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RESEARCH ARTICLE

WAVELET TRANSFORM BASED QR CODE WATER MARKING ALGORITHM

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ABSTRACT

In the digital world copyright protection and authentication have become more significant, in order to achieve this digital different watermarking techniques are introduced for the security. We propose an algorithm in wavelet domain using wavelet transformation for a digital invisible watermarking is to embedded into a QR code image. In our method we embed a binary image logo considered as watermark embedded into one of selected wavelet subband. The experimental results show that our method has more robustness to attacks in different considerations and it can achieve a viable copyright protection and authentication.

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INTRODUCTION

Barcode becomes 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 (http://www.denso-wave.com/qrcode/indexe. html). Bar codes are linear one-dimensional codes and can only hold up to 20 numerical digits, whereas QR codes are two-dimensional (2D) matrix barcodes that can hold 7,089 numeric characters and 4,296 alphanumeric characters, and 1,817 kanji characters of information (Jun-Chou Chuang *et al*., 2010).

In this paper, we describe a novel method to embed the QR code into still digital images. Most of the recent work in watermarking can be grouped into two categories: spatial domain methods, and frequency domain methods. Because frequency domain methods have better robustness than spatial domain, almost a11 techniques embed watermarks in the frequency domain, such as DCT and DWT (Lumini and Maio, 2000; Alattar, 2004). To increase robustness against JPEG degradation of the watermarked image, we embed the watermark in low frequency domains of DWT.

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II.QR CODE

A. QR code (http://en.wikipedia.org/wiki/QR_code)

QR (Quick Response) Codes, are 2-dimensional bar codes that encode text strings and were introduced by the Japanese corporation Denso Wave Incorporated (6). QR codes are considered as the evolution of the one dimensional barcodes. They are able to encode information in both vertical and horizontal direction, thus able to encode several times more information than the one dimensional barcodes. QR codes consist of black and white modules which represent the encoded data.

B. QR Code structure

Here we use as an example version 2, see Figure 1, which is the size that is most widely used, and based on (Kieseberg *et al*., 2010; Russ Cox. QArt Codes, 2012; Thonky.com. QR Code Tutorial, 2012; Esponse. Innovative QR Code campaigns (About QR codes), 2013) analyze the structure of the QR Code

(1) Finder Pattern: The three identical structures that are located in the upper corners and in the bottom left corner enable the decoder software to recognize. the QR code and determine the correct orientation. These patterns also allow 360 degree (omni-directional) high-speed reading of the code. These structures consist of a 3 X 3 black square

surrounded by white modules that are again surrounded by black modules.

(2) Separators: The white separators that surround the Finder Patterns have width of one pixel and make it easier to distinguish the patterns.

(3) Timing pattern: A sequence of black and white modules that help the decoder software to determine the width of a single module.

(4) Alignment Pattern: This pattern allows the QR reader to correct for distortion when the code is bent or curved. The alignment pattern appears on version 2 and higher and the number of alignment patterns used depends on the version selected fro the encoding.

(5) Format Information: This section consists of 15 bits and contains the error correction rate and the selected mask pattern of the QR code. The error correction level can be identified from the first two modules of the timing pattern (see Figure 2.2). The format information is read first when the QR code is decoded.

(6) Data: After the data is converted into Reed-Solomon-encoded data bits, it is stored in 8 bit parts (codewords) in the data section.

(7) Error Correction: The data codewords are used in order to generate the error correction (EC) codewords, which are stored in the error correction section.

(8) Remainder Bits: This section contains empty bits if the data or the error correction bits cannot be divided into 8 bit codewords without a remainder.

