Research on Blind Watermarking Embedding Algorithms of Permutation DCT Domain Medium Frequency Coefficient Based on Image Acquisition

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Abstract: A blind watermarking algorithm based on the replacement of intermediate frequency coefficients in discrete cosine transform domain (DCT) is introduced. The adaptive embedding method of digital watermarking is studied with this algorithm. The proposed blind watermarking algorithm for replacing IF coefficients in DCT domain not only breaks through the traditional watermarking embedding formulas, such as additive algorithm, but also solves the problem that the extracted watermarking contains DCT coefficients of the original image, thus affecting the detection accuracy, and gives the verification. The algorithm combines the masking property of HVS, so that the embedding energy of watermark information has adaptive characteristics, which ensures that the embedded watermark is robust to some common image processing operations under the premise of invisibility. The experimental results verify the effectiveness of the proposed algorithm.

1. Introduction

With the development of network technology and the spread of digital products, copying and modifying becomes more and more convenient and fast. However, the copyright protection of digital products is becoming more and more serious [1]. Digital photos are easy to spread, easy to store and can be copied on a large scale. At the same time, digital photos are easy to modify. People can make various modifications to the obtained digital photos to achieve their desired effects. However, digital watermarking technology embeds images, signatures and serial numbers representing the author's information into digital products and achieves the purpose of copyright protection in the circulation and use of digital products [2]. In addition to the legal and management means similar to the copyright protection of traditional works, it should also provide technical protection for the characteristics of digital works. The research of digital watermarking technology is rapidly developed under the requirements of this application [3]. In this paper, a color image blind watermarking algorithm based on image acquisition and DCT is proposed. This algorithm uses the brightness masking and texture characteristics of HVS to embed water of different energy in different types of blocks in the lower frequency sub-band CTT domain of image wavelet transform. coefficient. The algorithm does not require some assumptions or processing in watermark detection, which solves the above problem of watermark embedding; at the same time, the algorithm makes the embedded watermark fundamentally irreversible.

2. Embedding and Detection of Watermark

2.1 The selection of watermark

The watermark W0 chosen in this paper follows Gaussian distribution with zero mean and one variance. However, considering the needs of the algorithm itself, some too small and too large values in the watermark will be filtered out. Since the watermark is replaced by too small a value. The intermediate frequency coefficient is easily affected by noise, which reduces the robustness of watermark. But with too large a value substitution. The domain intermediate frequency coefficient also significantly reduces the visual quality of the image itself [4]. The main information of the image is concentrated in DC and low frequency components, which is also the sensitive part of

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human vision. The algorithm avoids the processing of this part of data. The human eye is most sensitive to the distortion of the middle brightness region of the image, and the sensitivity to brightness decreases parabolically toward both ends as the brightness increases or decreases, that is, the brightness masking characteristic; the discrete cosine transform is a real transform, which has a good Energy compression and decorrelation capabilities, and a variety of fast algorithms, all of which make DCT transforms very attractive in the research of digital watermark embedding algorithms [5]. After replacing the intermediate frequency with an excessive value, the visual quality of the image itself is significantly reduced, which affects the imperceptibility of the watermark. So choose the following watermark value as the embedded image watermark:

$$W_m = \{w_0, 0.4 < |w_0| < 1\} \tag{1}$$

2.2 Selection of visual models

In order to coordinate robustness and imperceptibility, the human visual model is used as the constraint condition for the intermediate frequency coefficients to be replaced. In this paper, we use the HVS model for DCT domain [6].

$$\begin{aligned} \log T_{ij} &= \log\left[T_{\min}\left(f_{i0}{}^2 + f_{0j}{}^2\right)^2 / \left(f_{i0}{}^2 + f_{0j}{}^2\right)^2 - 4(1-r) f_{i0}{}^2 f_{0j}{}^2\right] + k\left(\log\left[\sqrt{f_{i0}{}^2 + f_{0j}{}^2} / f_{\min}\right]\right) \\ T_{ijk} &= T_{ij}(c_{00k} / \bar{c}_{00})^{\alpha_T} \end{aligned} \tag{2}$$

