Performance Comparison of DCT and Walsh Transforms for Watermarking using DWT-SVD

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***Abstract*—This paper presents a DWT-DCT-SVD based hybrid watermarking method for color images. Robustness is achieved by applying DCT to specific wavelet sub-bands and then factorizing each quadrant of frequency sub-band using singular value decomposition. Watermark is embedded in host image by modifying singular values of host image. Performance of this technique is then compared by replacing DCT by Walsh in above combination. Walsh results in computationally faster method and acceptable performance. Imperceptibility of method is tested by embedding watermark in HL2, HH2 and HH1 frequency sub-bands. Embedding watermark in HH1 proves to be more robust and imperceptible than using HL2 and HH2 sub-bands.**

Keywords—Discrete Wavelet Transform (DWT); Discrete Cosine Transform (DCT); Singular Value Decomposition (SVD); watermarking.

I. INTRODUCTION

Advancement in technology has resulted in use of digital data which includes text, images, audio, video and multimedia data. Technology has also made it easy to duplicate/manipulate the contents of these data by various means. Piracy is a very good example of this. Thus authentication of data becomes obvious requirement before it is made available as digital data. Authentication includes information of owner of data within data itself to avoid taking undue credit as well as to prevent tampering of data. Digital watermarking is one of the most popular techniques used for digital data authentication.

Watermark is secret information which is embedded into a digital signal. Digital signal into which watermark is embedded is called as host signal or cover signal. Host signal can be text, image, audio or video data. Depending on the type of host signal, watermarking is classified as text watermarking, image watermarking, audio watermarking and video watermarking[1]. Image watermarking can be further classified into transform domain watermarking and spatial domain watermarking based on how the watermark is embedded into an image. Transform domain watermarking is one in which image is first transformed using appropriate transformation technique and then watermark is embedded into transformed coefficients of image. Spatial domain watermarking refers to directly modifying pixel values of an image to embed watermark into it. Transform domain watermarking is complex as compared to spatial domain watermarking but it is more robust also. Watermarking technique is said to be robust with respect to transformations, if watermark embedded into digital image can be easily extracted even if any attempts are made to change the data contents thereby degrading the host image. Discrete Wavelet Transform[2],[8],[13] and Discrete Cosine Transform[3],[8],[13] are most popular transforms used for Transform domain watermarking. Singular Value Decomposition[4],[8] is yet another popular approach for the same. In this paper an attempt has been made to exploit strengths of all these techniques to provide robust and imperceptible watermarking technique. Other characteristics of a good watermarking technique are perceptibility and security. Perceptibility refers to the ability to notice existence of watermark into image. Low perceptibility is desirable. Security of watermarking algorithm refers to inability to extract data contents by unauthorised party even after knowing embedding and extraction algorithm.

II. RELATED WORK

In literature, various approaches have been tried out for digital watermarking using wavelet transform and singular value decomposition. Xi-Ping and Qing-Sheng Zhu [5] have proposed a wavelet based method using sub-blocks of image. Instead of applying wavelet transform on whole image, it was applied to local sub-blocks. These sub-blocks were randomly extracted from original image. Watermark was embedded into part of frequency coefficients of these sub-bands by computing their statistical characteristics. A Mansouri, A Mahmoudi Aznaveh, F Torkamani Azar [6] have proposed a method using Complex Wavelet Transform (CWT) and singular value decomposition (SVD). The watermark was embedded by combining singular values of watermark in LL band of transformed image. The method proposed by them is non-blind watermarking because singular values of original image are required in extraction phase. Rashmi Agarwal and K. Venugopalan [7] have proposed a SVD based method for watermarking of color images. Each plane of color image is separately treated for embedding and extracting process. Different scaling factors were used to test the robustness of their method. Satyanarayana Murty. P. and P. Rajesh Kumar[8] have proposed a hybrid DWT-DCT-SVD based approach. HL frequency band was selected by them for embedding purpose. Method proposed in this paper is motivated by their work. Satendra Kumar, Ashwini Kumar Saini, Papendra Kumar[9] have also proposed a watermarking scheme based on discrete wavelet transform and singular value decomposition. They have used three level wavelet transform and then by modifying singular values of cover image, watermark is embedded into it. Medium frequency bands i.e. HL3 and LH3 were preferred for embedding. PSNR and Normalized Cross Correlation (NCC) values were used to measure the effectiveness of the method. Krishnamoorthi and Sheba Kezia[10] proposed a watermarking technique based on orthogonal polynomial based transformation for copyright protection of digital images. A visual model was used to determine strength of watermarking. This visual model was used to generate Just Noticeable Difference (JND) by analyzing low level image characteristics like texture, edges and luminance of cover image in polynomial based transformation domain. Ko-Ming-Chan and Long-Wen Chang[11] have proposed a watermarking system which embeds two different watermarks –robust and fragile into spatial and frequency domain separately. Robust watermark is embedded in wavelet coefficients of LL band whereas fragile watermark is embedded in least significant bits of watermarked image. Advanced encryption standard- Rijndeal block cipher was used to make watermarking technique public. Veysel Atlantas, A Latif Dogan, Serkan Ozturk [12] proposed a DWT-SVD based watermarking scheme using Particle Swarm Optimizer (PSO). Singular values of each sub-band of cover image are modified by different scaling factors. Modifications were further optimized using PSO to obtain highest possible robustness.

