Performance Analysis of DWT Based Digital Image Watermarking Using RGB Color Space

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Abstract
The digital images are copied and transmitted widely with the development of the internet rapidly. Nowadays protecting the copyright of the digital image has become an important topic. To solve the copyright protection problem for multimedia images many watermarking techniques have been proposed. In this paper, performance analysis of robust color image watermarking scheme based on discrete wavelet transform-singular value decomposition (DWT-SVD) is proposed and tested with RGB color space. Image is decomposed by 3 level DWT and then SVD is applied on selected subband and watermark. The decomposition is done with ‘Haar’ which is simple, symmetric and orthogonal wavelet. The comparative performance in R, G and B color space in HL3 subband is presented. The quality of the watermarked image and extracted watermark is measured using peak signal to noise ratio and normalized correlation respectively. PSNR and NC values are tested for 5 different values of scaling factor. The proposed scheme is also tested for different attacks like noise addition, Median filtering attack, image sharpening etc.

Keywords - Digital Watermarking, Discrete Wavelet Transform (DWT), Haar Wavelet, Scaling Factor, Singular Value Decomposition (SVD)

1. Introduction
In the ever changing world of global data communications, inexpensive Internet connections, and fast-paced software development, security is becoming more and more of an issue. Security is now a basic requirement because global computing is inherently insecure. 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. 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. The features of watermarking include robustness and perceptibility.

Digital image watermarking method can be classified into two classes: spatial domain watermarking and frequency domain watermarking. In spatial domain (generally less complex, less robust and less secure), the pixel values of cover image are directly modified for watermark embedding. In frequency domain (relatively robust, secure and imperceptible), the cover image is transformed to other domain (using Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Discrete Fourier Transform (DFT)) for watermark embedding. Compared to spatial domain techniques, frequency domain watermarking techniques proved to be more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking algorithm. The performance improvements in DWT based digital image watermarking algorithms could be obtained by increasing the level of DWT.

In the proposed method, information is hidden in RGB space of a color image. The features of SVD technique are combined with DWT to embed data in frequency domain of cover data. The paper is organized as follows. The review of related work is given in section II. Section III briefly reviews the DWT and SVD transformation, and proposed scheme for embedding the watermark into the color image. Results and discussion
is given in Section IV followed by conclusion in Section V.

2. Related work

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.

Most of the image watermarking schemes are applicable for gray level images [2], [4], [6], [9], [10] and some schemes are related to color images [1], [3], [7]. This paper focuses on the performance of DWT based watermarking in HL subband using RGB color space. The previous work which had been done on digital watermarking by using DWT technique and other techniques is described below. Dharwadkar et al. [1] proposed a DWT- SVD based non-blind watermarking Scheme which embeds the watermark into cover image in (Red, Green, Blue) RGB space. The combination of Discrete Wavelet Transformation and Singular Value Decomposition of Blue channel is used to embed the watermark. One-level DWT is applied into the B channel and four subband coefficients are used to embed watermark which is very difficult to remove or destroy. The scheme was found robust to various types of image processing attacks. Chih-Chin Lai et al. [2] proposed a hybrid image-watermarking scheme based on discrete wavelet transform (DWT) and singular value decomposition (SVD) where the watermark is embedded on the singular values of the cover image’s DWT subbands. One-level Haar DWT is applied to decompose the cover image into four subbands and SVD is applied only to the intermediate frequency subbands. Experimental results of the proposed technique have shown both the significant improvement in imperceptibility and the robustness under attacks. Bhagyashri et al. [3] proposed DWT- SVD robust watermarking technique for color images in YUV color space. One-level Haar DWT technique is applied to YUV matrices to decompose it into different range of frequency bands. The quality of the watermarked image is maintained with the value of 36 dB and the algorithm is robust against common attacks such as addition of noise, histogram equalization and cropping. Nikita Kashyap et al. [4] proposed a robust image watermarking technique based on 3-level DWT. This method embeds invisible watermark into the original image by using alpha blending technique. Daubecheis wavelet is used here for watermark embedding. Experiment result shows that the 3- level DWT provide better performance than 1-level and 2-level DWT. Gunjal et al. [5] proposed an overview of transform domain robust digital image watermarking algorithms with DWT-DCT combined approach which can significantly improve PSNR with compared to only DCT based watermarking methods. Akhil et al. [6] proposed a robust image watermarking technique based on 1-level DWT (Discrete Wavelet Transform). This method embeds invisible watermark into salient features of the original grayscale image using alpha blending technique. Experiment result shows that the embedding and extraction of watermark is depend only on the value of alpha. Nilanjan Dey et al. [7] proposed a DWT based Steganographic technique for color image. Cover image is decomposed into four sub bands using DWT. They embed each color plane of the secret image in HH subbands by alpha blending technique in the corresponding sub bands of the respective color planes of the original image. In this approach the generated stego image is imperceptible and security is high.

