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SVD-DWT Based Digital Video Watermarking Using Fused Images and Low-Middle Frequency Bands

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Abstract— ***Now days, Robust Video watermarking become a challenge for researchers as it is used to sustain the copyrights of the owner. Most of the developed watermarking algorithm based on frequency domain because this approach provides better results as compare to spatial domain approach. In this paper we proposed a Graphical User Interface (GUI) based SVD-DWT Video Watermarking using Fused Images and Low-Middle frequency bands. In this work, two watermark images are used in fused manner using wavelet fusion. The basic approach used in this work is to utilize the benefits of Singular Value Decomposition (SVD) and Discrete Wavelet Transform (DWT). For embedding watermark Low and Middle frequency bands are used as they provide more robustness against geometric attacks such as cropping, rotation etc. The performance of the proposed algorithm has been evaluated using two parameters such as Peak Signal to Noise Ration (PSNR) and Correlation Coefficient (CC) under various noise attacks like Gaussian and Salt & Pepper Noise attacks, geometric attacks – rotation and cropping. The simulation results shows that proposed method has better results as compared to SVD-DWT hybridization, DWT and SVD approaches.***

Keywords— ***Correlation Coefficient (CC), Discrete Wavelet Transform, Fused, Singular Value Decomposition***

I. INTRODUCTION

In recent times, due to enormous developments in internet technology, multimedia information i.e. audio, images and video have found wide applications. Digital watermarking is one of the best solutions to avoid illegal copying, modifying and redistributing multimedia data [1]. As far as the security is concern while transferring any multimedia content, digital watermarking becomes popular. Many types of watermarking techniques had been proposed so far. Watermarking is a process of embedding some data into original multimedia content in hidden manner. Embedded watermark can be extracted at later stage in order to claim copyrights [2]. While designing any watermarking algorithm there are some requirements that had to be fulfilled. These requirements are as following [3]:

- Transparency or Fidelity: The watermark must be embedded in such a manner that it does not affect the quality of the original content.
- Robustness: It is defined as the ability to detect the watermark in the presence of various signal manipulation operations. These operations can be applied in international or unintentional manner but the robustness of an algorithm entirely depends upon the maximum limit of noise that can be tolerated by system.
- Capacity: This indicates that how many numbers of bits can be embedded in cover media or original content.

Till now for different multimedia contents such as images, audio and video etc. a number of watermarking algorithms exist but still these algorithms had some limitations especially for video watermarking techniques. Thus, Digital video watermarking is novel technology used for copyright shield of digital media that inserts authentication information in multimedia data which can be used as evidence of ownership. Most of the proposed video watermarking schemes are based on the techniques of image watermarking. But video watermarking introduces several issues that are not exists in image watermarking [4]. The basic digital video watermarking is shown in Fig. 1.

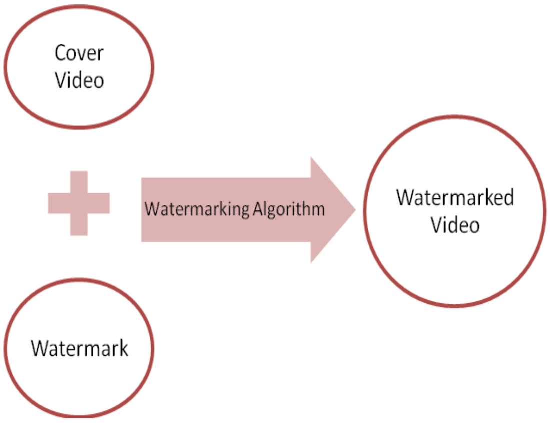

Fig. 1 Digital Video Watermarking

There exists a number of watermarking techniques depends upon many factors exposed in Fig. 2.

