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Analysis of Wavelet Based Digital Hybrid Watermarking

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***Abstract*— Watermarking is an intellectual protection system where the content whether an image or video is embedded with a watermark information. This embedding is done in such a way that the image perceptibility is not affected. In this paper, the hybrid techniques where Discrete Wavelet Transform (DWT) is used have been analyzed by embedding the watermark in each of the bands which are obtained after applying DWT. In this paper, analysis of hybrid techniques which is a combination of Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) are obtained. The hybrid combinations which are used to embed a watermark into image or video are DWT-SVD and DCT-DWT-SVD. The techniques are evaluated by parameters like Peak Signal to Noise Ratio (PSNR), Mean Absolute Error (MAE), Image Quality Index (IQI) and correlation.**

Keywords—**Watermarking, spatial frequency, DCT, DWT, SVD, PSNR, Correlation, MAE, IQI.**

I. INTRODUCTION

As the number of computers that are integrated onto the network are increasing at a drastic rate, the ease of copying and distribution of digital content have become easier and faster. This digital era where all the data are now processed digitally, lacks an intellectual protection system so that the illegal copy and distribution of digital content is forbidden. Watermarking is such an intellectual protection system where the data whether image or video is embedded with a watermark that can be a company logo or some random bits. Watermarking is embedding information into the cover image or video which will be able to show the ownership in case of any copyright issue.

The main types of watermarking are spatial domain and frequency domain. Spatial and frequency domain techniques again have different classification. Spatial domain watermarking has Least Significant Bit (LSB) [1] method where LSB value of cover image or frames of a video is replaced with LSB bits of watermark image and visible watermarking can be done using LSB method. Frequency domain watermarking makes use of techniques like Discrete Wavelet Transform (DWT) [1-7] and Discrete Cosine Transform (DCT) [1-6]. Applying DWT to an image or a video frame divides the image into four sub bands namely: LL, LH, HL, HH which represents the approximation and details of an image.

With the basic watermarking techniques, well known mathematical transformations are also used. Singular Value Decomposition (SVD) [4] and Principal Component Analysis (PCA) [7] are examples of such mathematical tools. SVD is used to decompose any rectangular real or complex matrix. PCA uses an orthogonal transformation which converts a set of observations which are possibly correlated variables into a set of values of uncorrelated variables.

The watermarking techniques can be applied on individual basis or some of the techniques such as DWT and DCT can be combined and a hybrid class of watermarking can be build. Hybrid techniques can be formed by combining DWT-SVD [4, 8], DCT-SVD [4, 8] and DCT-DWT-SVD [4, 8]. In this paper a hybrid watermarking technique consisting of DWT-SVD and DCT-DWT-SVD is used for watermarking image and video. Since DWT is used in both the techniques, embedding can be done in any of the bands of DWT. In this paper, embedding is done in different bands one by one and depending upon the values of objective parameter obtained, the best band is selected.

The paper is divided into 5 sections. Section II and III explains the hybrid watermarking algorithm for image and video respectively. Simulation results are discussed in section IV. Section V concludes the paper.

II. ALGORITHM FOR IMAGE WATERMARKING USING HYBRID TECHNIQUES

The methodology aims to model a hybrid watermarking technique using DWT- DCT- SVD.

Watermark Embedding Procedure [4]

The image to be watermarked and the watermark image are selected and one level DWT is applied to the cover and watermark image. The 1-D Discrete Wavelet Transform (DWT) decomposes the image into sub-images or subbands, 3 details and 1 approximation namely LL, LH, HL and HH. For colour images YCbCr colour space is used instead of RGB model. Out of the four DWT bands, DCT is applied to

the selected band for both cover and watermark image. DCT represents data in terms of frequency space rather than an amplitude space. The Discrete Cosine Transform is a technique for converting a signal into elementary frequency components. The SVD transform is applied to the obtained DCT coefficients. Every real matrix [*A*] can be decomposed into a product of three matrices as given in equation 1: [4] [8]

$$[A] = [U]\,[\Sigma]\,[V^T] \quad (1)$$

where [*U*] *and* [*V*] are orthogonal matrices and
[Σ] = diag (λ_1, λ_2 ,...).

