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The Color Image Digital Watermarking Algorithm Based on Coordinate Transformation and Quaternion Fourier Transform

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Abstract: *With the rapid development of information technology and Internet technology, people can easily exchange and transmit digital information, which not only brings convenience to people's work and life, but also brings rampant piracy of digital media. In the face of the temptation that pirated digital media can obtain huge benefits, some people are desperate to steal digital media works without copyright and sell and spread them at will. In this case, digital media copyright protection and anti-theft version authentication are very important measures to solve the current problems, and digital watermarking(DW) technology is an important method of digital media copyright protection and authentication, so it is more and more concerned and studied by researchers. This paper mainly studies the color image DW algorithm based on coordinate transformation and quaternion Fourier transform, including quaternion representation of color image, Fourier transform analysis, log polar transformation, watermark embedding and watermark extraction. Experimental results show that in the noise range, the smaller the compression ratio is, the more complete the watermark information can be extracted. When the image compression ratio reaches 80%, the watermark information can be completely extracted.*

Keywords: *Color Image, Digital Watermarking, Quaternion Fourier Transform, Coordinate Tran sformation*

1. Introduction

With the development of computer network communication technology, especially the rapid development of the Internet, people can easily exchange and transmit digital information [1-2]. The use of computers, printers, fax machines, digital scanners and other electronic equipment can quickly transmit digital information to all parts of the world, exchange important information, publish articles on the Internet, do a variety of academic exchanges and e-commerce activities [3-4]. However, while the Internet is convenient and fast, digital information media is also quietly spreading, facing the rampant piracy market. How to protect the interests of the original authors of the current digital media and protect the copyright of digital media has become a hot research topic [5-6]. The problems of copyright ownership and product authentication caused by the extensive use of digital products have been unable to be solved by traditional cryptography technology. As an extension of traditional cryptography, DW provides solutions to the copyright protection and malicious tampering of images, audio, video and other multimedia [7-8]. For the purpose of copyright protection and content authentication, DW technology hides special information in the content of digital media by digital embedding. Now, DW is more and more used in many aspects, such as tamper identification of digital content, data tracking and detection [9-10].

In the research of color image DW algorithm, many scholars at home and abroad have made some achievements. Hu X and Li D point out that whether the watermarking algorithm is good or not, we need to choose the appropriate evaluation index and evaluation method according to the specific application situation. Although the evaluation theory of watermarking system is not perfect and the evaluation standard is not unified, some research institutions have launched some evaluation systems [11]. Liu X and others pointed out the uncertainty of watermarking algorithm. They constructed the

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implementation problem of uncertainty to prove that the potential illegal copier may induce the watermark detector to answer yes. So far, there is no watermarking algorithm, which can ensure that the watermark still exists reliably after being attacked by various human beings [12].

This paper studies the color image DW algorithm, and explores the color image digital watermark under coordinate transformation and quaternion Fourier transform. This paper mainly studies the implementation process of DW, and understands several common attack methods of DW, and also studies the existing problems of DW technology. This paper describes the research of quaternion and color image, and understands the analysis of Fourier transform, logarithm polar transformation and watermark embedding and proposing. At the same time, the paper analyzes the extraction rate of JPEG compression attack by the digital watermark algorithm through experimental research, and analyzes the extraction rate of rotation angle.

2. DW of Color Image

2.1. Implementation Process of DW

The process of preserving the secret information is called digital watermark technology by embedding secret information into digital image, voice, video and other multimedia forms of digital products, or modifying the local information of the carrier. After the carrier information changes, it does not affect the continued use of the original carrier, and the embedded information is not perceived by the third party, but can be recognized and certified by the appraiser of the institution. Through the identification and extraction of information in the carrier, we can make correct judgment on the source of the carrier, the content of hidden information, the information of the buyer of the product, whether the product is under malicious attack, etc. The purpose of protecting the carrier copyright can be achieved. The implementation process of digital watermark is mainly divided into two processes: embedding and extracting. The digital watermark signal and key to be hidden are put into the carrier works by some mathematical algorithm, which completes the embedding process. The signal to be embedded can be random signal without meaning, but also meaningful data string, image, even audio and video signal and other multimedia information. The carrier works can be multimedia data such as documents, images, audio and video. The carrier contains certain copyright mark information after embedded process, which can be put into use formally and not known by other users. Multimedia signal may be attacked by random or artificial in the process of using. Once there is a dispute, the detection process can be started. The digital works to be checked and watermark key are input into the detector together. After the information is extracted by operation, the authenticity and ownership of the work can be determined. In this process, we can derive a variety of watermark algorithms, which can be applied in different situations.

