DWT-SVD Combined Full Band Robust Watermarking Technique for Color Images in YUV Color Space

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***Abstract*-Due to the advancement in Computer technology and readily available tools, it is very easy for the unknown users to produce illegal copies of multimedia data which are floating across the Internet. In order to protect those multimedia data on the Internet many techniques are available including various encryption techniques, steganography techniques, watermarking techniques and information hiding techniques. Digital watermarking is a technique in which a piece of digital information is embedded into an image and extracted later for ownership verification. Secret digital data can be embedded either in spatial domain or in frequency domain of the cover data. In this paper, a new singular value decomposition (SVD) and discrete wavelet transformation (DWT) based technique is proposed for hiding watermark in full frequency band of color images (DSFW). The quality of the watermarked image and extracted watermark is measured using peak signal to noise ratio (PSNR) and normalized correlation (NC) respectively. It is observed that the quality of the watermarked image is maintained with the value of 36dB. Robustness of proposed algorithm is tested for various attacks including salt and pepper noise and Gaussian noise, cropping and JPEG compression.**

***Index Terms*—Digital watermarking, Discrete Wavelet transformation technique, SVD-Watermarking, Transform Domain watermarking.**

I. INTRODUCTION

In recent days, usage of computer networks for communication and for information sharing leads to increase in size of Internet. As the size of the Internet grows, the volume of multimedia data (images, text, video / audio) floating around also increases day by day. As many advanced tools are readily available to duplicate and modify those data in the Internet easily, security is the major concern, which requires some mechanisms to protect digital multimedia data. Thus watermarking is a technique which supports with feasible solution.

Digital Watermarking is defined as the process of hiding a piece of digital data in the cover data which is to be protected and extracted later for ownership verification [1]. Some of the important applications of watermarking technique are copyright protection, ownership verification, finger printing, and broadcast monitoring. The features of watermarking include robustness and perceptibility. Robustness indicates the resistivity of watermark against different types of attacks such as cropping, rotating, scaling, low pass filtering, resizing, addition of noise, JPEG compression, sharpness, histogram equalization and contrast adjustment. Those attacks are either intentional or unintentional. Robustness is the property which is important for ownership verification whereas the fragility is important for image authentication. Robustness of watermarking algorithm is obtained to a maximum level when information is hidden in robust components of cover data. The increasing perceptibility will also decrease the quality of watermarked image.

Generally information could be hidden, directly by modifying the intensity value or pixel value of an image or its frequency components [2]. 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 short Fourier transformation (DSFT), Discrete Cosine Transformation (DCT) [3][4], Walsh Hadamard transformation (DHT) [5][6], and Discrete wavelet Transformation (DWT)[7][8][9][10]. 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 the proposed method DSFW, information is hidden in YUV space of a color image. The features of SVD technique [11] are combined with DWT to embed data in frequency domain of cover data. The review of related work is given in section II. In section III overview of singular value decomposition is given. The proposed algorithm is discussed in detail in section IV. Results and analysis of proposed algorithm is discussed in section V.

II. REVIEW OF RELATED WORKS

Review of literature survey has been conducted on discrete wavelet transformation combined with singular value decomposition techniques for hiding information in digital color images.

In [8], two level decomposition of DWT is applied to transform an image into bands of different frequency and a particular band is converted into blocks of size 4x4 for embedding data. Each of those blocks is SVD transformed and watermark is hidden into diagonal matrix of every block. The similarity between the original watermark and the

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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 [9] the DWT is combined with SVD technique to hide data in high frequency band of an image. This scheme performs well for variety of image processing operations. In [10] 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 and 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 [12] both cover image and watermark image are pre processed to hide watermark in transform domain. The performance evaluation shows that the algorithm is robust against attacks such as cropping, Gaussian noise, JPEG compression and low pass filtering.

In [14], three level decomposition of DWT is applied on an 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 [15].Experimental results show its better performance for compression, cropping and scaling attack.

