SVD Based Blind Video Watermarking Algorithm

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Abstract

In this paper, a new blind video watermarking algorithm is proposed based on the Singular Value Decomposition. The watermarks can be detected without the original video or any other information of the original singular values. Experiments show that the algorithm bears desirable robustness on MPEG-2 compression, median filtering, small rescaling, and rotation, etc.

1. Introduction

Digital watermarking [1] is a means to embed copyright information into a digital multimedia data such as image, audio, video, etc. Usually, watermarks can be embedded in the spatial or the transform domain of the original multimedia data and in most cases, watermarks should be perceptually unnoticeable and robust to retrieve from the protected multimedia data.

In video watermarking, watermark can be embedded in spatial domain [2] and transform domain like DCT[2-5], DFT[6] and DWT[8-9] . Now we consider the Singular Value Decomposition (SVD), which could be a desirable transform for watermarking. Traditionally, SVD is employed in image compression and other signal processing scenarios. In recent papers [10] and [11], SVD based image watermarking algorithms are proposed, declaring that their watermarking algorithm are blind. But as described in [10], the two algorithms need the singular values or the orthogonal matrices for retrieving. Note that once the singular values are modified, the order of singular values may be different, which causes incorrect detection of the watermarks. So we must get the position information of the modified singular values in advance. Since these two algorithms need cover work relevant information for watermark retrieving, they cannot be used in video watermarking applications considering the huge storage of the cover work relevant information.

In this paper, a novel SVD based blind video watermarking algorithm is proposed. Considering the visible quality and robustness, the watermarks are embedded in specially selected singular values, and the original order can be maintained in our algorithm. Experiments demonstrate the algorithm's good robustness to MPEG-2, shifting, small rescaling, and median filtering, etc. The watermarking algorithm is described in section 2. The experiments are presented in Section 3, and the conclusion and the future work in Section 4.

2. Algorithm and implementation

2.1 Basic idea

The theoretical analysis of the singular values of an image suffering geometric distortions is provided in [11]:

- The matrix and its transpose have the same non-zero singular values.
- The matrix and its row-flipped or column-flipped have the same non-zero singular values.
- The non-zero singular values of matrix are the constant ratios to its scaled matrix (which is row or column repeated several times).

Every real matrix A can be decomposed into three matrices $A = U\Sigma V^T$, where U and V are the orthogonal matrices, $UU^T = I$, $VV^T = I$ and $\sum = diag(\lambda_1, \lambda_2 \dots)$ .The $\lambda_1, \lambda_2 \dots$ are the singular values of A which are sorted decreasingly. The columns of U are called the left singular vectors of A. The columns of V are called the right singular vectors of A. And the singular value decomposition can be formulated as:

$$A = U_1\lambda_1 V_1^T + U_2\lambda_2 V_2^T + \cdots + U_r\lambda_r V_r^T \quad (1)$$

where *r* is the rank of matrix *A*.

Because of above properties, SVD can be used for watermarking against geometrical distortions. The key

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to blind watermarking is to maintain the original order of singular values.

2.2 Watermark embedding

Before the watermark embedding, the original binary watermark sequence must be modulated as a sequence consisting of "1" (modulated from "1") and "-1" (modulated from "0"). In order to keep the order of singular values and robustness to some attacks such as MPEG-2, the watermark embedding process is as follows:

a). Apply SVD to the whole cover frames A: $A = U\Sigma V^T$. The $\lambda_1, \lambda_2, \cdots$ are the singular values of the cover frames.

b). Modify the singular values of the cover frames according to the robustness and visibility:

$$\lambda_i^{'} = 0.5\cdot((\lambda_{i-1} + \lambda_{i+1}) + \alpha \cdot w_i \cdot (\lambda_{i-1} - \lambda_{i+1}))$$

Because the largest singular values are more important to the image quality, and the smallest singular values are more sensitive to the noise, we choose the middle singular values to embed the watermarks.

c).Get the watermarked video frame $A^{'} = U\Sigma^{'}V^T$, $\Sigma^{'} = diag(\lambda_1^{'}, \lambda_2^{'}, \cdots \lambda_r^{'})$ where r is the rank of $A^{'}$.

2.3 Watermark extraction

The watermark extracting process is as follows:

a). Apply SVD to whole watermarked frame $A^{'}$: $A^{'} = U\Sigma^{'}V^T$, and the $\lambda_1^{'}, \lambda_2^{'}, \cdots$ are the singular values of image.

b). Extract the watermarks from the singular values:

$$\begin{cases} w_i = 0; & if \lambda_i^{'} > 0.5\cdot(\lambda_{i-1}^{'} + \lambda_{i+1}^{'}) \\ w_i = 1; & if \lambda_i^{'} < 0.5\cdot(\lambda_{i-1}^{'} + \lambda_{i+1}^{'}) \end{cases}$$

3. Experimental results and analysis

The watermarks are the basic M-sequence. In our experiments, it is 880 bits in length. And the videos for tests are MPEG-2 standard test sequences i.e. "Mobile", "Boating" and "Racing". All the video sequences conform to PAL standard with the resolution of 720×576. There are 220 frames in each video sequence. Watermarks are embedded in the luminance channel of the video frames. The watermark intensity is 0.48 and 4 bits is embedded in each frame at the 3rd, 5th, 7th and 9th SVD coefficients. Assuming the coefficient for watermarking to be λ_i ($1 \le i \le 576$), we find in our experiments that if $\lambda_{i-1} - \lambda_{i+1} > 40$, the algorithm can achieve a good robustness.

