Transform Domain Image Watermarking using DCT, DWT and SVD

Azmat Rana, N. Lakshmi, Arun Vaishnav

Abstract: ***In the past of years of development of digital communication and network communication technology with increase in transferring documents all over the world, the authenticity and ownership of document is also important and challenging to control. To solve these problems so many techniques evolved which comes under transform domain and spatial domain based watermarking techniques. Most commonly used popular digital image watermarking techniques based on Transform Domain are like Discrete Cosine Transformation (DCT), Discrete Fourier Transformation (DFT), Discrete Wavelet Transformation (DWT) and Singular Value Decomposition (SVD) transformations. But with lot of introduced techniques there must be a standard parameterized study required which compares them individually and explain their actual performance. In this paper, we implement watermarking using Transform Domain based techniques DCT, DWT and SVD and compare them practically on standard parameters like imperceptibility & robustness with use of standard attacks. For the analysis of them we take standard images for implementation of digital image watermarking. All work done in Matlab platform. Experimental result shows the performance quality of DCT, DWT and SVD based watermarking techniques with standard quality parameters.***

Keywords: Digital Image Watermarking, Discrete Cosine Transformation, Discrete Wavelet Transformation, Singular Value Decomposition.

I. INTRODUCTION

With the development of advanced technologies in communication provides ease of transmission and sharing of documents globally using the Internet. With ease of transmission it also increases illegal operations in this data transmission like illegal duplication, modification, authorization and authentication with ownership issues. Therefore, the protection of the intellectual properties of digital media becomes an important task in digital data transmission. To overcome these problems in digital media transmission various techniques introduced to control them one of this is watermarking techniques which are being used for authorization and authentication including copyright protection of the digital data communication.

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The watermarking techniques can be broadly classified in two categories known as Spatial Domain and Transform Domain [1]. Where in case of Spatial Domain techniques they uses bit level manipulations in the original image document and implements watermarked image document but in case of Transformation Domain based techniques it uses frequency domain manipulation using DCT, DWT etc. and transforms original digital image into frequency domain. It is reported in available literature that Transform Domain Watermarking Techniques are more robust and efficient in comparison to Spatial Domain techniques. Digital image watermarking techniques has two main properties called as imperceptibility and robustness in watermarking. The imperceptibility describes that the visual or appearance quality of the watermarked image where as the robustness describes the resilience structure of the watermarked document against the different types of attacks applied on the watermarked document. So robust watermarking technique means the watermark that could be extracted or recovered well even when the watermarked image is changed and altered by different type of noises and attacks. However so many image watermarking schemes defined and algorithms were proposed by researchers to improve the quality of watermarking [2-5]. In this paper we compare and analyze performance of transform domain watermarking techniques using standard parameters. The structure of paper divides in five sections, Section 1 includes introduction. In Section 2, we present the review on transform domain based watermarking techniques like Discrete Cosine Transformation (DCT), Discrete Wavelet Transformation (DWT) and Singular Value Decomposition (SVD) technique in brief that we are going to be use in implementation of digital image watermarking. In Section 3, we describe common algorithm used for implementation as well as extraction of watermark using one of the defined transform domain based technique. In Section 4, we discuss experimental results and presents comparative results generated by transform domain watermarking techniques. Finally, we draw a conclusion presenting the advantages and drawbacks of the each of the technique.

II. WORK DONE ON TRANSFORM DOMAIN WATERMARKING TECHNIQUES

A. Discrete Cosine Transformation

DCT domain based watermarking technique can be classified as Global DCT watermarking technique and the Block based DCT watermarking technique.