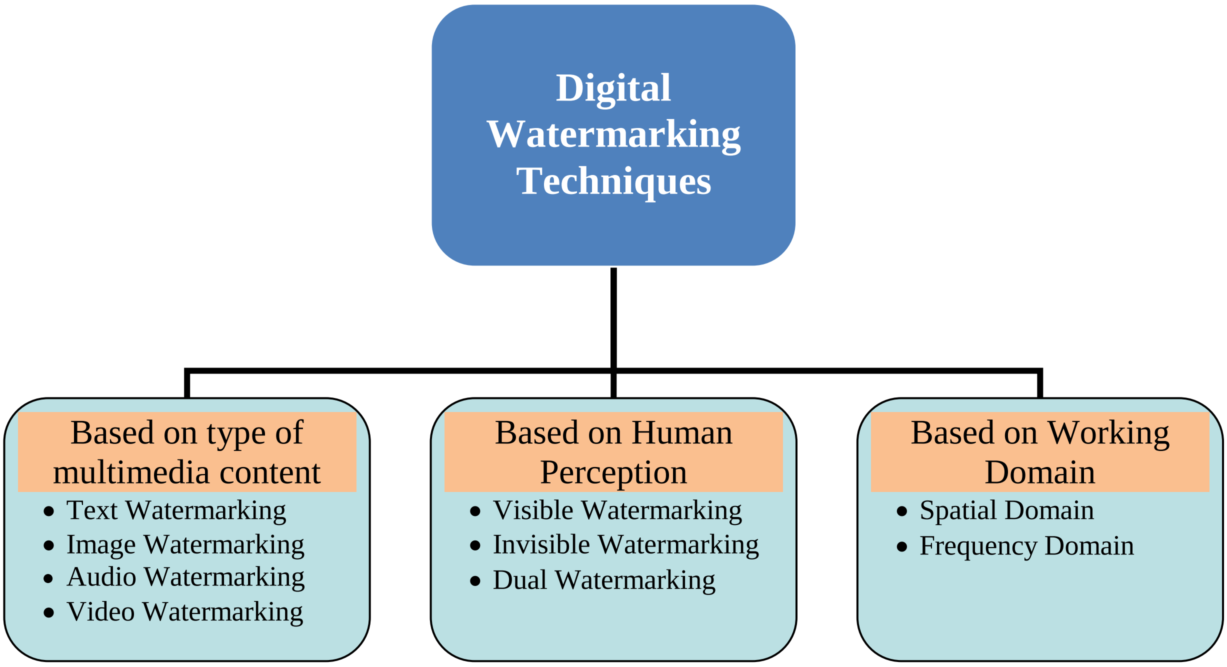

Fig. 2 Digital Video Watermarking Techniques

In this paper we proposed SVD-DWT based video watermarking technique that utilizes low and middle frequency components for embedding the multiple watermarks in fused manner. Now here is brief outline of this paper, in section I introduction regarding digital watermarking has been presented followed by some related work whose core is related to video watermarking in section II. In section III SVD and DWT has been discussed followed by proposed video watermarking technique in section IV. Section V covers results and conclusion and finally in section VI future scope of this work presented.

II. RELATED WORK

A lot of work has been done in the field of video watermarking including spatial and frequency domain approaches in visible or invisible manner. In this section some important work done had been presented.

Hemdan et al. [5] proposed a hybrid image watermarking technique using Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) using multiple fused watermarks through wavelet fusion algorithm. In this work firstly cover image is transformed into wavelet components using DWT, in parallel order watermark images get fused to form a single watermark matrix. Then SVD is applied on cover image frequency components obtained using DWT. The diagonal component of SVD has been utilized for adding watermark matrix to obtain a new modified matrix. Then SVD is applied on new modified matrix and finally the watermarked image obtained by taking the inverse DWT (IDWT) of the multiplication of orthogonal components of original image and diagonal component of modified matrix. For extraction of watermark reverse process was utilized. For performance measurement the parameters used were Peak Signal to Noise Ration (PSNR) and Correlation Coefficient. Results were tested against cameraman image. In the presence of no noise PSNR achieved up to 64.31 with correlation coefficient 1. In presence of Gaussian noise with variance 0.01 the PSNR achieved 20.69. In this work filtering and cropping effects also discussed. The proposed technique performed well as compare to traditional watermarking techniques in terms of robustness and perceptual quality. The main limitation of this work is that it does not deal with time consumption in watermarking process because for any watermarking process it is very important factor as well as noise like salt & pepper must be considered. As a future scope of this work this technique can be implemented for digital videos also and by increasing the number of levels of DWT the robustness can be further improved.

Madhesiya et al. [6] proposed an advanced digital watermarking technique which was based on Singular Value Decomposition (SVD), Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Arnold transform. In this work the compression property of DCT, scalability of DWT, resiliency of SVD and robustness of Arnold transform utilized. For experimental purpose gray-scale image of Lena with size 256x256 was used and same image with dimension 64x64 used as watermark image. For performance measurement PSNR was calculated. Robustness of the technique was estimated using Gaussian noise attack, cropping and rotation attacks, JPEG compression and blurring attacks. This work was only limited for images only and can be extended for videos also.

Khan et al. [7] introduced a combined watermarking system for images using DCT, DWT and SVD. In this work for embedding the watermark firstly single level DWT was applied at cover image and then on HH band DCT is applied. After this, SVD applied at zigzag DCT coefficients. Traversing the embedding procedure in reverse order results in extraction of the watermark. PSNR and Normalized Correlation (NC) were computed. This work was only limited for images only and can be extended for videos also.

Rathod et al. [8] proposed hybrid video watermarking technique using DWT and SVD. In this work in first phase the continuous movie clip is converted into still video frames, then two dimensional DWT is applied on video frames followed by SVD for embedding the watermark signals. After this still frames were converted into .avi format movie using MATLAB software. For extraction of watermark again watermarked video converted into still frames and then DWT is applied. Then SVD is applied and watermark signal was extracted as a difference of new matrix and original SVD diagonal component. This proposed method found to be better than DCT technique as it is more imperceptible, robust and fast processing time.

