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Frequency Domain Digital Watermarking Algorithm Based on Arnold Transform and Quaternion Fourier Transform

Yongqiang Ma, Wei Sun, Peifang Zhang, Shunli Wang

School of Computer Science, Jining Normal University, Wulanchabu, 012000, China

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Abstract: In recent years, with the advancement of Internet technology and the rapid popularization of personal mobile terminals, while the dissemination of digital multimedia products such as images and videos has been facilitated, the risk of tampering and forgery of original data has also increased. The resulting problems of data content security and copyright authentication are becoming more and more serious. DW technology provides a solution to this information security problem. This paper mainly studies a frequency-domain digital watermarking algorithm (DWA) based on Arnold transform and quaternion Fourier transform. The advantage is that the three color channels of the image can be represented as a whole, and the frequency domain information of the image can be obtained. Using cat face transform and Fourier transform, the watermark information is embedded into the host's frequency domain information. The inverse Fourier transform is performed on the host frequency domain image embedded with the watermark information, so that a color image embedded with the secret information is obtained, thereby realizing information hiding. Each step here is reversible, and the process of extracting the watermark is the reverse of the above process. In this paper, the problem of whether the real part of the inverse Fourier transform of quaternion is zero is discussed in detail, and the practicability of the algorithm is verified through a series of data analysis. Through the comparison of experimental data, it is found that the average visual quality score of 0.9731 is higher than the average of 0.9402 of the traditional algorithm under the premise of using the text algorithm, which means that the frequency domain DW based on Arnold transform and quaternion Fourier transform Algorithms are better than other algorithms.

1. Introduction

DW technology refers to using the redundancy of the original carrier information to add the key, that is, the watermark information, to the carrier content itself in a specific way, so as to realize the copyright protection of the original carrier. Aiming at the problems existing in the current color image watermarking algorithm, in order to improve the traditional color image watermarking algorithm, the quaternion algebra theory is firstly applied to describe the color image as a whole. Through the information hidden in the carrier, the purpose of confirming the content creator, purchaser, transmitting secret information or judging whether the carrier has been tampered can be achieved. DW technology is an important research direction of information hiding technology [1]. Quaternions have high-dimensional characteristics, and can represent a color image as a pure quaternion matrix to achieve simultaneous processing of three color components. To sum up, the quaternion transform domain color image encryption algorithm based on chaotic system has important practical significance and broad research prospects.

In recent years, many researchers have explored the frequency-domain DWA based on Arnold transform and quaternion Fourier transform, and achieved good results. Schyndel et al. first generated a watermark in the form of an M-sequence, compressed the image pixel bits, and replaced the watermark with the lowest pixel bit. This type of watermark has certain robustness, but it is easy to be eliminated [2]. Cox et al. proposed an algorithm for embedding watermarks in the discrete cosine transform domain [3]. Kunder proposed to embed the watermark in the discrete wavelet transform domain [4]. Dr. Xing Yan from Hefei University of Technology in my country proposed a color image decomposition algorithm, but this algorithm is only for grayscale images of watermarked images. At present, scholars at home and abroad have done a lot of research on the application of frequency-domain DW algorithms based on Arnold transform and quaternion Fourier transform. These previous theoretical and experimental results provide a theoretical basis for the research in this paper.

Aiming at the problems existing in the frequency domain DW algorithm, in order to improve the traditional frequency domain DW algorithm, the theory of Arnold transform and quaternion Fourier transform is firstly applied to describe the frequency domain DWA as a whole. At the same time, the visual characteristics of the frequency-domain DWA of Arnold transform and quaternion Fourier transform are studied, and the corresponding visual perception model is designed. The adaptive adjustment of the quantization step size, combined with the watermark embedding and watermark extraction schemes, research and design the frequency domain DWA framework based on Arnold transform and quaternion Fourier transform, which can effectively improve the invisibility of the algorithm and enhance the image quality. Visual Perceptual Quality and Applications of Frequency Domain DW Algorithms.

