A Novel Video Watermarking Technique Based On Multiresolution Singular Value Decomposition

NOUIOUA Imen
Laboratoire Croissance et Caractérisation de Nouveaux Semi-conducteurs (LCCNS) – Département d'Electronique - Université FERHAT Abbas de Sétif
imen_bou84@hotmail.fr

AMARDJIA Nourredine
Laboratoire Instrumentation Scientifique (LIS) – Département d'Electronique
Université FERHAT Abbas de Sétif
amardjia_nour@yahoo.fr

***Abstract*— In this paper, a new robust video watermarking technique is proposed which combines Singular Value Decomposition (SVD) and its multiresolution form (MR-SVD). The experimental results obtained through the proposed scheme demonstrate that this technique provides imperceptible watermarks and is robust against several attacks like noise addition, rotation and MPEG compression.**

Keywords- Video watermarking; Singular Value Decomposition (SVD); Multiresolution-SVD (MR-SVD).

I. INTRODUCTION

Due to the extraordinary revolution of internet, the digital multimedia (movie, music, and image) can be easily obtained with low cost and high quality. Therefore, owners and creators of digital products are concerned about illegal copying of their products. The Digital Watermarking has been proposed as a solution to the problem of copyright protection [1].

The basic idea of the "watermarking" is to embed a robust and subliminal (invisible or inaudible) data into multimedia elements [2].

Watermarking techniques can be classified into two classes: spatial domain and frequency domain. The spatial domain methods embed the watermark by modifying the pixel values of the host directly, but in the frequency domain techniques, the watermark is embedded by modifying the transform coefficients of the host. The most commonly used transforms are the Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT), the Discrete Wavelet Transform (DWT) and the singular value decomposition (SVD) [3, 4].

Kakarala and Ogunbona [5] have proposed a multiresolution form of the SVD (MR-SVD) and showed how it could be used for signal analysis. A new video watermarking scheme is presented here, where the SVD is combined with the MR-SVD.

This paper is organized as follow. To understand our scheme, we introduce in the next section the concept of SVD and MR-SVD transformation techniques. In section three, we propose our video watermarking method where we describe the watermark embedding and extraction processes. In section four, we present the experimental results and in section five, we compare our results with existing work done by previous researchers. The conclusions of our study are stated in section six.

II. THEORETICAL FUNDAMENTALS

A. *Singular Value Decomposition*

Singular Value Decomposition is said to be a significant topic in linear algebra by renowned mathematicians. Also SVD has shown its usefulness in variety of applications including image processing and watermarking.

If A is a matrix representing for example an image of size m*n, then the SVD of A is given by:

$$A = U*S*V^T \tag{1}$$

Where U and V are orthogonal matrices and S is a diagonal matrix $S = \mathrm{diag}(\{s_1, s_2 \ldots s_n\})$

s_1, s_2… s_n are the singular values (SV) of A, which observe the condition $s_1 \geq s_2 \geq \ldots \geq s_n$; These SV represent the energy of the image and have very good stability [6].

B. *Multiresolution singular value decomposition*

The MR-SVD represents a signal as a series of an approximation and details like the DWT. This section explains how the MR-SVD, introduced in [5], works.

1) *1D Multiresolution Singular Value Decomposition*

Let X=[x(1) … x(N)] represent a finite extent 1-D signal. Assume that N is divisible by 2L for some L ≥1. Let the data matrix at the first level, denoted X1, be constructed so that its top row contains the odd-numbered samples and the bottom row contains the even-numbered samples:

$$X_1 = \begin{pmatrix} x(1) & x(3) & \ldots & x(N-1) \\ x(2) & x(4) & \ldots & x(N) \end{pmatrix} \tag{2}$$

Let U_1 be the eigenvector matrix bringing the scatter matrix $T_1=X_1 X_1^T$ into diagonal form:

$$U_1^T T_1 U_1 = S_1^2 \tag{3}$$

Where $S_1^2=\mathrm{diag}\{s_1(1)^2, s_1(2)^2\}$ contains the squares of the two singular values, with $s_1(1) \geq s_1(2)$.

