Robust and Imperceptible Image Watermarking Using Redundant Discrete Wavelet Transform and Singular Value Decomposition

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Abstract: ***This paper present a substantial image watermarking technique to achieve proof of ownership and copyright protection. Various techniques are developed in order to protect the data from illegal access. In this paper we discussed about the image watermarking technique which is substantial against various attacks. In digital image watermarking, a secure or watermark image embedded inside the cover image to show the authenticity and proof of ownership.In this paper we proposed a hybrid technique RDWT-SVD which is used for image watermarking. In this technique both cover image and secure image are decomposed using 3-level redundant discrete wavelet transform, and then SVD apply to HL3 band of both cure image and secure image. After this singular value of cover image is replace by modified singular value for embedding watermark. Then place the embedded watermark image in various attacks, after this extract watermark image and compare it by using PSNR and MSE values. Experimental results are provided to show that the technique is substantial against various attacks.***

Keywords: Discrete wavelet transform (DWT), Redundant discrete wavelet transform (RDWT), Singular value decomposition (SVD), Inverse redundant discrete wavelet transform (IRDWT), Human visual system (HVS), Spatial frequency localization, Peak-signal-to-noise-ratio(PSNR),Mean square error(MSE).

1. Introduction

In recent few years the illegal access of data and manipulation of multimedia file over internet is a very serious problem. The case is more critical in the sense of video and content privacy. Therefore a need of a robust method in order to protect the image and video from copyrights has become an essential constraint. Invisible watermarking provides copyright protection of data by hiding the watermark data inside the cover image or video. Watermarking is also done by embedding additional information called digital signature or watermark into the image or video data contents such that it can be detected or extracted later to make authentication about the multimedia data. The watermarking algorithm can be categorized into two domains: spatial domain and transform domain.

In spatial domain technique the watermark is embedded directly by modifying pixels value of the cover image by the pixels value of watermark image, while in transform domain scheme watermark embedded by modifying transform domain scheme [1, 2]. The algorithm of spatial domain is less robust to various attacks because the changes are made at least significant bits (LSB) of cover image or original image. Rather than this in transform domain the watermark is embedded by changing the magnitude of coefficients in the transform domain. Discrete cosine transform (DCT), Discrete wavelet transform (DWT), Redundant discrete wavelet transform (RDWT) and Singular value decomposition (SVD) techniques are used for embedding watermark inside the cover image in transform domain [3, 5].This technique provides more robustness to various common attacks [7]. DWT has excellent spatial frequency localization property, which is very suitable to identify the area in cover image where watermark is embedded. Due to spatial frequency localization property the watermark is more robust and imperceptible in DWT. Over the advantage of spatial frequency localization property, DWT has also some drawbacks. The major drawback of discrete wavelet transform is that it does not provide shift invariance due to down sampling of its bands. The down sampler is connected after to each filter bank which causes a major change in the wavelet coefficients of image even for the minor shifts in the input image. The shift invariance of DWT causes inaccurate extraction of cover image and the watermark image [8].

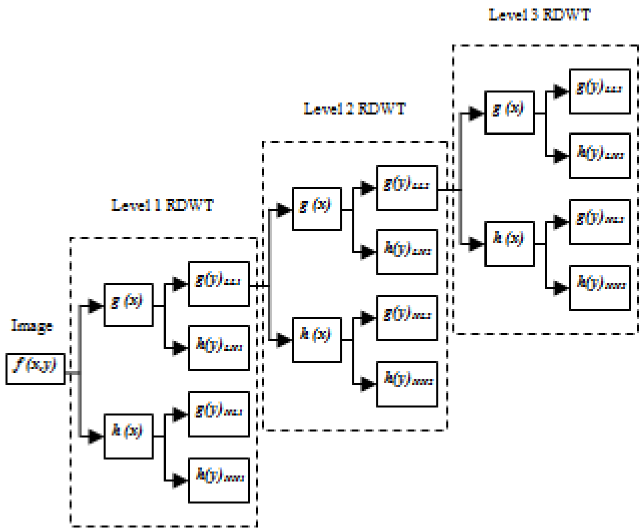
Since in watermarking we have to know the exact location where the watermark information is embedded, hence to overcome this problem researcher have proposed using redundant discrete wavelet transform. Down samplers are eliminated from each filter-bank iteration in redundant discrete wavelet transform. Since frame expansion increases after removing down sampling, hence it provides robustness with respect to additive noise. The most important property of singular value decomposition (SVD) the slightly variation of singular value do not affect the visual perception of the image, which provide more robustness and imperceptibility to the image watermarking. Since applying SVD of image directly is a computationally complex process hence there is a proposed technique of hybrid RDWT-SVD based image watermarking which reduce the computation complexity of SVD. In this proposed technique, a new method for non-blind image watermarking that is robust against affine transformation. The suggested method represents a watermarking scheme based on redundant discrete wavelet transform and singular value decomposition. In this technique first 3-level RDWT applied to both cover image and watermark image then apply singular value decomposition to third level HL band of coverimage and cover image. After decomposition modify the singular value of cover image with the singular value of watermark image. The advantage of proposed technique is that it robust against various image processing attacks. To represent the efficiency of complete data security of the proposed technique various parameters will be used like, peak signal to noise ratio (PSNR) and mean square error (MSE).

