INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS…..

DWT-SVD Based Robust Digital Image Watermarking using Adaptive Median Filter

Ashok Kumar[1] and Sukhreet Singh Brar[2]

[1] M.Tech, Centre for Computer Science and Technology,
Central University of Punjab, Bathinda Punjab (India), Pin no.151001
ashokjajoria58@gmail.com
[2] Assistant Professor, Centre for Computer Science and Technology,
Central University of Punjab, Bathinda Punjab (India), Pin no.151001
sukhreet.brar@gmail.com

***Abstract**: In the recent times to protect the copyright in digital images, the digital watermarking has emerged. Various techniques of watermarking have evolved, each having different advantages under different scenarios. Primarily the watermark can either be inserted in spatial domain or transform domain. The transform domain based watermarking techniques are more robust than spatial domain techniques. This paper presents, a new robust digital image watermarking technique, based on Discrete Wavelet Transform and Singular Value Decomposition (i.e. DWT-SVD) using Adaptive median filter. The embedding of watermark is done in the high frequency band (HL) by modifying the SVD values. The proposed scheme has been tested in MATLAB environment against various attacks. Simulation results show that the proposed technique can survive a variety of attacks (including JPEG compression attacks).*

***Keywords:** Digital Watermarking, Wavelet Transforms, Singular Value Decomposition.*

1. INTRODUCTION

In recent years, due to the growth of Internet, there is a rapid increase in the pirated digital multimedia (such as images, audios, videos or texts) and the speed of distribution of such multimedia has led to the need to protect the contents against illegal manipulation. The digital multimedia data can easily modify by any unauthorized person, who may claim its ownership on the later stage. To avoid this, the owners, authors, publishers and providers of such media, are disinclined to grant the distribution of their documents in a networked environment [1]. Thus, the need to create a robust technique to protect the intellectual property rights of content owners against unauthorized modifications, and its redistribution on the network, becomes the primary motivation behind digital watermarking [1], [2].

Digital watermarking is the method of hiding secret information in a digital environment. The secret information should be invisibly embedded in a way that allows it to be extracted or discovered later for security reasons. Broadly, watermarking can be classified into two categories: spatial domain and transform domain. In spatial domain watermarking, watermark is directly embedded into the host image by modifying the pixel value [3], [4]. In transform domain watermarking, watermark information is embedded in transformed coefficients of host image such as discrete cosine transform (DCT) [5], [6], discrete Fourier transform (DFT) [7], discrete wavelet transform (DWT) [8], redundant discrete wavelet transform (RDWT) [9], radon transform [10], and singular value transform (SVD) [8], [11]. Transform domain based watermarking techniques are more robust against both the geometrical attacks like scaling, rotation, cropping, and non-geometrical or image processing attacks such as noise, filtering, and lossy JPEG compression [12].

Digital watermarking consists of two modules: the embedding process module and the extraction or detection process module. A number of prerequisites need to be satisfied by each watermarking scheme. The primary requirements related to any watermarking are robustness, capacity, imperceptibility, and security [12]. Robustness is the resistance of an embedded watermark against geometrical attacks like scaling, rotation, cropping, and non-geometrical attacks such as noise, filtering, and lossy JPEG compression. Capacity is the number of watermark bits that can be embedded in a host image [13], [14]. The similarity between the host image and watermarked image is known as imperceptibility. Imperceptibility is also called as fidelity or perceptual transparency [15]. To evaluate imperceptibility performance, the peak signal to noise ratio i.e. PSNR metric is used. MSE should be minimum for a good watermarking system. A good imperceptibility means that the watermarked image looks nearly similar to the host image. In the watermarking system, the minimum acceptable value of PSNR is 38 dB [16]. A trade off always exists among the imperceptibility, robustness, and capacity; for example, increasing the embedding capacity in an image may improve its robustness but it may also degrade its imperceptibility simultaneously and vice versa [12]. The security refers to the fact that any unauthorized person cannot detect watermark without knowing the embedding scheme. To detect the watermark, based on the information required by the detector the watermarking schemes can be classified as under [13], [17]:

- Non-blind schemes: needs both the original image and the secret key(s) for watermark embedding
- Semi-blind: requires both the secret key(s) and the watermark bit sequence
- Blind schemes: needs only the secret key(s)

In order to have higher robustness and imperceptibility; transforms based hybrid (combination of two or more transforms) watermarking schemes are used [2], [8], [11], [13], [18], and [19].

This paper is organized as follows: Section 2 describes the related work in the field of watermarking. Adaptive Median

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS…..

Filter, DWT, and SVD transforms are briefly described in Sections 3. Section 4 presents the proposed watermark embedding and extraction procedures. Then, in Section 5; the results of the proposed scheme are illustrated. In Section 6, a comparative analysis of proposed scheme with existing schemes is discussed. Finally, the conclusions and future work are given in Section 7 and 8.

