An Efficient Color Image Watermarking Scheme Using Dwt and SVD

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ABSTRACT - *In this paper, we are proposing an effective, robust and imperceptible color image watermarking scheme using DWT AND SVD. Recent developments in digital image and Internet technology help the common users to easily produce illegal copies of the images. In order to solve the copyright protection problems of the image, several watermarking schemes have been widely used. Very few watermarking schemes have been proposed for defining the copyrights of color image. To resolve the copyright protection problem of color image, we propose an effective, robust and imperceptible color image watermarking scheme. This scheme embeds the watermark into cover image in (Red, Green, Blue) RGB space. The combinations of Discrete Wavelet Transformation (DWT) and Singular Value Decomposition (SVD) of Blue channel is used to embed the watermark. The singular values of ditTerent subband coefficients of Blue channel are modified using different scaling factors to embed the singular values of the watermark. The copy of the watermark is embedded into four subband coefficients which is very difficult to remove or destroy. The combinations of DWT and SVD increases the security, robustness and imperceptibility of the scheme.*

1. Introduction

The security and authenticity issues of digital image are becoming popular than ever, due to the rapid growth of multimedia and Internet technology. On Internet, digital images are easily and widely shared among the different users at different geographical places. Every day large amount of digital images are transmitted over the Internet in various applications. As digital technology allows unauthorized reproduction of digital images, the protection of the copyrights of digital image is a very important issue. Image watermarking schemes are used to protect the digital images. Image watermarking is the process of embedding an imperceptible data (watermark) into cover image. The image watermarking schemes have been widely used to solve the copyright protection problems of digital image related to illegal usage or distribution. Several image watermarking schemes are proposed, considering different viewpoints. The image Watermarking schemes are classified into different types based on domain of processing, visibility of watermark and rigidity of scheme. Based on the domain of processing, the watermarking schemes are classified into two categories: spatial-domain and frequency-domain schemes. Spatial domain schemes embed the watermark by directly modifying the pixel values of the cover image and these schemes are less complex in computation. On the other hand, transform domain schemes embed the watermark by modulating the frequency coefficients in a transformed domain such as, Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT) and Discrete Wavelet Transformation (DWT).

Transformed domain schemes are more robust when compared to spatial domain schemes. The wavelet domain based texture and luminance characteristics of all image subband to embed the watermark using Human Visual System (HVS). The robustness of the wavelet domain scheme is increased. The wavelet transform is applied on chaotic logistic map. This is robust to geometric attacks but sensitive to filtration and sharping. In 2004, Kundur et. a1. proposed scheme that addresses a multi-resolution fusion based logo watermarking scheme. In this scheme, the gray-level logo image is decomposed using one level decomposition and the cover image is divided into the blocks of the size equal to the size of subband of logo image. In fusion process the four subbands of different orientation of logo image are added to the blocks of same orientation. In B.N. Chatterjii scheme to achieve high imperceptibility in image watermarking the HVS characteristic are used to select the significant coefficients of DWT decomposed cover image. This scheme uses the pixel wise masking model to calculate the weight factors for the wavelet coefficients of cover image. The wavelet transform decomposes the image into standard subband sets which are not necessarily the optimal representation for images. The Singular Value Decomposition (SVD) is numerical technique for diagonalizing the image matrices in which transform domain consist of basis state that is optimal.

To achieve high robustness against attacks like Gaussian noise, compression and cropping the combination of SVD and DWT are used. In 2006, Liu Liang et. al. proposed scheme, where the two-level DWT is applied on the cover image to produce the different subbands of frequency. The selected frequency subband is converted into blocks of each size 4 x 4. The SVD is applied on each of these blocks and the watermark is hided into diagonal matrix of the block. The combination of DWT- SVD was proposed to insert the watermark into the high frequency subband of cover image.

This scheme is rigid to different types of image processing operations. In 2007, Qiang L. et. al proposed a scheme that decomposes the cover image into K levels subband coefficients using DWT. The SVD is applied on subbands LH and H L subbands and the watermark is embedded into these SVD transformed subbands. The rigidity of this scheme is analyzed considering different types of image processing operations. In few schemes, both watermark and cover mages are pre-processed in transformed domain to achieve high rigidity.