2.2. Common Attack Methods of Image DW

The attack method of digital watermark is modified on the existing DW scheme, and the robustness of the test is good or bad. The watermark system can be judged by different detection attack methods. The attack methods are generally divided into malicious attacks and unintentional attacks, including median filtering, image rotation, Gaussian noise attack, JPEG compression, image cutting, etc. intentional attacks generally include the extraction of forged watermark, false positive detection, multiple watermarks and collusion watermark. The evaluation of watermark scheme is related to the specific attack. The following two different attacks are described in detail.

(1) Unintentional attack

Unintentional attacks include JPEG compression, noise processing, median filtering, fuzzy sharpening, set attack and so on. JPEG compression is a common image processing method, robust watermark must have a certain anti JPEG compression processing. Noise processing is also very common, when the multimedia works in the process of communication will always be mixed with some noise. Median filter is widely used in image processing, and it is also one aspect of the general robust watermark to meet the requirements. In blurring and sharpening, blurring makes the carrier image blurry, while sharpening makes the carrier image clear. However, geometric attack is difficult to overcome. It is not to damage the watermark in the carrier, but to change the synchronization of watermark extraction, unable to find the distribution of watermark information, thus unable to extract the watermark. Clipping and rotation are common geometric attack methods.

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(2) Intentional attack

The main attack methods include the extraction of forged watermark, false affirmation detection, multiple watermark and collusion watermark. The extraction of fake watermark mainly refers to the attack malicious tamper by adding their own watermark to the carrier works to show that they are their works. False positive detection is that malicious tamper can get correct results when extracting watermark through some strategies, which makes the watermark effect invalid. Multiple watermark is a malicious tamper who adds another watermark to the carrier works. He can extract the added watermark information. Collusion watermark is a kind of carrier works that malicious tamper has embedded watermark information. It can eliminate watermark information or cause owner to get corresponding watermark information through enough information.

2.3. Main Problems of DW Research

At present, the research of DW has entered a new stage. The initial stage of widely using various mathematical tools for modeling has passed, some algorithms that can not be used in practice are gradually abandoned, and the algorithms with practical conditions are retained and developed. But because the research of DW needs the support of multi-disciplinary theory, the theoretical basis of each discipline is different. There are some problems in the theoretical research, such as how to establish a practical and effective watermark model, how to improve the embedding capacity of watermark information and so on. There are some problems in the application: how to build a public service watermarking protocol platform, how to realize the positioning of webpage information tampering, how to reduce the operating cost of watermarking technology and promote it to ordinary consumers. Among them, spatial domain watermarking algorithm and quaternion frequency domain watermarking algorithm,the following problems still exist in law.

The algorithm of quaternion Fourier transform (QFT) which can be applied to color image is still based on the algorithm of special direction as projection axis. Among them, the calculation method of one-sided QFT is the most, while the calculation method of two-sided QFT is less due to the complexity of calculation, so it can not be widely used. At present, the main problem is how to use the appropriate method to derive the universal solution of QFT, and apply it to color images, which fully reflects the correlation between the channels using quaternion algorithm.

The research of DW based on QFT is still in the initial stage of exploration. All kinds of algorithms have basically realized the modeling process of embedding and extracting DW. However, the form of resisting attacks is limited, the robustness is not strong, and it can not fully reflect the advantages of using quaternion as color image watermarking. Therefore, how to improve the ability of quaternion DW against signal processing attacks and geometric attacks is the main problem.

In the past, there are some shortcomings in the spatial DW algorithm, such as small embedding amount, the masking function can not make a clear judgment on the image, poor visual perception ability, weak robustness and so on. As a result, the innovation speed of the spatial DW algorithm is slow, and it can not meet the application requirements; It does not fully reflect that the spatial algorithm is relatively simple and fast. Therefore, how to improve the effect of spatial watermarking masking function and enhance the preprocessing ability of watermarked image is still the main problem in the development and application of spatial watermarking algorithm.

DW based on printing and scanning mostly focuses on the carriers such as PDF file, word document, Oracle database and so on. The practical application of printing and scanning technology based on image is rare, especially the lack of low-cost and fast algorithm for the public. How to find the algorithm that can resist printing and scanning is the main problem of DW application.

2.4. Quaternion and Color Image Research

Quaternion consists of one real part and three imaginary parts. The three vector components of quaternion are similar to the three RGB channels of color image. A color image is composed of three RGB color components coupled in proportion, and can be expressed in the form of matrix, which coincides with a pure quaternion matrix. Therefore, each pixel in the color image matrix can be represented by a pure quaternion, and the whole color image is a pure quaternion matrix. The abscissa and ordinate are represented by M and N respectively, and each pixel is represented as follows:

$$f(x,y) = R(x,y)i + G(x,y)j + B(x,y)k \tag{1}$$

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When dealing with color image problems, the general rules of most algorithms are: single channel processing and multi-channel synthesis, which results in poor color correlation. The advantage of using quaternion to describe color image is that the color image can be regarded as a whole and the inner correlation between each color channel can be fully preserved. Because of the unique properties of quaternion, in recent years, many researchers have started a lot of research work based on the color image quaternion model. At present, the application of quaternion research in color image registration, edge detection, target tracking, filtering, face recognition, DW technology and other fields, has achieved good results.

