A COLOR IMAGE BLIND DIGITAL WATERMARKING ALGORITHM BASED ON QR CODE

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ABSTRACT

With the rapid development of network technology and multimedia, the current color image digital watermarking algorithm has the problems of small capacity and poor robustness. In order to improve the capacity and anti-attack ability of digital watermarking. A color image blind digital watermarking algorithm based on QR code is proposed. The algorithm combines Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT). First, the color image was converted from RGB space to YCbCr space, and the Y component was extracted and the second-level discrete wavelet transform is performed; secondly, the LL2 subband was divided into blocks and carried out discrete cosine transform; finally, used the embedding method to embed the Arnold transform watermark information into the block. The experimental results show that the PSNR of the color image embedded with the QR code is 56.7159 without being attacked. After being attacked, its PSNR is more than 30dB and NC is more than 0.95. It is proved that the algorithm has good robustness and can achieve blind watermark extraction.

KEYWORDS

QR Code, Color Image, Arnold Transform, DWT

1. INTRODUCTION

With the development of the Internet, various digital products have appeared on the Internet. At the same time, with the rapid development of information digitization, there has also been a problem that copyright is not easy to protect [1]. Digital watermarking is a method to solve the problem of copyright protection. According to different embedding methods, it is divided into spatial domain watermark and transform domain watermark. The current digital watermark embedding into the vector transform domain better image can be improved watermark robustness and security [2].

The transform domain watermark technology embeds watermark information into the corresponding frequency coefficients through frequency domain transformation. Common methods include DWT and DCT. The low-frequency component embedding watermark through DCT transformation has strong robustness However, the anti-attack ability is weak[3]. The mixed use of DWT and DCT can balance the robustness and imperceptibility of the watermark image.
Quick response code (quick response code) referred to as QR code, it can store a lot of information. Therefore, using QR code as a watermark can not only improve the robustness of the watermark, but also store more copyright information [4]. Arnold transform has periodicity and is widely used in image scrambling. Using its characteristics to transform QR code information can improve the security of watermarking [5].

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2. RELATED WORK

He et al. [6] proposed a color image watermarking algorithm based on discrete wavelet transform, discrete cosine transform and singular value decomposition (DWT-DCT-SVD). First, convert the carrier image from RGB color space to YUV color space; then, perform a layer of discrete wavelet transform on the brightness component Y, use discrete cosine transform to decompose the low frequency and divide it into blocks, and perform singular value decomposition on each block ; Finally, embed the watermark into the carrier image. However, there is a problem with the DWT-DCT-SCD method. A non-blind watermark image is needed to extract the watermark in the experiment and the watermark non-QR code is used in the experiment. Xu Jiangfeng et al. [7] proposed a digital watermarking scheme combining QR code, chaotic system and DWT-DCT. Carry out DWT operation on the carrier image and perform 4×4 block and DCT operation on the low frequency subbands. Then embed the QR code watermark through the chaotic system into the carrier image. The experimental results show that after the Gaussian noise attack, the PSNR value and NC value are low. The experiment uses gray-scale images, which is less practical. To solve the above problems, this paper proposes a color image blind digital watermarking scheme based on QR code. This scheme selects a color image as the carrier image, converts the RGB color space to the YCbCr color space, embeds the watermark into the luminance component Yand uses the Arnold transformation to encrypt the QR code. While improving the security and robustness of the watermark. It also increased the amount of watermark informatione.

2.1. Discrete Wavelet Transform

In digital image processing, it is necessary to discretize continuous wavelet and wavelet transform. Discretized wavelet and corresponding wavelet transform are called discrete wavelet transform [8]. Discrete wavelet transform is a spatio-temporal scale analysis method of information analysis theory and signal. It has multiple scales in the space and frequency domainand can continuously decompose images from low resolution to high resolution [9,10]. In addition, the DWT algorithm has a wide range of applications in the digital watermarking field. At present, many innovative and efficient joint algorithms related to DWT have been proposed.

In this paper, the RGB color space of the color carrier image is transferred to the YCbCr color space. Perform DWT transformation on Y component to obtain the horizontal and vertical low frequency LL, the horizontal low frequency and the vertical high frequency LH, the horizontal high frequency and the vertical low frequency HL, high-frequency components HH in the horizontal and vertical directions. DWT is performed on the LL subband again to obtain the low frequency component LL2. The low-frequency components represent image features. The high-frequency components represent the edges and details of the image. Embedding the watermark in the low frequency component LL2 can improve the robustness. As shown in Figure 1.

