A Hybrid & Robust Wavelet Based Video Watermarking Scheme for Copyright Protection Using Principal Component Analysis

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Abstract— ***Digital video watermarking has been widely used technology for copyright protection of the digital media. It prevents the illegal distribution of the digital data. Watermarking is the process of embedding some information in the digital media and then transmitting it. The extraction of this watermark will indicate the originality of the digital data. The additional information could be very easily transmitted along with the video without affecting the quality of the original video. In this paper, a hybrid approach based on two effective techniques is used. The first technique Discrete Wavelet Transform divides the video frames into sub-bands and the second technique Principal Component Analysis is applied on each LL and HH sub blocks. Watermark is embedded into those sub-bands to obtain the watermarked video as good as that of the original video.***

***Keywords*— Video Watermarking, Frame Extraction, Discrete Wavelet Transform, Principal Component Analysis, Binary Watermark.**

I. INTRODUCTION

A large amount of digital data can be copied and stored easily and without loss in fidelity. Hence, it becomes very important to use some kind of copyright protection system. In order to protect the digital media (video, audio, image), an additional information called as the watermark is embedded in the digital data. This watermark carries the owner's information. The content is protected by encrypting before its transmission and thus protected from copying. Watermarking can be considered as a part of information hiding science called steganography. Thus, when anybody copies such content, hidden information is copied as well since it is embedded and hidden into the digital data. Hence, digital video watermarking proves to be a good solution to reduce the illegal distribution and determines the authenticity and ownership of the data.

Different schemes are proposed to achieve more robustness and imperceptibility in the literature. Many schemes are based on the image watermarking techniques can be done for the videos with some significant changes.

There are two main approaches for embedding the watermark in the video based on their working domain [11]. The first one is the spatial domain, in which embedding is done by modifying the values of the pixels in the host image/video [24-25]. Least Significant bit (LSB) technique is the most frequently used method. In this method each pixel is used to embed the watermark or the copyright information. This technique uses the entire cover image to store the watermark that enables a smaller object to be embedded multiple times. This is most straight forward method but not much robust against a variety of attacks. The second category is the transform domain techniques in which embedding of the watermark is done in the frequency domain of the video frames by modifying the transform coefficients of the frames of the video sequence[1-2]. Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT), the Discrete Wavelet Transform (DWT), and Principal Component Analysis transform are the commonly used transform domain techniques. The frequency domain watermarking schemes are relatively more robust than the spatial domain watermarking schemes, particularly in lossy compression, noise addition, pixel removal, rescaling, rotation and cropping[1].

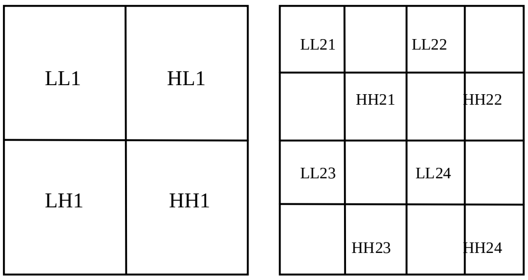
In this paper, we propose an imperceptible and robust video watermarking algorithm based on DWT and PCA. DWT is more efficient than other transform methods because of its excellent localization properties providing compatibility with the Human Visual System (HVS). This paper describes the complete embedding to obtain the watermarked video almost similar to the original video and the extraction process that gives the watermark back that needs to be compared with the original watermark.

II. Proposed Watermarking Scheme

In our work we propose the hybrid scheme by considering multilevel DWT and then applying PCA to it. Watermark is embedded into higher levels of wavelet transform to achieve more robustness.

A. Discrete Wavelet Transform

The most advanced and useful transform domain watermarking technique is Discrete Wavelet Transform (DWT). DWT is a hierarchical transform. It is a transform based on frequency domain. 1-D discrete wavelet transform decomposes an image or a video frame into sub-images, i.e., 3 details and 1 approximation. 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. 2-D DWT further divides the image or a video frame into 16 sub-bands. Each sub-band formed by 1-D DWT is further divided into 4 sub-bands. LL_1 is divided into LL_{21}, LH_{21}, HL_{21}, and HH_{21} and so on as shown in figure.



