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A VIDEO WATERMARKING ALGORITHM BASED ON TURBO CODES IN THE MULTI-TRANSFORM DOMAIN

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Abstract

In this work, a robust watermarking algorithm is presented for video copyright protection. The algorithm is based on hybrid transforms using the combination of DWT and DCT. In the scheme, the luminance component of the key frames is firstly decomposed by a DWT, and then the approximation sub-band in the wavelet domain is selected on which DCT is applied. Following that, the watermark information which is sorted by the pseudo-random and encoded by Turbo codes is embedded into the DCT domain. The experimental results show that the proposed algorithm not only has better invisibility, but also has better robustness to a variety of common attacks.

***Keywords*:**

Video Watermarking, Turbo codes, DWT, DCT

1. INTRODUCTION

With the rapid development of network multimedia technology, the protection of the integrity and authenticity of the video works have begun facing unprecedented challenges. Digital watermarking technology which has been used as the evidence that verify the integrity of the contents or copyright is an effective means of protecting the security of digital products.

Digital watermarking technology that the initial research is focused on the digital image watermarking has developed a series of mature algorithms that resist all kinds of attacks, such as filtering, noise, cropping and compression [1]. In addition to have anti-attack characteristics of image, video watermark also need to be able to resist the attacks that are the unique attributes of video frames, such as restructuring, dropped frames and frame frequency changes, etc. Due to the shortcoming of spatial video watermarking algorithm that can be embedded into less information, poor stability and difficult to resist various geometric attacks, the study of existing video watermarking algorithm are concentrated in the transform domain. DCT domain, DWT domain, DFT domain are all common transform domains, more research and more mature algorithms are applied into DCT domain. Because of the various advantages and disadvantages of different transform domains, a different transformation study that watermark is embedded into different transformation organically combined domain. The study that multi-resolution characteristics of DWT [2] and compression capabilities and energy to relevance, will study a combination of both have been publicly reported. Literature [3] proposes a watermarking algorithm which transforms video sequences in both spatial domain DCT and temporal domain DWT. In the algorithm, the DC components of each video frame in DCT domain are first extracted to make a sequence, and then DWT is performed on both of the DC sequence and watermark sequence to complete the watermark information embedding. In the literature [4], the key frames are firstly decomposed by a DWT transform, and then the vertical sub-graph and the horizontal sub-graph in discrete cosine transform are decomposed. Finally, the watermark information is embedded into the DCT domain.

Based on the error correction capability of Turbo codes [5], in this paper, the watermark information is sorted by pseudo-random and encoded by Turbo codes while the luminance component of the key frames is decomposed by a DWT transform. Then the approximation sub-band in DWT domain is decomposed by 4 × 4 DCT transform. Finally, the watermark information which is sorted by the pseudo-random and encoded by Turbo codes is embedded into the DC coefficients of DWT transform.

2. WATERMARK SCRAMBLE

2.1 THE PRINCIPLES OF TURBO CODES

Turbo codes [6] are a recursive systematic convolutional code which is concatenation in parallel and have the capability of maximum error correction. The basic principle of this code is that interleaver multiple recursive systematic convolutional codes with feedback function concatenated in parallel or serial. In the encoding of the code, the input information *dk* which goes through interleaver imports the RSC encoder and exports in parallel from the end of the encoder. The output code of RSC encoder which is regarded as check codes and system code are in parallel / serial converted into Turbo Code which is any rates. In order to improve the decoding ability of Turbo code, the thoughts of Iterative soft decision decoding is applied into decoding process. The coding process is shown in Fig.1.

