DC Coefficients Based Watermarking Technique for color Images Using Singular Value Decomposition

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***Abstract*– As DC coefficients are perceptually most significant and more robust to many unintentional attacks (signal processing) and intentional attacks (unauthorized removal), in this paper we proposed a robust non-blind watermarking algorithm based on DC coefficients for color images. DC coefficients are obtained by applying discrete wavelet transformation technique (DWT) followed by block based Discrete Cosine Transformation (DCT) technique. The RGB color spaces of the cover image are decomposed into different frequency bands using wavelet decomposition and block based DCT is applied. DC matrix is SVD decomposed to obtain singular values in which watermark is to be hidden. The proposed algorithm increases the watermarking capacity of cover data watermark and provides robustness against many signal processing operations and intentional attacks. The quality of the extracted watermark from green and blue color spaces is very good. The measured psnr and NC values are tabulated.**

***Index Terms*— Digital Watermarking, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD).**

I. Introduction

With the development of web communication and multimedia technology, more and more digital multimedia signal can be transmitted through Internet which in turn vulnerable to various attacks. Among today's information security techniques, multimedia watermarking techniques have been developed greatly and become a kind of powerful tool for protecting multimedia content. Watermarking is the process of embedding data into a multimedia content such as an image, audio or video file for the purpose of copy right protection, ownership verification, broadcast monitoring, authentication etc. The important properties of watermarking algorithm include imperceptibility, robustness, security and watermark recovery with or without the original data [1]. In order to be robustness, it is preferred to embed the watermark in perceptually most significant components, but this may affect the visual quality of the image and watermark may become visible. If perceptually insignificant coefficients are selected for embedding then the watermark may be lost by common signal processing operations. Thus determining the place of watermark is a conflict between robustness and fidelity and it is purely application dependent.

Generally information could be hidden either by directly modifying the intensity value of pixels or frequency coefficients of an image. The former technique is called spatial domain technique and later is called frequency domain technique. To obtain frequency components of an image, it needs to be transformed using any one of the transformation techniques such as Discrete Fourier Transformation (DFT), Discrete Cosine Transformation (DCT) [3]. Discrete wavelet Transformation (DWT)[4]. In transform domain casting of watermark can be done in full frequency band of an image or in specific frequency band such as in low frequency band or in high frequency band or in middle frequency band.

In this paper we proposed a new robust watermarking algorithm that combines the features of discrete wavelet transform, singular value decomposition and discrete cosine transformation techniques. The advantages of the proposed method are its robustness and its capacity. Robustness is achieved through embedding of watermark in most significant coefficients (DC coefficients) and capacity is increased by using three channels (RGB) of color image. The proposed algorithm is tested against various signal processing operations and many attacks and found that the algorithm is robust. The robustness is tested by measuring the similarity of original and extracted watermark which is more than 90 percent for all kinds of attacks except the rotation attack.

The rest of the paper is organized as follows; Review of related works is given in section II. Preliminaries of DWT-DCT-SVD techniques are discussed in section III. Proposed algorithm is discussed in section IV. Performance evaluation is elaborated in section V. Concluding remarks are given in section VI.

II. Review of Related Works

Review of literature survey has been conducted on discrete wavelet transformation (DWT), discrete cosine transform (DCT) combined with singular value decomposition (SVD) techniques for hiding information in digital color images. In [2] the image is divided into many block of size 8x8 and it is block transformed using DCT technique. These transformed blocks are randomly shuffled to decorrelate and to spread the watermark across the entire image. The mid band blocks are selected from the permuted blocks to embed watermark. This system is more robust than SVD based method. In [3] the cover is decomposed into four bands. The high frequency band is inverse transformed to obtain high frequency image and it is SVD decomposed to

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embed watermark by modifying high frequency components. Results show that the system is withstanding certain attacks including geometric attacks.