The first algorithms presented by Cox et al. used Global DCT watermarking approach to embed a robust watermark with the perceptually significant portion of the Human Visual System. Embedding of watermark in the perceptually significant portion of the image has its own advantages because most compression schemes remove the perceptually insignificant portion of the original image [3]. Discrete Cosine Transformation is a technique in which it converts digital data into cosine frequency components which further used for various kind of processing [6, 7]. It converts given Image x of *M x N* sized into frequency domain by following equation [8].

$$y(M,N)=\sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}a_u a_v\sum_{u=0}^{M-1}\sum_{v=0}^{N-1}X(M,N)\cos\frac{(2M+1)u\pi}{2M}\cos\frac{(2N+1)v\pi}{2N} \quad (1)$$

Where x *(u, v)* is the DCT coefficient with row *u* and column *v*. The values of a_u and a_v both set to $1/\sqrt{2}$ when *u. v*=0, otherwise 1.

Converted image again reconverted back to the original using the inverse of it by the following equation [9].

$$y(M,N)=\sqrt{\frac{2}{u}}\sqrt{\frac{2}{v}}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1}a_u a_v x(u,v)\cos\frac{(2M+1)u\pi}{2M}\cos\frac{(2N+1)v\pi}{2N} \quad (2)$$

The DCT not only converts the main information of original image into the smallest low frequency coefficients, but also it can cause to minimize the image blocking effect, which reduces the information centralizing and the computing complication of it. The DCT breaks an image into different frequency bands which makes it much easier to embed watermarking information into the middle frequency bands of an image. It invisibly embeds the watermark image with the original image that improves lossy data compressions also, which is major reasonable issue to embed the watermark into the middle-frequency range only of the image.

B. Discrete Wavelet Transformation

The basic mechanism used in DWT for image processing is to decompose the image into sub-images with different independent frequency distribution. So the original image transformed and decomposed into four sub-bands of images created by DWT. Out of them there will be three high frequency parts sub-bands generally called as HL, LH and HH and one low frequency part sub-band called as LL of sub-image. In Figure 1 it display 2 level wavelet transformed process of the original image, where HL, LH, HH are the horizontal high frequency, the vertical high frequency and the diagonal high frequency parts of the image and LL is the approximation of the low frequency part of the image. The high-frequency part like horizontal, vertical and diagonal part represents the information about the original image like texture, edge, etc. The low frequency part used to represents an important component which can be decomposed continuously. The quality of the image is diffused better and the stronger image intensity can be embedded with more levels of decomposed image generated by wavelet transformation.

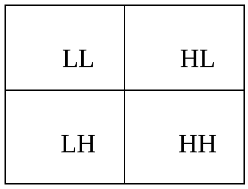


Fig. 1 Wavelet decomposition

C. Singular Value Decomposition Technique

SVD is one of the effective numerically based analysis technique which is used to analyze matrices or the matrix form data [12-14]. In SVD transformation, a matrix can be decomposed into three matrices that are the same size as the original matrix. The real *n x n* matrix *A* can be transformed easily using SVD transformation into three components named as *U, D* and *V* respectively, such that[13]

$$[U \;\; D \;\; V] = \text{SVD}(A), \qquad A' = UDV^T$$

$$\begin{bmatrix} u_{1,1} & K & u_{1,n} \\ u_{1,2} & K & u_{2,n} \\ M & K & M \\ u_{1,n} & K & u_{n,n} \end{bmatrix}\begin{bmatrix} \sigma_{1,1} & K & 0 \\ 0 & \sigma_{2,1} & 0 \\ & M & \\ 0 & K & \sigma_{n,n} \end{bmatrix}\begin{bmatrix} v_{1,1} & K & v_{1,n} \\ v_{1,2} & K & v_{2,n} \\ M & K & M \\ v_{1,n} & K & v_{n,n} \end{bmatrix}^T$$

$$=\sum_{i=1}^{n}u_i\sigma_i v_i^{\tau} \quad (3)$$

where *U* and *V* components are *n x n* real unitary matrices with small singular values, and the *D* component is an *n x n* diagonal matrix with larger singular value entries which satisfy $\sigma_{1,1}\geq\sigma_{2,2}\geq\ldots\geq\sigma_{r,r}>\sigma_{r+a,r+1}=\sigma_{n,n}=0$. A' is the reconstructed matrix after the inverse SVD transformation. The relationship between *A*, and the three matrices *U*, *D*, and *V* satisfies $Av_i=\sigma_i\mu_i$ and $\mu_i^T A=\sigma_i v_i^T$.

