Comparative Performance Analysis of Digital Image Watermarking Scheme in DWT and DWT-FWHT-SVD Domains

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Abstract-Robust, secured, high embedding capacity and invisible digital image watermarking techniques are key requirements in the world of information security. Many existing images watermarking techniques fail to achieve perceptual quality and robustness simultaneously under high payload scenario promising strong security, because these requirements conflict each other. This paper presents non-blind digital image watermarking technique and its comparative performance analysis in discrete wavelet transform (DWT) and DWT-Fast WalseHadamard transform-Singular value decomposition (DWT-FWHT-SVD) domains. The simple, symmetric and orthogonal 'Haar' wavelet is used for DWT decomposition and Fibonacci-Lucas transform along with affine transforms are used to implement embedding security. The experimental results show better performance in DWT-FWHT-SVD domain than DWT domain for candidate images of 512x512 size namely Lena, peppers, baboon, lake and plane and grey scale watermark of 256x256 sizes. In DWT-FWHT-SVD domain, better perceptual quality is achieved with Lena image giving peak signal to noise ratio (PSNR) =75.8446, peppers image with PSNR=82.8343, baboon image with PSNR=94.0575, lake image with PSNR= 86.9526 and plane with PSNR=89.9170 with significant quality of extracted watermark. For all test images with varying scale factor in the range of K=0.25 to 0.55, PSNR and normalized correlation (NC) values are better with compared to DWT domain. As DWT-FWHT-SVD based results found superior, we further focused on DWT-FWHT-SVD domain and demonstrated that our technique is robust against 19 various noise addition and filtering attacks. The DWT-FWHT-SVD domain technique is also found superior than existing redundant-DWT-SVD based method against 12 different attacks.

Keywords- DWT, Decomposition, Affine, DWT-FWHT-SVD, Fibonacci-Lucas, administration

I.INTRODUCTION

Advances in communication technology demands strong security for image, audio and videos data that is transmitted via internet and mobile phones. Digital image watermarking hides appropriate information in original image for copyright protection without degradation of the perceptual quality and ensuring difficulty to be removed simultaneously [1]. Followings are candidate applications where digital image watermarking based security solutions can play key role: image copyright communication for right management and protection , multimedia message service (MMS) in mobile phones, central bureau investigations (CEI) and other crime investigation agencies, nationwide and worldwide e-voting systems used in parliamentary, presidential or municipal, nationwide and worldwide distance education, android based applications used in mobile phones using Java programming language, health insurance companies, car insurance companies for decisions for accidental medical allowances, accidental damaged vehicles, banking services including multinational companies with requirement of secure image databases and their transmission, secured passport identifications, e-health technology with telepathy, teleradiology, telecare, teleneurology, telesurgery, medical images . Obama administration is offering between $44,000 and $64,000 to promote physicians those use Electronic Medical Record (EMR) system in their medical practices [2]. Imperceptibility, robustness, payload and security are four attributes those determine quality of image watermarking scheme [1]. The remaining part of paper is organized as follows: Section-II gives survey of work related to DWT and composite transforms, section-III gives mathematical background of DWT, FWHT, SVD and Fibonacci-Lucas transform along with affine transforms used for scrambling the watermark. In section-IV comparative of DWT and DWT- FWHT-SVD based methodology is presented. Experimentation and results are elaborated in section-V while conclusion is drawn in section-VI.