2. Redundant Discrete Wavelet Transform (RDWT)

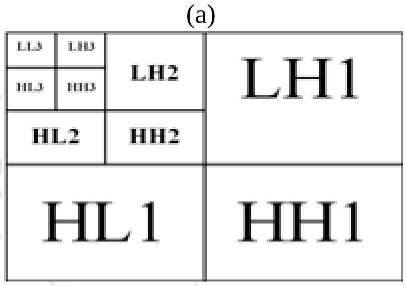
DWT has spatial frequency localization property which is used to find the location where a watermark is embedded. This property provides the high imperceptibility to the image and quality of cover image is not degraded. Apart from this advantage DWT has many disadvantages. The major disadvantage of DWT is that it does not provide shift invariance. A down sampler is connected after each filter bank iteration which causes a significantly change in the wavelet coefficient even for the minor shift. The shift invariance of DWT causes inaccurate extraction of the cover and watermark image [8]. To overcome this problem caused by shift invarianceredundant discrete wavelet transform (RDWT)is established. RDWT eliminates the down sampling from the each filter-bank iteration. There are many advantages of RDWT over the other transform domain techniques:

- It provides the shift invariance.
- Frame expansion increases the robustness with respect to additive noise.
- From removing down sampling we get the exact location and broad area for embedding the watermark.

In the RDWT analysis the redundant representation of the input sequence is obtained by eliminating down sampling. Since frame expansion increases the robustness from various attacks and noise. RDWT based Digital image processing is more robust than DWT. In DWT, the sizes of each sub-band is decreases when the decomposition level increases but in RDWT each sub-band maintains the same size as the original image. In redundant discrete wavelet transform image is decomposed into four components LL,LH, HL, and HH. LL band contains the average information of image, LH band contain the vertical component, HL band contains the horizontal component and HH band contains the diagonal component of image. Here we are using 3-level RDWT decomposition. In three level decomposition first the image is decompose in the four sub-bands, this is level 1 decomposition of image after this the LL1 band of image is again decomposed into four sub-bands, this decomposition is level 2 decomposition of image. After this image's LL2 band again decompose into the four sub-bands. Here we are decomposing LL band because only LL band of image contains the average information of image.



(a)



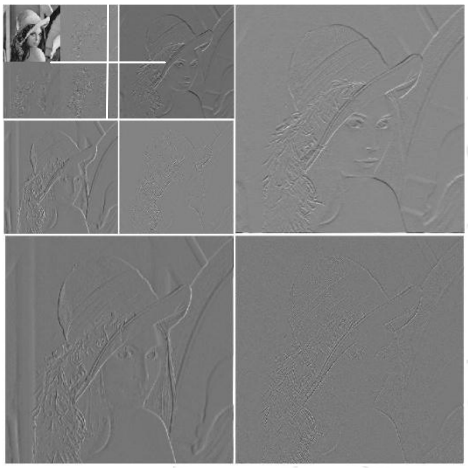
(b)

Figure 1: 3-Level Redundant Discrete Wavelet Transform of an image.

