International Journal of Security and Its Applications
Vol. 9, No. 4 (2015), pp. 203-216
http://dx.doi.org/10.14257/ijsia.2015.9.4.19

Blind Watermarking Scheme based on U matrix Through QSVD Transformation

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Abstract

In this paper, a novel blind color image watermarking technique using U matrix through QSVD transformation **is** *proposed to protect the intellectual property rights of color images. The proposed method tries to insert the watermark through moderating the coefficient of the quaternion elements in U matrix. .In this method, the color image is considered as an array of pure quaternion numbers. Then the array of pure quaternion is divided into non-overlapping blocks and we perform QSVD to the block to get the U matrix. The watermarking is inserted into the coefficient of the quaternion elements in the first column of the U matrix. Besides, in the procedure of watermark insertion and extraction, ensuring higher fidelity and robustness and resilience to several possible image attacks have been considered. The experimental results showed that the proposed method performance created watermarked images with better PSNRs and more robustness versus several attacks such as Salt &Pepper noise, Brightness adjustment, Sharpen and Blurring and Clipping.*

Keywords: *Watermarking; Quaternion; QSVD; U matrix*

1. Introduction

In the last decades, the internet and multimedia technology has been developed rapidly. Therefore, illegal distribution, duplication and modification of the multimedia cause serious problems to the protection of intellectual property rights. How to protect the copyright of the digital products is the main motivation of the research on digital watermarking technology. Digital watermarking is regarded as a powerful technique to solve the problems caused by illegal operation [1, 2]. Technically, watermark is a non-removable digital code, robustly and imperceptibly embedded in the original (host) data, which contains information about the origin, status, and/or destination of the data [3].

The watermarking algorithm can be applied on gray or color images. In the past, there were a lot of papers aimed to research on watermarking technology in the original gray image. For example, in [4], a content-based watermarking scheme was proposed to embed the 224 bits watermark into 512×512 grayscale image. C. Deng and X. Gao *etc*. presented a geometrically robust image watermarking scheme based on local histogram in which a 20-bits pseudo-random bipolar sequence was embedded into 512 × 512 grayscale image[5]. From above, we can see that the watermark capacity was only 0.004b/p because the watermarks were imbedded into one sub-band of grayscale host image.

Nowadays, in order to imbed many bits into the original image, color image watermarking has been researched. Compared with gray-level image, the color one has two advantages [6]: (1) can hide a greater amount of data; (2) can attain higher fidelity, which is because the color perception depends not only on the luminance but also on the

ISSN: 1738-9976 IJSIA

chrominance. For example, S.Hongqin and L.V.Fangliang [7] presented a method that transforms the original color image from RGB to the YUV color space and scrambled by Fibonacci transformation. The authors propose the algorithm for still color image based on double scrambling technique and the wavelet transform. A robust blind method that inserts the watermark by linear interpolation in all SVD components matrixes (U, S, and V) of Red channel has been proposed in [8]. In [9], a watermarking algorithm for color image based on HSI color space and discrete wavelet transform (DWT) has been proposed. In this method, sub-blocks of intensity are divided and sorted according to the human visual system (HVS) characteristic. Then, binary watermark is embedded by modifying the DWT coefficients of low frequencies in the selected sub-blocks. [10] Suggested a watermarking technique that uses Artificial Immune Recognition System (AIRS) to protect color image intellectual property rights. The watermark is embedded in the blue channel of a color image. M-bit binary sequence embedded into the color image is used to train AIRS. Extracting the watermark is carried out using AIRS.

From the above methods, we can see that authors has been embedded the watermark information into a color channel of the color images losing color information , does not consider the watermarking algorithm on the whole without losing color information. In order to overcome the drawback, a new color image blind watermarking scheme based on quaternion and QSVD is proposed in this paper. In this proposed method, the color image is considered as an array of pure quaternion numbers. Then the array of pure quaternion is divided into non-overlapping blocks and performs QSVD to the block to get the U matrix. The watermarking is inserted into the coefficient of the quaternion elements in the first column of the U matrix. In this way, we can process the host image in a holistic manner without losing color information. A series of experiments show that the proposed scheme can attain better invisibility and stronger robustness against many common processing attacks, and the comparison with the related algorithms also reveals the higher efficiency of the proposed algorithm.

The rest of the paper is organized as follows. The basic theory of the Proposed Algorithm is given in Section 2. In Section 3, the proposed watermark embedding and extraction method is described in detail. The experimental results are given and the corresponding analysis is discussed in Section 4. The conclusion is drawn in Section 5.