Now let:

ISBN : 978-81-925233-8-5

$$\hat{X}_1 = U_1^T X \quad (4)$$

The top row of $\hat{X}_1$, denoted $\hat{X}_1$ (1, :), contains the approximation component that corresponds to the largest eigenvalue. The bottom row of $\hat{X}_1$, denoted $\hat{X}_1$ (2, :), contains detail component that corresponds to the smallest eigenvalue.

Let $\Phi_1 = \hat{X}_1$ (1, :) and $\Psi_1 = \hat{X}_1$ (2, :) represent the approximation and detail components respectively. The successive levels of decomposition repeats the procedure described above by placing the approximation component Φ1 in place of X. Hence the MR-SVD can be written as:

$$X \rightarrow \left\{\Phi_L, \{\Psi_l\}_{l=1}^{L}, \{U_l\}_{l=1}^{L}\right\} \quad (5)$$

Where L is the desired level of the decomposition

2) 2D Multiresolution Singular Value Decomposition

We briefly describe here the 2D MR-SVD. The first level decomposition of the image proceeds as follows. Divide the M × N image X into non-overlapping 2×2 blocks and arrange each block into a 4×1 vector by stacking columns to form the data matrix X_1.

The Eigen-decomposition of the 4*4 scatter matrix is:

$$T_1 = X_1 X_1^T = U_1 S_1^2 U_1^T \quad (6)$$

Let

$$\hat{X}_1 = U_1^T X_1 \quad (7)$$

The top row of the resulting matrix, $\hat{X}_1$ (1, :), is rearranged to form an M/2 x N/2 matrix which is considered as the smooth (approximation) components of the image. The remaining rows of, $\hat{X}_1$ (2, :), $\hat{X}_1$ (3, :), $\hat{X}_1$ (4, :) contain the detail components, which are denoted Ψ_1, Ψ_2, Ψ_3 respectively. The complete transform can be represented as follows:

$$X \rightarrow \left\{\Phi_L, \{\Psi_l^1, \Psi_l^2, \Psi_l^3\}_{l=1}^{1}, \{U_l\}_{l=1}^{L}\right\} \quad (8)$$

The original image X can be reconstructed from the right hand side since the steps are reversible.

As an example, the one-level MR-SVD decomposition of the image "Cameraman" using a program written in Matlab is depicted in Figure 1.

III. The Proposed MR-SVD Video Watermarking

In this section we describe the proposed video watermarking based on the MR-SVD. We take the size of the binary watermark equal to the approximation part of the first level decomposition of the original video frame, derived by applying the MR-SVD.

Figure 1. Original «Cameraman » image and its 1-level MR-SVD form

A. Embedding Procedure

The steps of the watermark embedding process can be summarized as follows:

1. The original video is partitioned into groups of k frames.
2. Every frame of the group is converted from the RGB color space to the YCbCr one.
3. Every luminance frame Y is transformed into 1-Level MR-SVD decomposition to get approximation and detail components {Φ, Ψ1, Ψ_2, Ψ3}
4. The SVD is applied to the component {Φ} of the MR-SVD of the luminance Y for each frame of the group k of frames of the original video

$$\phi(k) = U_\phi(k) S_\phi(k) V_\phi^T(k) \quad (9)$$

k=1, 2…C, C is the number of frames.

5. The same binary watermark sequence W is added to the S_k matrix of each video frame of the group k of frames.

$$E(k) = S_\phi(k) + \alpha * W \quad (10)$$

α is a scale factor.

6. The SVD is applied on each E(k) matrix of each video frame of the group k of frames.

$$E(k) = U_w(k) S_w(k) V_w^T(k) \quad (11)$$

7. Inverse SVD is applied on the modified singular values $S_w(k)$ and $U_\phi(k)$, $V_\phi(k)$ values are obtained from (9) to build the modified approximation part of the frames.
8. The inverse MR-SVD is applied on the modified approximation part to get the modified luminance part Y´ of the frames.
9. Reconstruct the watermarked video frame from the modified luminance part Y´ and chrominance part Cb and Cr of the original frame by converting the YCbCr into RGB color space.