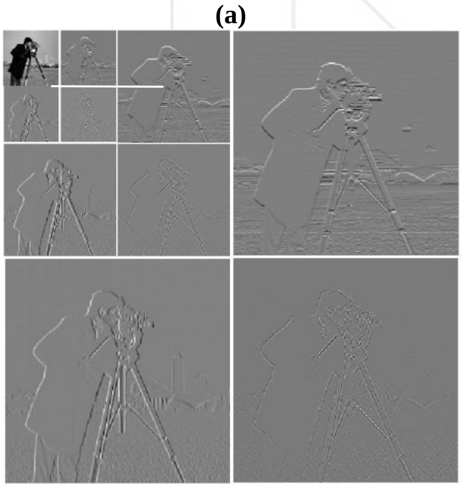
In three level decomposition first the image is decompose in the four sub-bands, this is level 1 decomposition of image after this the LL1 band of image is again decomposed into four sub-bands, this decomposition is level 2 decomposition of image. After this image's LL2 band again decompose into the four sub-bands. Here we are decomposing LL band because only LL band of image contains the average information of image. As we can see in figure1, firstly 2-D image is decompose into four sub-bands LL1, LH1, HL1, HH1 then LL1 Band is again decompose into four sub-bands which is LL2, LH2, HL2, HH2, after this the LL2 band again decompose into four sub-bands which is LL3, LH3, HL3, HH3. Now after 3-level decomposition we are applying singular value decomposition to the HL3 band of the decomposed image. For embedding watermarking we have to know the exact location of image where human visual system (HVS) is less sensitive. Since human eyes are very sensitive to the low frequency component i.e. LL sub-bands hence the watermark can be embedded in the other three bands.In Level 1 RDWT transform the image is transformed into four components as shown in figure.2:

1) Top left component contains the average information of an image, which is low frequency of the original image.
2) Top right component contains the horizontal details of the original image.
3) Bottom left component contains the vertical details of the original image.
4) Bottom left component contains the diagonal details, which is also the high frequency component of the original image.

Figure 2: level 1 Redundant Discreet Wavelet Transform of an Image.



(a)



(b)

Figure 3. 3-Level decomposition of the (a)Cover image (Lena 256x256) and (b) Watermark image (Cameraman 256x256).

In this project we are apply level 3 decomposition to both cover image and watermark image as shown in figure.3. for robustness of image under various attacks. After decomposing the SVD apply to both HL3 band of cover image and watermark image.

3. Singular Value Decomposition (SVD)

Singular value decomposition is developed for the wide verity of application like signal and image processing application. It is used in various applications such as image compression, noise reduction and image hiding. SVD is the numeral analysis tool which is used to analyze image matrices. Several watermarking techniques are based on singular value decomposition because it has many advantages. When SVD is alone applied it increases the computation complexity hence we are using hybrid SVD based algorithm such as RDWT-SVD. The SVD of an image matrix is defined as follows:

$$A = U\,S\,V^T \qquad (1)$$

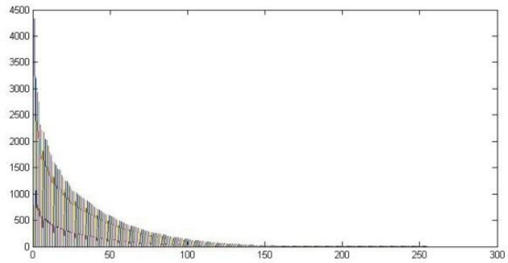
Where U and V are the orthogonal matrix and, S is singular matrix or diagonal matrix which is given by:

$$S = \begin{bmatrix} \sigma_{11} & 0 & 0 & 0 & \cdots & 0 \\ 0 & \sigma_{22} & 0 & 0 & \cdots & 0 \\ 0 & 0 & \sigma_{33} & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & \sigma_{nn} \end{bmatrix} \qquad (2)$$

