



## Simulative Investigation on 3, 4 and 5 Level Discrete Wavelet Transform for Digital Video Watermarking

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**Abstract**— In today's scenario most of the multimedia contents are transferred and shared via Internet. As internet in multimedia content sharing become common, the chances of illegal copying and use of these contents increases. Thus, to sustain copyrights of multimedia contents watermarking is a good solution. Digital watermarking is a course of embedding a signal, known as the watermark, into an original signal in an undetectable manner. In this paper, the main objective is to demonstrate a Discrete Wavelet Transform (DWT) based video watermarking because video piracy is the major challenge when dealing with copyright protection. For watermarking video we use an image and random signals with different power coefficients are used. As watermarking is concerned it may degrade the quality of original contents so that the performance of the DWT based watermarking technique will be checked against Peak Signal to Noise Ratio (PSNR). Also, in this work a complete simulation investigation has been done using various levels of DWT such as 3, 4 and 5 levels. For measuring robustness of the system parameters such as Correlation Coefficient (Cr) and Success Rate (SR) also calculated. Robustness also measured in the presence of Gaussian noise and Salt & Pepper Noise.

**Keywords**— Correlation Coefficient (Cr), Digital Watermarking, Discrete Wavelet Transform, Internet, PSNR, SR

### I. INTRODUCTION

The practice of internet has been extremely achieved heights recently in recent years. Thus, internet becomes an appropriate solution that facilitates an excellent allotment of digital media over the world as well as it is increasing the insecurity of copyright protection and alteration of digital records. A huge amount of data is pirated, edited and circulated without the awareness of vendor and owner [1]. Piracy results in economic degradation for industries/business dealing with the production of movies, music, images etc. Thus, to prevent copyrights a good solution is digital watermarking. Watermarking is process of embedding some logo, signals, symbol etc. in cover media in the invisible manner. Watermarks can be embedded in two ways either visible or invisible [2]. As the image/video contents are concern its quite easy to temper these in order to eliminate the embedded watermark thus, the tolerance of sustaining the watermarks in the presence of noise is a major issue in watermarking field. Today's trend is video based real time applications such as real time video conferencing, wireless video transmission, on demand video playing etc. and the first requirement of such applications is secure sharing of videos [3].

Before designing any watermarking algorithm one must consider three major parameters perceptual excellence, robustness and capacity. The perceptual excellence deal with the quality of the video after embedding watermarks, robustness reflects the strength of the algorithm against noise and capacity of a watermarking technique indicate the number of bits that can be embed in cover multimedia contents [4]. Watermarks can be embedded in a cover medium using two alternates that are – Spatial Domain and Frequency Domain. Spatial domain also known as time domain that means in spatial domain multimedia content such as image, video etc. represented by pixels in two dimensions it means watermarks are directly embedded on independent pixels. Least Significant Bit (LSB) is the most widely used spatial domain approach. In frequency domain firstly using any transform technique time domain parameters has to convert into frequency components. Normally the transforms used for this purpose are Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) [5]. Out of these mentioned frequency domain approaches DWT has many advantages over others such as multi-resolution, robustness, complexity etc. In this paper a simulative investigation has been proposed which shows the performance of DWT at various resolutions. The objective of this paper to embed a watermark in a video using 3, 4 and 5 level DWT approaches and then evaluate the performance in term of perceptual excellence, robustness and computational time.

### II. RELATED WORK

From the last decades, the watermarking has attained the great position in the field of research. It receives the attention since, it presented as the solution for avoiding the copyrights infringement of multimedia contents in uncontrolled environment. The requirements of an effective watermarking depend upon applications. There are different views for the digital watermarking requirements and application by the different researchers. Here down, major researches, those with core related to this proposed work.

Kundur et al. [6] presented a novel technique for watermarking of still images based on DWT fusion method. The watermark will embed using a key parameter which guide for embedding secret information at desired pixel location. This key is user defined and can't determine by others. This work also includes analysis to compute the probability of false positive and false negative results.

Rathore et al. [7] proposed a blind DWT based video watermarking algorithm for copyright protection. The watermark is embedded into high frequency sub-band coefficients of DWT to improve the invisibility of the watermark in the video. The watermarks are firstly scrambled then encode to minimize the error probabilities during watermark extraction. In this work key based pseudo random watermark signals were used as watermark and uses interleaving of error detection codes at selected coefficients. Experimental results shows that the proposed work perform well in terms of robustness against attacks such as frame deletion, frame averaging etc.

Brannock et al. [8] proposed technique for digital watermarking which utilizes the properties of DWT. Algorithm used a database of multiple images with various properties. Eight families of wavelets, both orthogonal and bi-orthogonal are compared for efficacy. When comparing with Steganography, watermarking add the property of robustness, which has the ability to withstand attacks like Gaussian noise, linear filtering, compressing image as JPEG by using transforms. In this paper, author basically discussed about blind watermarking that is invisible to the naked eye and extracted without the knowledge of original host image. There is a trade-off between robustness, perceptibility and watermarking payload. The achieved average PSNR is 25dB. In this work, three types of noise applied to the image are Gaussian, Salt and Peppers and Speckle. This work concludes that out of eight wavelet families the performance of Haar wavelet was outstanding.

