A WAVELET-BASED VIDEO WATERMARKING

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ABSTRACT

In this paper, we present a robust digital video watermarking technique. For robustness to geometric transformation, a watermark is embedded in the DWT domain. A watermark is created by shaping an author and video dependent pseudo-random key generation by which is formed us. As a result, the watermark adapts to each video to ensure invisibility and robustness. Furthermore, the watermark is statistically undetectable. In this method, embedded data are recovered without the original image. To robustness of the proposed method is tested by applying different types of attacks. The tests show good performances against common signal processing procedures such as noise addition, MPEG4 compression, adding mask image, Gaussian blur and scaling.

I. INTRODUCTION

Recently, digital products are widely used and the acquisition, copying and transmission of such products become very easy because of the development of computer networks and multimedia technology. So, digital watermark technique which aims at copyright protection of digital contents becomes more and more important. Digital watermarking is the technique which embeds an invisible signal including owner identification into multimedia data such as audio, video, images for copyright information.

Different digital watermark algorithms have been proposed. These algorithms are mostly frequency domain techniques for still images [1-5] and for video [6]. Zhu et al. proposed a unified approach to digital watermarking of both images and video [7]. Watermark methods for video have also been presented in the recent papers [8-11], in which watermark embedded into MPEG bit stream directly. The methods in [8-10] hide data into motion vector information in the MPEG-1 or MPEG-2 compressed domain, while the method in [11], which is under consideration, embed watermark into DCT coefficients of I frames of video.

The rest of the paper is organized as follows: Section 2 introduces the proposed method for digital watermarking. The pseudo-random key generation is explained in Section 3. In Section 4 and 5 describes the embedding and recovering process as a function of the algorithm parameters respectively. In Section 6, some experimental results are given and conclusions are provided in section 7.