2. RELATED WORK

The SVD transform always shows good performance, in terms of stability of its singular values, in the hybrid watermarking schemes. Furthermore, the SVD is preferred to be implemented with other transforms because it requires extensive computations if applied separately onto images. In Liu et al. [20], the host image is decomposed using SVD, and the watermark image is then directly embedded into the singular values of the host image. Ganic et al. [13] have proposed a hybrid scheme based on DWT and SVD in which wavelet transform is applied on the image then, the SVD is performed on each sub band, and embedding is done in all sub-bands. Zhang et al. [21] have proposed a DWT-SVD based digital image watermarking scheme in which DWT is applied to the original image. After that SVD is applied to the low frequency (LL) sub-band and the watermark image is passed through Arnold transform and SVD. The singular value matrix of the watermark image is embedded into the singular value matrix of the original image. Kapre et al. [22] have proposed an image watermarking scheme based on SVD-DWT in which the watermark is embedded in the high frequency (HH) sub-band by using SVD. The scheme shows performance against a variety of image processing attacks (excluding JPEG compression, median filter, and scaling attack). Lai et al. [8] have proposed a digital image watermarking based on DWT-SVD technique. Here after applying the DWT, the host image is decomposed into four sub-bands (LL, LH, HL, and HH) and then SVD is applied on only LH and HL sub-bands. The watermark image is divided into two halves and then it is embedded into the singular values of LH and HL respectively, but this scheme is still insufficient in terms of capacity. Lagzian et al. [9] have proposed a robust image watermarking technique based on RDWT-SVD and followed the same steps used by Ganic et al. [13]. The scheme has good performance against some attacks, but the algorithm has a weakness in terms of security because the SVD is directly applied to the watermark, which leads to the false positive problem [11], [23], [24]. Rastegar et al. [11] have proposed a hybrid image watermarking scheme in which the radon transform is applied to the host image. The singular values of LH3 and HL3 sub-bands are modified by the singular values of the binary watermark. Kaur et al. [3] have proposed a semi-blind composite image watermarking scheme based on DWT-SVD technique that is robust against various attacks (excluding JPEG compression and scaling attack). Watermark is embedded in high frequency (HH) sub-band by modifying the values of SVD. Kaur et al. [25] have proposed a robust image watermarking technique based on DWT-SVD using the median filter. The original image is passed through the median filter; then the image is decomposed into 1-level using DWT. The singular values of the 1-level DWT sub-bands are modified by the singular values of the gray watermark. The main drawback of the median filter is that, it modifies both noisy as well as noise-free pixels. Bhatnagar et al. [26] have proposed a novel logo watermarking scheme using biometrics inspired key generation. The scheme has low watermark capacity, and it is not that robust against gaussian and salt & pepper noise attacks. Ali et al. [27] have proposed an optimal DWT-SVD based image watermarking scheme using self-adaptive differential evolution (SDE). Watermarking is done in the wavelet domain and the principle component of the watermark is embedded into the cover image instead of its singular values to avoid the false positive problem. The scheme has good performance against some attacks but the visual quality of extracted watermark is not so good in under some attacks; such as gaussian noise and sharpening attacks. Thabit et al. [28] have proposed a novel robust reversible watermarking scheme based on the Slantlet transform matrix, that is robust against various attacks (excluding the median filter and rotation attack). Das et al. [29] have proposed a blind robust image watermarking scheme using the DCT inter-block coefficient correlation. The scheme lacks in robustness against various noise attacks. Ali et al. [30] have proposed a novel robust image watermarking scheme in the wavelet domain based on the SVD and artificial bee colony (ABC) algorithm, in which redistributed invariant wavelet transform (RIDWT) is applied on the host image. The low frequency sub-band (LL) of RIDWT image is segmented into non-overlapping blocks. The most suitable embedding blocks are selected using the human visual system for the watermark embedding. Corresponding to each attack over the eleven test images, the average Normalized Correlation (NC) value is 0.9552. Wang et al. [31] have proposed a robust digital image watermarking scheme based on local polar harmonic transform. The results show that the proposed image watermarking scheme which is robust against various attacks, but the main problem of the scheme is its low watermark capacity.

Therefore after going through the related work, it is found that there is a trade-off between imperceptibly and robustness. So there is a scope of improvement in terms of robustness with an acceptable degree of imperceptibility. In this paper, a new technique based on DWT-SVD using adaptive median filter is proposed. The Adaptive median filter function is used on host image, then the 1-level DWT is applied to the output of the filter. Embedding is done using the singular value of high frequency sub-band HL. The proposed scheme is a semi-blind and demonstrated a high resistance against geometrical and non-geometrical attacks (especially JPEG compression and noise attacks).

3. NUMERICAL ANALYSIS

3.1 Adaptive median filter:

The main problem of a standard median filter (SMF) is that it only work for low density noise. At high density noise, it exhibits large window sizes blurring and inacceptable noise suppression for small window sizes [32]. When the noise level exceeds, 50% of the edge details is not retained by the standard median filter

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS.....

[33]. In the low noise density cases, SM filter works better for noise removal and detail preservation. In the cases of high noise density, SM filter modifies both noisy as well as noise-free pixels, so the denoising performance is not so good in high noise density [33]. Hence, to solve the above problem the adaptive median filter scheme has been used which removes the noise even at high noise density levels. The Adaptive Median Filter performs spatial processing to determine which pixels in an image have been affected by impulse noise. The steps used to implement the adaptive median filter are documented in [33].

3.2 Discrete wavelet transform:

A two-dimensional row and column decomposition of DWT is depicted in figure 1 [34]. The LL is the low frequency sub-band of approximation image, HL is a high frequency sub-band of horizontal edge of the image, LH is a high frequency sub-band of vertical edge of the image and HH is a high frequency sub-band of diagonal edge of image [25].

The high frequency sub-bands are usually used for watermarking since the human eye is less sensitive to changes in edges. The energy of image is concentrated at lower frequency sub-band LL and therefore embedding the watermark in LL sub-band, may degrade the quality of the image [4]. However, embedding the watermark in these low frequency sub-bands may increase robustness. The edges and texture details of the image are included in high frequency sub-band HH and the human vision system is not generally sensitive to the changes in such sub-band. This property allows the watermark to embed without being perceived by the human vision. Many DWT based algorithms are used for digital watermark embedding in the middle frequency sub-bands LH and HL, doing so the robustness, imperceptibility performance can be achieved [4].