Gandhe et al. [9] proposed invisible watermarking using Discrete Wavelet Transform (DWT) in which the watermarked video will get by watermarking the alternate pixels of the host video and replaced by the pixel values of watermark video/image. This type of watermarking provides a means of forensic analysis for combating media piracy. In this work 2-Level DWT is used for embedding the watermark. At 1-Level of DWT the components LL1, LH1, HL1 and HH1 were obtained. Further, LL1 decompose into LL2, LH2, HL2 and HH2. The 1-Level DWT was also applied at watermark image. Replace the alternate pixels of middle and high frequency components of cover video with low and middle frequency components of watermark image to get watermarked video. This watermarking technique provides robustness to geometric attack such as rotation, cropping, contract alteration, time editing without compromising the security of the watermark.

Hu et al. [10] proposed a blind video watermarking scheme using the stability of low frequency components in 1D-DWT. Firstly, the 1D-DWT applied to the luminance of two consecutive frames and obtained a low frequency image, which is same size as raw frame then low frequency is partitioned into equal sized sub images. Then calculate the average pixel value of each block and embed watermark as a binary image in these blocks. The watermark will extracted by computing the average pixel value of low frequency image. For embedding watermark 21st and 22nd frame of 100 frames video are taken and the watermark is successfully detect in the presence of Gaussian noise up to the variance of 0.006.

Matis et al. [11] compare DWT based two watermarking methodologies. This paper present, a new method for video watermarking that uses the knowledge already available from watermark embedding into the still frames. This work also indicate the various digital watermarking methods for videos such as methods based on watermarking in still images, methods based on a video-time dimension, methods based on video compression standards. The video taken for watermarking is of 10 second duration with dimensions of 352x288. The watermark is a binary image of size 88x72. The watermark was embedded using approximation coefficients and diagonal coefficients. Primary disadvantages of the proposed methods are computing time and the need of the original video in the watermark extraction process.

Patel et al. [12] proposed invisible video watermarking using 4-Level DWT. In this work, the watermark image is decomposed into 8-bit plane, scrambled and embedded into the mid-frequency DWT coefficients. The original video will decompose into frames using scene change analysis. Genetic Algorithm (GA) will be used for further enhancing the quality of the watermarked video. The proposed method demonstrate effective performance under common attacks in video such as frame dropping, frame averaging additive noise and lossy compression.

Panchal et al. [13] proposed a digital watermarking scheme on extracted key frames from uncompressed color video with another color watermark video using DWT. So, more information is embedded into original video while reducing the computation time and complexity compared to other schemes.  $X^2$  method was used to extract key frames from original uncompressed video. Then decompose watermarked video frames and extracted key frames using 4-Level DWT approach. The watermark would embed in high frequency components using a secret key method. IDWT was used to produce watermarked video.

Kashyap et al. [14] proposed 3-Level DWT based robust image watermarking technique. In this technique, a multi-bit watermark is embedded into the low frequency sub-band of a cover image by using alpha blending technique. The insertion and extraction of the watermark in the grayscale cover image is found to be simpler than other transform techniques. The proposed method is compared with the 1-level and 2-level DWT based image watermarking methods by using statistical parameters such as Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE). In alpha blending technique, the decomposed components of the host image and the watermark are multiplied by a scaling factor and are added. This method shows a significant improvement in terms of PSNR as compare to 1-Level and 2-Level DWT.

Tabassum et al. [15] demonstrate 3-Level DWT based digital video watermarking proposal using identical frame extraction. Intensity histogram was utilized to extract the identical frames. For embedding the watermarks HL, LH and HH that is middle and high frequency bands are used. More than 45 dB PSNR was achieved.

### III. DISCRETE WAVELET TRANSFORM

The concept of DWT was given by Croiser, Esteban and Galand in 1967 [16]. Applying DWT on an image will divide that image into four frequency components using wavelet filters. These frequency components are known as LL (low low), LH (low high), HL (high low) and HH (high high). As the levels of DWT going on increases the LL component of previous level will be treated as the input for next level for further decomposition. As compare to DCT in DWT has following advantages.

- Human Visual System (HVS) is more realistic.
- Multi-resolution approach.
- DFT and DCT are full frame transform, and hence any change in the transform coefficients affects the entire image except if DCT is implemented using a block based approach. However DWT has spatial frequency locality, which means if signal is embedded it will affect the image locally [16]. Hence a wavelet transform provides both frequency and spatial description for an image.

The various level decomposition of DWT shown in Fig. 1.