In 2002, Sun et al. proposed an SVD and quantization- based watermarking scheme. The *D* component with a diagonal matrix was explored. In the embedding procedure, the largest coefficients in *D* component were modified and used to embed a watermark. The modification was determined by the quantization mechanism.

III. ALGORITHMS FOR IMAGE WATERMARKING

For the comparative analysis we implement digital image watermarking using DCT, DWT and SVD based Transform Domain Techniques. For their implementation we uses following algorithms.

Algorithm 1: For creation of watermarking

Step 1: Read the cover and watermark Image.
Step 2: Convert both images into frequency domain (Using DCT or DWT or SVD as we require analyzing of watermark)
*Step 3:*Embed the watermark image with the cover image with the specific α Time.

Step 4: Retransform to convert them into original image back (Using IDCT, IDWT or inverse SVD)

Algorithm 2: For Extracting Watermark from Watermarked Image

Step 1: Read the Watermarked Image and the Cover Image.
Step 2: Convert both images into frequency domain (Using DCT/DWT/SVD)
Step 3: Subtract Cover Image from the Watermarked Image.
Step 4: Multiply Extracted Watermark with specific α Time.

We also apply different attacks on the watermarked image to check its robustness against the applied noises and attacks. For this purpose we use the common type of attacks and noises like Gaussian noise, Cropping, Rotation, Salt & Pepper, Resizing, Sharpening and Histogram Equalization, Scaling then analyze robustness of the watermark.

IV. MEASUREMENT OF ALGORITHMIC FEATURES

Imperceptibility is one of the aspect used for performance analysis it related to the visual quality of the watermarked image caused by embedding the watermark and another aspect is its Robustness which is related to its visual quality of watermark even after applying attacks on the watermarked image. Peak Signal to Noise Ratio is used to evaluate the performance of the image quality. When PSNR is more than 40 dB then human cannot virtually distinguish between original and constructed image. The PSNR between matrix *A* and *A'* is given by following equation [13].

$$PSNR = 10x\log_{10}(R^2 \Big/ \sum_{i=1}^{M}\sum_{j=1}^{N}\left[A(i,j) - A^{'}(i,j)\right]^2)) \quad (4)$$

Where i=1, 2, 3,…………..M and j=1, 2, 3,…………..N

Mean Square Error is another parameter to calculate difference between original and extracted one. The MSE can be calculated by the following equation [12].

$$MSE = (((I_1 - I_2)^2 /(m*n)) \quad (5)$$

Where:

I_1 : Retrieved image
I_2 : Original image
m : Number of rows
n : Number of columns

Normalized Cross Correlation (NCC) indicates the similarity between the extracted and the original watermarks. When NCC value is high then there has high similarity with the original watermark. The range of NCC is between 0 and 1. When its value near to unity it indicate high correlation and thus high robustness. Similarly Normalized Absolute Error (NAE), MD (Mean Difference), NC (Normalized Correlation), SSIM (Structural Similarity Index), AD (Average Difference) also gives difference between the original and the extracted one.

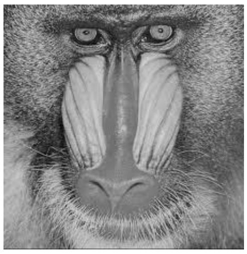
V. EXPERIMENTAL RESULTS

In this section, we analyze the qualitative and quantitative performance analysis of Watermarking technique respective to its imperceptiveness and robustness. For the comparative performance analysis of transform domain based watermarking schemes respectively to the robustness and imperceptibility has been done with different implemented watermarked images and then apply standard attacks over them. We use standard images as cover and the watermark image for watermark implementation. Figure 2 displays the used images for the purpose of watermark implementation.