The diagonal entries of [Σ] are called the singular values of [*A*], the columns of [*U*] are called the left singular vectors of [*A*], and the columns of [*V*] are called the right singular vectors of [*A*]. This decomposition is known as the Singular Value Decomposition (SVD) of [*A*]. The singular values obtained for the cover image are modified with the singular values of the DCT transformed watermark using equation 2.

$$\lambda_i^{*k} = \lambda_i^{k} + \alpha_k \lambda_{wi}, \; i = 1\ldots.., n \quad (2)$$

After obtaining the modified DCT coefficients, mapping the modified DCT coefficients back to their original positions and then performing inverse DCT and inverse DWT to produce the original image.

Watermark Extraction Procedure [4]

First apply one-level DWT to the watermarked image then apply DCT to the selected DWT band. Map the DCT coefficients into four quadrants: B1, B2, B3 and B4 and extract the singular values from each quadrant B_k, k= 1, 2, 3 and 4 using equation 3.

$$\lambda_{wi}^{k} = (\lambda_i^{*k} - \lambda_i^{k})/\,\alpha_k, \; i = 1\ldots.,n \quad (3)$$

Now construct the DCT coefficients of the watermark by using the singular vectors and then applying inverse DCT. Finally, applying inverse DWT to construct the watermark. The DWT-SVD embedding and extraction procedure is similar to the method mentioned above, with slight modifications in it. Since DCT is not used, the part where DCT is applied is to be removed. Thus the methods can be tested for robustness to different attacks and the best method can be obtained.

III. ALGORTHM FOR VIDEO WATERMARKING USING HYBRID TECHNIQUES

Watermark Embedding Procedure [8]

The cover or base video used is of foreman and V.E.S.I.T Logo of size 626×626 is used as watermark image. The algorithm used for invisible image watermarking using hybrid DWT-DCT-SVD technique is extended to watermark videos. First divide the video into frames F_i , i = 1, 2, 3…n. Then convert every video frame F_i from RGB to YCbCr colour matrix format. The Y matrix obtained is segmented into blocks of size $p_1 \times p_2$. Embedding can be done on all frames or on selected frames. In this study, embedding is done on selected frames for which spatial frequency (SF) [8] needs to be calculated. Overall activity level in an image is obtained by SF. The SF of an image block of size $M_1 x N_1$ is defined in equation 4:

$$SF = \sqrt{RF^2 + CF^2} \quad (4)$$

Where RF and CF are the row and column frequencies and are defined in equation 5 and 6:

$$RF = \sqrt{\frac{1}{M_1 N_1} \sum_{m=1}^{M1} \sum_{N=2}^{N1} [l(m,n) - l(m,n-1)]^2} \quad (5)$$

$$CF = \sqrt{\frac{1}{M_1 N_1} \sum_{N=1}^{N1} \sum_{m=2}^{M1} [l(m,n) - l(m-1,n)]^2} \quad (6)$$

An image or video frame is divided into blocks and SF is obtained for each block. The values of SF are stored in descending order. Based on the SF value, significant blocks are selected by comparing the SF values with a threshold. The threshold is selected on a trial and error basis depending upon the values of spatial frequency obtained. Those blocks which have SF values less than or equal to threshold are selected as significant blocks which are then used for making reference image f_{ref} which is of size m× n. One level DWT is performed on the reference image and watermark image. After applying DWT, four subbands are obtained. Any band out of LL, LH, HL and HH is selected and on the selected band DCT is applied. After obtaining the DCT coefficients, SVD transform is applied on the DCT Coefficients of the reference and watermark image. The singular values of reference image are modified with the singular values of watermark. Then inverse SVD is performed on the reference image followed by inverse DCT and inverse DWT on reference image and the coefficients obtained are divided into blocks of size $p_1 \times p_2$ and mapped onto their original positions for constructing the watermarked image. Finally converting the video frames from YCbCr to RGB color matrix and reconstructing frames into final watermarked video scene F_i^*.

