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# Color Image Blind Watermarking Algorithm Based on QR Decomposition and Voting in DWT Domain

Junxiang Wang [1,*], Ying Liu [1] and Yonghong Zhu [1]

*[1]Jingdezhen Ceramic Institute, Jingdezhen, 333403, China*
** Tel :+086-0798-8465857, e-mail: wjx851113851113@163.com*

### Abstract

*To achieve a better trade-off between robustness and imperceptibility, a blind watermarking algorithm based on QR decomposition and voting for color image in DWT domain is proposed in the paper. Most of the existing QR decomposition based watermarking schemes take the first row of R matrix into consideration while in our approach the watermark is embedded by modifying the first column element of Q matrix. In the embedding process, DCT is applied to the R, G and B color components, respectively. Then DWT is utilized on the DCT coefficients of each component and acquire corresponding LL, HL, LH, and HH. Later, the associated DWT coefficients in LH and HH are decomposed with QR decomposition and the watermark message is embedded into the first column of Q matrix by changing $Q_{21}$ and $Q_{31}$ with stable characteristic. In the extraction phase, a redundant watermark scheme with voting method is used to improve the robustness of the watermarking algorithm. Experimental results show that the proposed algorithm, compared with the existing methods is robust enough to resist common signal attacks including filtering, noising, small cutting and JPEG compressing.*

***Keywords**: blind watermarking; QR decomposition; DWT; redundant watermark; voting*

## 1. Introduction

The requirement for multimedia copyright protection is gradually improved, due to the fact that more and more people tend to publish their works in the form of multimedia. The traditional encryption technology can transform the original meaningful data stream into mess and achieve the purpose of hiding the real message. But it cannot protect the multimedia data from infringing and faking. Under this kind of situation, as the supplement of traditional encryption technology, digital watermarking technique meets the requirement and gains great development. There are two important issues existing in the watermarking scheme. Firstly, the watermark is able to be extracted from watermarked image after common signal operation processing attacks, meanwhile, the watermark is difficult to detect or destruct in an illegal way. Secondly, the watermarked image and the cover image should be sufficiently close to the senses and no obvious degradation in vision aspect.

According the embedding methods, the digital watermarking algorithm can divide into two groups, i.e. spatial/ time domain and frequency domain digital watermarking algorithm. The time domain watermarking algorithm directly change the pixels of the cover image, so it is simpler and faster, but not robust enough to resist common signal attacks. However, frequency domain digital watermarking algorithm change the frequency domain coefficients of the cover image, so its computation complexity will be higher, but robust enough to resist common signal attacks.

Currently, common-used transform techniques for digital watermarking scheme can be roughly sorted into four categories, Discrete Wavelet Transform [1-3], Discrete Cosine Transform [4], Discrete Fourier Transform [5] and Contourlet Transform [6]. Rahman and Rabbi（2015）proposed DWT-SVD based new watermarking idea in RGB color space. They suggested embedding the watermark into the R plane of vertical direction high frequency region. Experimental results demonstrated that their algorithm is robust to the

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common attacks. Lei *et al*.[2] have proposed a SVD–DCT based blind and robust audio watermarking scheme, in the approach a binary watermark is embedded into the high-frequency band of the SVD–DCT block with the synchronization code technique. Sun *et al*.[3] proposed copyright protection scheme based on overlapping DCT and SVD. They use the Direct current (DC) coefficients extracted from transformed blocks to form a DC-map and some random position are selected from the map to construct an ownership share for copyright verification. In [4], a blind watermarking algorithm based on block DCT for dual Color Images is proposed, which analyzed the features of spread spectrum technology and human visual system, to better achieve the copyright protection of color image. Kang et al.[5] proposed a DWT-DFT composite watermarking scheme robust to both affine transform and JPEG compression. In their approach, spread-spectrum-based informative watermark with a training sequence are embedded in the coefficients of the LL sub band in the DWT domain while a template is embedded in the middle frequency components in the DFT domain. Experimental results show that their scheme can achieve a high synchronization and strong robustness. In [7], the cover image and the water message are applied to Contourlet Transform and SVD, respectively. The water message is embedded into the cover image by add up the corresponding singular value.