In the literature, many schemes uses the SVD-DWT based embedding for gray scale image watermarking. The proposed scheme embeds the monochrome watermark into color cover image. The color image is represented by Red (R), Green (G) and Blue (B) channels. Out of these three channels, change in the intensity of R channel is the most sensitive to human eyes whereas for B channel it is least sensitive. Hence, in the proposed scheme the the blue channel is considered for embedding. The wavelet transform of image gives four frequency sub-band coefficients. In image processing each subband is resistant to different types of attacks or transformations. For example, the low frequency subband coefficients are less robust to geometrical distortions and histogram equalization. In the proposed scheme the copy of the watermark is embedded into all subband coefficients which is hard to destroy the watermark even after the different types of attacks on the watermarked images. To improve the robustness of the scheme the watermark is embedded into singular values of different sub-band coefficients obtained from B channel of the color image.

The paper is organized as follows. Section II briefly reviews the DWT and SV D transformation. Proposed scheme for embedding the watermark into the color image is given in Section III. Results and discussion is given in Section IV followed by conclusion in Section V.

2. DWT And SVD Decomposition

In this section we discuss in brief about the Discrete Wavelet Transform and Singular Value Decomposition of images.

A. Discrete Wavelet Transform

In two dimensions Wavelet transformation, the wavelet representation can be computed with a pyramidal algorithm. The two-dimensional wavelet transform that we describe can be seen as a one-dimensional wavelet transform along the x and y axes. Mathematically the wavelet transform is convolution operation, which is equivalent to pass the pixel values of an image through a lowpass and highpass filters. A separable filter bank to the image is represented as follows:

$$L_n(\vec{b}) = [H_x * [H_y * L_{n-1}] \downarrow 2,1] \downarrow_{1,2} (\vec{b})$$

$$D_{n1}(\vec{b}) = [H_x * [G_y * L_{n-1}] \downarrow 2,1] \downarrow_{1,2} (\vec{b})$$

$$D_{n2}(b) = [G_x * [H_y * L_{n-1}] \downarrow 2,1] \downarrow_{1,2} (b)$$

$$D_{n3}(b) = [G_x * [G_y * L_{n-1}] \downarrow 2,1] \downarrow_{1,2} (b) \quad (1)$$

Where * represents the convolution operator, ↓2,1(↓1,2) represents subsampling along the rows (columns) and Lo = I(x) is the original image. H and G are the lowpass and bandpass filter respectively. Ln is obtained by lowpass filtering and is therefore referred to as low resolution image at scale n. The Dnl are obtained by bandpass filtering in a special direction and thus contains the directional detail information at scale n, they are referred to as the detail images.

<table>
<tr><td>LL_2</td><td>HL_2</td><td rowspan="2">HL_1</td></tr>
<tr><td>LH_2</td><td>HH_2</td></tr>
<tr><td colspan="2">LH_2</td><td>HH_2</td></tr>
</table>

Figure 1: Layout of individual bands at second level of DWT decomposition.

The original image *I* is thus represented by set of subimages at several scales; $\{\{L_d, D_{nl}\} | l = 1,2,3, n = 1,2,3, \ldots, d\}$, which is multi-scale representation with depth *d* of the image *I*. The image is represented by two dimensional signal function, wavelet transform decomposes the image into four frequency bands, namely, the LL_1, HL_1, , LH_1, and HH_1 bands. *H* and *L* denotes the highpass and lowpass filters respectively. The approximated image *LL* is obtained by lowpass filtering in both row and column directions. The detailed images, *LH*, *HL* and *HH* contains the high frequency components. To obtain the next coarse level of wavelet coefficients, the subband LL_1 alone is further decomposed and critically sampled. Similarly LL_2 will be used to obtain further decomposition. By decomposing the approximated image at each level into four sub images forms the pyramidal image tree. This results in two-level wavelet decomposition of image as shown in the Figure 1.

B. Singular Value Decomposition

The Singular Value Decomposition of image *I* of size mxn is obtained by the operation

$$I = USV^T \quad (2)$$

where Ui s column-or thogonal matrix of size mx n , W is the diagonal matrix with positive or zero elements of size n x n and transpose of n x n orthogonal matrix V .

The diagonal entries of matrix S are known as the singular values of I. The columns of U matrix are known as left singular vector and the columns of the matrix V are known as the right singular vector of I.Thus, each singular value represents the luminance of image layer and the corresponding pair of singular vector represents the geometry of the image layer. In SVD based image watermarking, several approaches are possible.

