Research on Robust Algorithm of Color Holographic Watermark Based on DCT-DWT

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Abstract. Based on the DCT-DWT algorithm, a new method for embedding color holographic watermarks into color carrier images is proposed. The color watermark image and the color carrier image are divided into three channels: R, G, and B. The hologram is generated for each channel's watermark image by a four-step phase shift method, and the hologram is subjected to Arnold transformation. The carrier image is decomposed by first-order wavelet, the watermark embedding space is changed from spatial domain to transform domain, low-frequency components are extracted and segmented, the scrambled holographic watermark images are respectively sub-channel embedded in the carrier image by discrete cosine transform. The experimental results show that the algorithm is robust and can resist some conventional attacks. In this algorithm, the watermark image is transformed into a hologram, which increases the difficulty of decryption.

1. Introduction

With the development of society, digital watermark technology has made great progress, especially the application of color digital watermarking. Compared with binary watermark and grayscale watermark, it contains more information and is more convenient. So this technology has been applied in many fields. Therefore, research on color digital watermarks has become particularly important. The image watermark algorithm can be divided into spatial domain algorithm and transform domain algorithm by scope[1-2]. The spatial domain algorithm has the advantages of easy implementation, fast calculation speed and high embedding efficiency. The transform domain algorithm uses various image transformation methods to transform the image firstly, then the watermark is embedded in the transform domain of the image. Finally the image is restored by inverse transform. Watermark also needs to be extracted in the transform domain[3-6]. Transform domain algorithms are often combined with Arnold transform and singular value decomposition (SVD) to further improve the performance of the algorithm[7-10].

Computer Generated Hologram (CGH) is a hologram obtained by computational method, but an optical method is still used for reproduction. The data encryption and information hiding technology of optical information security technology is a new generation of information security theory and technology that has begun to develop in the world in recent years. The encryption and concealment of optical information can be carried out in multiple degrees of freedom space. It has many advantages such as multi-dimensional "large capacity", high design freedom, "high robustness", natural parallelism, and difficulty in cracking. Therefore, the research on embedding and extraction algorithm based on computational holography technology has not only theoretical significance but also important application prospects, and its market potential is huge. In this paper, the watermark image is
transformed into a hologram, the watermark is embedded with discrete cosine transform and discrete wavelet transform. The robustness of watermark and the difficulty of decryption are enhanced.

2. Transform Domain Algorithms

2.1 Discrete Wavelet Transform
Discrete wavelet transform is a tool for modern spectral analysis. It concentrates most of the energy of an image on low-frequency components. The intermediate-frequency and high-frequency coefficients are the detailed information of images at different scales and resolutions. It can not only investigate the frequency domain characteristics of the local time domain process, but also the time domain characteristics of the local frequency domain process, so even for non-stationary processes, it is very easy to handle. In addition, the coarse edges of the wavelets can best represent the image because it eliminates the ubiquitous blockiness of discrete cosine transform compression.

2.2 Discrete Cosine Transform
Discrete cosine transform (DCT) is mainly used to compress data or images. It can transform signals from spatial domain to frequency domain and has good de-correlation performance. This is because DCT has a strong energy concentration characteristic, and can concentrate most of the energy in the low frequency part.

3. Four-Step Phase-Shifting Method
The basic principle of the phase shift method is to move the reference mirror regularly through the phase shifter on the reference arm of the interferometer, so that the optical path difference between the reference beam and the test beam changes, and the position of the stripe moves accordingly. The intensity of any point in the interference field is cosine-changed, three or more interferograms of different phases are acquired by the photosensitive electronic component CCD:

\[ I(x,y,\theta)=|R_0(x,y)\exp(i\theta)+O_0(x,y)\exp(i\Phi)|^2 = |R_0|^2+|O_0|^2+2R_0O_0\cos\phi \]  

In the formula: \( \theta \) is the introduced stepped phase shift angle, R and O are the amplitudes of the plane wave and scattered light reaching the CCD of the recording medium respectively, \( \Phi \) is the angle between the original and the Z axis.