Saxena et al. [9] proposed DWT-SVD based semi blind image watermarking technique using high frequency bands of DWT because these bands are less susceptible to noise. The concept of semi-blind watermarking is that in which secret key and the watermark bit sequence must be known to extract the watermark. The main reason to choose SVD is that singular values do not change significantly when a small perturbation is added to the image. The results of this work have been evaluated using 256x256 grayscale images. Scaling factor used in this work having value 0.02. The PSNR value between 20dB to 50dB was achieved. The main limitation of this work is that it consumes too much time in embedding and extraction process and is limited only for images that can be extend to videos also.

Agarwal et al. [10] demonstrate a hybrid digital video watermarking scheme based on discrete wavelet transform and singular value decomposition. In this work instead of using binary image as a watermark as in [19], grayscale images are used as a watermark. The video frames firstly converted into YCbCr color space and then decomposing the luminance part (Y component) into four sub-bands using DWT, after this SVD applied on low frequency part that is LL band for embedding watermark image. This scheme was tested against rotation, cropping, histogram stretching, JPEG compression, salt and pepper noise, frame averaging etc.

III. PRELIMINARIES

The work proposed in this paper mainly utilizes Singular Value Decomposition (SVD) and Discrete Wavelet Transform (DWT). In this section we elaborate these two techniques in detail.

A. Singular Value Decomposition (SVD)

SVD is a mathematical tool used for reduction of any two dimensional matrix problems. An image can also be represented by two dimensional matrices. Thus, SVD can be used in image processing due to its properties such as transpose, stability etc. The mathematical model used in SVD explained here [11]. SVD of an mxn matrix M is a factorization of M into a product of three matrices given by (1).

$$M = U \sum V^T \tag{1}$$

where U is mxm matrix, V is nxn matrix and both these matrices are orthogonal matrices (Matrix M is orthogonal if $M*M^T=I$). Σ = diag ($\sigma 1, \sigma 2, \ldots, \sigma p$) is mxn diagonal matrix with ($\sigma 1, \sigma 2, \ldots \sigma p \geq 0$). σi are called singular values of M and they are positive square root of the eigenvalues of MM^T. The columns of U (orthogonal eigenvector of MM^T) are called left singular vectors of M while columns of V (orthogonal eigenvector of M^TM) are called right singular vectors of M. SVD is a method for transforming correlated variables into a set of uncorrelated ones that better expose the various relationship among the original data items. Hence, SVD can be treated as a method for data reduction [11].

B. Discrete Wavelet Transform (DWT)

In numerical analysis and functional analysis, a Discrete Wavelet Transform (DWT) is any wavelet transform for which the wavelets are disjointedly sampled. As with other wavelet transforms, a key benefit it has over Fourier transforms is temporal resolution: it captures both frequency and location information (location in time). The main feature of DWT is multi-scale representation of function. By using the wavelets, given function can be analyzed at various levels of resolution. The DWT is also invertible and can be orthogonal [12]. The first DWT was invented by the Hungarian mathematician Alfréd Haar. For an input represented by a list of 2^n numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale: finally resulting in 2^n-1 differences and one final sum [13]. The Haar DWT illustrates the desirable properties of wavelets in general. First, it can be performed in O(n) operations; second, it captures not only a notion of the frequency content of the input, by examining it at different scales, but also temporal content, i.e. the times at which these frequencies occur. Combined, these two properties make the Fast wavelet transform (FWT) an alternative to the conventional Fast Fourier Transform (FFT).

IV. PROPOSED WORK

In this proposed work DWT and SVD are used for embedding watermark information in fused manner. The complete work is divided into two parts embedding and extraction. Now, one by one both parts have been explained in this part including their mathematical models, algorithm and flow charts.

A. Wavelet based Image Fusion

Before actual watermarking starts, the watermark images get fused to provide the mechanism that can embed multiple watermarks in the original content. In this work, 2-D Discrete Stationary Wavelet Transform (SWT) has been used for the fusion of watermark images. In Matlab 'swt2' command performs a multilevel 2-D stationary wavelet decomposition using either a specific orthogonal wavelet or specific orthogonal wavelet decomposition filters. The Discrete Wavelet

Transform is not a time invariant transform. The way to restore the translation invariance is to average some slightly different DWT, called un-decimated DWT, to define the stationary wavelet transform (SWT). On the other hand, in decimated algorithm; the filters are functional first to the rows and then to the columns. In this case, however, although the four images formed (one approximation and three detail images) are at half the resolution of the original; they are the same size as the original image [14]. Let X (m,n) and Y (m,n) are the images to be fused, the decomposed low frequency sub-images of X (m,n) and Y (m,n) are L_X (m,n) and L_Y (m,n) respectively. The fused low frequency sub-image FZ (m,n) is given by (2).

$$FZ(m,n) = a1 * L\_X(m,n) + a2 * L\_Y(m,n) \qquad (2)$$

where a1 and a2 are scaling constants. Take the absolute values of horizontal details of the image and subtract the second part of the image from first one.

$$D = (abs(H1L1)-abs(H2L1))>=0 \qquad (3)$$

For fused horizontal part make element wise multiplication of D and horizontal detail of first image and then subtract another horizontal detail of second image multiplied by logical not of D from first. Find D for vertical and diagonal parts and obtain the fused vertical and details of image. Same process is repeated for fusion at first level. Fused image is obtained by taking inverse stationary wavelet transform [15]. The complete fusion process is shown in Fig. 3.