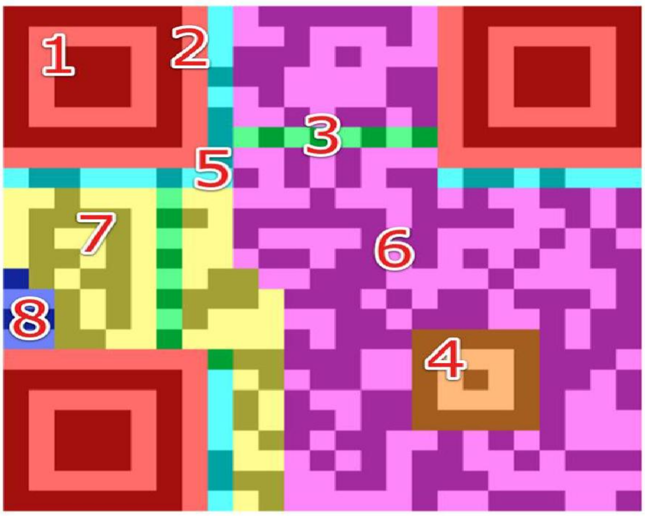
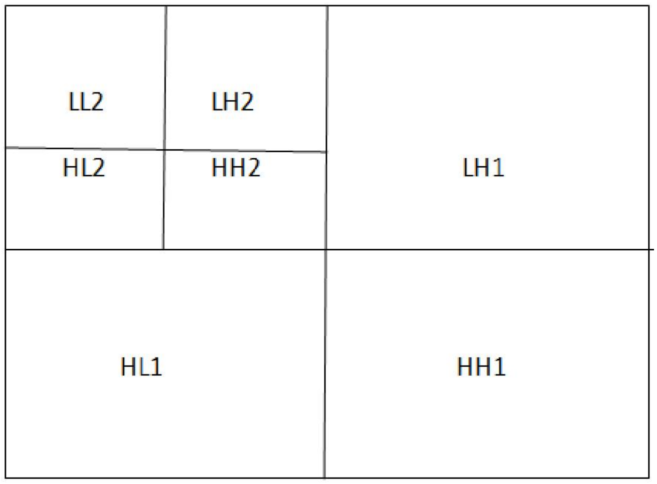


Figure 1. Structure of QR Code Version 2 (from Kieseberg *et al.*, 2010)

III. The proposed watermarking process

In this paper we have chosen a watermark as binary image of Burapha University logo. In the frequency domain we perform the embedding process on QR code image using watermark. As shown in the figure we have to decompose the QR code image by two levels using two-dimensional wavelet transformation. To recover the embedded watermark we do not need the original QR code image subsequently.

In our algorithm have two steps: watermark embedding and watermark extraction.



A. Watermark Embedding

The following outlined procedure is for the embedding process (Fig.3)

Step of watermark image with secret key

i. The watermark image was produced as a bit sequence of watermark **S**. The data and background values were set to 1 and –1, respectively.

$$\mathbf{S} = \{s_{i,} 1 \le i \le N\}, s_i \epsilon \{-1,1\} \quad (1)$$

where *N* is the total number of pixels in the watermark image.

ii. The pseudo-random sequence **(P)** whose each number can take a value either 1 or –1 was randomly generated with a secret key for embedding and extracting of the watermark.

$$\mathrm{P} = \{p_{i,} 1 \le i \le N\}, p_i \epsilon \{-1,1\} \quad (2)$$

Step of QR code image

I. The two-level DWT of $M \times M$ image (t_i) was computed for QR code image.

II. A watermark was then embedded in subband LH2 or HL2 or HH2. According to the rule:

$$t_i^{'} = t_i + \alpha . p_i . s_i, i = 1,2, \dots, N \quad (3)$$

where t_i is input image. $t_i^{'}$ is output image with watermark. α is a magnitude factor which is a constant determining the watermark strength.

III. After that, the inverse DWT (IDWT) was then applied to obtain the watermarked image.

IV. Compute PSNR.

B. Watermark Extraction

The watermark extraction algorithm did not use the original QR code image. A prediction of the original value of the pixels is however needed. Thus, a prediction of the original value of the pixels was performed using noise elimination technique.