Watermark Extraction Procedure [8]

The extraction is done taking watermarked image as its input. The watermarked video scene is divided into frames F_i^*, i = 1, 2, 3…n and each watermarked video frame F_i^* is converted from RGB to YCbCr color matrix format. Using the positions of significant blocks, the reference image is obtained from the watermarked Y matrix. On both watermarked reference image and original reference image DWT and then DCT are performed. The SVD transform is applied to both DCT coefficients of watermarked reference image and original reference image. The singular values of the watermark are extracted and the watermark is obtained and finally the image watermark is obtained from all frames.

The algorithm for watermarking using DWT-SVD is as follows.

Watermark Embedding Procedure for DWT-SVD

The embedding algorithm for DWT-SVD can be implemented by modifying the embedding algorithm of DWT-DCT-SVD. The hybrid watermarking using DWT-SVD does not make use of DCT in it. Therefore, the algorithm can be modified by removing the part where DCT is applied onto the video frame. The rest of the algorithm remains same.

Watermark Extraction Procedure for DWT-SVD

The extraction algorithm for DWT-SVD can be implemented by modifying the extraction algorithm of DWT-DCT-SVD. The algorithm can be modified by removing the part where DCT is applied onto the video frame. The rest of the algorithm remains same.

IV. SIMULATION RESULTS

Objective image parameters such as PSNR (in dB), MAE, IQI and Correlation are used for the analysis purpose. The imperceptibility of any watermarking system is evaluated by obtaining the values of Peak Signal to Noise Ratio (PSNR) [6] [7] and robustness to different attacks is evaluated by obtaining the value of normalized correlation. If the reconstructed image is close to the original image, then Mean Square Error (MSE) is small and PSNR takes a larger value. PSNR is dimensionless and is expressed in dB .When watermark is added to the host image, the host image quality decreases, thus a higher value of MSE is obtained and due to which a lower value of PSNR is obtained.
For $N \times M$ image MSE is calculated using equation 7:

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} [y(i,j) - x(i,j)]^2 \quad (7)$$

PSNR is calculated using equation 8:

$$PSNR = 10 \log\left(\frac{L_{\max}^2}{MSE}\right) \quad (8)$$

Where y and x are respective luminance values of original and watermarked image. $L_{\max}$ is maximum possible pixel value of image.
Mean Absolute Error (MAE) is average of absolute difference between the reference signal and test image. It is given by the equation 9:

$$MAE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} |x(i,j) - y(i,j)| \quad (9)$$

Image Quality Index (IQI) can be used as image and video quality distortion measure. It is mathematically defined by modeling the image distortion relative to the reference image as a combination of three factors: loss of correlation, luminance distortion, and contrast distortion. Let $x = \{xi \,|\, i = 1,2,3,\ldots, N\}$, $y = \{yi \,|\, i = 1,2,3,\ldots, N\}$ be the original and the test images, respectively. The IQI is defined by equation 10:

$$Q = \frac{4 \times \sigma_{xy} \times \bar{x} \times \bar{y}}{(\sigma_x^2 + \sigma_y^2) \times ((\bar{x})^2 + (\bar{y})^2)} \quad (10)$$

where $\bar{x}$, $\bar{y}$, σ_x^2 , σ_y^2 and σ_{xy} are given as:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i$$

$$\bar{y} = \frac{1}{N} \sum_{i=1}^{N} yi$$

$$\sigma_x^2 = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2$$

$$\sigma_y^2 = \frac{1}{N-1} \sum_{i=1}^{N} (y_i - \bar{y})^2$$

$$\sigma_{xy} = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})$$

The dynamic range of Q is [0, 1].Best value Q=1 is achieved when $y_i = x_i, i = 1,2,\ldots,n$.

Correlation defines the similarity between same pixel positions of the two images where one image is original watermark and other can be extracted watermark or extracted watermark from the attacked watermarked video frames. The correlation factor ρ [2] is computed using equation 11:

$$\rho(w,W) = \frac{\sum_{i=1}^{N} w_i W_i}{\sqrt{\sum_{i=1}^{N} w_i^2} \sqrt{\sum_{i=1}^{N} W_i^2}} \quad (11)$$

Where N is the number of pixels in watermark, w and W is the original and extracted watermarks respectively. The correlation factor can take values between -1 and 1.