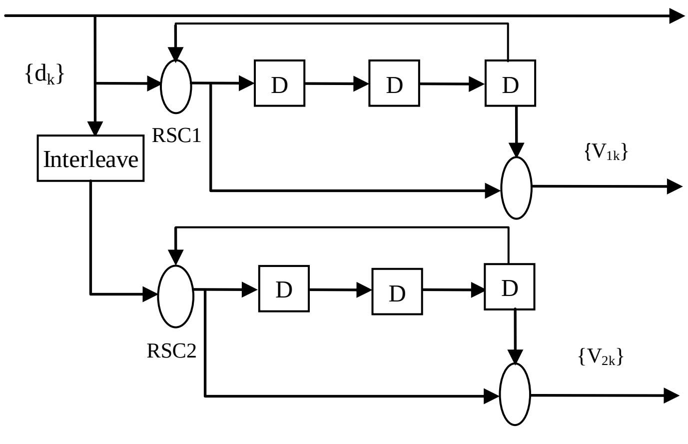


Fig.1. Turbo Code encoder

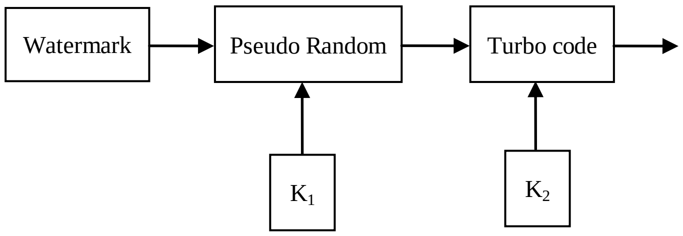


Fig.2. The watermark generation

2.2 THE GENERATION OF WATERMARK INFORMATION

Watermark scrambling can effectively destroy the correlation between pixels in the watermark image accordingly avoiding the phenomenon of block effect. The method can not only improve the security of the watermark can also be used to improve the robustness of watermark.

The pseudo random sequence generator is used to generate a one-dimensional binary watermark sequence. In consideration of the enhanced video watermarking security, the key k_1 is used to control the watermark scrambling, the key k_2 is used to control Turbo coding in order to get scrambled watermark information as shown in Fig.2.

3. DISCRETE WAVELET AND DISCRETE COSINE

3.1 DISCRETE WAVELET TRANSFORM

As shown in Fig.3, the video frame is decomposed into a low frequency approximation image and three high frequency detail sub images by wavelet decomposition, where LL, denotes the approximation sub-image, HL says the horizontal sub-graph, LH says the vertical sub-graph, and HH says the diagonal direction graph. The energy of the video frame mainly concentrates on the low frequency part, so the low frequency subband decomposition can proceed while the other high frequency portion of the little energy, high frequency part mainly expresses the frame edge information and also has the obvious direction characteristics.

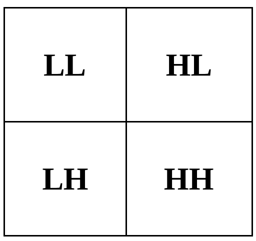


Fig.3. DWT decomposition model

3.2 DISCRETE COSINE TRANSFORM

Discrete cosine transform is used in the global transformation from image space to frequency space, its core is a real cosine [7]. In this paper, the approximation sub-band of luminance component of Video frame in DWT domain is decomposed by 4 × 4 DCT transform.

The mathematical formula of discrete cosine transform is defined as:

$$S(u,v)= \frac{2}{N}C(u)C(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}S(X,Y)\cos\left(\frac{\pi u(2x+1)}{2N}\right)\cos\left(\frac{\pi u(2y+1)}{2N}\right) \quad (1)$$

The corresponding inverse cosine transform is

$$S(x,y)= \frac{2}{N}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1}C(u)C(v)S(u,v)\cos\left(\frac{\pi u(2x+1)}{2N}\right)\cos\left(\frac{\pi u(2y+1)}{2N}\right) \quad (2)$$

where, the coefficients $C(u)$ and $C(v)$ are defined as,

$$C(u)=C(v)=\begin{cases}\frac{1}{\sqrt{2}}, & u=0 \text{ or } v=0\\ 1, & u,v=1,2,...,N-1\end{cases} \quad (3)$$

4. VIDEO WATERMARKING ALGORITHM

Because the Ycbcr color space can be separated the luminance component and chrominance component effectively, therefore, before the watermark is embedded into the key video frame, the selected key frames is performed in the conversion of color space. In this approach, the sequence of the selected video frames is converted RGB space into Ycbcr space.

4.1 WATERMARK EMBEDDING

The steps of algorithm of video watermark embedding are as follows:

Step 1: The key frames are selected from video sequence, and then the selected key frames are converted from RGB color space to Ycbcr color space, and luminance component of the key frames in Ycbcr color space is extracted.

Step 2: The luminance component that is extracted from key frames is decomposed by a wavelet transform, and makes four sub-graphs: low frequency sub-graph, the horizontal direction sub-graph, the vertical direction sub-graph, and the diagonal direction sub-graph. The watermark information is chosen to be embedded in the approximation sub image.

Step 3: Two-dimension 4 × 4 DCT is carried on the approximation image Y_k of the k^{th} key frame as defined in literature [8]. If the size of the video frame is $M \times N$, then $m \times n$ ($m = M/4$, $n = N/4$) blocks are made.

Step 4: Extract all the DC coefficients of 4 × 4 DCT blocks in one-dimensional array, each four coefficients for on group, and then one-dimensional 4 × 1 DCT is carried on the groups.

Step 5: The transformed groups are arranged in ascending order according to sum of absolute value of the third coefficient and fourth coefficient in each 4 × 1 group.