(a) (b)

Figure 1. DWT Sub-bands in (a) level 1 (b) level 2

B. Principal Component Analysis

Principal Component Analysis is a linear transformation technique that conveys most information about the image to principal components. It 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. PCA is basically used to hybridize the algorithm. It has the inherent property of removing the correlation amongst the data i.e. the wavelet coefficients and helps in distributing the watermark bits over the sub-band used for embedding. This results in a more robust watermarking scheme that is resistant to almost all possible attacks.

C. Embedding Procedure

Figure 2 shows the embedding of the watermark and the procedure is explained. In our proposed work, binary watermark is embedded in the LL and HH sub-bands of the resulting 2-D DWT transformations. Embedding the watermark in both LL and HH makes the scheme robust to a variety of low and high frequency characteristic attacks[1].

The following is the complete embedding procedure:
Step1: Divide the video into frames. Consider each frame and convert the RGB frames to YUV frames. Resize the frames into (2Nx2N).

Step 2: Choose the luminance component Y of each frame and apply 1-level DWT on it. This gives 4 sub-bands each of NxN – LL_1, HL_1, LH_1, HH_1. For each of the sub-band, apply DWT again and it gives 16 sub-bands each of (N/2)x(N/2) – LL_{11}, HL_{11}, LH_{11}, HH_{11}, LL_{12}, HL_{12}, LH_{12}, HH_{12}, LL_{21}, HL_{21}, LH_{21}, HH_{21}, LL_{22}, HL_{22}, LH_{22}, HH_{22}.

From these sub-bands, select only LL_{11},HH_{11}, LL_{12}, HH_{12}, LL_{21}, HH_{21}, LL_{22}, HH_{22} for embedding process.

Step 3: Divide each selected sub-bands with N/2xN/2 dimension into nxn non-overlapping blocks where the number of blocks is k = (N/2xN/2)/(nxn). Apply PCA to each block as described.

1. For each block B_{si} (nxn) compute the mean of the block M_i, where B_{si} represent block number i in the selected sub-band, the block zero mean A_i as follows:

$$A_i = E\,(B_{si} - M_i) \qquad (1)$$

2. Calculate the principal component scores.
For each block, calculate the covariance matrix C_i of the zero mean block A_i as:

$$C_i = A_i \text{ X } A_i^T \qquad (2)$$

where T denotes the matrix transpose operation.

3. Each block is transformed into PCA components by calculating the eigenvectors corresponding to eigen values of the covariance matrix:

$$C_i\Phi = \lambda_i\Phi \qquad (3)$$

Where λ_i is the matrix of eigen values and Φ is the matrix of eigenvectors

4. Compute the PCA transformation of each block to get a block of uncorrelated coefficients by:

$$Y_i = \Phi^T A_i \qquad (4)$$

where Y_i is the principle component of the i^{th} block.