In [4] Image is transformed by DWT technique to K level. The middle frequency band LH and HL are SVD transformed and watermark is hidden. Similarly in low frequency and high frequency band the watermark is embedded using distributed discrete wavelet transform method (DDWT). Both algorithms are tested against attacks ad proved that they are robust against cropping attacks. For attacks such as Gaussian Noise, contrast adjustment, sharpness, histogram equalization, and rotation the proposed scheme is robust by exploiting the advantage of the SVD watermarking technique. In [5], three level decomposition of DWT is applied on image to get ten bands of frequencies. All ten bands of frequency coefficients are SVD transformed to embed watermark. A new watermarking scheme for images based on Human Visual System (HVS) and Singular Value Decomposition (SVD) in the wavelet domain is discussed. Experimental results show its better performance for compression, cropping and scaling attack.

In [6] two level decomposition of DWT is applied to transform an image into bands of different frequency and a particular band is selected and converted into blocks of size 4x4 for embedding data. Each of those the blocks are SVD transformed and watermark is hidden into diagonal matrix of every block. The similarity between the original watermark and the extracted watermark from the attacked image is measured using the correlation factor NC. The algorithm shows that when DWT is combined with SVD technique the watermarking algorithm outperforms than the conventional DWT algorithm with respect to robustness against Gaussian noise, compression and cropping attacks. In [7] a new algorithm is proposed for embedding watermark in color images. The blue color channel of the image is decomposed to obtain four frequency bands and the selected band is SVD transformed to to hide watermark. This scheme performs well for JPEG compression attacks. In [8] the new non-invertible method is proposed by combining DWT and SVD technique. The performance evaluation shows that the algorithm is robust against attacks such as cropping, Gaussian noise, JPEG compression. In [9] human visual system is exploited while embedding watermark. In [10], DWT and SVD techniques are combined to embed watermark in YUV channel. YUV channels are decomposed by applying wavelet transformation technique followed by SVD technique. Since the watermark is hidden in full band of YUV channel, the DSFW is robust to many signal processing attacks. In [12], the DWT technique is applied to decompose input image and LL band is converted into many blocks for DCT transformation. Only DC coefficients are selected and a new matrix is formed , this new matrix is SVD decomposed for watermark embedding

Based on the review performed many works are existing for embedding watermark by combining DWT and SVD techniques for intensity images. In the proposed work the watermark is embedded in the DC components of transformed color image. In order to increase the robustness, the low frequency band can be selected. But to increase the capacity of the watermark full band can also be used. The selected band is divided into block of size 2x2 which in turn DCT transformed to obtain only DC coefficients. These DC coefficients are SVD transformed to embed watermark in singular values.

III. Prelminaries

A. Discrete Cosine Transform

DCT is another important transformation technique which is widely used due to its energy compaction and decorrelation properties. DCT technique is faster than discrete Fourier transform since the bases are cosine function for the former technique and complex function for the later technique

The transformed matrix consists of both AC and DC coefficients. If the DCT technique is applied on block of size NxN then it is called block DCT. In DCT transformed block the left top corner element is called as DC coefficient which is perceptually significant and the remaining coefficients are called AC coefficients which are perceptually insignificant. These coefficients are zigzag scanned to obtain frequency components of an image in decreasing order. These DC and AC components are modified to embed watermark in it [3][11]. Equ. 1 and 2 are used for taking transformation and inverse transformation of an image.

$$c(0,0) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} f(x,y)$$

$$c(u,v) = \frac{2}{\sqrt{MN}} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} c(u,v) \cos\left(\frac{(2x+1)u\pi}{2M}\right) \cos\left(\frac{(2y+1)v\pi}{2N}\right) \quad (1)$$

Where $u = 1,\ldots,M-1$, $v = 1,\ldots,N-1$.
The inverse transform is

$$f(x,y) = \frac{1}{\sqrt{MN}} c(0,0) + \frac{2}{\sqrt{MN}} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} c(u,v) \cos\left(\frac{(2x+1)u\pi}{2M}\right) \cos\left(\frac{(2y+1)v\pi}{2N}\right) \quad (2)$$

B. Discrete Wavelet Transform

DWT is a transformation technique is used to represent an image in a new time and frequency scale by decomposing the input image into low frequency, middle and high frequency bands. The value of low frequency band is the averaging value of the filter whereas the high frequency coefficients are wavelet coefficients or detail values. [4].