III. Discrete Wavelet Transform, Discrete Cosine Transform And Singular Value Decomposition

A. Discrete Wavelet Transform(DWT)[13]

Wavelets are special mathematical functions that represent scaled and shifted copies of finite length waveform. DWT is based on wavelets and analyzes the signal into its frequency components at multiple resolutions. Applying wavelet transform on two dimensional images divides image into four sub-bands LL, LH, HL and HH which consist of low frequency, middle frequency and high frequency components of an image. Maximum energy of an image is concentrated in LL sub-band whereas high frequency components in HH sub-band correspond to edges and textures [8]. Hence imperceptible watermarking can be achieved by using these high frequency components for embedding.

B. Discrete Cosinet Transform(DCT)

Discrete Cosine Transform converts the signal into its elementary frequency components. After applying DCT, most of the energy of a signal is concentrated into top left corner of an image. Due to this property, DCT is widely used in image compression. This property also helps in watermarking for selecting appropriate frequency coefficients to embed the watermark.

C. Singular Value Decomposition (SVD)

Singular Value Decomposition is a matrix factorization technique having many applications in image processing. Since digital image is a two dimensional matrix, SVD can be applied to it. If I is a digital image of dimension M*N, then applying SVD on I decomposes it into three matrices U, S and V with following relationship.

$$I=USV^T$$

Here U is a M*M unitary matrix, V is a N*N unitary matrix and S is M*N matrix whose first r diagonal values are Eigen values of positive definite matrix $I^T * I$. Coefficients of matrix U, S or V can be appropriately selected and altered for watermark embedding.

IV. Proposed Method

In this paper a hybrid approach for watermark embedding and extraction has been proposed. Two combinations have been used to compare their performances. First combination is of DWT, DCT and SVD, whereas second combination is of DWT, Walsh and SVD. Thus main aim here is to compare performance of DCT and Walsh when combined with DWT and SVD. Further different frequency sub-bands (HL2, HH2 and HH1) of host image are tried for embedding purpose in order to observe the effect of frequency band selection on robustness and perceptibility. Experiments are carried out on 10 different color host images of size 256*256*8 by embedding five different color images / logos of size 128*128*8 into each host image. Let H be the host image and W be the watermark. WI refers to watermarked image. Embedding and Extraction algorithms given below are for HL2 Frequency sub-band. Same steps are conducted for HH2 and HH1 sub-band. For using HH1 frequency sub-band to embed watermark single level discrete wavelet transform is taken instead of two level DWT.

A. Embedding Algorithm

Embedding algorithm further can be subdivided into four sub-processes: a) Transformation of host image, b) Transformation of watermark, c) Embedding process and d) Generating stego image. Each of these are explained below.

a) Transformation of host image

*1) Apply two level Discrete wavelet transform on host image H separately on each plane. This gives us the wavelet transformed image H' of size 64*64*8. We also get an image which can be distinguished into four different frequency bands namely LL2, HL2, LH2 and HH2.*

2) On HL2 sub-band of individual plane of wavelet transformed image i.e. H', apply DCT/WALSH transform. This results into DCT/WALSH transformed image say H".

*3) Arrange H" in zigzag manner and then form four quadrants out of it say Q1, Q2, Q3and Q4 of size 32*32*8 each.*

b) Transformation of watermark

*4) Repeat step 1 and step 2 on watermark image W to get W" of size 32*32*8.*

5) Apply Singular Value Decomposition on each quadrant obtained in step 3. This decomposes each quadrant into 3 matrices U, S and V. S is the singular value matrix used for embedding purpose.

6) Apply Singular Value Decomposition on W'' obtained in step 4. This decomposes W'' into 3 matrices U', S' and V'.

c) Embedding watermark

7) Scale the S matrix of each quadrant of H'' by value say K using Equation (1) to get S''. Different values of scaling factor k have been tried out to observe its effect on robustness and perceptibility.

$$S'' = S + KS' \quad (1)$$

d) Generating stego image

*8) Using S'', reconstruct quadrants of H''. i.e. Qi'= U*S''*V.*

9) Rearrange these new quadrants by inversing the zigzag procedure to get modified H''.

10) Take inverse DCT/WALSH of modified H'' to get H'.

11) Take two- level inverse Discrete Wavelet Transform of H' obtained in Step 10 to get watermarked image WI.

B. Extraction Algorithm

Similar to embedding algorithm, extraction algorithm is divided into three sub-processes: a) Transformation of watermarked image, b) Extraction of watermark, c) Reconstruction of watermark. Each of these are explained below.

a) Transformation of host image

*1) Apply two-level Discrete wavelet transform on watermarked image WI separately on each plane. This gives us the wavelet transformed image WI' of size 64*64*8. This image can be distinguished into four different frequency bands namely LL2, HL2, LH2 and HH2.*

2) On HL2 sub-band of individual plane of wavelet transformed image i.e. WI', apply DCT/WALSH transform. This results into DCT/WALSH transformed image say WI''.

*3) Arrange WI'' in zigzag manner and then form four quadrants out of it say Q1, Q2, Q3and Q4 of size 32*32*8 each.*

4) Apply Singular Value Decomposition on each quadrant obtained in step 3. This decomposes each quadrant into 3 matrices U, S and V.

b) Extraction of watermark

5) Extract singular values from watermarked image using modified and original singular values of R G B planes of host image using Equation (2).

$$S' = (S'' - S)/K \quad (2)$$

c) Reconstruction of watermark

6) These extracted singular values are then used to construct DCT/Walsh transform coefficients of watermark say W'' from each quadrant.