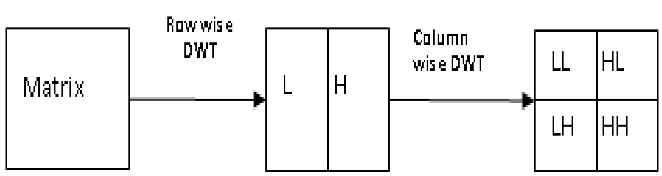

Figure 1: Two-dimensional discrete wavelet transform

3.3 Singular value decomposition:

SVD is a numerical analysis tool that has demonstrated its variety of applications including image watermarking, image hiding and noise reduction etc. [2], [35]. In SVD transformation, a matrix can be decomposed into three matrices that are of the same size as that of the original matrix [36].

Consider an image as matrix A of size N × N with rank r. Using SVD, the matrix A is shown as below form

$$SVD\ (A) = USV^T \quad \textbf{(1)}$$

Where U and V are N × N orthogonal matrices, UU^T=I and VV^T=I. Columns of U and V are left and right singular vectors respectively. S is a diagonal matrix which has the singular values σi, in decreasing order. Therefore

$$SVD\ (A) = \begin{bmatrix} u_{11} & \cdots & u_{1n} \\ \vdots & \ddots & \vdots \\ u_{n1} & \cdots & u_{nn} \end{bmatrix} \begin{bmatrix} \sigma_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma_{nn} \end{bmatrix} \begin{bmatrix} v_{11} & \cdots & v_{1n} \\ \vdots & \ddots & \vdots \\ v_{n1} & \cdots & v_{nn} \end{bmatrix} \quad \textbf{(2)}$$

$$= \sum_{i=0}^{r} u_i \sigma_i v_i^T \quad \textbf{(3)}$$

Where r=rank of matrix A

u_i & v_i= left and right singular vectors

The singular values specify the luminance value of an image layer while the corresponding singular vectors specify the geometry of the image [12]. The main reason to use SVD based image watermarking schemes is the good stability of its singular values, meaning that the quality of image cannot degrade even for large changes in singular values [12], [20], [36].

4. PROPOSED SCHEME

The main aim of this proposed scheme is to obtain the extracted watermark similar to the original watermark. The proposed scheme is a semi-blind scheme as the original image in not required for the extraction. The proposed scheme has two procedures: watermarking embedding and extraction procedure as shown in figure 2 and 3, respectively:

4.1 Watermark embedding procedure

The value of the scaling factor is taken as 0.2 (α) to embed the watermark in the high frequency sub-band (HL) of the image. The steps of watermark embedding procedure are as discussed below:

1. First of all the adaptive median filter function is applied on the host image A (i, j) and thereby a reference image I (i, j) is obtained.
2. 1-level DWT is applied on the reference image I (i, j) and the watermark image W (i, j).

$$[LL_I, HL_I, LH_I, HH_I] = DWT(I) \quad \textbf{(4)}$$

$$[LL_W, HL_W, LH_W, HH_W] = DWT(W) \quad \textbf{(5)}$$

3. After that, the 1-level inverse discrete wavelet transform (IDWT) is applied on high-frequency sub-band (HL) of both images.
4. The HL sub-band of both the images i.e. I (i, j) and W (i, j) is decomposed using SVD.

$$HL_I = U_I S_I V_I \quad \textbf{(6)}$$

$$HL_W = U_W S_w V_W \quad \textbf{(7)}$$

5. In the next step, the singular values of I (i, j) are modified by the singular values of W(i, j).

$$S_I^* = (S_I + \alpha(S_W)) \quad \textbf{(8)}$$

(Where α is the watermark scaling factor)

6. The modified HL_I sub-band of the reference image is obtained as:

$$HL_I = U_I S_I^* V_I \quad \textbf{(9)}$$

7. 1-level DWT is applied on HL_I (obtained in step 6) and the new HL_I^* is obtained.

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS…..