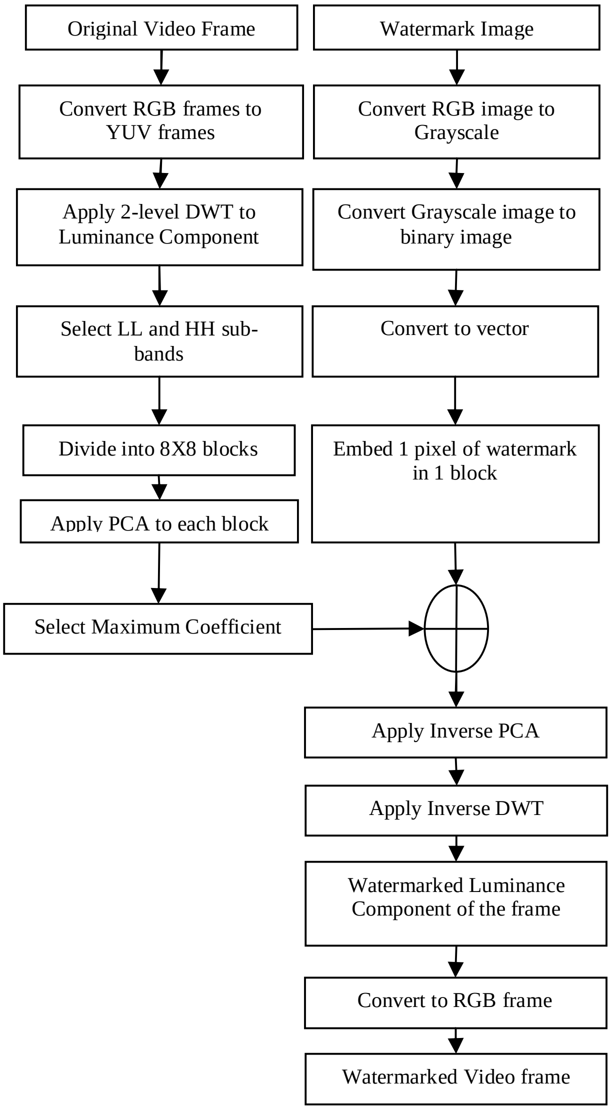


Figure 2: Watermark Embedding Procedure

Step 4: Convert the RGB 8x8 watermark image to grayscale. Then the grayscale image is converted to binary image. Convert the binary image into a vector
W= {w1, w2,….w8x8} of zeros and ones.

Step 5: Each bit of the watermark image is embedded into each block of the sub-band obtained after 2-level DWT. The watermark bits are embedded with strength
α into the maximum coefficient of each PC block Yi.
The embedding equation is:

$$Y'_i = Y_i + \alpha W \qquad (5)$$

where Yi represents the principal component matrix of the i^{th} sub block. α is the watermark embedding strength. The value of α in this algorithm is 9 for all selected wavelet bands.

Step 6: Apply inverse PCA on the modified PCA components to obtain the modified wavelet block by using -

$$A_i = \Phi^T Y_i' \qquad (6)$$

Step 7: Apply the inverse DWT to obtain the watermarked luminance component of the frame. Finally reconstruct the RGB watermarked frame and obtain the watermarked video.

D. Extraction Procedure

Figure 3 shows the extraction of the watermark and the procedure is explained. In our proposed work, the steps used for extraction are same as that of embedding but in the reverse direction.

The following is the complete extraction procedure:

Step 1: Divide the watermarked video into frames. Consider each frame and convert the RGB frames to YUV frames.

Step 2: Choose the luminance component Y of each frame and apply 1-level DWT on it. This gives 4 sub-bands each of NxN – LL_1, HL_1, LH_1, HH_1. For each of the sub-band, apply DWT again and it gives 16 sub-bands each of (N/2)x(N/2) – LL_{11}, HL_{11}, LH_{11}, HH_{11}, LL_{12}, HL_{12}, LH_{12}, HH_{12}, LL_{21}, HL_{21}, LH_{21}, HH_{21}, LL_{22}, HL_{22}, LH_{22}, HH_{22}.

From these sub-bands, select only LL_{11},HH_{11}, LL_{12}, HH_{12}, LL_{21}, HH_{21}, LL_{22}, HH_{22} for extraction process. Choose LL and HH sub-bands and divide them into nxn non-overlapping blocks.

Step 3: For each block, apply PCA transformation as described in the embedding procedure.

Step 4: The watermark is extracted by applying the following equation:

$$W' = (Y'_i - Y_i) / \alpha$$

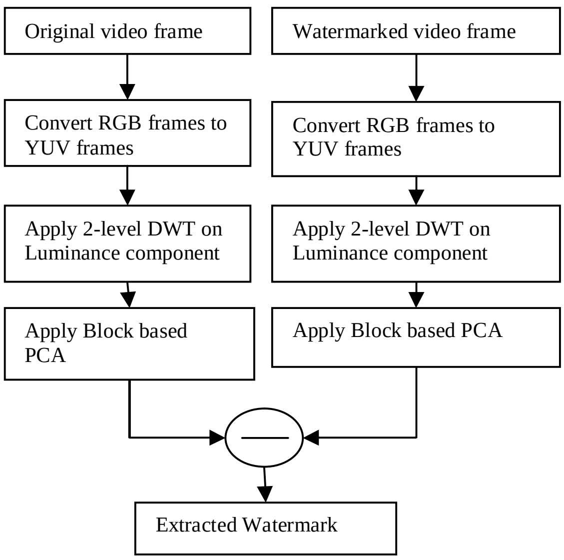


Figure 3: Watermark Extraction Procedure

Step 5: The extracted watermark is compared with the original watermark by computing the similarity measure between them as follows:

Normalized Correlation (NC) is the measure of robustness of the watermark. Its peak value is 1.