Step 6: The scrambled watermark by Turbo Code is embedded in rearranged arrays, and the embedding strategy is as follows:

a) Denote by K^{th} threshold value which is used for watermark embedding, x the third coefficient of the elected group for embedding watermark, y the fourth coefficient of the elected group for embedding watermark, and their difference is $d(i) = x\text{-}y$.

b) When the watermarking is 1, tries to keep the absolute value of the sum of the third coefficient and the fourth coefficient in this group invariable, and makes the third coefficient is K greater than the fourth coefficient, which is divided into three kinds of situations specifically.

- If the difference $d(i)$ is less than 0, then $x = x + (K + |d(i)|)/2$, $y = y - (K + |d(i)|)/2$.
- If the difference $d(i)$ is greater than or equal to 0, but less than the threshold value K, then $x = x + (K - |d(i)|)/2$, $y = y - (K - |d(i)|)/2$.
- If the difference $d(i)$ is greater than or equal to the threshold value K, both of the third coefficient and the fourth coefficient are unchanged.

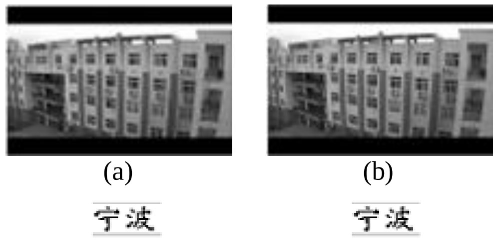
where, $1 \leq i \leq L2$, and it expresses the serial number of current array that will be embedding watermarking, $L2$ is not only the total number of arrays to be embedding watermarking, but also the length of watermarking sequence.

c) When the watermarking is 0, tries to keep the absolute value of the sum of the third coefficient and the fourth coefficient in this group invariable, and makes the fourth coefficient is K greater than the third coefficient. The process is the same as above, but need to exchange x and y.

d) When the process of watermark embedding is completed, one-dimensional 4 × 1 IDCT is carried on the watermarked array, and the transformed coefficients are restored to their original positions, and then carries on two-dimensional 4 × 4 IDCT to obtain a new approximation image. Finally, the IDWT is performed to get the luminance component of the watermarked video frames.

4.2 WATERMARK EXTRACTION

The watermark extraction is the inverse process of the watermark embedding. Firstly, the secret key which is saved in the process of embedding is used to obtain the key frames that the watermark information is embedded in. Secondly, the approximation sub-band of luminance component of key frame in DWT domain is decomposed by 4 × 4 DCT transform. Thirdly, the DC component in each 4 × 4 block is withdrawn, and every four coefficients are arranged in a group to conduct one-dimensional 4 × 1 DCT. Fourthly, the transformed groups are arranged in ascending order according to the sum of the third coefficient and the fourth coefficient in each 4 × 1 group. Fifthly, begin with the first group, watermarking is extracted from the rearranged arrays, if the third coefficient is greater than the fourth coefficient in the array, then extracted watermarking is 1; otherwise, extracted watermarking is 0. Sixthly, the extracted watermark sequence is decoded by Turbo code decoder and scrambled pseudo random inversely by pseudo random to get the original watermark.



(a) (b)

(c) (d)

Fig.4. Embedding and extraction experiments. (a). Original video frame, (b). Watermarked video frame, (c). Original watermark image, (d). Extracted watermark image

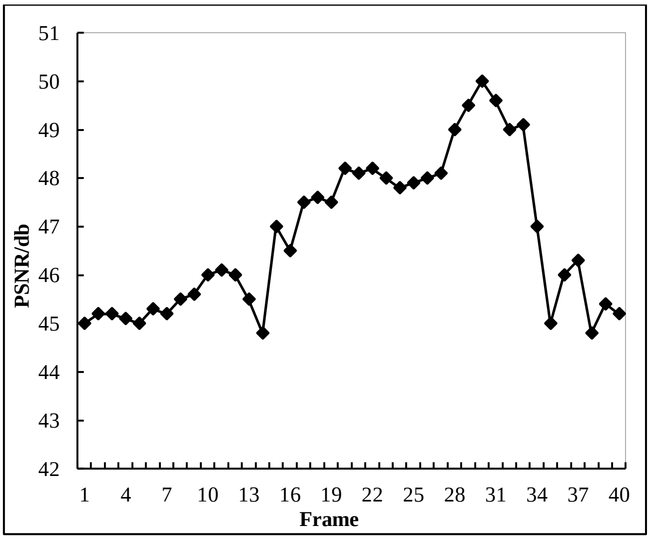


Fig.4(e). Embedding and extraction experiments- PSNR values of watermarked video frames