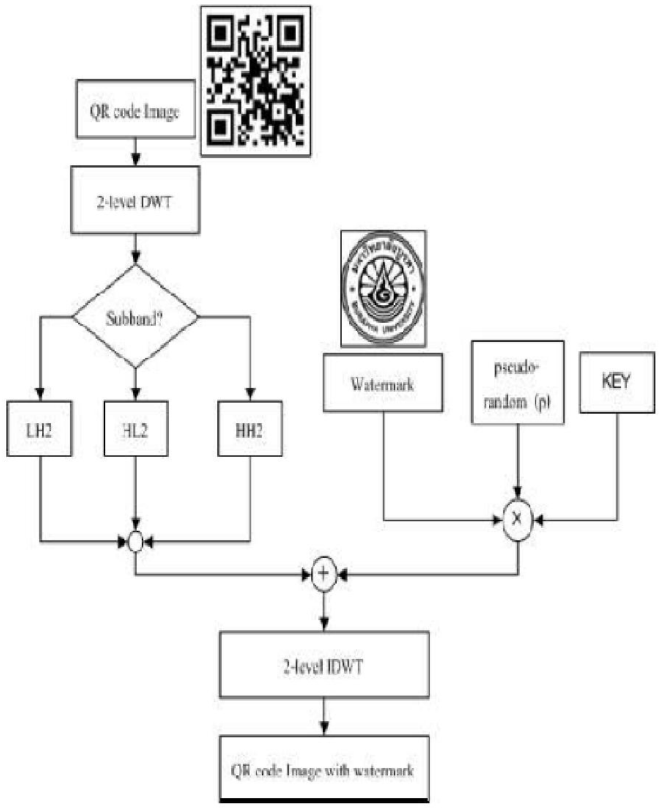


Fig. 3. Watermark Embedding Process

In this paper, we use an averaging 3×3 mask whose elements were fixed to 1/9. The extraction process are outlined as follows (Fig.4):

I. The predicted image $\widehat{t_\iota}$could be obtained by smoothing the input image t_i^* with a spatial convolution mask. The prediction of the original value can be defined as:

$$\widehat{t_\iota} = \frac{1}{c \times c} \sum_{i}^{c \times c} t_i^* \qquad (4)$$

where c is the size of the convolution mask. The watermarked image and the predicted image were DWT transformed independently.

II. The estimate of the watermark $\widehat{S_\iota}$ is indicated by the difference between t_i^* and $\widehat{t_\iota}$ as:

$$\delta = t_i^* - \widehat{t_\iota} = \alpha . p_i . \widehat{s_\iota} \qquad (5)$$

III. The sign of the difference between the predicted and the actual value is the value of the embedded bit:

$$sgn(\delta_i) = p_i . \widehat{s_\iota} \qquad (6)$$

IV. Compute NC

The watermark was then estimated by multiplying pseudo-random number to the embedded bit. If an incorrect pseudo random sequence was to be used, the scheme would not work.

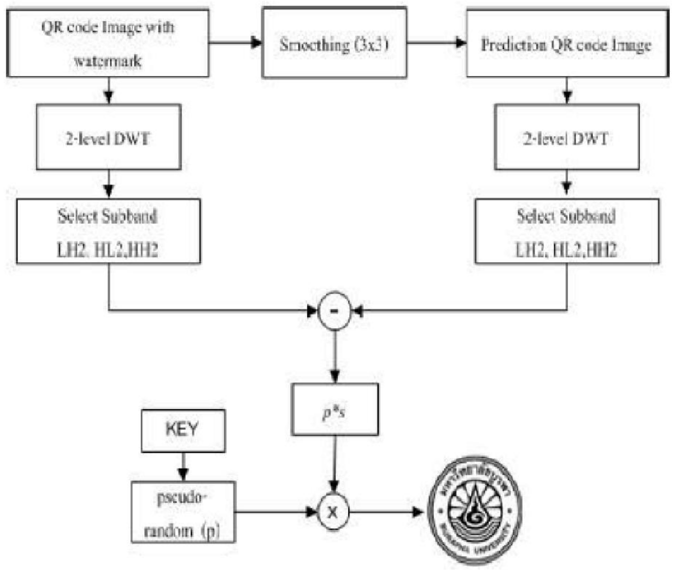


Fig. 4. Watermark Extracting Process

IV. RESULTS

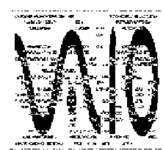
Subband	PSNR	NC	Extracted watermark
LH	43.0615	0.9525	
HL	43.1514	0.9611	
HH	44.2675	0.9916	

Table III

Attack Type	PSNR	NC	Decode QR code
Salt & Pepper Noise (0.02)	40.8837	0.9851	√
Salt & Pepper Noise (0.05)	38.4989	0.9687	√
Gaussian Noise (0.02)	37.2879	0.9945	√
Gaussian Noise (0.05)	37.1402	0.9943	√
JPEG (40)	39.3897	0.9942	√
JPEG (50)	39.3897	0.9942	√