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

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.

III. Experimental Results

A number of video sequences have been tested with the proposed scheme. Original frames and the watermarked video frames that are obtained are almost similar. The watermark is extracted from the watermarked video and its robustness is checked calculating its normalized correlation.

The original video frames may be of any size, they are resized to 512x512. After applying 1-level DWT, a sub-band of 256x256 is obtained. Applying DWT to this sub-band gives sub-bands of 128x128. Each LL and HH sub-band in which the watermark is to be embedded is of size 128x128.

These sub-bands of size 128x128 are divided into 64 blocks of size 16x16. To each of this block, 1 pixel of binary watermark image (8x8) is embedded.

A sequence of original frames is shown in figure 4 below for the video that is considered. The frames are resized and then embedding is performed. After embedding, again the frames are resized into their original size.

(a)

(b)

(c)

Figure 4: (a) 1st Frame (b) 20th Frame (c) 40th Frame of the original video.

Watermark image is of size 8x8. This RGB watermark is first converted into gray scale image and then to binary watermark image. Binary watermark image is then converted into a vector with 8x8(64) values. The watermark image as is shown in figure 4 below.

(a)

(b)

(c)

Figure 5: (a) Original watermark image (b) Grayscale watermark image (c) Binary watermark image.

The result of embedding these watermark image pixels into the sub-bands of the video frame is the watermarked video. Figure 6 shows the sequence of frames of the watermarked video.

(a)

(b)

(c)

Figure 6: (a) 1st Frame (b) 20th Frame (c) 40th Frame of the watermarked video.

The watermarked video contains the watermark image as some kind of hidden ownership information. Watermark image when extracted from the watermarked video gives the information about the owner.

The process of extraction is almost similar to embedding procedure in reverse direction. In order to obtain the 8x8 watermark image, original video frames and watermarked video frames are considered. 2-level DWT is applied on the frames and then PCA is applied on the resultant of DWT. The extracted watermark image is as shown in figure 7 below.

(a)

(b)

Figure 7: (a) Original watermark (b) Extracted Watermark.

The NC value is 1 indicating the exact extraction of the watermark. The performance of the watermarking system is evaluated in terms of its imperceptibility and robustness against various attacks. The Peak-Signal-To-Noise Ratio (PSNR) is used to measure the visual quality of watermarked and attacked frames. It is defined as:

$$PSNR = 10\log_{10}\frac{255^2}{MSE}$$

where MSE (mean squared error) between the original and distorted frames and is defined as follows:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - I'(i,j)]^2$$

Where M,N give the size of the frame. I(i,j) and I'(i,j) are the pixel values at location (i,j) of the original and distorted frame. However, robustness is measured by NC.

The original frames and the watermarked frames is shown in the figure 4 and 6. The measured average PSNR for all the frames is calculated to be 37.4694db and the watermarked frames appeared to be almost similar to that of the original video frames.

IV. Conclusion

In this paper we performed the embedding procedure on the video and obtained the watermarked video without much affecting its quality. Also performed the extraction of the watermark and checked for its robustness by calculating the normalized correlation. Our proposed scheme is based on i.e. multi level DWT in conjunction with the PCA transform. Watermark that indicates the owner's information is only embedded in the low frequencies and high frequencies sub-bands obtained by the wavelet decomposition. Imperceptibility of the watermark is achieved by embedding the watermark in high frequency sub-bands and robustness is achieved by embedding in low frequency sub-bands. The performance of the scheme is evaluated by calculating the PSNR.

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