7) Take inverse DCT/Walsh transform of W'' to get W'.

8) Take inverse wavelet transform of W' to get extracted watermark EW.

Table I below shows host images of size 256*256*8 used for experimentation. Images from left to right and top to bottom are Lena, Mandrill, Peppers, Balls, Puppy, Tiger, Flower, Ganesh, Titanic and Waterlili.

TABLE I. HOST IMAGES USED FOR EXPERIMENTATION

Table II below shows five different logos/images of size 128*128*8 used as watermark. Images from left to right and top to bottom are NMIMS, Austral, Bear, Logo and CCD.

TABLE II. WATERMARK IMAGES USED FOR EXPERIMENTATION

V. RESULTS

C. Results for embedding process using DCT and Walsh with DWT-SVD

Table III on next page shows host image Lena after embedding watermark into its HL2, HH2 and HH1 frequency components using DCT. These results are for K=0.05(except HH1), 0.1, 0.2, 0.4 and 0.6. It can be seen that, as scaling factor is increased ($0 \leq K \leq 1$), quality of host image is degraded. This is due to considerable changes taking place into singular values of frequency components of host image with increased value of K. Table IV shows host image Lena after embedding watermark into its HL2, HH2 and HH1 frequency components using Walsh. Observations for Walsh are also similar to that of DCT.

Comparisons of results obtained for DWT-DCT-SVD and DWT-Walsh-SVD combinations are shown in following graphs. Fig. 1 shows comparison of Mean Absolute Error (MAE) between host image and watermarked image for different values of scaling factor K, when watermark is embedded in HL2 sub-band using DCT and Walsh with DWT-SVD.

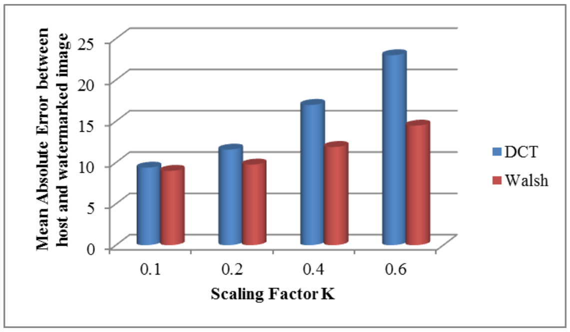


Fig. 1. Comparison of Mean Absolute Error (MAE) between host image and watermarked image for different values of scaling factor K when watermark is embedded in HL2 sub-band using DCT and Walsh with DWT-SVD.

From Fig.1 it can be observed that Walsh transform shows more imperceptibility than DCT for all scaling facto values. Fig. 2 and Fig. 3 show Mean Absolute Error between host and watermarked image for different scaling factor K when watermark is embedded in HH2 and HH1 sub-bands respectively with DWT-SVD.

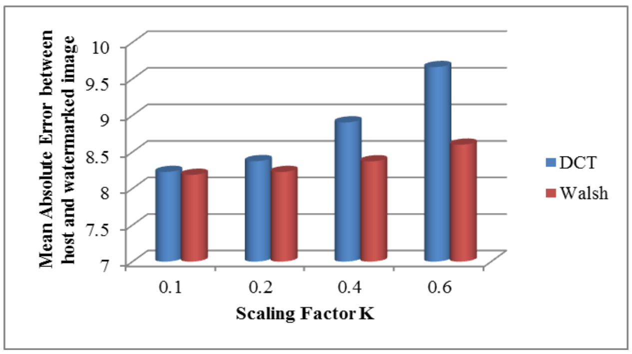


Fig. 2. Comparison of Mean Absolute Error (MAE) between host image and watermarked image for different values of scaling factor K when watermark is embedded in HH2 sub-band using DCT and Walsh with DWT-SVD.

Fig. 2 clearly shows that Walsh transform with DWT-SVD for HH2 sub-band is more imperceptible than DCT with DWT-SVD.

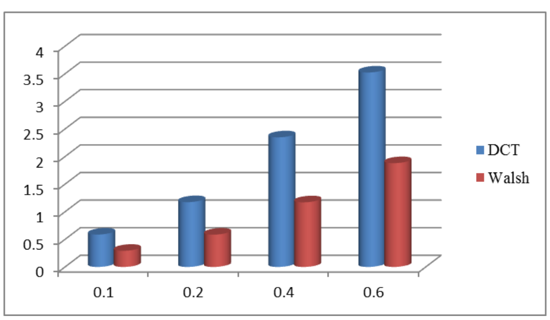


Fig. 3. Comparison of Mean Absolute Error (MAE) between host image and watermarked image for different values of scaling factor K when watermark is embedded in HH1 sub-band using DCT and Walsh with DWT-SVD.

Difference in imperceptibility for DCT and Walsh is more significant for HH1 sub-band as shown in Fig. 3.

