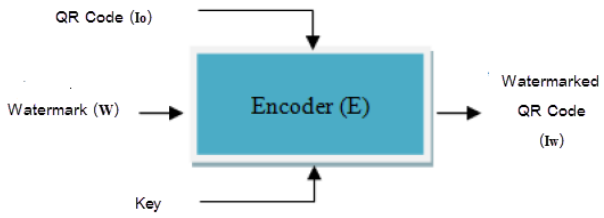

Fig. 2 The embedding watermark in QR Code

The extracting function D for a watermark is defined as (9):

$$(W,T)=D(I_W) \quad (9)$$

Where I_W is the watermarked QR Code desires to extract the watermark of information.

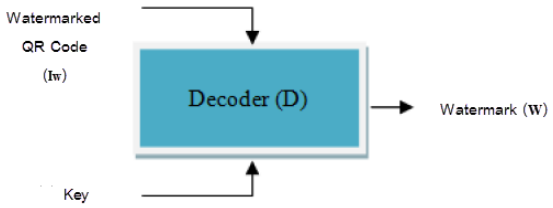

Fig. 3 The extracting watermark in QR Code.

IV. Experimental Results and Analysis

In our approach, we are embedding and extracting a watermark through a standard encode and decode QR Code method. We use error correcting level L or 7% recovery codewords because we concentrate compare DFT with DWT in embedding and extracting. We use an original QR Code sizes 512x512 pixels and a watermark sizes 64x64 pixels. In this paper, we choose Haar Wavelet Transform in discrete wavelet transform and all can decode QR Code image.

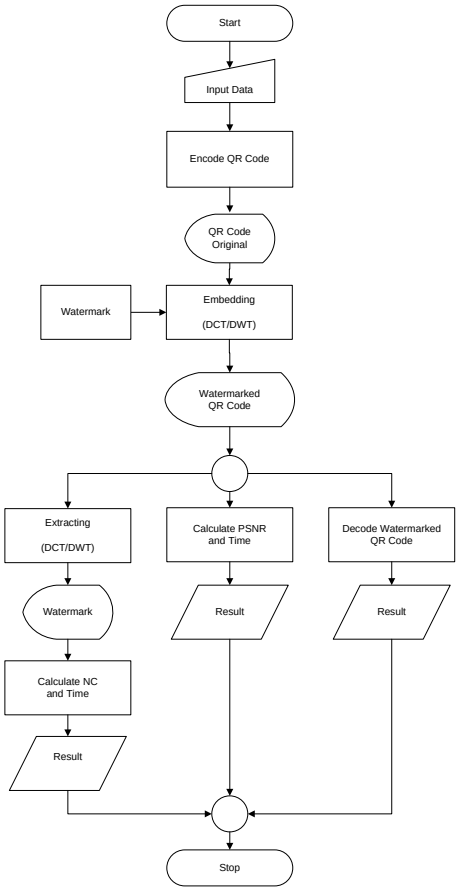

Fig. 4 The process to compare DCT with DWT

TABLE I
The Results in Embedding and Extracting

Content	DFT	DWT
Chulalongkorn		
PSNR	47.3690	67.0528
Time	0.5928	6.1620
NC	0.1686	0.9805
Time	2.1840	3.1668
Computer		
PSNR	47.2418	67.0528
Time	0.5928	6.3960
NC	0.1772	0.9805
Time	2.1684	2.9016
Engineer		
PSNR	47.2526	67.0528
Time	0.6084	6.9264
NC	0.1747	0.9805
Time	2.0748	2.9952
QR Code		
PSNR	47.3112	67.0528
Time	0.5616	6.2244
NC	0.1816	0.9812
Time	2.0592	2.8860
Watermark		
PSNR	47.3692	67.0528
Time	0.5772	6.0216
NC	0.1696	0.9807
Time	2.1996	3.2136

The content is an information about data to encode and decode QR Code and PSNR value is the quantity of efficiency in embedding that defined as

$$PSNR = 10 \log_{10}(\frac{255^2}{MSE}) \quad dB \qquad (10)$$

For MSE can defined as

$$MSE = \frac{\sum (f_w(x,y) - f(x,y))^2}{n} \quad (11)$$

$f_W\ (x,\ y)$ is a data of QR Code image that is embedded watermark already. $f\ (x,\ y)$ is a data of original QR Code image and n is size of pixel. Time is a period of time to embedding and extracting. NC value is the quantity of efficiency in extracting that defined as

$$NC = \frac{\sum_i \sum_j W_{(i,j)} - W'_{(i,j)}}{\sum_i \sum_j \left[W_{(i,j)}\right]^2} \quad (12)$$