2 .The Basic Theory

2.1. Quaternion Representation of a Color Image

The quaternion, which is a type of hypercomplex numbers, was formally introduced by Hamilton in 1843[8].A quaternion consists of one real part and three imaginary parts as follows:

$$q = a + bi + cj + dk \tag{1}$$

Where a, b, c, and d are real numbers, and $i, j, and\ k$ are complex operators obeying the following rules

$$i^2 = j^2 = k^2 = -1, ij = -ji = k, jk = -kj = i, ki = -ik = j \tag{2}$$

A quaternion can be regarded as the composition of a scalar part and a vector part: $q = S + V$,where $S = a, \mathrm{V} = bi + cj + dk$ .If a quaternion q has a zero scalar part ($a = 0$),then q is called pure quaternion, and if

The norm of q is defined as

$$\|q\| = \sqrt{a^2 + b^2 + c^2 + d^2} \tag{3}$$

Euler's formula holds for quaternion, that is

q has a unit norm ($[U\,S\,V] = QSVD(\mathrm{A})$), then q is called unit pure quaternion.

$$e^{\mu\phi} = \cos(\phi) + \mu\sin(\phi) \qquad (4)$$

Where μ is any unit pure quaternion, we also have: $\left\| e^{\mu\phi} \right\| = 1$.

In [9], Sangwine proposed to encode the three channel components of a RGB image on the three imaginary parts of a pure quaternion, that is

$$f(\mathrm{x,y}) = f_R(\mathrm{x,y})\mathrm{i} + f_G(\mathrm{x,y})j + f_B(\mathrm{x,y})\mathrm{k} \qquad (5)$$

Where $f_R(\mathrm{x,y})$, $f_G(\mathrm{x,y})$ and $f_B(\mathrm{x,y})$ are the red, green and blue components of the pixel, respectively, and i, j and k are the complex operators. In recent years, quaternion has been utilized more and more in color image processing domain. Obviously, the advantage of using quaternion to represent the color image is that we can process the image in a holistic manner without losing color information.

In order to make the quaternion matrix more convenient to operate, each component of the pixel was normalized, that is

$$f(\mathrm{x,y}) = (f_R(\mathrm{x,y})\mathrm{i} + f_G(\mathrm{x,y})j + f_B(\mathrm{x,y})\mathrm{k})/256 \qquad (6)$$

Fig.1 illustrates the details of using quaternion to represent the color image.

0.668 i+ 0.375 j+ 0.4258 k	0.7695 i+ 0.4727 j+ 0.5195k	0.7852i+0.4922 j+ 0.5156k	0.7734i+0.4766 j+ 0.4805k
0.7266i+0.4336 j+ 0.4727k	0.7891i+0.4961 j+ 0.5313k	0.7891i+0.4961 j+ 0.5156k	0.7695i+0.4766 j+ 0.4766k
0.7773i+0.4844 j+ 0.5117k	0.8047i+0.5117 j+ 0.5391k	0.7773i+0.4844 j+ 0.5k	0.7617i+0.4727 j+ 0.4727k
0.8008i+0.4922 j+ 0.5195k	0.8008i+0.5039j+ 0.5195k	0.7656i+0.4727 j+ 0.4844k	0.7656i+0.4727 j+ 0.4727k

Figure 1. The Details of using Quaternion to Represent the Color Image (4×4)

2.2 QSVD of Color Image

Supposing A, the quaternion matrix singular value decomposition (QSVD) of A can be represented as follows[11]:

$$A = U diag(\sigma_1, \sigma_2, \cdots, \sigma_n)\mathrm{V} \qquad (7)$$

Where QSVD(A), $\sigma_1 \geq \sigma_2 \geq \cdots \geq \sigma_n \geq 0$ are n eigenvalues of A, (7) can be simply represented by

$$[U\ \mathrm{S}\ \mathrm{V}] = \mathrm{QSVD(A)} \qquad (8)$$

According to (5), a color image can be represented by the quaternion matrix. A color image with m rows and n columns can be represented by

$$A = (q_{ij})_{m \times n}, q_{ij} \in Q \qquad (9)$$

The quaternion theory introduces many new methods and theory into color image processing. These methods treat the three channels of a color image as an integer to handle, so the intrinsic mapping relational ship between three channels can be maintained. In order to embed watermark information to the image, the color image is transferred by QSVD,

$$[U\,S\,V] = QSVD(\mathrm{A}) \qquad (10)$$

Where S is a diagonal matrix, and it can be written as

$$S = diag(\sigma_1, \sigma_2, \cdots, \sigma_n) \qquad (11)$$

For example:

$$\begin{bmatrix} 0.668\,i + 0.375\,j + 0.4258\,k & 0.7695\,i + 0.4727\,j + 0.5195k & 0.7852i + 0.4922\,j + 0.5156k & 0.7734i + 0.4766\,j + 0.4805k \\ 0.7266i + 0.4336\,j + 0.4727k & 0.7891i + 0.4961\,j + 0.5313k & 0.7891i + 0.4961\,j + 0.5156k & 0.7695i + 0.4766\,j + 0.4766k \\ 0.7773i + 0.4844\,j + 0.5117k & 0.8047i + 0.5117\,j + 0.5391k & 0.7773i + 0.4844\,j + 0.5k & 0.7617i + 0.4727\,j + 0.4727k \\ 0.8008i + 0.4922\,j + 0.5195k & 0.8008i + 0.5039\,j + 0.5195k & 0.7656i + 0.4727\,j + 0.4844k & 0.7656i + 0.4727\,j + 0.4727k \end{bmatrix}$$

$$= U \begin{bmatrix} 4.1348 & 0 & 0 & 0 \\ 0 & 0.1464 & 0 & 0 \\ 0 & 0 & 0.0173 & 0 \\ 0 & 0 & 0 & 0.0058 \end{bmatrix} V \qquad (12)$$

Where, U =

$$\begin{bmatrix} -1.717e-005 + 0.3644\,i + 0.2146\,j + 0.2377\,k & -7.953e-004 + 0.4572\,i + 0.4217\,j + 0.3835k & -0.03768 + 0.0582i + 0.03979\,j + 0.3138k & -0.01641 + 0.1616i + 0.1041\,j + 0.2964k \\ -7.992 - e007 + 0.3737i + 0.2248\,j + 0.2441k & 4.695e-005 + 0.1363i + 0.1083\,j + 0.1019k & 0.02503 + 0.06905i - 0.04026\,j - 0.3773k & 0.03423 - 0.3565i - 0.2271\,j - 0.6167k \\ 2.162e-005 + 0.3792i + 0.2307\,j + 0.2472k & 7.161e-004 - 0.2007i - 0.2172\,j - 0.1849k & 9.9095e-3 - 0.006987i - 0.06966\,j - 0.5684k & -0.01577 + 0.3148i + 0.1488\,j + 0.4131k \\ 6.82e-005 + 0.3804i + 0.2293\,j + 0.2438k & 1.253e-003 - 0.3689i - 0.3004\,j - 0.2769k & 5.925e-003 - 0.0008622i + 0.07222\,j + 0.6421k & -0.002074 - 0.1188i - 0.02526\,j - 0.08905k \end{bmatrix} \qquad (13)$$

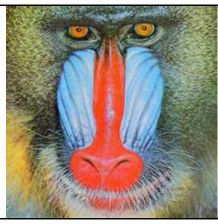
Now, we express the coefficient of the quaternion elements in U matrix by $f_{i,j}^{m}$. Among the i, j and m, $i\,(1 \le i \le 4)$ represents the number of rows of U matrix ; $j\,(1 \le j \le 4)$ represents the number of columns of U matrix; $m\,(1 \le m \le 3)$ represents the sequence of the imaginary part of the quaternion elements in U matrix.

From the formula (13), we can see:

$$f_{1,1}^{1} \approx f_{2,1}^{1} \approx f_{3,1}^{1} \approx f_{4,1}^{1},\ f_{1,1}^{2} \approx f_{2,1}^{2} \approx f_{3,1}^{2} \approx f_{4,1}^{2},\ f_{1,1}^{3} \approx f_{2,1}^{3} \approx f_{3,1}^{3} \approx f_{4,1}^{3} \qquad (14)$$

In order to verify the formula (14), some experiments is done to calculate the average values of $f_{1,1}^{1}/f_{2,1}^{1}$, $f_{1,1}^{1}/f_{3,1}^{1}$, $f_{1,1}^{1}/f_{4,1}^{1}$, $f_{1,1}^{2}/f_{2,1}^{2}$, $f_{1,1}^{2}/f_{3,1}^{2}$, $f_{1,1}^{2}/f_{4,1}^{2}$, $f_{1,1}^{3}/f_{2,1}^{3}$, $f_{1,1}^{3}/f_{3,1}^{3}$, $f_{1,1}^{3}/f_{4,1}^{3}$ respectively .A number of common benchmark RGB images with 256×256 pixels size are applied for the experiments, such as Lena, Barbara, Mandrill. Each image is divided into 4×4 block. The results of experiments are shown in Table 1.