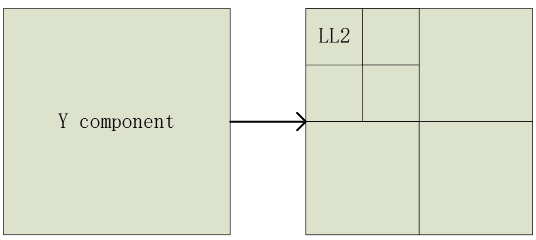


Figure 1. Wavelet decomposition diagram.

2.2. Discrete Cosine Transform

Discrete Cosine Transform can transform the spatial domain signal into the frequency domain signal and has good decorrelation performance [11,12]. The important information of the image after discrete cosine transform is concentrated on the middle and low frequency coefficients. The position is the upper left corner of the DCT matrix, which has the ability to resist attacks. After being attacked, the embedded watermark information can still be extracted [13,14]. In this paper, the LL2 subband is divided into blocks, the blocks are subjected to DCT transformation, then the medium and low frequency coefficients are selected for watermark embedding. the DCT inverse transformation completes the image reconstruction.

2.3. Arnold Transform

The watermark image contains important information. The Arnold transform is used to scramble the image to achieve information encryption. At the same time, the Arnold transform is periodic. The number of scrambling can be used as the watermark key to further enhance its security [15]. The periodicity of Arnold transformation refers to the continuous transformation of the original image, the original image is obtained after t times. The transformation period t is related to the size of the image M×N [16]. The Arnold transformation is defined as follows:

$$\begin{bmatrix} x^* \\ y^* \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (\bmod N) \qquad (1)$$

Among them, (x, y) represents the pixel position before image scrambling, (x^*, y^*) represents the image pixel location after scrambling, N represents the order of the image matrix.

QR code is a type of matrix two-dimensional code. It has many characteristics such as high-speed reading, high capacity, support for error correction processing, wide coding range, low costand easy production. Due to the high capacity of QR codes, using QR codes as digital watermarks can increase the information capacity. Because of its support for error correction processing, the robustness of the watermark can also be improved.

3. EMBEDDING AND EXTRACTION OF WATERMARK

This article uses QR code as a watermark which adds more information and improves the security of the watermark. The use of color images as carrier images is more widely used.

3.1. Embedded Watermark

(a) Convert the color carrier image from RGB color space to YCbCr color space according to the algorithm flow and extract the brightness component Y. (b) Perform a two-level DWT transformation on the luminance component to obtain the low frequency subband LL2, then implement 2×2 block division on the LL2 subband to obtain a block matrix. (c) Perform DCT transformation on each block (dct=dct(LL2)) to obtain the transformed DCT matrix. Then extract the first value in the matrix from the DCT transformed block to form a new matrix F. (d) Use Arnold transform algorithm to scramble the original watermark image W to get the scrambled watermark W^* . (e) Embed the watermark W^* into the matrix F using equations 2 and 3 to obtain the matrix F^* . Then replace each value of the matrix F^* with the first value of each block in turn, and perform inverse DCT transformation on each block to obtain $LL2^*$.

$$\lambda_1^* = \begin{cases} \lambda_1 - T + 3a/4 & T \geq a/4 \\ \lambda_1 - T - a/4 & other \end{cases} \quad W^*(i,j) = 0 \qquad (2)$$

$$\lambda_1^* = \begin{cases} \lambda_1 - T + 5a/4 & T \geq 3a/4 \\ \lambda_1 - T + a/4 & other \end{cases} \quad W^*(i,j) = 1 \qquad (3)$$

Among them, $T = \lambda_1 \bmod a$, a is the embedding strength. Used to control the invisibility and robustness of embedded watermarks. λ_1 represents each value in each block matrix. λ_1^* Represents the embedded value.

(f) Implement the second-level inverse DWT transformation on the obtained in the previous step to obtain the component. The brightness component of the embedded QR code is converted from the YCbCr color space to the RGB color space to obtain the color carrier image embedded in the QR code. Figure 2 is a flowchart of watermark embedding.