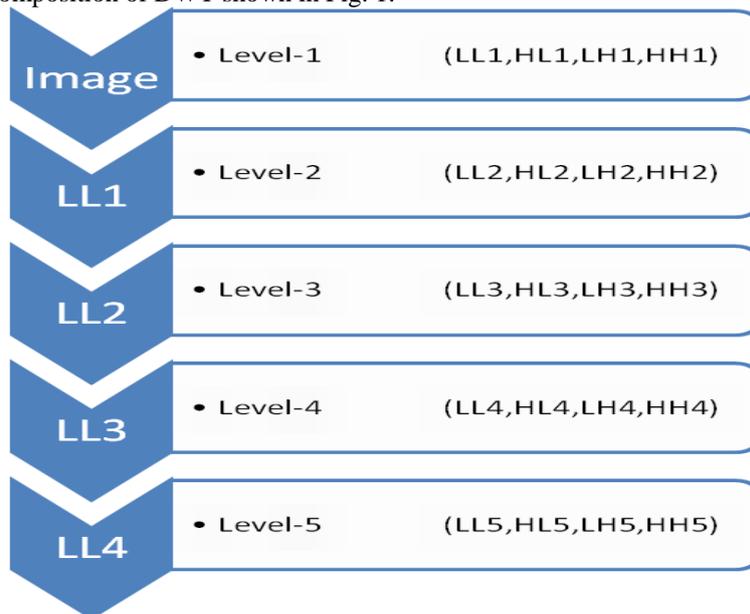


Fig. 1 Multi Level Decomposition of DWT

The input for each level is shown on the left side of the Fig. 1. For each level low pass and high pass filters are used to decompose the image.

### IV. PROPOSED DIGITAL VIDEO WATERMARKING TECHNIQUE

The complete watermarking process composed of two phases – Embedding and Extraction phases. Both these phases are explained in this section including their mathematical models used. This section only consider the 5-level DWT that is proposed one but the simulation results also include with 3 and 4 levels of DWT.

#### A. Embedding Phase

The flow chart of embedding phase is shown in Fig. 2. The complete algorithm consists following steps.

Step 1: Convert the continuous test video into still frames and their grayscale conversion for further processing.

Step 2: Enter the watermark image with extension and convert into grayscale.

Step 3: Enter the secret key that will also require initiating the extraction phase.

Step 4: Apply 5-Level DWT on each frame and watermark image.

Step 5: Insert watermark image's low frequency component (L\_LL5) in test video's low frequency component (LL5) using scaling parameter alpha 0.05 as per (1).

$$WM = (LL5) + \alpha * (W\_LL5) \quad (1)$$

Step 6: Generate three random watermark signals and convert them into column vector.

Step 7: Insert watermark signal in middle and high frequency components using (2).

$$mDWT_n(x, y) = DWT_n(x, y) + \sigma | DWT_n | WMI(x, y) \quad (2)$$

Step 8: Apply inverse 5-Level DWT to reconvert frequency domain into spatial domain that results in watermarked video.

#### B. Extraction Phase

The flow chart of embedding phase is shown in Fig. 3. The complete algorithm consists following steps.

Step 1: Convert watermarked video into still frames.

Step 2: Enter secret key to initiate extraction phase, the key must be same as entered in embedding phase.

Step 3: Apply 5-Level DWT on each frame of watermarked video.

Step 4: Extract image watermark using (3) in low frequency component of watermarked frame after applying 5-level DWT.

$$WMI_{recovered} = WM(LL5) - (LL5) \quad (3)$$

Step 5: Generate same watermark signal coefficients that were used in embedding phase so as to provide threshold value for detection given in (4).

$$Ts = \frac{\sigma}{N * N} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} |DWT_n(x, y)| \quad (4)$$

Step 6: Now compute the value of each DWT coefficient using (5) and compare with threshold given by (4).

$$DWT_{coeff.} = \frac{1}{N * N} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} DWT_n * WI(x, y) \quad (5)$$

Step 7: Compare  $DWT_{coeff.}$  with  $Ts$ , if  $DWT_{coeff.} > Ts$ , then watermark detection considered.