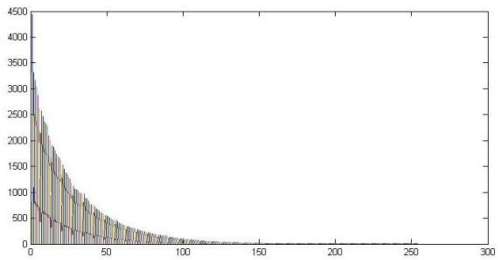
Here S is an nxn diagonal matrix whose diagonal elements are $\sigma_{11}, \sigma_{22}, \sigma_{33}, \sigma_{44} \ldots \ldots \sigma_{nn}$. The diagonal elements of SVD satisfy the following conditions $\sigma_{11} \geq \sigma_{22} \geq \sigma_{33} \geq \sigma 44 \ldots\ldots \geq \sigma nn$. The propertiesof SVD in the digital image watermarking are as follows:

- SVD represents the intrinsic algebraic property of an image. Here the singular value (S) represents brightness and singular vectors (U and V) represent the geometrical property of an image.
- Singular value of an image is highly stable i.e., when small disturbance added to an image it does not change its significant singular value.
- SVD can be either a square matrix or rectangular matrix.
- The singular values of image matrix is in decreasing order hence it has many small singular values as compared to the first value. Due to this even if we ignore this small singular value in the reconstruction of image it does not degrade the quality of image.

Singular value of the cover image (Lena) and watermark image (Cameraman) is shown in figure below, which is the singular value of HL3 band of both cover image and watermark image.



(a)

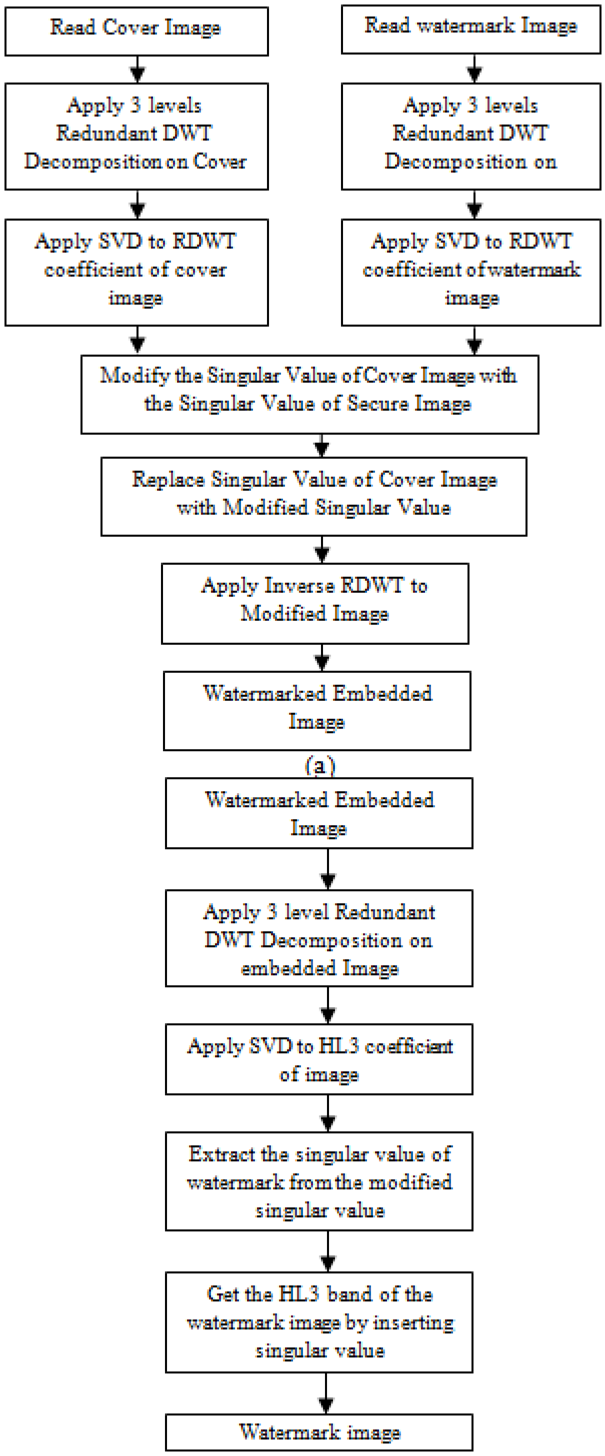


(b)

Figure 4: (a) Singular value for HL3 band of cover image (Lena). (b) Singular value for HL3 band of Watermark image(Cameraman).

