Hiding Data In Video Using Discrete Wavelet Transform And Principal Component Analysis

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Abstract

Digital video watermarking has been proved to be the most widely used technique for protecting the digital data from its illegal distribution over the internet. This technique protects the digital media by additionally inserting some ownership information data called the watermark in the original video. Without affecting the quality of the original video, the additional information could be very easily transmitted along with the video. In this paper, a novel approach of video watermarking is introduced. In this approach, initially the frames are extracted from the video. The frames are then treated as images and divided into sub-bands by applying Discrete Wavelet Transform. Then Principal Component Analysis is applied on each LL and HH sub blocks and 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.*

1. Introduction

Due to an explosive growth in the multimedia technology, a large number of digital content can be copied and stored easily and without loss in fidelity. Hence, it is 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 protected content is encrypted during the transmission and the storage at recipient's side and thus protected from copying. Watermarking can be considered as a part of information hiding science called steganography. Steganographic system embeds hidden information into the digital data so that it is not noticeable. Thus, when anybody copies such content, hidden information is copied as well. Hence, digital video watermarking proves to be a good solution to reduce the illegal distribution and determines the authenticity and ownership of the data.

In the literature, different schemes are proposed to achieve more robustness and imperceptibility. Most of the schemes are based on the image watermarking techniques. But for using the same techniques on the video, some significant changes are to be done.

Basically, 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 which 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. This technique embeds the watermark in the frequency domain of the video frames. Here, embedding of the watermark is done the watermark by modifying the transform coefficients of the frames of the video sequence[1-2]. The commonly used transform domain techniques are Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT), the Discrete Wavelet Transform (DWT), and Principal Component Analysis transform. 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 2007, Hanane H.Mirza et al. [3] propose a new digital video watermarking scheme based on Principal Component Analysis by embedding a watermark in the three color channels RGB of an input video file. An imperceptible watermark is embedded into the three different RGB channels of the video frame separately using PCA transform. The main advantage of this approach is that the same or multi-watermark can be embedded into the three color channels of the image in order to increase the robustness of the watermark.

In 2009, Sadik. A.M .Al-Taweel et. Al. [13] proposed a novel DWT-based video watermarking algorithm based on a three-level DWT using Haar filter. Salwa A.K Mostafa et. al. [4] presents a technique for embedding a binary logo watermark into video frames. PCA is applied to each block of the two bands (LL – HH) which result from Discrete Wavelet transform of every video frame. In 2011, Sanjana Sinha et. al. [2] proposed a hybrid digital video watermarking scheme based on Discrete Wavelet Transform (DWT) and Principal Component Analysis (PCA). Manish Choubisa et. al. [7] proposed algorithm of digital watermarking technique based on DCT (Discrete Cosine Transformation) using permuting the image. Through adjusting the block DCT coefficient of the image the watermarks are invisible.

In 2012, Nisreen I Yassin et. al. [1] introduced a comprehensive approach for digital video watermarking, where a binary watermark image is embedded into the video frames. Each video frame is decomposed into sub-images using 2 level discrete wavelet transform then the Principle Component Analysis (PCA) transformation is applied for each block in the two bands LL and HH. The watermark is embedded into the maximum coefficient of the PCA block of the two bands. Poulami Ghosh et. al. [14] proposed a novel watermarking technique where both visible and invisible watermarks are embedded in a video.

Nikita Kashyap et. al. [6] have implemented a robust image watermarking technique for the copyright protection based on 3-level discrete wavelet transform (DWT). In this technique a multi-bit watermark is embedded into the low frequency sub-band of a cover image by using alpha blending technique. Kshama S. Karpe et. al. [12] presents a novel technique for embedding a binary logo watermark into video frames, based on Discrete Wavelet Transform (DWT) and Principal Component Analysis (PCA).U.Mehraj Ali, et. al. [5] proposed a wavelet based watermarking technique with the combination of PCA transform. 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.

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 procedure to obtain the watermarked video almost similar to the original video.