For Foreman as cover image and VESIT Logo as watermark, PSNR (in dB), MAE, IQI and Correlation values for evaluating hybrid technique using DWT-SVD and DWT-DCT-SVD for different bands of DWT are tabulated in Table 1 and Table 2 respectively.

TABLE 1: PSNR (IN DB), MAE, IQI AND CORRELATION VALUES FOR EVALUATING HYBRID TECHNIQUE USING DWT-SVD FOR DIFFERENT BANDS.

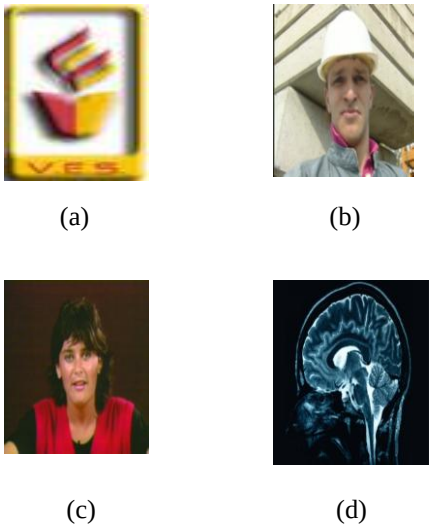
Parameters evaluated for	Para-meters	Different bands			
		LL	LH	HL	HH
Original and Watermarked Image	PSNR	50.59	50.77	50.77	50.78
	NC	0.9999	0.9999	0.9999	0.9999
	MAE	0.5246	0.5032	0.5048	0.5000
	IQI	0.9100	0.9148	0.9095	0.9111
Original and Extracted	PSNR	8.26	23.01	21.19	19.12
	NC	0.7688	0.9674	0.9557	0.9383

Watermark	MAE	75.7912	12.8014	15.2320	18.8676
	IQI	0.3919	0.8803	0.8456	0.8076

TABLE 2: PSNR (IN DB), MAE, IQI AND CORRELATION VALUES FOR EVALUATING HYBRID TECHNIQUE USING DWT-DCT-SVD FOR DIFFERENT BANDS.

Parameters evaluated for	Parameters	Different bands			
		LL	LH	HL	HH
Original and Watermarked Image	PSNR	50.59	50.77	50.77	50.78
	NC	0.9999	0.9999	0.9999	0.9999
	MAE	0.5246	0.5032	0.5048	0.5000
	IQI	0.9100	0.9148	0.9095	0.9111
Original and Extracted Watermark	PSNR	8.26	23.01	21.19	19.12
	NC	0.7688	0.9674	0.9557	0.9383
	MAE	75.7912	12.8014	15.2320	18.8676
	IQI	0.3919	0.8803	0.8456	0.8076

From the values obtained in Table 1 and Table 2, good PSNR (in dB), MAE, IQI and correlation values are obtained in LH band as compared to other bands. The PSNR (in dB), MAE, IQI and correlation values obtained for original and extracted watermark was least in LL band indicating that the watermark is extracted with losses and therefore not at all suitable for embedding the watermark. From the values obtained for all the bands, embedding and extraction in LH band gives good results. Table 3 and Table 4 shows results for DWT-SVD, Table 5 and Table 6 shows results for DWT-DCT-SVD and for this three colour images of foreman, Miss_am and an MRI image are used as cover image and VESIT Logo of size 48×92 is used as watermark which is shown in figure 1.



(a) (b)

(c) (d)

Figure 1 (a) VESIT Logo (Watermark) (b) Foreman (c) Miss_am (d) Test MRI image

The PSNR, MAE, IQI and Correlation values obtained for the hybrid technique using DWT-SVD for original and watermarked image where embedding is done in LH band, is tabulated in Table 3 and for original and extracted watermark it is tabulated in Table 4.