II. RELATED WORK

As per embedding domain, digital image watermarking techniques are categorized as spatial domain and transform domain. Spatial domain techniques like least significant bit methods are simple for implementation but they are less secured and have low watermark information hiding capacity. In transform domain, the watermark is inserted into transformed coefficients of cover image giving more robustness against watermarking attacks and having more watermark information hiding capacity as watermark information is spread out to entire cover image. Here, survey of some existing DWT based and composite transforms based techniques are presented. As, DWT provides multi resolution and exact reconstruction of decomposed image, it has become researchers focus for image watermarking. DWT based image watermarking techniques are presented by Chuntao Wang et al.[3], N. Bi et al.[4], D. Kundur et. al.[5], Mohsen Zareian et al.[6] and V. Senthil et al.[7]. Many researchers have already tried composition of two or three transforms to take benefit of special properties of individual transform. The combined DCT-DWT based technique is proposed by KetaRaval et al.[8]. The combine DWT-DCT based technique is proposed by Saied AmirgholipourKasmani et al.[9] where binary watermarked image is embedded in specific sub bands of 3-level transformed of host image. Each of DWT sub band is selected and then DCT values are computed. The 'generated and embedding is done in DCT middle frequencies. Few researchers have combined DWT and SVD to take advantage of their individual special properties. The DWT and SVD transforms are combined by Hailiang Shi et al.[lO] to implement rotation, scaling and translation(RST) invariant scheme. Priyanka Singh et al.[II] used hybrid DWT-SVD based color image watermarking scheme in YUV and YIQ color spaces. The scheme tested 512x51 size cover images to check imperceptibility and robustness in terms of Peak Signal to Noise Ratio (PSNR) and Normalized Cross Correlation (NCC) respectively. The method gives better performance of Y color space. Chih-Chin Lai et al. [12] used DWT and SVD hybridization and proved robustness against geometric attacks. Samira Lagzian et al.[13] presented Redundant Discrete Wavelet Transform (RDWT)-SVD based method that embeds data in all low, middle and high frequency sub bands of DWT. DWT-DFT composition is used by Xiangui Kang et al.[14] to achieve robustness against almost all affine transforms and JPEG compression attacks. SivavenkateswaraRao. V et al.[15] combined DWT,DCT and SVD for optimization of robustness and fidelity.

III.MATHEMATICAL BACKGROUBD

A. DWT

Discrete wavelet can be represented as[16],

$\Psi_{j,k}(t) = a_0^{-j/2}\, \psi\, (a_0^{-j}\, t - k\, b_0)$ (1)

For dyadic wavelet a_0=2 and b_0=1, Hence we have,

$\Psi_{j,k}(t) = 2^{-j/2}\, \psi\, (2^{-j}\, t - k)j,\ k \in Z$ (2)

When image are passed through series of low pass and high pass filters, DWT decomposes the image into sub bands of different resolutions. Decompositions can be done at different DWT levels. At level l, DWT decomposes image into four non-overlapping multi-resolution sub bands: LLl, HLl, LH1 and HH1 as shown in fig.1. Here, LLl is low frequency component whereas HLl, LHI and HHI are high frequency components.

LL1	HL1
LH1	HH1

(a)

(b)

Fig.1. One level DWT decomposition (a) Four sub band (b) Decomposition Of Lena image

The diagonal Sub band HHI includes edges and textures of the image. In compression attack with thresh holding coefficients above specific threshold are removed. Horizontal sub band HLI and vertical sub band LHI are middle frequency sub bands. However, human visual system (HVS) is more sensitive in vertical than horizontal. Hence, the better choice for watermark embedding is HLl region.

B. FWHT

The Walsh-Hadamard transform decomposes a signal into a set of basic functions that are rectangular or square waves with values of +1or -1. These basis functions are non-sinusoidal, orthogonal transformation technique. The FWHT is able to represent signals with sharp discontinuities more accurately using fewer coefficients than the FFT. For 2-D image FWHT coefficients are calculated by first row wise then column wise. The FWHT and IFWHT for a signal x (t) of length N are defined as [17]

$$y_n = \frac{1}{N}\sum_{i=0}^{N-1} x_i \quad WAL(n,i) \qquad (3)$$

$$x_i = \sum_{i=0}^{N-1} y_n \; WAL(n,i) \qquad (4)$$

Where i = 0, 1 ,….N-1 and WAL (n, i) are Walsh functions.
The First eight Walsh functions have following values:

Index	Walsh Function Values
0	11 1 1 1 1 1 1
1	11 1 1 - 1- 1- 1 -1
2	11 - 1- 1- 1- 11 1
3	11 - 1- 11 1 - 1- 1
4	1- 1- 11 1 - 1- 11
5	1- 1- 11 - 11 1 - 1
6	1- 11 - 1- 11 - 11
7	1- 11 - 11 - 11 – 1

C. SVD

Singular values of an image have very good stability. The minor variations in singular values do not affect much effect on perception quality of given image. The largest of singular values shows slight changes for most common geometric attacks. SVD of an image A with size MxN is represented as[12],

$$A=U\sum V^T \quad (5)$$

Where, U and V orthogonal matrices such that,

Thus we have,

$$A=\lambda_1 U_1 V_1^T + \lambda_2 U_2 V_2^T + \cdots\ldots + \lambda_r U_r V_r^T \quad (6)$$

Where, r is rank A.

