SVD AND WAVELET FEATURES IN NON BLIND WATERMARKING SCHEME FOR HIGH QUALITY RECONSTRUCTED IMAGES IN RGB SPACE

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Abstract— Protection of the digital image has become an important issue due to development of the multimedia and internet technology. Web based multimedia integrates variety of media, such as images, text, sound and , video, animation and internet data transmission is become challenging .Common user can easily produce illegal copies of the image. Watermarking is the major technology to achieve copyright protection. Many watermarking schemes have been proposed for watermarking the color image. Digital image watermarking plays great role against any attack and its evaluation is also challenging task for color image. In this paper robust digital color image watermarking scheme is revisited and analyzed to resolve the copyright issue. This scheme embeds monochrome watermark into color image in RGB space. The blend of Singular Value Decomposition (SVD) and Discrete Wavelet Transform (DWT) is used to embed the watermarking image. Red, Green and Blue channel of the color image are separated. Blue channel of the color image decomposed into four sub bands (LL, LH, HL, HH). Then singular value decomposition has applied to all four sub bands and modified its singular value with the singular value of watermark. Modification in all four sub bands allows the development of the watermarking scheme and is robust to wide range of geometric attacks. This scheme is found robust to various image processing operations such as Gaussian, salt and pepper noise, speckle noise. Experimental results suggests that SVD and wavelet transform trained watermark embedded scheme exhibits optimized performance when tested against a broad class of images having similar visual qualities in the reconstructed images.

Index Terms— Non blind watermarking, DWT, SVD, Copyright protection, wavelets.

I. INTRODUCTION

Networked multimedia systems have recently gained more and more popularity due to the ever increasing amount of information that is stored and transmitted digitally [1, 9]. Data security and applications have been expanded rapidly because of the limiting factor in the progress of multimedia networked services. The publishers, authors and cloud service providers of multimedia data are reluctant to allow the distribution of their documents in a networked environment. This copyright violence is the inspiring factor in developing new encryption technologies. A digital watermark is a code carrying information about the copyright owner, the authorized consumer,. the creator of the work. The watermark is intended to be permanently embedded into the digital data and the problems related to the copyright of intellectual property in digital media. The watermark should not change the content of the work or information in the image, video or audio.

In the image watermarking schemes, watermarks differ considerably in their visibility. These are classified into 4 categories image, text, audio and video watermarking [2]. Watermarking schemes are classified into two groups: frequency-domain schemes and spatial-domain. The most common and simplest watermarking techniques in spatial-domain technologies are least significant bit method. In this method embedding watermarks procedure is done by directly changing pixel values of host images. Spatial domain technologies are having limited robustness and very limited information can be embedded in spatial domain. Normally spatial domain methods are less complex but not robust against various attacks. DCT, DFT and DWT are popular transform domain techniques. Normally transform domain coefficients are modified by the watermark in the transform domain [3].To obtain the watermarked image the inverse transform is finally applied. But higher computational costs are expected in frequency domain methods. Transformation domain methods are more robust and resistance against existing attacks .

Image watermarking algorithm can also use Singular Value Decomposition (SVD) and All Phase Biorthogonal Transform (APBT) for copyright protection. The Scale-Invariant Feature Transform (SIFT) algorithm is used to obtain a series of scale-invariant feature points[5]. To improve the invisibility and robustness of the multiplicative watermarking algorithm, Laplacian distribution in the wavelet domain is used [6]. Laplacian distribution model are used to model the wavelet coefficients of the image and blind watermark detection method makes use of maximum likelihood scheme.

The rest of the paper is organized as follows. Section II provides preliminary notations and concepts to address the watermarking, discrete wavelet transform and Haar filters. Proposed solution for watermarking embedding method described in section III.

In section IV usefulness of this proposed algorithm is demonstrated on a diverse set of simulated result. Section V presents final conclusion and direction for future work.

II. FEATURES OF THE WATERMARKING

Perceptual invisibility is that modification caused by the watermark embedding which degrade the perceived image quality. Robustness of watermarking depends on the information capacity of the watermark, the watermark strength / visibility, and the detection statistics. Size, content color depth of the image also influences the robustness of watermarking.