To summarize, from Fig. 1, Fig. 2, and Fig. 3, it can be observed that distortion caused in host image due to embedding watermark is much less for Walsh as compared to DCT in all three frequency sub- bands, i.e. Walsh shows higher imperceptibility than DCT. It also indicates that, embedding watermark into high frequency components leads to higher imperceptibility which is a requirement for good watermarking technique. Though higher frequency components are more susceptible to various image processing attacks especially image compression, it is affordable in watermarking. The reason is that, main purpose of watermarking is to provide authentication of data contents which makes the image compression issue secondary. MAE can be directly related to perceptibility because it is the absolute difference between two images and hence noticeable by Human Visual System (HVS). Table VI shows result images for watermark extraction when no attacks are performed on watermarked image (K=0.6) for HL2, HH2, HH1 sub-band using DCT.

TABLE III. WATERMARKED IMAGES FOR LENNA HOST IMAGE IN HL2, HH2 AND HH1 FREQUENCY SUB-BANDS FOR DIFFERENTVALUES OF SCALING FACTOR K USING DWT-DCT-SVD

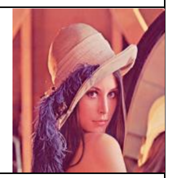
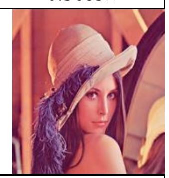
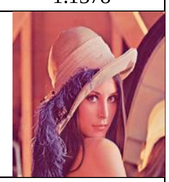
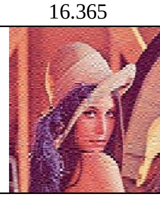
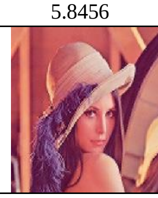
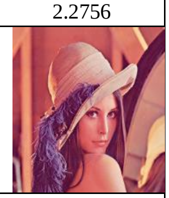
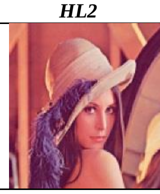
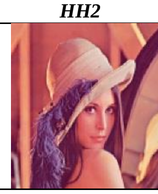
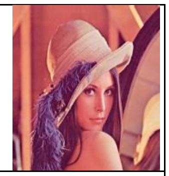
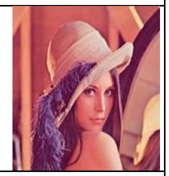
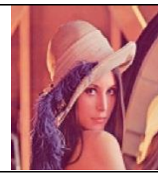
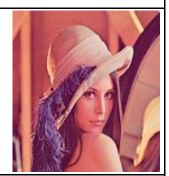
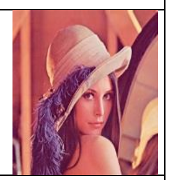
Scaling Factor (K)	Watermarked Images (DWT-DCT-SVD)		
	HL2	***HH2***	***HH1***
K=0.05			-
RMSE	9.8622	9.5669	-
MAE	5.6053	5.0714	-
K=0.1			
RMSE	10.754	9.6301	0.97263
MAE	6.7203	5.1099	0.56891
K=0.2			
RMSE	13.755	9.8784	1.9453
MAE	9.6149	5.2676	1.1378
K=0.4			
RMSE	21.985	10.814	3.8905
MAE	16.365	5.8456	2.2756
K=0.6			
RMSE	31.2	12.214	5.8358
MAE	23.544	6.6577	3.4134

TABLE IV. WATERMARKED IMAGES FOR LENNA HOST IMAGE IN HL2, HH2 AND HH1 FREQUENCY SUB-BANDS FOR DIFFERENTVALUES OF SCALING FACTOR K USING DWT-WALSH-SVD

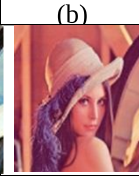
Scaling Factor (K)	Watermarked Images (DWT-WALSH-SVD)		
	HL2	***HH2***	***HH1***
K=0.05			-
RMSE	**9.6239**	**9.551**	-
MAE	**5.2354**	**5.062**	-

K=0.1			
RMSE	**9.8549**	**9.5669**	**0.48631**
MAE	**5.6192**	**5.0718**	**0.27981**
K=0.2			
RMSE	**10.729**	**9.6302**	**0.97263**
MAE	**6.7407**	**5.1111**	**0.55963**
K=0.4			
RMSE	**13.678**	**9.8785**	**1.9453**
MAE	**9.6179**	**5.269**	**1.1193**
K=0.6			
RMSE	**17.522**	**10.279**	**2.9179**
MAE	**12.864**	**5.5206**	**1.6789**

D. *Attacks on watermarked images:*

Generally attacks on digital image can be categorized into two groups. Attacks which affect the pixel values of image and which affect geometry of image [7]. In the work presented in this paper, five different types of attacks have been performed. These attacks are contrast stretching, image cropping, Gaussian noise, histogram equalization and image resizing. Table V below shows Lena image watermarked with ‘NMIMS’ image (K=0.6) after performing various attacks on it. Images in Fig. 4 from left to right and top to bottom correspond to contrast stretching, cropping, adding Gaussian noise (0.1 variance), histogram equalization, and resizing. Robustness plays an important role here because, watermark should survive the attacks performed on host image for successful authentication. Due to space constraints, results of watermark extraction without any attack are shown in Table VI only for K=0.6 for HL2, HH2 and HH1 sub-band with DWT-DCT-SVD. Table VII shows results of watermark extraction without any attack for K=0.6 for HL2, HH2 and HH1 sub-band with DWT-Walsh-SVD.