Four-step phase-shifting algorithm refers to the process of recording the hologram, according to a certain state of the object, using the phase shifter to the reference light to take 4 different phase shift value, is generally 0, \( \pi/2 \), \( \pi \), 3\( \pi/2 \), the recorded four maps of the intensity distribution by (2) can be:

\[ I(x,y,0)=|R_0|^2+|O_0|^2+2R_0O_0\cos\phi \]

\[ I(x,y,\pi/2)=|R_0|^2+|O_0|^2+2R_0O_0\sin\phi \]

\[ I(x,y,\pi)=|R_0|^2+|O_0|^2-2R_0O_0\cos\phi \]

\[ I(x,y,3\pi/2)=|R_0|^2+|O_0|^2-2R_0O_0\sin\phi \]  

The complex amplitude distribution of object wave at CCD can be obtained by using four-step phase-shifting algorithm:

\[ O(x,y)=I/4R[[I(x,y,0)-I(x,y,\pi)]+j[I(x,y,\pi/2)-I(x,y,3\pi/2)]] \]  

Formula (3) is the formula for digital hologram reconstruction. This method can eliminate zero-order image and conjugate image, improve the signal-to-noise ratio of digital hologram, and improve the quality of reconstructed image.

4. Principles and Steps

4.1 Embedding watermark
In order to increase the confidentiality of the watermark, we use the four-step phase shift method to generate four holograms (I1-I4) for the RGB components of the watermark image. Taking the R channel as an example, four holograms are generated as R1-R4, the size of each hologram is 256*256.
R1 is used as a holographic watermark. In order to further increase the security of the watermark, we perform an Arnold transform on R1 and then embed it into the carrier image. At the same time, the RGB components of the original carrier image are respectively subjected to the first-order wavelet decomposition, the low-frequency component CA1 is extracted, the size is 1024*1024, and the low-frequency component is divided into 256*256 blocks, each block is 4*4, each block is subjected to DCT transformation. The first element of each block is taken out to form a DC component matrix with the size of 256*256. In this paper, the holographic watermarks R1, G1, and B1 are respectively embedded in to the DC component matrix, then the inverse discrete cosine transform and the inverse discrete wavelet transform are performed on the carrier image to obtain the image of the three channels embedded in the watermark. The carrier images of the three channels are combined to obtain a color carrier image containing the watermark. The schematic diagram is as follows:

![Figure 1. Schematic diagram of embedding watermark](image)

### 4.2 Extracting watermark

The original carrier image and the carrier image containing watermark are respectively divided into three channels, and the R, G, and B components of the two images are respectively subjected to the first-order wavelet decomposition to extract low-frequency components. The low-frequency components are divided into 4*4 blocks, and DCT transform is performed on each block. The first element of each block is taken out to form a matrix with the size of 256*256. The two matrices are subtracted, and the R, G, and B components of the holographic watermarks are obtained. The holographic watermarks are inversely transformed by Arnold to obtain the original holographic watermarks. Then the original watermarks images of R, G and B channels are reconstructed by equation (3), the three images are superimposed to obtain the original color watermarks image.

### 5. Analysis of experimental results

In this experiment, a color lenna image of 2048*2048 was used as the carrier image, a 256*256 color image was used as the original watermark image. When the embedding strength K value is chosen to be 0.1 (the optimal K value of different images is different, usually not more than 0.2), the peak signal-to-noise ratio (PSNR) of the carrier image containing watermark is 57.1769db. The algorithm has good transparency and the embedding effect is shown below.

![Figure 2. Carrier image](image)

![Figure 3. Original watermark image](image)
No attack: The NC value of the reconstructed watermark image is 0.9939, and the watermark image is shown in Figure 6 and Figure 7. It can be seen that the image has a good effect.

This algorithm also has good resistance to other attacks, as shown in Table 1:

| Types of attack    | Attack parameters | Attacked carrier images | Extracted Watermark | NC value |
|--------------------|------------------|-------------------------|---------------------|----------|
| Zoom in            | 2                |                         |                     | 0.8017   |
| Zoom out           | 0.25             |                         |                     | 0.8208   |
| Gaussian noise     | 0.001            |                         |                     | 0.8018   |
6. Conclusion

In this paper, in order to enhance the robustness of the algorithm, the original watermark image is replaced with a holographic watermark. The low-frequency components of the first-order wavelet decomposition of the carrier image are transformed by discrete cosine transform, which changes the embedding space. The experimental results show that the algorithm can resist conventional attacks well, and important features of the watermark are preserved. In the anti-shear attack, when the degree of clipping of the carrier image reaches 1/2, a relatively complete watermark can be extracted.

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