4. Proposed combine RDWT-SVD Technique

The proposed technique is based on the hybrid RDWT-SVD technique. The procedure for embedding and extracting watermarking using RDWT-SVD is shown in figure 5(a) and 5(b) respectively.



(b)

Figure5: (a) Watermark embedding process, (b) Watermark extraction process.

Any watermarking algorithm basically consist of two sections, first is embedding watermark image and second one is extracting watermark image from the embedded cover image. The proposed watermark embedding and extraction is given by as follows:

1) Watermark embedding algorithm

a) Apply 3 level haar redundant discrete wavelet transform to decompose cover image (A) and the watermark image (W) into four sub bands (LL3, LH3, HL3, HH3).

b) Apply singular value decomposition to HL3 band of both cover image and watermark image.

$$A_{HL3} = U_A S_A V_A^T \tag{3}$$

$$W_{HL3} = U_W S_W V_W^T \tag{4}$$

c) Modify the singular of the cover image with the singular value of watermark image with scaling factor.

$$S^*_A = S_A + \alpha S_W \tag{5}$$

Where α represents the scaling factor(we are using α =0.2 for embedding watermark into HL3 band).

d) Replace the singular value of cover image with modified singular value to obtain the modified image as follows:

$$A^*_{HL3} = U_A S^*_A V_A^T \tag{6}$$

e) Now finally, apply the inverse redundant discrete wavelet transform to obtain the watermarked image.

2) Watermark extraction algorithm

a) Apply 3 level redundant discrete wavelet transform to watermarked image to decompose image into four sub bands (LL3, LH3, HL3 and HH).

b) Apply SVD to HL3 band of image as follows:

$$A^*_{HL3} = U_A S^*_A V_A^T \tag{7}$$

c) Singular value of the watermark can be extracted as follows:

$$S_W = (S^*_A - S_A)/\alpha \tag{8}$$

d) From the singular value we get the HL3 band of the watermark image as follows:

$$W_{HL3} = U_W S_W V_W^T \tag{9}$$

e) Finally apply 3 level inverse redundant discrete wavelet transform (IRDWT).

5. Performance Evaluation and Simulation Results

The proposed RDWT – SVD scheme is implemented using MATLAB. This watermark technique is tested in various standard images which are considered as cover images. The scaling factor is used for HL3 band is 0.2. The proposed RDWT-SVD technique is imperceptible and substantial against various image processing attacks. Imperceptibility means after embedding watermark the coverimage and the watermarked image is almost same i.e. human visual quality of the cover image should not be much affected. To calculate the imperceptibility of an image here we are using peak signal-to-noise ratio (PSNR).The peak signal to noise ratio is given by as follows:

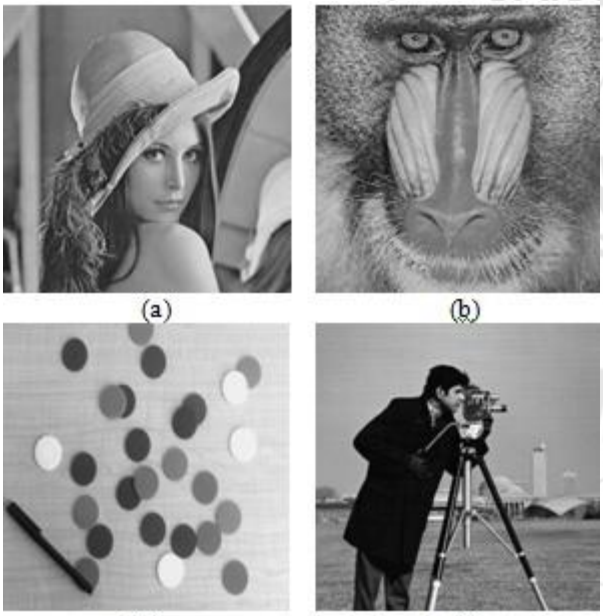
$$PSNR = 10\log_{10}\left[\frac{max^2}{MSE}\right] \quad (10)$$

Where max represents maximum number of pixel value of an image and MSE is mean square error between the cover image and watermark image, which is given by:

$$MSE = \frac{1}{m*n}\sum_{i=1}^{m}\sum_{j=1}^{n}[I_1(i,j) - I_2(i,j)]^2 \quad (11)$$

Where m is number of rows and n is number of columns of an image. I_1 represents cover image and I_2 represent the watermarked image.