Table 1. The Results of Experiments to Calculate the $f^m_{i,j} / f^m_{i',j'}$

	Lena	Barbara	Mandrill
			
$f^1_{1,1} / f^1_{2,1}$	1.0000	1.0030	1.0089
$f^1_{1,1} / f^1_{3,1}$	1.0035	1.0122	1.0201
$f^1_{1,1} / f^1_{4,1}$	1.0089	1.0188	1.0237
$f^2_{1,1} / f^2_{2,1}$	1.0056	1.0039	1.0064
$f^2_{1,1} / f^2_{3,1}$	1.0239	1.0161	1.0181
$f^2_{1,1} / f^2_{4,1}$	1.0522	1.0246	1.0219
$f^3_{1,1} / f^3_{2,1}$	1.0009	1.0048	1.0115
$f^3_{1,1} / f^3_{3,1}$	1.0062	1.0224	1.0336
$f^3_{1,1} / f^3_{4,1}$	1.0112	1.0372	1.0394

From the Table 1, we can see that $f^1_{1,1} / f^1_{4,1}$ > $f^1_{1,1} / f^1_{3,1} > f^1_{1,1} / f^1_{2,1}$ **→1,** $f^2_{1,1} / f^2_{4,1} > f^2_{1,1} / f^2_{3,1}$ > $f^2_{1,1} / f^2_{2,1}$ **→1,** $f^3_{1,1} / f^3_{4,1} > f^3_{1,1} / f^3_{3,1} > f^3_{1,1} / f^3_{2,1}$ **→1.** We can draw a conclusion that coefficients of imaginary part of $U(2,1)$ are closest to the coefficients of imaginary part of $U(1,1)$.

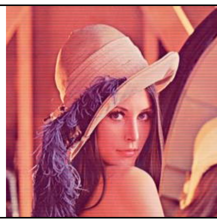
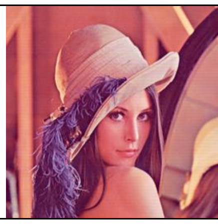
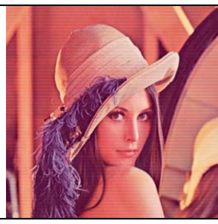
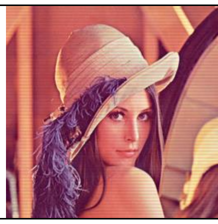
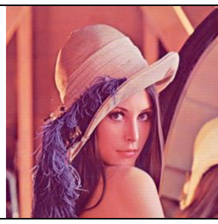
Now, we choose the coefficients of imaginary part of $U(2,1)$ and $U(1,1)$ as our research
objects. In order to visualize the impact of the coefficients to the whole image, a series of experiments has been done.

In light of Table 2, we can see that in the same degree that the $f^m_{i,j}$ being changed, $PSNR_2$ is the largest value in the $PSNR$ values of the $f^m_{1,1}$ being changed and $PSNR_5$ is the largest value in the $PSNR$ values of the $f^m_{2,1}$ being changed .From above we can draw a conclusion that alteration to the second coefficient of imaginary part of $U(1,1)$ or $U(2,1)$ leads to the minimum effect on the original color image. According to Table 2 and the actual effect of observation, we choose to moderate the third coefficient of imaginary part of $U(1,1)$ or $U(2,1)$ to the insert the watermark information to the original image.

3 .Our Proposed Algorithm

This section describes our proposed novel blind color image watermarking technique using U matrix through QSVD transformation is to protect the intellectual property rights of color images, which insert the watermark through moderating the coefficient of the quaternion elements in U matrix. The two procedures are described in Subsections 3.1 and 3.2, respectively.

Table 2 the Recovered Image being Changed the $f_{1,1}^m$ or $f_{2,1}^m$ of U

	$f_{1,1}^m = 1.05\ f_{1,1}^m$	$f_{1,1}^m = 1.1\ f_{1,1}^m$	$f_{1,1}^m = 1.2\ f_{1,1}^m$
Image with $f_{1,1}^1$ being changed			
$PSNR_1$	47.0656	44.4820	41.2342
Image with $f_{1,1}^2$ being changed			
$PSNR_2$	47.4407	45.2274	42.8115
Image with $f_{1,1}^3$ being changed			
$PSNR_3$	46.9574	44.4722	42.7238
	$f_{2,1}^m$ =(1/1.05) $f_{2,1}^m$	$f_{2,1}^m$ =(1/1.1) $f_{2,1}^m$	$f_{2,1}^m$ =(1/1.2) $f_{2,1}^m$
Image with $f_{2,1}^1$ being changed			
$PSNR_4$	47.0556	44.4314	41.1257
Image with $f_{2,1}^2$ being changed			
$PSNR_5$	47.3318	45.2276	42.8094
Image with $f_{2,1}^3$ being changed			
$PSNR_6$	46.9915	44.9226	42.7472