8. In the last step, 1-level IDWT is applied using LL_I, HL_I^*, LH_I, and HH_I to obtain the watermarked image.

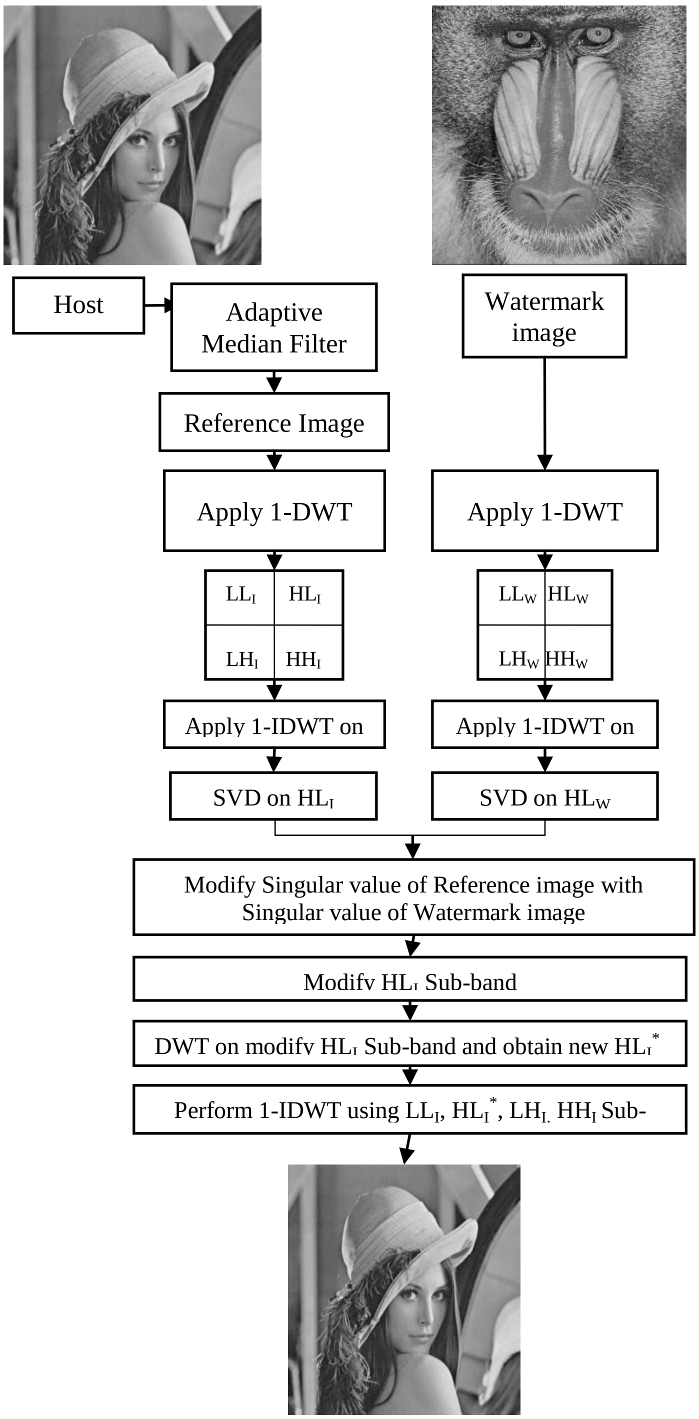

Figure 2: Watermark embedding procedure

4.2 Watermark extraction procedure:

The steps of watermark extraction procedure are as discussed below:

1. 1-level DWT is applied on the watermarked image WI (i, j).

$$[LL_{WI,}HL_{WI}, LH_{WI}, HH_{WI}] = DWT(WI) \quad \textbf{(10)}$$

2. After that, the 1-level IDWT is applied on high frequency sub-band (HL_{WI}) of watermarked image.
3. Perform the SVD transform on the high frequency sub-band (HL) on the watermarked image, reference image and watermark image as in embedding process in step 4.
4. In the next step, the singular values of the watermark image are extracted from high frequency sub-band (HL) as:

$$S_{EW} = ((S_{WI} - S_I)/\alpha) \quad \textbf{(11)}$$

5. Then, the high frequency sub-band (HL) of W(i,j) is modified using:

$$HL_{EW}^* = U_W S_{EW} V_W \quad \textbf{(12)}$$

6. 1-level DWT is applied on HL_{EW}* (obtained in step 5) sub-band and the new HL_{EW}** is obtained:
7.

$$HL_{EW}^{**} = DWT(HL_{EW}^*) \quad \textbf{(13)}$$

8. In the last step, the IDWT is applied using HL_{EW}** and other three sub-bands to obtain the watermark image LL_w, LH_w, and HH_w

5. SIMULATION RESULTS

Both the schemes (i.e. proposed scheme and existing scheme (Kaur et al. [25])) are simulated in the MATLAB environment and various tests are performed using different images such as Lena, pepper, boat, Barbara, Goldhill, and pirate of size 512 ×512 as shown figure 4. Baboon image of size 512×512 is used as the watermark image. The performance of both schemes are investigated with various experiments in terms of imperceptibility and robustness against various attacks experiments in terms of imperceptibility and robustness against various attacks.

The PSNR is used to estimate the imperceptibility, a term used to evaluate the similarity between the host image and a watermarked image. The PSNR can be defined as follows:

$$PSNR = 10log10\left(\frac{MAX_i^2}{MSE}\right) \quad \textbf{(14)}$$

Where MSE is defined as the Mean square error between the host image and watermarked image. The mean square error can be expressed as:

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=1}^{N-1}[\{x(i,j) - y(i,j)\}^2] \quad \textbf{(15)}$$

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS…..

