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A ROBUST IMAGE WATERMARKING SYSTEM BASED ON EDWT AND SVD

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ABSTRACT

A novel technique for reversible digital image watermarking which is robust against image manipulations and transformations is proposed in this paper. An extended variant of Discrete Wavelet Transform (DWT) is utilized for the decomposition of images. In Extended Discrete Wavelet Transform (EDWT), sampling processes are avoided form DWT during analysis step and synthesis step respectively. EDWT is applied to watermark image as well as cover image results in shift invariance and accurate extraction of watermark. Singular Value Decomposition (SVD) is then applied to sub-bands that have low frequency of occurrence in the image. Watermarking pixels are embedded inside the wavelet coefficients of unmodified host image and this will overcome security issues. This method is robust against various types of noises and attacks occur while transferring the image though a channel. Performance of the proposed method is compared with the performance of DWT-SVD watermarking scheme. The performance is compared in terms of correlation and PSNR.

Keywords: extended discrete wavelet transform (EDWT), down sampling, up Sampling, shift invariance, robust watermarking.

1. INTRODUCTION

Due to the world wide availability of internet, there is an increase in the distribution of pirated digital media. These media has to be protected against attackers who can easily modify the content and claim the ownership [1]. Main objective of researchers in digital watermarking is to develop a robust method to protect copyrights of data owners and publishers against piracy and redistribution. Watermarking is the process of adding data into multimedia such as audio, images or videos to increase security and protect copyright. A watermarking methodology consists of algorithms to embed and extract data. It is easy to track the watermark in a media and it can only be accessed with the help of a secret key. Watermarking schemes are sub divided into various types based on the information needed for extracting watermark. In Non-blind type scheme original image and secret key is necessary for detecting watermark. Secret key and watermark is required in Semi-blind type watermarking schemes. Blind watermarking strategy requires secret key alone for the detection of watermark. Watermark embedding process can be performed in either spatial domain or transform domain. Computational complexity is low in the case of spatial domain embedding methods, but they are vulnerable to various types of attacks [2]. Transform domain embedding schemes provide robustness against various attacks and it is a better choice for reliable watermarking.

Commonly used transform based technique is the modification of SVD coefficient of cover image using watermark image. SVD based image watermarking scheme was initially proposed by Liu *et al* [3]. They applied SVD to the cover image and the coefficients are modified by adding watermark. Then they applied SVD again on the result image to find the updated singular values. Singular values thus obtained are then combined with known components to obtain watermarked image. Ganic *et al* [4] embedded singular values extracted from gray level watermark onto singular values in the sub-bands of DWT. Chandra *et al* [5] inserted singular values obtained from watermark image onto the singular values obtained from host image. Major flaw of this method is the reduction in the quality of watermarked image. The watermark extracted is not found to have robustness against common types of attacks. To circumvent these drawbacks, DWT and Discrete Cosine Transform (DCT) were incorporated with SVD. Rastegar *et al* [6] proposed an improved hybrid technique for watermarking depended on radon transform and 3-level DWT. Singular values in level three of DWT sub-bands are then modified employing the singular values of watermark image. Shanthi *et al* [7] combined DWT with SVD and the results obtained are better compared to normal DWT algorithm in terms of robustness against compression, noise as well as cropping attacks.

Amini *et al.* [8] combined DWT and block SVD to develop a dual watermarking technique based on principal component analysis. Best sub band for the embedding process is selected on the basis of variance in intensity of each block. This method boosts the robustness and security features of watermarked image. Bhatnagar *et al*. [9] developed DWT-SVD dual watermarking technique in which secondary watermark is added to the primary watermark. This watermark (primary) is embedded into the given host image.

From the experimental result analysis it is clear that the watermarked image exhibits serious degradation when exposed to some image processing attacks. Liu et al. [10] proposed a DWT oriented dual blind, watermarking method. This method can be used for generating invisible and robust watermark for image validation and copyright protection. Major drawback of this method is the unsatisfactory tamper localization. Mohanty *et al.* [11] developed a method combining invisible and visible block for dual watermarking. Watermark embedding is

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performed by obtaining the variance and mean of each block.

Even though DWT methods exhibit good performance in watermarking, they suffer from various drawbacks mentioned above. To overcome these drawbacks, a novel method for watermarking using Extended Discrete Wavelet Transform (EDWT) is proposed in this paper. This paper is systematically arranged in four sections. First section is the introduction, second section illustrates the proposed EDWT-SVD watermarking method, third section discusses the experimental results and finally the conclusion about the paper is given in section four.