TABLE V. VARIOUS ATTACKS ON LENA IMAGE AFTER EMBEDDING ‘NMIMS’ IMAGE INTO IT (A) CONTRAST STRETCHING (B) CROPPING (C) GAUSSIAN NOISE (D) HISTOGRAM EQUALIZATION (E) RESIZING

		
(a)	(b)	(c)
		
(d)	(e)	

E. *Results of watermark extraction from HL2, HH2 and HH1 sub-bands against various attacks using DCT with DWT-SVD:*

Fig. 4(a), (b), (c) and (d) below show performance comparison of different sub-bands against various attacks for K=0.1, 0.2, 0.4, 0.6 using DCT.

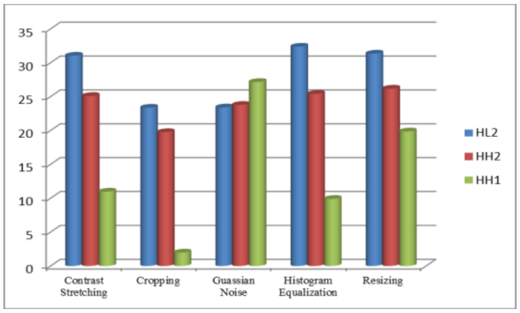


Fig. 4. .(a) Mean Absolute Error between original and extracted NMIMS watermark from HL2, HH2 and HH1 for K=0.1 and DCT

From Fig.4 (a), it can be noticed that for different attacks performed on watermarked image with K=0.1, HH1 sub-band gives smaller value of MAE than HL2 and HH2 sub-bands (except for Gaussian noise attak.). This in turn indicates more robustness when watermark is embedded in HH1 sub-band.

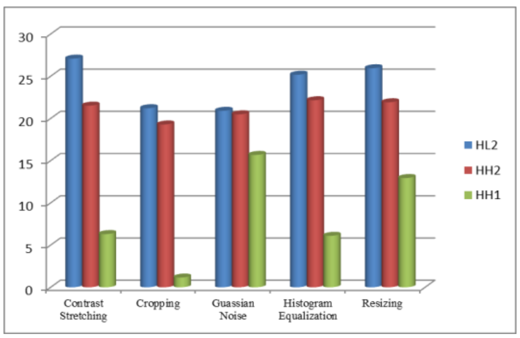


Fig. 4. (b) Mean Absolute Error between original and extracted NMIMS watermark from HL2, HH2 and HH1 for K=0.2 and DCT.

However, from Fig. 4(b) it is observed that with K=0.2, for all attacks, HH1 gives smallest value of MAE. Also these MAE values are smaller as compared to MAE values for K=0.1in previous case.

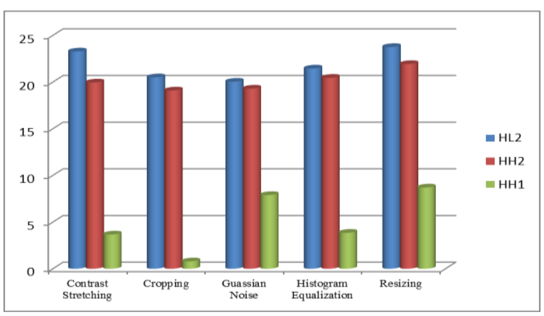


Fig. 4. (c) Mean Absolute Error between original and extracted NMIMS watermark from HL2, HH2 and HH1 for K=0.4 and DCT.

From Fig. 4.(c), we can say that HH1 is much better in robustness than HL2 and HH2 for K=0.4. MAE values are further reduced with increase in value of K.

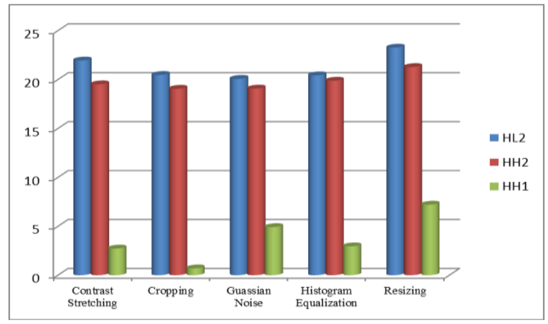


Fig. 4. (d) Mean Absolute Error between original and extracted NMIMS watermark from HL2, HH2 and HH1 for K=0.6 and DCT

This improvement in robustness for HH1 sub-bands continues for higher value of K(K=0.6) as shown in Fig.4 (d),

Thus it can be concluded that as we increase the value of scaling factor, watermark recovered from attack are closest to original watermark for HH1 sub-band. Similar results are observed for Walsh with DWT-SVD.

Further, for each sub-band, robustness of DCT and Walsh is compared by considering average MAE between original and extracted watermark for different attacks and for different values of K. For this, average MAE is computed over 10 host images for each attack in HL2, HH2 and HH1 sub-band separately. It is observed that robustness shown by Walsh transform is acceptable with less computational cost for each sub-band except for Gaussian noise in HH1 sub-band. This Comparison of robustness (MAE) for DCT and Walsh with K=0.6 is shown in Fig. 5(a)-(c). Watermarks extracted from each quadrant of HH1 sub-band for various attacks and K=0.6 using DWT-DCT-SVD and DWT-Walsh-SVD are shown in Table VIII and Table IX respectively.

