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Discrete Wavelet Transform (DWT) based Digital Video Watermarking Technique using Principal Component Analysis (PCA)

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Abstract **– Digital watermarking techniques can be classified into spatial or transform domains. Transform domain techniques like DCT, DWT and PCA always gives more robust output than spatial domain. Recently hybrid digital video watermarking scheme based on Discrete Wavelet Transform (DWT) and Principal Component Analysis (PCA) is used for video watermarking. These transform domain technique always give more robust output than DCT and DWT. 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. Experimental result shows no visible difference between the watermarked frames and original frame. It also shows PSNR, NC values of the watermarked video frames against various attacks.**

Keywords **– Digital Video, Binary Watermark, Discrete Wavelet Transform, Principal Component Analysis.**

I. Introduction

Recently, the users of networks, especially the World Wide Web are increasing rapidly. The reproduction, manipulation and the distribution of digital multimedia (images, audio and video) via networks become faster and easier. Hence, the owners and creators of the digital products are concerned about illegal copying of their products. As a result, security and copyright protection are becoming important issues in multimedia applications and services [1]. Copyright protection inserts authentication data such as ownership information and logo in the digital media without affecting its perceptual quality.

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 for removal of the watermark. Many digital watermarking schemes have been proposed for still images and videos. Most of them operate on uncompressed videos, while others embed watermarks directly into compressed videos. 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.

II. Literature Review

Different digital video watermarking algorithms have been proposed by different Authors.S. Sinha *et.al.*[1] proposed robust digital video watermarking scheme using DWT &PCA against various attacks. S.A.K. Mostafa *et.al.*[2] has combined the DWT with PCA algorithm to increase robustness and invisibility. U Mehraj Ali *et.al.*[3]emphasizes the assessment and systematic the quality of enhanced information infused image. T.Sridevi *et.al.*[4] comparative study of five watermarking schemes. P.Ghosh *et.al.*[5] proposed Novel Digital watermarking Technique for video copyright protection. R. Dubolia *et.al.* [6] compared DWT and DCT with respect to PSNR at a different threshold values. A.A. Hood *et al.*[7] reviewed the proposed schemes and also the various attacks on the watermarks. N.I.Yassin *et. al.*[8] proposed scheme shows high robustness against several attacks. M. Jianshengtal *et.al.*[9]simulated and presented results show that this algorithm is invisible and has good robustness for some common image processing operation. A.Essaouabi *et. al.*[10] proposed blind wavelet based digital watermarking for video. S. Rao *et al.* [11] provided an overview of the concept of digital watermarking focusing on its various applications. P.Pandey *et.al.* [12] Reviewed on the latest methodologies and application on the principle Component Analysis (PCA) has been done in the area of image processing. Some techniques embed watermark in the spatial domain by modifying the pixel values in each frame, but these methods are not robust to attacks and common signal distortions. In contrast, other techniques are more robust to distortions when they add the watermark in the frequency domain. In these types of schemes, the watermark is embedded by modifying the transform coefficients of the frames of the video sequence. Widely used frequency transforms are DFT (Discrete Fourier Transform), FFT (Fast Fourier Transform), DCT (Discrete Cosine Transform) and DWT (Discrete Wavelet

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Transform)[2]. Wavelet transforms is a new time-frequency analyzing method to localize spatial and frequency domain. Many watermark algorithms are implemented using discrete wavelet transform. It is proved practically that discrete wavelet transform based watermarking is robust due to its filtering characteristics and can withstand most of the attacks. Video watermarking is not just an extension of image watermarking as by exploiting the temporal properties of video higher degree of robustness can be achieved

III. Watermarking Scheme

The watermarking algorithm basically utilizes two mathematical techniques: DWT and PCA.

A. Discrete Wavelet Transform

The most advanced and useful transform domain watermarking technique is Discrete Wavelet Transform (DWT). DWT is a hierarchical transform. DWT offers multi resolution analysis i.e. it has the capabilities to study or analyze a signal at different levels [4]. 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 1-D DWT (Fig. 1) is an application of the 2-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.

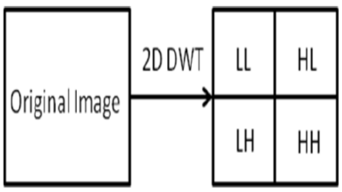

Fig.1. DWT Subband

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 [3].

Figure 2 shows the embedding and Figure 3 shows the 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.