TABLE 3: PSNR (IN DB), MAE, IQI AND CORRELATION VALUES FOR EVALUATING HYBRID TECHNIQUE USING DWT-SVD WHERE EMBEDDING IS DONE IN LH BAND (ORIGINAL AND WATERMARKED IMAGE).

Cover Image	DWT-SVD			
	Original and Watermarked Image			
	PSNR	Correlation	MAE	IQI
Foreman	50.77	0.9999	0.5032	0.9148
Miss_am	51.68	0.9998	0.4100	0.8939
MRI Image	51.55	0.9999	0.4321	0.9591

TABLE 4: PSNR (IN DB), MAE, IQI AND CORRELATION VALUES FOR EVALUATING HYBRID TECHNIQUE USING DWT-SVD WHERE EMBEDDING IS DONE IN LH BAND (ORIGINAL AND EXTRACTED WATERMARK).

Cover Image	DWT-SVD			
	Original and Extracted Watermark			
	PSNR	Correlation	MAE	IQI
Foreman	23.01	0.9674	12.8014	0.8803
Miss_am	21.44	0.9637	15.5805	0.8656
MRI Image	31.56	0.9944	4.9512	0.9564

The PSNR, MAE, IQI and Correlation values obtained for the hybrid technique using DWT-DCT-SVD for original and watermarked image where embedding is done in LH band, is tabulated in Table 5 and for original and extracted watermark it is tabulated in Table 6.

TABLE 5: PSNR (IN DB), MAE, IQI AND CORRELATION VALUES FOR EVALUATING HYBRID TECHNIQUE USING DWT-DCT-SVD WHERE EMBEDDING IS DONE IN LH BAND (ORIGINAL AND WATERMARKED IMAGE).

Cover Image	DWT-DCT-SVD			
	Original and Watermarked Image			
	PSNR	Correlation	MAE	IQI
Foreman	50.77	0.9999	0.5032	0.9148
Miss_am	51.68	0.9998	0.4100	0.8939
MRI Image	51.55	0.9999	0.4321	0.9591

TABLE 6: PSNR (IN DB), MAE, IQI AND CORRELATION VALUES FOR EVALUATING HYBRID TECHNIQUE USING DWT-DCT-SVD WHERE EMBEDDING IS DONE IN LH BAND (ORIGINAL AND EXTRACTED WATERMARK).

Cover Image	DWT-DCT-SVD			
	Original and Extracted Watermark			
	PSNR	Correla-tion	MAE	IQI

Foreman	23.01	0.9674	12.8014	0.8803
Miss_am	21.44	0.9637	15.5805	0.8656
MRI Image	30.98	0.9935	5.1995	0.9505

From Table 3 to 6, the parameter values obtained for the three test cover images gives good PSNR and correlation values between original and watermarked image. The parameter values obtained for all test images as cover image and VESIT Logo as watermark gives good correlation values between original and extracted watermark image for the hybrid technique DWT-SVD and DWT-DCT-SVD. The PSNR values between original and extracted watermark in far better for DWT-SVD and DWT-DCT-SVD thus indicating that the watermark is extracted with fewer losses. Thus embedding and extraction in LH band gives good results.

For Foreman as cover image and VESIT Logo as watermark, the information about robustness to different attacks for DWT-SVD and DWT-DCT-SVD, is obtained by correlation values between original and extracted watermark, obtained for different bands of DWT and are tabulated in Table 7 and Table 8.

TABLE 7: CORRELATION VALUES FOR DWT-SVD FOR DIFFERENT BANDS (WITH ATTACK).

Attacks	Different bands			
	LL	LH	HL	HH
Gaussian	0.66213	0.76794	0.76674	0.72918
Rotate	0.81732	0.83068	0.75622	0.69583
Resize	0.76528	0.76951	0.71126	0.70338
Motion Blur	0.27026	0.66813	0.76053	0.32326

TABLE 8: CORRELATION VALUES FOR DWT-DCT-SVD FOR DIFFERENT BANDS (WITH ATTACK).

