International Journal of Research in Engineering, Science and Management
Volume-1, Issue-9, September-2018
www.ijresm.com | ISSN (Online): 2581-5782

Principal Component Analysis Based Digital Video Watermarking

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***Abstract*—In this paper we are going to discuss how to prevent our digital media such as video, audio and image from unauthorized copying or illegal stealing of data. Digital watermarking is one method of providing copyright protection by embedding the watermark in our media. Watermark can be a visible or invisible logo or any text or sequence of numbers. In digital video watermarking embedding of watermark in our video is done with different methods. Mostly used methods are DWT based digital video watermarking, PCA based digital video watermarking. We apply PCA algorithm for video watermarking process as this is one of the easiest methods of extracting the relevant information from a set of confusing data set. This statistical method deals with a large a large data set to reduce the dimensionality problem, to covert large number of variable to small number of variable. First a video is converted in to frame then embedding of watermark in RGB planes is done in order to increase the robustness (the ability of tolerating perturbations with changing its initial configurations). Attacks are mean, median, gaussian noise etc.**

***Index Terms*— PCA, DWT, copyright protection, RGB planes.**

I. Introduction

Digital Watermarking is one of the widely used methods used for the security or copyright protection of our digital media. As there are number of websites that allow number of users to upload their data such as audio, video, image on their websites. There is huge possibility for unauthorized stealing or copying of data. To provide security to digital media watermarking, steganography, cryptography all techniques are used. The concept of watermarking is derived from the steganography technique. In steganography process, we hide a secret message or digital media into an ordinary message and extraction of it at its destination where as in cryptography the encryption of message before transmission and the decryption of message at receiver side with a key. No one can access the data without the correct key. In digital video watermarking process, we insert a watermark or message signal (any visible or invisible symbol or logo or sequence of numbers) into our video or carrier signal and the digital media is sent over the internet for transmission and the extraction of watermark is done by authenticated person. Watermarking should be robust so that various types of malicious attacks like gaussian noise, mean, median etc., must not deteriorate the original quality of video.

Most of video watermarking techniques are based on image watermarking but video watermarking has some issues such as synchronization of audio, video at the time of merging. There are various video watermarking schemes are present but in this paper implementation of PCA algorithm is used of video watermarking where use of feature extraction algorithm is used to extract relevant data from a set of confusing data. Firstly, the video is converted into number of frames and after this each frame used for watermarking is decomposed in to Red, Green, Blue planes.

II. Application of Digital Video Watermarking

There are number of applications of Digital Video Watermarking given below.

A. *Broadcast Monitoring*

In broadcast monitoring system there is the instalment of monitoring site in the transmission area. The owner embeds the watermark into digital media and the extraction of watermark is done at the monitoring site before broadcasting.

B. *Copyright Protection*

As there is big amount of multimedia broadcast over the internet every day, there is huge possibility of duplicating the data so intellectual copyright protection is very necessary. Digital video watermarking is used to provide copyright protection even after transmission of data.

C. *Fingerprinting*

In fingerprinting technique we use a software that identifies video by its fingerprint and also recognize the extract and then compresses the distinguishing components into video. Many software is available those extract the fingerprint. The detection and identification of video is done by comparing the extracted fingerprints with others.

D. *Security*

In case of official documents such as identity cards or passports there is the requirement of certification. For security purpose, watermarks may be used for certification, authentication, and conditional access. Certification is an important issue for official documents, such as identity cards or passports.

E. Tampering with Images

Another application is the authentication of image content. The goal of this application is to detect any alterations and modifications in an image.

III. Attacks in Digital Video Watermarking

To reduce the watermark presence with the goal to forge or corrupt the digital image, one can apply various attacks on the watermarked image. The attacks can be applied to spectral components of the watermarked image or to transformed spectral components as well. Usually, the attacks are performed like applying some filters to the watermarked image. Very often images are undergone to compression procedure, especially spectral images. So, compression as an attack leading to watermark removal is also considered. In our study, we used following compression and filtering algorithms

1. Compression with PCA/wavelet transform
2. Mean filtering
3. Median filtering with 3×3 and 5×5 windows
4. On the Laplacian of the Gaussian transform with different sigma values.

IV. Principal Component Analysis Theorem

Principal component analysis invented in 1901 by models such as face recognition. This linear transform has been widely used in data analysis and compression. PCA is used to reduce the dimensionality of a data set consisting of large number of irrelated variables. PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number of distinct principal components is equal to the smaller of the number of original variables or the number of observations minus one. This transformation is defined in such a way that the first principal component has the largest possible variance, and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to the preceding components. The resulting vectors are an uncorrelated orthogonal basis set. PCA is sensitive to the relative scaling of the original variables.