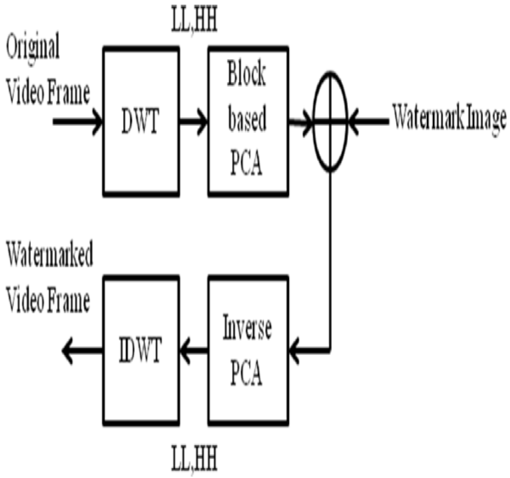

Fig.2. Watermark embedding algorithm

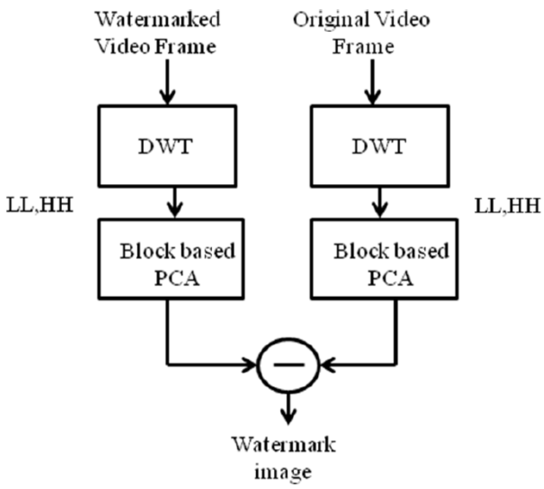

Fig.3. Watermark extraction algorithm

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C. Algorithms for watermarking using DWT AND PCA

Algorithm 1:

a) Embedding Procedure

Step 1: Convert the n × n binary watermark logo into vector W = {w1, w2… wn × 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 into each sub-block by first obtaining the principal component scores by Algorithm 2. The embedding is carried out as equation 1.

$$Score'_i = Score_i + \alpha W \qquad (1)$$

Where $Score_i$ represents the principal component matrix of the ith sub-block.
Step 7: Apply inverse PCA on the modified PCA component 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 no 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.

$$W'_i = \frac{(Score'_i - Score_i)}{\alpha} \qquad (2)$$

Where W_i' is the watermark extracted from the i^{th} subblock

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 δ_i of the elements of vector D_i
Step 3: Compute a i Z ccording to the following equation

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

Here Z_i represents a cantered, scaled version of D_i of the same size as that of D_i.
Step 4: Carry out principal component analysis on Z_i to obtain the principal component coefficient matrix coefficient.
Step 5: Calculate vector $Score_i$ as

$$Score_i = Z_i \times coeff_i \qquad (4)$$

Where $Score_i$ represents the principal component scores of the i^{th} sub-block.

IV. Results and Discussion

A 400 × 300 colour image is taken from video sequences as the cover image and watermark of size 100 × 100 is embedded in to the cover image using, Hybrid DWT-PCA technique. The watermark bits are embedded with strength α in to each sub band frequency. In which strength α is varied in between two level i.e. minimum level (α =10), maximum level (α =170). The performance of the algorithm has been measured in terms of its imperceptibility and robustness against the possible attacks like Gaussian noise addition, Salt pepper noise, Cropping noise, Rotate Noise, Median filtering Noise, Contrast Adjustment Noise, Histogram equalization etc.

Result of Proposed Watermarking Scheme

Hybrid DWT-PCA α =10

Fig.4. Watermarked Frame

Fig.5. Watermarked Video

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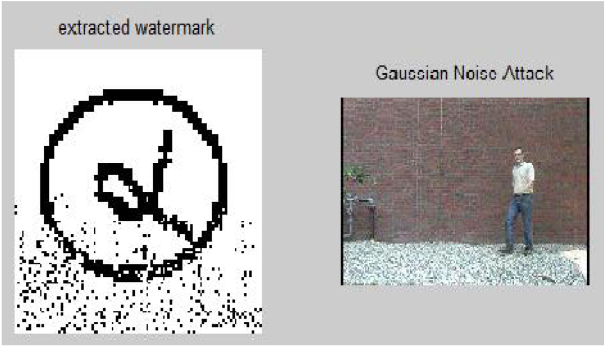

Fig.6. Video Frame after addition Gaussian Noise and Extracted watermark from video frame of Gaussian Noise

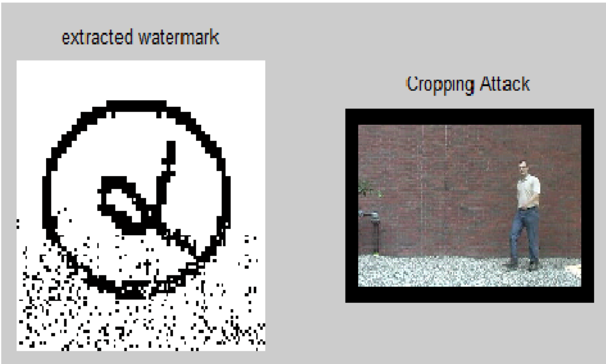

Fig.7. Video frame after addition of Cropping attack and Extracted watermark from Video frame of Cropping noise