2. Related Theoretical Overview and Research

2.1 Topic Text Generation Models for Corpora

2.1.1 Quaternion representation of frequency domain numbers

Considering the set of quaternions as a multi-dimensional real number space, quaternions represent a four-dimensional space. Compared with the two-dimensional space of complex numbers, quaternions and their related theories are widely used in the field of color image processing, including color image processing. noise, segmentation, pattern recognition, and watermarking. Quaternions are extensions of real numbers and complex numbers, so color images can be represented by a quaternion matrix. Formulated as： $f(m,n) = f_i(x,y)i + f_j(x,y)j + f_k(x,y)k$ [5]. In this way, we can treat the color image as a whole, instead of three grayscale images as in the past.

2.1.2 Image Quality Evaluation Criteria

There are two kinds of image quality evaluation, subjective and objective. Different people, under different circumstances, will give different evaluations, so the uncertainty of subjective evaluation is high, so we generally use the method of objective evaluation. Several common objective evaluation methods are mainly peak signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR) and correlation coefficient (NC). The larger the peak signal-to-noise ratio and the signal-to-noise ratio, the better, and the closer the correlation coefficient is to 1, the better [6-7]. Peak signal-to-noise ratio is an objective measure of image distortion or noise levels. In the experiments, the peak signal-to-noise ratio was used to evaluate the quality difference between the embedded image and the original image, and the results were expressed in decibels.

2.1.3 Design of Watermark Embedding and Watermark Extraction Process

Compared with traditional color image processing, the advantages shown by quaternions have attracted many researchers. Researchers of watermarking technology have proposed many algorithms based on different transformations in the quaternion domain. Compared with traditional watermarking methods, these algorithms show better performance in resisting various signal attacks. Now, we will combine Arnold transform and quaternion Fourier transform to design an adaptive quantization step size. Next, we introduce the embedding and extraction process of the watermarking scheme in detail, and through the invisibility test and robustness evaluation experiments respectively, it is proved that Effectiveness of Watermarking Algorithms [8].

Watermarking schemes are generally evaluated from three aspects: invisibility, robustness and embedding capacity. Invisibility means that after embedding the watermark information, the human eye cannot perceive the visual difference between the watermark image and the original carrier image [9]. Robustness refers to the resistance of the algorithm to signal attacks, that is, the watermarked image can still extract identifiable watermarks after being attacked by various image signals during the transmission process of the network space. Embedding capacity refers to the size of the watermark that the carrier can carry in the algorithm. Among them, invisibility and robustness are a pair of contradictions. Under the premise of satisfying a certain embedding capacity, the quality of the watermarking algorithm is evaluated according to these two parameters.

2.2 Introduction to Quaternions

The concept of quaternion was first proposed in the 1840s. Quaternion can be regarded as an extension of traditional complex numbers. It consists of a real part and three imaginary parts. The basic form is: $q=a+bi+cj+dk$, where i, j, and k are imaginary units [10]. In the process of color image processing, most algorithms convert it to grayscale or separately process it on three channels, without considering the correlation and integrity among the three channels of color images [11]. As an effective mathematical tool, quaternion fully considers the spectral correlation between color channels and effectively describes the chromaticity information of the image. It is widely used in image registration, pattern recognition, edge detection, DW and image processing. Tamper detection, etc.

This paper proposes an image scrambling algorithm based on Arnold transform and quaternion Fourier transform. In view of the fact that the traditional Arnold algorithm does not satisfy the Kirkhoff criterion and the algorithm has the characteristics of periodicity, an improved Arnold algorithm based on the optimal number of scrambling rounds of image blocks and sub-blocks is proposed [12]. The encrypted images obtained by using this algorithm and the traditional Arnold algorithm are respectively evaluated for performance, and it is found that the gray value distribution of the encrypted images obtained by the improved algorithm is more uniform, has a smoother autocorrelation image and a lower correlation coefficient, and The key and ciphertext can be completely separated, satisfying the Kirkhoff criterion.

3. Experiment and Research

3.1 Experimental Method

The cat face transformation, also known as the Arnold transformation, acts on an image to change the position of the pixels without changing the pixel values. is the scrambling transformation of the image. Usually, multiple cat face transformations are performed on an image to achieve the purpose of scrambling. For an N ×N image, the cat face transformation is defined as follows:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \bmod N \tag{1}$$

Where (x', y') is the new coordinate obtained by the pixel point (x, y) after a cat face transformation. It's called the cat face transformation because it was originally an experiment on an image of a cat face. It can be seen from the definition that every time a cat face transformation is performed, the position of the pixel point moves once, and after many times, the original image will become unrecognizable.