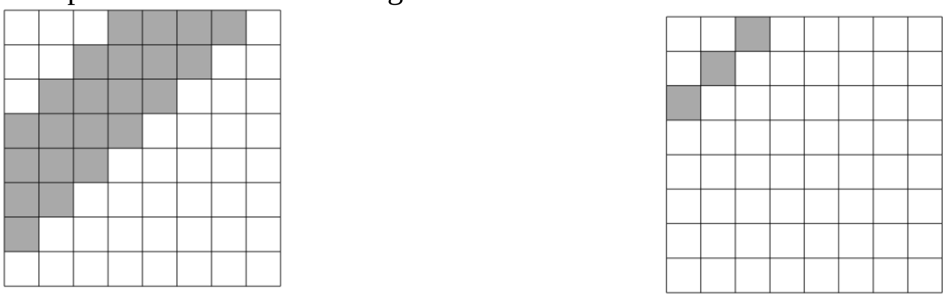
Among them, parameter $T_{\min} = 1.548$; $f_{\min} = 3.68$, k=1.728, r=0.7; $\alpha_T = 0.649$; f_{i0} and f_{0j} are the horizontal and vertical spatial frequencies of the DCT basis function, respectively, and the formula is as follows:

$$f_{i0} = i / 2N\omega_x,\ f_{0j} = j / 2N\omega_y \tag{3}$$

Digital watermarking technology has a variety of classification criteria: visible and invisible watermarks based on visual effects, robust and fragile watermarks based on resistance to attack [6]. The host image is subjected to one or more layers of lifting scheme wavelet decomposition, and its lower frequency subband is considered. If the amount of embedded watermark information is small, only the low frequency subband can be considered [7]. The DCT transform is performed on each sub-block image in turn, and the watermark information hidden by the sub-block is obtained according to the specific DCT coefficient relationship of the embedded watermark, and the watermark information of each sub-block image is extracted. The algorithm is based on the parity decomposition method for the optimization of the even row and column operations. For the odd rows, the trigonometric function is integrated and the difference operation is obtained, and the approximate symmetry is obtained, which reduces the number of multiplications, thus improving the operation [8]. In watermark detection, many small signals can be collected to obtain watermark information when the embedding position of the watermark is known. The algorithm is embedded in the low frequency region, so it has high robustness and can withstand JPEG compression, filtering, noise, cropping and other attacks. The masking model formula is no longer used in this algorithm. At the same time, it is considered that the medium and high frequency coefficients of the original image are lost after being replaced by watermarks, resulting in large deviation in threshold calculation when using masking model formula in detection.

2.3 Selection of intermediate frequency coefficient

Low-frequency coefficients and high-frequency coefficients are not selected as replacement coefficients because most energy coefficient values of low-frequency concentrated images are usually large. If replaced, image distortion will be obvious, while high-frequency coefficients are vulnerable to attack. At present, most color cameras used to acquire digital images use RGB format, but because RGB space is a color display space, it is generally not very suitable for human visual characteristics [9]. In addition, the number of intermediate frequency coefficients that can be embedded with watermark given in document [10] is 22, as shown in Figure 1-a. Since the algorithm embeds too many watermarks in the same image block, this will significantly distort the image. The main idea of the watermark embedding algorithm is to first divide the original carrier image into 8 × 8 sub-blocks, and perform DCT transformation on each sub-block, and select the DCT mid- and low-frequency coefficients of each sub-block. In addition, the algorithm has a dozen coefficients close to the high frequency coefficient after zigzag scanning, which is vulnerable to attack and reduces the robustness of the watermark. The intermediate frequency coefficient selected by the algorithm can overcome the above drawbacks. The DCT domain frequency coefficients embedded in this experiment are shown in Figure 1-b.



2-aSelection region of IF coefficients in reference [10]