The DWT can be used to decompose image as a multistage transform. In the first stage, an image is decomposed into four subbands LL1, HL1, LH1, and HH1, where HL1, LH1, and HH1 represent the finest scale wavelet coefficients, while LL1 stands for the coarse level coefficients, i.e., the approximation image. Fig.1 shows the one level wavelet decomposition of an image [12].

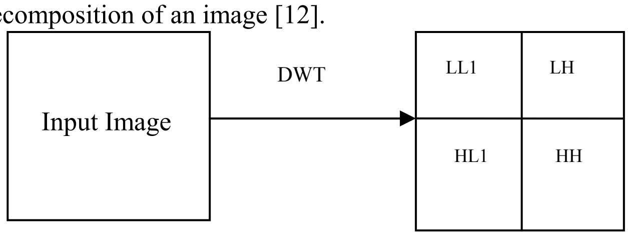

Fig. 1 One level of Wavelet decomposition

C. Singular Value Decomposition

SVD is a mathematical tool used to analyze matrices. In

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SVD, a given matrix A is decomposed into three matrices such that, $A=USV^T$ where U and V are orthogonal matrices and $U^TU=I$, $V^TV=I$, I is an identity matrix. The diagonal entries of S 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 matrix A. Usually, watermark is embedded in the singular matrix, and if the watermark is embedded in the orthogonal matrices of SVD then the perceptibility of host image is improved it is not robust to many attacks because the matrix elements of orthogonal matrices are very small.The three main properties of SVD from the view point of image processing applications are [4]:

1. The singular values of an image have very good stability, that is, when a small perturbation is added to an image, its singular values do not change significantly.
2. Each Singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image.
3. Singular values represent intrinsic algebraic properties.

IV. Proposed Algorithm

Proposed algorithm combines the properties of DWT, DCT and SVD techniques to increase the robustness and capacity of the algorithm by selecting significant coefficients and number of color channels. The procedure for embedding and extracting the watermark is given below.

A. *Watermark embedding algorithm*

In the proposed work the Lena color image of size 512 x 512 is considered as cover image. DWT technique is applied to decompose the color spaces into different frequency bands using dB1 filter. Watermark size determines the selection of one or all the frequency bands. Each band is divided into many blocks of size 4x4 and DCT is applied to all the blocks. In DCT transformed block the energy is compact in its DC component only. DC matrix is formed by collecting DC components of all the blocks and it is decomposed by SVD technique to get the singular matrix in which watermark is to be hidden. Watermark embedding and extraction process is shown in the Fig. 2 and Fig 3. The steps for embedding watermark are given below.

Let A be the cover image, then

1. Decompose the input image A into RGB color channels
2. Apply DWT to decompose RGB color channels of an image into various frequency bands. Size of the watermark determines the number of color spaces and number of frequency bands for embedding watermark.

$$[LL_R, LH_R, HL_R, HH_R] = 2dwt('R','dB1')$$
$$[LL_G, LH_G, HL_G, HH_G] = 2dwt('G','dB1')$$
$$[LL_B, LH_B, HL_B, HH_B] = 2dwt('B','dB1')$$

3. Divide the middle frequency band into smaller blocks of size 4x4 and apply DCT to each block, B_{ij}

$$B_{ij=}DCT_{LH}\ (B_{ij})$$

4. Extract the DC coefficients σ_{ij} from every DCT transformed blocks, and build a new matrix C, which is decomposed by applying SVD,

$$C = USV^T$$

5. Let W be the watermark and decompose it using SVD technique

$$U_W S_W V_W = SVD(W)$$

6. Modify the singular values of 'C' matrix by using the singular values of watermark.

$$S = S + \propto S_W$$

7. Combine the modified singular values with the orthogonal matrices of 'C',

$$S2 = U * S1 * V^T$$

8. Replace the original DC's σ_{ij} by the modified DC's $\tilde{\sigma}_{ij}$ in each block $\tilde{B}_{ij}$ .Then apply inverse DCT to each block of low frequency band to reconstruct low frequency band of DWT decomposed image.
9. Step 3 to step 8 is repeated for hiding watermark in other bands of a channel.
10. Step 2 to step 9 is repeated for hiding information in other color channels.
11. Inverse wavelet transformation technique is applied to get the watermarked color space.
12. The RGB color spaces are combined to reconstruct the watermarked image A^w.