In video watermarking process there is a conversion of video into frames then separately apply PCA transform on sub planes of selected RGB frame are prior to watermarking process.

By finding PCA transform matrix, we are able to find the Principal components of subpixel of each subframes. Eigen vector corresponding to highest eigen value is first principal component and corresponding to second highest value is second principal component and so on.

Step-1: Primary importance is to find the transform matrix[Φ]that is used to find the transform of all subpixels. For statistical analysis divide the frame into number of subframes. Each subframe is an independent vector of pixels. Frame data vector can be given as

$$V = (v_1, v_2, v_3 \dots\dots.. v_n)^T \tag{1}$$

Where T denotes transpose of a matrix. Each subframe has n^2 pixels. Each vector v_i has n^2 components and the mean of the population is given by

$$\mu_V = E\{V\} \tag{2}$$

Step 2: The covariance is given by the eq. 3

$$C_V = E\{(V- \mu)(V- \mu)^T\} \tag{3}$$

The components of C_V are denoted by C_{ij} It represents the covariances between the random variable components v_i and v_j. The component C_{ii} denotes the variance of the component v_i. The spread of the component values around its mean value is indicated by the variance of a component. When the two components v_i and v_j of the data are uncorrelated then their covariance is zero ($C_{ii} = C_{ij} = 0$). The covariance matrix is always symmetric.

Using a sample of vectors $v_1, v_2, v_3 \dots\dots.. v_n$, one can calculate the sample mean and the sample covariance matrix as the estimates of the mean and the covariance matrix.
Now each subframe is transformed into uncorrelated coefficient by finding the eigen values and corresponding eigen vectors of covariance matrix.

$$C_v\Phi = \lambda_v\Phi \tag{4}$$

Where $\Phi = (e_1, e_2, e_3 \dots\dots. e_{n^2})$ Eigen vectors according to corresponding Eigen values $\lambda(\lambda_1 \geq \lambda_2 \geq \lambda_3 \dots\dots. \lambda_{n^2})$

Step 3: Conversion of subframes into PCA components. This can be done with the inner product of subframe with the basic function [Φ]. The de-correlation of original frame V can be done with the basic function frame [Φ].

$$Y = \Phi^T V = (y_1, y_2, y_3 \dots y_m)^T \tag{5}$$

It gives corresponding value of principal component of each subframe. For each subframe we insert the watermark within selected component.

Step 4: Watermark extraction can be done by applying inverse PCA algorithm with the help of given formula:

$$V = (\Phi^T)^{-1} Y$$
\(6)

V. Embedding Process

All the steps involved in Digital video watermarking process are shown in the Fig. 1.

A. Video Acquisition

The video in which watermarking is to be done, is uploaded for performing all the operations with the help of MATLAB.

Video, Audio Splitter: Video Audio splitter is used to separate both audio and video.

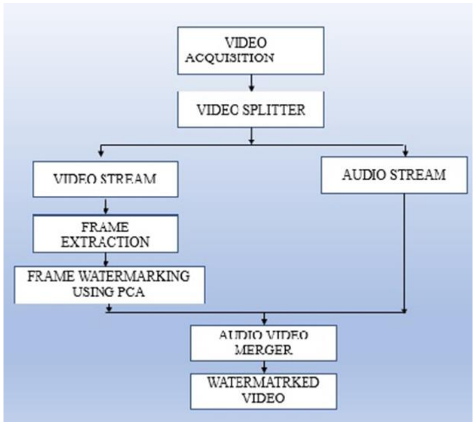

Fig. 1. Embedding process

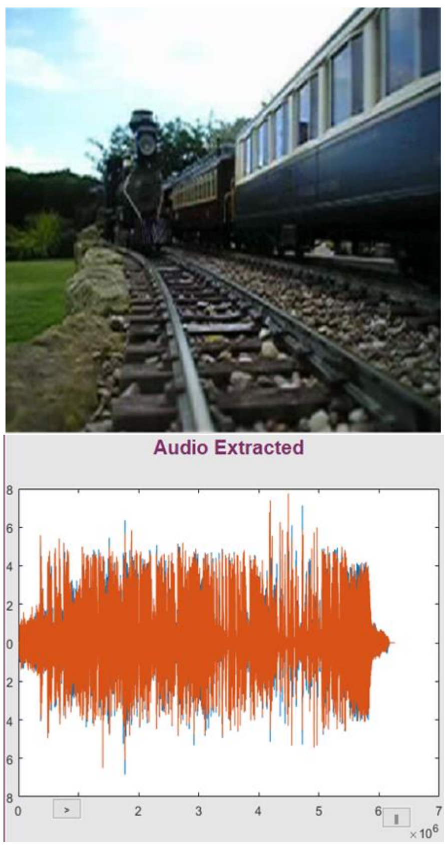

Fig. 2. Separated video and audio (X axis represents frequency in Hertz, Y axis represents intensity in decibel)

Video to frame conversion: Video used for watermarking process is a mute recording without any sound. Any video can be considered to be made up of number of frames. Formation of video through number of frames can be represent in hierarchical order as shown in the figure.

