Digital Video Watermarking using Discrete Wavelet Transform and Principal Component Analysis

Sanjana Sinha, Prajnat Bardhan, Swarnali Pramanick, Ankul Jagatramka, Dipak K. Kole, Aruna Chakraborty.
Department of Computer Science & Engineering
St Thomas' College of Engineering and Technology
Kolkata, India.
{aruna.stcet@gmail.com, dipak.kole@gmail.com, sanjanasinha89@gmail.com}

***Abstract* - Due to the extensive use of digital media applications, multimedia security and copyright protection has gained tremendous importance. Digital Watermarking is a technology used for the copyright protection of digital applications. In this paper, a comprehensive approach for watermarking digital video is introduced. We propose a hybrid digital video watermarking scheme based on Discrete Wavelet Transform (DWT) and Principal Component Analysis (PCA). PCA helps in reducing correlation among the wavelet coefficients obtained from wavelet decomposition of each video frame thereby dispersing the watermark bits into the uncorrelated coefficients. The video frames are first decomposed using DWT and the binary watermark is embedded in the principal components of the low frequency wavelet coefficients. The imperceptible high bit rate watermark embedded is robust against various attacks that can be carried out on the watermarked video, such as filtering, contrast adjustment, noise addition and geometric attacks.**

Keywords:- Digital video; binary watermark; Discrete Wavelet Transform; Principal Component Analysis.

I. INTRODUCTION

The popularity of digital video based applications [1] is accompanied by the need for copyright protection to prevent illicit copying and distribution of digital video. Copyright protection inserts authentication data such as ownership information and logo in the digital media without affecting its perceptual quality. In case of any dispute, authentication data is extracted from the media and can be used as an authoritative proof to prove the ownership. As a method of copyright protection, digital video watermarking [2, 3] has recently emerged as a significant field of interest and a very active area of research. Watermarking is the process that embeds data called a watermark or digital signature into a multimedia object such that watermark can be detected or extracted later to make an assertion about the object. The object may be an image or audio or video. For the purpose of copyright protection digital watermarking techniques must meet the criteria of imperceptibility as well as robustness against all attacks [4-6] for removal of the watermark.

Many digital watermarking schemes have been proposed for still images and videos [7]. Most of them operate on uncompressed videos [8-10], while others embed watermarks directly into compressed videos [8, 11]. The work on video specific watermarking can be further found in [12-15]. Video watermarking introduces a number of issues not present in image watermarking. Due to inherent redundancy between video frames, video signals are highly susceptible to attacks such as frame averaging, frame dropping, frame swapping and statistical analysis.

Video watermarking approaches can be classified into two main categories based on the method of hiding watermark bits in the host video. The two categories are: Spatial domain watermarking where embedding and detection of watermark are performed by directly manipulating the pixel intensity values of the video frame. Transform domain [16-18] techniques, on the other hand, alter spatial pixel values of the host video according to a pre-determined transform and are more robust than spatial domain techniques since they disperse the watermark in the spatial domain of the video frame making it difficult to remove the watermark through malicious attacks like cropping, scaling, rotations and geometrical attacks. The commonly used transform domain techniques are Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT), and the Discrete Wavelet Transform (DWT).

In this paper, we propose an imperceptible and robust video watermarking algorithm based on Discrete Wavelet Transform (DWT) [19-25] and Principal Component Analysis (PCA) [26-28]. DWT is more computationally efficient than other transform methods like DFT and DCT. Due to its excellent spatio-frequency localization properties, the DWT is very suitable to identify areas in the host video frame where a watermark can be embedded imperceptibly. It is known that even after the decomposition of the video frame using the wavelet transformation there exist some amount of correlation between the wavelet coefficients. PCA is basically used to hybridize the algorithm as it has the inherent property of removing the correlation amongst the data i.e. the wavelet coefficients and it helps in distributing the watermark bits over the sub-band used for embedding thus resulting in a more robust watermarking scheme that is resistant to almost all possible attacks. The watermark is embedded into the luminance component of the extracted frames as it is less sensitive to the human visual system (HVS).