As per the review many algorithms are available to hide watermark in intensity images rather than color images. In DSFW, color image is taken as cover data in which all the pixel color components are highly correlated, so the cover data in RGB color domain is converted into YUV domain where intensity(Y) and chrominance (UV) components are decorreleted. Secret data can be hidden either in intensity components or in color components. The quality of watermarked data and extracted watermark is calculated using peak signal to noise ratio (PSNR) and normalized correlation coefficients respectively. DSFW algorithm is tested against many image processing and geometrical attacks.

III. OVERVIEW OF SINGULAR VALUE DECOMPOSITION

Singular value decomposition is a linear algebra technique used to solve many mathematical problems [11]. The theoretical background of SVD technique in image processing applications to be noticed is [15]:

a) The SVs (Singular Values) of an image has very good stability, which means that when a small value is added to an image, this does not affect the quality with great variation.
b) SVD is able to efficiently represent the intrinsic algebraic properties of an image, where singular values correspond to the brightness of the image and singular vectors reflect geometry characteristics of the image.
c) An image matrix has many small singular values compared with the first singular value. Even ignoring these small singular values in the reconstruction of the image does not affect the quality of the reconstructed image

Any image can be considered as a square matrix without loss of generality. So SVD technique can be applied to any kind of images. If it is a gray scale image the matrix values are considered as intensity values and it could be modified directly or changes could be done after transforming images into frequency domain.

The SVD belongs to orthogonal transform which decompose the given matrix into three matrices of same size [3]. To decompose the matrix using SVD technique it need not be a square matrix. Let us denote the image as matrix A. The SVD decomposition of matrix A is given using (1)

$$A = USV^T \qquad (1)$$

U and V are unitary matrices such that $UU^T = I$, $VV^T = I$, where I is an Identity matrix.

$U = [u1, u2, u3 \dots un]$ $V = [v1, v2, v3 \dots vn]$, U matrix is called left singular values and V matrix is called right singular values. The decomposition of matrix A is obtained using (2).

$$SVD(A) = U\,S\,V^T = U \begin{bmatrix} D & 0 \\ 0 & 0 \end{bmatrix} V^T \qquad (2)$$

$S = \begin{bmatrix} D & 0 \\ 0 & 0 \end{bmatrix}$ such that all the elements in main diagonal are in decreasing order like $\sigma_1 \geq \sigma_2 \geq \sigma_3 \geq \dots \sigma_n \geq 0$,

where S is the diagonal matrix having in its main diagonal all positive singular values of A. Number of nonzero values equals the rank of the matrix. These positive singular values can be used to embed watermark. The order of singular matrix is same as A, and hence the resultant matrix is also square. Hence images of equal size can be taken as cover object.

IV. PROPOSED SYSTEM – DSFW

A. Embedding Procedure

The block diagram for embedding watermark in transform domain using SVD technique is shown in Fig.1. As color image is used as cover data in the proposed system DSFW, the RGB value of each pixel is converted into RGB color spaces [13] [12] in which only R components constitute R color space, G components constitute G color space and B components constitute B color space. Watermark can be hidden in any one or in the three color channels. Since pixel values are highly correlated in RGB color spaces, information can be hidden in YUV color spaces. The RGB components of color image is converted into RGB color spaces which in turn is converted into YUV color spaces using (3).The YUV color spaces consists of luminance (intensity) and chrominance (color) components. The input image in YUV domain is shown in Fig.3. The Y component consists of intensity values whereas the UV components consist of chrominance values of color image. The energy content of Y component is higher than the chrominance components of U and V. In DSFW, YUV color spaces are used for embedding secret data after transformed into frequency coefficients using Haar wavelet. The Haar wavelet is a tool which is used to convert given image into four band of frequency by decompose it. In each level of decomposition the input image is decomposed into four band of frequencies named LL, LH, HL and HH band. Each band of frequency is SVD transformed and watermark is hidden in the singular values (diagonal elements) of singular matrix. Then inverse SVD technique and inverse wavelet transformation technique is applied to get the watermarked image.