Scene: A number of shots that form semantic unit.

Shot: All frame within single camera action.

Frame: One static frame from a series of static frames constituting a video.

Frame Extraction:

The video used for watermarking have total number of frames are 227. Frame number 127 is chosen for watermarking. On this frame all the operations are performed.

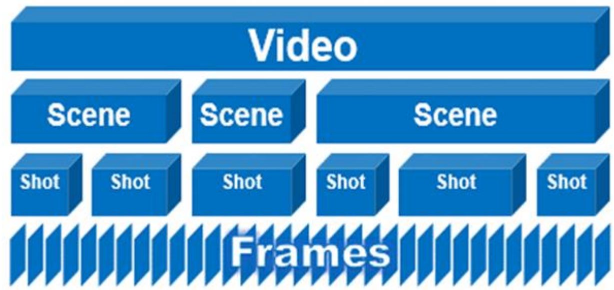

Fig. 3. Video to frame conversion

Fig. 4. Selected frame for watermarking

Frame conversion into RGB colour model: In order to embed the watermark within the original colour frame of size V (N, N), firstly separate the frame V (N, N) to three RGB colour channels. Respectively red, green, and blue subframe are given by V_R (N, N), V_G (N, N) and V_B (N, N) shown in Fig. 3.

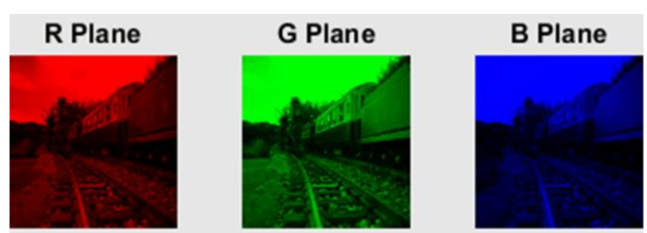

Fig. 5. Frame conversion into RGB planes

PCA Transform: Here PCA transform is applied to each of three color sub-frames V_R, V_G and V_B .Here each subframe is subdivided into certain n number of sub- frames respectively. PCA basis function for each of sub-frame is given as $[\Phi]_R$, $[\Phi]_G$, $[\Phi]_B$. Three PCA coefficients are Y_R, Y_G, Y_B.

Insertion of watermark: Find significant coefficient of each of three coefficients to insert a watermark. Watermark w is a random signal that consists of a pseudo noise sequence of length M. The values of w are random real number with normal distribution, $W = w_1, w_2 \ldots \ldots . w_M$. Then embedding of watermark into predefined components of each PCA sub-block uncorrelated coefficients. The embedded coefficients are now modified for each sub-frame given by the equation:

$$(y_i)_w = y_i + \alpha\,(y_i) w_i \tag{7}$$

Where α is the strength parameter. Now obtain $y_w R$, $Y_W G$ and $Y_W B$.

Watermark logo: This can be a sequence of binary numbers or any signature that works as a watermark in the given media. Here we are using the symbol of our college KNIT.

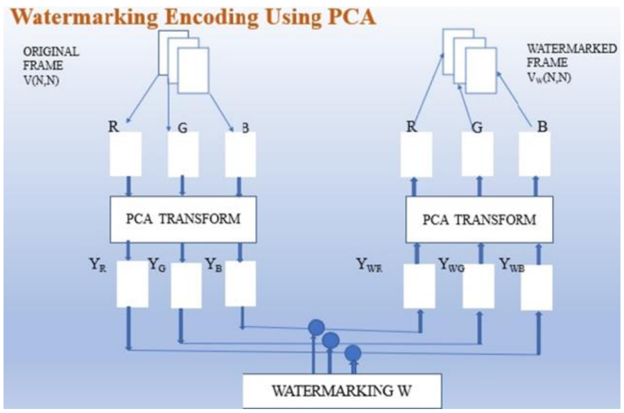

Fig. 6. Watermarking using PCA method

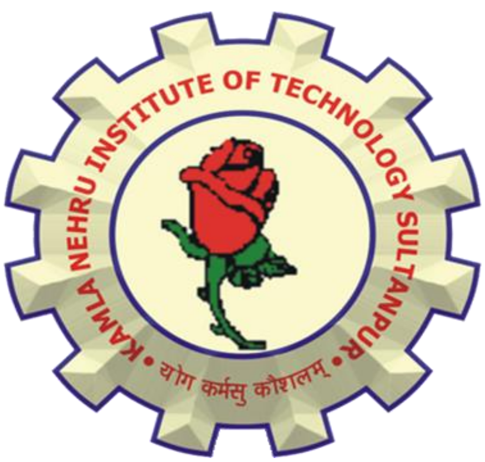

Fig. 7. Selected logo for watermarking

Recovery of watermarked frame: In order to recover three RGB watermarked channels is done by inverse PCA process.