$W_{(i,\ j)}$ and $W'_{(i,\ j)}$ are represent an intensity of original watermark at position $(i,\ j)$ and watermark from extracting respectively. We additional experiment by encode 5 words are namely "Embedding", "Extracting", "Look-up table", "Key" and "Suppat Rungraungsilp 5370368121 Master of Engineering Program in Computer Engineering Chulalongkorn University". We can calculate all PSNR as follow (in vertical is value of PSNR that has unit in dB and in horizontal is order of QR Code image that is encoded).

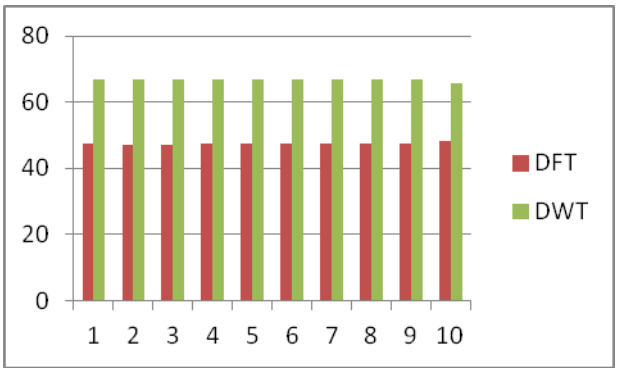

Fig.5 A graph shows all PSNR

We can calculate all NC as follow (in vertical is value of NC and in horizontal is order of QR Code image that is encoded.

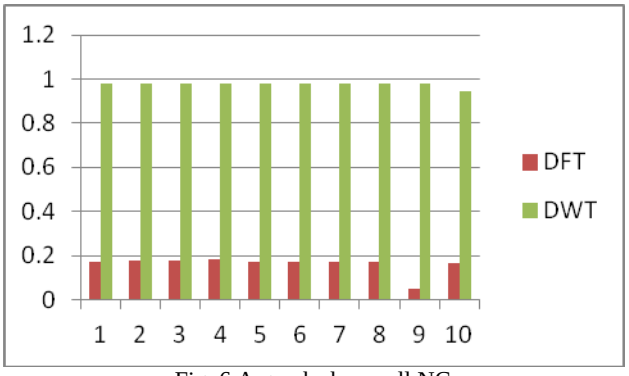

Fig. 6 A graph shows all NC

We can calculate all time to embedding as follow (in vertical is value of time that has unit in millisecond and in horizontal is order of QR Code image that is encoded).

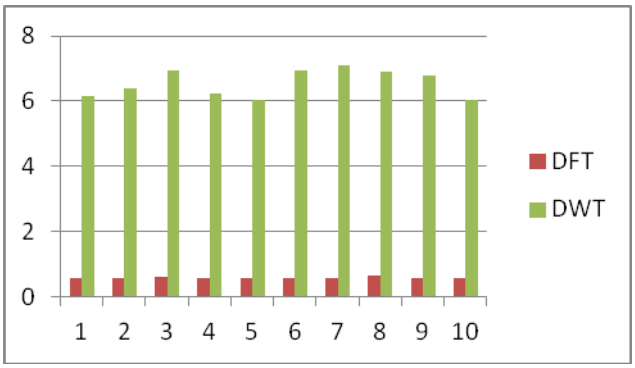

Fig 7. A graph shows all Time (PSNR)

We can calculate all time to extracting as follow (in vertical is value of time that has unit in millisecond and in horizontal is order of QR Code image that is encoded).