The paper is organized as follows. Section II contains the watermarking scheme. Section III contains the experimental results and finally Section IV gives the conclusion.

II. Watermarking Scheme

The watermarking algorithm basically utilizes two mathematical techniques: DWT and PCA. The significance of using these techniques in watermarking has been explained first.

A. Discrete Wavelet Transform

The Discrete Wavelet Transform (DWT) is used in a wide variety of signal processing applications. 2-D discrete wavelet transform (DWT) decomposes an image or a video frame into sub-images, 3 details and 1 approximation. The approximation sub-image resembles the original on 1/4 the scale of the original. The 2-D DWT (Fig. 1) is an application of the 1-D DWT in both the horizontal and the vertical directions. DWT separates the frequency band of an image into a lower resolution approximation sub-band (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. Embedding the watermark in low frequencies obtained by wavelet decomposition increases the robustness with respect to attacks that have low pass characteristics like filtering, lossy compression and geometric distortions while making the scheme more sensitive to contrast adjustment, gamma correction, and histogram equalization. Since the HVS is less sensitive to high frequencies, embedding the watermark in high frequency sub-bands makes the watermark more imperceptible while embedding in low frequencies makes it more robust against a variety of attacks.

LL1	HL_1
LH_1	HH_1

Figure 1. DWT subbands.

B. Principal Component Analysis

Principal component analysis (PCA) is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables. PCA is a method of identifying patterns in data, and expressing the data in such a way so as to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the advantage of graphical representation is not available, PCA is a powerful tool for analyzing data. The other main advantage of PCA is that once these patterns in the data have been identified, the data can be compressed by reducing the number of dimensions, without much loss of information. It plots the data into a new coordinate system where the data with maximum covariance are plotted together and is known as the first principal component. Similarly, there are the second and third principal components and so on. The maximum energy concentration lies in the first principal component.

The following block diagram (Fig.2) shows the embedding and extraction procedure of the watermark. In the proposed method the binary watermark is embedded into each of the video frames by the decomposition of the frames into DWT sub bands followed by the application of block based PCA on the sub-blocks of the low frequency sub-band. The watermark is embedded into the principal components of the sub-blocks. The extracted watermark is obtained through a similar procedure.

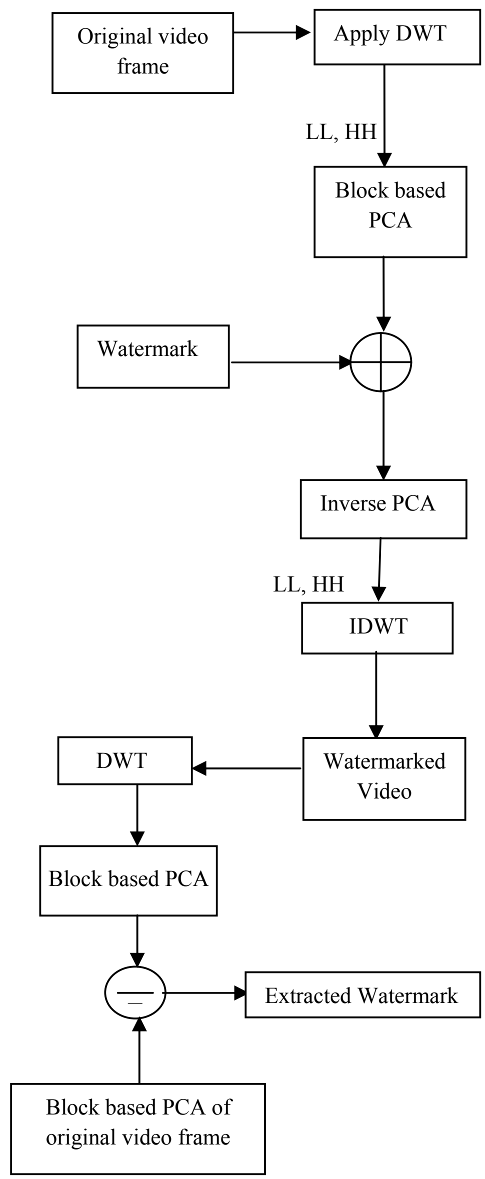


Figure 2. Block Diagram of Watermarking

C. Algorithms for watermarking using DWT AND PCA

Algorithm 1:

a) Embedding Procedure

Step 1: Convert the n × n binary watermark logo into a vector W = { w_1, w_2 , ……, $w_{n\times n}$ } of '0's and '1's.

Step 2: Divide the video (2N × 2N) into distinct frames.

Step 3: Convert each frame from RGB to YUV colour format.

Step 4: Apply 1-level DWT to the luminance (Y component) of each video frame to obtain four sub-bands LL, LH , HL and HH of size N x N .

Step 5: Divide the LL sub-band into k non-overlapping sub-blocks each of dimension n × n (of the same size as the watermark logo).

Step 6: The watermark bits are embedded with strength α into each sub-block by first obtaining the principal component scores by Algorithm 2. The embedding is carried out as equation 1.

$$score_i^{'} = score_i + \alpha W \tag{1}$$

where $score_i$ represents the principal component matrix of the i[th] sub-block.

Step 7: Apply inverse PCA on the modified PCA components of the sub-blocks of the LL sub-band to obtain the modified wavelet coefficients.

Step 8: Apply inverse DWT to obtain the watermarked luminance component of the frame. Then convert the video frame back to its RGB components.

b) Extraction Procedure

Step 1: Divide the watermarked (and possibly attacked) video into distinct frames and convert them from RGB to YUV format.

Step 2: Choose the luminance (Y) component of a frame and apply the DWT to decompose the Y component into the four sub-bands LL , HL , LH , and HH of size N×N.

Step 3: Divide the LL sub-band into n × n non-overlapping sub-blocks.

Step 4: Apply PCA to each block in the chosen subband LL by using Algorithm 2.

Step 5: From the LL sub-band, the watermark bits are extracted from the principal components of each sub-block as in equation 2.

$$W_i^{'} = \frac{(score_i^{'} - score_i)}{\alpha} \tag{2}$$

where $W_i^{'}$ is the watermark extracted from the i[th] sub-block.

Algorithm 2:

The LL sub-band coefficients are transformed into a new coordinate set by calculating the principal components of each sub-block (size n x n).

Step 1: Each sub-block is converted into a row vector D_i with n2 elements (i=1,2…k).

Step 2: Compute the mean μ_i and standard deviation σ_i of the elements of vector D_i .

Step 3: Compute Z_i according to the following equation

$$Z_i = \frac{(D_i - \mu_i)}{\sigma_i} \tag{3}$$

Here Z_i represents a centered, scaled version of D_i , of the same size as that of D_i .

Step 4: Carry out principal component analysis on Z_i (size 1 x n^2) to obtain the principal component coefficient matrix coeffi (size $n^2 \times n^2$).

Step 5: Calculate vector $score_i$ as

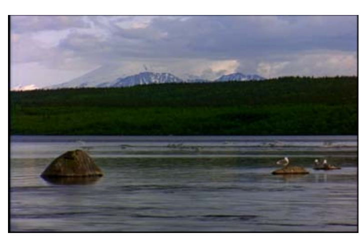
$$score_i = Z_i \times coeff_i \tag{4}$$

where $score_i$ represents the principal component scores of the i[th] sub-block.

III. Experimental Results

The proposed algorithm is applied to a sample video sequence 'Lake.wmv' using a 32 × 32 watermark logo. The grayscale watermark is converted to binary before embedding. Fig. 3(a) and 3(b) show the original and the watermarked video frames respectively. Fig. 4(a) is the embedded watermark and Fig. 4(b) is the extracted binary watermark image.