2.5. Property Analysis of Fourier Transform

For an image (the size is MXM), after Fourier transform f (m, n) and f (U, V), the following properties should be satisfied, if the original image rotates clockwise φ The frequency spectrum also rotates after Fourier transform, which can be expressed as follows:

$$f(m,n)=\frac{1}{\sqrt{MN}}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1}e^{u_1 2\pi\frac{mu}{M}}F(u,v)e^{u_2 2\pi\frac{nv}{N}} \tag{2}$$

$$F(u,v)=\frac{1}{\sqrt{MN}}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}e^{-u_1 2\pi\frac{mu}{M}}f(m,n)e^{-u_2 2\pi\frac{nv}{N}} \tag{3}$$

It can be found that the traditional Cartesian coordinate system can not achieve invariance to the image scaling and translation, so another coordinate system is needed to realize this function.

2.6. Logarithmic Polar Coordinate Transformation

The formula of logarithmic polar transformation of coordinate (x, y) is:

$$x=e^{\rho}\cos\theta, y=e^{\rho}\sin\theta(0\le\theta\le 2\pi) \tag{4}$$

If the image (x, y) is rotated, the corresponding polar transformation form after scaling is as follows:

$$\left|F(\rho,\theta)\right|=\left|\sigma^2\right|I(\rho-\ln\sigma,\theta-\phi) \tag{5}$$

The rectangular coordinate system in the Fourier transform domain is transformed into the polar coordinate system, and the concentric ring is selected as the region to be embedded. When sampling in the ring region, if the coordinates of the sampling point are non integer, all the four integer points in the neighborhood of the sampling point are included in the investigation range, and the value of the sampling point is estimated by bilinear interpolation. This watermarking algorithm can effectively resist rotation, scaling and translation attacks.

2.7. Watermark Embedding and Analysis

Aiming at the problem that color image watermarking can not resist geometric attacks, this paper proposes the following color image watermarking scheme. Because the color image can be expressed by pure quaternion, the corresponding quaternion matrix is transformed into the ordinary quaternion matrix after QFT,the specific formula is as follows:

$$F(u,v)=A(u,v)+B(u,v)i+C(u,v)j+D(i,v)k \tag{6}$$

The analysis shows that the real part of the quaternion Fourier transform satisfies the following formula, where m and N are the size of the image, and the formula is as follows:

$$A(u,v)=-A(M-u,N-v) \tag{7}$$

If the corresponding frequency domain matrix of pure quaternion after QFT is not modified, the real part of quaternion obtained by inverse transformation of iqft is still zero. Because the real part of the color image after QFT has the characteristics of symmetry, if the real part is used as the embedding area, and the watermark information is embedded symmetrically according to the formula, the

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information carried by it is dispersed into the imaginary part of the original quaternion. It is proved that the real part of the new quaternion is zero. Therefore, the information embedded in the real part can not be lost after iqft, and the visual error caused by the embedded information is spread to the whole image, which is not easy to cause subjective detection.

3. Experimental Study

3.1. Subjects

This paper mainly studies the color image DW algorithm based on coordinate transformation and quaternion Fourier transform, including quaternion representation of color image, Fourier transform analysis, log polar transformation, watermark embedding and watermark extraction.

3.2. Experimental Process Steps

This paper studies the color image DW algorithm, and explores the color image DW under coordinate transformation and quaternion Fourier transform. This paper mainly studies the implementation process of DW, understands several common attack means of image DW, and also studies the existing problems of DW technology. This paper describes the quaternion and color image research, understand the Fourier transform property analysis, log polar transformation analysis and watermark embedding and proposed. At the same time, the extraction rate of JPEG compression attack and rotation angle of DW algorithm are analyzed by experiments.

4. Experimental Research and Analysis of Color Image DW

4.1. Extraction Rate of DW Algorithm against JPGE Compression Attack

In order to study and understand the results of DW algorithm under various JPEG compression attacks and Gaussian noise and salt and pepper noise attacks, this paper selects the comparison of the extraction rate of each attack to study the results of the algorithm's anti compression ability to the watermark image. The results are shown in Table 1.