2. METHODOLOGY

DWT is popular for its superior space-frequency localization property and it is a convenient tool to determine the areas of original image in which a watermark can be eventually inserted. But DWT has some demerits in watermarking scenario. One of the major demerits is the shift variance in the output. Shift variance arises because of down sampling steps after each filtering level. A minor variation can generate considerable variation in wavelet coefficients of input image. When the level of decomposition increases, the size of sub-band is reduced and the spatial region under consideration is small. The filter up-sampling process embeds holes between the filters. The filter banks in 2-level DWT are depicted in Fig.1. The generation of DWT coefficients is given in the equations below:

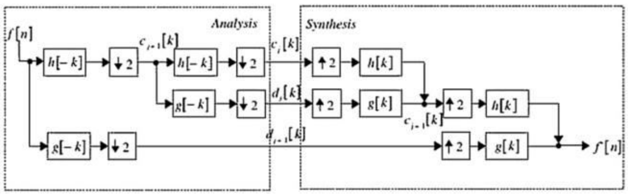

Figure-1. Filter Banks in 2-Level DWT.

$$c_j[k] = (c_{j+1}[k] * h[-k]) \downarrow 2 \quad (1)$$

$$d_j[k] = (c_{j+1}[k] * g[-k]) \downarrow 2 \quad (2)$$

$$c_{j+1}[k] = ((c_j[k] \uparrow 2) * h[k] + (d_j[k] \uparrow 2) * g[k]) \quad (3)$$

During the extraction of watermark and cover image, shift variance may lead to inaccuracy. To surmount this problem, an altered variant of DWT is proposed in this paper. EDWT eliminates down-sampling steps from the normal DWT implementation. If the size of sub bands is same as that of original image, significant textures will be present in the same spatial field of each sub-band. Based on those observations, it is clear that the local texture inside EDWT can be captured with increased accuracy. This will enable us to use the exact amount of local texture. EDWT can steer the casting of watermark into regions having advanced texture insensitive to Human Visual System (HVS). The filter banks of 2 level EDWT is shown in Figure-2. The generation of EDWT coefficients is given in the equations below.

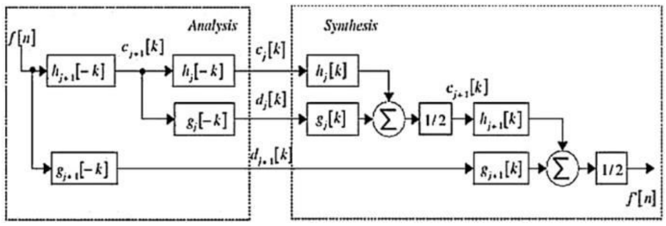

Figure-2. Filter Banks in 2-Level EDWT.

$$c_j[k] = (c_{j+1}[k] * h_j[-k]) \quad (4)$$

$$d_j[k] = (c_{j+1}[k] * g_j[-k]) \quad (5)$$

$$c_{j+1}[k] = \frac{1}{2}(c_j[k]) * h_j[k] + (d_j[k]) * g_j[k]) \quad (6)$$

Singular Value Decomposition (SVD) is a technique developed for multiple ranges of applications. This method is used in signal processing and image processing applications such as image reduction, image hiding, image compression, image watermarking, noise removal etc. SVD has been successfully applied to several watermarking approaches. If SVD alone is applied on an image the computational complexity is very high and accuracy is reduced. Therefore SVD is combined with other methods and hybrid algorithms have been developed such as DWT-SVD. These algorithms seldom use pixel values to embed watermark. Watermark is directly embedded into the transform domain coefficients of host image. SVD is a tool that can numerically analyze matrices by further decomposing given matrix into 3 new matrices. If F is an image, it can be defined as $F \in R^{nm}$, where R defines the domain of real numbers. SVD of the given input image F is calculated using

Equation 7. U and V are orthogonal matrices where U, $V \in R^{nm}$. S represents the diagonal matrix $S \in R^{nm}$.

$$F = USV^T \quad (7)$$

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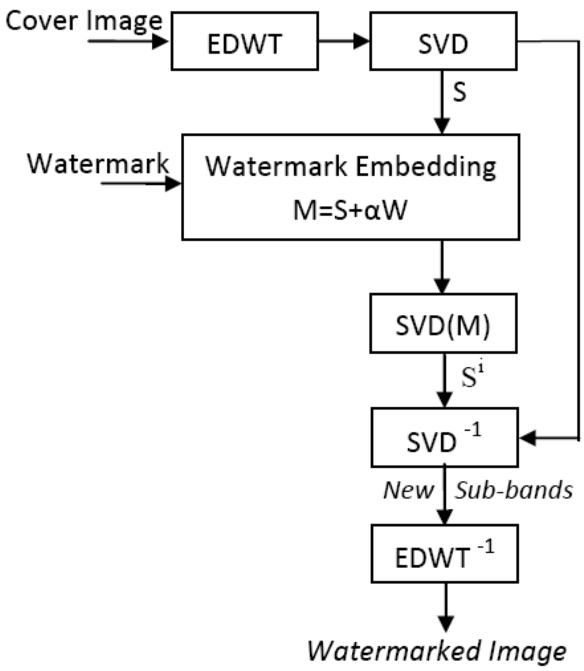

Figure-3. Watermark embedding process.