Results of the individual watermarking technique have been compared on the basis of standard parameters. The different order of attack on the Watermarked Image has been shown in Figure 3. We have shown results in Tables after comparison between the original image and the extracted image form the implemented watermarked image on the basis of DCT, DWT and SVD Technique respectively. Table I shows that the DCT technique is not better with attacks cropping, Rotation, blurring and resizing. Table II shows that the DWT technique is not better with rotation, Histogram Equalized and Blurring attack. Table III shows that the SVD based watermarking is more imperceptive compare to the DCT and DWT technique because in each parameter it is giving better performance compare to the other watermarked technique. Figure 4 displays the plotting of individual parameters like PSNR, MSE, AD, SSIM, NC and NCC which calculate after applying different attacks on the each implemented transform domain based watermarked image which implemented in the any one of the DCT, DWT or SVD based technique.

(a) Cover Image

(b) Cover Image



(c) Watermark Image

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(d) Watermarked Image

Fig. 2: (a) and (b) Cover Image, (c) Watermark Image and (d) Watermarked Image

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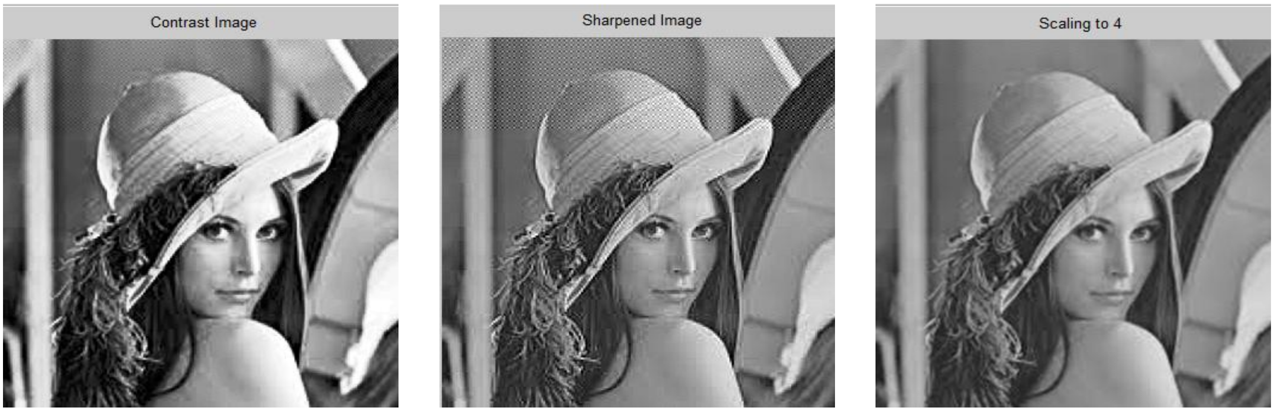


Fig 3: Different attacks applied on watermarked image

Table-I: Results between original and extracted watermark image using DCT, DWT and SVD

	NAE	MD	NCC	NC	SSIM	PSNR	MSE	AD
DCT based Watermarking	28.9475	26355	3.88E-05	1.81E+04	-1.61E-06	105.566	1.81E+04	-0.7343
DWT based Watermarking	0.0662	17	1.0031	45.1791	0.9662	69.1195	45.1791	-0.4736
SVD based Watermarking	0.3907	178	0.8775	114.4319	-0.0476	60.2901	114.4319	5.5125

