

A Video Zero-watermark Algorithm Based on the Contourlet Transform

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Abstract. A video zero-watermark algorithm is proposed based on Contourlet transform, which has been hailed as the "real" tool to capture the geometric structure of the two-dimensional signal. The algorithm uses Contourlet transform to deal with each frame image of the original video, and select the low frequency coefficients to construct the zero-watermark. The experimental results show that the algorithm makes the imperceptibility and robustness have a good compromise and can resist MPEG compression and other common video attack effectively.

Keywords: Video, Zero-watermark, Contourlet Transform

1.1 Introduction

Traditional watermark algorithms may have a certain degree of damage to the original data. The zero-watermark is gradually being recognized by the majority of scholars, and the concept of zero-watermark is proposed by Wen Quan et al.¹ The idea is to construct the watermark with the important features of the original data, and any information of the original data is not changed. There is no quality degradation or water quantity constrained.

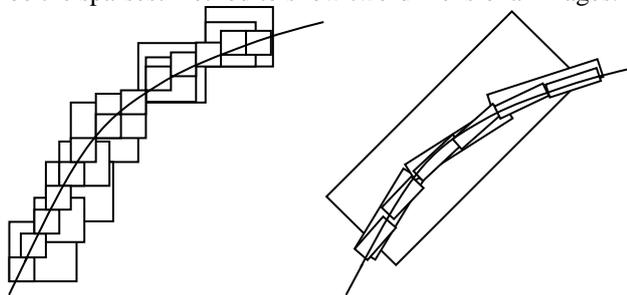
The wavelet transform has been widely applied to the watermark technology. It approaches the goal with the point singularity as the basis of one-dimensional signal, but the poor directional selectivity makes it can't effectively capture the contour information.¹ The Contourlet transform was proposed by M. N. Do and M. Vetterli in 2002, and it can achieve arbitrary direction decomposition at any scale. It is almost the critical sampled. A great advantage is for describing the image contour and texture information. It caused the note of domestic scholars at the end of 2003. The Contourlet transform had been used to denois the image by Deng Chengzhi et al in 2004. It was added to the digital watermark by Li Haifeng et al in 2006.² A considerable achievement is made in image watermark, audio water-

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mark and other fields for the next few years. It was the first time that the Contourlet transform was introduced to the video watermarking in 2008, and so far Wu Yiquan et al have achieved good results in the field of the Contourlet video watermark. This paper presents a new algorithm based on the achievements of the predecessors, and construct zero-watermark with the Contourlet transform coefficients.

1.2 Introduction of Contourlet Transform

Contourlet transform is a new image representation method, and it is the new development of wavelet transform. The wavelet transform scales the square with the same size as the support interval of the two-dimensional space, it may produce a lot of redundant with large-scale square to approach the same curve, and the precision is poor. With small scale square to approximate the curve can improve the accuracy, but data volume may increases as shown in **Fig. 1.1 (a)**. The wavelet representation is not the sparsest method to show two-dimensional images. Contourlet transform support interval of two-dimensional space is long strip of different scales, it uses the different sizes long strip to approximate the curve flexibility, and it can not only improve the accuracy, but also does not generate a large amount of data as shown in **Fig. 1.1 (b)**. The Contourlet transform is considered to be the sparsest method to show two-dimensional images.



(a) Wavelet approximation method (b) Contourlet approximation method

Fig. 1.1 Wavelet and contourlet approximation method

The Contourlet transform is composed of two parts:⁴

1. Laplacian Pyramid Filter

Using Laplacian Pyramid Filter (LP) to decompose the sub-band of the original image, and the purpose is to capture the singular points in the image signal. LP decomposition produces an the difference image between the original image and the low-pass image, then the low-pass image is decomposed to get the next low-pass image and the next difference image. Such filtering is down gradually, and we get multi-resolution decomposition of the image.

2. Directional Filter Bank

Directional Filter Bank (DFB) is mainly used to combine the singular points in the same direction into the same coefficient, namely the Contourlet transform coefficient. When the DFB decompose the image in k layers, the frequency domain is decomposed into $2k$ sub bands in each layer, and each band is the type of wedge. The Contourlet filter principle diagram is shown in **Fig. 1.2**. **Fig. 1.3** is two layers Contourlet frequency decomposition map whose direction number is 4, and C_3 is the low pass sub-band, the other is band-pass sub-band.