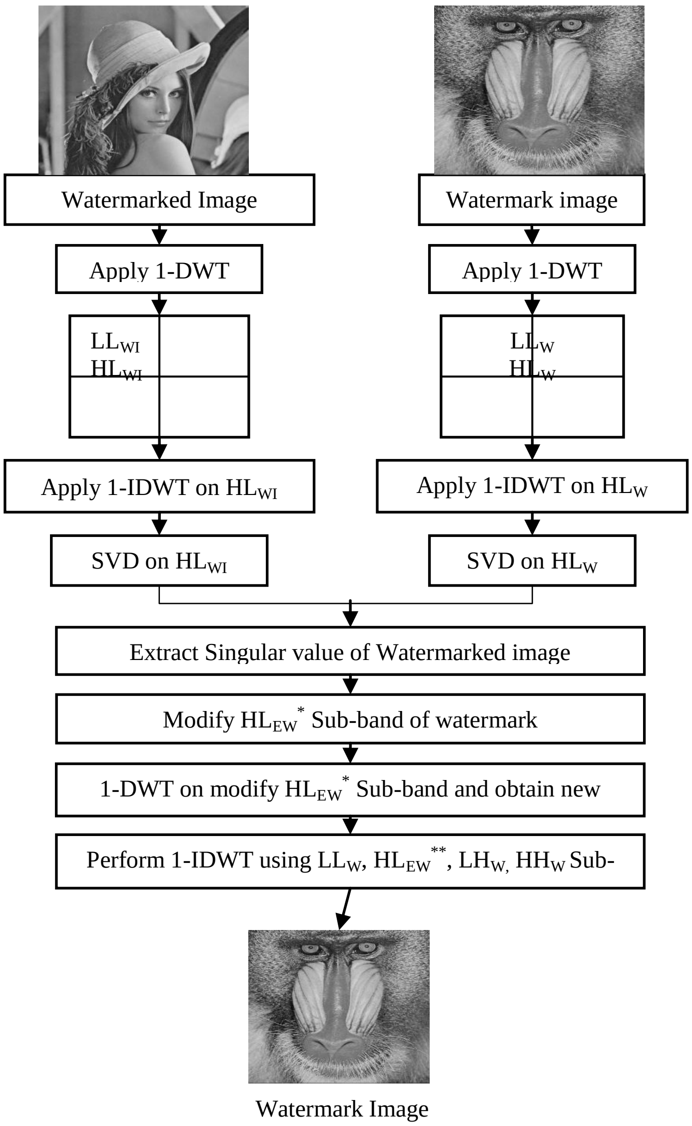

Figure 3: Watermark embedding procedure

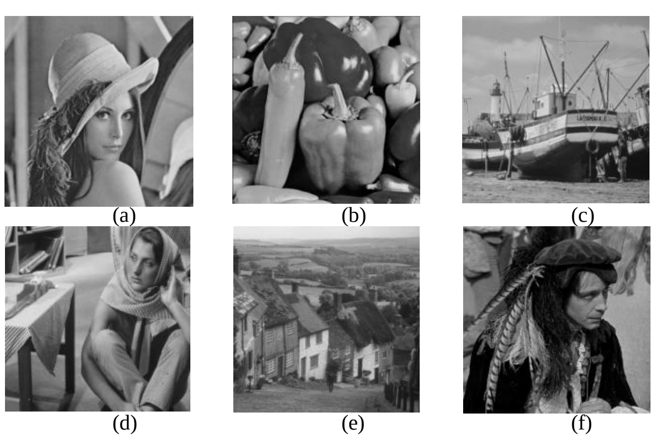

Figure 4: Host images: (a) Lena; (b) Pepper; (c) Boat; (d) Barbara; (e) Goldhill; (f) Pirate.

To measure the robustness, NC parameter is used by evaluating the similarities between the original and extracted watermark, after which attacks should be judged subjectively. In general, the NC value of 0.75 or higher is acceptable [37]. Normalized Correlation is evaluated as:

$$NC = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} w\,(i,j) \times w'(i,j)}{\sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} w(i,j)^{\,2}} \times \sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} w'(i,j)^{\,2}}} \tag{16}$$

Where w (i, j) and w' (i, j) represent original watermark and the extracted watermark respectively.

5.1 Imperceptibility of the proposed scheme

The proposed scheme gives the PSNR value in the acceptable range (>38dB), therefore it is reasonably imperceptible. The watermarked images are as shown in figure 5, where higher PSNR values are achieved with all the testing images (Lena image (39.4789 dB), (Pepper image (39.5959 dB), Boat image (39.4877 dB), Barbara image (39.4929 dB), Goldhill image (39.4841 dB), and Pirate image (39.6016 dB)).

5.2 Robustness of the proposed scheme

The proposed scheme achieves high robustness, as shown in the tables 1 to 9. Table 1 to table 9, present the NC values of the extracted watermarks in the proposed scheme against various types of attacks. Non-geometrical attacks such as noise attacks (e.g., salt and pepper, gaussian and speckle noise), filtering (median filter), gamma correction and JPEG compression attacks are applied. Scaling and rotation attacks are selected as geometrical attacks. The proposed scheme shows high resistance in HL sub-band.

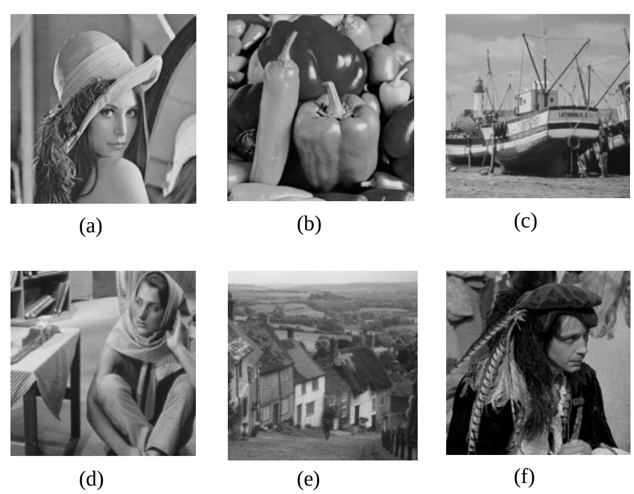

Figure 5: Watermarked image: (a) Lena (39.4789 dB); (b) Pepper image (39.5959 dB); (c) Boat image (39.4877 dB); (d) Barbara image (39.4929 dB); (e) Goldhill image (39.4841 dB) and (f) Pirate image (39.6016 dB).

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS.....