Table-II: Results of DCT based watermark after applying attacks

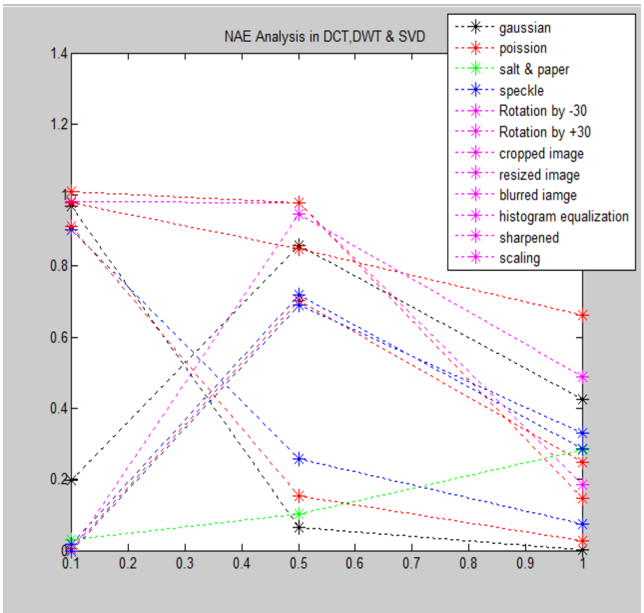
	NAE	MD	NCC	NC	SSIM	PSNR	MSE	AD
Gaussian noise	0.1978	1	0.8862	0.1035	0.7928	22.6803	0.1035	0.0156
Poission noise	0.0037	0	1	0.002	0.9961	62.3832	0.002	-0.002
Paper & salt noise	0.0299	1	0.9813	0.0156	0.9687	41.5888	0.0156	0.0039
Speckle noise	0.0168	1	0.9925	0.0088	0.9824	47.3425	0.0088	-9.77E-04
Rotation by -30	0.9813	1	0.1623	0.5137	0.0033	6.6617	0.5137	0.3633
Rotation by +30	1.0112	1	0.1567	0.5293	-0.0208	6.3621	0.5293	0.3535
Cropped image	0.9683	1	0.4888	0.5068	-0.0132	6.7957	0.5068	0.0283
Resized to 200x200	0.903	1	0.3433	0.4727	0.0687	7.4939	0.4727	0.2148
Blurred image	0.9776	1	0.4944	0.5117	-0.024	6.6998	0.5117	0.0176
Histogram Equalized	0	0	1	0	1	0	0	0
Sharpened Image	0	0	1	0	1	0	0	0
Scaling to 4	0.9104	1	0.5354	0.4766	0.0457	7.4116	0.4766	0.0098

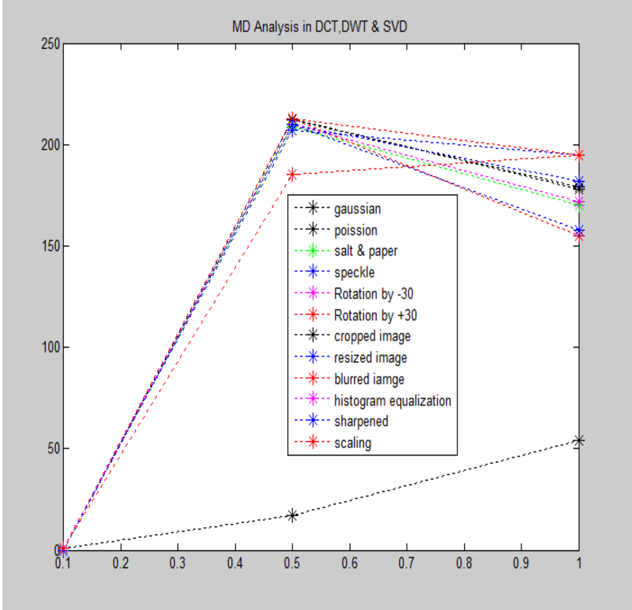
Table-III: Results of DWT based watermark after applying attacks