A. DISCRETE WAVELET TRANSFORM

For image discrete wavelet transform can be calculated using pyramidal algorithm. The image can be considered as the two dimensional signal. A signal is split into two parts, usually the high frequency and the low frequency part.

Filters of different cutoff frequencies are used to analyze the signal at different resolutions. Let us suppose that x[n] is the original signal, spanning a frequency band of 0 to π rad/s. The original signal x[n] is first passed through a half band high pass filter g[n] and a low pass filter h[n]. After the filtering, half of the samples can be eliminated according to the Nyquist's rule, since the signal now has the highest frequency of π/2 radians instead of π. The signal can therefore be sub sampled by 2, simply by discarding every second sample. This constitutes one level of decomposition and can mathematically be expressed as follows:

$$y_{high}[k] = \sum_n x[k]g[2k - n] \qquad (3)$$

and

$$y_{low}[k] = \sum_n x[k]h[2k - n] \qquad (4)$$

where $y_{high}[k]$ and $y_{low}[k]$ are the outputs of the high pass and low pass filters, respectively, after subsampling by 2. The above procedure can be repeated for further decomposition. The outputs of the high pass and low pass filters are called DWT coefficients and by these DWT coefficients the original image can be reconstructed. The reconstructed process is called the Inverse Discrete Wavelet Transform (IDWT). The above procedure is followed in reverse order for the reconstruction. The signals at every level are up sampled by two, passed through the synthesis filters g'[n], and h'[n] (high pass and low pass, respectively), and then added. The analysis and synthesis filters are identical to each other, except for a time reversal. Therefore, the reconstruction formula becomes

$$x[n] = \sum_n (yhigh[k]g[-n + 2k] + ylow[k]h[-n + 2k]) \qquad (5)$$

To ensure the above IDWT and DWT relationship the following orthogonality condition on the filters H(ω) and G(ω) must hold:

$$|H(w)|^2 + |G(w)|^2 = 1 \quad (6)$$

where $H(w) = \sum_n h[n]\, e^{-jn\omega}$ and $G(w) = \sum_n g[n]\, e^{-jn\omega}$.

An example of such H(ω) and G(ω) is given by

$$H(w) = \frac{1}{2} + \frac{1}{2} e^{-j\omega} \quad (7)$$

and

$$G(w) = \frac{1}{2} - \frac{1}{2} e^{-j\omega} \quad (8)$$

which is known as the Haar filters. The DWT and IDWT for an one-dimensional signal can be also described in the form of two channel tree structured filter banks.

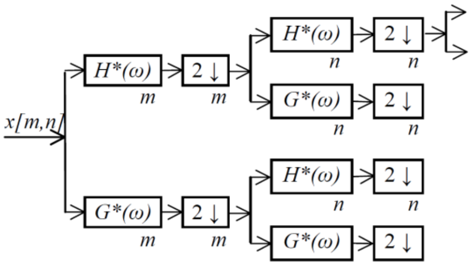


Fig.1: One level DWT for the image

The DWT and IDWT for a two dimensional image x[m,n] can be similarly defined by implementing DWT and IDWT for each dimension m and n separately $DWT_n[DWT_m[x[m, n]]$, which is shown in Fig.1. An image can be decomposed into a pyramidal structure, which is shown in Fig. 2, with various band information: low-low frequency band LL, low-high frequency band LH, high-low frequency band HL, high-high frequency band HH.

LL	HL
LH	HH

Fig.2: Single level Decomposition using DWT

The Singular Value Decomposition (SVD) is a numerical technique used to diagonalize matrices in numerical analysis[7,8]. It is an algorithm developed for a variety of applications. The Singular Value Decomposition is a widely used technique to decompose a matrix into several component matrices, exposing many of the useful and interesting properties of the original matrix. The decomposition of a matrix is often called a factorization. Ideally, the matrix is decomposed into a set of factors (often orthogonal or independent) that are optimal based on some criterion. For example, a criterion might be the reconstruction of the decomposed matrix.