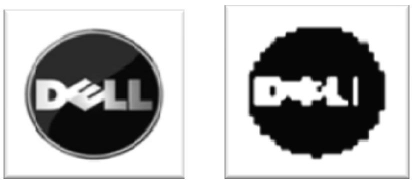
The performance of the algorithm has been measured in terms of its imperceptibility and robustness against the possible attacks like noise addition, filtering, geometric attacks etc.



(a)

(b)

Figure 3. (a) Original Video frame (b) Watermarked video



(a) (b)

Figure 4. (a) Original watermark (b) Extracted binary watermark

***PSNR* :** The Peak-Signal-To-Noise Ratio (PSNR) is used to deviation of the watermarked and attacked frames from the original video frames and is defined as:

$$PSNR = 10Log_{10}(255^2 / MSE) \qquad (5)$$

where MSE (mean squared error) between the original and distorted frames (size m x n) is defined as:

$$MSE = (1/mn)\sum_{i=1}^{m}\sum_{j=1}^{n}[I(i,j) - I'(i,j)] \qquad (6)$$

where I and I' are the pixel values at location (i, j) of the original and the distorted frame respectively. Higher values of PSNR indicate more imperceptibility of watermarking. It is expressed in decibels (dB).

***NC* :** The normalized coefficient (NC) gives a measure of the robustness of watermarking and its peak value is 1.

$$NC = \frac{\sum_i \sum_j W(i,j) \cdot W'(i,j)}{\sqrt{\sum_i \sum_j W(i,j)}\sqrt{\sum_i \sum_j W'(i,j)}} \qquad (7)$$

where W and W' represent the original and extracted watermark respectively. After extracting and refining the watermark, a similarity measurement of the extracted and the referenced watermarks is used for objective judgment of the extraction fidelity. The following images represent stills taken from the watermarked video in after attacks have been carried on it.

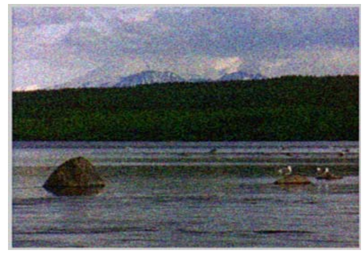


Figure 5. Video frame after addition of Gaussian noise

Figure 6. Video frame after addition of ‘salt and pepper’ noise

Figure 7. Video frame after rotation by 5 degrees

Figure 8. Video frame after resizing

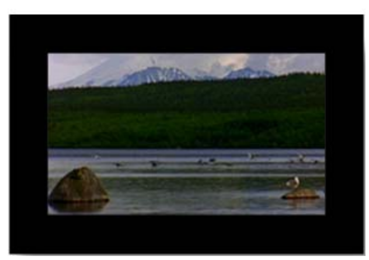


Figure 9. Video frame after cropping

Figure 10. Video frame after Gamma Correction (variance 0.5)

Figure 11. Video frame after applying Contrast Adjustment(factor 30).

Figure 12. Video frame after applying automatic equalization.

Figure 13. Video frame after applying sharpening filter (factor 50).

Figure 14. Video frame after median filtering (3x3 box filter).

Fig. 5 and Fig. 6 show the watermarked video frame after the addition of gaussian noise and 'salt and pepper' noise respectively. Fig. 7 shows the effect of carrying out video frame rotation by an angle of 5 degrees. Fig. 8 shows the watermarked video frame after resizing first by a factor of half followed by a factor to 2 to return it to its original size. Fig. 9 shows the cropped video frame. Figures 10-14 show the effect of applying gamma correction (variance 0.5), contrast adjustment and automatic equalization. Fig. 14 and Fig. 15 show the resultant video after applying sharpening filter and median filter (3×3 box filter) respectively.

The following table shows the value of the data collected from the watermarked video after performing the various attacks as shown previously.