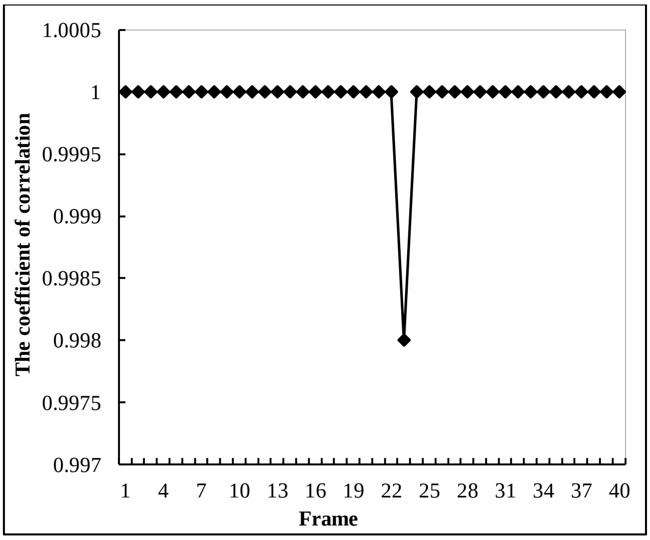


Fig.4(f). Embedding and extraction experiments- NC values

5. EXPERIMENTAL RESULTS

In the experiments, MATLAB software is used for simulation. Fig.4 presents an experiment for an uncompressed AVI video. The size of the video image is 720 × 480 pixels, while the binary image is used as the watermark; its size is 40 × 20 pixels as shown in Fig.4. The Fig.4(a) shows an original video frame, Fig. 4(b) shows the watermarked video frames, Fig.4(c) is the original watermark image, Fig.4(d) is the extracted watermark image, Fig.4(e) is the PSNR values of watermarked video frames, Fig.4(f) presents the normalized correlation coefficient (NC) between the original watermark image and the extracted watermark image. As can be seen, preferably the watermark information is embedded into the video, the video quality that is embedded the watermark is almost not affected. The PSNR values of all frames are above 45dB, the correlation coefficient between the original frame and the watermarked frame is 1, almost everywhere. It further verifies the transparence of the proposed watermarking algorithm.

In order to test the robustness of the proposed watermark embedding method, various attacks, such as noise, median filtering, shearing, and compressing have been made on the watermarked. Table.1 has listed the NC values between the original watermark and the extracted watermarks after the corresponding attacks. It can be seen from the Table.1 that the extracted watermark image is highly similar to the original image. Fig.5 shows the curves of NC for H.264 and MPEG-2 attacks. The results still indicate that the provided algorithm has strong robustness. The above experimental results show that the proposed watermarking algorithm has strong robustness to the above attacks.

Table.1. The NC values of different types of attacks

The Type of Attack	**The attack strength and NC value**		
Salt and pepper noise	d = 0.005	d = 0.01	d = 0.02
	NC = 0.9823	NC = 0.9293	NC = 0.8803
White Gaussian noise	$\delta^2 = 0.001$	$\delta^2 = 0.002$	$\delta^2 = 0.004$
	NC = 0.9890	NC = 0.9328	NC = 0.8893
Median filter	3*3	5*5	7*7
	NC = 0.9763	NC = 0.9345	NC = 0.8973
The frame shear	10*10	20*20	40*40
	NC = 0.9812	NC = 0.9571	NC = 0.9122

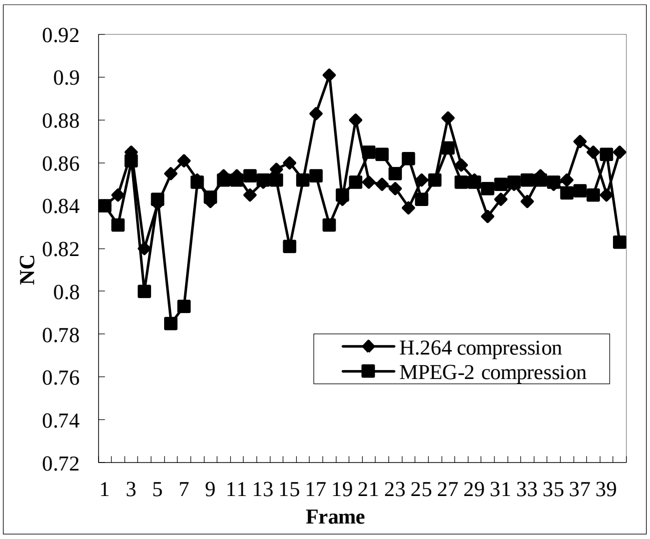


Fig.5. The NC values after H.264 and MPEG-2compression attacks

6. CONCLUSION

For enhancing the security of watermarking, Turbo Codes is applied to scramble watermark image before embedding, and the joint DWT-DCT is performed on each video frame to embed the scrambled watermark information. The embedded watermarking can be extracted without original video signal, realizing watermarking blind detection. The experimental results show that the algorithm has better robustness against noise, filtering, shear and compression.

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