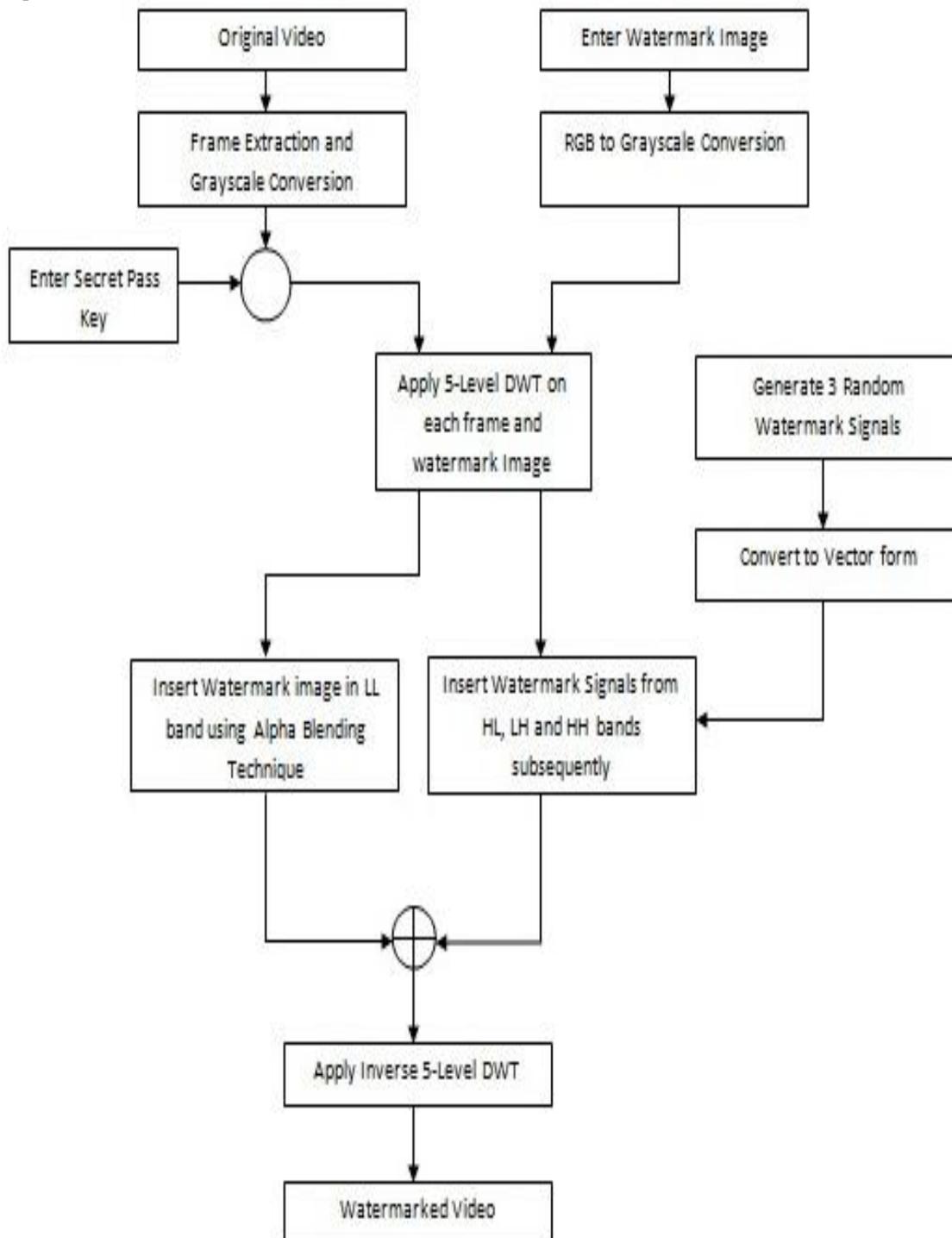


Fig. 2 Proposed Embedding Procedure

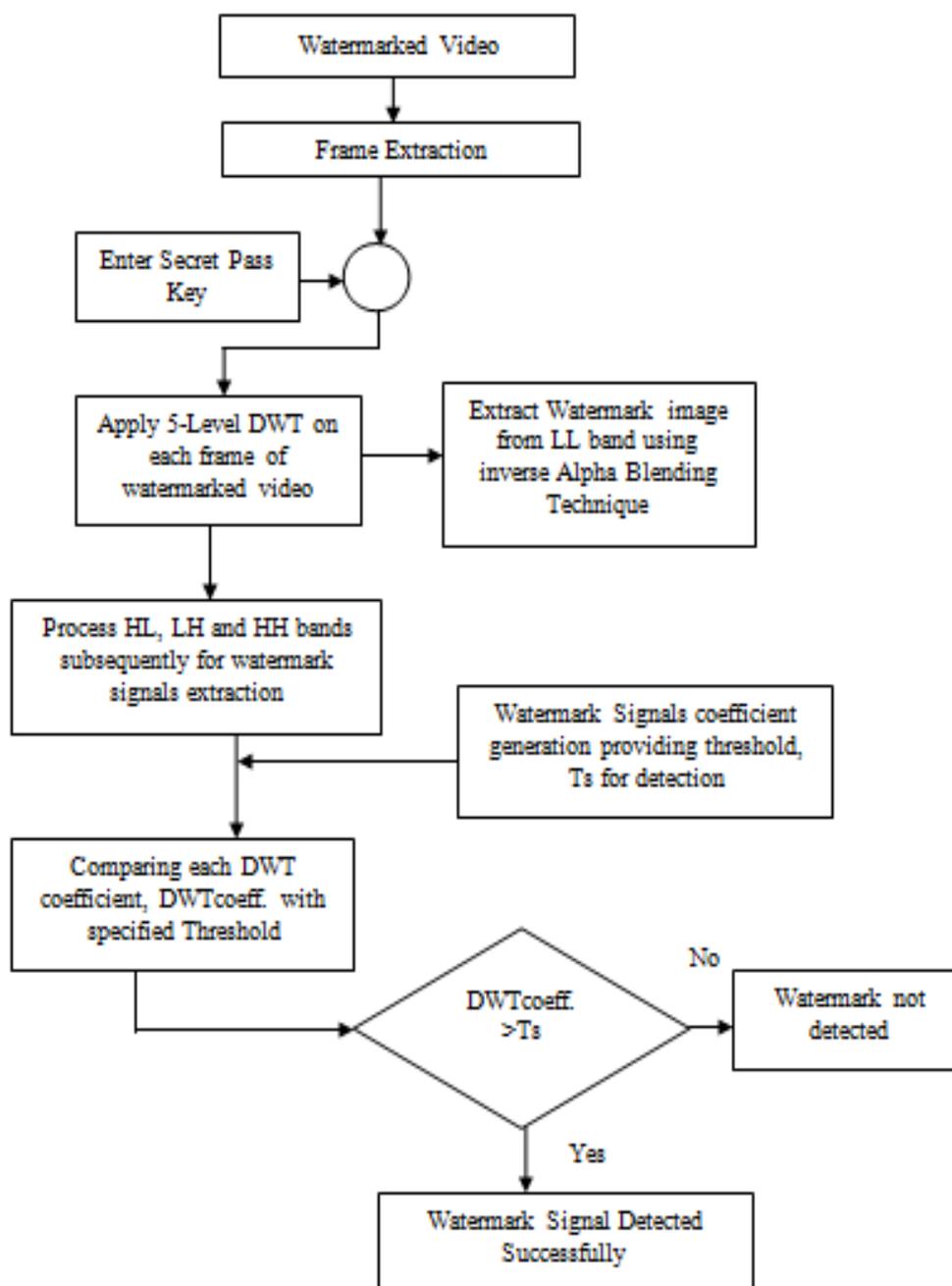


Fig. 3 Proposed Extraction Procedure

### V. SIMULATION RESULTS

In this section we introduced simulation outcomes and their evaluation. The experimental results of 5-Level DWT are demonstrated and compare it with 3 and 4 Level DWT.

#### A. Simulation Parameters

In this a test video of dimensions (640x360) consisting of total 60 frames has been used. The source of test video is YouTube. The watermark image used having dimensions (225x225). The simulation has performed on MATLAB (R2012a) version 7.14, Core i5 2.53 GHz CPU, 3GB RAM machine. Some sample frames of test video shown in Fig. 4.



Fig. 4 Reference frames of test video

The watermark image is shown in Fig. 5.



Fig. 5 Watermark Image

### B. Evaluation Parameters

For measuring the performance of watermarking technique the following parameters are used.

1) *PSNR*: Peak Signal to Noise Ratio is used to measure the quality of the video after embedding the watermark. It is usually measured in dB. Thus, this parameter can be used for perceptual excellence measurement. But PSNR cannot be directly calculate before this we have to find out Mean Square Error between original and watermarked frames by using (6) followed by (7) for PSNR.

$$MSE = \left( \frac{1}{M * N} \right) \sum_{i=1}^M \sum_{j=1}^N (a_{ij} - b_{ij})^2 \quad (6)$$

$a_{ij}$  means the pixel value at position (i, j) in the cover-frame and  $b_{ij}$  means the pixel value at the same position in the corresponding watermarked image.