SVD is based on a theorem from linear algebra which says that a rectangular matrix A can be broken down into the product of three matrices - an orthogonal matrix U, a diagonal matrix S, and the transpose of an orthogonal matrix V. The theorem is usually presented something like this:

$$A_{mn} = U_{mm} S_{mn} V^{T}_{nn}$$

The main properties of SVD from the view-point of image processing applications are: 1) the singular values (SVs) of an image have very good stability, that is, when a small perturbation is added to an image, its SVs do not change significantly. 2) SVs represent intrinsic algebraic image properties.

III WATERMARKING EMBEDDING METHOD

A the color image a of size m x n is considered for watermarking. Red, green and blue channel of image a separated. The blue channel is considered for watermarking. The blue channel is considered for the watermark because human eyes are less sensitive to change in the blue channel. On the blue channel one level discrete wavelet transform (DWT) is applied to generate subband coefficients LL,LH, HL,HH of size m/2 x n/2. The Singular Value Decomposition (SVD) is applied to all four subband coefficient

$$A_i = U_{Ai} S_{Ai} V_{Ai}^{T} \quad (9)$$

for all i ={LL,LH,HL,HH}.The monochrome watermark W of size m/2 X n/2 is considered as the watermark. The singular value decomposition is applied on the watermark to obtain

$$W = U_W S_W V_W^{T} \quad (10)$$

The singular matrix of the watermark S_W is added with the singular value matrix of the S_{Ai} for all i = {LL,LH,HL,HH} with the watermarking scaling factor to get new singular values

$$S_{Ai}' = S_{Ai} + \alpha S_W \qquad (11)$$

The modified subband coefficients A_i for all $i = \{LL,LH,HL,HH\}$ is obtained by

$$A_i' = U_{Ai}\, S_{Ai}'\, V_{Ai}^T \qquad (12)$$

Name the modified coefficient as {LL',LH',HL',HH'}.The watermarked blue channel of the image is obtained by applying inverse DWT to the modified subbands{LL',LH',HL',HH'}. The Red, Green and watermarked blue channel are combined to get watermarked color image B. The PSNR and Correlation coefficient between the original image 'A' and watermarked image 'B' is calculated by

$$MSE = \frac{\sum_{M,N}[I1(m,n) - I2(m,n)]^2}{MXN} \qquad (13)$$

MSE(mean square error) calculated using the Eq.13 where M and N are the number of rows and columns in the image respectively. PSNR can be calculated by

$$PSNR = 10 \log_{10} \left[\frac{R^2}{MSE}\right] \qquad (14)$$

R is the maximum fluctuation in the input image data type.

A Watermarking Embedding Algorithm

Step 1: Consider the color image A of size mxn. Separate the Red, Green and Blue channel.

Step 2: Consider the blue channel of image A and apply one level dwt to obtain {LL,LH,HL,HH} subbands coefficients. Each subband will have the size m/2 x n/2.

Step 3: Consider the monochrome watermark W of size m/2 x n/2.

Step 4: Apply singular value decomposition all four subbands coefficient of A

$$A_i = U_{Ai} S_{Ai} V_{Ai}^T \qquad i \in \{LL,LH,HL,HH\}$$

Step 5: Apply singular value decomposition to the watermark W

$$W = U_W\, S_W\, V_W^T$$

Step 6: Obtain the new singular value matrix

$$S_{Ai}' = S_{Ai} + \alpha\, S_W \qquad i \in \{LL,LH,HL,HH\}$$

Step 7: Construct the new subbands by following method

$$A_i' = U_i\, S_{Ai}'\, V_i^T \qquad i \in \{LL,LH,HL,HH\}$$

Step 8: Construct the watermarked blue channel by applying Inverse DWT to modified subband coefficients {LL',LH',HL',HH'}

Step 9: By combining the red, green and watermarked blue channel we get the watermarked color image B.