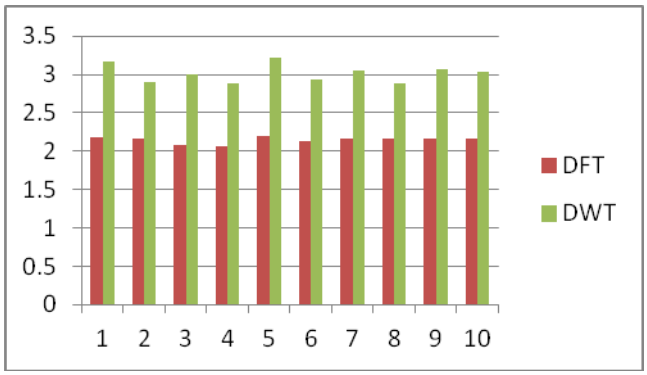

Fig. 8 A graph shows all Time (NC)

Next, we add experimental to find the limitation by start encode QR Code 1 character and add more 1 character in next encode QR Code. We encode QR Code until the watermark from extracting can't understand a word then stop. The original watermark as follow.

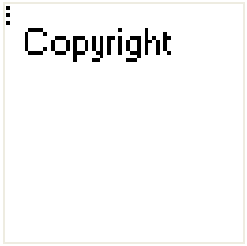

Fig. 9 The original watermark

We can calculate all PSNR as follow.

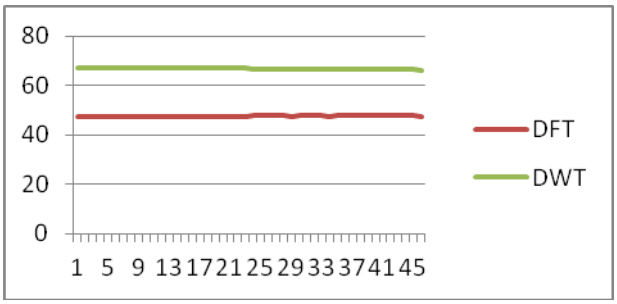

Fig. 10 A graph shows all PSNR

We can calculate all NC as follow.

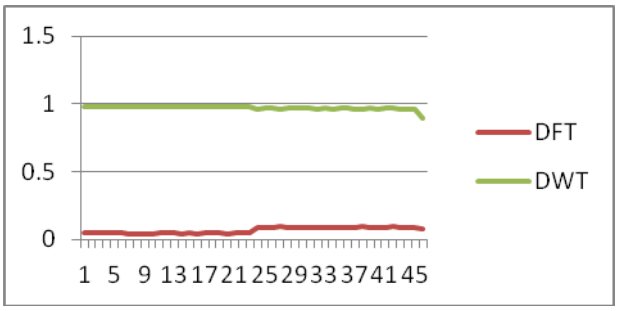

Fig. 11 A graph shows all NC

We can calculate all time to embedding in millisecond as follow.

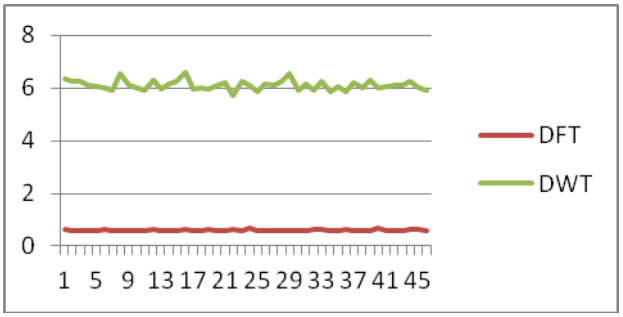

Fig. 12 A graph shows all Time (PSNR)

We can calculate all time to extracting in millisecond as follow.

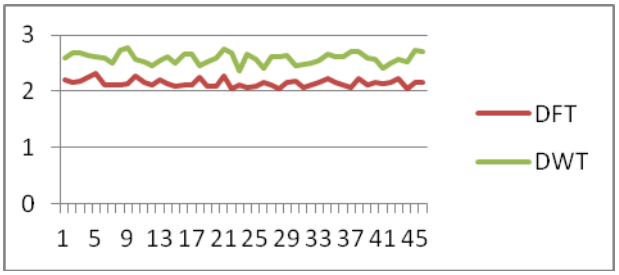

Fig. 13. A graph shows all Time (NC)

V. Conclusion and Future Work

The maximum characters to encode QR Code for DFT is 23 characters that we can understand word from extract of a watermarked QR Code but the DWT is different because it can be more encoded QR Code. In DFT, the range of NC is between 0.04 up to 0.10. In DWT, the range of NC is between 0.89 up to 0.98. DFT and DWT technique can be combined with the other technique to has better performance. They can be combined with Discrete Wavelet Transform (DWT) or Single-Value Decomposition (SVD) method respectively.

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