$$PSNR = 10 \log_{10} \frac{255^2}{MSE} \quad (7)$$

2) *Success Rate (SR)*: This parameter indicates that how much successful watermark detection has done, it means that it is used to indicate that how much system is robust against noise. It is the ratio of total number of extracted watermarks to the total number of embedded watermarks. It is given by (8).

$$SR (\%) = \frac{\text{Number of Successfully Extracted Watermarks}}{\text{Number of total embedded watermark}} * 100 \quad (8)$$

3) *Correlation Coefficient (Cr)*: for measuring robustness for an image watermark two dimensional correlation coefficient has been calculated using equation (9).

$$Cr = \frac{\sum_x \sum_y (A_{xy} - \bar{A})(B_{xy} - \bar{B})}{\sqrt{(\sum_x \sum_y (A_{xy} - \bar{A})^2)(\sum_x \sum_y (B_{xy} - \bar{B})^2)}} \quad (9)$$

where  $\bar{A}$  is mean of A and  $\bar{B}$  is mean of B, x and y are pixel coordinates.

4) *Computational Time*: This performance parameter indicates the total time spend in watermarking process. In this factor both embedding time and extraction time will be considered.

### C. Perceptibility Excellence

The perceptual visibility can be measured on the basis of Peak Signal to Noise Ratio (PSNR) of original video frames and watermark frames. Normally, the PSNR of above 30dB considered as good quality of the watermarked video frames. Table I shows the PSNR values achieved with and without noise factors in case of 3, 4 and 5-DWT.