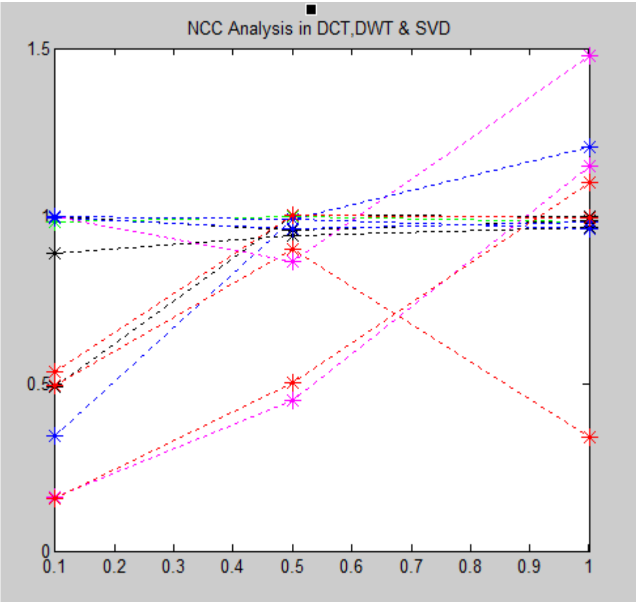
	NAE	MD	NCC	NC	SSIM	PSNR	MSE	AD
Gaussian noise	0.857	213	0.9422	123.3333	0.0421	59.0769	123.3333	-0.1724
Poission noise	0.7027	212	0.957	122.4587	0.1168	59.1481	122.4587	0.7167
Paper & salt noise	0.1023	209	0.9997	48.8399	0.7754	68.3404	48.8399	-0.3292
Speckle noise	0.7199	210	0.9621	120.724	0.1023	59.2908	120.724	-0.5337
Rotation by -30	0.9785	210	0.4479	192.2979	0.0012	54.6354	192.2979	66.6114
Rotation by +30	0.9768	213	0.5003	185.364	0.008	55.0026	185.364	59.7271
Cropped image	0.0662	17	1.0031	45.1791	0.9662	69.1195	45.1791	-0.4736
Resized to 200x200	0.256	207	0.9917	89.4016	0.5103	62.2945	89.4016	0.1137
Blurred image	0.8471	213	0.8986	127.6571	0.0333	58.7324	127.6571	5.3811
Histogram Equalized (Contrasted)	0.9477	210	0.8651	135.429	0.0273	58.1414	135.429	9.9651
Sharpened Image	0.6913	210	0.9887	112.518	0.1265	59.9947	112.518	-3.1867
Scaling to 4	0.1525	185	1.0023	71.2867	0.755	64.5587	71.2867	-0.561

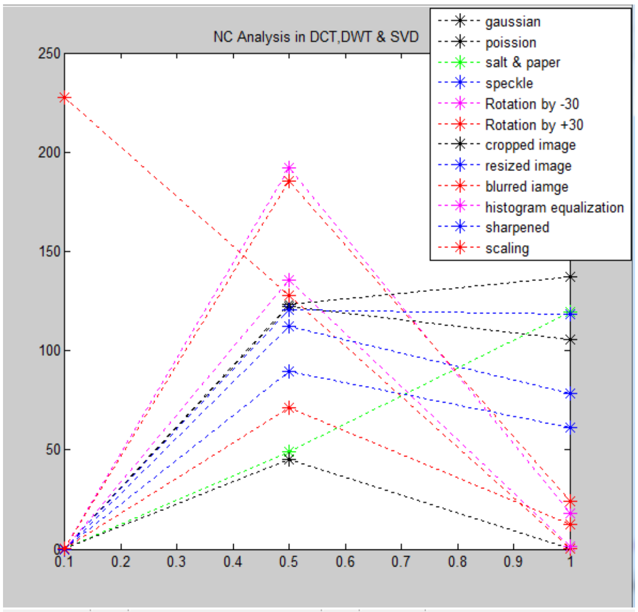
Table-IV: Results of SVD based watermark after applying attacks