The processes in EDWT–SVD watermark embedding method is depicted in Figure-3. 1-level EDWT is performed on host image to obtain 4 sub-bands (LL, LH, HL and HH) as a result of decomposition. SVD is then applied to all sub-bands, as given below. *i* indicates the sub bands of host image.

$$F_w^* = U^{*i} S^{*i} V^{*iT} \tag{7}$$

Singular Values (S^i) of each sub band is modified by directly applying the watermark. Then SVD is induced to the resultant image.

$$S^i + \alpha W = U_W^i S_W^i V_W^{iT} \tag{8}$$

Where, α is the scaling factor. If α = 0.025, watermark is induced into the sub-band LL. If α = 0.005, watermark is induced into others sub-bands (HL, LH, HH).

Inverse SVD is executed to find the modified EDWT coefficients for the sub-bands.

$$F_{update}^i = U^i S^i V^{iT} \tag{9}$$

Finally, inverse EDWT is applied to the modified four sets of EDWT coefficients to obtain the watermarked image F_W.

$$F_W = EDWT^{-1} \tag{10}$$

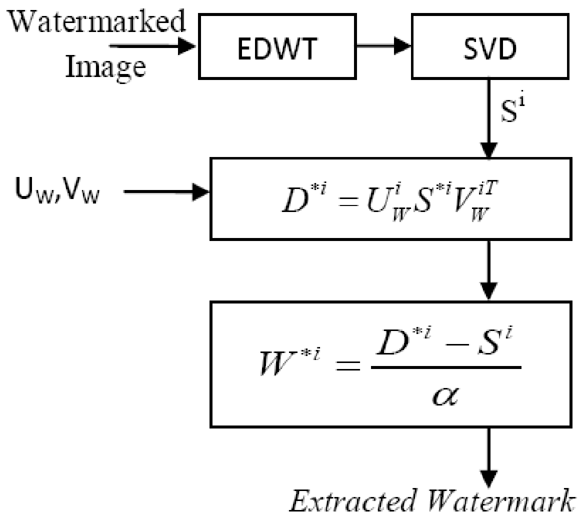

Figure-4. Watermark extraction process.

The processes in EDWT–SVD watermark extraction method is depicted in Figure-4. EDWT is applied to the watermarked image F_W^* (probably distorted) and four sub-bands (LL, LH, HL, and HH) are obtained. Then SVD is induced to all sub-bands and singular values of watermarked image are induced to the resultant image as given below,

$$F_w^* = U^{*i} S^{*i} V^{*iT} \tag{11}$$

$$D^{*i} = U_W^i S^{*i} V_W^{iT} \tag{12}$$

Then watermark is extracted using the equation,

$$W^{*i} = \frac{D^{*i} - S^i}{\alpha} \tag{13}$$

3. EXPERIMENTAL RESULTS

Before The proposed methodology is implemented using MATLAB 2017b and tested using standard gray scale images (cover and watermark) of size 256x256. 'Lena' image is used as cover image and 'Cameraman' image is used as watermark image. The host and watermark used in this experiment are depicted in Fig.5. The proposed EDWT–SVD method is implemented and the performance is evaluated using various experiments in terms of robustness and imperceptibility against different types of attacks. Imperceptibility is the measure of visual quality of host image after inducing watermark. In this work, Peak Signal to Noise Ratio (PSNR) is enumerated to compute the grade of imperceptibility. PSNR is computed using Equation 14.

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(a) (b)

Figure-5. (a) Cover image, (b) Watermark image.

$$PSNR = 10\log_{10}\left(\frac{\max[x(i,j)]^2}{MSE}\right) \tag{14}$$

Mean Square Error (MSE) is given by the equation,

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}[x(i,j)-y(i,j)]^2 \tag{15}$$