Table I Perceptibility Measure (PSNR in dB)

	PSNR Achieved without Noise				PSNR Achieved without Noise		
	3-DWT	4-DWT	5-DWT		3-DWT	4-DWT	5-DWT
	82.15	82.3741	82.6159		82.15	82.3741	82.6159
Gaussian Noise (Variance)	PSNR Achieved with Noise			Salt & Pepper Noise (Density)	PSNR Achieved with Noise		
0.001	38.6573	38.6805	38.7041	0.001	57.0514	57.166	57.1122
0.002	34.8257	34.8355	34.8391	0.002	54.1252	54.0728	54.0917
0.007	30.7108	30.7086	30.7088	0.007	48.6879	48.7004	48.6693
0.01	30.0227	30.0191	30.0196	0.01	47.1534	47.1379	47.1228
0.02	29.0612	29.0577	29.0579	0.02	44.1293	44.1345	44.1102
0.03	28.6646	28.6624	28.6615	0.03	42.3556	42.3618	42.3757
				0.05	40.1458	40.1476	40.1592

In terms of perceptual quality of cover video frames and watermarked video frames the PSNR (Peak Signal to Noise Ratio) is almost same in case of 3,4 and 5-level DWT with and without noise attacks. This can be shown in Fig. 6 and Fig. 7 for test video having 60 frames for Gaussian and Salt & Pepper noise respectively.

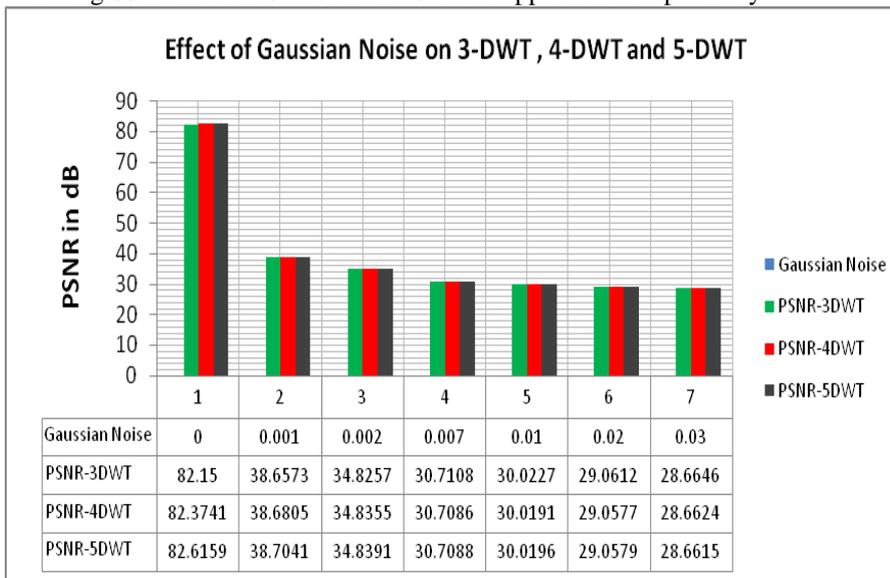


Fig. 6 PSNR comparison of 3-DWT, 4-DWT and Proposed 5-DWT with Gaussian Noise

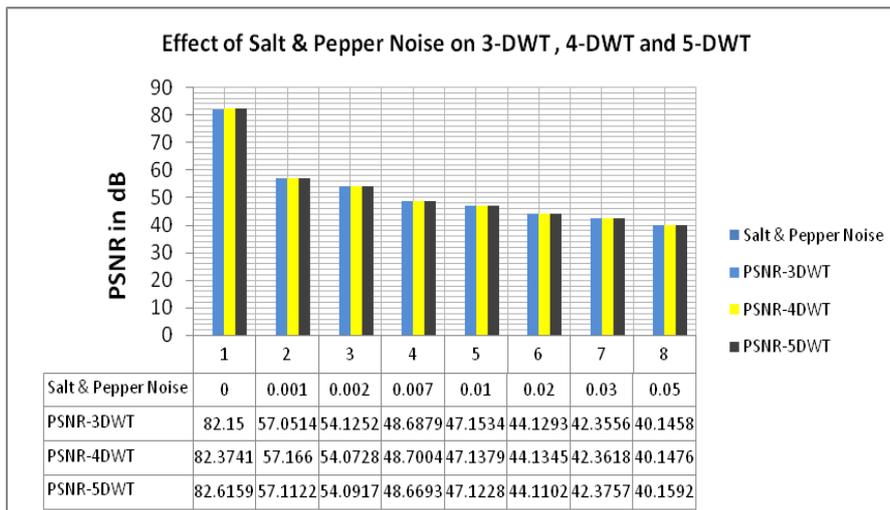


Fig. 7 PSNR comparison of 3-DWT, 4-DWT and Proposed 5-DWT with Salt & Pepper Noise

#### D. Robustness

It ensures the availability of watermarked signal even in the presence of attacks. For measuring robustness, we introduce a parameter known as Success Rate (SR). As well as for extracted watermark image must be correlated to the original embedded watermark image in order to show how much extracted watermark resembles with original one. Table II and Table III shows the robustness of 3, 4 and 5-Level DWT with cover video in which 3 random watermark signals was embedded as well as Correlation Coefficient (Cr) between original watermark image and extracted watermark image.