Table 1 Salt & Pepper Noise Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Salt and Peppers noise 1	0.8259	0.8265	0.8262	0.8270
Salt and Peppers noise 0.5	0.8544	0.8529	0.8540	0.8550
Salt and Peppers noise 0.1	0.9281	0.9264	0.9272	0.9301
Salt and Peppers noise 0.01	0.9939	0.9939	0.9939	0.9949
Salt and Peppers noise 0.001	0.9999	0.9999	0.9999	0.9999

Table 2 Speckle Noise Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Speckle noise 1	0.8565	0.8675	0.8551	0.8636
Speckle noise 0.5	0.8704	0.8813	0.8675	0.8814
Speckle noise 0.1	0.9333	0.9436	0.9250	0.9470
Speckle noise 0.01	0.9938	0.9962	0.9924	0.9963
Speckle noise 0.001	0.9999	0.9999	0.9998	0.9999

Table 3 Gaussian Noise Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Gaussian noise 1	0.8395	0.8416	0.8411	0.8419
Gaussian noise 0.5	0.8476	0.8491	0.8477	0.8492
Gaussian noise 0.1	0.8822	0.8875	0.8846	0.8855
Gaussian noise 0.01	0.9685	0.9719	0.9706	0.9718
Gaussian noise 0.001	0.9988	0.9990	0.9988	0.9990

Table 4 Gaussian filter Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Gaussian filter (3, 3)	0.9893	0.9857	0.9880	0.9845
Gaussian filter (5, 5)	0.9868	0.9821	0.9831	0.9780
Gaussian filter (7, 7)	0.9845	0.9795	0.9798	0.9749
Gaussian filter (9, 9)	0.9837	0.9786	0.9784	0.9736
Gaussian filter (11, 11)	0.9834	0.9783	0.9780	0.9732

Table 5 Median filter Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Median filter (3, 3)	0.9948	0.9957	0.9966	0.9931
Median filter (5, 5)	0.9911	0.9922	0.9912	0.9845
Median filter (7, 7)	0.9883	0.9897	0.9874	0.9805
Median filter (9, 9)	0.9874	0.9879	0.9846	0.9774
Median filter (11, 11)	0.9861	0.9865	0.9827	0.9755

Table 6 JPEG Compression Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
JPEG Compression Q=90	1.0000	1.0000	1.0000	1.0000
JPEG Compression Q=70	0.9997	0.9997	0.9993	0.9998
JPEG Compression Q=50	0.9991	0.9991	0.9993	0.9995
JPEG Compression Q=30	0. 9982	0.9982	0.9985	0.9987
JPEG Compression Q=10	0.9944	0.9954	0.9964	0.9944

Table 7 Gamma correction Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Gamma correction 1	1.0000	1.0000	1.0000	1.0000
Gamma correction 0.8	1.0000	1.0000	0.9999	0.9999
Gamma correction 0.5	0.9950	0.9996	0.9978	0.9981
Gamma correction 0.3	0.9918	0.9985	0.9922	0.9926
Gamma correction 0.1	0.9850	0.9966	0.9767	0.9762

Table 8 Rotation Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Rotation 50°	0.9969	0.9916	0.9941	0.9931
Rotation 20°	0.9965	0.9929	0.9952	0.9952
Rotation 2°	0.9965	0.9935	0.9962	0.9944
Rotation -20°	0.9975	0.9931	0.9964	0.9958
Rotation -50°	0.9980	0.9922	0.9954	0.9920

Table 9 Scaling Attacks

Attacks	Lena (NC)	Peppers (NC)	Boat (NC)	Goldhill (NC)
Scaling (512-256-512)	0.9896	0.9844	0.9870	0.9817
Scaling (512-1024-512)	0.9989	0.9983	0.9989	0.9984

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS…..

Under non-geometrical attacks, the noise addition attacks such as salt and pepper, speckle and gaussian noise (as noise addition attacks) are added to the watermarked image. The proposed scheme is evaluated with various densities and magnitudes, as shown in Tables 1, 2 and 3. The proposed scheme shows higher resistance against all noising attacks. The second type of non-geometrical attack is the filtering attack. Two types of filtering or de-noising attacks (Gaussian and median filter) are applied in the proposed scheme. These attacks are employed with five different mask sizes (e.g., 3 × 3, 5 × 5, 7 × 7, 9 × 9 and 11 × 11). Tables 4 and 5 display the NC values of the extracted watermarks and higher values of the NC show high resistance against these attacks. The third type of non-geometrical attack is JPEG compression attack. In our experiments, the host images are compressed by 5, 10, 30, 50, 70 and 90 compression rates. The NC values of the extracted watermarks under the JPEG compression attacks of the original watermarked image are depicted in Table 6. The fourth non-geometrical attack is the Gamma correction attacks, the gamma values are varied from 0.1 to 1, as shown in Table 7. Table 7 indicates the ability of the proposed scheme to resist against these attacks.
The proposed scheme is also tested against different types of geometrical attacks. The proposed scheme exhibits high resistance against rotation attacks, as shown in Table 8. The watermarked images are tested under different rotation angles, such as 50, 20, 2, -20 and -50. The watermarked image is tested with different scaling parameters, as shown in Table 9.
Therefore, the proposed scheme has proved its efficiency in resisting various non-geometrical and geometrical attacks and will be applicable in many watermarking applications accordingly.

5. COMPARATIVE ANALYSIS

The imperceptibility in terms of PSNR, of the existing and proposed scheme are compared in table 10 in Lena's image. Table 11 compares the NC values of the two schemes under various attacks on Lena's image.
It is found that the imperceptibility of the proposed scheme is slightly less than the Kaur et al. [25] but higher than the results of Lagzian et al. [9]. But the proposed scheme yields better NC values than the other schemes under all type of noise attacks and JPEG compression attack (quality up to the value of Q=30). Therefore the proposed scheme has higher robustness than the other one and at the same time it has a reasonably good imperceptibility too.