(a) RGB Image (b) Y Component (c) U Component (d) V Component

Fig.1 RGB Image Transformed into YUV Color Space

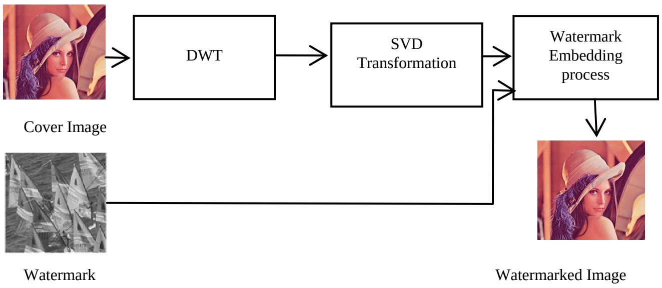


Fig.2. Process of Embedding Watermark in an Image

A. *Algorithm for Embedding Watermark*

In the proposed method, full band frequency is selected to hide watermark in all the three channel of YUV color space. The embedding factor or control factor is used to control the energy of the watermark and it is denoted as α and its value range from 0 to 1 (0≤α≤1). The algorithm for hiding information is given below:

Step 1 RGB components of color image A is converted into YUV color spaces using (3)

$$y = (0.257 * R) + (0.504 * G) + (0.098 * B) + 16$$
$$v = (0.439 * R) - (0.368 * G) - (0.071 * B) + 128$$
$$u = (0.148 * R) - (0.291 * G) + (0.439 * B) + 128 \quad (3)$$

Step 2 Discrete wavelet transformation technique is applied to YUV matrices to decompose it into different range of frequency bands. For each level of decomposition, input image matrix Y is transformed into four band of frequency named LLY,LHY,HLY,HHY(5). Similarly U and V image matrices are also transformed into four band of frequencies using (5)

$$[LL, LH, HL, HH] = DWT\ (Y, U, V) \quad (5)$$

Step 3 SVD technique is applied on each band of YUV color spaces of cover data as well as on watermark using (6).

$$[U\ S\ V] = SVD\ (Band)$$

$$[U'\ S'\ V'] = SVD\ (W) \quad (6)$$

Let *U*, *V* be orthogonal matrices, *S* is a diagonal matrix. The diagonal matrix *S* is used to embed watermark in its diagonal elements using (7). Here Band represents any one of the frequency band such as LL, LH, HL and HH.

$$S'' = S + \alpha S' \quad (7)$$

The watermark S' is embedded into the non-zero elements of the diagonal matrix *S* to obtain the watermarked diagonal matrix S''.

Step 4 Inverse SVD is applied on watermarked S'' matrix to get the modified Image Band using (8)

$$Band' = [U * S'' * V] \quad (8)$$

Step 5 Inverse transformation Technique is applied to get the watermarked image matrices of Y,U,V using (9)

$$[Y', U', V'] = DWT\ (LL', LH', HL', HH') \quad (9)$$

Step 6 YUV color spaces are converted into $R'G'B'$ color spaces by (10)

$$A' = YUV(R'G'B') \quad (10)$$

where A' is an watermarked Image

B. *Algorithm for Extracting Watermark*

During Extraction process, the RGB components of the watermarked color image are converted into YUV color spaces which in turn can be converted into frequency coefficients of four bands. Each band of frequency is SVD transformed to extract watermark from the diagonal elements. The block diagram of watermark extraction procedure is shown in Fig.3.

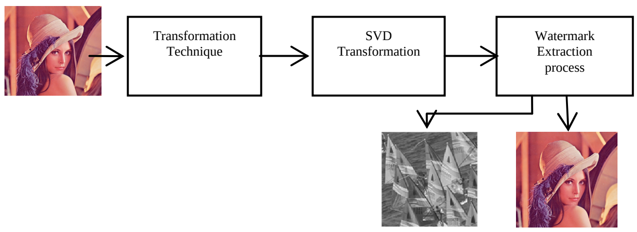


Fig.3. Process of Extracting Watermark from an Image

Step 1 Let *A'* be a watermarked image matrix, apply transformation technique to convert RGB color space into YUV color space using (11)

$$Y'U'V' = RGB(A') \quad (11)$$

Step 2 Wavelet transformation Technique is applied to YUV matrices to decompose it into different range of frequency bands in (12).