In literature most methods involve multiple execution stages and are highly complex. In this paper, we tried to propose a new simple methodology to hide a grayscale image within color image using alpha blending technique. Experiment result shows that the embedding and extraction of watermark is depend only on the value of alpha. Nilanjan Dey et al. [7] proposed a DWT based Steganographic technique for color image. Cover image is decomposed into four sub bands using DWT. They embed each color plane of the secret image in HH subbands by alpha blending technique in the corresponding sub bands of the respective color planes of the original image. In this approach the generated stego image is imperceptible and security is high.

3. Background review and the proposed approach

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

3.1 DWT

The image is represented by two dimensional signal function, wavelet transform decomposes the image into four frequency bands, namely, the LL1, HL1, LH1 and HH1 bands. H and L denote 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 contain the high frequency components. To obtain the
next coarse level of wavelet coefficients, the subband LL1 alone is further decomposed and critically sampled. Similarly to perform third level decomposition DWT is applied to LL2 band which decompose this band into the four subbands. By decomposing the approximated image at each level into four sub images forms the pyramidal image tree. The three-level wavelet decomposition of image is shown in the fig. 1 below.

![Fig. 1: Layout of individual bands at third level of DWT decomposition](image)

Here LL3 is low frequency subband (Approximate sub band). LH3, HL3 and HH3 are high frequency sub bands. HL3 called horizontal sub band, LH3 called vertical sub band and HH3 called diagonal Sub band. The majority of image energy concentrates in LL3. Hence modification in this low frequency sub band will cause severe and unacceptable image degradation. Hence watermark is not embedded in LL3 sub band. The good areas for watermark embedding are high frequency sub bands (HL3, LH3 and HH3), because human naked eyes are not sensitive to these sub bands and unable to detect any modification in high frequency sub bands. But HH3 sub band includes edges and textures of the image. Hence HH3 is also excluded. The rest options are HL3 and LH3. But Human Visual System is less sensitive in horizontal than vertical. Hence, in this paper HL3 i.e. Horizontal Sub band is selected for watermarking embedding.

3.2 SVD Based Watermarking

The SVD belongs to orthogonal transform which decompose the given matrix into three matrices of same size. To decompose the matrix using SVD technique it need not be a square matrix. Let us denote the image as matrix I. The SVD decomposition of matrix I of size m x n (m ≥ n) is obtained by the operation:

\[ I = U S V^T \]  
(1)

U and V are unitary matrices such that UUT=I, VVT=I, where I is an Identity matrix. U=[u1,u2,u3,...,un], V=[v1,v2,v3...vn], U is column-orthogonal matrix of size m x n, and transpose of n x n orthogonal matrix V. 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. The SVD decomposition of matrix I is obtained by the following equation:

\[ SVD (I) = U S V^T = U \begin{bmatrix} D & 0 \\ 0 & 0 \end{bmatrix} V^T \]  
(2)

S is a matrix such that all the elements in main diagonal are in decreasing order like σ1≥σ2≥σ3≥ ......σn ≥0, S is the diagonal matrix with positive or zero elements of size n x n. Number of nonzero values equals the rank of the matrix. These positive singular values can be used to embed watermark. The diagonal entries of matrix S are known as the singular values of I. The order of singular matrix is same as I, and hence the resultant matrix is also square. Hence images of equal size can be taken as cover object.

3.3 Proposed DWT- SVD Watermarking Scheme

The proposed scheme uses the color image I of size 512*512 as the cover image and the color image is transformed into R, G and B channels. Human eyes are less sensitive to change in the intensity of the B channel. On the B channel 2-D, three-level DWT is applied to generate subband coefficients LL3, LH3, HL3, HH3. The SVD decomposition is applied on HL3 subband coefficients and watermark. In this technique the singular values of watermark are added to the singular values of the DWT transformed B channel using watermark scaling factor K.

\[ S'' = S + KS' \]  
(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. Similar algorithms can be followed for watermark embedding in R and G components.
3.3.1 Watermark Embedding:

For embedding watermark color image is used as host image, the RGB value of each pixel of the cover image is converted into RGB color space in which only R component constitute R color space, G component constitute G color space and B component constitute B color space. The input image in RGB domain is shown in fig. 2.