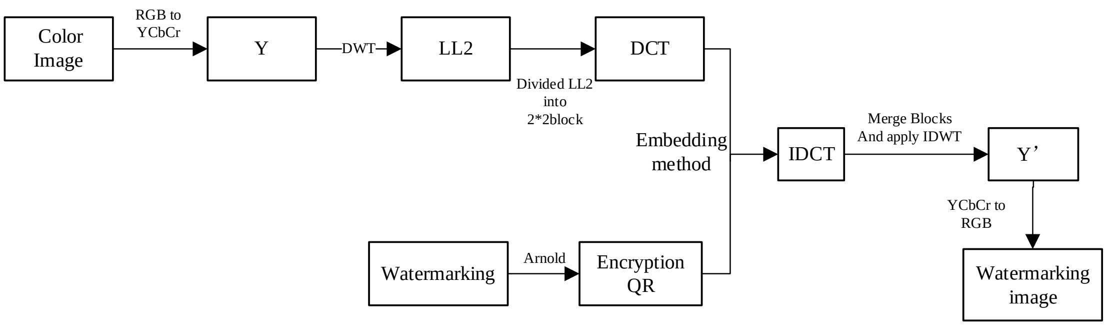


Figure 2. Watermarking embedding flow chart.

3.2. Extract Watermark

(a)First, convert the color carrier image embedded with QR code from RGB color space to YCbCr color space and extract the brightness component Y^*. (b) Perform two-level DWT transformation on the luminance component to obtain the low-frequency subband. Then perform 2×2 block on the subband. (c) Perform DCT transformation on each block to obtain the transformed DCT matrix. dct=dct($LL2^*$). Then extract the first value in the matrix from the block after DCT transformation to form a matrix F^*. (d) The extraction of watermark information is the reverse process of watermark embedding. The watermark is extracted by equations 4.

$$W(i,j) = \begin{cases} 1 & T > a/2 \\ 0 & other \end{cases} \qquad (4)$$

(e) According to the obtained W^* in the previous step. Then perform Arnold transformation on it. Finally the watermark W is extracted. Figure 3 is a flow chart of watermark extraction.

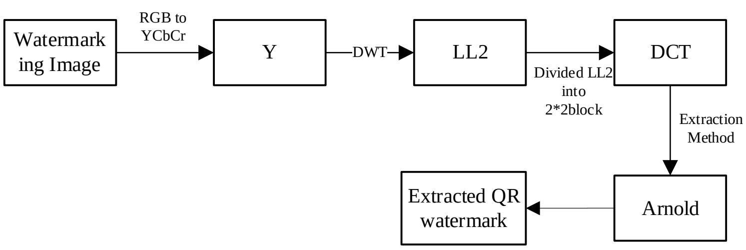
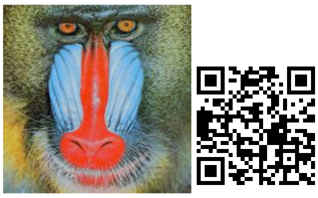


Figure 3. Watermarking extraction flow chart.



(a)Color Image (b)QR Code

Figure 4. Experiment Pictures.

4. THE EXPERIMENTAL RESULTS

The experimental environment is: Intel Core i5-4210M CPU; 2.60GHz frequency; Windows 10 64-bit operating system; Matlab2018a software. Select the color carrier image with 512×512 pixels, the 64×64 QR code is the watermark and the QR code carries the information. Figure 4(a) is a color carrier image, and Figure 4(b) is a QR code watermark image.

4.1. Watermark Evaluation Standard

Experiments usually use peak signal-to-noise ratio (PSNR) to measure the difference between the QR code-embeddsssed image and the unembedded original image. The greater the PSNR, the higher the recognition of the image embedded in the QR code with the original image. The definition of PSNR is:

$$PSNR = 10\log_{10}\frac{255^2 M \times N}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}(I^*(x,y) - I(x,y))^2} \tag{5}$$

Among them, I^* represents a watermarked color carrier image and I represents a color carrier image. When the PSNR value is greater, the color carrier image is closer to the watermarked color carrier image. The embedded watermark effect is better. PSNR>30dB usually means that the watermark is invisible and the image quality is better.

The normalized correlation coefficient (NC) represents the similarity between the original watermark and the extracted watermark. The NC value ranges from 0 to 1. The closer the NC value is to 1, the higher the similarity between the original watermark and the extracted watermark. The definition of NC is:

$$NC = \frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} W(x,y)W^*(x,y)}{\sqrt{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} W(x,y)^2 \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} W^*(x,y)^2}} \tag{6}$$

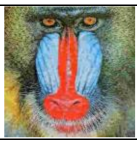
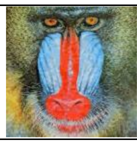
Among them, W represents the original watermark image. W^* represents the extracted watermark image.

4.2. Analysis of Results

In order to test the robustness of the algorithm, the experiment uses JPEG compression, noise filtering, cropping attack, rotation attack and median filtering to attack watermarked images.

a) JPEG compression.

Table 1. JPEG Compression.