$$[LL', LH', HL', HH'] = DWT\ (Y'U'V') \quad (12)$$

Step 3 SVD transformation is applied on full band of wavelet transformed YUV matrices

$$[U\ S''\ V] = SVD\ (Band') \quad (13)$$

Where $Band'$ means one of wavelet transformed frequency bands of YUV matrices

Step 4 Watermark is extracted using (14)

$$S' = (S'' - S)\ /\alpha \quad (14)$$

Step 5 Apply inverse SVD on retrieved watermark using unitary matrices U and V

$W' = U S' V$

Step 6 The similarity of original watermark and extracted watermark is measured using (15).

$$NC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} w(i,j) * w_e(i,j)}{\sqrt{\sum_{i=1}^{n}\sum_{j=1}^{m} w^2(i,j)}\ \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{m} w_e^2(i,j)}} \quad (15)$$

where W and W_e are original and extracted watermark.

V. PERFORMANCE ANALYSIS

The performance of algorithm DSFW is analyzed through the results which are obtained by embedding large sized watermark in all the three channels of cover image in YUV space. The quality of the watermarked image can be measured either subjectively or objectively and it is observed that both subjective and objective quality of watermarked image is good. The PSNR is the objective criteria used to measure the quality of the watermarked image. Similarly the quality of the extracted watermark is measured by comparing it with the original watermark and is called similarity measure. The peak signal to noise ratio and normalized correlation are obtained using (15) and (16) respectively.

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(f(i,j) - f'(i,j))2 \quad (16)$$

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (17)$$

$f(i,j)$ and $f'(i,j)$ represent the pixel values of original host image and the watermarked image respectively and parameters *m*,*n* specify row and column size of images respectively.

In the DSFW the boat image of size 256 X 256 is taken as watermark whereas the lena image of size 512 X 512 is taken as cover image and watermark is hidden in full band of Y, U and V channels of cover data. The original image, watermark image and watermarked is shown in Fig.4. The quality of the watermarked image is measured through PSNR and calculated values are tabulated in Table.1. Similarly the measured normalized correlation values are tabulated in Table.2

Fig.4 (a) Original Image (b) Watermark (c) Watermarked Image

Fig.4 (c) shows that the watermarked image quality is not degraded and also the watermark is imperceptible, so the proposed algorithm is characterized as imperceptible algorithm. The proposed algorithm is tested in YUV channels. The extracted watermark from three channels (YUV) under normal condition without any attack is shown Fig 5. which shows that watermark could be embedded in any one of the channel if computer network is highly secured. But normally the communication networks are not secured and also noisy in nature. It is required to identify a good channel to embed watermark such that it should withstand maximum possible attacks which may be intentional or unintentional. The extracted watermark after salt and pepper noise, Gaussian noise, cropping and histogram equalization attacks are shown in Fig.6, Fig.7, Fig. 8 and Fig.9 respectively. Table 1 shows the quality of the watermarked image through peak signal to noise ratio.

(a)Y Channel (b) U channel (c) V Channel
Fig.5 Extracted Watermark from YUV Channel without attack

The calculated value of PSNR is above 36 decibels in Y channel and 33decibals in U channel and 30 in V channel respectively. The PSNR value shows that the quality of the watermarked image is good and not degraded much when information is added in the Y channel than U and V channel.

Table.1
PSNR values of Watermarked image Under normal condition

Frequency Band / Color Channel	Low frequency PSNR (dB)	Middle Frequency PSNR (dB)	Middle Frequency PSNR (dB)	High Frequency PSNR (dB)
Y Channel	**36.6107**	**36.6107**	**36.6107**	**36.6107**
U Channel	**33.9529**	**33.9529**	**33.9529**	**33.9529**
V Channel	**30.2643**	**30.2643**	**30.2643**	**30.2643**

Table.2
Similarity Measure of Extracted and Original Watermark (NC)

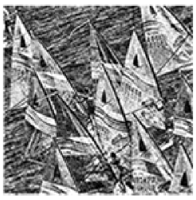
Frequency Band / Color channel	Low frequency (NC)	Middle Frequency (NC	Middle Frequency (NC)	High Frequency (NC)
Y Channel	**0.9980**	**0.9980**	**0.9980**	**0.9980**
U Channel	**0.9994**	**0.9994**	**0.9994**	**0.9994**
V Channel	**0.9498**	**0.9498**	**0.9498**	**0.9498**

Normalized correlation of extracted watermark is measured for non-tampered image and tabulated in Table.2. It shows that the quality of the extracted watermark from U channel is good as its NC is 0.9994 compared to calculated NC of Y and V channels. Thus the algorithm shows that the watermark can be hidden in U channel than Y and V.