Attacks	Different bands			
	LL	LH	HL	HH
Gaussian	0.66777	0.76954	0.75721	0.72754
Rotate	0.81732	0.83068	0.75622	0.69583
Resize	0.76528	0.76951	0.71126	0.70338
Motion Blur	0.27026	0.66813	0.76053	0.32326

From all the values obtained in Table 7 and Table 8, good correlation values are obtained in LH band as compared to other bands. Correlation values obtained for original and extracted watermark was least in LL band for Gaussian and motion blur indicating that the technique will not be robust to these attacks if watermark embedding and extraction is done in LL band. From the values obtained for all the bands, embedding and extraction in LH band gives good results.

Correlation values between original and extracted watermark, for different attacks are obtained for foreman as cover and VESIT Logo as watermark where embedding is done in LH band, is tabulated in Table 9.

TABLE 9: CORRELATION VALUES FOR ALL HYBRID TECHNIQUES (WITH ATTACK).

Techniques / Attacks	DWT-SVD	DWT-DCT-SVD
Gaussian attack [1e-3]	0.76794	0.76954
Rotate attack [5 degree]	0.83068	0.83068
Resize attack [0.9]	0.76951	0.76951
Motion Blur [5 5]	0.66813	0.66813

From Table 9, the correlation values between original and extracted watermark for Gaussian attack is better for DWT-DCT-SVD as compared to DWT-SVD which indicates that the DWT-DCT-SVD technique is more robust to Gaussian attack as compared to DWT-SVD or the basic techniques. Both the techniques are more robust to rotate and resize attack as compared to motion blur attack with acceptable correlation values.

The algorithms were also tested on videos for their performance. A standard test video "foreman" is selected as cover video and "VESIT Logo" of size 626×626 is used as watermark. Watermark is embedded using the hybrid techniques in the reference frame which is selected based on spatial frequency of each block of a video frame. The PSNR and correlation values between original and watermarked frames for first 60 frames with an interval of 5 frames for DWT-SVD for different bands of DWT are tabulated in Table 10 and Table 11 respectively.

TABLE 10: PSNR (IN DB) VALUES FOR ORIGINAL AND WATERMARKED FRAME FOR DWT-SVD WITH DIFFERENT BANDS.

Frame No	PSNR			
	LL	LH	HL	HH
5	50.53	50.91	50.90	50.92
10	50.89	51.08	51.05	51.05
15	51.26	51.09	51.16	51.14
20	51.12	51.09	51.10	51.09
25	51.25	51.16	51.18	51.15
30	51.35	51.11	51.14	51.20
35	51.20	51.10	51.11	51.11
40	51.28	51.11	51.11	51.12
45	51.30	51.10	51.10	51.15
50	51.29	51.10	51.15	51.14
55	51.30	51.13	51.12	51.14
60	51.33	51.09	51.10	51.12
Average	51.18	51.09	51.10	51.11

TABLE 11: CORRELATION VALUES FOR ORIGINAL AND WATERMARKED FRAME FOR DWT-SVD WITH DIFFERENT BANDS.

Frame No	Correlation			
	LL	LH	HL	HH
5	0.9525	0.9876	0.9759	0.9844
10	0.9550	0.9878	0.9845	0.9752
15	0.9748	0.9934	0.9884	0.9827
20	0.9489	0.9964	0.9877	0.9791
25	0.9381	0.9851	0.9804	0.9824
30	0.9562	0.9848	0.9867	0.9786
35	0.9735	0.9911	0.9821	0.9762
40	0.9600	0.9863	0.9850	0.9798
45	0.9583	0.9899	0.9863	0.9784
50	0.9647	0.9904	0.9872	0.9812
55	0.9577	0.9876	0.9829	0.9798
60	0.9677	0.9893	0.9845	0.9888

The PSNR and correlation values between original and watermarked frames for first 60 frames with an interval of 5 frames for DWT-DCT-SVD for different bands of DWT are tabulated in Table 12 and Table 13 respectively.

TABLE 12: PSNR (IN DB) VALUES FOR ORIGINAL AND WATERMARKED FRAME FOR DWT-DCT-SVD WITH DIFFERENT BANDS.