The columns of U and V are left and right singular vectors of A.

$UU^T = I$ and $VV^T = I$,

Σ is summation of diagonal entries $\lambda_1, \lambda_2 \ldots \ldots \ldots \ldots$ given the singular vector of A.

D. Fibonacci-Lucas Transform with Affine Transform

The 'watermark scrambling methods' are used to transform meaningful watermark information into disordered and unsystematic patterns so that extractor cannot identify watermark directly after watermark extraction process. The Fibonacci-Lucas transform is combination of Fibonacci transform and Lucas series. It can be defined as[18],

$$F_n \begin{pmatrix} x1 \\ y1 \end{pmatrix} = \begin{bmatrix} F_i & F_{i+1} \\ L_i & L_{i+1} \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix} (mod\ N) (7)$$

Where, first row of equation (7) adopted from Fibonacci series and second row is adopted from Lucas series.

$(x, y)\epsilon\{0, 1, \ldots.. N-1\}$: Original image.

$(x1, y1)$: Fibonacci-Lucas transformed Image.

F_i Is the i^{th} term of Fibonacci series .

L_i is the i^{th} term of Lucas series , (i=1,2,3,4,5……..except 3).

N: Size of digital Image.

After scrambling the watermark using Fibonacci- Lucas Transform, affine transform 'clockwise rotation by theta degree' is applied to scrambled watermark before embedding it into cover image. Mathematically, rotation affine transform is represented as [19],

$$x = w\cos\theta - z\sin\theta \quad (8)$$

$$y = w\sin\theta + z\cos\theta \quad (9)$$

Where, θ is angle of rotation.

IV. PROPOSED METHODOLOGY

The proposed method is implemented in DWT- FWHT-SVD as well as in DWT domain. The DWT- FWHT-SVD domain methodology is presented in part-A here, while DWT based methodology is explained in Part-B.

A. DWT-FWHT-SVD DOMAIN METHODOLOGY

The DWT- FWHT-SVD based watermark embedding

Input: 'Cover Image', Watermark W. **Output: Water marked Image, PSNR**	
Steps:	
1:	Read 512x512 size grey scale ' Cover Image'. [M,N]=size(Cover Image)
2:	Apply one level DWT to ' Cover Image' using 'Haar' wavelet to give four non overlapping sub bands: [LLI ,HLI ,LHI,HH 1] = dwt2(cover image, 'Haar');
3:	Apply 'Fast Walse-Hadamard Transform' to 'HLI ' sub band. temp=fwht (HLI)
4:	Apply 'Singular Value Decomposition' (SVD) to 'temp' [U, S,V]=SVD (temp)
5:	Read 256x256 grey scale watermark say 'W'.
6:	Apply 'Fibonacci-Lucas transform and affine transform clockwise rotation by angle 'theta' to give scrambled watermark 'WI'
7:	Perform embedding of WI with cover image, with scale factor KI. SI =S+KI*WI
8:	[UI, SS, VI] =SVD (SI) CWI =U*SS*V'

9:	Apply inverse SVD to get 'New_HLI' component as: New HL I =ifwht(CWI)
10:	Perform one level inverse DWT with 'New_HLI ' component to form 'Watermarked Image' as: Watermarked Image = idwt2(LL I ,New_HLI ,LHI ,HH I ,'haar',[M,N]);
11:	Display 'Watermarked Image' and PSNR

Algorithm is presented Table-I and DWT- FWHT-SVD based Watermark extraction shown in Table-II