$$V_w = (\Phi^T)^{-1} Y_w \tag{8}$$

Once all three watermarked channels $V_w R$, $V_W G$ and $V_W B$ are separately recovered. We retrieve the watermark frame $V_w(N, N)$ by superimposing all three watermarked channels.

Video Construction with frames: Now video reconstruction is done in the reverse order as shown in figure 1. First collection of watermarked frames to shot, shot to scene, scene to sequences, sequences to video. Now with the help of audio video merger we reproduce watermarked video file.

Fig. 8. Watermarked RGB planes

Decoding Process: In Fig. 9, the detection process is shown.

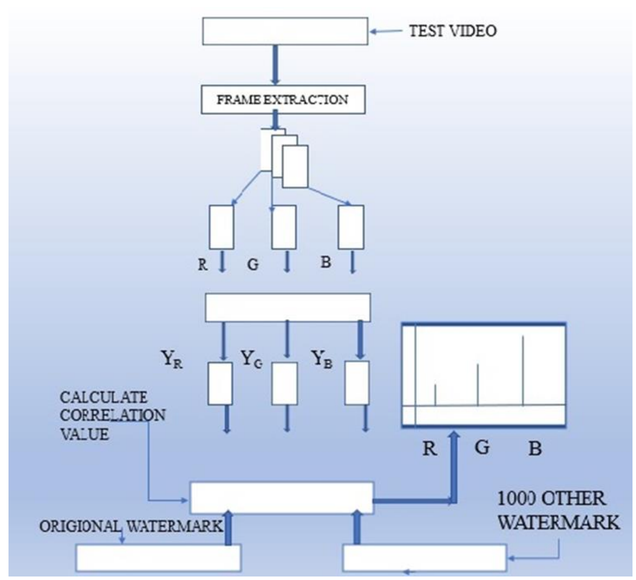

Fig. 9. Detection after comparison with other watermarks

The extraction of watermark is done by converting the video into frames and after this by applying correlation-based detection for each frame. By comparing the extracted watermark with 100 other watermark we can we check the authenticity of watermark. This comparison is done by finding PCA coefficients for each frame.

Let us consider we have a watermarked frame$V^*(N, N)$, in order to test weather watermark is present or not. We need PCA coefficients Y_R^*, Y_G^*, Y_B^* for each watermarked sub-frame $V^*{}_{R(}N, N)$, $V^*{}_{G(}N, N)$, $V^*{}_{B(}N, N)$ respectively.

Correlation Formula is given by

$$(CV) = \frac{WY^*}{M} \frac{1}{M} \sum_{i=1}^{M} w_i y_i{}^* \tag{9}$$

VI. Results and Discussion

MSE: Average of squares of deviation, caused by difference from the value of estimator and estimated value.

$$MSE = \sum_{i=1}^{M} \sum_{j=1}^{N} [f(i,j) - f'(i,j)])^2 \tag{10}$$

Where M and N are the rows and columns of the frame. $f(i, j)$ is the original image and $f'(i, j)$is the watermarked frame.

PSNR: Peak signal to noise ratio is the ratio between maximum possible powers of a signal to the power of corrupting noise that affects the fidelity of its representation.

$$PSNR = 10 \log_{10} \frac{Max^2}{MSE} \tag{11}$$

Here *Max* is the maximum possible pixel value of the image. When pixels are 8 bits per sample. Its grey image value is 255.

Detection Rate: In our algorithm as the PSNR rate increases the Detection rate is decreases. In watermarking, noise is considered as the copyright logo/secret image and signal is the original video frame. When the signal content is increased, we cannot detect the water marking or secret image (visibility is less).