A common method is to apply SVD to the entire cover image and modify all the singular values to embed the watermark. The important property of SVD based watermarking is that the large of the modified singular values of image will change by very small values for different types of attacks. The theoretical analysis of the effects of geometrical distortion is provided.

3. Proposed Scheme

The proposed scheme uses the color image I of size m x n as the cover image and the monochrome image W of size Algorithm 1: Watermark embedding algorithm input : The color image I of size m x n and the monochrome watermark W of size m/2 x n/2 output: The watermarked color image I' of size mxn.
1) Separate Red (R), Green (G) and Blue (B) channels from the color image I of size m x n
2) Apply one-level DWT on B channel to produce the subband coefficients {LL, LH, H L, H H} of the size m/2 x n/2. 3) Apply SVD on the each subband coefficients II = UISIV I to get the singular values AL i = 1,2, ... ,n/2, of Sl, l E {LL,LH,HL,HH} 4) Apply SVD on watermark W = UwSw Vw to get the singular values Af', i = 1,2, ... , n/2 of Sw 5) for l +- 1 to {LL,LH,Hl,HH}

6) Apply inverse SVD using the singular value, i = 1,2, ... ,n/2 of l E {LL,LH,HL, HH} to get modified subbands using 1'1 = Ul S'I V i . 7) Apply inverse DWT on modified subband coefficients to produce the watermarked B channel. 8) Transform the R, G and watermarked B channels into color image. m/2 x n/2 as the watermark. The color image is transformed into R, G and B channels of size m x n. Human eyes are less sensitive to change in the intensity of the B channel. On the B channel the one-level DWT is applied to generate subband coefficients LL, LH, H L, H H of size m/2 x n/2.

The SVD decomposition is applied on all subband coefficients and watermark. The singular values of watermark (Aw) are added to the singular values (AI for l E {LL, LH, H L, H H}) of the DWT transformed B channel using watermark scaling factor a.
(3) On the modified subband coefficients of B the inverse DWT is applied to achieve the embedded B channel. The embedded B channel is combined with R and G channel to achieve
watermarked color image. The proposed scheme is non-blind watermarking scheme which uses the cover image and watermark to extract the watermark. The extraction algorithm uses the color image I, watermarked color image I' each of size m x n and the monochrome watermark image W of size m/2 x n/2. The color image and the watermarked color images are transformed into R, G and B channels. On the B channel of the both cover images the one-level DWT is applied to generate subband coefficients LL, LH, H L, H H of size m/2 x n/2. The SVD decomposition is applied on all subband coefficients of both cover images and watermark. The singular values of watermark (Aw) are extracted from the singular values (AI for l E {LL,LH,HL,HH}) and (..\1 for l E {LL', LH', H L', H H'}) of the DWT transformed Bchannels of color image and watermarked color image using scaling factor a. \ _..\1 - A Aw - l (4) a The extracted singular values of watermark are combined with other matrices of watermark to generate the watermark image. The embedding and the extraction algorithms are given in Algorithm 1: and Algorithm 2: respectively. Algorithm 2: Watermark extraction algorithm input : The cover color image I, watermarked cover image I' and watermark W of size m/2 x n/2 output: The monochrome watermark W of size m/2 x n/2 1) Separate R, G and B channels from the color image I of size m x n 2) Separate R', G' and B' channels from the watermarked image l' of size m x n 3) Apply SVD on watermark W = UwSw Vw to get the singular values Af', i = 1,2, ... , n/2 of Sw 491 4) Apply one-level DWT on Band B' channel to produce the subband coefficients {LL, LH, H L, H

H} and {LL',LH',HL',HH'} of the size m/2 x n/2. 5) Apply SVD on all the subband coefficients Band B' to produce singular values A□ and .-\1 i = 1,2, ... , m/2, n = 1,2, ... ,n/2 with l E {LL,LH,HL,HH} using II = UISIV I.
6) for l +- 1 to {LL,LH,Hl,HH} do for i +- 1 to m/2 do for j +- 1 to n/2 do end
end
end
Af' = (□□ - AD/a
7) Construct the four watermark images using singular vectors Wi = ulnslnv□ where l = {LL,LH,HL,LL} 8) Extracted Watermark vectors contain non binary value since the watermark is a monochrome image this vector is optimized by using root mean square value.
Wi = round(WI/RMS(WI)) to recover the watermark.