<table>
<thead>
<tr>
<th>RGB image</th>
<th>R component of image</th>
<th>G component of image</th>
<th>B component of image</th>
</tr>
</thead>
</table>

Fig. 2: RGB Image Transformed into RGB Color Space

Watermark can be hidden in any one or in the three color channels 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 the proposed method, HL3 subband is selected to hide watermark in all the three channel of RGB color space. The embedding factor or control factor is used to control the energy of the watermark and it is denoted as K and its value range from 0 to 1 (0≤K≤1).

Discrete wavelet transformation technique is applied to RGB matrices to decompose it into different range of frequency bands. For each level of decomposition, input image matrix B is transformed into four band of frequency named LL, LH, HL, HH. Similarly R and G image matrices are also transformed into four band of frequencies using (4):

\[ [LL, LH, HL, HH] = DWT (R, G, B) \] (4)

The block diagram for embedding watermark in transform domain using SVD technique is shown in fig. 3.

After applying 3 level DWT, HL3 subband and watermark is used for SVD transformation and watermark is hidden in the singular values (diagonal elements) of singular matrix.

\[ [U \ S \ V] = SVD (HL3) \]
\[ [U’ \ S’ \ V’] = SVD (W) \] (5)

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 (6):

\[ S’’ = S + KS’ \] (6)

The watermark S’ is embedded into the non zero elements of the diagonal matrix S to obtain the watermarked diagonal matrix S’’. Then inverse SVD technique and inverse wavelet transformation technique is applied at Level3, Level2 and Level1 Sequentially to get the watermarked image.
3.3.2 Watermark Extraction:

The block diagram of watermark extraction process is shown in fig. 4.

![Watermark Extraction Diagram](image)

During extraction process, let I1 be a watermarked image matrix, separate R, G, B component from RGB color space. The RGB components of the watermarked color image are converted into frequency coefficients of four bands.

\[ [LL', LH', HL', HH'] = \text{DWT} (R', G', B') \]  

After applying 3 level DWT, SVD transformation is applied on HL3 subband of wavelet transformed RGB matrices to extract watermark from the diagonal elements. Watermark is extracted using (8):

\[ S' = (S'' - S)/K \]  

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

4. Experimental Results

The performance of algorithm is analyzed through the results which are obtained by embedding gray scale watermark in all the three channels of cover image in RGB space. PSNR is 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 (PSNR) and normalized correlation (NC) are obtained using following equation.

\[ \text{MSE} = \frac{1}{n_{\text{row}} \times n_{\text{column}}} \sum_{i=1}^{n_{\text{row}}} \sum_{j=1}^{n_{\text{column}}} [(R(i,j) - R2(i,j))^2 + (G(i,j) - G2(i,j))^2 + (B(i,j) - B2(i,j))^2] \]

\[ \text{PSNR} = 10 \log_{10} \left( \frac{1}{\text{MSE}} \right) \]

For color images with three RGB values per pixel, the definition of PSNR is the same except the MSE is the sum over all squared value differences divided by image size and by three.

\[ \text{NC} = \frac{\sum_{i=1}^{n_{\text{row}}} \sum_{j=1}^{n_{\text{column}}} (L[i,j] W[i,j])}{\sqrt{\sum_{i=1}^{n_{\text{row}}} \sum_{j=1}^{n_{\text{column}}} L[i,j]^2} \sqrt{\sum_{i=1}^{n_{\text{row}}} \sum_{j=1}^{n_{\text{column}}} W[i,j]^2}} \]

Where, L [i, j] is original watermark image and W [i, j] is extracted watermark, nrow is height of image and ncolumn is width of image. The watermark is extracted from HL3 subband of host image.

![Original and Watermarked Images](image)

Fig. 5: Original color image with 512 * 512 size, Watermark image with 64 * 64 size, Watermarked image
Here the image of size 64*64 is taken as watermark whereas the image of size 512*512 is taken as cover image and watermark is hidden in HL3 subband of R, G and B channels of cover data. The original color image, watermark image and watermarked image is shown in fig. 5. 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 RGB channels.