TABLE I. RESULT ANALYSIS

Attack	PSNR	NC
GAUSSIAN NOISE	31.1564	0.6861
SALT & PEPPER NOISE	24.4592	0.6548
CROPPING	28.3373	0.6801
ROTATION	28.8256	0.6510
RESIZING	41.4628	0.6068
MEDIAN FILTERING	39.1676	0.5771
GAMMA CORRECTION	24.0749	0.5913
SHARPENING FILTER	40.0710	0.5313
CONTRAST ADJUSTMENT	32.4420	0.5192
AUTOMATIC EQUALIZATION ATTACK	46.4597	0.6540

Frame dropping: Frame dropping means dropping one or more frames randomly from the watermarked video sequence. If we drop too many frames, the quality of the watermarked video will decrease rapidly. In our experiment, we only drop one frame randomly. Due to embedding the same watermark into each frame, it will not affect the extraction of the watermark completely from attacked watermarked video by frame dropping except that number of the extracted watermarks will differ.

Frame swapping: Frame swapping means switching the order of frames randomly within a watermarked video sequence. If we swap too many frames, it will degrade the video quality. We have extracted all the watermarks from the video after frame swapping.

Frame averaging: Since the frames are watermarked with the same information, the watermarked videos are not subject to the risk of watermark estimation by frame averaging since the watermark signal gets amplified on averaging.

Thus from the experimental results it is quite evident that the watermarking algorithm is robust against all possible attacks. Other than its computational complexity it has no disadvantages.

IV. CONCLUSION

The algorithm implemented using DWT-PCA is robust and imperceptible in nature and embedding the binary watermark in the low LL sub band helps in increasing the robustness of the embedding procedure without much degradation in the video quality. As a future work the video frames can be subject to scene change analysis to embed an independent watermark in the sequence of frames forming a scene, and repeating this procedure for all the scenes within a video.

REFERENCES

[1] Yeo and M.M. Yeung, “Analysis and synthesis for new digital video applications,” icip, International Conference on Image Processing (ICIP'97),vol. 1, pp.1,1997.

[2] M. Natarajan , G. Makhdumi1,“Safeguarding the Digital Contents: Digital Watermarking,” DESIDOC Journal of Library & Information Technology, Vol. 29, May 2009, pp. 29-35.

[3] C.I. Podilchuk, E.J. Delp “Digital watermarking: algorithms and applications,” Signal Processing Magazine, Vol 18,pp. 33-46, IEEE, July 2001.

[4] G. Doërr, J.L. Dugelay, “Security Pitfalls of Frame-by-Frame Approaches toVideo Watermarking,” Signal Processing, IEEE Transactions, vol. 52, pp. 2955 – 2964, 2004.

[5] M. K. Thakur, V. Saxena, J. P.Gupta, “A Performance Analysis of Objective Video Quality Metrics for Digital Video Watermarking,” Computer Science and Information Technology (ICCSIT), 2010, 3rd IEEE International Conference ,Vol. 4, pp. 12 - 17,2010.

[6] S. Voloshynovskiy, S. Pereira, T. Pun, “Watermark attacks,” Erlangen Watermarking Workshop 99, October 1999.

[7] G. Langelaar, I. Setyawan, and R. Lagendijk, "Watermarking Digital Image and Video Data: A State of - Art Overview," IEEE Signal Processing Magazine, vol. , pp. 20-46, Sep. 2000.

[8] F. Hartung and B. Girod, “Watermarking of uncompressed and compressed video,” Signal Processing, 1998,vol. 66, no. 3,pp. 283-301.

[9] T. Khatib, A. Haj, L. Rajab, H. Mohammed, “ A Robust Video Watermarking Algorithm”, Journal of Computer Science, vol. 4, pp. 910-915, 2008.

[10] T. Tokar, T. Kanocz, D. Levicky, “Digital watermarking of uncompressed video in spatial domain,” 9th International Conference on Radioelectronica, IEEE, pp. 319-322, 2009.

[11] J. Meng, and S.Chang, “Embedding Visible Video Watermarks in the Compressed Domain”, International Conference on Image Processing, ICIP 98, Proceedings, vol.1,pp. 474-477 ,1998.

