A Chaos-based Watermarking Algorithm for Video Authentication

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Abstract: Watermarking can be achieved copyright protection and authentication. This paper proposed a blind digital watermarking algorithm in wavelet domain based on chaotic map. The chaotic map was employed to improve the security and used for embedding positions of watermark. The results show the proposed algorithm is more robustness to attacks.

Keywords-- **Watermark, Video, Chaotic Map, Wavelet**

1. Introduction

Watermarking is a process of embedded data for copyright protection and authentication. Copyright protection involves the authentication of video content and ownership and can be used to identify illegal copies of a video [1].

There are several watermarking schemes applied to digital video in the literatures [2-4]. In [2], proposes a novel method based on pattern recognition. A watermarking signal embedded into the AC coefficients in DCT domain of video frames. In [3], presents a method to combine the SVD and frame synchrony in watermark. Embedding video watermark uses part of a spread spectrum sequence of video images. The embedded algorithm has been done in two bands of video [4].

This paper presents the watermarking in video QCIF format. The algorithm is embedded a watermark on two subband of Y and U component [4]. A chaotic 1D discrete map [5] used to determine the embedding positions.

2. Background

2.1 Discrete Wavelet Transform [6]

Discrete Wavelet transform (DWT) is a linear transformation that operates on a data vector whose length is an integer power of two, transforming it into a numerically different vector of the same length. It is a tool that separates data into different frequency components, and then studies each components with resolution matched to its scale. DWT is computed with a cascade of filtering.

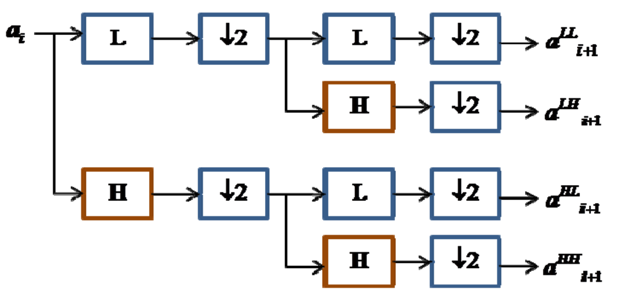


Figure 1. Wavelet decomposition for two-dimensional.

H and L denotes high and low-pass filters respectively, ↓ 2 denotes subsampling. Outputs of this filters are given by equations (1) and (2)

$$a_{i+1}[p] = \sum_{n=-\infty}^{\infty} l[n-2p]a_i[n] \quad (1)$$

$$d_{i+1}[p] = \sum_{n=-\infty}^{\infty} h[n-2p]a_i[n] \quad (2)$$

Where $l[n]$ and $h[n]$ are coefficients of low and high-pas filters respectively. Elements a_i are used for next step of the transform and elements d_i, called wavelet coefficients, determine output of the transform.

2.2 Chaotic Map

A chaotic map is evolution function that shows some sort of chaotic behavior. Maps were parameterize by a discrete-time or a continuous-time parameter. Discrete maps usually get the form of iterated functions. There are several different iterative processes, such as Logistic map, Baker's map, complex squaring map, complex quadratic map and complex cubic map etc. This paper used cubic maps [5] for embedding positions of watermark. Theory about Chaos in the cubic mapping can be found in [8].

3. Watermark Embedding

A binary image was a watermark. The Y and U component are decomposed by two-dimensional wavelet decomposition and each subband is embedded by watermark image. Figure 2 shown a diagram of the watermark embedding process.

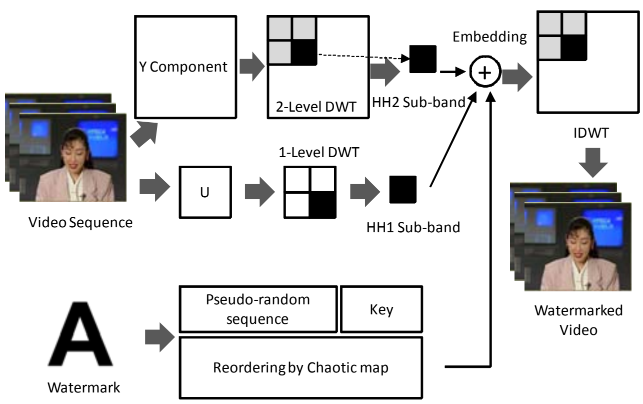


Figure 2. A diagram of the proposed watermark embedding process.

The result of chaotic 1D discrete map [5] (using cubic maps) was sorted by ascending order and then used to determine the embedding positions. The product of a watermark and pseudo random sequences ($P_i \bullet S_i$) at a given position was then reordered, with respect to the sorted index. A watermark was embedded in both HH_2 subband of Y component and HH_1 subband of U component. According to the rule in Eq. 3:

$$I_i' = I_i + \left(\alpha \bullet P_i \bullet S_i\right), i = 1, 2, ..., \mathrm{N} \tag{3}$$

where I_i is input video sequence. I_i' is output video sequence with watermark. α is a magnitude factor which is a constant determining the watermark strength. P_i is pseudo random sequence which each number can take a value either 1 or –1. S_i is a bit sequence of watermark and the value are set to 1 or -1, as data and background, respectively.