B. *Watermark Extraction Algorithm*

1. Convert the watermarked image into RGB color spaces.
2. Apply DWT to decompose the respective color space of a cover image in which watermark is hidden.

$$[LL, LH, HL, HH] = 2dwt('colorspace','filtername')$$

3. Divide middle frequency band into smaller 4x4 blocks and apply DCT to each block, B^*_{ij} .
4. Extract the DC coefficients σ_{ij} from every DCT transformed blocks and construct a new matrix C, which could be decomposed by SVD technique,

$$C=U^* S^* V^{*T}$$

5. Extract the singular values from C matrix, then compare the difference between the watermarked singular values and host image singular values, $S3=(S^* - S)/\alpha$.
6. Combine the obtained singular values with the orthogonal matrices of watermark,

$$W^* = U_w\ S3\ V_w^T$$

7. Repeat the same procedure to extract the watermark from other bands.

In the proposed method, to extract the watermark from all frequency bands, it uses original cover image. So, this algorithm is can be classified as non-blind watermarking technique. The above embedding and extraction algorithm can be tested for all the three color spaces of (RGB) an image. The embedding of proposed algorithm is shown in Fig. 1.Similarly the extraction process is shown in Fig 2.

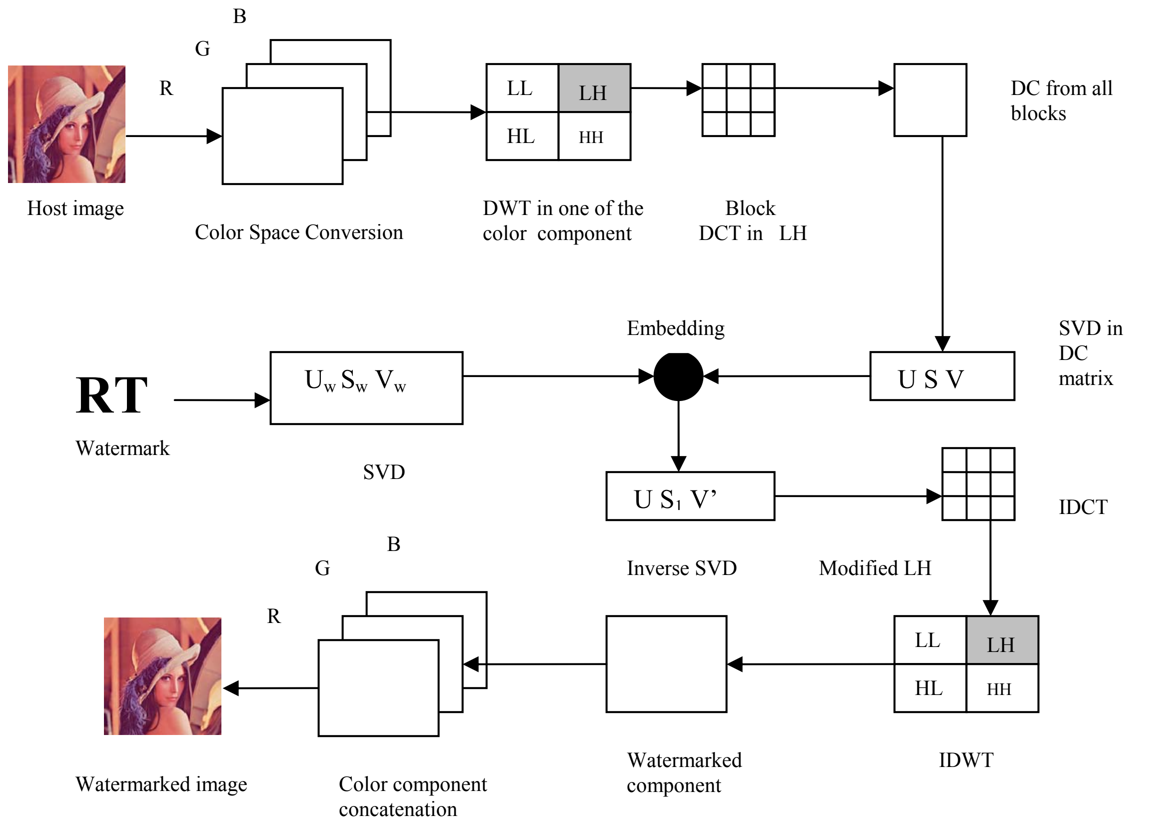

Fig. 2 Watermark embedding process

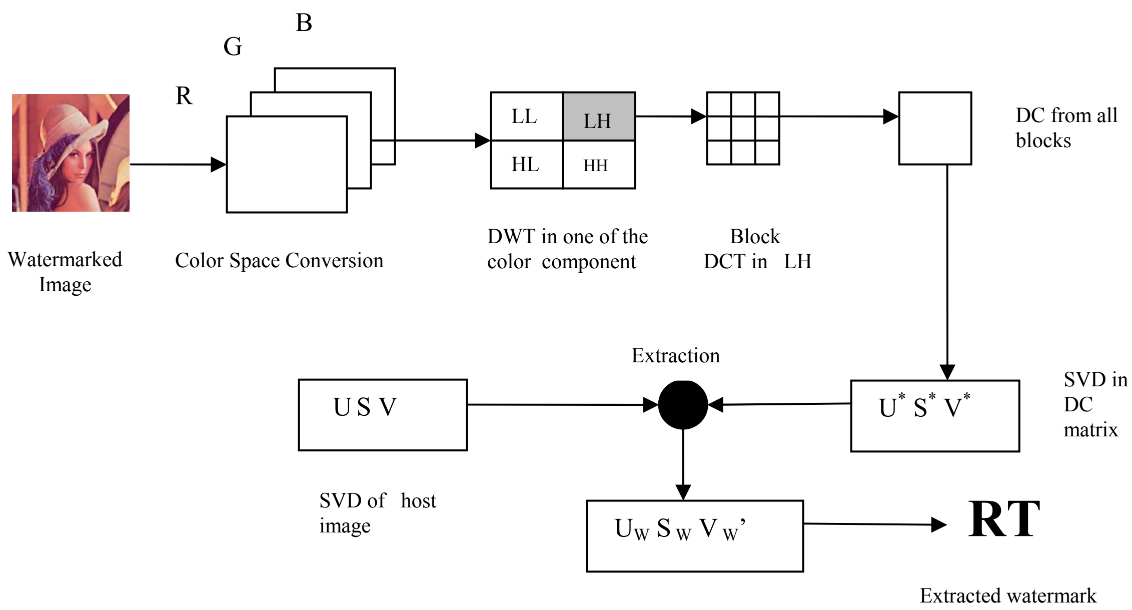

Fig. 3 Watermark extraction process

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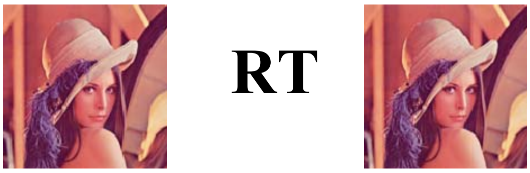
V. Performance Evaluation

In this proposed algorithm the Lena image of size 512x512 is taken as test image and the size of watermark considered is 64x64. Selected embedding intensity value is 0.1 for all frequency bands. Based on particular application the frequency band and the color channel can be selected. If the size of the watermark is small then any one of the color channel can be selected and application decides the frequency band. This proposed algorithm is tested by embedding watermark in all frequency band of red , green and blue color space.

The original image, watermark and watermarked image are shown in Fig 4(a), 4(b) and 4(c) respectively. Similarly the extracted watermarks are shown in Fig.5.