3.1 Embedding Procedure

In order to use the coefficient of imaginary part of $U(2,1)$ and $U(1,1)$ to imbed a watermark to a host image, we explored the $f_{1,1}^{m}$ and $f_{2,1}^{m}$ **of** U as the Table 2 represents. Based on our observation, in the same degree that the $f_{1,1}^{m}$ or $f_{2,1}^{m}$ being changed, alteration to the second coefficient of imaginary part of $U(1,1)$ or $U(2,1)$ leads to the minimum effect on the original color image. An overview of the embedding procedure is shown in Figure 1. The size of host color image I represented by quaternion is $m \times n$ .The host image is divided into nooverlapping block B_i of size 4×4 , where $1 \le i \le \lfloor \frac{m}{4} \rfloor \times \lfloor \frac{n}{4} \rfloor$ and $I = B_1 \cup B_2 \cup \cdots \cup B_{\lfloor m/4 \rfloor \times \lfloor n/4 \rfloor}$ .The watermark W is a binary image of size $u \times v$ bits , where W $= (w_1, w_2, \cdots, w_{\lfloor \frac{m}{4} \rfloor \times \lfloor \frac{n}{4} \rfloor})$ and $w_1 \in \{1, 0\}$. Apply QSVD to B_i and get $[U_i, S_i, V_i]$. In order to embed the watermark to the host color image, we change the values of the $f_{1,1}^{2}$ and $f_{2,1}^{2}$ in the matrices $U_i(1,1)$ according to the value of the pixel of the watermark bit. The changing procedure of the values of the $f_{1,1}^{2}$ and $f_{2,1}^{2}$ in the matrices $U_i(1,1)$ is as follows.

If the watermark bit is "1", $f_{2,1}^{2} = (1+\alpha) * f_{1,1}^{2}$; if the watermark bit is "0", $f_{2,1}^{2} = (1/(1+\alpha)) * f_{1,1}^{2}$. According to the Table2, $0.05 \le \alpha \le 0.2$.

The embedding algorithm in detail is as following a few steps:

Step 1: Using the normalized quaternion to represent the host color image I .

Step 2: Divide the host color image into nonoverlapping blocks B_i of size 4×4

Step 3: Apply QSVD to B_i and get $[U_i, S_i, V_i]$

Step 4: Embedding the watermark information to the values of the $f_{1,1}^{3}$ and $f_{2,1}^{3}$ in the matrices $U_i(1,1)$ on the basis of the value of watermark bit. If the watermark bit is "1", $f_{2,1}^{3} = (1+\alpha) * f_{1,1}^{3}$; if the watermark bit is "0", $f_{2,1}^{3} = (1/(1+\alpha)) * f_{1,1}^{3}$. $0.05 \le \alpha \le 0.2$.

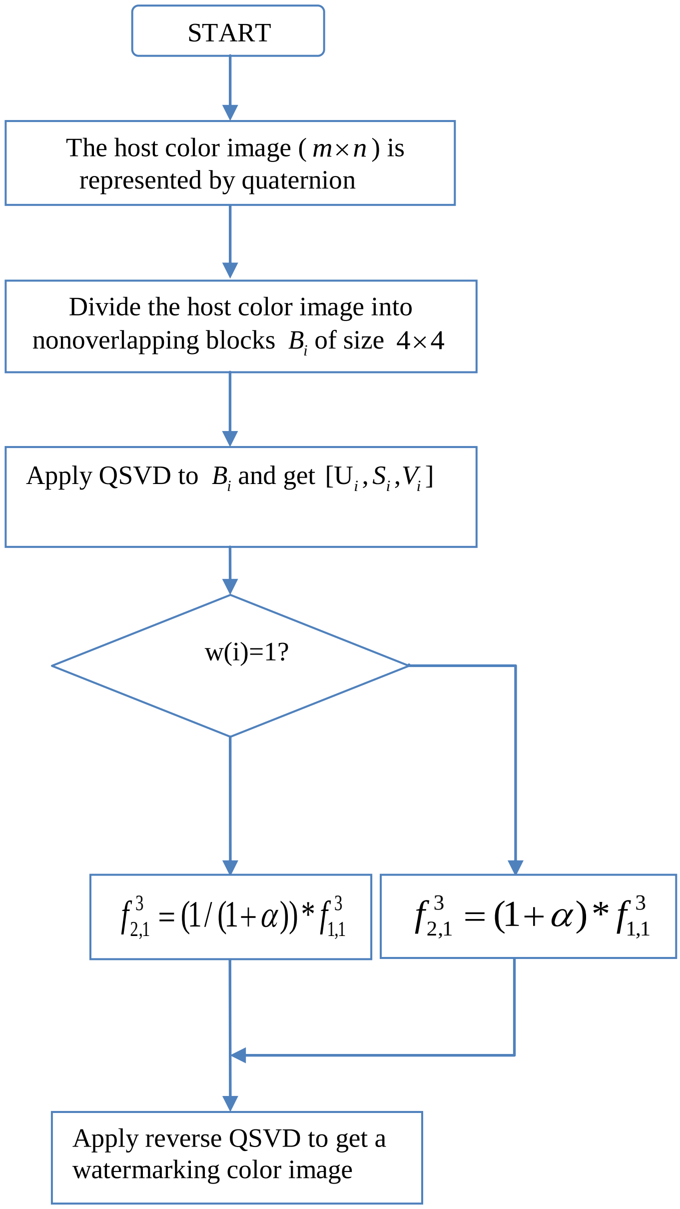
Step5: Apply reverse QSVD to get a watermarking color image I^*