In image processing, the Fourier transforms we use are all discrete forms.

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

Where f(m,n) (0 ≤m≤M -1, 0≤n ≤N -1) can represent an M ×N color image.

3.2 Experimental Requirements

Combining Arnold (cat face) transform and quaternion Fourier transform, a frequency-domain DWA is proposed. The purpose is to embed a color image (watermark image) g0(x,y) to be kept secret into the host image f In (x,y), f0(x,y) is obtained, and the difference between f0(x,y) and f(x,y) should be as small as possible. In general, it is difficult to find hidden information from f0(x, y). Even if there is hidden information, the secret image cannot be extracted without knowing the algorithm and key. Because of the advantages of quaternion Fourier transform in solving the fidelity problem of frequency domain watermarking algorithm, the establishment of Arnold transform and quaternion domain Fourier transform model is studied, and the fusion quaternion domain Fourier transform model is studied. The DW method is of great significance.

4. Analysis and Discussion

4.1 Invisibility Test Analysis

In this experiment, in order to verify the performance of the proposed color image watermarking algorithm incorporating quaternion visual features, we selected five standard color images for research and analysis. To evaluate the imperceptibility of the embedded watermarking scheme, we use the text algorithm to compare with the QDFT algorithm, and their visual quality scores are compared with the experimental data as follows:

Table 1: Invisibility Test Analysis Table

Image item	Text algorithm	QDFT algorithm
Image I	0.9824	0.9586
Image II	0.9457	0.9124
Image III	0.9638	0.9352
Image IV	0.9921	0.9268
Image V	0.9816	0.9402

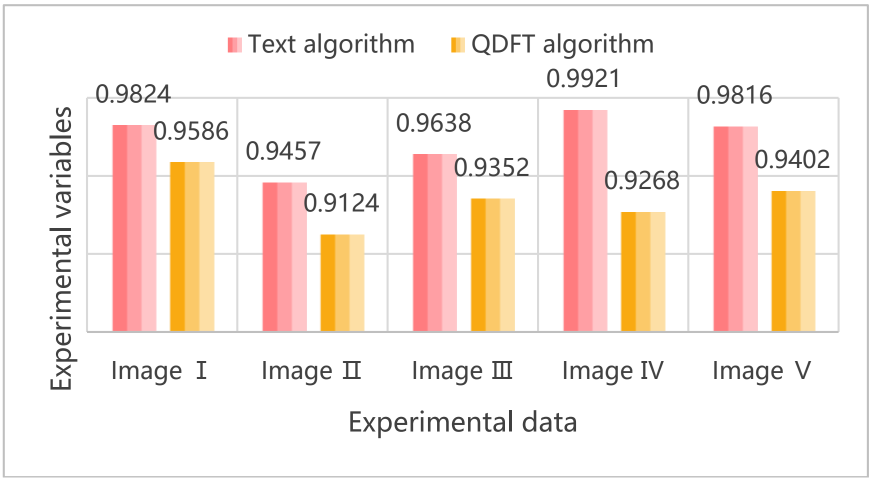

Figure 1: Invisibility test analysis diagram

From the above data analysis, it can be seen from the results that the visual quality scores under different watermarking algorithms are compared. The visual quality scores under the text algorithm are 0.9824, 0.9457, 0.9638, 0.9921, and 0.9816, respectively, with an average value of 0.9731. The visual quality scores under the traditional QDFT algorithm are 0.9586, 0.9124, 0.9352, 0.9268 and 0.9402, respectively, and the average value of the algorithm is 0.9346. Through the comparison of experimental data, it is found that the average value of the visual quality score 0.9731 is higher than the average value of 0.9402 of the traditional algorithm under the premise of using the text algorithm, which means that the frequency domain DW based on Arnold transform and quaternion Fourier transform The algorithm is better than other algorithms, and the algorithm proposed in the text has certain advantages.