2-bThe selection area of intermediate frequency coefficient in this algorithm

Fig. 1. The selection area of intermediate frequency coefficient

2.4 Embedding watermark

In order to obtain the appropriate intermediate frequency coefficient, the visual critical difference T is taken as the threshold for selecting the intermediate frequency coefficient. When the intermediate frequency coefficient I>T in the selected area, it is eligible for replacement. However, due to the problem of coefficient sign change in the replacement, for example, when the intermediate frequency coefficient is positive, it becomes negative after the replacement. When the intermediate frequency coefficient is large, this replacement is easy to cause serious image distortion, and the larger intermediate frequency coefficient is not replaced. The innovation of the algorithm lies in that instead of directly superimposing watermark information of 1 or 0 on the embedding coefficient, two random sequences of 1 row and 8 columns are used instead of watermark information of 1 or 0, and the random sequence is superimposed on the embedding coefficient. In the image compression, the quantization template used by the Y component is different from the U and V components, and more information is retained. Therefore, embedding the watermark on the component is beneficial to enhance the robustness of the watermark, and the Y component represents the luminance information of the image. Therefore, using the Y component for texture analysis will more accurately detect the texture of the image. When the embedded watermark is 1, it is equal to Fmean+Q, and Q is the embedding strength, which can be modified according to the embedding effect. By performing IDCT transformation on the modified DCT coefficient block, an image of the watermark can be obtained. The algorithm for embedding the watermark in the IF coefficient of this experiment is as follows:

$$I' = \begin{cases} \alpha W & \beta T > I > T \\ I & otherwise \end{cases} \tag{4}$$

Where I' is the DCT coefficient of the embedded watermark; α is the magnification of the watermark W; BT is the upper limit of the selected intermediate frequency coefficient I. When calculating the magnification α, this experiment transforms the watermark embedding formula as follows:

$$I' = \begin{cases} I + (\alpha W - 1) & BT > I > T \\ I & otherwise \end{cases} \tag{5}$$

For the convenience of calculation, let ∑ WI = 0. Therefore, when βT is determined, given the PSNR, the magnification α is easily obtained. For a Lena image of size 512 x 512, let β = 7, PSNR = 46, resulting in α ≈ 7.

2.5 Watermark detection

The core idea of the watermark extraction algorithm is to first block the water-printed image, and then perform DCT transform on each sub-block image, then determine the DCT coefficient sequence embedded in the watermark information according to the watermark embedding position, and use the autocorrelation function to obtain the watermark information. The ultimate recipient of the image is human. Therefore, making full use of the HVS characteristics is very important for the processing of image information. Once it is destroyed during the detection, it can only be judged by the similarity, and there is a chance of misjudgment. Meaningful watermark means that watermark itself is also a kind of digital work, such as digital image, digital audio and video, etc. Compared with the conventional additive embedding algorithm, the algorithm adds a mediation parameter β on the basis of only one mediation parameter α, and the role of β is to adjust the size of the original coefficient of the watermark embedding position. The general image processing process will not change this part of data. On the contrary, in order to erase the watermark in the process of destroying the watermark, attackers will inevitably cause a serious decline in image quality, thus increasing the difficulty of attacking the watermark.

Watermark detection uses the similarity formula defined by Cox et al.

$$sim(W, I') = \frac{WI'}{\sqrt{I'I'}} \tag{6}$$

Where: W I' is the inner product of vectors W and I', and I' is the watermark coefficient contaminated by noise.

$$R = \begin{cases} 1 & s > \gamma \\ 0 & s < \gamma \end{cases} \tag{7}$$

Where: R represents the result of detecting the watermark, 1 indicates the existence of the watermark, when the similarity value s is greater than the threshold γ; 0 indicates that the watermark does not exist, when the similarity value s is smaller than the threshold γ.

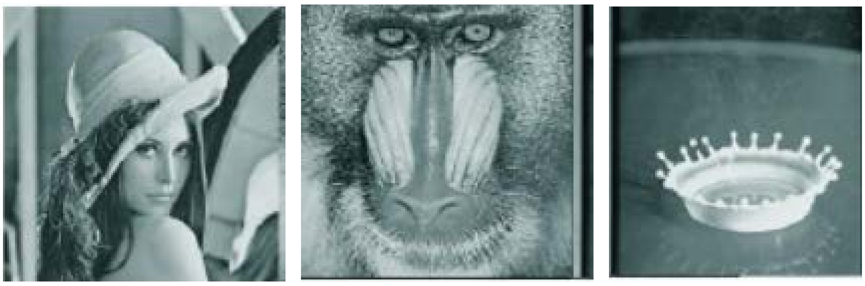
In order to make the watermark signal can be visually recognized, a binary image is selected as the watermark information. The advantage of binary images is obvious compared to the use of sequence values as watermarks. There is a threshold for the watermark embedding strength. Above this threshold, the image will be distorted. Below this threshold, the visual system cannot feel the existence of the signal, that is, the invisibility of the watermark is realized. This value is affected by the complexity of the background texture. Based on the above considerations, the author proposes a blind watermark embedding algorithm based on the addition of intermediate frequency coefficients based on additive embedding. When the sequence value is used as a watermark, after the watermark is attacked, it is impossible to judge whether the extracted watermark information is correct and can only be identified through similarity detection. However, for binary images, even if attacked, the image information can still be effectively identified as long as the attack degree is not large enough. This watermark is intuitive and easy to understand and has stronger persuasion. Although the watermark image extracted under the attack condition has certain distortion, the human eye can easily distinguish the watermark information, which shows that the algorithm has strong robustness to common image processing.