4. Watermark Extracting

Figure 3 and 4 shown the watermark extracting process. This process does not require the original video sequence to recover the embedding signature. A prediction of the original value of the pixels of video sequence is to use 3×3 mask.

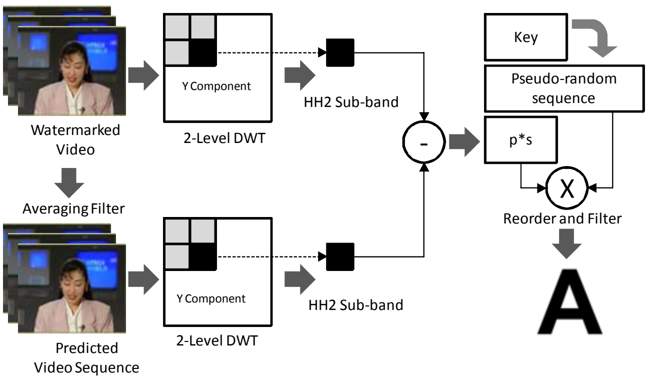


Figure 3. A diagram of the proposed watermark extracting process of Y component.

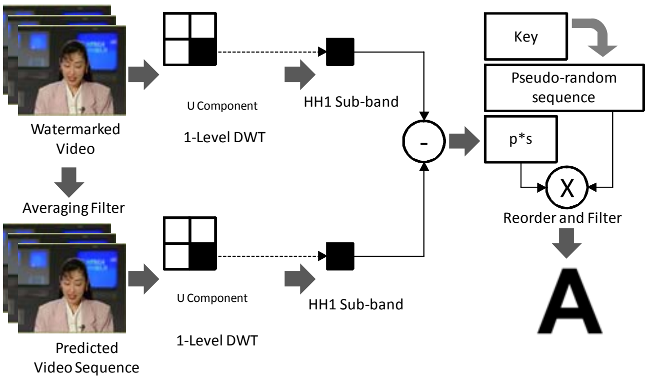


Figure 4. A diagram of the proposed watermark extracting process of U component.

The predicted video sequence $\left(I'\right)$ can be obtained by smoothing the input video sequence $\left(I'\right)$ with a spatial convolution mask. The prediction of the original value can be defined as Eq. 4.

$$\widehat{I}_i = \frac{1}{c \times c} \sum_{i=1}^{c \times c} I_i' \tag{4}$$

Where c is the size of the convolution mask. The watermarked video and the predicted video are DWT transformed independently, and on each subband is selected to generate a I' and $\widehat{I}$ respectively.

From Eq. (3), the estimate of the watermark $\hat{S}$ is indicated by the difference between I^* and $\widehat{I}$ the equation can be represented as:

$$\delta = I_i^* - \widehat{I}_i = \alpha \cdot P_i \cdot \widehat{S}_i \tag{5}$$

Therefore, the sign of the difference between the predicted and the actual value is the value of the embedded bit:

$$sgn(\delta_i) = P_i . \widehat{S}_i \tag{6}$$

The watermark was estimated by multiply pseudo random sequence to the embedded bit. If a wrong pseudo random sequence is used, the program does not work.

5. Experimental Results

5.1 Performance Evaluations

A similar measurement between the original watermark (w) and the extract watermark w' was computed by using normalized correlation (NC), as in Eq. 7.

$$NC = \frac{\sum_{i=1}^{M} w_i w_i'}{\sum_{i=1}^{M} w_i^2} \tag{7}$$

In addition, the quality of the watermarked video compared to original video was measured based on the Peak Signal to Noise Ratio (PSNR). The PSNR formula is expressed as follows:

$$PSNR = 10 \log \frac{\left(2^b - 1\right)}{\left(\frac{1}{m \times n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left(O(i,j) - \mathrm{R}(i,j)\right)^2\right)} \tag{8}$$

b is the number of bits used to represent in the pixel. $m \times n$ is a size of image. $O(i,j)$ is the original pixel value. $\mathrm{R}(i,j)$ is the reconstructed pixel value.

5.2 Simulation Setup

A QCIF video sequence, of size 176x144 pixels was used for the experiment. Fig 6(a) and 7(a) shown the 40^{th} Akiyo sequence and shown the 40^{th} Carphone sequence. The watermark image was a binary image, as shown in Fig. 5. The watermarking was tested with the following parameters: magnitude factor are 5-15 and the key was 100.