Table 1. Analysis of extraction rate of DW attacks

Compression ratio	30%	50%	80%	100%
Anti JPEG compression extraction effect	0.05	0.02	0	0
Anti Gaussian noise extraction effect	0.02	0.03	0.07	0.15
Anti salt and pepper noise extraction effect	0.02	0.03	0.06	0.15

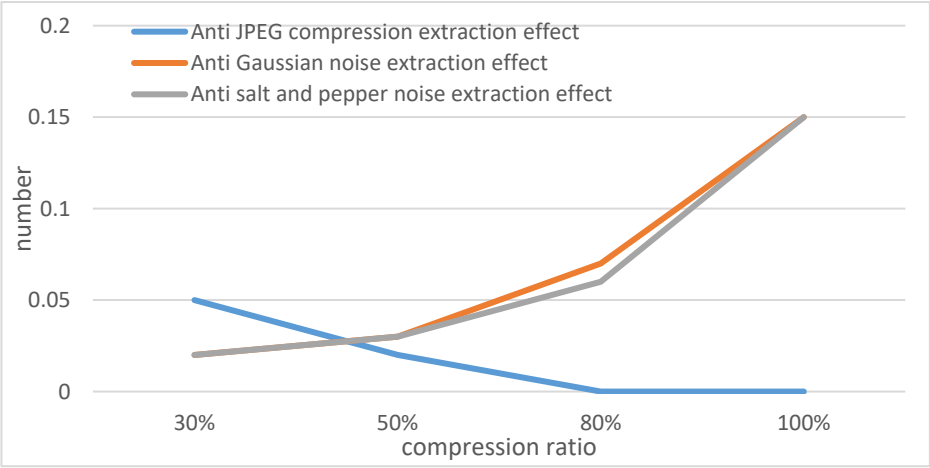

Figure 1.Analysis of extraction rate of DW attacks

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It can be seen from Figure 1 that the algorithm improves the anti compression performance of the watermark image to a certain extent. When the image compression rate reaches 80%, the watermark information can be completely extracted. When the compression ratio is large, although it can not be completely extracted, the embedded image content can be clearly distinguished from the extracted image. In the noise range, the smaller the compression ratio is, the more complete the watermark information is extracted, and the larger the compression ratio is, the less the watermark information is extracted.

4.2. Extraction Rate of DW Algorithm against Rotation Angle Attack

In order to study and understand the difference between the actual rotation angle and the estimated angle when the DW algorithm is attacked by the rotation angle, this paper extracts and selects the comparison of the extraction rate of each attack rotation angle to study the results of the anti rotation ability of the algorithm to the watermark image. The results are shown in Table 2.

Table 2.Extraction rate of DW algorithm against rotation angle attack

Actual rotation angle	Detection angle	BER
30	30.2	0.02
60	60.1	0.01
90	90	0
120	120.3	0.03
150	149.9	0.01
180	180	0

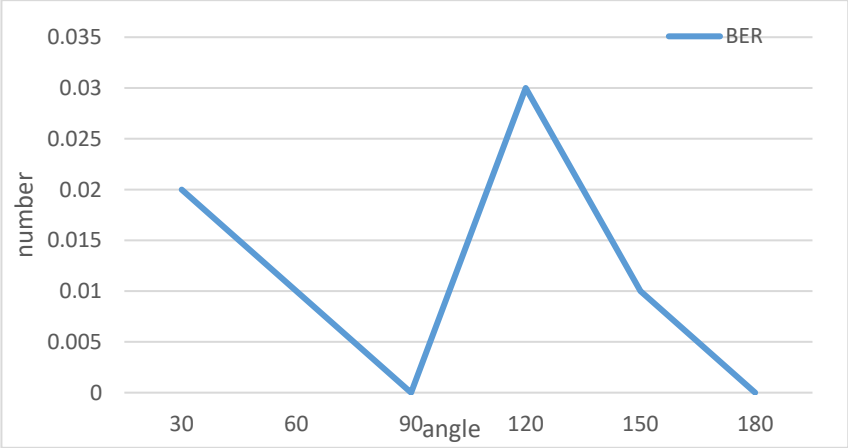

Figure 2.Extraction rate of DW algorithm against rotation angle attack

As shown in Figure 2, for rotation attack, the actual rotation angle and estimated angle, and the extracted results are not very different. At the special angle 90 and 180, the error bit rate is zero. Although the angle of other rotation angle estimation is slightly error, it has little influence on the final result, and the extracted image information is relatively complete.

5. Conclusions

Color image DW can prevent rampant copyright theft, which is an important technical means of digital media copyright protection and anti-theft version authentication. This paper studies the color image DW algorithm based on coordinate transformation and quaternion Fourier transform to improve the anti attack ability of color image DW. This paper mainly studies the implementation process of DW, understands several common attack means of image DW, and also studies the existing problems of DW technology. This paper describes the quaternion and color image research, understand the Fourier transform property analysis, log polar transformation analysis and watermark embedding and proposed. At the same time, through the experimental research and analysis of the extraction rate of JPEG compression attack and rotation angle extraction rate of DW algorithm, the reliability of the color image DW studied in this paper is proved.

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