Table-II DWT-FWHT-SVD based Watermark Extraction

Input: Watermarked _Image, Cover _Image, Output: 'Recovered _Watermark'	
Steps:	
1:	Read 512x512 size 'Watermarked_Image'.
2:	Apply One level DWT to 'Watermarked_Image' to separate 'Recovered_HLI' component as: [LLI, Recovered_HLI, LHI, HHI] = dwt2(Watermarked _ Image,'Haar');
3:	Apply ' Fast-Walse-Hadamard Transform': NCWI=fwht(Recovered HL I)
4:	Apply Singular Value Decomposition [UU,S2,VV]=SVD(NCWI)
5:	Read 512x512 size grey scale ' cover_ image'. [M,N]=size(Cover _Image)
6:	Apply one level DWT to ' Cover _Image' using 'Haar' wavelet to give four non overlapping sub bands: [LLI ,HLI ,LHI ,HHI] = dwt2(Cover _Image,' Haar');
7:	Apply 'Fast Walse-Hadamard Transform' to 'HLI ' sub band. Temp=fwht (HLI)
8:	Apply 'Singular Value Decomposition' (SVD) to 'temp'. [U,S,V]=SVD (temp)
9:	Find SN using component: S2 in step 4 and components: UI and VI in step 8 of watermark embedding process. SN=UI *S2*VI '
10:	'Scrambled_ Watermark' can be found as follows: Scrambled_ Watermark=(SN-S)/K I ;
11:	Apply Fibonacci-Lucas transform with key used in embedding algorithm and then use affine anticlockwise rotation by angle 'theta' to give 'Recovered_ Watermark' .
12:	Display 'Recovered _Watermark' and NC

B. DWT DOMAIN *METHODOLOGY*

To implement DWT domain 'image embedding algorithm', FWHT and SVD steps are skipped from Table-I and to implement DWT domain 'image extraction algorithm' FWHT and SVD related steps are skipped from table-II. The rest of the algorithmic steps will be applied in same sequence as given in Table-I and table-II

V. EXPERIMENTATION AND RESULTS

The proposed work is implemented using Java Net beans IDE version 7.3 and Mat lab[version 8.0.0.7837(R20l2b)]. The experimentation is carried out on personal computer with Intel(R), Core(TM) i3-2310M, processors rated at 2.10 GHz, main memory of 4 GB and 32 bit Microsoft Windows 7 operating system. The variety of tests are carried out to evaluate perceptual quality, robustness with high payload capacity for grey scale images of 5l2x5l2 sizes and grey scale watermark of 256x256 sizes. The online OsiriX database [20] including CVG-UGR images used for testing in DWT as well as DWT-FWHT-SVD domain. Fig.2. shows sample output of DWT-FWHT--SVD based method with original cover image baboon, original watermark cameraman, scrambled watermark, watermarked image baboon, extracted watermark and recovered watermark cameraman

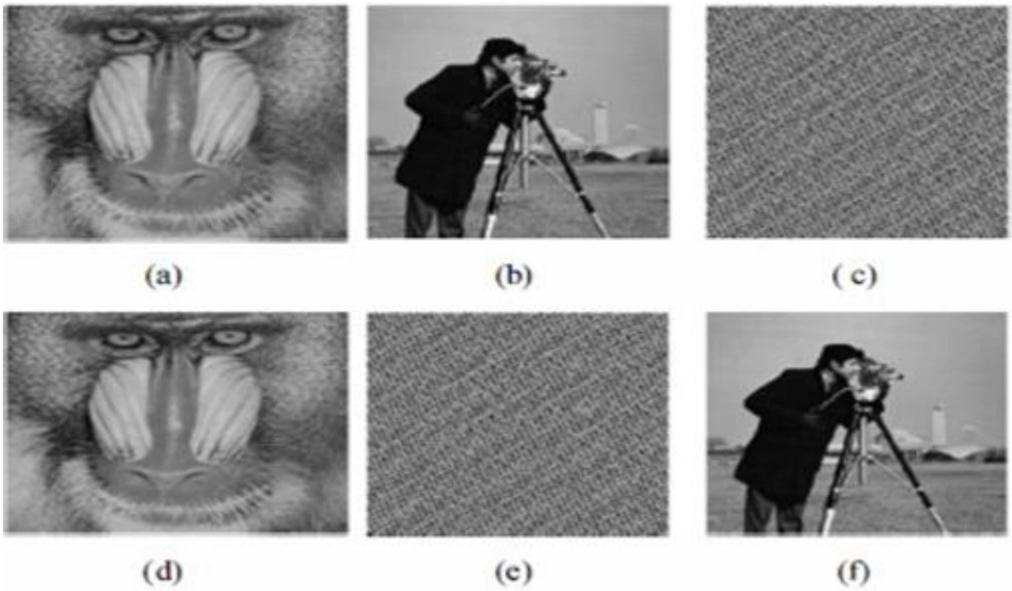

Fig.2. Sample output of DWT-FWHT--SVD based method a)Original Cover Image b) Original Watermark c) Scrambled Watermark d)Watermarked Image e) Extracted Watermark f) Recovered Watermark(Images are resized for display purpose)