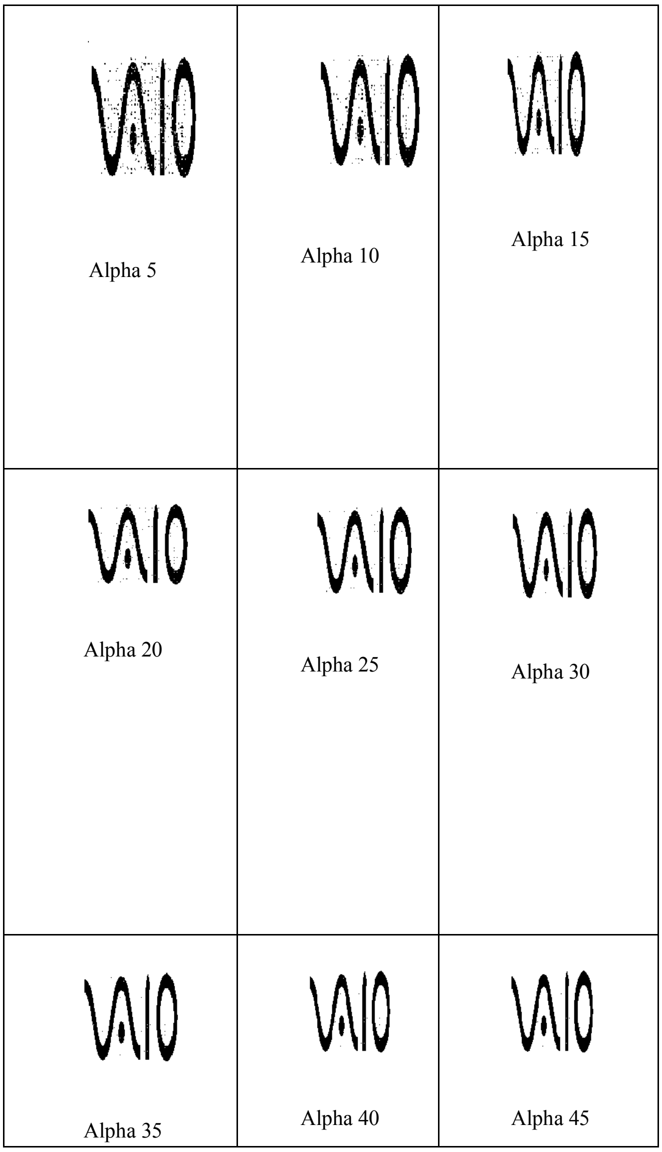
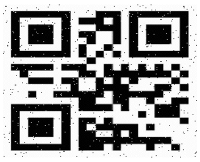
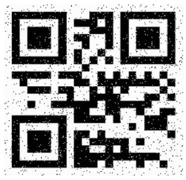
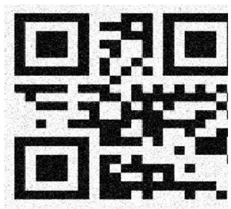
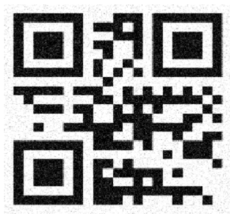
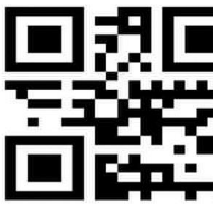


Figure 7. Watermark Extration

Table I. PSNR and NC of QR code Image

α	PSNR	NC	DECODE QR Code
5	47.1617	0.9826	✓
10	44.1514	0.9934	✓
15	42.3905	0.9961	✓
20	41.1411	0.9967	✓
25	40.1720	0.9975	✓
30	39.3802	0.9980	✓
35	38.7107	0.9986	✓
40	38.1308	0.9991	✓
45	37.6193	0.9995	✓

Attack Type	Attacked QR code image	Extracted Watermark
Salt & Pepper noise (0.02)		
Salt & Pepper noise (0.05)		
Gaussian noise (0.02)		
Gaussian noise (0.05)		
JPEG (40)		
JPEG (50)		

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