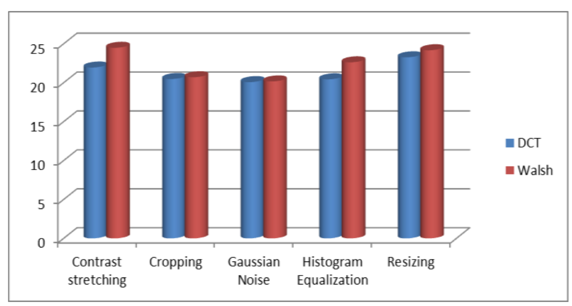


Fig. 5. a) Comparison of average MAE for DCT and Walsh for HL2 sub-band (K=0.6, 'NMIMS' Watermark)

From Fig. 5(a), it is observed that MAE between original and extracted watermark from HL2 sub-band is slightly more for Walsh as compared to DCT and hence it is acceptable.

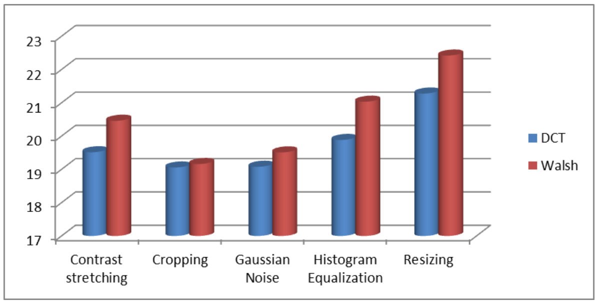


Fig. 5. (b) Comparison of average MAE for DCT and Walsh for HH2 sub-band (K=0.6, 'NMIMS' Watermark)

From Fig. 5(b), it is observed that MAE between original and extracted watermark from HH2 sub-band is slightly increased for Walsh. It is still acceptable because MAE for embedding process using Walsh is better than DCT.

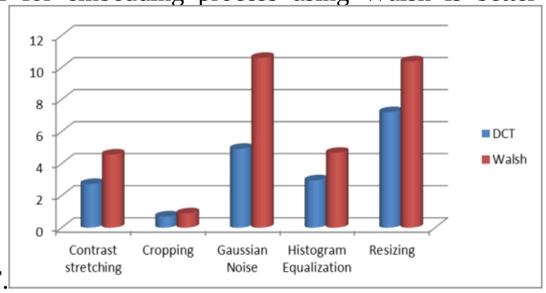


Fig. 5. (c) Comparison of average MAE for DCT and Walsh for HH1 sub-band (K=0.6, 'NMIMS' Watermark)

From Fig.5(c), it can be said that the performance of Walsh is acceptable for extraction from HH1 sub-band since MAE values are much smaller as compared to MAE values for HL2 and HH2 sub-band for watermark extraction process

TABLE VI. WATERMARKE EXTRACTED FROM FOUR QUADRANTS OF HL2, HH2 AND HH1 SUB-BAND OF LENA HOST IMAGE FOR K =0.6USING DWT-DCT-SVD WHEN NO ATTACK IS PERFORMED ON IT.

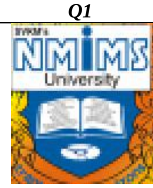
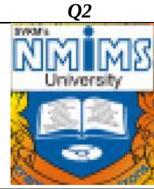
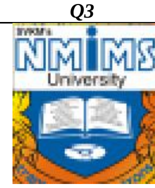
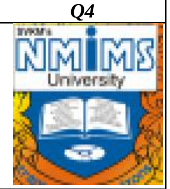
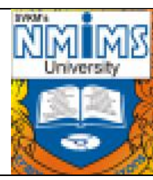
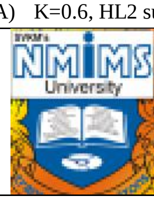
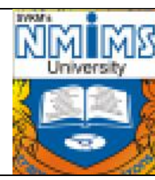
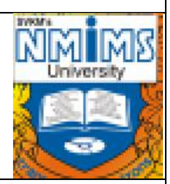
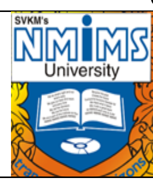
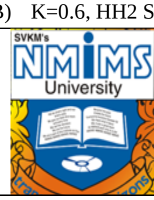
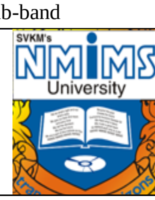
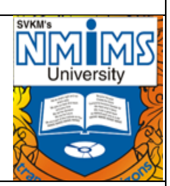
	Extracted Watermark			
Attacked Image	***Q1***	***Q2***	***Q3***	***Q4***
				
RMSE=31.2	33.391	33.382	33.384	33.395
AME=23.544	19.403	19.37	19.379	19.375
(A) K=0.6, HL2 sub-band				
				
RMSE=12.214	33.198	33.198	33.198	33.199
AME=6.657	18.793	18.792	18.792	18.804
(B) K=0.6, HH2 Sub-band				
				
RMSE=5.835	0.0355	0.1074	0.1322	0.2004
MAE=3.413	0.0012614	0.011536	0.017476	0.04
(C) K=0.6, HH1 sub-band				

TABLE VII. WATERMARKE EXTRACTED FROM FOUR QUADRANTS OF HL2, HH2,HH1 SUB-BAND OF LENA HOST IMAGE FOR K=0.6 USING DWT-WALSH-SVD WHEN NO ATTACK IS PERFORMED ON IT.