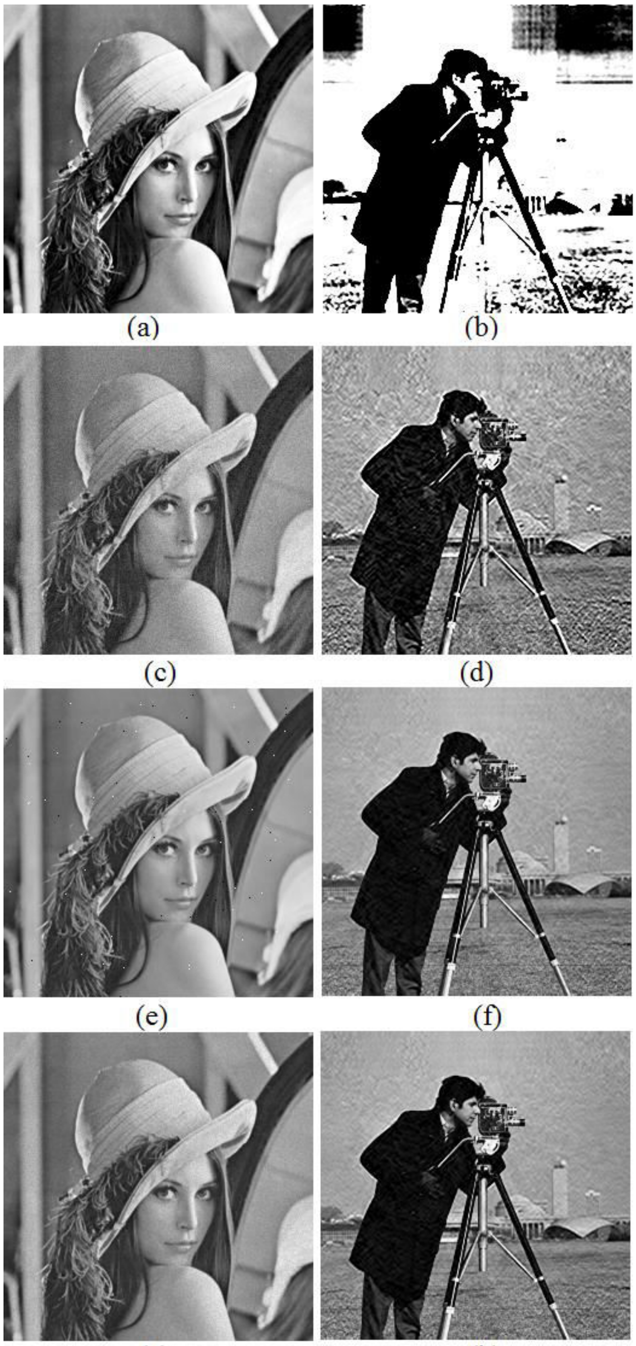
The watermarked image and extracted watermark obtained using proposed methodology are shown in Fig.6. Here the watermarked image is not affected by noise and the extracted watermark is of good quality. By comparing host image with watermarked image, the value of PSNR obtained is 37.65 dB.

(a) (b)

Figure-6. Output images (a) Watermarked image, (b) Extracted watermark.

To evaluate the robustness of proposed algorithm, simulated attacks are applied on the watermarked image. The attacks used in this experiment are histogram equalization, rotation, Gaussian noise, speckle noise and salt & pepper noise. Correlation Coefficient (CC) denotes the resemblance between extracted and original watermarks. Standard correlation coefficient is expressed in Equation (16).

$$Correlation = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2}\sqrt{\sum(y-\bar{y})^2}} \tag{16}$$



(a) (b) (c) (d) (e) (f) (g) (h)

Figure-7. Watermarked Image Attacked with Simulated Noise and Corresponding Extracted Watermark (a) Histogram Equalization (b) Extracted Watermark from Histogram Equalized Image, (c) Gaussian Noise, (d) Extracted Watermark from Gaussian Noise Affected Image, (e) Salt & Pepper Noise, (f) Extracted Watermark from Salt & Pepper Noise Affected Image, (g) Speckle Noise, (h) Extracted Watermark from Speckle Noise Affected Image.

Proposed EDWT-SVD algorithm is compared with standard DWT-SVD scheme. From the values obtained for CC and PSNR it is clear that the proposed watermarking scheme is superior to the existing

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methodology. Table-1 shows the detailed comparison between DWT-SVD and EDWT-SVD in terms of various attacks. The shift invariance attribute of EDWT-SVD algorithm is the major reason behind the robustness of watermarking method.

Table-1. Comparison of Watermarking Algorithms.

Simulated attacks	DWT-SVD		EDWT-SVD	
	CC	PSNR	CC	PSNR
Histogram Equalization	0.6519	6.73	0.7621	8.93
Gaussian Noise	0.9119	20.09	0.9464	21.51
Salt & Pepper Noise	0.9868	27.19	0.9931	30.78
Speckle Noise	0.9839	27.03	0.9912	29.54

4. CONCLUSIONS

We presented a novel watermarking scheme using EDWT-SVD to embed a watermark image that can have the same size of host image. The shift invariance property of EDWT and the modification of singular values of host image increased the robustness and imperceptibility of proposed methodology. The PSNR value obtained for noiseless watermark image is 37.6 dB. The results demonstrate that this method has remarkable robustness against numerous attacks in comparison with DWT based method. EDWT is shift invariant, and it introduces frame expansion in the image. Frame expansion is useful to increase robustness in the presence of additive noise.

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