In experimentation, we used Fibonacci-Lucas periodicity (p)=256 and affine angle theta=I80. Here objective is to test are two major quality measures of watermarking techniques: perceptual transparency and robustness with given grey scale watermark. Perceptual transparency means perceived quality of image should not be destroyed by presence of watermark. The major attribute to measure image quality is PSNR. Higher PSNR implies better quality of watermarked image. Initially, the Mean Square Error (MSE) is found and PSNR is calculated using MSE. MSE between two input images A(i,j) and B(I ,j) is given by [17],

$$MSE = 1/M+N\sum_{i=1}^{M}\sum_{j=1}^{N}[A(i,j) -]\,B(i,j)]^2 \quad (10)$$

Where, M*N is size of images, A (i, j) is pixel of original image, B(i, j) is pixel values of watermarked image. Now, PSNR of two images A and B of size M*N is given by[17],

$$PSNR\ (db) = 10\log 10 = \frac{(Max1)^2}{\frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}[A(i,j)-B(i,j)]^2} \quad (11)$$

Where, Max1 is 255 for grey scale image. Robustness is measure of resistance of watermark against intentional or unintentional attacks. NC is measure attribute to measure robustness of image under consideration. NC measures the similarity and difference between 'embedded watermark' and 'recovered watermark'. Mathematically, NC between two watermarks W_1 and W_2 is given by[I7],

$$NC = \frac{\sum_{i=1}^{N} w_1 w_2}{\sqrt{\sum_{i=1}^{N} w_1}\sqrt{\sum_{i=1}^{N} w_2}} \quad (12)$$

From Table-III, it is clear that PSNR and NC values of candidate images 'Lena', 'peppers', 'baboon', 'lake' and 'plane' images are better in DWT-FWHT-SVD domain than DWT domain for all valued of scale factor K=0.I5 to k=0.55.

Table-III: Comparative PSNR and NC values obtained in DWT-FWHT-SVD and DWT domain

Scale Factor(K)		**K-0.15**		**K-0.25**		**K-0.35**		**K-0.45**		**K-0.55**	
Domain under testing		DWT-FWHT-SVD	DWT Domain	DWT-FWHT-SVD	DWT Domain	DWT-FWHT-SVD	DWT Domain	DWT-FWHT-SVD	DWT Domain	DWT-FWHT-SVD	DWT Domain
Lena	PSNR	63.0838	56.5244	53.4900	49.4717	48.9526	45.6589	45.9909	43.5288	43.7463	42.7983
	NC	0.9880	0.9799	0.9967	0.9815	0.9984	0.9824	0.9989	0.9887	0.9993	0.9915
Peppers	PSNR	71.0842	65.6577	57.4476	53.5387	51.3259	47.6427	47.7191	45.6586	45.2709	43.7983
	NC	0.9837	0.9818	0.9946	0.9887	0.9976	0.9889	0.9988	0.9915	0.9993	0.9987

Baboon	PSNR	85.8064	79.6788	73.5081	68.5286	63.4716	59.6428	55.8935	52.3246	51.1279	48.7984
	NC	0.9748	0.9739	0.9813	0.9808	0.9919	0.9915	0.9976	0.9924	0.9989	0.9967
Lake	PSNR	76.5244	71.8894	62.6585	57.8994	54.6751	51.6578	50.5514	46.5084	47.2506	44.5289
	NC	0.9815	0.9808	0.9924	0.9815	0.9971	0.9909	0.9928	0.9908	0.9963	0.9924
Plane	PSNR	80.6577	76.6754	65.8892	62.4718	57.7983	53.1478	53.5287	49.4716	49.6427	46.4716
Lena	NC	0.9799	0.9708	0.9908	0.9815	0.9958	0.9918	0.9975	0.9924	0.9986	0.9973