	Extracted Watermark			
Attacked Image	***Q1***	***Q2***	***Q3***	*Q4*

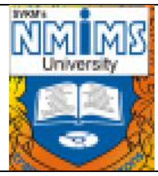
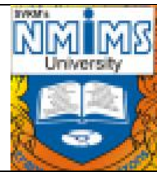
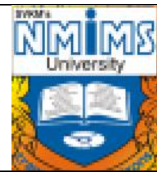
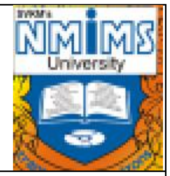
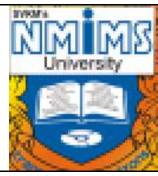
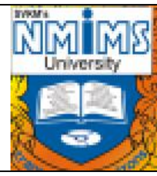
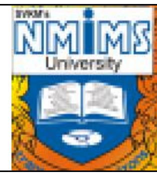
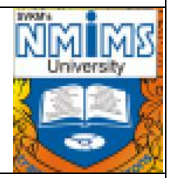
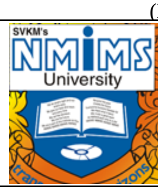
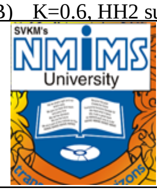
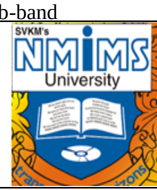
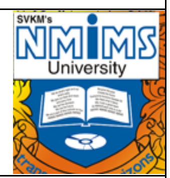
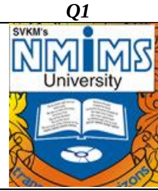
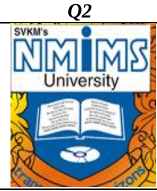
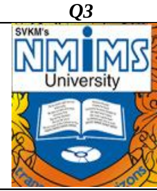
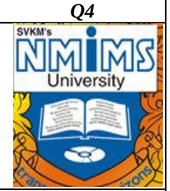
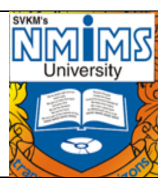
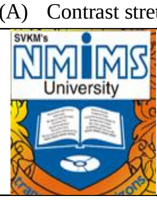
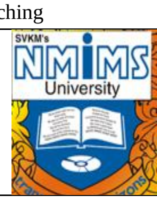
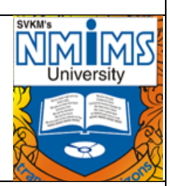
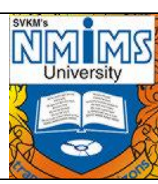
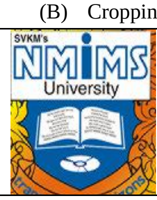
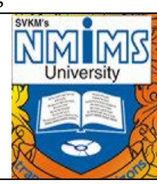
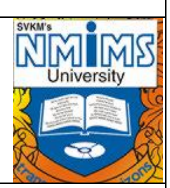
				
RMSE=17.522	33.227	33.232	33.228	33.236
AME=12.864	18.977	19	18.981	18.993
(A) K=0.6, HL2 sub band				
				
RMSE=10.279	33.196	33.197	33.197	33.196
AME=5.520	18.782	18.78	18.783	18.782
(B) K=0.6, HH2 sub-band				
				
RMSE=2.917	0.0285	0.0433	0.0251	0.0406
AME=1.678	0.0008138	0.0018717	0.000631	0.00165
(C) K=0.6,HH1 sub-band				

TABLE VIII. WATERMARKE EXTRACTED FROM FOUR QUADRANTS OF HH1 SUB-BAND OF LENA HOST IMAGE FOR K=0.6 USING DWT-DCT-SVD FOR (A) CONTRAST STRETCHING, (B) CROPPING, (C) GAUSSIAN NOISE, (D) HISTOGRAM EQUALIZATION (E) IMAGE RESIZING ATTACKS.

	Extracted Watermark			
Attacked Image	***Q1***	***Q2***	***Q3***	***Q4***
				
RMSE=29.29	5.5803	5.5303	5.983	6.8927
AME=25.048	2.8771	2.8503	3.0178	3.3298
(A) Contrast stretching				
				
RMSE=55.921	0.62653	0.801	0.73025	0.46367
AME=18.936	0.22917	0.32019	0.3264	0.16331
(B) Cropping				
				
RMSE=	10.8816	10.085	9.7701198	8.9896803
AME=	6.05751546	5.61658	5.4804688	5.09706624
(C) Gaussian noise				