3.2 Extracting Procedure

In this paper, we propose a blind watermarking algorithm that the watermark information is extracted without the original host image and the original watermark information. Figure 2 presents a flowchart of our extracting procedure. The watermarking image is first divided into nonoverlapping blocks of B_i^* of size 4×4 .Apply QSVD to the block B_i^* and get $[U_i^*, S_i^*, V_i^*]$ .Subsequently, we can get the value of the watermark bit from the $U_1^*(1,1)$ and $U_1^*(2,1)$ .The criterion of achieve the value of the watermark bit is as following : If $(1+\alpha-\Delta) * f_{1,1}^{*3} \le f_{2,1}^{*3} \le (1+\alpha+\Delta) * f_{1,1}^{*3}$, w(i) =1; else, w(i) =0. At last , composite the w (i) to form the extracted watermark.

4. Experiment Results and Analysis

This section is divided into three subsections. The first will introduce the evaluation criteria. The second subsection will introduce the visual result of the proposed algorithms. Third subsection will compare the algorithm with other existing algorithms. A set of experiments was developed in the MATLAB R2010b environment, while all measurements are performed on a Lenovo laptop with a 2.1 GHz Intel Pentium processor and 4 GB of RAM.A number of common benchmark RGB images with 256×256 pixels size are applied for the experiments, while the binary watermark Logo sized as 64×64 bits (4096bits in total) is used as the watermark information (Fig.3)



No **Yes**

Figure 1. Flowchart of Embedding Procedure

4.1 Evaluation Criteria

In general, there are two measures; *PSNR* (peak signal-to-noise) and *BCR* (bit correction ratio) were used to evaluate the performance of our proposed scheme. The PSNR value, which is defined in Equation (12), was used to measure the image quality of the watermarked and original images.