To improve the performance of the watermarking algorithms, some matrix decomposition based schemes [1, 2, 3, 5, 12], like SVD, QR decomposition and Schur decomposition are employed into watermarking approaches by many researchers of watermarking field. Musrrat *et al*.[1] proposed an optimized watermarking technique based on self-adaptive DE in DWT–SVD transform domain. In this scheme the performance of differential evolution (DE) algorithm is significantly affected by its parameters setting that are highly problem dependent and the watermark is self-adaptive embedded into the host image by optimizing the scaling factors. Goyani *et al*.[11] presented block and non block based watermarking scheme performed in DCT domain using SVD and the analysis of simulation result shows that block based watermarking schemes are superior to non block based watermarking schemes in visual quality but inferior to non block based watermarking schemes in robustness. In [6], A novel image watermarking algorithm based on Contourlet Transform (CT), SVD technique and QR factorization is proposed. In this scheme the original image and the watermark image are transformed into sub-bands by Contourlet Transform and The LL frequency coefficients are further factorized using SVD. At the same time, the LL coefficients of watermark after CT are decomposed by QR factorization and the obtained QR decomposed coefficients are further factorized by SVD technique. This scheme shows good fidelity and robustness against common signal attacks. In [10], a blind color image watermarking scheme based on QR factorization is developed. in the approach the host color image is divided into non-overlapping pixel blocks. Then, each selected pixel block is applied QR factorization. The watermark message is embedded into $r_{14}$ of the first column of R matrix for the change of other elements in the first column will directly affect on the corresponding R matrix element except $r_{14}$. Gunjan *et al.* [12] have proposed a Schur factorization and SVD based digital watermarking scheme in the CT domain. In this paper the original image and watermark are both decomposed by CT. SVD is applied on the lowest frequency coefficients of original image after CT. The watermarks after CT are decomposed by Schur factorization. The obtained watermark is further factorized by SVD. The changed coefficients of singular values in watermark are embedded into the singular values of original image. A. Mohammad *et al*.[13] presented a new Schur based digital watermarking scheme for ownership protection. Compared with other existing watermarking algorithms, especially SVD based watermarking algorithms which are easier suffer the false positive detection problem, the proposed algorithm is more robust against most common attacks including geometrical distortions, filtering, noising, and JPEG compressing.

A new secure and blind color image watermarking scheme based on the DWT and QR decomposition was developed in this paper. In order to increase the robustness of our method against all kinds of attacks, four sub-bands including LL, LH, HL, HH are obtained after applying DWT on the host image and a gray watermark image is embedded into the color image by changing the stable characteristic got by using QR decomposition. Experimental results that the proposed method is more robust than some existing approaches and is able to recover the watermark message against several signal processing operations which including filtering, noising, small cutting and JPEG compressing.

This paper is organized as follows. Section 1 introduces the development trends of digital watermarking. Section 2 introduces the correlative techniques used in our scheme. Subsequently, sections 3 depicts watermark embedding and extraction algorithm. Section 4 presents the experimental results. Finally, conclusions are made in Section 5.

## 2. Related Techniques

### 2.1. Discrete Wavelet Transform

The digital image can be regarded as a discrete two-dimensional matrix, so the DWT can be adopted to decompose the digital image, the concrete two levels of decomposition process is shown in Fig.1.

As we can see from Fig.1, the DWT transform is actually a process of spectrum separation, the image is divided into two spectrum segments, low frequency and high frequency region. In the high frequency region, it can be divided into vertical direction high frequency region (HL) and horizontal direction high frequency region (LH). To the best knowledge of image processing theory, the average luminance of the image is represented by the low frequency region, while the high frequency region represents the texture, contour, edge and noise.

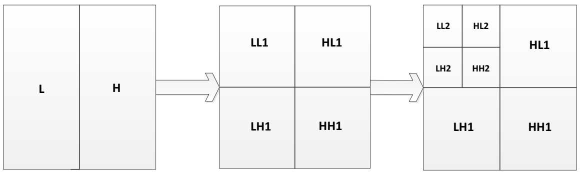



**Figure 1. The Process of Discrete Wavelet Transform**

### 2.2. QR Decomposition

In QR decomposition, a matrix of size $m \times n$ can be represented as:

$$A = Q \cdot R \tag{1}$$

where $Q$ is an orthonormal matrix and $R$ is an upper triangular matrix. The standard orthogonal basis is generated by column space of matrix A through Gram-Schmidt. $A$ and $Q$ denoted as $A = [a_1, a_2, ...., a_n]$ , $Q = [q_1, q_2, ...., q_n]$ respectively. The upper triangular matrix $R$ can be calculated by using following Eq.2.

$$R = \begin{bmatrix} \langle a_1, q_1 \rangle & \langle a_2, q_1 \rangle & \cdots & \langle a_n, q_1 \rangle \\ 0 & \langle a_2, q_2 \rangle & \cdots & \langle a_n, q_2 \rangle \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \langle a_n, q_n \rangle \end{bmatrix} \tag{2}$$

where $\langle a,q \rangle$ is an inner product formula.