4. Experimental Results

The series of experiments are conducted to analyze the effect of embedding and extraction algorithm on the color image. In these experiments the color image of size 400 x 300 and monochrome watermark of size 200 x 150 are considered. Figure 2 and Figure 3s hows sequence of outputs of embedding and extraction algorithms, where helicopter image is used as the test image and a binary pattern "N ITW" is used as the watermark. Figure 4 shows the watermarked Lena cover images with different image processing attacks on it. The effect of different image processing attacks on color image is analyzed considering the watermarked Lena color image as shown in Figure 4 (a). The contrast of a color image is usually adjusted to enhance the quality of image. Figure 4 (b) show the result of applying contrast enhancement on Lena image by increasing 10 % the brightness of image. Image retouching operation is used to improve the quality of image using sequence of operations like erasing, zooming, etc. Figure 4 (c) show the result of watermarked Lena image on which retouching operations are applied. Figure 4 (d) show the effect of sharpening on Lena image, where a special type of 2D un-sharp contrast enhancement filter is applied on the watermarked Lena image.

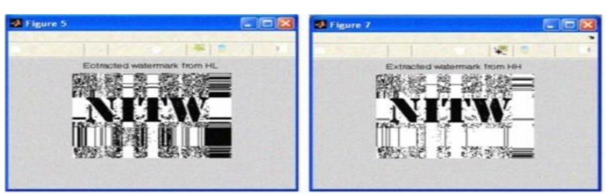
The un-sharp contrast enhancement filter enhances edges, and other high frequency components of an image, by subtracting a smoothed ("un-sharp")v ersion of an image from the original image. Image sepia toning is used in image prints which are exposed to sepia in order to replace the metallic silver in the photo emulsion with a silver compound. By doing so the developer could change the color, but also increase the tonal range of the image. sepia toning is applied on image by adjusting gradient map,filter adjustment and black and white adjustment. Figure 4 (e) is how the sepia toned Lena cover image. Figure 4 (f) and 4 (g)shows the Lena cover images with operations like modifying blurring and image warmify.T he color images have three important perceptual attributes, which are hue, saturation and brightness. The most obvious is hue, which denotes whether the color appears red, orange, yellow, green, blue or purple. The saturation denotes the extent to which the hue is apparent. The saturation is zero for gray, black and white. Brightness represents the lightness of a color, low for black, medium for grays and browns, and high for yellow and white. These three attributes are orthogonal to each other, thus saturation and brightness can be changed without affecting the hue of a color. Figure 4 (h) show the effect of increasing the saturation on Lena color image. Table I shows that the extracted watermarks from four subbands of attacked cover image which are highly similar to the original watermark. The similarity between extracted watermark and original watermark is measured by Normalized Correlation (NC) using following equation

$$NC = \frac{\sum_{i=1}^{M}\sum_{J=1}^{N}(I[i,j]I^{'}[i,j])}{\sum_{i=1}^{M}\sum_{J=1}^{N}(I[i,j])2}$$

where, I(i, j) is original image and I'(i, j) is modified image, M is height of image and N is width of image. The geometrical invariant property of the proposed scheme is analysed considering the effect of scaling and rotation on watermarked Lena image. Figure 5 (a) and 5 (b) shows the effect of geometrical scaling and rotation attacks on watermarked Lena color image. The watermark is extracted from four subbands of Lena image.

(a) Color ove Image (b) Watermark (c) Blue Channel

(d) DWT decomposed (e) watermarked blue (O watermarked color blue channel image)



(e) Extracted watermark from HL of B (f) Extracted watermark from HH of B

Figute 3. Watermark extraction

T he similarity between extracted and original watermark is measured by NC.

5. Conclusion

We have proposed a DWT- SVD based non-blind watermarking scheme. The SVD is an efficient tool for watermarking in the DWT domain. To embed the watermark into cover image the scaling factor is chosen from a wide range of values for all subbands. The same watermark is embedded into four subbands which is very difficult to remove or destroy. The rigidity of the proposed scheme is analyzed by considering various types of image processing attacks. The scheme was found robust to various types of image processing attacks.

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