Frame No	PSNR			
	LL	LH	HL	HH
5	50.53	50.91	50.90	50.92
10	50.89	51.08	51.05	51.05
15	51.26	51.09	51.16	51.14
20	51.12	51.09	51.10	51.09
25	51.25	51.16	51.18	51.15
30	51.35	51.11	51.14	51.20
35	51.20	51.10	51.11	51.11
40	51.28	51.11	51.11	51.12
45	51.30	51.10	51.10	51.15
50	51.29	51.10	51.15	51.14
55	51.30	51.13	51.12	51.14
60	51.33	51.09	51.10	51.12
Average	51.18	51.09	51.10	51.11

TABLE 13: CORRELATION VALUES FOR ORIGINAL AND WATERMARKED FRAME FOR DWT-DCT-SVD WITH DIFFERENT BANDS.

Frame No	Correlation			
	LL	LH	HL	HH
5	0.9525	0.9876	0.9759	0.9844
10	0.9550	0.9878	0.9845	0.9752
15	0.9748	0.9934	0.9884	0.9827
20	0.9489	0.9964	0.9877	0.9791
25	0.9381	0.9851	0.9804	0.9824
30	0.9562	0.9848	0.9867	0.9786
35	0.9735	0.9911	0.9821	0.9762
40	0.9600	0.9863	0.9850	0.9798
45	0.9583	0.9899	0.9863	0.9784
50	0.9647	0.9904	0.9872	0.9812
55	0.9577	0.9876	0.9829	0.9798
60	0.9677	0.9893	0.9845	0.9888

From Table 10 to 13, the PSNR values for DWT-SVD and DWT-DCT-SVD for all bands are above acceptable level. But by looking at the correlation values for the two techniques for different bands, the values are obtained higher with LH band thus indicating that the embedding and extraction is better with LH band. The PSNR values for original and watermarked frames for first 60 frames with an interval of 5 frames where embedding is done in LH band for both the hybrid technique is tabulated in Table 14. The correlation values of original and extracted watermark for all frames which are watermarked are tabulated in Table 15.

TABLE 14: PSNR VALUES (IN DB) FOR ORIGINAL AND WATERMARKED FRAME

Frame No	DWT-DCT-SVD	DWT-SVD
5	50.91	50.91
10	51.08	51.08
15	51.09	51.09
20	51.09	51.09
25	51.16	51.16
30	51.11	51.11
35	51.10	51.10
40	51.11	51.11
45	51.10	51.10
50	51.10	51.10
55	51.13	51.13
60	51.09	51.09
Average	51.09	51.09

From Table 14, the PSNR for all the two techniques are well above acceptable level for all frames, thus indicating that all

the techniques have good imperceptibility property. The average PSNR for the entire video using DWT-SVD and DWT-DCT-SVD was found out to be 51.09 dB which are well above acceptance level.

TABLE 15: CORRELATION VALUES FOR ORIGINAL AND EXTRACTED WATERMARK WITHOUT ATTACK

Frame No	DWT-DCT-SVD	DWT-SVD
5	0.9876	0.9876
10	0.9878	0.9878
15	0.9934	0.9934
20	0.9964	0.9964
25	0.9851	0.9851
30	0.9848	0.9848
35	0.9911	0.9911
40	0.9863	0.9863
45	0.9899	0.9899
50	0.9904	0.9904
55	0.9876	0.9876
60	0.9893	0.9893

The correlation values for the hybrid techniques, without any attack are tabulated in Table 15 for 60 frames of the video with an interval of five frames.
From Table 15, it can be observed that DWT-SVD and DWT-DCT-SVD techniques have good correlation values. It can be observed that embedding watermark in frame no. 20 gives better correlation values and therefore more robustness as compared to other frames.

V. CONCLUSION

The MAE values obtained are lower, PSNR obtained is higher, Correlation and IQI values are found to be better for the hybrid technique for image watermarking in LH band. The hybrid technique using DWT-DCT-SVD give good correlation values for Gaussian attack as compared to DWT-SVD. Embedding was done in different bands i.e. LL, LH, HL and HH. The results obtained for video with LH band provided good correlation and PSNR values as compared to other bands.

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