B. WATERMARK EXTRACTION METHOD

The watermarked image 'B' of size (mXn) is considered . The Red, Green and Blue Channel of B are separated. The one level DWT is applied to the blue channel of the B to get four subbands {LL1,LH1,HL1,HH1}. The subbands are of the size m/2Xn/2. The singular value decomposition is applied on all four subbands to get

$$Bj = U_{Bj}\, S_{Bj}\, V_{Bj}^T \qquad (15)$$

for all j = {LL1,LH1,HL1,HH1}.The original image A of size(mXn) is considered. The Red, Green and Blue channel of A is separated. One level DWT is applied on the blue channel to get four subband coefficients {LL,LH,HL,HH}. The singular value decomposition is applied on all four subband to get

$$Ai = U_{Ai}\, S_{Ai}\, V_{Ai}^T \qquad (16)$$

for all i = {LL,LH,HL,HH}. The matrix C_k is obtain by

$$C_k = (Bj - Ai) / \alpha \qquad (17)$$

The value of k is k = 1 for i = LL and j = LL1, k = 2 for i = LH and j = LH1, k = 3 for i = HL and j = HL1, k = 4 for i = HH and j = HH1. The size of the C_k is m/2Xn/2. Consider only diagonal element of the Ck and find the singular value by the following method. Only diagonal elements are considered because in singular value decomposition singular value matrix(S) is the diagonal matrix. So all the entries other than diagonal elements are zero.

for i =1 to n/2 do

$$D(i,i)=sqrt[[\{C_1(i,i)\}^2+\{C_2(i,i)\}^2+\{C_3(i,i)\}^2+\{C_4(i,i)\}^2]/4] \qquad (18)$$

end.

The values other then diagonal element are made zero. The size of D is m/2 X n/2. Then apply singular value decomposition to the watermark W to get

$$W = U_W\, S_W\, V_W^T \qquad (19)$$

Reconstruct the watermark using the extracted singular values.

$$W' = U_W\, D\, V_W^T \qquad (20)$$

Calculate the PSNR and correlation coefficient between W and W' to check the similarity between the original watermark and extracted watermark. Same experiment is done by Appling different types distortion to the watermarked image B, and PSNR(Eq.13 and Eq.14) and correlation coefficient are calculated.

(i) Watermark Extraction Algorithm

Step 1: Separate Red, Green and Blue channel of the watermarked image B.
Step 2: Apply one level DWT to the Blue channel of the watermarked image to get {LL',LH',HL',HH'} subbands. The subbands are of size m/2xn/2.
Step 3: Separate Red, Green and Blue channel of the original image A.
Step 4: Apply one level DWT to Blue channel of the original image A to get {LL,LH,HL,HH} subbands.
Step 5: Obtain the matrix C by following method

$C_k = (B_j - A_i)/\alpha$

k = 1 for i = LL and j = LL'
k = 2 for i = LH and j = LH'
k = 3 for i = HL and j = HL'
k = 4 for i = HH and j = HH'
The size of the C_k is m/2xn/2
Step 6: Consider only the diagonal element of the C_k and find the singular matrix by the following method.
for i = 1 to n/2 do
$D(i,i) = \text{sqrt}[[\{C_1(i,i)\}^2+\{C_2(i,i)\}^2+\{C_3(i,i)\}^2+\{C_4(i,i)\}^2]/4]$ end
The values other then the diagonal element in D is made zero.
Step 7: Apply singular value decomposition to the watermark W

$$W = U_W S_W V_W^T$$

Step 8: Reconstruct the watermark by using Extracted singular value matrix D.

$$W' = U_W D V_W^T$$

III. EXPERIMENTAL RESULTS

We consider color of images of size 512X512 and watermark of size 256X256 in this experiment and we got the following results.

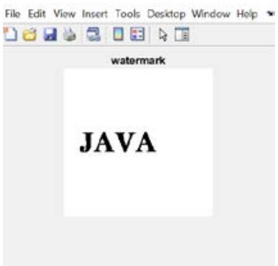


Fig. 3: Watermark used in the experiment size 256X256

Some sets of experiments were carried out in order to evaluate the strength of the proposed algorithm.