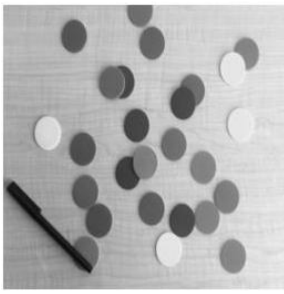
The imperceptibility can be calculated by visually comparing cover image with the watermarked image as shown in figure below. Here we are using cover images (Lena,Baboon and peppers) and watermark image (Cameraman) for watermark embedding as shown in figure.6.After embedding watermark image, cover image is compared with the watermarked image to calculate imperceptibility. Watermarked images are shown in figure.7.



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

Figure 6: (a) Cover image (Lena 256x256), (b) Cover image (Baboon 256x256), (c) Cover image (Chips256x256), (d) Watermark image (Cameraman 256x256).

(a) (b)



(c)

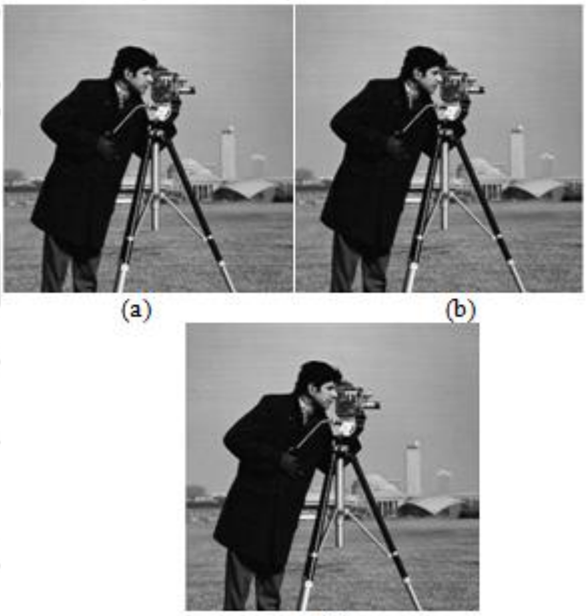
Figure 7: (a) Watermarked Lena image (b) Watermarked Baboon image (c) Watermarked Chips image.

PSNR for different images are given in table 1. High PSNR value shows, low degradation in image. Hence after applying proposed technique, the PSNR value of embedded image is improved.

Table 1: PSNR value of different images

Image Name (256x256)	*PSNR*
LENA	57.0513
BABOON	56.9805
CHIPS	58.7959

Extracted watermark image for different cover images are shown in figure 8.



(a) (b) (c)

Figure 8: Extracted watermark images (Cameraman) from (a) Lena image (PSNR=43.4587), (b) Baboon image (PSNR=43.4424), (c) Chips image (PSNR=43.3102).

Watermark image under various attacks and its PSNR and MSE is shown in table 2. Under various attacks and noise PSNR of watermark image and extracted watermark image was not variate in large amount, hence the proposed technique is substantial under various image processing attacks.

Table 2: PSNR and MSE values of secure image and extracted secure image for proposed technique RDWT-SVD

Noises and Attacks	***RDWT-SVD***	
	MSE	*PSNR*
Without Noise	2.93234	43.4587
Gaussian Noise	3.14937	43.1486
Contrast Attack	3.05836	43.2759
Salt Pepper Noise	4.65746	41.4493
Speckle Noise	3.17583	43.1122
Poisson Noise	2.35262	44.4153
Shift Attack	2.93234	43.4587

6. Conclusion

A new hybrid technique for image watermarking RDWT-SVD is proposed in this paper. Redundancy in RDWT technique provides high robustness to watermarked image under various image processing attacks. In proposed technique it is clear that SVD provide good stability, because it provides high imperceptibility under various attacks. The performance is evaluated by using PSNR and MSE. Simulation results shows that the proposed technique is robust against various types of attacks.

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