[12] P.W. Chan, M.R Lyu, R.T. Chin, “A Novel Scheme for Hybrid Digital Video Watermarking,” IEEE Transactions on Circuits and Systems For Video Technology, vol. 15, no. 12, December 2005.

[13] G. Doërr, J.L. Dugelay , “A guide tour of video watermarking,” Signal Processing: Image Commun., vol. 18, no. 4, pp. 263–282, April 2003.

[14] Y. R. Lin, H.Y. Huang and W.H Hsu, “An embedded watermark technique in video for copyright protection”, IEEE,18th International Conference on Pattern Recognition , vol 00., pp. 795-798, 2006.

[15] C.V. Serdean, M.A. Ambroze., M. Tomlinson, J.G. Wade, “DWT Based Video Watermarking for Copyright Protection, Invariant to Geometrical Attacks”, Proceedings of the 3rd International Symposium on Communication Systems Networks and Digital Signal Processing – CSNDSP'02, Stafford, UK, pp. 15-17 July 2002.

[16] I. J. Cox, J. Kilian, F. T. Leighton and T. Shamoon, “Secure spread spectrum watermarking for multimedia,” IEEE Trans. on Image Processing, 1997, vol 6, no 12,pp. 1673-1687.

[17] C.H. Li and S.S. Wang, “Transform-Based Watermarking for Digital Images and Video,” IEEE International Conference, June1999.

[18] S. Sinha, S. Pramanick, A. Jagatramka,P. Bardhan,D.K. Kole,A. Chakraborty, “Digital Video Watermarking using Singular Value Decomposition”, Proceedings on IEEE EDS Student Paper Conference, pp. 53-56, 2011.

[19] A-Haj and T. Manasrah, “Non-Invertible Copyright Protection of Digital Images Using DWT and SVD,” Digital Information Management, 2007, ICDIM '07, 2nd International Conference ,vol. 1, pp. 448 – 453, 2007.

[20] X. Kang, WenjunZeng , J. Huang, “A Multi-band Wavelet Watermarking Scheme” , International Journal of Network Security ,vol 6 ,no 2, pp. 121–126, Mar 2008.

[21] T. Hu, J. Wei, “A digital video watermarking scheme based on 1D-DWT”, IEEE, International Conference on Biomedical Engineering and Computer Science , 2010, pp. 1-3.

[22] S.J., Kim, S.H. Lee, T.S. Kim, B.S. Kim and K.I. Lee, "A Video Watermarking Using the Spread Spectrum Technique in the 3D Wavelet Transform Domain", Proceedings of the International Conference on Imaging Science, Systems and Technology '04, June 2004.

[23] H. Liu, N. Chen, J. Huang, “A Robust DWT-Based Video Watermarking Algorithm”, Proceedings of the International Conference on Signal and Image Processing Applications (ICSIPA), IEEE, pp. 352 – 356,2000.

[24] X. Niu, S. Sun, “A New Wavelet-Based Digital Watermarking for Video,” Proceedings of the 9th IEEE Digital Signal Processing Workshop, pp. 241-245, July 1999.

[25] C.X. Wang, X. Nie, X. Wan, W.B. Wan and F. Chao, “A Blind Video Watermarking Scheme Based on DWT”, Fifth International Conference on Intelligent Information Hiding and Multimedia Signal Processing, IEEE, vol. 1, pp. 434-437, 2009.

[26] T.D. Hien, Y.W. Chen, Z. Nakao, “PCA Based Digital Watermarking”, KES 2003, LNAI 2773, pp. 1427-1434, 2003.

[27] S.A.K. Mostafa, A.S. Tolba, F. M. Abdelkader, H.M. Elhindy, “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.

[28] E. Yavuz, Z. Telatar, “Digital Watermarking with PCA Based Reference Images”, ACIVS 2007, Springer-Verlag, Lecture Notes in Computer Science, pp.1014-1023, 2007.