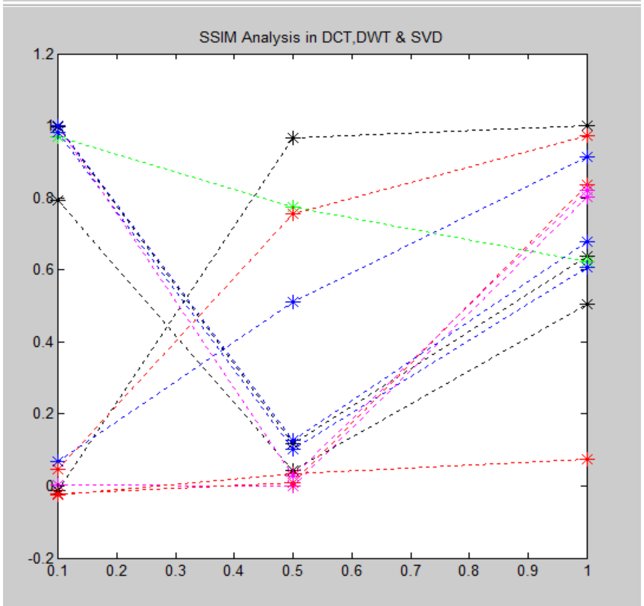
	NAE	MD	NCC	NC	SSIM	PSNR	MSE	AD
Gaussian noise	0.424	197	0.9671	137.2741	0.5042	58.4701	137.2741	11.4066
Poission noise	0.2496	179	0.9877	105.5787	0.6393	61.0953	105.5787	5.6015
Paper & salt noise	0.2823	170	0.9815	119.6954	0.6237	59.8404	119.6954	7.3849
Speckle noise	0.2857	182	0.9797	118.1032	0.6077	59.9743	118.1032	7.2912
Rotation by -30	0.1859	172	1.1465	18.1930	0.8026	78.6795	18.193	-18.4718
Rotation by +30	0.1467	155	1.1012	24.3593	0.8367	75.7608	24.3593	-11.9226
Cropped image	0.0018	54	0.9997	0.3196	0.9997	119.0955	0.3196	0.0425
Resized to 200x200	0.0754	195	0.9616	61.4021	0.9132	66.5155	61.4021	3.0473
Blurred image	0.6625	195	0.3402	227.6738	0.0727	53.4108	227.6738	82.6477
Histogram Equalized (Contrasted)	0.489	172	1.4793	1.5754	0.8207	103.1446	1.5754	-62.738
Sharpened Image	0.3288	158	1.2043	78.399	0.6792	64.0718	78.399	-19.4203
Scaling to 4	0.0276	195	0.9927	12.4645	0.9725	82.4611	12.4645	0.3009

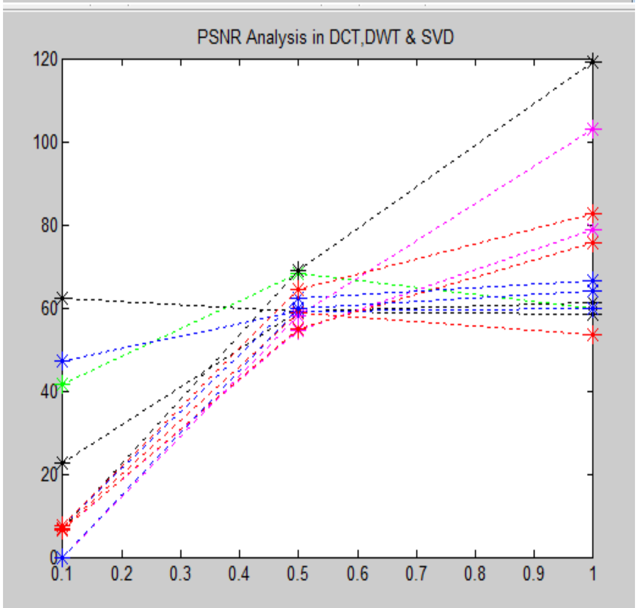

NAE Analysis in DCT,DWT & SVD
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
gaussian
poission
salt & paper
speckle
Rotation by -30
Rotation by +30
cropped image
resized image
blurred iamge
histogram equalization
sharpened
scaling


MD Analysis in DCT,DWT & SVD
250
200
150
100
50
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
gaussian
poission
salt & paper
speckle
Rotation by -30
Rotation by +30
cropped image
resized image
blurred iamge
histogram equalization
sharpened
scaling


NCC Analysis in DCT,DWT & SVD
1.5
1
0.5
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1


NC Analysis in DCT,DWT & SVD
250
200
150
100
50
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
gaussian
poission
salt & paper
speckle
Rotation by -30
Rotation by +30
cropped image
resized image
blurred iamge
histogram equalization
sharpened
scaling