Table 10 Imperceptibility Comparison using PSNR (dB) for Lena Image of proposed scheme, Kaur et al. [25] and Lagzian et al. [9]

(Lagzian et al. [9])	Existing scheme (Kaur et al. [25])	Proposed scheme
37.52	45.5652	39.4789

Table 11 Comparison of NC value of Proposed Scheme with Kaur et al. [25] and Lagzian et al. [9]

Attacks	(Lagzian et al. [9])	Existing scheme (Kaur et al. [25])	Proposed scheme
Rotation (50^0)	0.9989	0.9991	0.9951
Salt and Peppers noise (0.005)	0.9959	0.9945	0.9981
Salt and Peppers noise (0.001)	0.9985	0.9996	0.9999
Gaussian noise (0.005)	0.9792	0.9730	0.9854
Gaussian noise (0.001)	0.9971	0.9965	0.9988
Median filter (3,3)	0.9942	0.9991	0.9948
Gaussian lowpass filter (3,3)	-	0.9971	0.9893
Poisson noise	-	0.9917	0.9965
Histogram value	0.8530	0.9982	0.9928
Scaling (512-256-512)	-	0.9966	0.9896
Scaling (512-1024-512)	-	0.9994	0.9989
Gamma correction (0.6)	-	0.9999	0.9996
Gamma correction (0.8)	-	1.0000	1.0000
Speckle noise (0.02)	-	0.9708	0.9841
Speckle noise (0.04)	0.8896	0.9475	0.9661
Sharpening	-	0.9977	0.9933
JPEG Compression Q=90	-	0.9999	1.0000
JPEG Compression Q=70	-	0.9991	0.9997
JPEG Compression Q=50	0.9983	0.9987	0.9991
JPEG Compression Q=30	-	0.9979	0.9982
JPEG Compression Q=10	-	0.9972	0.9944
JPEG Compression Q=5	-	0.9966	0.9914

6. CONCLUSIONS AND FUTURE WORK

In this paper, a new hybrid and robust image watermarking scheme, based on the DWT-SVD using adaptive median filter function, is proposed. The scheme has been simulated in Matlab R2014b by taking a grayscale watermark. The simulated result gives a good combination of imperceptibility and robustness. The scheme yielding higher NC values under various attacks and also

INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY
WINGS TO YOUR THOUGHTS…..

has good imperceptibility. The proposed scheme has also been compared with the other watermarking schemes. For different noise attacks (i.e., salt & pepper, speckle and gaussian noise), the proposed scheme outperforms the other schemes in term of NC value by a significant margin. Also, in the case of JPEG compression attack; the proposed scheme yields better quality up to Q=30. So, it is concluded that the proposed scheme may be used for robust watermarking.
As the future work, this technique can be extended with multi-level DWT to enhance PSNR and Normalized Correlation values. Also the technique can be tried to analyze the color images and video watermarking.

References

[1] **T.D. Hien, Z. Nakao, Y.-W. Chen, Robust multi-logo watermarking by RDWT and ICA, Signal Processing. 86 (2006) 2981–2993.**

[2] **N.M. Makbol, B.E. Khoo, Robust blind image watermarking scheme based on redundant discrete wavelet transform and singular value decomposition, AEU-International J. Electron. Commun. 67 (2013) 102–112.**

[3] **R. Kaur, S. Jindal, Semi-blind Image Watermarking Using High Frequency Band Based on DWT-SVD, in: Emerg. Trends Eng. Technol. (ICETET), 2013 6th Int. Conf., IEEE, 2013: pp. 19–24.**

[4] **B.L. Gunjal, S.N. Mali, Comparative performance analysis of DWT-SVD based color image watermarking technique in YUV, RGB and YIQ color spaces, Int. J. Comput. Theory Eng. 3 (2011) 714–717.**

[5] **S.D. Lin, C.-F. Chen, A robust DCT-based watermarking for copyright protection, IEEE Trans. Consum. Electron. 46 (2000) 415–421.**

[6] **J.C. Patra, J.E. Phua, C. Bornand, A novel DCT domain CRT-based watermarking scheme for image authentication surviving JPEG compression, Digit. Signal Process. 20 (2010) 1597–1611.**

[7] **P. Premaratne, C.C. Ko, A novel watermark embedding and detection scheme for images in DFT domain, in: Image Process. Its Appl. 1999. Seventh Int. Conf. (Conf. Publ. No. 465), IET, 1999: pp. 780–783.**

[8] **C.-C. Lai, C.-C. Tsai, Digital image watermarking using discrete wavelet transform and singular value decomposition, Instrum. Meas. IEEE Trans. 59 (2010) 3060–3063.**

[9] **S. Lagzian, M. Soryani, M. Fathy, A new robust watermarking scheme based on RDWT-SVD, Int. J. Intell. Inf. Process. 2 (2011) 22–29.**

[10] **H. Zhu, M. Liu, Y. Li, The RST invariant digital image watermarking using Radon transforms and complex moments, Digit. Signal Process. 20 (2010) 1612–1628.**

[11] **S. Rastegar, F. Namazi, K. Yaghmaie, A. Aliabadian, Hybrid watermarking algorithm based on Singular Value Decomposition and Radon transform, AEU-International J. Electron. Commun. 65 (2011) 658–663.**

[12] **N.M. Makbol, B.E. Khoo, A new robust and secure digital image watermarking scheme based on the integer wavelet transform and singular value decomposition, Digit. Signal Process. 33 (2014) 134–147.**

[13] **E. Ganic, A.M. Eskicioglu, Robust DWT-SVD domain image watermarking: embedding data in all frequencies, in: Proc. 2004 Work. Multimed. Secur., ACM, 2004: pp. 166–174.**