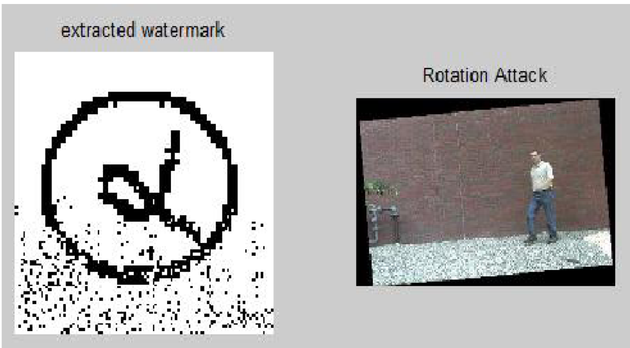

Fig.8. Video frame after addition of Rotation Attack and Extracted watermark from Video frame of Rotation noise

Fig.9. Video watermarked frame without attacks and extracted watermark from watermarked frame.

Proposed Watermarking Scheme

Hybrid DWT-PCA α =170

Fig.10. Watermarked Frame

Fig.11: Watermarked Video

Fig.12: Video Frame after addition Gaussian Noise and Extracted watermark from video frame of Gaussian Noise.

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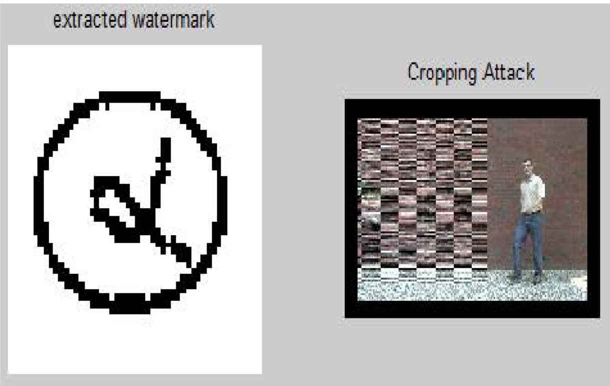

Fig.13: Video frame after addition of Cropping attack and Extracted watermark from Video frame of cropping noise

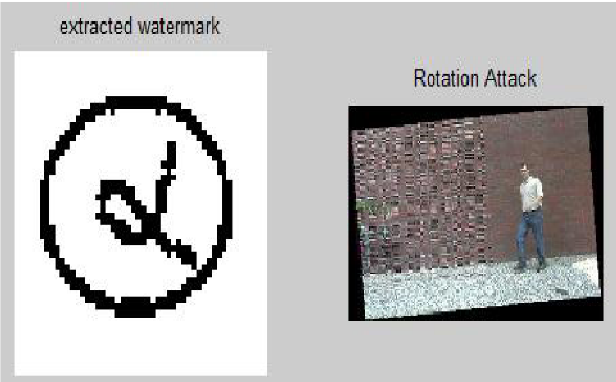

Fig.14. Video frame after addition of Rotation Attack and Extracted watermark from Video frame of Rotation noise

Fig.15. Video watermarked frame without attacks and extracted watermark from watermarked frame

Table 1: NC Value of Hybrid PCA- DWT with and without different attacks

Alpha	Guassian Noise (NC) With Attack	Cropping Noise (NC) With Attack	Rotate Noise (NC) With Attack	NC value of DWT-PCA without attacks
10	0.9727	0.9726	0.9726	0.9726
30	0.9852	0.9852	0.9853	0.9852
50	0.9913	0.9913	0.9914	0.9913
70	0.9956	0.9956	0.9957	0.9956
90	0.9986	0.9986	0.9987	0.9986
110	0.9992	0.9992	0.9992	0.9992
130	0.9996	0.9996	0.9996	0.9995
150	0.9999	0.9999	1	0.9999
170	1	1	1	1

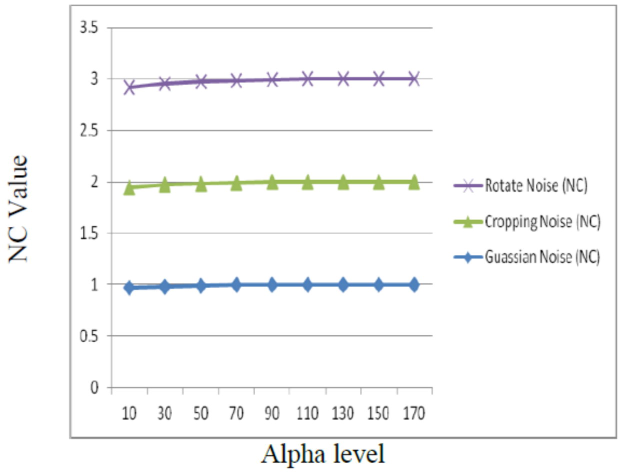

Fig.16. NC value of Hybrid PCA- DWT after applying different attacks.