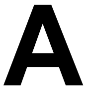


Figure 5. Original watermark image

5.3 Simulation Result

In this proposed method, we were embedding watermark in all frames of Y and U component of video sequences. The best of the magnitude factor was 8-10. Fig 6(b) shown the 40th Akiyo sequence with an embedded watermark with $\alpha = 8$. Fig 7(b) shown the 40th Caphone sequence with an embedded watermark with $\alpha = 8$. Figure 8 show extracted watermark of Akiyo sequence and Carphone sequence with $\alpha = 8$. In Table I, the PSNR of the Akiyo sequence is equal to 41.1830 dB. The NC is up to 0.8269 for Y component and up to 0.9837 for U component following Table II – III. Table IV show PSNR and NC of Carphone sequence.

Noise can occur in the process of transmissions, video signal can be destroyed by unpredictable noise in the network communication. We tested the robustness with Salt and Pepper noise, as the results shown in Table V.

(a) (b)

Figure 6. 40th Akiyo sequence with $\alpha = 8$ (a) original (b) with watermark

(a) (b)

Figure 7. 40th Carphone sequence with $\alpha = 8$ (a) original (b) with watermark

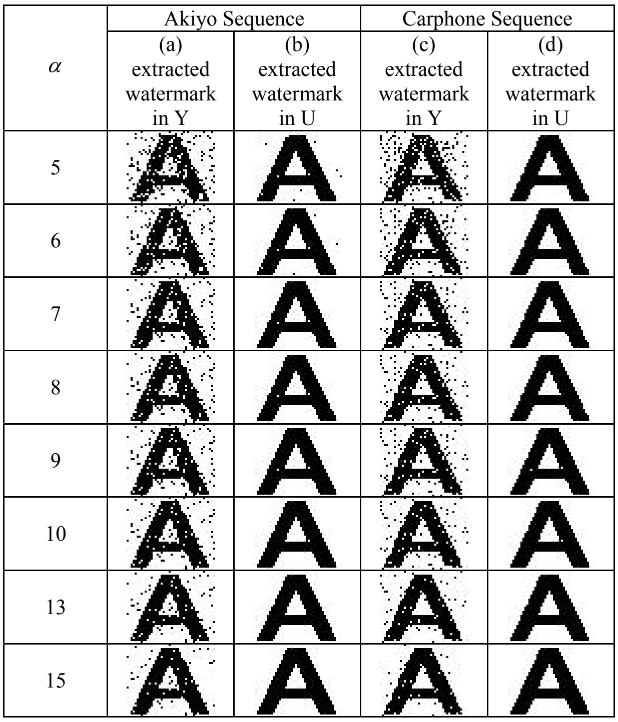


Figure 8. (a) extracted watermark of Akiyo sequence in Y component
(b) extracted watermark of Akiyo sequence in U component
(c) extracted watermark of Carphone sequence in Y component
(d) extracted watermark of Carphone sequence in U component

TABLE I. PSNR OF AKIYO SEQUENCE

α	5	6	7	8	9	10	13	15
[4]	45.860	43.316	41.661	41.183	40.541	39.089	37.199	35.424
Proposed	45.860	43.317	41.661	41.183	40.541	39.089	37.199	35.425

TABLE II. NC OF Y COMPONENT (AKIYO SEQUENCE)

α	5	6	7	8	9	10	13	15
[4]	0.7441	0.7953	0.8196	0.8245	0.8280	0.8491	0.8718	0.8984
Proposed	0.7347	0.7860	0.8243	0.8269	0.8309	0.8552	0.8786	0.9037

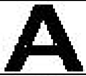
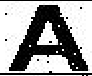
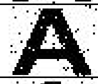
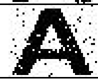
TABLE III. NC OF U COMPONENT (AKIYO SEQUENCE)

α	5	6	7	8	9	10	13	15
[4]	0.9665	0.9790	0.9812	0.9835	0.9884	0.9892	0.9927	0.9956
Proposed	0.9666	0.9773	0.9828	0.9837	0.9890	0.9922	0.9922	0.9940

TABLE IV. PSNR AND NC OF CARPHONE SEQUENCE

α	5	6	7	8	9	10	13	15
PSNR	45.860	43.316	41.661	41.183	40.541	39.088	37.199	35.424
NC (Y)	0.7151	0.7817	0.8197	0.8232	0.8266	0.8566	0.8825	0.9129
NC (U)	0.9810	09861	0.9875	0.9881	0.9922	0.9947	0.9943	0.9956

TABLE V. U COMPONENT WITH $\alpha = 8$

Attack Type	PSNR	NC	Extracted Watermark
No Attack	41.183	0.9837	
Salt and Pepper noise (0.005)	35.151	0.9581	
Salt and Pepper noise (0.01)	32.865	0.9333	
Salt and Pepper noise (0.02)	30.056	0.8867	

6. Conclusions

This paper presented a new watermarking algorithm based on chaotic 1D map. The method is archived by applying a watermarking technique on Y and U component. The embedding process is presented in wavelet domain. Experimental results show the proposed algorithm can be detected with an acceptable visual quality.

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