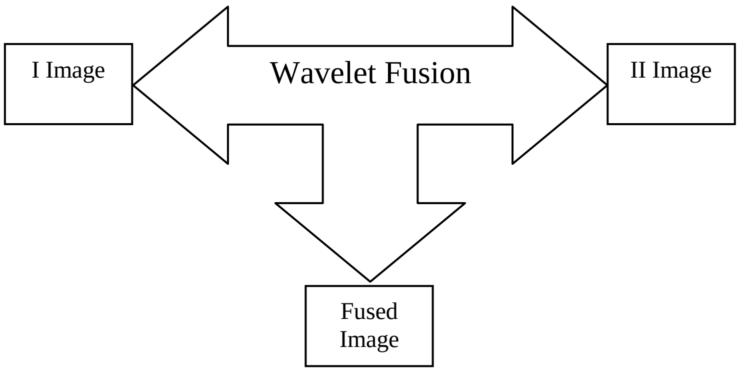

Fig. 3 Wavelet based Image Fusion

B. Embedding Phase of Proposed Algorithm

Once cover medium has been selected first of all 2-Level DWT applied on each individual frames and fused watermark result. Let the cover frame denoted by A(x,y) and fused watermark is B(x,y). The 1-Level DWT decompose A(x,y) and B (x,y) into A(x,y) = [LL, LH, HL, HH] and B(x,y) = [L_L, L-H, H_L, H_H] respectively. Now, take low and middle frequency bands and again apply 1-DWT as shown in Fig. 4 and Fig. 5 for original frame and watermark image.

Fig. 4 Low and Middle Frequency Decomposition of Cover Frame

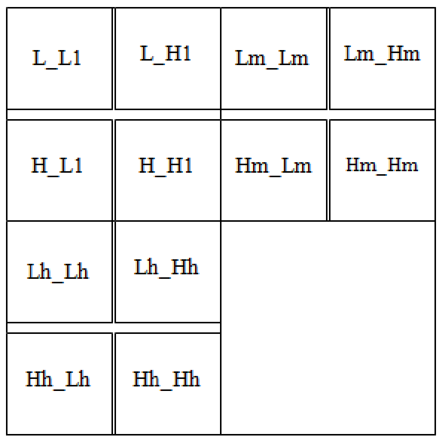

Fig. 5 Low and Middle Frequency Decomposition of Watermark Image

Now, apply SVD on the low frequency band obtained from low and middle frequency bands as given.

$$[U, S, V] = svd(LL1) \qquad (4)$$

$$[Um, Sm, Vm] = svd(LmLm) \qquad (5)$$

$$[Uh, Sh, Vh] = svd(LhLh) \qquad (6)$$

Embed the fused watermark image with the singular value of original content with a scaling coefficient given by (7), (8) and (9).

$$SigmaN = S + \alpha * L\_Li \qquad (7)$$

$$SigmaNm = Sm + \alpha * Lm\_Lm \qquad (8)$$

$$SigmaNh = Sh + \alpha * Lh\_Lh \qquad (9)$$

where α is a scaling coefficient and its value can be varied between 0 and 1, in this work its value is considered as 0.05. L_Li is low and Middle frequency bands such as L_L1, Lm_Lm and Lh_Lh. Now again apply SVD on SigmaN, SigmaNm and SigmaNh to obtain the orthogonal and singular components of watermarked frames.

$$[Uw, Sw, Vw] = svd\ (SigmaN) \quad (10)$$

$$[Uw1, Sw1, Vw1] = svd\ (SigmaNm) \quad (11)$$

$$[Uw2, Sw2, Vw2] = svd\ (SigmaNh) \quad (12)$$

Finally, the watermarked low and middle frequency components can be obtained by using (13), (14) and (15).

$$Aw = U*Sw*V^T \quad (13)$$

$$Bw = Um*Sw1*Vm^T \quad (14)$$

$$Cw = Uh*Sw2*Vh^T \quad (15)$$

Now, apply Inverse Discrete Wavelet Transform to get the watermarked frames.

$$WI\_LL = idwt2(Aw, LH1, HL1, HH1) \quad (16)$$

$$WI\_LH = idwt2(Bw, LmHm, HmLm, HmHm) \quad (17)$$

$$WI\_HL = idwt2(Cw, LhHh, HhLh, HhHh) \quad (18)$$

$$WI\_final = idwt2(WI\_LL, WI\_LH, WI\_HL, HH,) \quad (19)$$

These watermarked frames get converted into video result in watermarked video. The flow chart of proposed embedding algorithm is shown in Fig. 6.