2. Proposed Watermarking Scheme:

In our work we propose the hybrid scheme by considering multilevel DWT and then applying PCA to it. More robustness could be achieved by embedding the watermark into higher levels of wavelet transform.

2.1 Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) 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.

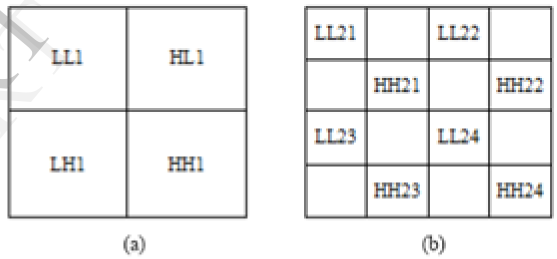

Figure 1. DWT Sub-bands in (a) level 1 (b) level 2

2.2 Principal Component Analysis

Principal Component Analysis is a linear transform technique to convey most information about the image to principal components. 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. It is a mathematical procedure that uses an orthogonal transformation. It converts a set of observations of correlated variables into a set of values of uncorrelated variables called principal components.

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. The watermark is embedded into the luminance component of the extracted frames as it is less sensitive to the Human Visual System (HVS).

2.3 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}, HH11, 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:

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

2. Calculate the principal component scores.

For each block, calculate the covariance matrix C_i of the zero mean block A_i as:

$$C_i = A_i \ X \ A_i^T \quad (2)$$

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:

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

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:

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

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

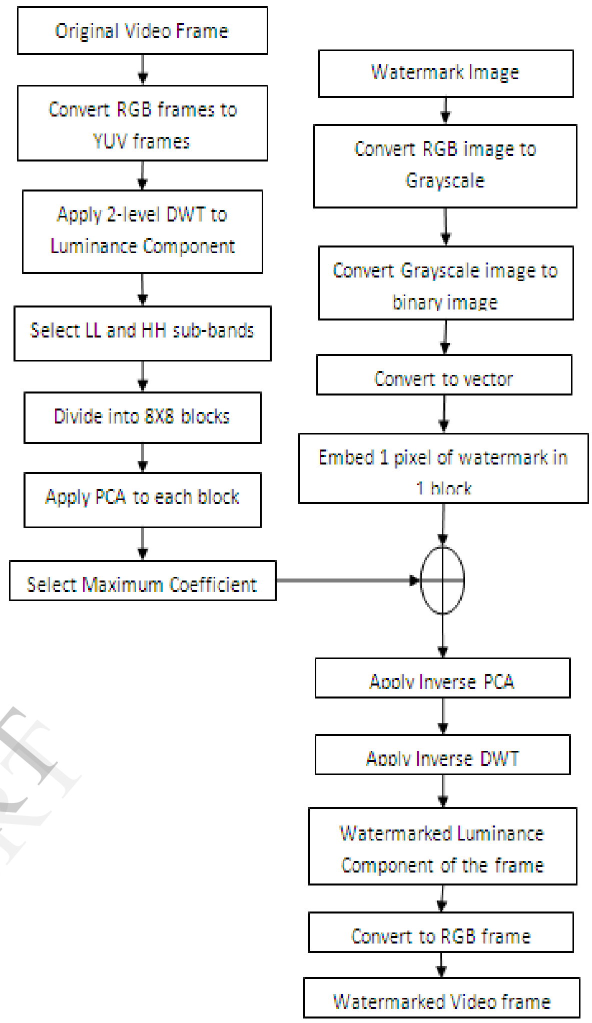

Figure 2: Watermark Embedding Procedure

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:

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

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 -

$$A_i = \Phi^T Y_i' \tag{6}$$

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.

3. Experimental Results

The proposed scheme is applied on a number of video frames and the watermarked video frames are obtained that are almost same as that of the original video.

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 3 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 3: (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 values. The watermark image as is shown in figure 4 below.

(a)

(b)

(c)

Figure 4: (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 5 shows the sequence of frames of the watermarked video.

(a)

(b)

(c)

Figure 5: (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.

4. Conclusion

In this paper we performed the embedding procedure on the video and obtained the watermarked video without much affecting its quality. Our proposed scheme is based on 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.

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