$$PSNR = 10 \log_{10} \frac{255^2}{MSE} dB \qquad (12)$$

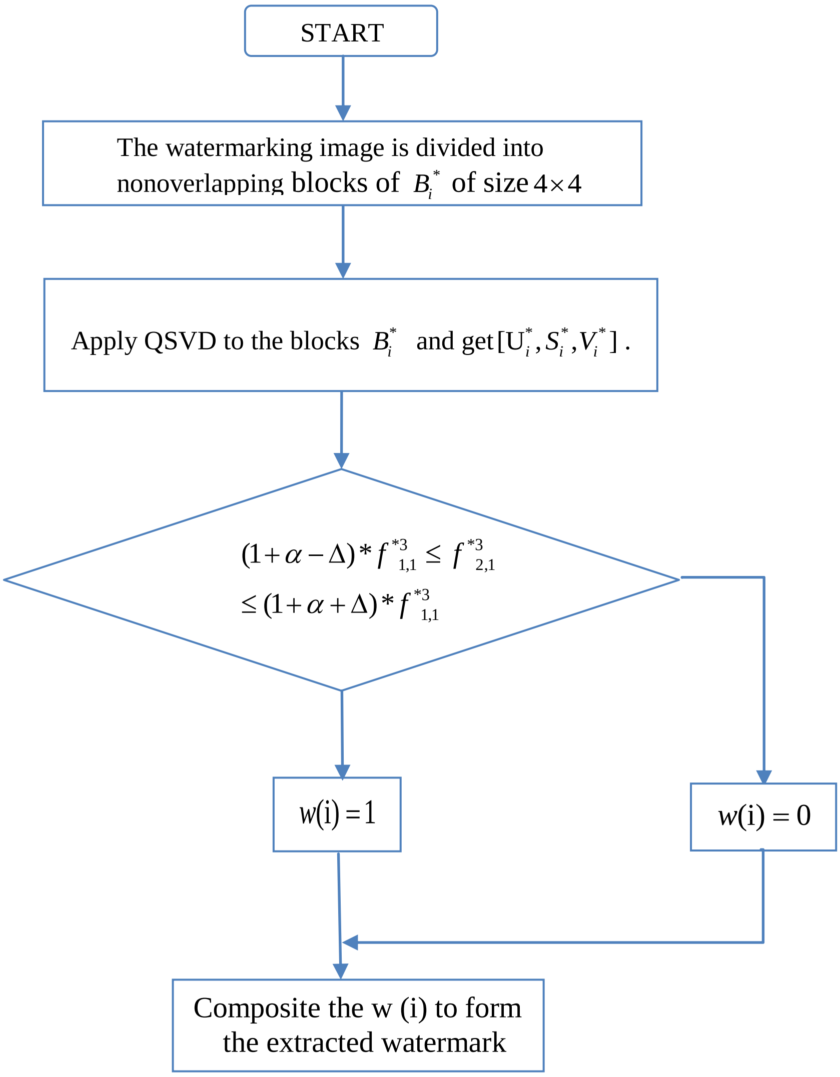


Figure 2. Flowchart of Extracting Procedure

Where 255 represents the maximum pixel value of a gray-level image, and the mean square error (MSE) of an image is depicted in Equation (13).

$$MSE = \frac{\sum_{r}^{ht}\sum_{s}^{wd}(x_{rs}-x'_{rs})^2}{H\times W} \tag{13}$$

(a) (b) (c) (d)

Figure 3. The Benchmark Images (a) Lena, (b) Barbara, (c) Mandrill and (d) the Binary Watermark Logo

Here, the notations ht and wd represent the height and width of an image, respectively. If $PSNR$ is used to measure the image quality of the watermarked image, x_{rs} is the pixel value of the position (r,s) in an original image and x'_{rs} is the pixel value of the watermarked image. Generally, the higher the $PSNR$ value of a watermarked image is, the better the image quality will be. Furthermore, the BCR defined in Equation (14) is used to measure the correction ratio of the extracted watermark.

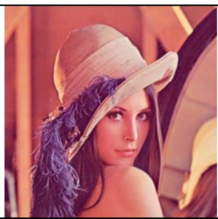
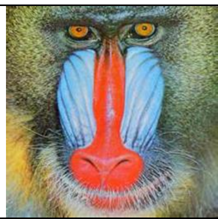
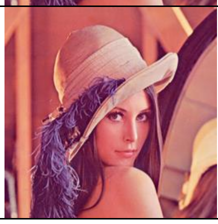
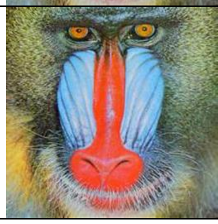
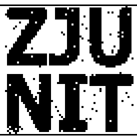
$$BCR = \frac{\sum_{i=1}^{n\times n} \overline{w_i \oplus w_i'}}{n \times n} \times 100\% \qquad (14)$$

Where w_i and w_i' are the i th binary value of the original watermark and of the extracted watermark, respectively, and $\oplus$ indicates an exclusive OR operator. Note that a higher BCR implies greater similarity between the original watermark and the extracted watermark.

4.2 The Experiment Results without being Attacked

The experiment results of the proposed watermark embedding algorithm without being attacked are shown in Table 2. From the Table 2, we can see that the watermark is imperceptible and there are no visible differences between the two by comparing theoriginal image signal with the image signal after embedding the watermark into the original image.

Table 2. The Experiment Results without Being Attacked

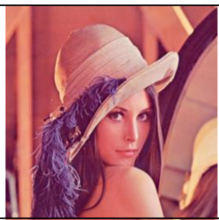
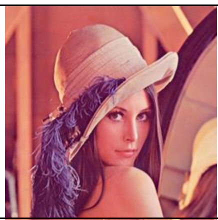
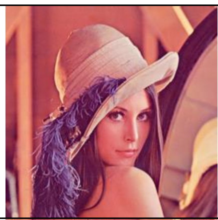
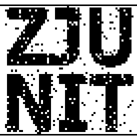
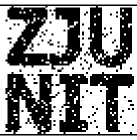
	Lena	Barbara	Mandrill
The original color image			
The watermarked color image			
$PSNR$	45.4810	45.7603	44.1480
The watermark Being extracted			
BCR	99.32%	98.46%	97.66%

4.3 The Experiment Results with being Attacked

In this section, a set of experiments were conducted to attack the watermarked color image in order to evaluate the proposed algorithm. The attacking conditions simulated for the algorithm's evaluation consisting of common signal processing: image clipping ,Salt &Pepper(0.002,0.005,0.01),Brightness adjustment(light , dark),Sharpen .
Table 3 shows us that the performance of the proposed scheme in image and BCR under Salt &Pepper noise in different degree. We can see that even thouth the watermarked

image is attacked by Salt &Pepper noise with a factor of 0.01, the BCR of the extracted watermark is still 95.80%

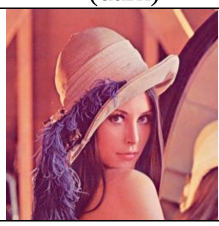
Table 3. The Experiment Results with being Attacked by Sal t& Pepper Noise