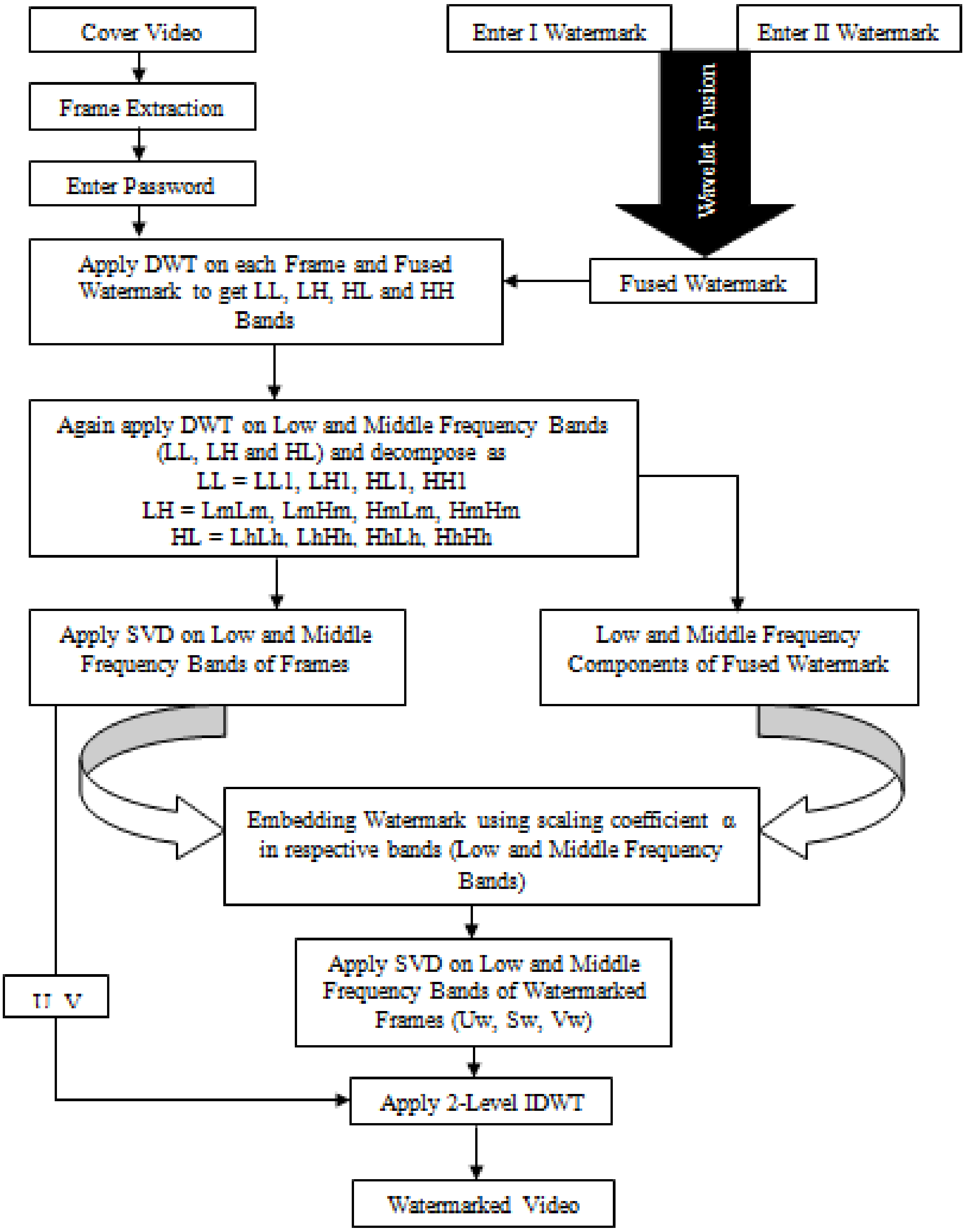

Fig. 6 Proposed Embedding Algorithm

C. Extraction Phase of Proposed Algorithm

First of all, before initiating watermark extraction phase the secret key must be checked against the key entered at the time of embedding. Once a key match found the extraction phase begins. The watermarked video gets converted into still frames. Apply 1-Level DWT on each watermarked frame. Let Z(x,y) a given watermarked frame and 1-Level DWT decompose into Z(x,y) = [LLw, LHw, HLw, HHw]. Now select low and middle frequency components as [A, B, C] for further decomposition using DWT given by (20), (21) and (22).