To the best knowledge of matrix theory, for a given image, the matrix has a unique decomposition. So QR factorization applied on digital image is more stability.

Also, we can obtain two significant conclusions according the above-mentioned theory.

1. The value of elements in the first row of $R$ are larger than the other row, it means the first row centralize the most energy of the image matrix. So $R$ matrix determines the complexity of the original image.

2. The value of elements in the first column of $Q$ represents the different relationship between the pixels. So they can effective resist common signal attacks. Therefore, an idea that embeds the watermark message into the first column of $Q$ is put forward.

In order to verify the stability of the value in the first column of $Q$,several typical attacks signal have been perform on the first column coefficients of $Q$.To simplify the process,$Q_{2,1}$and $Q_{3,1}$from a random block are selected as an effective example. The original image (Lena) of size $512\times512$ is shows in Fig. 4 and the above-mentioned typical attacks include ‘Gaussian noise’ and ‘Salt and pepper’ noise with strength 0.03, median filtering, contrast enhancement and sharpening.

As we can see from Fig.2, the symbol in the first column has not changed but in second, third and fourth has varied in different degree. So we draw a conclusion that the value in the first column of $Q$ is stable enough to embed watermark message.

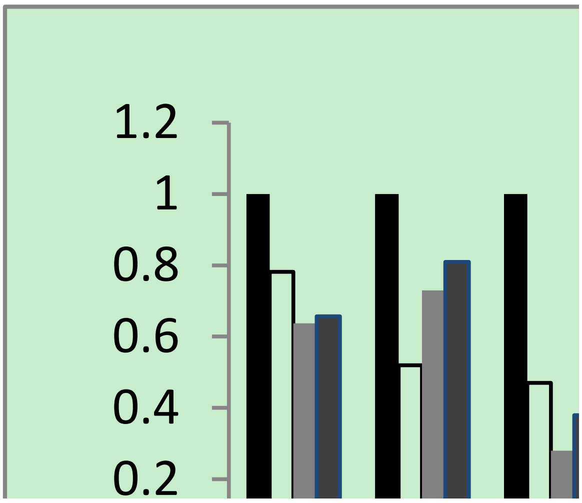



**Figure 2. Ratio of Invariant Symbol in Top Four Columns of Q matrix**

## 3. Watermark Embedding and Extracting Algorithm

### 3.1. Watermark Embedding Algorithm

In our embedding algorithm, we embed a binary watermark of size $16\times16$ in a color image (Lena) of size $512\times512$. Fig.4 and Fig.5 show the watermark and original color image, respectively. The watermark embedding framework is illustrated in Fig.3, and the embedding process is as follows:

1. The host color image is divided into three parts, i.e. R component, G component and B component.
2. DCT is applied on the three components, respectively.
3. The DCT coefficients are divided into $8\times8$ non-overlapping blocks

4. DWT is performed on the three components, LH and HH in R/G components and HH in B component are used to embed watermark, and each block is applied on QR decomposition.

5. One bit watermark message is embedded into one block by changing the value between $Q_{21}$ and $Q_{31}$. The embedding strength factor $\alpha(i, j)$ is various between each block, and we can calculate it by the following formula

$$\alpha(i, j) = \frac{abs(Q_{21}(i, j)) + abs(Q_{31}(i, j))}{2} * 3.5 \quad i, j \in [1, 2K\ 16] \tag{3}$$

The embedding process depends on the scheme shown in Table 2.