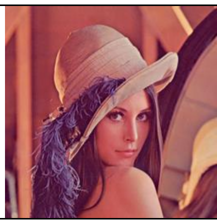
	Salt & Pepper 0.002	Salt & Pepper 0.005	Sal t& Pepper 0.01
The watermarked color image			
The watermarked color image with being attacked			
PSNR	31.9299	27.9806	24.9691
The watermark Being extracted			
BCR	98.75%	97.61%	95.80%

From Table 4, we can see that with being attacked by brightness adjustment and sharpen; our proposed algorithm shows superior performance. Especially, the PSNR of the tampered image is only 16.9989 dB , but the BCR of the extracted watermark is still 90.94%.It is clear that the proposed algorithm is robust to brightness adjustment and image sharpen.

There are a set of tests will investigate the performance of the proposed algorithm attacked under image clipping. In Table 5, we can see that the PSNRs of the tampered image attacked by image clipping are 16.9989dB, 19.9157dB and 22.1587dB, the BCRs of the extracted watermark are 98.95%, 98.46% and 98.58% respectively, which indicate that our method has the ability to resist attacks of image clipping.

Table 4. The Experiment Results with being Attacked by Brightness Adjustment and Sharpen

	Brightness adjustment (light)	Brightness Adjustment (dark)	Sharpen
The watermarked color image			

The watermarked color image with being attacked			
PSNR	16.9989	22.6570	35.1111
The watermark Being extracted			
BCR	90.94%	98.78%	95.83%

By comparing the performance of three similar watermark schemes with that of our proposed scheme in Table 6, neither extra data nor the original host image is required during the extracted procedure in our proposed scheme. Hwang et al.'s scheme [13] can provide high image quality and low robustness, which their scheme cannot work well after the watermarked images are attacked by other image processing attacks. With regard to Chandra's scheme [12], it requires both the original watermark and the original image during the watermark extraction procedure. Bao and Ma's scheme [11] successfully uses the quantization parameters to enhance the image quality of the watermarked image, but the quantization parameters must be stored for later watermark extraction.

Table 5. The Experiment Results with being Attacked by Image Clipping

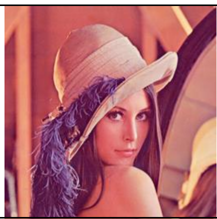
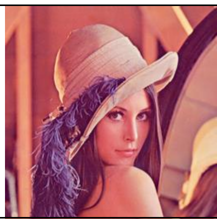
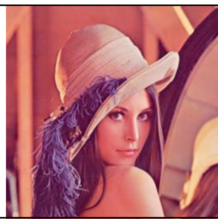
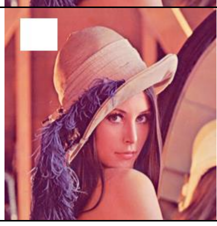
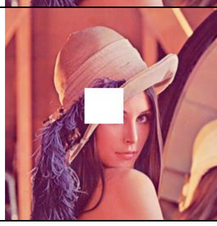
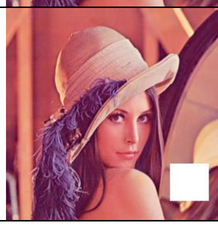
	Clipping(up)	Clipping(middle)	Clipping(down)
The watermarked color image			
The watermarked color image with being attacked			
PSNR	21.8387	19.9157	22.1587
The watermark Being extracted			
BCR	98.95%	98.46%	98.58%

Table 6. Performance Comparisons between other Watermark Schemes and Ours

Performance comparisons	Chandra [12]	Bao and Ma [11]	Hwang et al. [13]	Our scheme
Processing domain	SVD domain	Wavelet and SVD domains	Spatial domain	QSVD domain
Blind watermarking method	No	No	Yes	Yes
Robustness	High	High	Low	High
Embedding quality	High	General High	General High	General High
Extra data is required for watermark extraction	The original image and original watermark	Quantization factors	No	No

5. Conclusions

In this paper, a novel blind color image watermarking technique using U matrix through QSVD transformation is proposed to protect the intellectual property rights of color images. The proposed method tries to insert the watermark through moderating the coefficient of the quaternion elements in U matrix. .In this method, the color image is considered as an array of pure quaternion numbers. Then the array of pure quaternion is divided into non-overlapping blocks and we perform QSVD to each block to get the U matrix. The watermarking information is inserted into the coefficient of the quaternion elements in the first column of the U matrix. Besides, in the procedure of watermark insertion and extraction, ensuring higher fidelity and robustness and resilience to several possible image attacks have been considered. The experimental results showed that the proposed method performance created watermarked images with better PSNRs and more robustness versus several attacks such as Salt &Pepper noise, Brightness adjustment, Sharpen and Blurring and Clipping.

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