$$[LLw1\ LHw1\ HLw1\ HHw1] = dwt2\ (LLw) \quad (20)$$

$$[LmwLmw\ LmwHmw,\ HmwLmw,\ HmwHmw] = dwt2\ (LHw) \quad (21)$$

$$[LhwLhw,\ LhwHhw,\ HhwLhw,\ HhwHhw] = dwt2\ (HLw) \quad (22)$$

Apply SVD on low and middle frequency components as given by (23), (24) and (25).

$$[U1\ S1\ V1] = svd\ (LLw1) \quad (23)$$

$$[U2\ S2\ V2] = svd\ (LmwLmw) \quad (24)$$

$$[U3\ S3\ V3] = svd\ (LhwLhw) \quad (25)$$

Now make three matrices corresponds to low and middle frequency components that include fused watermark image by using (26), (27) and (28).

$$X = Uw*S1*Vw^T \quad (26)$$

$$Y = Uw1*S2*Vw1^T \quad (27)$$

$$Z = Uw2*S2*Vw2^T \quad (28)$$

The fused watermark can be obtained using (29), (30) and (31).

$$recovered\_LL = (X-S) / \alpha \quad (29)$$

$$recovered\_LH = (Y-Sm) / \alpha \quad (30)$$

$$recovered\_HL = (Z-Sh) / \alpha \quad (31)$$

Now, apply anti-fusion to separate out individual watermark images. Thus, the proposed algorithm introduced two main features – multiple watermarks using image fusion and increasing robustness by using middle frequency bands including low frequency bands of DWT. The flow chart of proposed extraction algorithm is shown in Fig. 7.

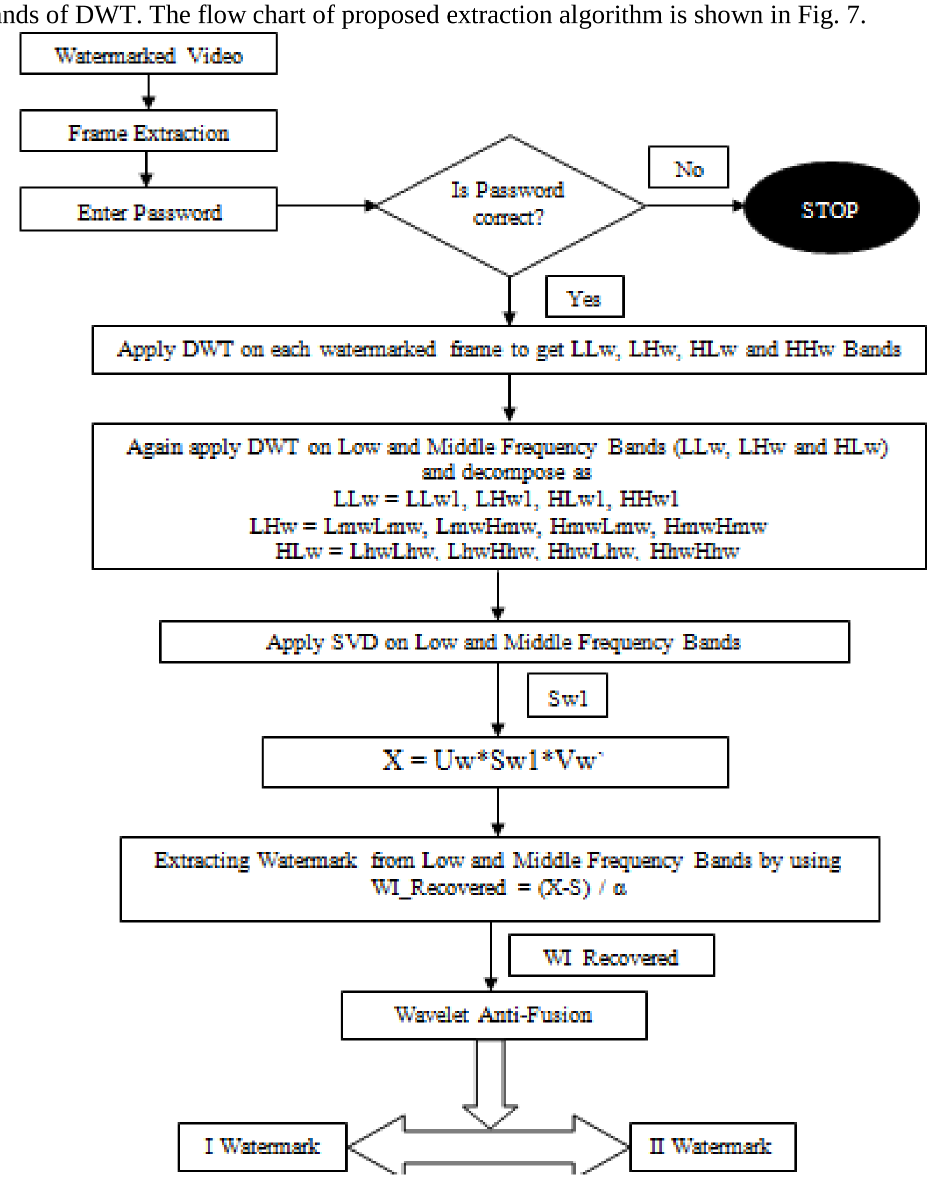

Fig. 7 Proposed Extraction Algorithm

V. SIMULATION RESULTS

In this section we present the simulation of our proposed watermarking algorithm in comparison with SVD and SVD-DWT hybrid approach.