Table II Robustness Measure using Success Rate

	SR (%) Achieved without Noise				SR (%) Achieved without Noise		
	3-DWT	4-DWT	5-DWT		3-DWT	4-DWT	5-DWT
	100	100	100		100	100	100
Gaussian Noise (Variance)	SR (%) Achieved with Noise			Salt & Pepper Noise (Density)	SR (%) Achieved with Noise		
0.001	100	100	100	0.001	100	100	100
0.002	100	100	100	0.002	100	100	100
0.007	66.6	66.6	66.6	0.007	100	100	100
0.01	66.6	33.3	66.6	0.01	66.6	100	100
0.02	0	33.3	33.3	0.02	66.6	100	100
0.03	0	0	33.3	0.03	33.3	66.6	66.6
				0.05	0	33.3	66.6

Table III Robustness Measure using Correlation Coefficient

	Cr Achieved without Noise				Cr Achieved without Noise		
	3-DWT	4-DWT	5-DWT		3-DWT	4-DWT	5-DWT
	0.99	0.99	0.99		0.99	0.99	0.99
Gaussian Noise (Variance)	Cr Achieved with Noise			Salt & Pepper Noise (Density)	Cr Achieved with Noise		
0.001	0.5467	0.8104	0.9031	0.001	0.74	0.9126	0.9376
0.002	0.4164	0.698	0.848	0.002	0.6181	0.8522	0.916
0.007	0.2275	0.4383	0.6164	0.007	0.3791	0.6636	0.8219
0.01	0.1865	0.3633	0.5216	0.01	0.3281	0.5863	0.7449
0.02	0.119	0.2253	0.3127	0.02	0.2215	0.4341	0.5989
0.03	0.0856	0.1535	0.2052	0.03	0.1793	0.3343	0.4774
				0.05	0.1293	0.2199	0.3118

The comparison of 3-Level DWT, 4-Level DWT with proposed 5-Level DWT method for robustness using noise effects in Test Video is presented in Fig. 8 and Fig. 9 for Gaussian and Salt & Pepper noise attacks respectively. Here we utilize Success Rate (SR) with respect to noise. As well as for showing robustness with extracted watermark image correlation coefficient (Cr) also plotted with respect to noise in Fig. 10 and Fig. 11.