[14] **A.A. Mohammad, A. Alhaj, S. Shaltaf, An improved SVD-based watermarking scheme for protecting rightful ownership, Signal Processing. 88 (2008) 2158–2180.**

[15] **I. Cox, M. Miller, J. Bloom, J. Fridrich, T. Kalker, Digital watermarking and steganography, Morgan Kaufmann, 2007.**

[16] **Y.-P. Lee, J.-C. Lee, W.-K. Chen, K.-C. Chang, J. Su, C.-P. Chang, High-payload image hiding with quality recovery using tri-way pixel-value differencing, Inf. Sci. (Ny). 191 (2012) 214–225.**

[17] **P. Saxena, S. Garg, A. Srivastava, DWT-SVD Semi-blind image watermarking using high frequency band, in: 2nd Int. Conf. Comput. Sci. Inf. Technol. Singapore April, 2012: pp. 28–29.**

[18] **G. Bhatnagar, A new facet in robust digital watermarking framework, AEU-International J. Electron. Commun. 66 (2012) 275–285.**

[19] **C.-C. Lai, An improved SVD-based watermarking scheme using human visual characteristics, Opt. Commun. 284 (2011) 938–944.**

[20] **R. Liu, T. Tan, An SVD-based watermarking scheme for protecting rightful ownership, Multimedia, IEEE Trans. 4 (2002) 121–128.**

[21] **L. Zhang, A. Li, Robust watermarking scheme based on singular value of decomposition in DWT domain, in: Inf. Process. 2009. APCIP 2009. Asia-Pacific Conf., IEEE, 2009: pp. 19–22.**

[22] **K.S. Bhagyashri, M. Joshi, Robust image watermarking based on singular value decomposition and discrete wavelet transform, in: Comput. Sci. Inf. Technol. (ICCSIT), 2010 3rd IEEE Int. Conf., IEEE, 2010: pp. 337–341.**

[23] **X.-P. Zhang, K. Li, Comments on“ An SVD-based watermarking scheme for protecting rightful Ownership,” Multimedia, IEEE Trans. 7 (2005) 593–594.**

[24] **H.-C. Ling, R.C.-W. Phan, S.-H. Heng, On the security of a hybrid watermarking algorithm based on singular value decomposition and Radon transform, AEU-International J. Electron. Commun. 65 (2011) 958–960.**

[25] **R. Kaur, S. Jindal, Robust Digital Image Watermarking in High Frequency Band Using Median Filter Function Based on DWT-SVD, in: Adv. Comput. Commun. Technol. (ACCT), 2014 Fourth Int. Conf., IEEE, 2014: pp. 47–52.**

[26] G. Bhatnagar, Q.M.J. Wu, P.K. Atrey, Robust logo watermarking using biometrics inspired key generation, Expert Syst. Appl. 41 (2014) 4563–4578.
[27] M. Ali, C.W. Ahn, An optimized watermarking technique based on self-adaptive DE in DWT–SVD transform domain, Signal Processing. 94 (2014) 545–556.
[28] R. Thabit, B.E. Khoo, Robust reversible watermarking scheme using Slantlet transform matrix, J. Syst. Softw. 88 (2014) 74–86.
[29] C. Das, S. Panigrahi, V.K. Sharma, K.K. Mahapatra, A novel blind robust image watermarking in DCT domain using inter-block coefficient correlation, AEU-International J. Electron. Commun. 68 (2014) 244–253.
[30] M. Ali, C.W. Ahn, M. Pant, P. Siarry, An image watermarking scheme in wavelet domain with optimized compensation of singular value decomposition via artificial bee colony, Inf. Sci. (Ny). 301 (2015) 44–60.
[31] X. Wang, Y. Liu, S. Li, H. Yang, P. Niu, Y. Zhang, A new robust digital watermarking using local polar harmonic transform, Comput. Electr. Eng. (2015).
[32] K.S. Srinivasan, D. Ebenezer, A new fast and efficient decision-based algorithm for removal of high-density impulse noises, Signal Process. Lett. IEEE. 14 (2007) 189–192.
[33] A. Bhatia, R.K. Kulkarni, Removal of High Density Salt-And-Pepper Noise Through Improved Adaptive Median Filter, (n.d.).
[34] N.A. Kumar, M. Haribabu, C.H. Bindu, Novel Image Watermarking Algorithm with DWT-SVD, Int. J. Comput. Appl. 106 (2014) 12–17.
[35] G.C.-W. Ting, B.-M. Goi, S.-H. Heng, Attack on a semi-blind watermarking scheme based on singular value decomposition, Comput. Stand. Interfaces. 31 (2009) 523–525.
[36] C.-C. Chang, P. Tsai, C.-C. Lin, SVD-based digital image watermarking scheme, Pattern Recognit. Lett. 26 (2005) 1577–1586.
[37] A. Al-Haj, Combined DWT-DCT Digital Image Watermarking, J. Comput. Sci. 3 (2007) 740–746.

Ashok Kumar received the B.Tech degree in Information Technology from Punjab Technical University, Jalandhar in the year 2013 and M.Tech degree in Computer Science & Technology from Central University of Punjab, Bathinda. His research area interest is in the area of image processing.

Sukhreet S. Brar received the B.Tech degree in Electronics and Communication Engineering from Punjab Technical University, Jalandhar in the year 2008 and M.Tech degree in Electronics and Communication Engineering from Punjabi University, Patiala in year 2011. His research area interest includes the area of Low power VLSI Design, and Digital Image Processing.