A. Parameters for Performance Evaluation

We consider three parameters for evaluation of the work. The parameters used are as following.

- Peak Signal to Noise Ratio (PSNR) for fidelity measurement.
- Correlation Coefficient (CC) for robustness measurement.
- Computational Cost for time consumption measurement.

B. Simulation Parameters

In this thesis work, two test videos are being considered for watermarking purpose and two images are used as a watermark in a fused manner using wavelet fusion. The various parameters related to test videos are mentioned in Table I.

Table I Simulation Parameters

Parameters	**Test Video-1**	**Test Video-2**
Dimension (width x height)	322 x 240	640 x 360
Duration in seconds	9	8
Total Frames	135	120
Frame Rate (Frames/sec)	15	15

The proposed algorithm has been implemented MATLAB (R2013a) version 8.1.0.604, Core2Duo CPU, 4 GB RAM machine. Images used as watermark is of '.jpeg' format with dimensions as 256x256 and 512x512 for watermark I and II respectively. The images used as watermark is shown in Fig. 8. and their fusion is shown in Fig. 9.

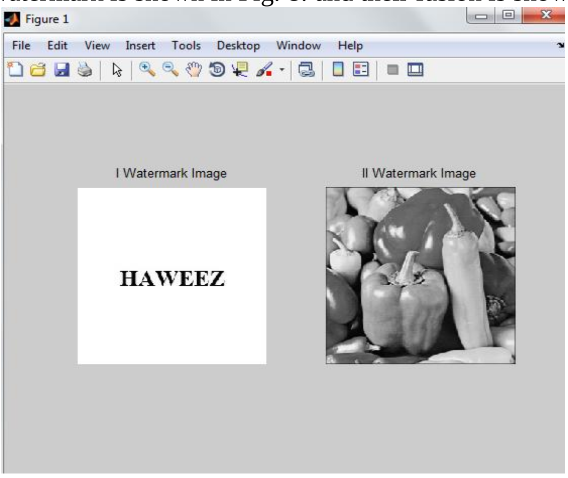

Fig. 8 Watermark Images

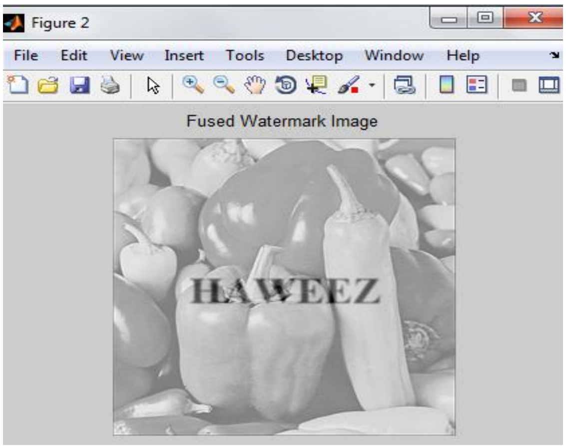

Fig. 9 Fused Watermarks

C. Fidelity Comparison

The comparison of proposed algorithm in terms of fidelity is shown in Fig. 10 and Fig. 11 for Test Video-I and Test Video-II respectively. The comparison has been done for various noise attacks such as Gaussian, Salt & Pepper, Rotation and Cropping attacks. From Fig. 10 and Fig. 11 it can be concluded that the proposed approach provides good quality of video after embedding watermark images.

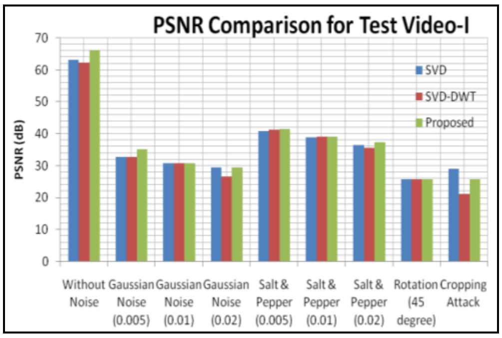

Fig. 10 PSNR Comparison for Test Video-I

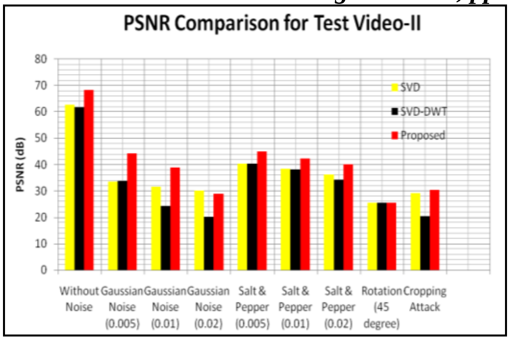

Fig. 11 PSNR Comparison for Test Video-II

The proposed Graphical User Interface based embedding phase of the watermarking algorithm is shown in Fig. 12.