$$\mu(i, j) = abs(Q_{21}(i, j)) - abs(Q_{31}(i, j)) \tag{4}$$

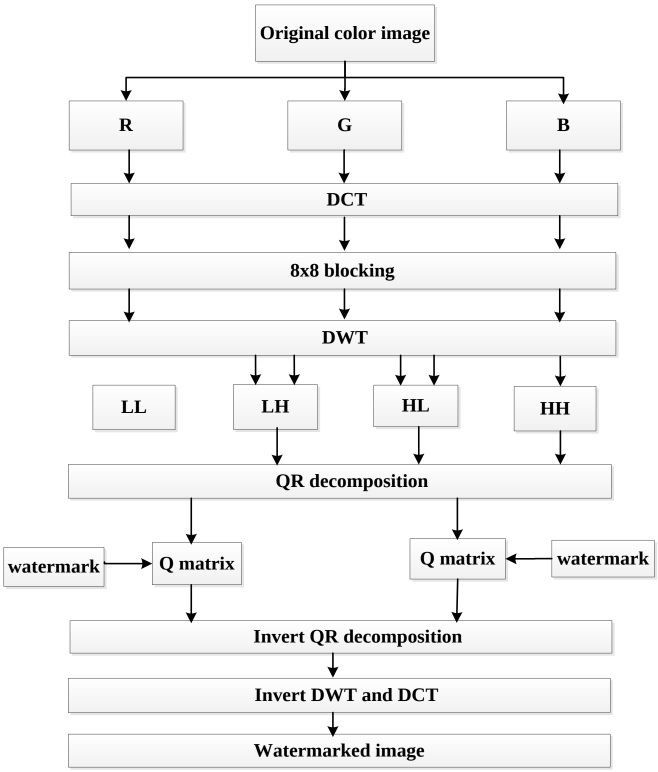



**Figure 3. Block Diagram of Proposed Watermark Embedding Algorithm**

6. Applied invert QR decomposition, invert DWT and invert DCT for reconstruction of the three components.

7. Recombine the three components to obtain the watermarked color image.

**Table 1. The Embedding Scheme**

| Criteria | The embedding scheme | |
|---|---|---|
| | watermark=1 | watermark=0 |
| $\mu(i,j) > \alpha(i,j)$ | $Q'_{21} = Q_{21}, Q'_{31} = Q_{31}$ | $Q'_{21} = Q_{31}, Q'_{31} = Q_{21}$ |
| $\mu(i,j) < -\alpha(i,j)$ | $Q'_{21} = Q_{31}, Q'_{31} = Q_{21}$ | $Q'_{21} = Q_{21}, Q'_{31} = Q_{31}$ |
| $0 < \mu(i,j) < \alpha(i,j)$ | $Q'_{21}$=abs($Q_{21}$)+(abs($\mu$(i,j)-$\alpha$(i,j)))/2<br>$Q'_{31}$=abs($Q_{31}$)-(abs($\mu$(i,j)-$\alpha$(i,j)))/2 | $Q'_{21}$=abs($Q_{31}$)-(abs($\mu$(i,j)+$\alpha$(i,j)))/2<br>$Q'_{31}$=abs($Q_{21}$)+(abs($\mu$(i,j)+$\alpha$(i,j)))/2 |
| $-\alpha(i,j) < \mu(i,j) < 0$ | $Q'_{21}$=abs($Q_{31}$)+(abs($\mu$(i,j)-$\alpha$(i,j)))/2<br>$Q'_{31}$=abs($Q_{21}$)-(abs($\mu$(i,j)-$\alpha$(i,j)))/2 | $Q'_{21}$=abs($Q_{21}$)-(abs($\mu$(i,j)-$\alpha$(i,j)))/2<br>$Q'_{31}$=abs($Q_{31}$)+(abs($\mu$(i,j)-$\alpha$(i,j)))/2 |

### 3.2. Watermark Extraction Algorithm

For watermark extraction, we assume that the grayscale watermark image consists of the values 0 and 1.The extracting procedure is just the inverse procedure of the embedding one .The specific steps to extract the watermark are as follows:

1.Get different color components of watermarked image and apply 2D-DCT on them.

2. The obtained DCT coefficients are divided into non-overlapping blocks and each block is performed 2D-DWT.

3. The selected sub-band of the three components is applied QR decomposition and the watermark message is extracted from the Q matrix by the following expression:

$$wateramrk = \begin{cases} 1 & if\ (abs(Q_{21}) > abs(Q_{31})) \\ 0 & if\ (abs(Q_{21}) > abs(Q_{31})) \end{cases} \quad (5)$$

4. To improve the robustness of the watermark, we proposed a redundancy watermark scheme based on voting method. In this algorithm, five watermarks are extracted from the original color image. They are denoted as $W_1, W_2, W_3, W_4$ and $W_5$ .The final watermark depends on the following two expressions:

$$W = W_1 + W_2 + W_3 + W_4 + W_5 \quad (6)$$

$$wateramrk = \begin{cases} 1 & if\ (W >= 3) \\ 0 & if\ (W < 3) \end{cases} \quad (7)$$

## 4. Experimental Results

In this section, we have tested the proposed scheme on six famous images from USC-SIPI image database of $512 \times 512$, referred to as “Lena”, “Peppers”, “Baboon”, “Airplane”, “Autumn” and “Butterfly”. The original images and the watermarked images are demonstrated in Fig.4. A binary image of size $16 \times 16$ and the extracted watermark with no attack are indicated in Fig.5.