As quality factor of baboon image is better, it shows superior performance than selected set of candidate images under testing. The method is robust in DWT-FWHT-SVD domain against 19 possible noise addition and filtering attacking. The details of performance the candidate images for noise addition and noise filtering attacks is shown in fig.3. The candidate watermarked images with maximum NC i.e. K=0.55, are selected for testing their performance under attacks. The Lena image with PSNR=43.7463 and NC=0.9993, peppers image with PSNR 45.2709 and NC 0.9993, baboon image with PSNR 51.1279 and NC 0.9989, lake image PSNR=49.2506, NC=0.9994, plane PSNR =49.6427, NC=0.9986 are selected for applying the noise addition and filtering attacks. Baboon image gives best performance for all noise attacks with density 0.001to 0.1. and for speckle noise with density 0.001.But, it shows poor performance against filtering attacks including median filtering, wiener filtering and Gaussian filtering while Lena image gives better performance against filtering attacks. The DWT-FWHT-SVD based method is also found out performing with compared with three different existing RDWT-SVD based method [2I] for 12 various noise addition and filtering attacks for 'peppers' image as shown in fig.4

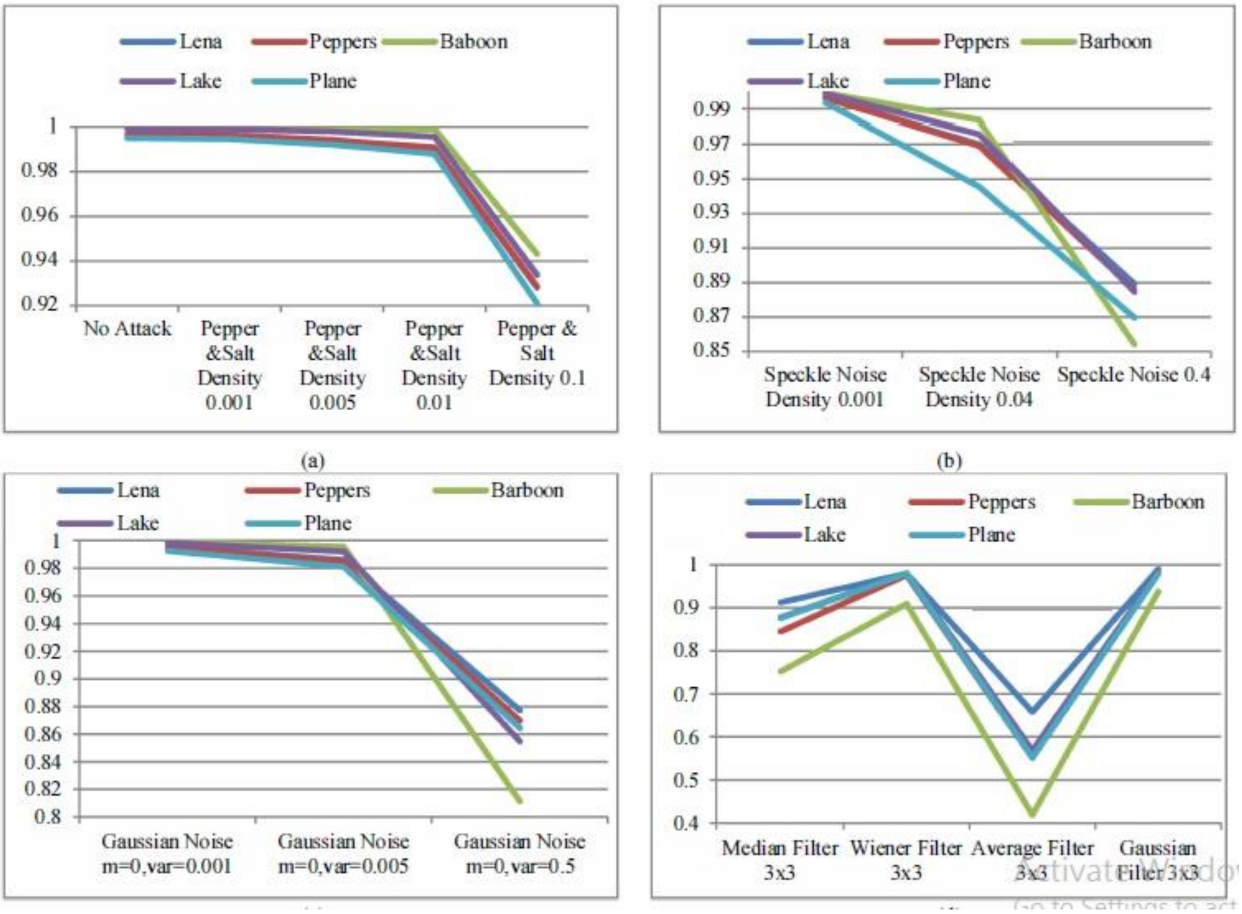

Fig.3. Robustness of DWT -FWHT-S VD against a)Pepper and Salt Noise b) Speckle Noise attack c)Gaussian Noise d) Filtering Attacks