(a) Host image (b) watermark (c) Watermarked image

Fig 4

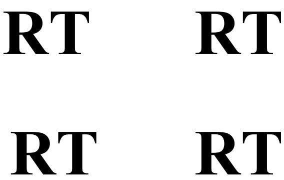


Fig.5 Extracted watermark from all Frequencies

In order to test the quality of the extracted watermark and cover data both subjective and objective measurements are used. The objective criteria are measured through (3), (4) and (5).

$$MSE = \frac{1}{MN}\sum_{I=1}^{M}\sum_{J=1}^{N}\left(\left(f(i,j) - f(i,j)\right)\right)^2 \quad (3)$$

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (4)$$

The quality of watermarked image is measured using peak signal to noise ratio (PSNR) value and it is observed that the value is 31.0847 db for all color component of RGB color space. Normalized correlation (NC) is a metric through which the degree of similarity between original watermark and extracted watermark is measured. The equation for measuring NC is shown in (5)

$$NC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} w(i,j)*w_e(i,j)}{\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} w^2(i,j)}\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} w_e^2(i,j)}} \quad (5)$$

If the watermarked image is not altered through intentional or unintentional attacks then the calculated normalized correlation (NC) is 1, means that the original and watermarked image is exactly similar. In the proposed work the watermark is hidden in red color space of the cover image using DWT-DCT-SVD technique and robustness is tested with various attacks such as compression, rotation , salt and pepper noise, Gaussian noise, image sharpening, histogram equalization, Gaussian blur, color contrast, cropping and resizing. These attacks are not aimed at removing the watermark, but trying to either destroy it or disable its detection and attempt to break the correlation between the extracted and the original watermark. This can be accomplished by shuffling the pixels that is the value of corresponding pixels in the attacked and the original image is the same, however, their location has been changed. Correlation value of extracted watermark after various attacks from red color space is shown in Table 1. Similarly correlation value of extracted watermark from green color space and blue color space after various attacks are shown in Table 2 and Table 3.respectively

The tabulated results show that the NC value is high when watermark is extracted from low frequency components and it is low for high frequency bands for attacks such as salt and pepper noise, Gaussian noise, compression, color contrast and cropping. Similarly the results for sharpening and resizing shows that the NC values for extracted watermark from high frequency bands are more than low frequency bands. But for rotation attack NC value is very low for all frequency components.

TABLE 1.CALCULATED NC VALUES OF EXTRACTED WATERMARK FROM THE RED COLOR SPACE

ATTACKS	**LL**	LH	HL	HH
Salt and peppers noise	0.999	0.996	0.997	0.573
Gaussian noise	0.998	0.994	0.995	0.524
Rotation	0.550	0.378	0.203	0.479
Sharpening	0.957	0.998	0.995	0.997
Histogram equalization	0.839	0.982	0.985	0.978
Cropping	0.996	0.436	0.556	0.391
Gaussian blur	0.999	0.999	0.999	0.991
Color contrast	0.990	0.931	0.958	0.956
Resize	0.849	0.973	0.967	0.962
Compression	0.981	0.759	0.839	0.741

As per the table 1, when the watermark is hidden in low and middle frequency band of red color channel the system is withstanding many attacks but it is not true if high frequency band is selected for embedding. System is not robust to cropping. Salt and pepper noise and Gaussian noise attacks when high frequency band is selected for the place of watermark. This algorithm withstanding compression attacks even if the place of a watermark is HH band as the NC value shows the similarity of extracted watermark is more than 70%. But the proposed algorithm is not robust to rotation and cropping attacks.

TABLE II. MEASURED NC VALUES OF EXTRACTED WATERMARK FROM THE GREEN COLOR SPACE

ATTACKS	LL	LH	HL	HH
Salt and peppers noise	0.999	0.997	0.998	0.994
Gaussian noise	0.999	0.993	0.995	0.986
Rotation	0.679	0.496	0.192	0.500
Sharpening	0.965	0.992	0.982	0.991
Histogram equalization	0.778	0.970	0.950	0.975
Cropping	0.994	0.861	0.451	0.376
Gaussian blur	0.999	0.997	0.993	0.952
Color contrast	0.999	0.999	0.999	0.999
Resize	0.924	0.990	0.950	0.852
Compression	0.980	0.756	0.827	0.732

Table 2 shows the NC values of extracted watermark and the original watermark from the green color channel. If the watermark is hidden in green color channel the system is not withstanding cropping and rotation attacks. The proposed system is robust to noise, sharpening, histogram equalization, color contrast, resize and compression attacks when the watermark is hidden in low (LL) and middle frequency (LH, HL) band. But when it is hidden in HH band it shows 70 % of similarity for compression attack.