As mentioned in section 1, robustness and imperceptibility are two significant evaluating indicators for a watermarking algorithm. The imperceptibility measured through Peak Signal-to-Noise Ratio (PSNR) or Structural similarity (SSIM), which is utilized to assess the quality between original image and extracted image. While the robustness calculated by Normalized Correlation Coefficient (NCC) or Accurate Rate (AR), which is used to evaluate the relativity between original watermark and extracted watermark. PSNR and SSIM can obtain by Eq.(8) and Eq.(10), respectively. NCC can be measured by the formula (9).

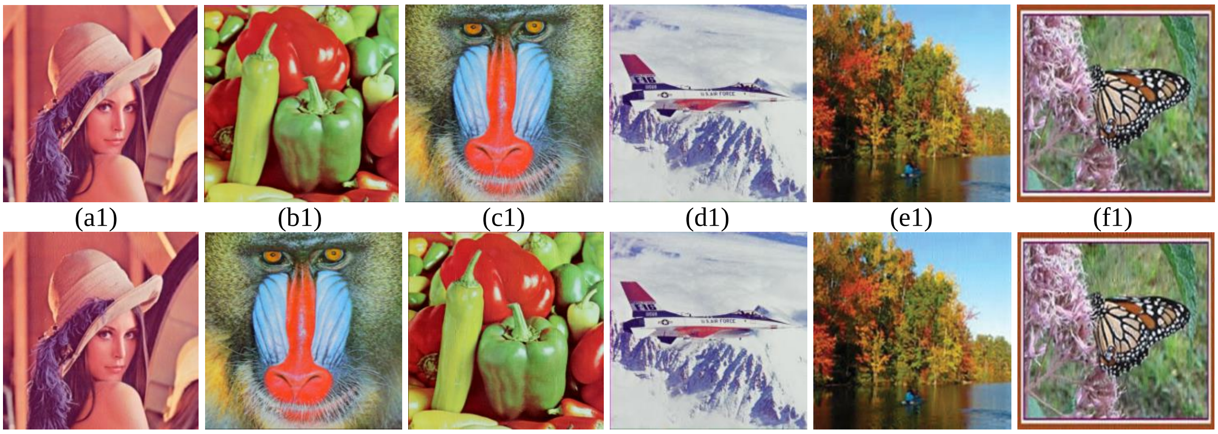
$$MSE = \frac{1}{M \times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(F(\mathrm{x,y}) - F^{'}(\mathrm{x,y}))^2,\ PSNR = 10\lg\frac{255^2}{MSE} \quad (8)$$

$$NCC(\mathrm{W,W}^{'}) = \frac{\sum_{i=0}^{X-1}\sum_{j=0}^{Y-1}W(\mathrm{i,j})W^{'}(\mathrm{i,j})}{\sqrt{\sum_{i=0}^{X-1}\sum_{j=0}^{Y-1}W^2(\mathrm{i,j})}\sqrt{\sum_{i=0}^{X-1}\sum_{j=0}^{Y-1}W^{'2}(\mathrm{i,j})}} \quad (9)$$

$$SSIM(H,H^{'}) = l(H,H^{'}) \times c(H,H^{'}) \times s(H,H^{'}) \quad (10)$$

Where $M$ and $N$ are the width and height of the color host image respectively, $F(\mathrm{x,y})$ and $F(\mathrm{x,y})^{'}$ represent the gray value of cover image and watermarked image, respectively. $W(\mathrm{i,j})$ and $W(\mathrm{i,j})'$ represent the binary value of original watermark and extracted watermark.

$l(H,H^{'}) = \frac{2\times\mu_H\times\mu_{H^{'}}+C_1}{\mu_H^{\ 2}+\mu_{H^{'}}^{\ 2}+C_1}$, $c(H,H^{'}) = \frac{2\times\delta_H\times\delta_{H^{'}}+C_2}{\delta_H^{\ 2}+\delta_{H^{'}}^{\ 2}+C_2}$, $s(H,H^{'}) = \frac{\delta_{H,H^{'}}+C_3}{\delta_H\times\delta_{H^{'}}+C_3}$, C1, C2 and C3 are positive real numbers, $\mu_H$ and $\mu_{H^{'}}$ are the mean values of $H$ and $H^{'}$, respectively. $\delta_H$ and $\delta_{H^{'}}$ are the standard variances of $H$ and $H^{'}$, respectively. $\delta_{H,H^{'}}$ is the covariance between $H$ and $H^{'}$.