Fig. 12 GUI for Watermarking Algorithm

D. Robustness Comparison

The comparison of proposed algorithm in terms of robustness is shown in Fig. 13 and Fig. 14 for Test Video-I and Test Video-II respectively. The comparison has been done for various noise attacks such as Gaussian, Salt & Pepper, Rotation and Cropping attacks. From Fig. 13 and Fig. 14 it can be concluded that the proposed approach provides high robustness especially for geometric attacks.

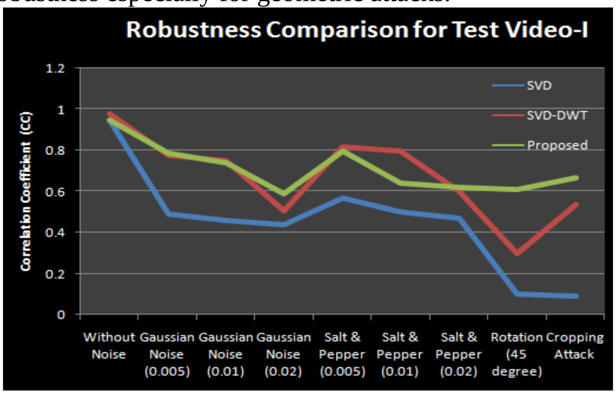

Fig. 13 Robustness Comparison for Test Video-I

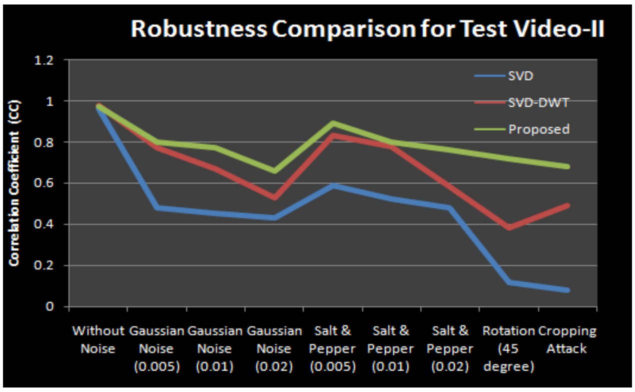

Fig. 14 Robustness Comparison for Test Video-II

E. Computational Cost

This parameter indicated the time required to perform watermarking. Actually, in practical application a technique having less computational cost can be treated as better one because in today's life most of the media transferred through internet and it is highly recommended that watermark must embed in real time processing. The comparison of Computation Cost related to SVD, SVD-DWT and Proposed Algorithm shown in Fig. 15.

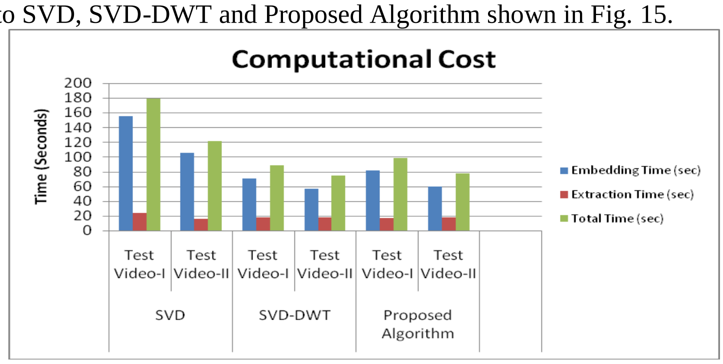

Fig. 14 Computational Cost Comparison

VI. CONCLUSIONS AND FUTURE SCOPE

In this work a SVD-DWT based Digital Video Watermarking using Fused Images and Low-Middle Frequency bands proposed. Various conclusions had been drawn from simulation results listed here.

- The proposed algorithm performs well as compare to SVD approach in terms of fidelity, robustness and computational time.
- Also, the proposed protocol is an enhancement of SVD-DWT hybrid approach [5] that utilizes only low frequency bands for embedding fused watermarks but in proposed low and middle frequency bands are used for embedding that result in more robustness especially against geometric attacks.
- The time required to execute the proposed algorithm is almost same required by SVD-DWT Hybrid approach.
- Proposed protocol is robust against Gaussian and Salt & Pepper Noise attacks.

Still there are scopes to improve this work. Though this watermarking scheme is resilient against translation but this work can be extend for other formats of video such as MPEG etc. Also an intelligent algorithm can be proposed that set the scaling factor for each frequency block independently by using neural networks.

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