The proposed algorithm was tested by attacks of MPEG-2 compression, shifting, rescaling and median filtering. Figure 1 to figure 6 show the original and watermarked video frame of "Mobile" "Boating" and "Racing". Table 1 shows the PSNR (Peak Signal Noise Ratio) of the first 25 watermarked frames of "Mobile". Table 2 shows the performance against these attacks.

Figure 1. **Original frames of "Mobile"**

Figure 2. **Watermarked frames of "Mobile"**

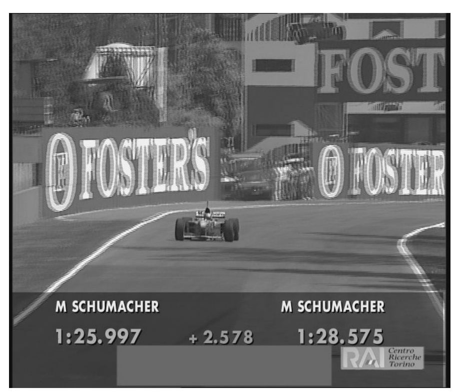

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Figure 3. **Original frames of "Racing"**

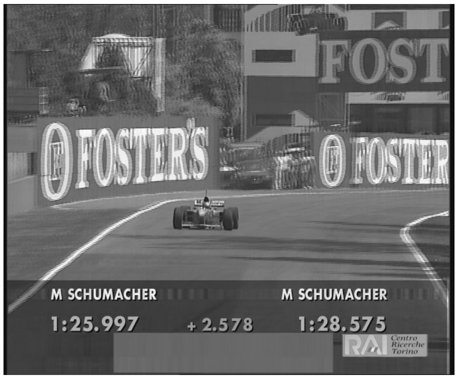

Figure 4. **Watermarked frames of "Racing"**

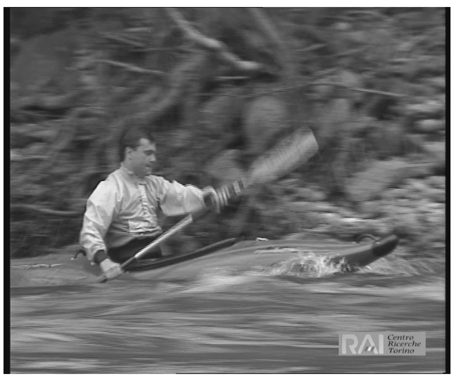

Figure 5. **Original frames of "Boating"**

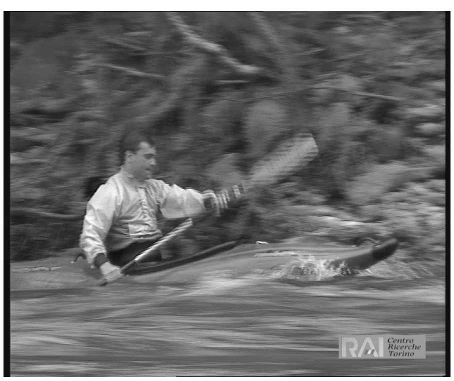

Figure 6. **Watermarked frames of "Boating"**

Table 1. PSNR of the first 25 watermarked frames of "Mobile"

Frame number	PSNR(dB)				
0-4	37.5	39.4	40.4	39.5	41.7
5-9	42.1	41.2	41.2	44.5	45.9
10-14	43.6	42.9	42.4	42.4	38.4
15-19	37.7	40.0	41.3	44.8	44.2
20-24	45.6	44.7	42.6	40.9	41.6

Table 2. Watermark extraction performance against typical attacks

Video sequence	attack	BER			
		1st bit	2nd bit	3rd bit	4th bit
Boating	MPEG-2 6Mbits/s	0	0	0	0
	MPEG-2 4Mbits/s	0	0	0	0
	Median filter	0	0	0	0
	Shift 1%	0	0	0	0
	Rotation and rescale -1degree	0	0.48	0.08	0.52
	Rotation and rescale 1degree	0.12	0.32	0.36	0.56
Mobile	MPEG-2 6Mbits/s	0	0	0	0
	MPEG-2 4Mbits/s	0	0	0	0
	Median filter	0	0	0	0
	Shift 1%	0	0	0	0
	Rotation and rescale -1degree	0.16	0.32	0.40	0.56
	Rotation and rescale 1degree	0.12	0.28	0.36	0.52
Racing	MPEG-2 6Mbits/s	0	0	0	0
	MPEG-2 4Mbits/s	0	0	0	0
	Median filter	0	0	0	0
	Shift 1%	0	0	0	0
	Rotation and rescale -1degree	0.08	0.28	0.12	0.52
	Rotation and rescale 1degree	0.16	0.32	0.12	0.52

According to the results in Table 1 and 2, our algorithm has a good robustness especially to MPEG-2 compression, even when the compression ratio is 4Mbits/s. Besides, we can see that it is well robust to shifting, and median filtering. If we embedded one bit each frame, the algorithm is also robust to rotation and rescaling.

4. Conclusions

As described above, our algorithm is robust to most attacks like MPEG-2 compression, rescaling, shifting, filtering, etc. Moreover it does not need any information in the detection process while other algorithms [10-11] need the information of singular values. In our future work, we will improve the algorithm to gain better performance against other attacks like rotation, cropping, etc.

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