TABLE III. MEASURED NC VALUES OF EXTRACTED WATERMARK FROM THE BLUE COLOR SPACE

ATTACKS	LL	LH	HL	HH
Salt and peppers noise	0.999	0.997	0.998	0.994
Gaussian noise	0.999	0.993	0.995	0.986
Rotation	0.679	0.496	0.192	0.500
Sharpening	0.965	0.992	0.982	0.991
Histogram equalization	0.778	0.970	0.950	0.975
Cropping	0.994	0.861	0.451	0.376
Gaussian blur	0.999	0.997	0.993	0.952
Color contrast	0.999	0.999	0.999	0.999
Resize	0.924	0.990	0.950	0.852
Compression	0.980	0.756	0.827	0.732

Table 3. shows the similarity measure of extracted watermark from blue color space. The calculated normalized coefficient between extracted watermark and the original watermark from color spaces red, green and blue are shown in Fig. 6, Fig.7 and Fig 8 respectively.

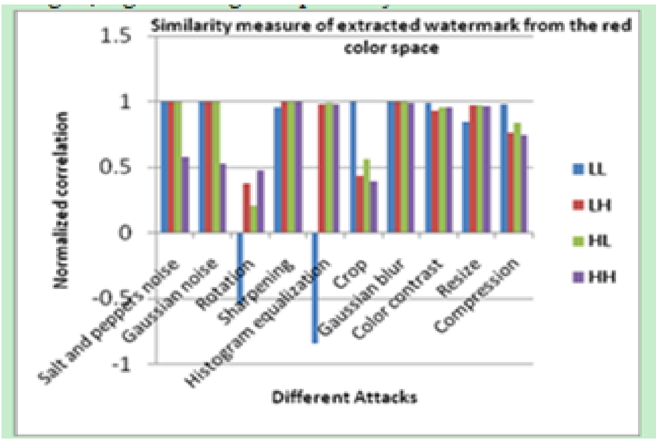


Fig. 6 Normalized Correlation of extracted watermark from red color space

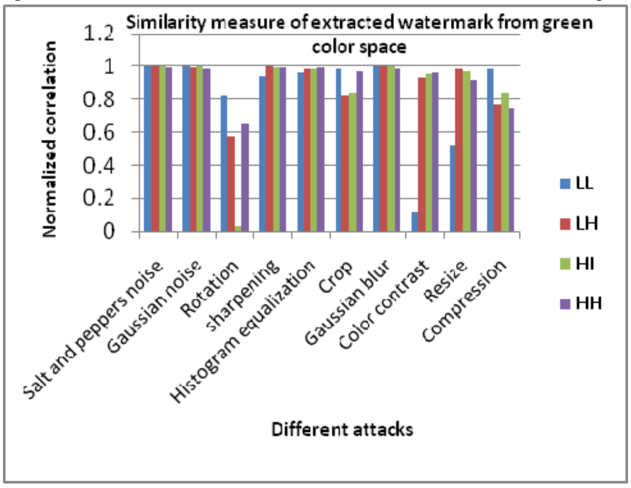


Fig. 7 Normalized Correlation of extracted watermark from green color space

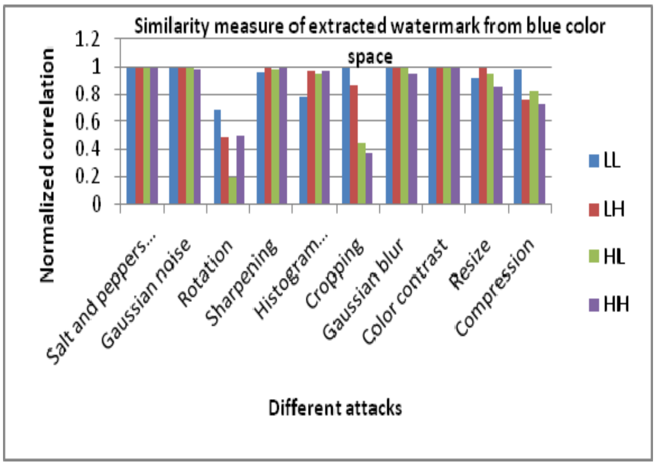


Fig. 8 Normalized Correlation of extracted watermark from blue color space

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TABLE.IV EXTRACTED WATERMARK FROM RED COLOR SPACE

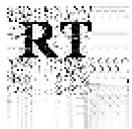
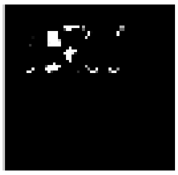
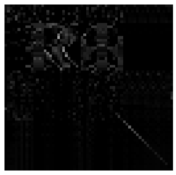
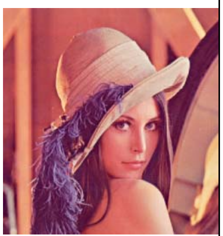
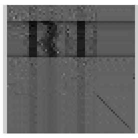
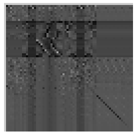
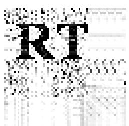
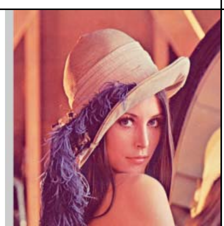
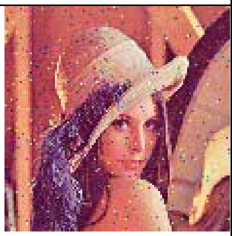
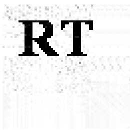
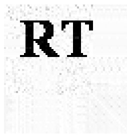
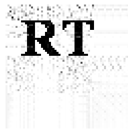
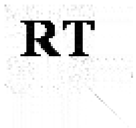
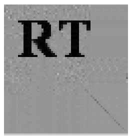
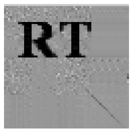