SSIM Analysis in DCT,DWT & SVD
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1


PSNR Analysis in DCT,DWT & SVD
120
100
80
60
40
20
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

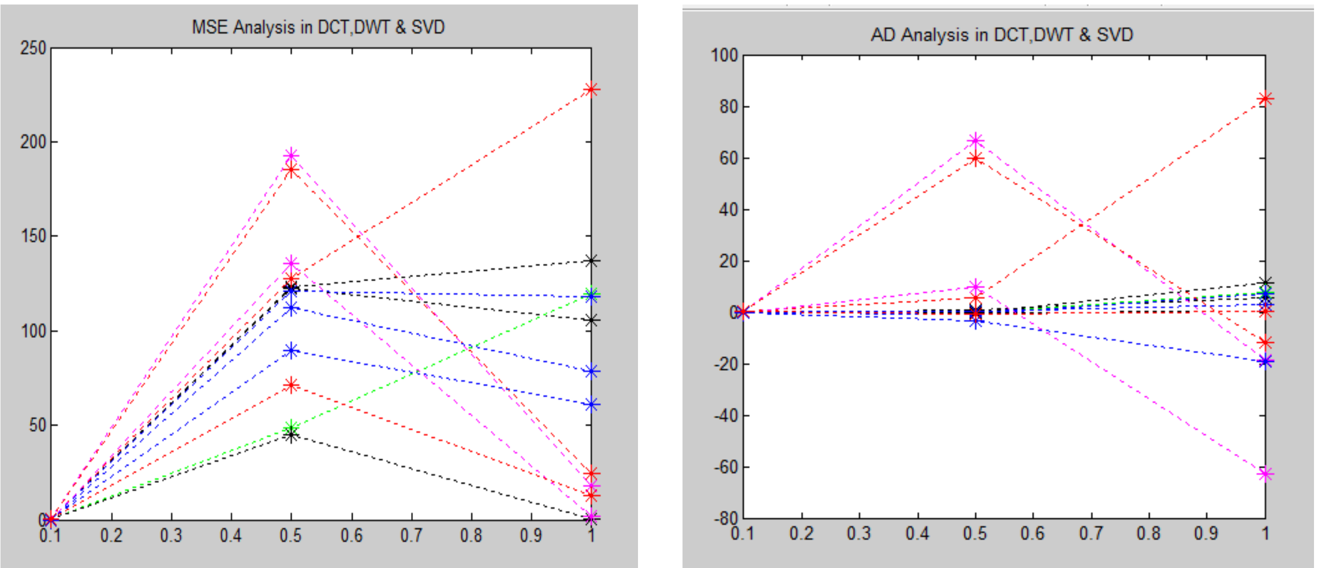


Fig 4: Plotting of parameters after applying attack on watermarked image implemented by DCT, DWT and SVD

VI. CONCLUSION

The work in this paper focuses on the digital image watermarking techniques performance analysis which based on transform domain like DCT, DWT and SVD. It provides comparative analysis between perceptual quality and robustness of the watermarked image against the standard noises and attacks. The results prepared, discussed and analyze them using Matlab. On the basis of the experimental results we can say that DCT / DFT based watermarking technique is simple in implementation respect to its algorithm, good in imperceptibility, Compatible with jpeg compression also. It has easier computation compared to the other techniques. It is reasonably less complex respect to execution but its lack of imperceptible in case of higher compression and makes the blocks visible. It is not better with attacks cropping, Rotation, blurring and resizing. DWT technique is simple excellent spatial localization technique. It is based on frequency spread so works with multi resolution. It has excellent time frequency analysis. It is good respect to the energy compaction and maintains robustness respect to the different attacks. It is compatible with jpeg for compaction, but it has computation complexity and less robust against to geometric attacks. It is not better with rotation, Histogram Equalized and Blurring attack.

SVD technique is resistance against geometric and other attacks so it is highly robust compare to the other transform based techniques. It has high energy Compaction. But it raises computation expenses in implementation. Most of the parameters it provides better results compare to other transform based watermarking techniques.

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