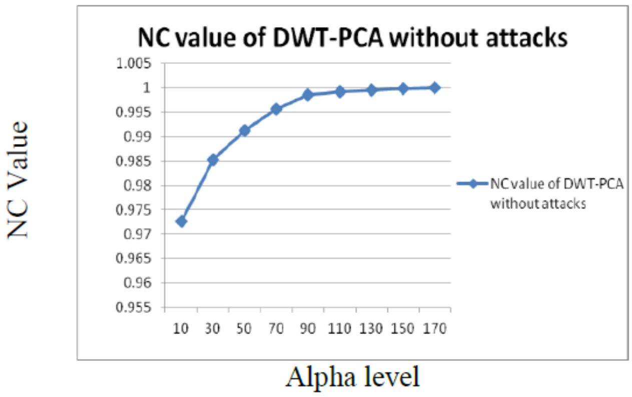

Fig.17. NC value of Hybrid DWT-PCA withouattacks

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Table 2: PSNR value of all transforms with attacks

Alpha	PSNR value of DCT with attacks	PSNR value of DWT with attack	PSNR value of DWT-PCA with attack
10	27.9555	45.5097	46.1594
30	27.9501	40.7385	41.3811
50	27.9421	38.52	39.1695
70	27.9324	37.0588	37.7082
90	27.9211	35.9673	36.6168
110	27.9084	35.0958	35.7453
130	27.8946	34.3703	35.0198
150	27.8798	33.7488	34.3983
170	27.8642	33.2053	33.8547

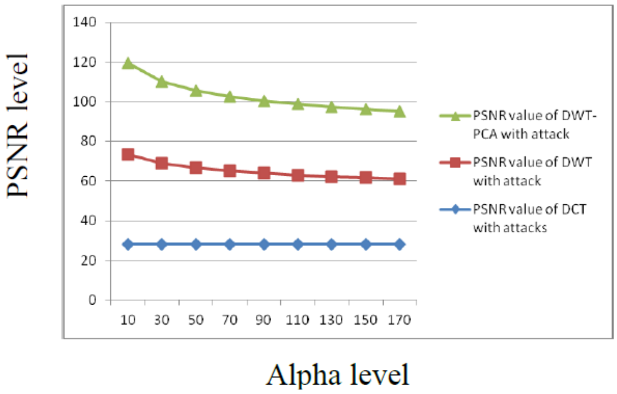

Fig.18. PSNR value all transforms after applying different attacks.

Table 3: PSNR value of all transforms without attacks

Alpha	PSNR value of DCT Without Attacks	PSNR value of DWT Without Attacks	PSNR value of DWT-PCA Without Attacks
10	31.0693	32.7907	32.7775
30	31.061	32.9672	32.9511
50	31.0494	33.2905	33.2254
70	31.0336	33.7039	33.5668
90	31.015	34.1804	33.9334
110	30.972	34.7574	34.3225
130	30.9257	35.3976	34.7151
150	30.9003	36.15	35.0377
170	30.8743	36.9846	35.2837

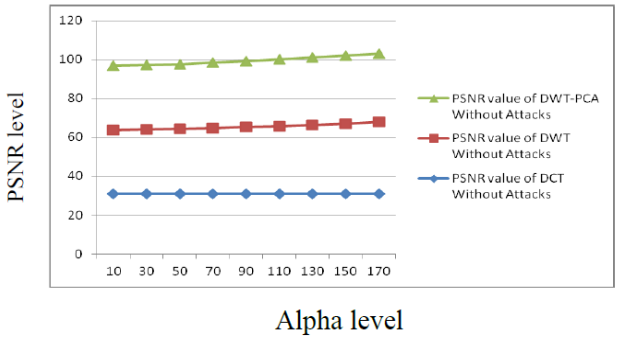

Fig.19. PSNR value all transforms before applying different attack

V. Conclusion

Experimental Results shows no visible different between the watermarked video and original video. It shows robustness of the watermarked video against various attacks. It also shows that video watermarking can be done using three frequency transforms methods such that DCT, DWT, Hybrid DWT-PCA. In DCT, DWT transform technique PSNR value decreases at higher value of embedding strength, and in Hybrid DWT-PCA transform technique, there is not much decrease in PSNR value at higher value of embedding strength.NC (Normalized Correlation) value of proposed method is almost equal to one.

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