B. Extraction Procedure

1. The watermarked video is divided into groups of k frames.

2. Every frame of the group is converted from the RGB color space to the YCbCr one.
3. Every luminance frame is transformed into1-Level MR-SVD decomposition to get $\{\Phi_W, \Psi_{W1}, \Psi_{W2}, \Psi_{W3}\}$
4. The SVD is applied to the component $\{\Phi_w\}$ of MR-SVD of the luminance Y for each frame of the group k of frames of the watermarked video:

$$\phi_w(k) = U^*(k) S_w^*(k) V^{*T}(k) \quad (12)$$

5. The watermark sequence is extracted as:

$$W^*(k) = \frac{U_w(k) S_w^*(k) V_w^T(k) - S_\phi(k)}{\alpha} \quad (13)$$

IV. Experimental results

In this section, we evaluate the performances of the proposed video watermarking technique in terms of imperceptibility and robustness. We use two different videos sequences: xylophone and tennis of resolution 240 x 320 and with frame rate of 20 fps. The watermark is a binary logo image with size 120*160. Here we have taken the scale factor $\alpha = 10$.

A. Imperceptibility performance

The transparency of the watermark is estimated by PSNR (peak signal to noise ratio). PSNR is measured in decibels (dB) as:

$$PSNR = 10 * \log_{10}\left(\frac{Max(I(i,j))^2}{EQM}\right) \quad (14)$$

$$EQM = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left|I_0(i,j) - I_r(i,j)\right|^2 \quad (15)$$

The PSNR of all frames of the video is given by:

$$PSNR = \frac{\sum_{k=1}^{C} PSNR}{\text{the number of frames,}} \quad (16)$$

The PSNR between the original video and watermarked video has values between 45 and 46 dB. This high PSNR values prove imperceptibility of the proposed method.

B. Robustness Performance

To verify the robustness of our watermarking technique, various types of attacks have been implemented such as JPEG compression, Adding noise, rotation, MPEG compression …

The comparison between the original watermark and the extracted watermark from the attacked watermarked video frames was measured by using the correlation factor NC.

$$NC = \frac{\sum_i\sum_j W(i,j)W^*(i,j)}{\sqrt{\sum_i\sum_j W(i,j)}\ \sqrt{\sum_i\sum_j W^*(i,j)}} \quad (17)$$

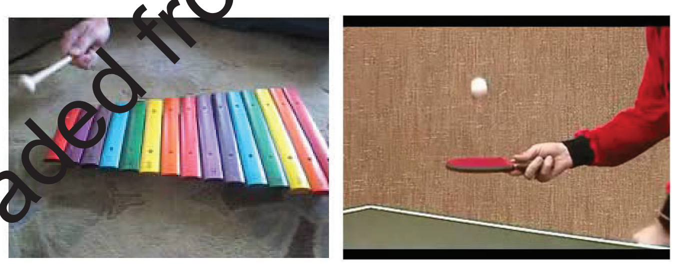


Figure 2. The first frames of video sequences used for testing.

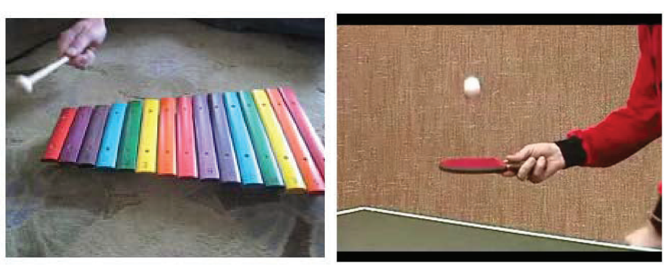


Figure 3. The first watermarked frames of video sequences.

(a) (b)

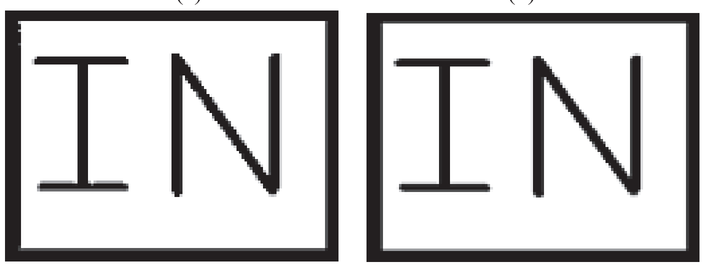
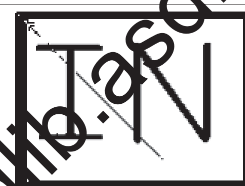


Figure 4. (a) original watermark, (b) extracted watermark.