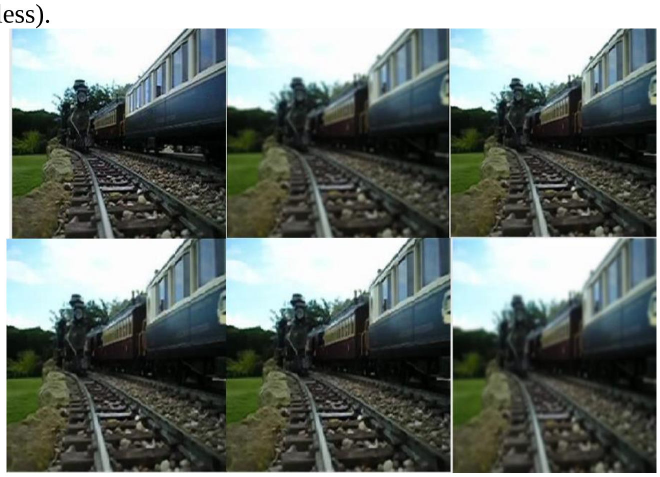

Fig. 10. Watermarked Frame with (a) No Attack (b) Mean attack (c) Median Attack (d) Gaussian Noise with σ = 2 (b) Gaussian Noise with σ = 4 (c) Gaussian Noise with σ = 6

Fig. 11. Watermark Extraction in RGB planes with no filter

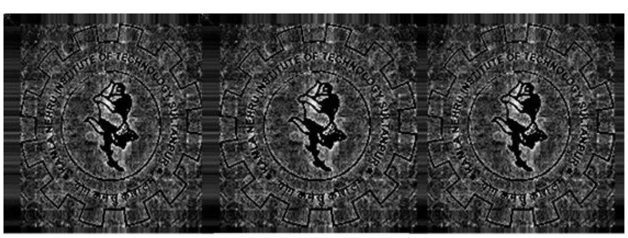

Fig. 12. Watermark Extraction in RGB planes with Mean filter attack

Fig. 13. Watermark Extraction in RGB planes with Median filter attack

Fig. 14. Watermark Extraction with Gaussian Noise with σ = 2

Fig. 15. Watermark Extraction with Gaussian Noise with σ = 4

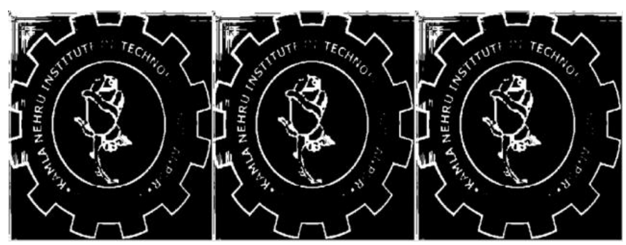

Fig. 16. Watermark Extraction with Gaussian Noise with σ = 6

Fig. 17. Unprotected RGB planes after watermark extraction

Computer Simulation: From video stream of 8 second, data rate 1150kbps, total bit rate 1374kbps, frame rate 25.00 frames/second, audio bit rate 224kbps, channels 2(stereo), Audio sample rate 44.100 kHz, we have selected frame no. 127 from total 212 frames for watermarking. Number of frames that are used for creating data set are 100, we have selected 1 frame for watermark and all others are selected for comparison of Eigen values in detection process.

Once we completed watermark embedding and extraction process, we conclude that there is not noticeable difference

TABLE I
EVALUATION OF MSE AND PSNR DUE TO MEAN, MEDIAN AND GAUSSIAN ATTACKS

Watermarked Frame	With Mean Attack	With Median Attack	With Gaussian attack sigma value 2	With Gaussian attack sigma value 4	With Gaussian attack sigma value 6	With no filter
MSE	.0036023	.0011902	0.0039284	0.005249	0.005780	1.10905e-05
PSNR	72.6872	78.169	72.1885	70.9026	70.6712	97.6813

TABLE II
AVERAGE PSNR AND DETECTION RATE FOR WATERMARKED FRAMES

Detection rate	$R_w = 0.90$, $G_w = 0.97$ $B_w = 0.71$
Frame PSNR(average)	77.90dB

between original and watermark extracted video. This can be assured by finding the value of PSNR that is shown in the Table-2. A number of signal processing attacks are applied to the watermarked video stream to check the robustness of our algorithm as shown in the Table-1. The overall watermark detection that is done after applying all the attacks as shown in the table.

VII. CONCLUSION

PCA is found to be an efficient watermarking scheme in terms of robustness. It is able to preserve the actual quality of video in spite of various attacks. Eigen frame extraction method used here is found to be efficient in terms of compacting energy of the frame and in providing proper partial reconstructions of colour frames. PCA is not a transform like DWT but is a calculation of vector basis for the vector space in which data are given and it is found to be superior as compare to many previously developed techniques like DCT, DWT. Detection ability is also very high as for any frame, main information is retained in many principal components so it is easy to select the principal component for embedding.

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