4.2 BER Comparative Analysis of Watermarking Schemes Corresponding to Frequency Domain Numbers

In order to verify the validity of the unit quaternion perception parameters, the quaternion perception parameters are now substituted into the frequency domain DWA fused with quaternion visual features. This experiment lists the comparison of the watermarking scheme BER corresponding to the quaternion of different units. The experimental data is shown in the following figure.

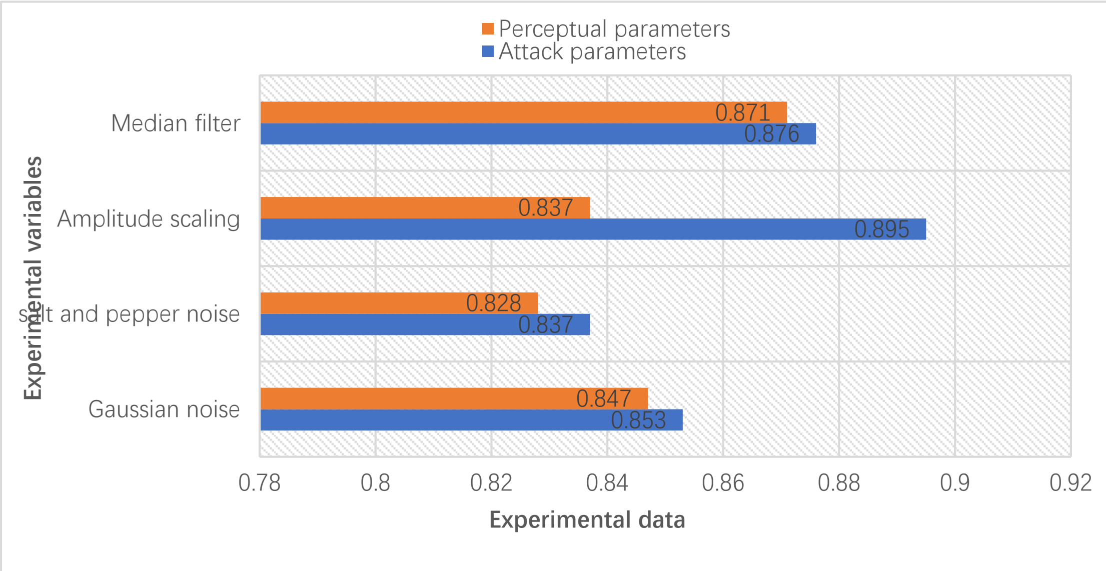

Figure 2: Comparative analysis diagram of BER of watermarking schemes corresponding to frequency domain numbers

As shown in the data in Figure 2, by comparing the BER of watermarking schemes corresponding to quaternions of different units, the attack parameter values of Gaussian noise, salt and pepper noise, amplitude scaling and median filtering are 0.853, 0.837, 0.895 and 0.871, respectively; their perceptual parameter values are 0.847, 0.828, 0.837, and 0.871, respectively. From the data performance in the above figure, the perceptual parameters corresponding to the watermark corresponding to the frequency domain numbers show better performance, with an average value of 0.865, which can extract identifiable watermark information.

5. Conclusions

This paper firstly studies and analyzes the related applications of Arnold transform and quaternion Fourier transform, and compares the frequency domain DWA research based on Arnold transform and quaternion Fourier transform with traditional DW algorithms And analysis, and through a series of experiments to prove that the frequency-domain DWA research based on Arnold transform and quaternion Fourier transform is superior to the traditional watermarking scheme in invisibility test analysis and frequency-domain digital corresponding watermarking scheme BER comparative analysis. The experimental data show that the research of frequency domain DWA based on Arnold transform and quaternion Fourier transform has certain feasibility, and has the value of promotion and application. On this basis, this paper studies the color image watermarking algorithm fused with quaternion domain visual features. Firstly, the current development of watermarking technology and the domestic and foreign status of watermarking algorithm in quaternion domain are introduced. The introduction of visual characteristics effectively improves the performance of the algorithm itself. By embedding the watermark identification information into the carrier image, people have poor visual sensitivity perception. In redundancy, while ensuring the visual quality of the watermark, the robustness of the algorithm against signal attacks is effectively improved.

Acknowledgments

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