3. Analysis of Experimental Results

Lena, baboon, splash 3 gray-scale images with a size of 512×512 are selected as the experimental objects so that α = 7 and β = 7. In Table 1, the partial similarity values after the attack and the number of images with watermarks successfully detected are listed. The original images listed in table 1 are shown in Figure 2(a)-(c). In the figure, the watermarked image of lena image, salt and pepper noise attack image and 1/16 image of the remaining original image after center cutting are respectively given, and the rest of lena image is replaced by pure black. Using the characteristics of HVS, the embedded watermark strength is effectively combined with human visual characteristics, so that the embedded watermark strength is adaptive, i.e. different watermark strengths are embedded in different image blocks. For JPEG compression processing, both watermarking algorithms show strong robustness. When the quality factor QF drops to 50, the watermark image after JPEG compression processing can still be recognized. It can be seen from the results that the hardware-implemented copyright protection blind watermarking algorithm has higher PSNR value than other software algorithms. The watermarked image has lower PSNR value and can resist multiple image attacks, and the algorithm is simple to calculate and suitable for hardware implementation.

Table 1 Similarity value after the watermarked image is attacked

	Lena	Baboon	Splash
4× 4 median filter	22.34	12.28	28.27
FMLR	8.39	10.01	9.63
linear 1.007- 0.010	10.15	13.07	19.22
sharpening- 3- 3	11.07	15.24	17.51



(a)lena (b)baboon (c)splash

Fig. 2. Lena image

Three watermarked images were used as the target of attack, that is, there were 30 images that were attacked, and 22 images with watermarks were successfully detected, with a success rate of 90.13%. The peak signal-to-noise ratio (PSNR) is used to evaluate the distortion degree and normalized cross-correlation coefficient of the image quality of the carrier image and the original carrier after watermark embedding. The NC quantize evaluates the degree of distortion of the extracted watermark and the quality of the original watermark. Moreover, if the longitudinal observation of the test results after the attack will be found, the detection success rate is also 9/10 = 90%. Generally speaking, this shows that each watermarking image has strong robustness to attack. Wavelet transform based on lifting scheme speeds up the algorithm to a certain extent, realizes passive extraction, so it is a blind watermarking algorithm. Both watermarking methods show strong robustness. The NC value of the watermarking extracted by the latter algorithm is higher than that of the former one after three kinds of image processing. Therefore, when selecting the embedding object, we do not need to consider whether the host image matches the embedding object completely. We can choose to embedding the watermarking information into all the blocks of the image, or embedding the watermarking information into only part of the image blocks. The whole embedding method is flexible and changeable, so it has a wide range of applications.

4. Conclusion

In this paper, a blind watermarking algorithm is proposed, which achieves watermarking embedding by replacing the IF coefficients in DCT domain, breaking through the traditional watermarking embedding method. In order to maximize the robustness of the watermarking and the adaptive embedding of the watermarking, a human visual model is used. The algorithm can make the strength of the embedded watermarking adaptively embedding according to the shielding property of the image in HVS, thus reasonably harmonizing the contradiction between invisibility and robustness. Through a lot of simulation experiments and attack tests, and using the objective evaluation criteria of peak signal-to-noise ratio (PSNR) and image normalization value, the experimental results of the algorithm are compared and analyzed horizontally. In VLSI implementation, the pipeline structure is adopted to ensure the real-time performance of the watermarking algorithm, and the time-sharing multiplexing multiplication unit method is adopted to reduce the consumption of hardware resources. Experimental results show that the algorithm is robust to noise interference, compression, filtering and clipping, and the normalized correlation coefficient of the extracted watermark is above 0.6. At the same time, due to the adoption of the algorithm, the extracted watermark does not contain the DCT coefficient of the original image, so that the watermark detection accuracy is higher. This paper discusses this in detail and proves the robustness of the algorithm to attacks through experiments.

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