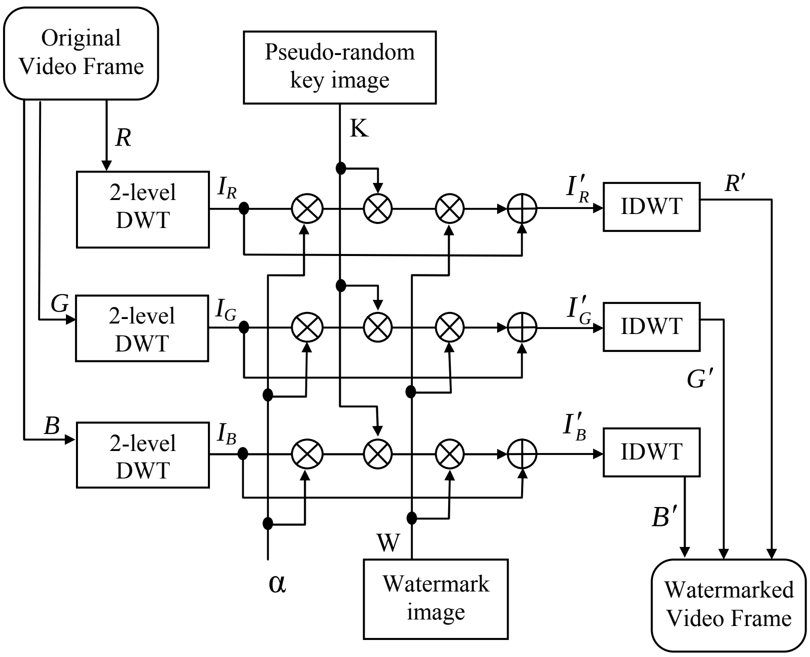


Fig. 1 Watermark embedding algorithm

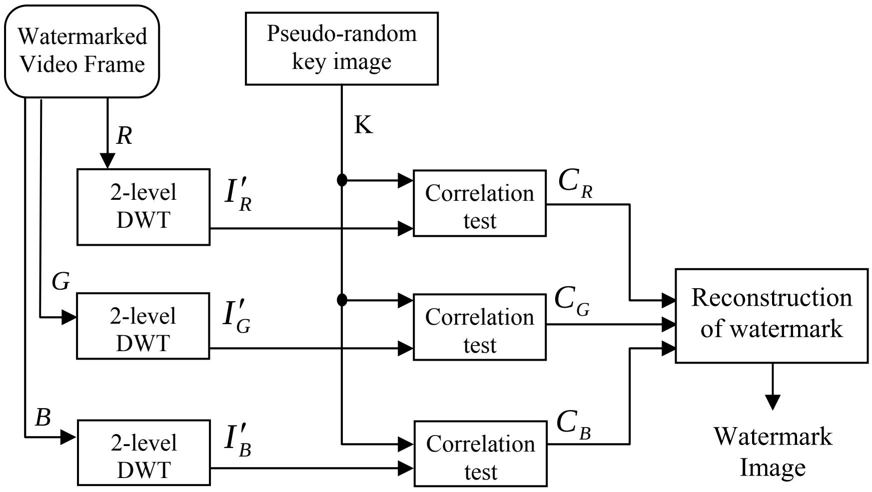


Fig. 2 Watermark extraction algorithm.

II. PROPOSED WATERMARKING TECHNIQUE

The proposed watermark embedding technique has four steps: 1) Two-Level DWT of each color, 2) pseudo-random key generation, 3) watermark insertion, 4) IDWT. The block diagram of embedding algorithm is shown in Figure 1.

The watermark extraction diagram is shown in Fig. 2. Each color of the watermarked video frame has transformed to wavelet domain and early generated pseudo-random key image taken into correlation test. These results are used to reconstruct watermark.

III. PSEUDO-RANDOM KEY GENERATION

Each highest-level subbands in 2-level DWT have four related pixels coming from lower subbands. They gather in 2x2 sub-matrices. So we generate a 2x2 pseudo-random key matrix for each watermark pixel. Let's say we have a matrix sized 176x144 in HL_1 subband. So our key image will be 176x144 and watermark image size with 88x72, which is a quarter size of the key image. The subband and pixel relation of an image is shown in Fig. 3.

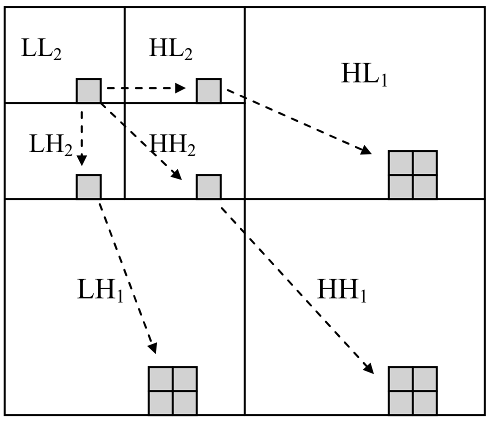


Fig. 3 Two-Level DWT with related pixels

The generated 2x2 pseudo-random matrix consists of "+1" and "-1" values whose mean value is not 0 or 1. For example mean value of (1, 1, 1, -1) is 0.5. This prevents from division by zero problems when calculating correlations in watermark extraction.

IV. WATERMARK EMBEDDING

Watermark is embedded in each LH_1 and HL_1 subbands of the red, green and blue (R, G, B) values. Let I_R be the red color of the original frame, K be the key image, α be the robustness coefficient and W be the watermark image. Then the embedded red color I'_R is calculated as shown in (1).

$$I'_R = I_R + a \cdot K \cdot W \tag{1}$$

The watermark matrix consists of "+1" and "-1" values. For each watermark pixel embedding is done by using 2x2 related pixel areas from I_R and from key image K. This process is repeated for G and B values of the video frame. Because the effect of watermark in each color space (R, G and B) is different, by applying watermarking algorithm increases the correlation probability in extraction step.