(a1) (b1) (c1) (d1) (e1) (f1)

(a2) (b2) (c2) (d2) (e2) (f2)

**Figure 4. Test Images (a1)–(f2) and Watermarked Images (a2)–(f2)**

(a) (b)

**Figure 5. (a) Original Watermark Image and (b) Extracted Watermark Image**

### 4.1 Imperceptibility Analysis

The image quality can be evaluated by the original images and the watermarked images, the assessment will achieved over six above-mentioned images based on the values of PSNR and SSIM metrics given in Table.2. Experiments show that our scheme can achieve a high visual quality in the PSNR and SSIM.

### 4.2 Robustness Analysis

To verify the robustness of the above-mentioned algorithm, we performed some common attack signal processing operations on the watermarked Lena image, Such as, cropping (Cr) including 1/4 corner-cropping (Ccr) and side-cropping (Scr), Scaling (Scl), median filtering (Md), Low-pass filtering (Lp) , mean filtering (Mf), Gaussian filter (Gf), Gaussian noise (Gn), Salt and pepper noise (Spn) and speckle noise (Sn). Some results indicated in Fig.6 demonstrated the effectiveness of the watermarking scheme proposed in this paper.

Three independent comparative experiments have been done. First, we compare our scheme with the method proposed in [7]. Here, we adopt AR as evaluating indicator and the results are shown in Table.3. In the second experiment, we compare NCC for the proposed scheme and method mentioned in [8] and the results are shown in Fig.7 and Tab.4. Final, we compare our voting scheme with non-voting method, the result in Fig.8 shows the NCC of voting method for some standard images, such as “peppers” and “baboon”, is higher than the non-voting method.


**Figure 6. The Extracted Watermark Image and the Value of NCC Under Different Attacks**

**Table 2. PSNR between Original and Watermarked Image**

| Standard images | Lena | Peppers | Baboon | Airplane | Autumn | Butterfly |
|---|---|---|---|---|---|---|
| PSNR(dB) | 40.13 | 40.76 | 40.36 | 39.56 | 38.78 | 40.89 |
| SSIM | 0.9924 | 0.9852 | 0.9940 | 0.9950 | 0.9945 | 0.9932 |

**Table 3. Extracted Watermark's AR Value Comparison between Proposed Scheme and [7]**

| Attack | AR of extracted watermark | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | [7] method | | | | Proposed method | | | |
| | Airplane | Autumn | Butterfly | Peppers | Airplane | Autumn | Butterfly | Peppers |
| Mf(3x3) | 0.8875 | 0.8591 | 0.8931 | 0.8093 | 0.9345 | 0.9156 | 0.9423 | 0.9213 |
| Gn(0.001) | 0.8409 | 0.8255 | 0.8813 | 0.8265 | 0.8907 | 0.8266 | 0.8548 | 0.8770 |
| Gn(0.002) | 0.8326 | 0.8208 | 0.8740 | 0.8243 | 0.8854 | 0.8212 | 0.8512 | 0.8801 |
| Gn(0.003) | 0.8287 | 0.8064 | 0.8771 | 0.8999 | 0.8801 | 0.8079 | 0.8417 | 0.8766 |
| JPEG(90) | 0.8104 | 0.8272 | 0.8452 | 0.8125 | 0.9920 | 0.9704 | 0.9812 | 09974 |
| JPEG(80) | 0.8135 | 0.8050 | 0.8503 | 0.8974 | 0.9866 | 0.9484 | 0.9540 | 0.9813 |
| JPEG(70) | 0.8104 | 0.8930 | 0.8349 | 0.8082 | 0.9510 | 0.9118 | 0.9238 | 0.9577 |
| Spn(0.001) | 0.9956 | 0.9900 | 0.9255 | 0.9961 | 0.9920 | 0.9676 | 0.9833 | 1.0000 |
| Spn(0.002) | 0.9946 | 0.9410 | 0.9207 | 0.9934 | 0.9866 | 0.9538 | 0.9866 | 0.9947 |
| Spn(0.003) | 0.9915 | 0.9110 | 0.9211 | 0.9895 | 0.9839 | 0.9540 | 0.9731 | 0.9920 |