			
(a)JPEG(10%)	(b)Extracted(a=1)	(c)JPEG(80%)	(d)Extract(a=1)

In the experiment, the JPEG compression attack was performed on the image. Table 1(a)-(d) are the results of the JPEG compression attack under different factors. It can be measured that the extracted QR code can be recognized by the machine.

According to the data in Table 2, when the JPEG compression factor is 10%, the PSNR value is 48.9158 and the NC value is 1. At this time, the QR code can still be identified, indicating that the algorithm in this paper is robust against JPEG compression attacks and can ensure the integrity of the watermark information.

Table 2. JPEG Compression attack data.

Methods	Compression Ratio					
	10%	20%	30%	40%	60%	80%
PSNR/dB	48.9158	50.0294	50.6425	51.0356	51.6767	52.5922
NC	1	1	1	1	1	1

b) Noise attack. The experiment uses salt and pepper noise and Gaussian noise attacks, as shown in Table 3.

Table 3. Noise attack.

			
(a)SaltandPepper(0.15)	(b)Extracted(a=2)	(c)Gaussian(0.04)	(d)Extract(a=2)

Table 4.Noise attack data.

Method	Salt and Pepper Noise			Gaussian Noise			
	0.01	0.05	0.15	0.01	0.02	0.03	0.04
PSNR/dB	45.3121	41.7544	37.9263	43.0325	42.9243	42.7836	42.5694
NC	1	1	09687	1	0.9997	09995	0.9962

It can be seen from Table 4 that the PSNR value of the color carrier image embedded with the QR code is attacked by salt and pepper noise and Gaussian noise respectively. The PSNR value is also above 30dB. It indicating that the attacked carrier image shows strong robustness and can resist noise attack. From the perspective of the NC value, the extracted watermark maintains a high consistency with the original watermark and the extracted watermark can be identified.

c) Cropping attack. It can be seen from the different cropping areas in Table 6 that the QR code is embedded in the frequency domain of the carrier image.The cropping of different areas can still maintain a high NC value, the PSNR value can also be maintained above 30dB and the QR code can be Identified. Therefore, this algorithm has good resistance to shearing attacks.

Table 5. Cropping attack.

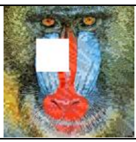
			
(a)Cropping(1/16)	(b)Extracted(a=2)	(c)Cropping(1/128)	(d)Extract(a=2)

Table 6. Cropping attack data.

Method	Cropping Ratio					
	1/8	1/16	1/32	1/64	1/128	1/256
PSNR/dB	41.3916	41.3724	43.0706	45.3883	45.8662	46.0592
NC	0.9600	0.9589	0.9782	0.9868	0.9928	0.9951

d) Rotation attack and Median filtering. It can be concluded from Table 7 that the algorithm can resist rotation attacks and median filtering. The PSNR values are all above 30dB, and the NC values remain above 0.9. It shows that the algorithm has good robustness.

Table 7. Rotation attack and Median filtering data.

Method	Rotation Angle		Median Filtering
	5°	10°	[3×3]
PSNR/dB	42.4715	40.4322	45.2474
NC	0.9693	0.9558	0.9991

e) Comparison results. It can be seen from Table 8 that in the median filter attack, the algorithm in this paper is better than the non-blind QR code watermarking algorithm in the literature [7]. In this paper, the NC values of Gaussian noise and salt and pepper noise are both higher than 0.9. When the JPEG compression factor is 30%, the NC value reaches 1, which is higher than the NC value in the literature [7]. It can be concluded that the algorithm in this paper is more robust than the algorithm in [7].

Table 8. Compare the results of different experiments.

Attacks	NC(Proposed Method)	NC(Reference [7])
JPEG Compression30%	1	0.9875
Cropping 1/16	0.9589	—
Gaussian Noise 0.04	0.9962	0.9300
Salt and Pepper Noise 0.05	1	0.9849
Median Filtering [3×3]	0.9991	0.9873

5. CONCLUSION

In this paper, color images are used as carrier images and QR codes are used as watermark information to increase the watermark information carrying capacity, it also improves the watermark's anti-attack ability. Implementation of Arnold transformation on QR code, then implementation of DWT, DCT and block operations on carrier images. attack experimental data show that the algorithm in this article is resistant to JPEG compression, clipping attack, Gaussian noise, salt and pepper noise, median filtering, and rotation attacks. The PSNR values are all above 30dB. The algorithm proposed in this paper also has shortcomings. In a rotation attack, when the rotation angle exceeds 12°, the extracted QR code will not be recognized and information cannot be obtained through the device. In view of the above problems, the algorithm needs to be continuously improved.

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