V. WATERMARK RECOVERING

The original image is not needed in watermark extraction. We only need a key image that was used before to embed watermark and a correlation coefficient β. Let I'_R be the red color of the watermarked frame, K be the key image and C_R be the red color correlation of the frame. The correlation is calculated as shown in (2).

$$C_R = \frac{\sum_i^M \sum_j^N \left(I'_{R(i,j)} - \overline{I'_R}\right) \cdot \left(K_{(i,j)} - \overline{K}\right)}{\sqrt{\sum_i^M \sum_j^N \left(I'_{R(i,j)} - \overline{I'_R}\right)^2 \cdot \sum_i^M \sum_j^N \left(K_{(i,j)} - \overline{K}\right)^2}} \tag{2}$$

C_M : Maximum of C_R , C_G and C_B

$\overline{I'_R}$: Mean value of the 2x2 image area

$\overline{K}$: Mean value of the 2x2 key image area

T : Threshold

β : Correlation coefficient

$\overline{C_M}$: Mean value of the C_M 's

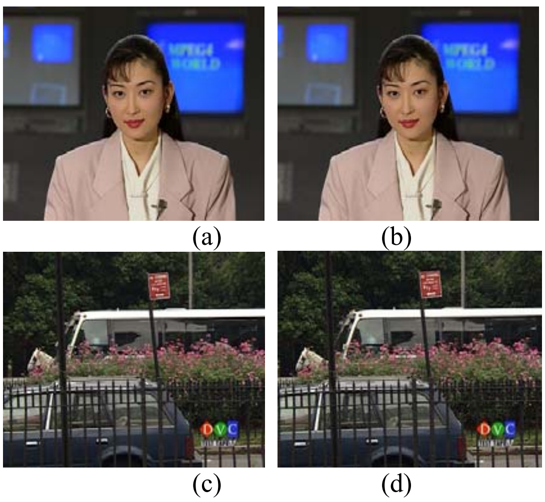
W' : Recovered watermark pixel

Again the I'_R and K values are taken into consideration as 2x2 matrices and C_R values for each watermark pixel is calculated one by one. After finding C_M for each pixel, (3) is used to decide the reconstructed watermark pixels. Threshold T is calculated with $T = \beta \cdot \overline{C_M}$ formula. According to our tests we choose β as 0.05.

$$W' = \begin{cases} 1 & if \quad C_M \geq T \\ 0 & if \quad C_M < T \end{cases} \tag{3}$$

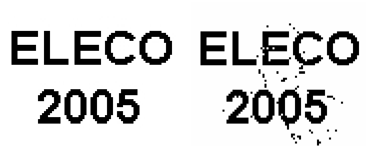
VI. EXPERIMENTAL RESULTS

Our watermarking algorithm has been tested over different videos. We considered two test sequences "Bus" and "Akiyo" in CIF format (352x288 pixels) are used in the experiment. The results of these tests are given in table 1. In Akiyo the neighboring colors are similar. So it is better to select a small embedding coefficient, α=5. However, Bus has wide color distribution compared to Akiyo. This enables us to select a bigger embedding coefficient for Bus, α=10. The size of the watermark, 88x72, is compatible with the embedding algorithm. First frame of the original and watermarked sequences, sample watermark and reconstructed watermark is shown In Figure 4.



(a) (b)

(c) (d)



(e) (f)

Fig. 4 Example sequence at 352x288 (a) Akiyo original, (b) watermarked at α=5, (c) Bus original, (d) watermarked at α=10, (e) watermark image size of 88x72 and (f) recovered watermark image

To test the errors on reconstructed watermarks we calculated bit errors (BER) using formula (4). The "bit_errors" represents the bit errors between original and reconstructed watermark.

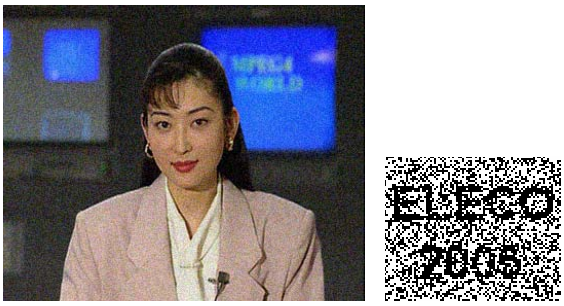
$$BER = \frac{bit\_errors}{total\_embedded\_bits} \cdot 100 \tag{4}$$

The tests show good performances against common signal processing procedures such as noise addition, video compression and scaling but we noticed that after rotation attack the watermark data was corrupted. The results of these tests are given in table 1. Below there are the results of different attacks:

- To test the robustness of the proposed algorithm against noise attack, we added white noise to watermarked image at 20% and extracted watermark data from corrupted watermarked frame with high BER values but the watermark was still recognizable with human eyes. Fig.5 shows the corrupted watermark image by white Gaussian noise and recovered watermark.
- We added Pills image by 60 % to the Bus sequence and found PSNR to be 11.47 dB, that is the changed frame is almost completely different. The recovered watermark, however, has BER=8.44 and all the characters in the watermark can be recognized. This is because the attack doesn't affect the low subbands in the wavelet domain. In Fig. 6 displays first frame of bus sequence by 60 % mask added and extracted watermark.
- All lossy compressions contain quantization steps. We have investigated system performance for MPEG4 compression attack. Akiyo sequence was compressed as low as 0.5 Mbits/s (0.1973 bit/pixel for 352x288 resolution 25 fps color video) and watermark was recovered with 18.80% BER. According to quantization process, the protection of watermark was easy at the frames which were low color distribution level. Therefore, proposed algorithm was quite robust to higher compression ratios. The result of this test is shown in Fig. 7.
- This method also tested with scale-down attack by 50% which decreases the pixel intensity of the frame and the watermark was detected with BER=18.73 and was still recognizable. The attack

on watermarked image and recovered watermark are shown in Fig. 8.

- Although the watermark data was recovered perceptually, we noticed that after rotation attack the watermark data was corrupted. The reason lies on watermark insertion algorithm.

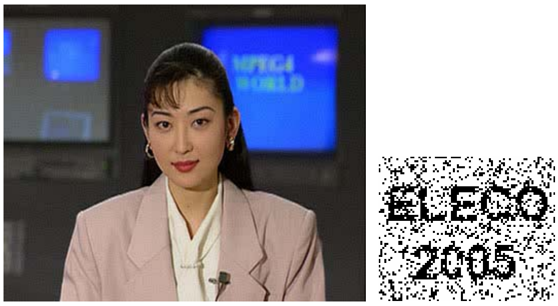


(a) (b)

Fig. 5 (a) First frame of Akiyo with 20 % white noise added and (b) extracted watermark, BER=34.3

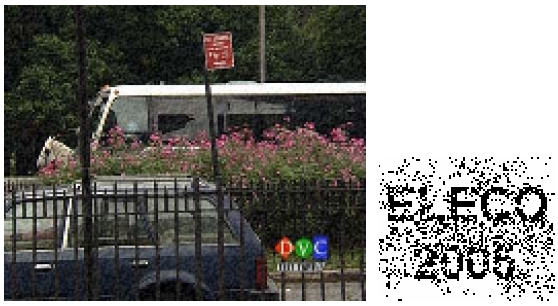
(a) (b)

Fig. 6 (a) First frame of Bus sequence with 60 % mask added, (b) extracted watermark, BER=8.44



(a) (b)

Fig. 7 (a) Akiyo MPEG4 0.5Mbit and (b) reconstructed watermark, BER=18.8



(a) (b)

Fig. 8 (a) Bus with 50% scale-down, (b) reconstructed watermark, BER=18.73

Table 1 Test results for first frame of Akiyo and Bus sequences.

	Akiyo at α=5		Bus α=10	
	PSNR(dB)	BER(%)	PSNR(dB)	BER(%)
Watermarked	37.05	-	31.05	-
Add Masking Image by 60%	12.36	11.3	11.47	8.44
Noise Addition (20%)	24.59	34.30	24.09	18.70
Gaussian Blur, Radius 2	28.51	16.05	24.56	23.52
MPEG4 Comp. at 0.5 Mbit	36.90	18.80	30.67	5.32
Scale down by 50%	27.43	8.32	20.78	18.73

VII. CONCLUSIONS

In this work, we propose a new wavelet-based video watermarking technique. A watermark which is an image is embedded in 3D DWT domain. The tests show good performances against common signal processing procedures. As shown in table 1, proposed algorithm was quite robust to noises. Further more bit errors were computed with related to watermarked video frames in different attacks. Experimental results, demonstrate that proposed technique was robust to signal processing techniques such as adding masking image, noise addition, Gaussian blur and scaling.

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