**Table 4. NCC Value of Extracted Watermark with Compare to [8]**

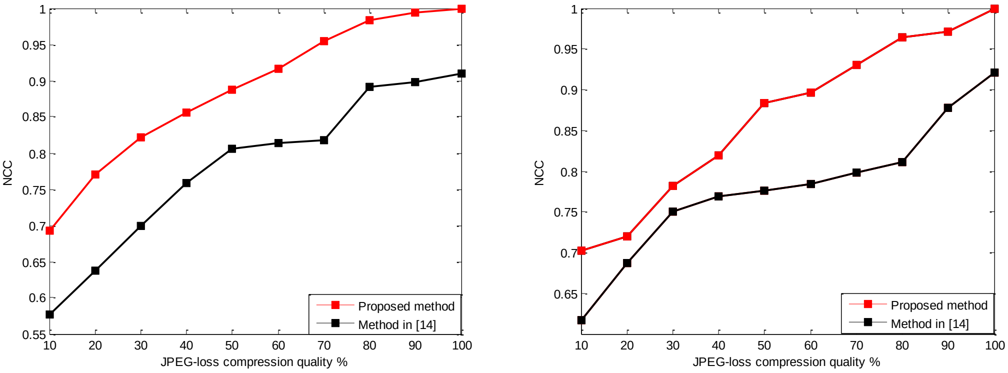
| Attack | NCC of extracted watermark | | | |
|---|---|---|---|---|
| | [8] method | | Proposed method | |
| | Peppers | Baboon | Peppers | Baboon |
| JPEG(100) | 0.99 | 1.0 | 1.0 | 1.0 |
| JPEG(50) | 0.68 | 0.93 | 0.92 | 0.97 |
| JPEG(20) | 0.58 | 0.78 | 0.74 | 0.90 |
| JPEG2000(100) | 1.0 | 1.0 | 1.0 | 1.0 |
| JPEG2000(50) | 0.67 | 0.72 | 0.96 | 0.99 |
| JPEG2000(20) | 0.63 | 0.61 | 0.89 | 0.97 |
| Scl 2.0 | 0.99 | 1.0 | 0.64 | 0.63 |
| Scl 0.5 | 0.64 | 0.52 | 0.65 | 0.65 |
| Mf 3×3 | 0.61 | 0.46 | 0.92 | 0.93 |
| Gf 3x3 | 0.62 | 0.69 | 0.86 | 0.89 |
| SS1 | 1.0 | 0.96 | 0.91 | 0.94 |
| SS2 | 0.86 | 1.0 | 1.0 | 1.0 |
| SS3 | 0.97 | 0.71 | 0.88 | 0.89 |
| Scr 25% | 0.73 | 0.75 | 0.94 | 0.99 |

Robustness is a significant assessment index of digital watermarking techniques for many applications. Robustness is the resistance against common signal attacks, including noise attacks, filter attacks and geometrical attacks. Fig.6 shows the NCC of the extracted watermark after the watermarked image were subjected to common signal processing operations and the results are obtained by using a system with given specifications: Intel(R) Core(TM) i3-4130 CPU @ 3.40 GHz, Win7 (32-bit operating System), and

MATLAB (R2010a) environment in this paper. As we shown in Fig.6, the watermark can extracted from the watermarked image for most signal processing operations except Scl. So we can draw a conclusion that the watermarking scheme not only showed robustness against noise and geometrical attacks but also showed robustness against uniform filter attacks.

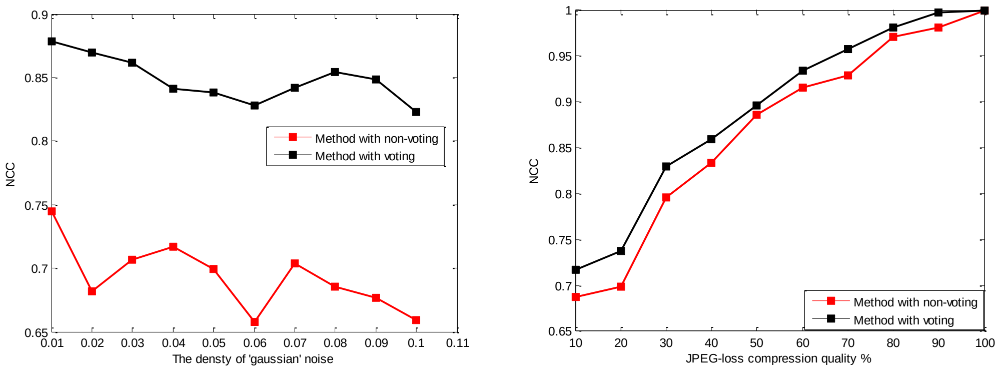
Furthermore, the experimental results are compared with three other schemes and the results in Table.4 are based on four common images referred to as “Airplane”, “Autumn”, “Butterfly” and “Peppers”. Fig.7 and Table.3 displayed extracted watermarks that have suffered the following types of attacks: Mf, Gf, Gn and Spn, JPEG compression, JPEG2000 compression, Scl and self-similarities. It is clear that the proposed scheme, compared with the method mentioned in [7], not only satisfies imperceptibility, but also has better robustness against common signal processing operations. What is more, the proposed watermarking method can realize the blind extraction of watermark without any original image message. So it’s reasonable to believe that the approach mentioned in this paper will be widely accepted.