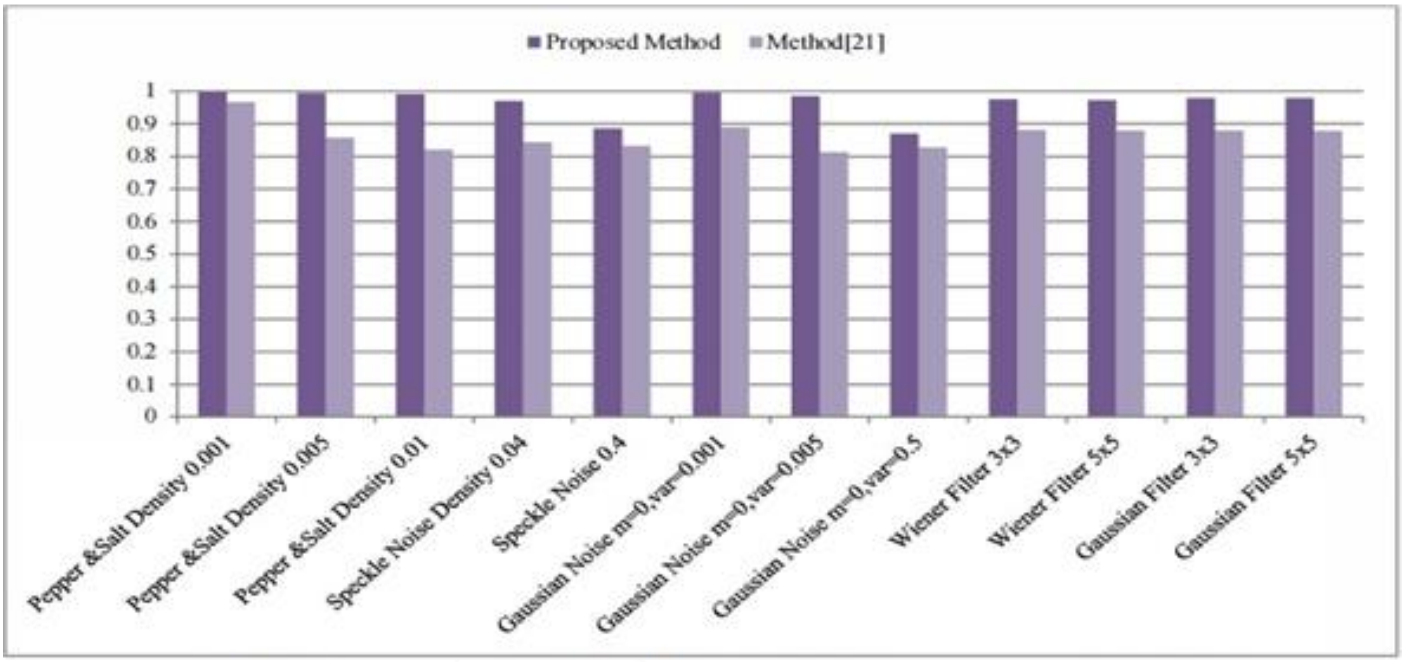

Fig.4. Robustness of proposed DWT-FWHT-SVD based method for 'peppers' compared to method [21]

VI. CONCLUSION

The achievement of imperceptibility, robustness, high embedding capacity and strong security in digital image watermarking techniques is challenging issue. The method proposed here fulfills these requirements simultaneously. The practical demonstration shows that performance of proposed method in DWT-FWHT-SVD domain is superior than DWT domain for 512x51 sizes candidate images Lena, peppers, baboon, lake and plane and 256x256 sizes grey scale watermarks. The proposed DWT-FWHT-SVD based method is strongly robust to 19 various noise additions and filtering attacks. The proposed method is also found superior than RDWT-SVD based method [21] against 12 various attacks. The security is implemented with Fibonacci-Lucas transform along with affine transform. This method can be extended for color images, medical images and video watermarking with replacement of DWT by 'Complex Wavelet Transform (CWT) or 'Complex and rotated wavelet transform' for more robustness and security

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