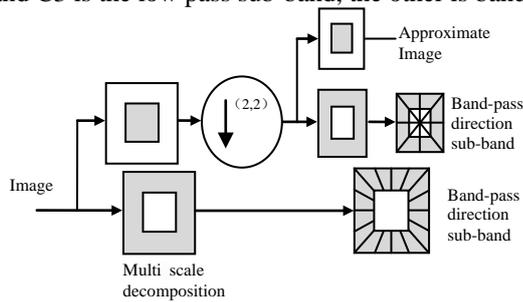


Fig. 1.2 Contourlet filters

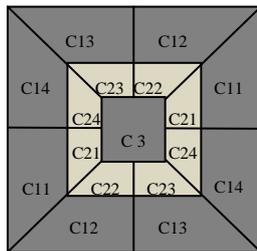


Fig. 1.3 Frequency decomposition map

Directional filter cannot provide sparse representation by itself, so the low frequency part of the image should be removed before application. Combination must be done between LP and DFB. After high-pass sub-bands of LP decomposition of image were put into DFB, singular point was gradually into a linear structure, so as to achieve the purpose of capturing image contour. The structure of LP combined with DFB is called pyramid directional filter banks (PDFB), which is the discrete Contourlet transform.

1.3 The Construction of Zero-Watermark

The algorithm process is shown in **Fig. 1.4**.

Step1: Watermark pretreatment. First, Arnold transform is performed on the original watermark image W , and frequency N is as the key ① to be saved, then the scrambled watermark image is encrypted by the second time and get watermarking w' which is processed by the Logistic mapping, and the initial value is as the key ② to be stored up.⁵ All pictures are shown in **Fig. 1.5**.

Step2: Video segmentation. Video is segmented into 30 frames, and each 6 frames are divided into one group to get 5 groups of lens. Get image entropy for 6 images in each shot respectively.⁴ The frame which has maximum entropy is defined as the key frame image to obtain 5 images to be processed.

Step3: Contourlet transform. The 5 images are processed by the Contourlet transform in order to obtain low frequency coefficients (one frame as an example), and it is a 128×128 matrix.

Step4: Zero-watermark construction. The absolute values are taken for each row and column of the matrix and are added to get the maximum row ROW_{max} and column COL_{max} . Get ROW_{max} and COL_{max} descending order respectively, take the top 32 values, and obtain two sequences, one is the row, and the other is the col. According to the **Formula 1.1**, the two sequences are quantified, and take the remainder for 2 into the sequence of [0, 1]. According to the **Formula 1.2** to do calculations, get the matrix whose size is 32×32 and its value is [0,1]. That is the feature matrix t of the original signal. The *XOR* operation is made by using the corresponding elements of t and w' to process the key image m .

Step5: The Gray code. If we set m as the key image word directly, it is easy to be broken. m is processed once again using the Gray code for the better security of watermark, and the key image m' is obtained and stored in the database.

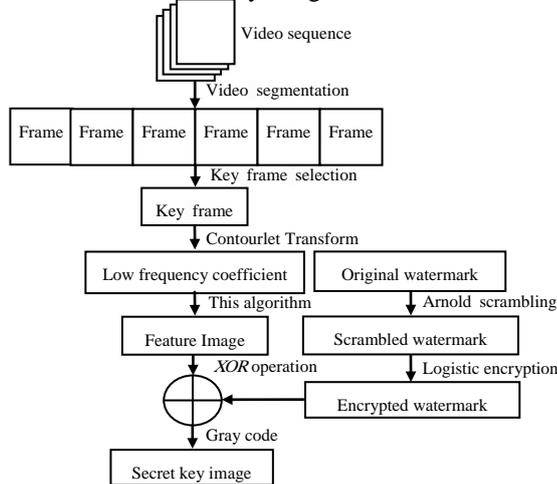


Fig. 1.4 Algorithm flowchart



(a) Original watermark (b) Arnold scrambling (c) Logistic encryption

Fig. 1.5 The original watermarking and image encryption



Fig. 1.6 the Contourlet transform simulation diagram



(a) Feature image t



(b) Processing key image m

Fig. 1.7 Feature image and processing key image

$$row(1, i)' = \text{mod}(\text{round}(\text{row}(1, i) / a), 2) \quad (1.1)$$

$$t(i, j) = \text{bitxor}(\text{row}(1, i), \text{col}(1, j), \text{col}(1, j)) \quad (1.2)$$

Watermark detection is the inverse process of construct, so it will not be repeated here.