Table.4 presents the comparison results of the proposed scheme with the other representative scheme proposed by Nasir *et al*.[8]. As Table.4 shows, the proposed scheme highly robust against JPEG compression, JPEG2000 compression, Mf, Gf, SS2(Self-Similarities2) and Cr attacks. We also compare NCC of extracted watermark under JPEG attack and Gaussian noise attack in proposed method and non-voting method. Fig.8 shows the experiment result for some standard images such as “Peppers” and “Baboon”.

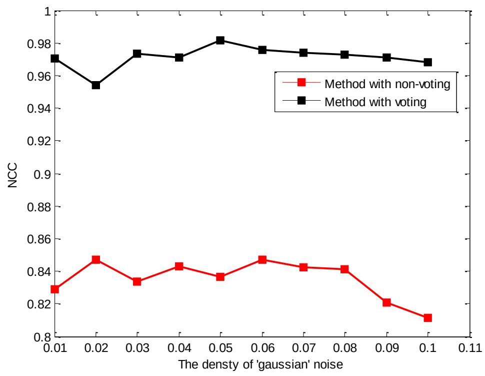


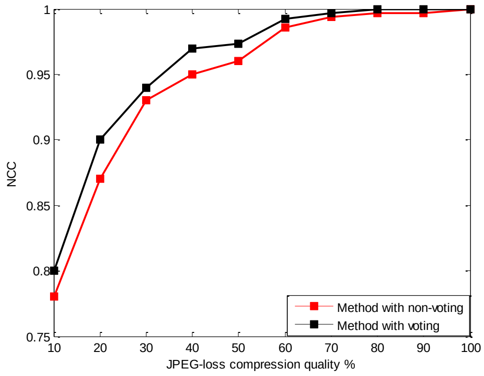

(a) (b)

**Figure 7. NCC of Extracted Watermark under JPEG Attack in Scheme [8] and Proposed Scheme: (a) Lena, (b) Peppers**




(a) (b)




1 (c) (d)

**Figure 8.NCC of Extracted Watermark under JPEG attack and Gaussian Noise Attack in Voting Method and Non-voting Method (a)Peppers under Gaussian Noise Attack, (b) Peppers under JPEG Attack, (c) Baboon under Gaussian Noise Attack, (d) Baboon under JPEG Attack**

## 5. Conclusion

QR decomposition and voting based algorithm for embedding a binary image into a color image is proposed to protect the multimedia copyright in this paper. In the embedding process, the approach takes the stable value in the first column of Q matrix into consideration and verifies the practicability of embedding the watermark into the DWT coefficients by adjusting the value of $Q_{21}$ and $Q_{31}$. Moreover, the redundant watermarks embedded into the sub-band of color image component will great improve the robustness of the approach. During watermark extraction, a voting method is adopted to extract the watermark message. Analysis of the proposed scheme concludes that the scheme has achieved a better trade-off between robustness and imperceptibility compared to some of the existing and related techniques. As the experimental results described, our scheme has the abilities to resist all kinds of signal attacks, like filtering, noise addition, cropping, and JPEG/JPEG2000 compression.

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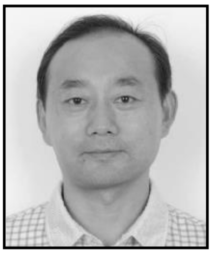
## Authors

**Junxiang Wang** Associate Professor at the School of Mechanical & Electronic Engineering, Jingdezhen Ceramic Institute (JCI). He received his Ph. D. degree from Sun Yat-sen University in 2012. His research interests cover image processing, information hiding, ceramic equipment intelligence. Corresponding author of this paper.

**Ying Liu** Postgraduate student at the School of Mechanical & Electronic Engineering, Jingdezhen Ceramic Institute (JCI). His interests is in image processing and information safety.



**Yonghong Zhu** Professor of Control Theory and Control Engineering at Jingdezhen Ceramic Institute(JCI). He received the B.S. and M.S. degree in Automation Engineering from Jiangxi Polytechnic University, Nanchang, China, in 1986 and 1989, respectively, and the Ph.D. degree in Control Theory and Control Engineering from Nanjing University of Aeronautics and Astronautics, Nanjing, China, in 2004. His research interests in the areas of networked control systems, robust adaptive control, intelligent control, hybrid control and information fusion.