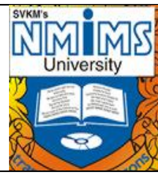
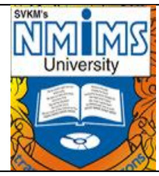
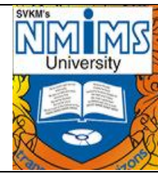
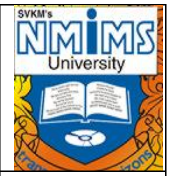
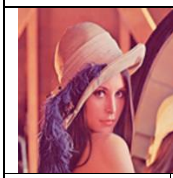
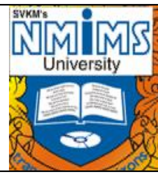
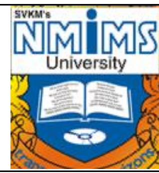
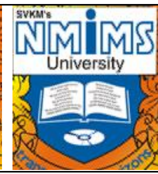
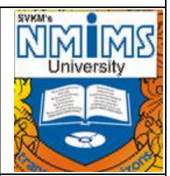
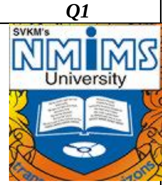
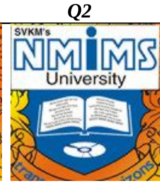
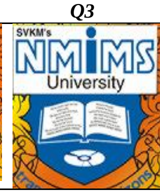
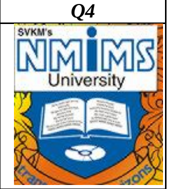
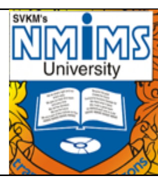
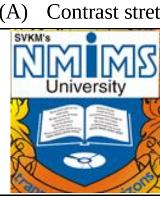
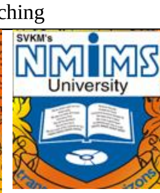
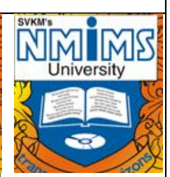
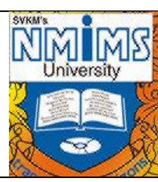
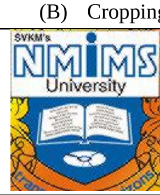
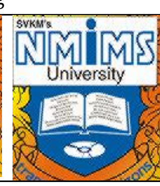
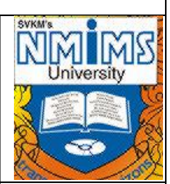
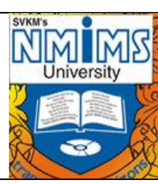
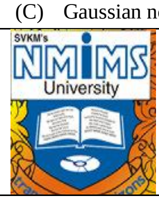
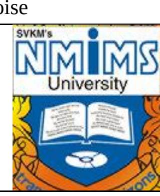
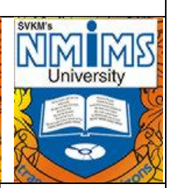
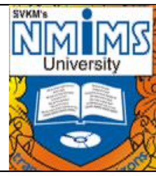
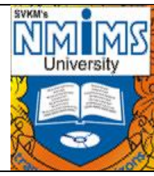
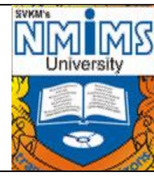
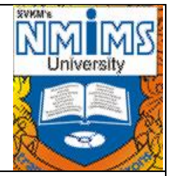
				
RMSE=48.849	7.5344	7.5138	7.8871	8.7403
MAE=41.249	3.4099	3.3394	3.5149	3.8415
(D) Histogram Equalization				
				
RMSE=10.883	10.561	11.349	12.644	15.791
MAE=6.171	4.7369	5.1686	5.8723	7.3549
(E) Resizing				

TABLE IX. WATERMARKE EXTRACTED FROM FOUR QUADRANTS OF HH1 SUB-BAND OF LENA HOST IMAGE FOR K=0.6 USING DWT-WALSH-SVD FOR (A) CONTRAST STRETCHING, (B) CROPPING, (C) GAUSSIAN NOISE, (D) HISTOGRAM EQUALIZATION (E) IMAGE RESIZING ATTACKS.

	Extracted Watermark			
Attacked Image	***Q1***	***Q2***	***Q3***	***Q4***
				
RMSE=29.29	8.4939	8.7267	9.4209	10.946
AME=25.046	4.3429	4.5289	4.9218	5.3963
(A) Contrast stretching				
				
RMSE=55.105	0.65387	0.81651	0.75272	0.55661
AME=18.937	0.24969	0.35659	0.32318	0.24801
(B) Cropping				
				
RMSE=34.397	23.3019	21.934226	21.1316	20.0063
AME=28.388	13.0506	12.1854	11.779	11.2329
(C) Gaussian noise				
				
RMSE=49.067	9.9075	10.48	11.655	12.931
MAE=41.454	4.6353	4.8488	5.468	5.9934
(D) Histogram Equalization				

				
RMSE=9.032	12.486	14.277	16.595	21.053
MAE=4.992	5.7634	6.8108	8.0143	9.9391
(E) Resizing				

VI. CONCLUSION AND FURTHER WORK

Following conclusions can be drawn based on the work presented in this paper. As value of scaling factor increases, MAE between host image and watermark becomes significant thereby reducing imperceptibility. However, loss of perceptibility is less when watermark is embedded in high frequency components of host image. Since high frequency components of an image correspond to edges and borders of an image, embedding watermark causes distortion in images. But this distortion is affordable as compared to distortion in image caused by embedding watermark in HL or LH frequency components. Frequently, in image processing attacks, high frequency components are eliminated which results into loss of watermark information. However, such elimination is possible or can be of major concern in data compression. In watermarking, main emphasis is on protecting copyright information or content identification and not on data compression. Thus, it is acceptable to embed the watermark image in high frequency components rather than in low or medium frequency components. Walsh transform when used with DWT-SVD results in computationally faster watermarking scheme. Robustness and imperceptibility provided by Walsh is acceptable when compared with DWT-DCT-SVD.

Further work includes use of different orthogonal transforms like slant, Hartley, Kekre's transform and wavelet transforms obtained from them for watermarking.

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