The robustness of DSFW algorithm is tested against various attacks such as addition of salt and pepper noise, Gaussian noise, cropping and histogram equalization. The original and extracted watermark after attacks from Y U and V channels are shown in Fig.6-9. The calculated values of normalized correlation coefficients are tabulated in Table 3 and Table 4.As per the observation the quality of both watermarked image and extracted watermark quality is high for additive noise attack when watermark is hidden into Y channel compared to U and V channel. For cropping attack the quality of the extracted watermark from V channel is better the quality of Y and U channel.

The DSFW algorithm is robust to cropping attack as watermark is hidden into full band of frequency of cover image.

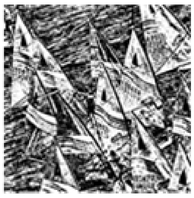
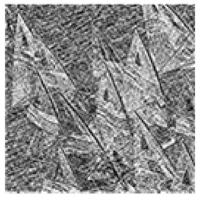





7(a) Gaussian attack 7(b) Y channel 7(c) U Channel 7(d) V Channel

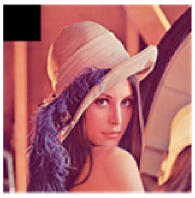
Fig.7 Extracted watermark after Gaussian noise attack from Y, U and V channel (Variance =0.01)

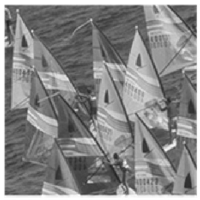


6 (a) Salt & Pepper Noise attack 6 (b) Y channel 6 (c) U Channel 6 (d) V Channel

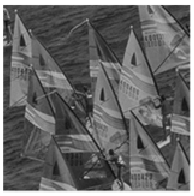
Fig.6 Extracted watermark after salt and pepper noise attack from Y, U and V channels (Variance =0.001)

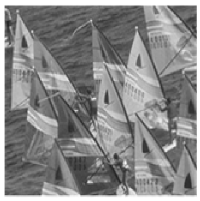


8(a) cropping attack 8(b) Y channel 8(c) U Channel 8(d) V Channel

Fig.8 Extracted watermark after cropping attack from Y, U and V channel



8(a) Histogram Equalization attack 8(b) Y channel 8(c) U Channel 8(d) V Channel

Fig.9 Extracted watermark after Histogram Equalization attack from Y, U and V channel

Table.3

Similarity Measure of Extracted and Original Watermark after noise addition attack

Domain	Salt & pepper Noise addition		Gaussian noise Addition	
	NC	PSNR	NC	PSNR
Y Channel	0.9818	36.6107	0.9372	36.6107
U Channel	0.7253	33.9529	.9325	33.9529
V Channel	0.5894	32.5579	0.8216	32.5579

Table.4
Similarity Measure of Extracted and Original Watermark after cropping and HISTOGRAM EQUALIZATION attack

Domain	Cropping		Histogram Equalization	
	NC	PSNR	NC	PSNR
Y Channel	0.9861	36.6107	0.9980	36.6107
U Channel	0.9984	33.9529	0.9425	33.9529
V Channel	0.9998	32.5579	0.9126	30.2643

VI. Conclusion and Future Work

DWT-SVD combined full band robust watermarking technique DSFW for color images in YUV color space is discussed in this paper. In this algorithm the multi-resolution capability of wavelet transformation technique is combined with singular value decomposition technique to make it robust. Since the watermark is hidden in full band of YUV channel algorithm DSFW is highly robust against common attacks such as addition of noise, histogram equalization and cropping, which are considered as one of the serious attacks. The quality of the extracted watermark shows that the new proposed algorithm is robust and also the quality of cover image is not degraded. In future, DSFW algorithm can be extended for streaming data as well to be tested against other possible attacks.

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