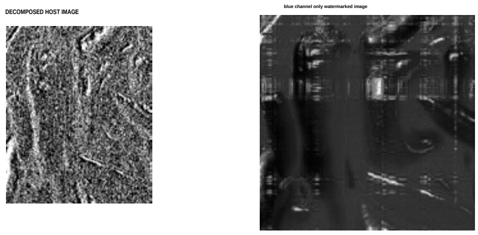


Fig. 4: Decomposed image with DWT of LL band and blue channel of the watermarked image.

Haar basis function which is superior to Fourier basis functions in this watermarking scheme performs multiresolution analysis of host image with localization both in time and frequency. It is shown in Fig.4. Blue channel of the cover image after watermarking process is also shown in Fig 4.

Fig.5: watermarked image and Blue channel of host image.

Fig.6 Extracted watermarked image

The results of the invisibility are shown in Figure 5. It shows that the watermark invisibility is satisfied. A binary pattern "JAVA" which is used as watermark with peppers cover image is extracted reasonably shown in fig 6. with proposed embedded and extraction algorithm.

Noise represents unwanted information which deteriorates image quality. Noise is defined as a process(n) which effect the acquired image (f) and is not part of the scene(initial signal s). Using the additive noise models, this process can be written as: f(i,j) = s(i,j) + n(i,j). Digital image noise may come from various sources. The acquisition process for digital image converts optical signal into electric signals and then into digital signals and is one processes by which the noise is introduced in digital images. Each conversion process experience fluctuations, caused by natural phenomena, and each of this steps adds a random value to the resulting intensity of given pixel. Moreover, to investigate the performance of proposed method in an objective way, we also evaluate the performance of the proposed watermarking method through the PSNR (Peak-Signal-to-Noise-Ratio, PSNR). Table 1,2,3. Shows the performance of the scheme with various cover images under Salt and Pepper noise with different density and geometric attack. Gamma correction used for image enhancement of watermarked image and results are shown in Table.4

TABLE 1: CORRELATION COEFFICIENT FOR DIFFERENT IMAGES

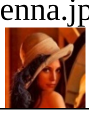
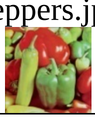
Image Name (All are of size512X512)	Correlation Coefficient between original and watermarked Image	Correlation Coefficient between Original and extracted watermark
Helicopter.jpg 	0.9978	0.8063
Lenna.jpg 	0.9968	0.9379
Peppers.jpg 	0.9984	0.8138

TABLE 2: PSNR FOR DIFFERENT IMAGES

Image Name (All are of size 512X512)	PSNR Between original and watermarked image in dB	PSNR between original atermark and extracted watermark in db
Helicopter.jpg	42.1355	44.0085
Lenna.jpg	53.9392	46.5923
Peppers.jpg	51.2525	47.9958

TABLE 3: CORRELATION COEFFICIENT AND PSNR FOR ROTATED WATERMARKED IMAGE

Angle of rotation of watermarked image	Correlation coefficient between watermark and extracted watermark	PSNR between watermark and extracted
30^{o}	0.9260	41.2393
45^{o}	0.9261	41.1597
60^{o}	0.9621	41.1597

TABLE 4: CORRELATION COEFFICIENT FOR GAMMA CORRECTION APPLIED WATERMARKED IMAGE

Gamma Correction (Gamma Values)	Correlation coefficient between watermark and extracted watermark	PSNR between original watermark and extracted watermark in dB
0.5	0.9864	44.0865
0.75	0.9907	44.5383
1.25	0.9780	42.7901
2.0	0.9950	45.2015
2.5	0.9953	45.2045

IV. CONCLUSION

DWT-SVD robust watermarking technique for color images in RGB color space is discussed in this paper. In this algorithm the discrete wavelet transformation technique is combined with singular value decomposition technique to make it robust. Since the watermark hidden in the DWT it is highly robust against attacks such as addition of noise, gamma correction and rotation of the image. The experimental results are shown in tables for different Geometric 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. More robust watermarks can be developed for color image along with carefully designed protocols governing their use alone with the combination of DCT-DWT-SVD

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