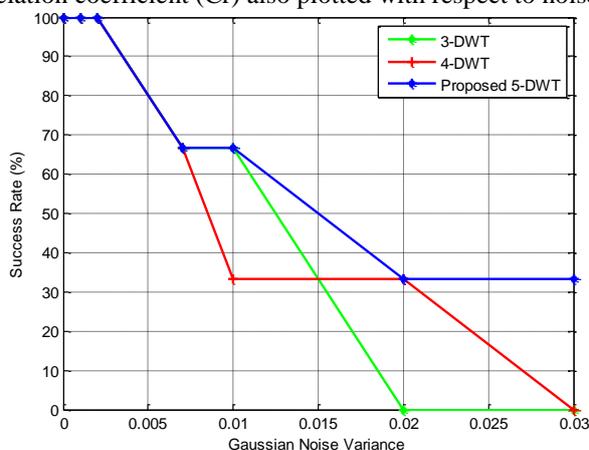


Fig. 8 Success Rate (%) for Gaussian Noise Attack

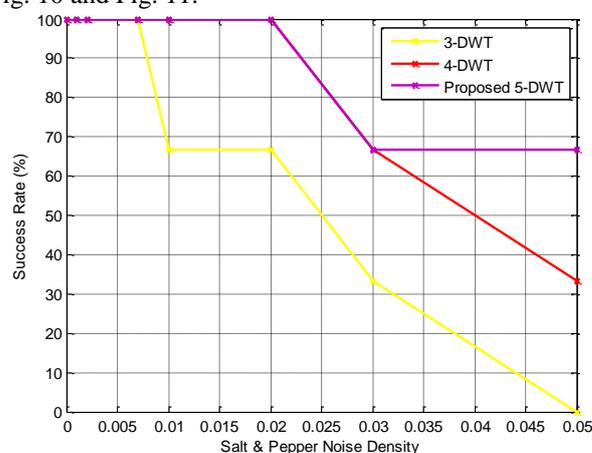


Fig. 9 Success Rate (%) for Salt & Pepper Noise Attack

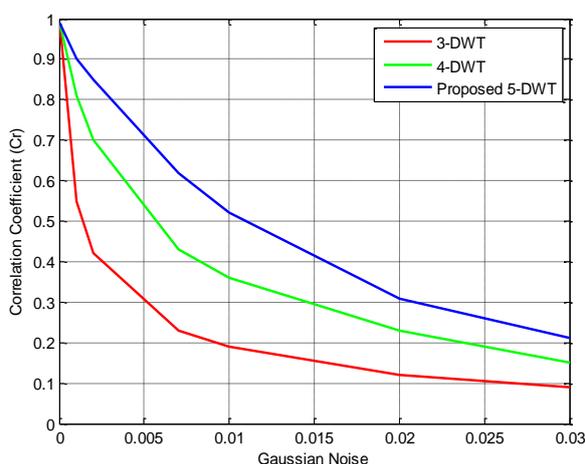


Fig. 10 Correlation Coefficient (Cr) for Gaussian Noise Attack

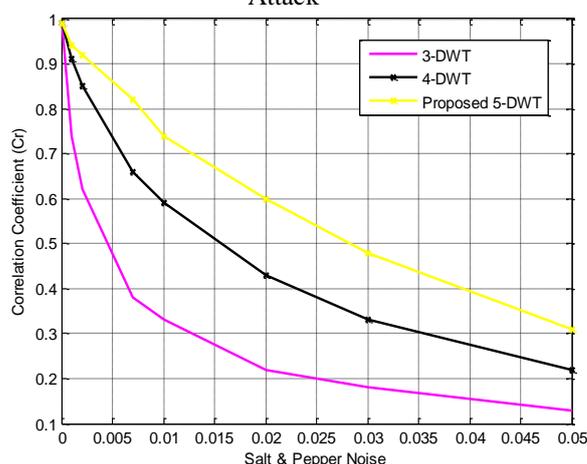


Fig. 11 Correlation Coefficient (Cr) for Salt & Pepper Noise Attack

The above figures clearly reflect that in proposed method the chances for successful watermark detection (%) on y axis in proposed 5-DWT method are more as compare to 3-DWT and 4-DWT watermarking approach. Also the extracted watermark correlation coefficient is more in case of proposed 5-DWT video watermarking technique.

E. Computational Time

This is also an important parameter in watermarking process. The time comparison between 3-DWT, 4-DWT and proposed method can be done using tic and toc command in MATLAB. Fig. 12 shows the computational time comparison between 3, 4 and 5-DWT methodologies.

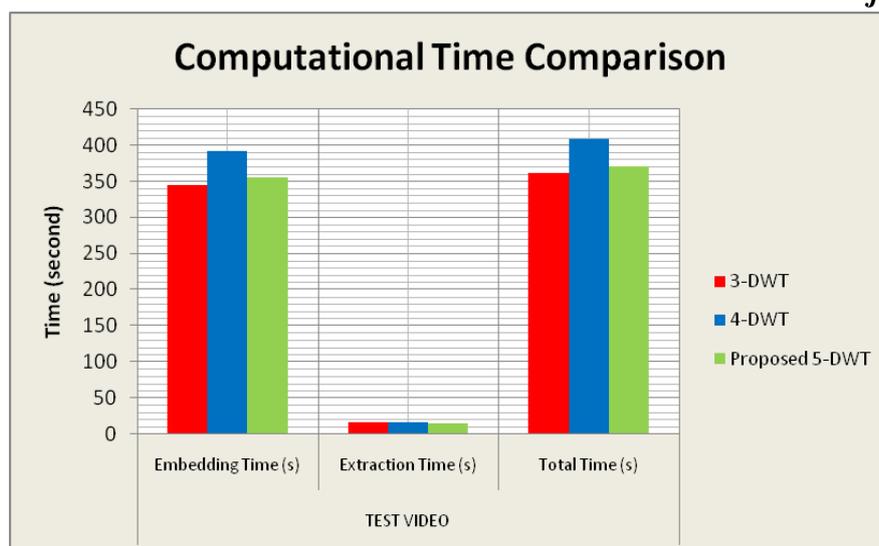


Fig. 12 Computational Time Comparison

From Fig. 12 the time efficiency in terms of embedding, extraction and total time is shown. For Test Video the total embedding and extraction time is nearly equal for 3-DWT, 4-DWT and Proposed 5-DWT algorithm. This indicates that even adding complexity in the watermarking process by increasing the levels of DWT, the total time consumption does not vary abruptly. Thus, proposed method shows improved results in terms of robustness and computational time while maintaining the quality of the video.

## VI. CONCLUSIONS AND FUTURE SCOPE

A novel approach for digital video watermarking has been proposed in this work. Since, videos are transferred over the internet and freely accessible to all, thus robust copyright protection has been one of the major objectives of watermarking methods. The robustness in 3-Level DWT approach was restricted up to the variance 0.01 in Gaussian noise for more than 50% watermarks detection but it will increased up to 0.015 variance with proposed approach. Similarly, robustness in 3-Level DWT approach was restricted up to the density 0.02 in Salt & Pepper noise for more than 50% watermarks detection but it will increased up to 0.05 density with proposed approach. The robustness in 4-Level DWT approach was restricted up to the variance 0.01 in Gaussian noise for more than 50% watermarks detection but it will increased up to 0.015 variance with proposed approach. Similarly, robustness in 4-Level DWT approach was restricted up to the density 0.04 in Salt & Pepper noise for more than 50% watermarks detection but it will increased up to 0.05 density with proposed approach. The quality of the video has not been significantly degraded with the increase in noise. The proposed method has approximately same value of PSNR achieved as in 3-Level DWT and 4-Level DWT approach. The time consumption for overall watermarking process does not affected massively after increasing the levels of DWT. As a future work, this work can be extended for compressed videos using other optimization techniques such as Singular Value Decomposition (SVD) with 5-Level DWT.

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