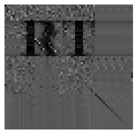
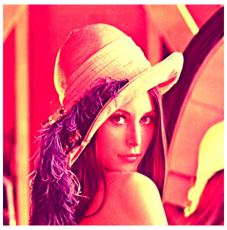
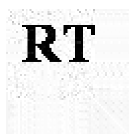
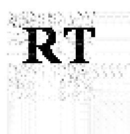
Watermarked image	Extracted wm from LL	Extracted Wm from LH	Extracted Wm from HL	Extracted Wm from HH
				
Compression Attack	0.9815	0.7662	0.8395	0.7473
				
Rotation Attack	- 0.8237	0.5772	0.0292	0.6512
				
Resize Attack	0.5203	0.9862	0.9698	0.9180
				
Sharpening Attack	0.9407	0.9964	0.9923	0.9953
				
Crop Attack	0.9838	0.8215	0.8454	0.9692

TABLE.V EXTRACTED WATERMARK FROM GREEN COLOR SPACE

Watermarked image	Extracted wm from LL	Extracted Wm from LH	Extracted Wm from HL	Extracted Wm from HH
				
Salt and pepper noise attack	0.9989	0.9982	0.9989	0.9926
				
Gaussian blur attack	0.9993	0.9992	0.9978	0.9816
				
Color contrast	0.1132	0.9295	0.9512	0.9654
				
Histogram equalization	0.9601	0.9884	0.9834	0.9940
				
Gaussian noise	0.9990	0.9949	0.9959	0.9832

VI. Conclusion

1. In the proposed algorithm the features of DWT-DCT-SVD techniques are combined.

2. Embedding of watermark is done only in DC components of all frequency bands to increase the robustness.

3. Algorithm is tested against many attacks and found to be robust. So that the new system can be used in applications such as copyright protection and ownership verification.

4. Watermark embedded in low frequency components are resistant to salt and pepper noise, Gaussian noise, Gaussian blur, cropping, color contrast and compression attacks. Similarly watermarks embedded in high frequency components are resistant to image sharpening, histogram equalization, rotation and resize.

5. It is found that the proposed algorithm is not robust to rotation attack in RGB color space and our future work is to design the new system robust to rotation attack.

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