The following table shows the extracted watermarks after performing the various attacks.

TABLE I. THE RESULTING EXTRACTED WATERMARKS AFTER DIFFERENT ATTACKS EMPLOYED.

Attack Type	Extracted Watermark	NC
JPEG compression Q =70		0.983
Salt and pepper noise		0.982
Poisson noise		0.982
Median filtering		0.9702
Rotation 30°		0.976
Cropping		0.9739
MPEG-2 compression		0.9813
H.264 compression		0.9809

V. COMPARISON BETWEEN THE PROPOSED MR-SVD VIDEO WATERMARKING AND OTHER SCHEMES

In order to study the performance of the proposed method, we compare it with existing method using DWT-SVD.

TABLE II. COMPARISON BETWEEN CORRELATION COEFFICIENTS OF THE PROPOSED SCHEME AND EXISTING METHODS.

Attack type	[9]	[10]	Proposed method
Salt and pepper noise	0.694	0.654	0.976
Median filtring	0.921	0.577	0.970
Rotation	0.891	0.651	0.976
Croping	/	0.680	0.973
JPEG compression	0.869	/	0.983

VI. CONCLUSION

In this paper a new robust video watermarking using MR-SVD is proposed. The proposed watermarking method works by applying 1-Level MR-SVD decomposition to convert video frames into bands of different frequencies. Then, the approximation {Φ} is SVD transformed and a watermark is embedded into the diagonal matrix of this band. The experimental results show that:

- The proposed video watermarking scheme is not only robust against common image processing operations as noise adding, JPEG compression, etc., but also robust against the geometric attacks such as cropping, and rotation.
- A comparison with different algorithms reveals the superiority of the proposed scheme.

REFERENCES

[1] S.A.K.Mostafa, A. S. Tolba , F. M. Abdelkader, and H. M. Elhin "Video Watermarking Scheme Based on Principal Component Analysis and Wavelet Transform," IJCSNS International Journal of Computer Science and Network Security, vol.9, No.8, August 2009.

[2] C. Rey, and J. Dugelay, "Un panorama des méthodes de tatouage permettant d'assurer un service d'intégrité pour les images," Traitement du Signal, 2001, pp. 283–295.

[3] R. T. Paul, "Review of robust video watermarking techniques," IJCA Special Issue on Computational Science – New Dimensions and Perspectives, no. 3, 2011, pp. 90–95.

[4] A. Hood, and N.J. Janwe , "Robust Video Watermarking Techniques and Attacks on Watermark," International Journal of Computer Trends and Technology, vol.4, 2013.

[5] R. Kakarala and P. Ogunbona, "Signal analysis using Multiresolution form of the Singular Value Decomposition," IEEE Trans. on Image processing, vol. 10, no. 5, May 2001.

[6] H. B. Razafindrandina and P. A. Randriamitantsoa, " Robust end Blind watermarking in the singular values domain," Journal Marocain de l'Automatique, de l'Informatique et du Traitement de Signal, Jan 2010.

[7] B. Akhbari and S. Ghaemmaghami, "Watermarking of still images using multiresolution singular value decomposition," proceedings of International Symposium on Intelligent Signal Processing and Communication Systems, Hong Kong, Dec 2009, pp. 325-328.

[8] S. Swarnalipi, S. Majumder, T. S. Das and S. K. Sarkar, "Binary Logo Watermarking Based on Multiresolution SVD", proceedings of International Conference on Computing and Control Engineering, Chennai, India, April 2012, pp.61.

[9] H. Agarwal, R. Ahuja, and S.S. Bedi, "Highly Robust and Imperceptible Luminance Based Hybrid Digital Video Watermarking Scheme for Ownership Protection," I.J. Image, Graphics and Signal Processing, vol.4, no.11, October 2012, pp. 47-52.

[10] S. Sinha, P. Bardhan, S. Pramanick, A. Jagatramka, D.K. Kole, A. Chakraborty, "Digital Video Watermarking using Discrete Wavelet Transform and Principal Component Analysis," International Journal of Wisdom Based Computing, vol. 1 (2), August 2011.