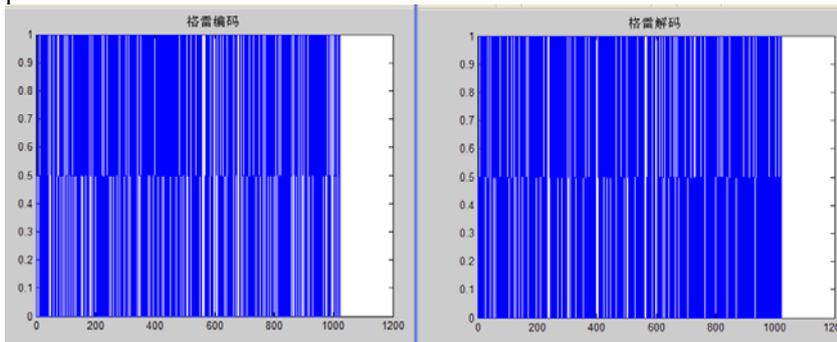


Fig.1.8 Gray codec simulation diagram



Fig.1.9 Secret key image m'

1.4 Experimental Results and Analysis

In order to prove the effectiveness of this algorithm, a series of attacks on the video demonstrates the robustness and invisibility. The extracted watermark quality is detected by the similarity (NC). Below is the contrast between the original image and the image with embedded watermark. It is the zero-watermark algorithm, the host has not any change, and the frame image is the same as the one with the watermark embedded.



(a) Original image



(b) Image after watermark embedding

Fig.1.10 Image before and after watermark embedding

In order to verify the robustness some attractions are added into video, such as the additive noise, frame trim attack at airspace, frame average, frame deletion attack at time domain. When extracting the watermark from the 5 key frames, we get 5 watermark images. The pixels of the same position are counted, if the value for the number of 1 is greater than 2, then the pixel value is 1, otherwise 0. **Table 1.1** shows various attack experimental results.

1. Noise attack: The Gauss noise, whose mean value is 0 with different variance, is used to attack the video sequence with the watermark. The watermark extracted under Gauss noise attacking with different intensities and the corresponding NC values are listed in table 1.
2. Frame trim: Experiments cut off a section of each frame in the video, the extracted watermark and the corresponding NC value under different cutting rate

indicates that the robustness of the watermark is still good when each frame image is clipped to 30%.

3. Frame average: Select different numbers of frames to process frame by frame average and experimental results show that the algorithm can resist this attack effectively.
4. MPEG compression: The extracted watermark and the corresponding NC value under different compression ratios have show that the algorithm has the certain ability to resist MPEG compression.
5. Frame deletion: Experiments are carried out on frame images, and results show that if the 5 key frames is not completely removed and watermark can be extracted successfully.

Table 1.1 Attack experimental results

Attack	Parameter values	Extracted watermark	NC
Variance	0.005		0.9853
	0.01		0.9357
	0.015		0.8698
Cutting ratio	10%		0.8950
	20%		0.8601
	30%		0.7900
The number of average frame processing	4		0.8950
	5		0.8601
	6		0.8079
Compression ratio	3:1		0.9613
	6:1		0.8921
	10:1		0.7481

Table1.1 (continued)

Delete key frame ratio	20%		0.9853
	40%		0.9147
	60%		0.8645

1.5 Experimental Results and Analysis

A kind of zero-watermark algorithm of video is put forward based on the Contourlet transform. Take advantage of Contourlet transform to describe image features, and its low frequency coefficient feature is used to construct zero-watermark. The security of watermark information is improved using the Arnold transform, chaotic encryption and Gray coding. Simulation experiments show that the algorithm's anti attack ability is better for noise, frame trim, frame average, MPEG compression and frame deletion and so on. Better robustness is shown, but the key image data storage capacity is too large. The next step is to change the algorithm to achieve smaller key data and better simulation results.

This work is supported by the Science & Technology Project of Heilongjiang province under Grant No. 12521056.

1.6 References

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