The quality of the watermarked image is measured through PSNR and calculated values using R, G and B color space for different scaling factor (i.e K) are tabulated in Table 1, Table 2 and Table 3 respectively. The calculated value of PSNR is above 74 decibels in R channel, 72 decibels in G channel and 69 decibels in B channel respectively. It is clear from the values that larger strength factor provides better robustness while a smaller strength factor gives good imperceptibility results. Here the NC value is 1. The PSNR value shows that the algorithm keeps the quality of the image and invisibility of embedded watermark without any attacks.

Table 1: Output Results for embedding watermark in R color space

<table>
<thead>
<tr>
<th>Scaling Factor</th>
<th>K1=0.01</th>
<th>K2=0.03</th>
<th>K3=0.05</th>
<th>K4=0.07</th>
<th>K5=0.09</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSNR</td>
<td>74.1073</td>
<td>73.2433</td>
<td>72.3376</td>
<td>71.4064</td>
<td>70.4632</td>
</tr>
<tr>
<td>MSE</td>
<td>0.0018</td>
<td>0.0020</td>
<td>0.0022</td>
<td>0.0024</td>
<td>0.0026</td>
</tr>
<tr>
<td>NC</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 2: Output Results for embedding watermark in G color space

<table>
<thead>
<tr>
<th>Scaling Factor</th>
<th>K1=0.01</th>
<th>K2=0.03</th>
<th>K3=0.05</th>
<th>K4=0.07</th>
<th>K5=0.09</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSNR</td>
<td>72.4670</td>
<td>71.6923</td>
<td>70.8780</td>
<td>70.0374</td>
<td>69.1816</td>
</tr>
<tr>
<td>MSE</td>
<td>0.0021</td>
<td>0.0023</td>
<td>0.0025</td>
<td>0.0027</td>
<td>0.0030</td>
</tr>
<tr>
<td>NC</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 3: Output Results for embedding watermark in B color space

<table>
<thead>
<tr>
<th>Scaling Factor</th>
<th>K1=0.01</th>
<th>K2=0.03</th>
<th>K3=0.05</th>
<th>K4=0.07</th>
<th>K5=0.09</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSNR</td>
<td>69.5147</td>
<td>68.8751</td>
<td>68.2011</td>
<td>67.5018</td>
<td>66.7849</td>
</tr>
<tr>
<td>MSE</td>
<td>0.0029</td>
<td>0.0031</td>
<td>0.0033</td>
<td>0.0035</td>
<td>0.0038</td>
</tr>
<tr>
<td>NC</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

The extracted watermark from three channels (RGB) under normal condition without any attack is shown in fig. 6. 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.

Fig. 6 : Detected watermark without any attack from RGB channel

The robustness of algorithm is tested against various attacks such as Salt and pepper noise, Speckle noise, Image Sharpening, Median filtering attack and Gaussian noise attack. The calculated values of normalized correlation coefficients are tabulated in Table 4. As per the observation the quality of both watermarked image and extracted watermark is high for Speckle noise and Median filtering attack when watermark is hidden into R channel compared to G and B channel. For Speckle noise and Median filtering attack the quality of the extracted watermark from R, G and B channel is above 0.99 which shows best recovery of watermark.
Table 4: Results of applying some types of attack on the watermarked image for scaling factor = 0.05

<table>
<thead>
<tr>
<th>Attacks</th>
<th>R channel</th>
<th>G channel</th>
<th>B channel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PSNR</td>
<td>NC</td>
<td>PSNR</td>
</tr>
<tr>
<td>Salt and Pepper noise</td>
<td>48.5041</td>
<td>0.9589</td>
<td>48.6164</td>
</tr>
<tr>
<td>Speckle noise</td>
<td>67.4039</td>
<td>0.9983</td>
<td>66.5540</td>
</tr>
<tr>
<td>Image Sharpening</td>
<td>49.5590</td>
<td>0.9145</td>
<td>49.2939</td>
</tr>
<tr>
<td>Median Filtering attack</td>
<td>69.1121</td>
<td>0.9924</td>
<td>68.0517</td>
</tr>
<tr>
<td>Gaussian noise</td>
<td>45.8635</td>
<td>0.9040</td>
<td>45.8094</td>
</tr>
</tbody>
</table>

The extracted watermark after attacks from R, G and B channels are shown in fig. 7.

In fig. 8 and fig. 9, Comparative results of scaling factor versus PSNR and scaling factor versus MSE in R, G, B Channels are given.

![Graph](Scaling Factor Versus PSNR for R, G, B channels for HL3 subband)

![Graph](Scaling Factor Versus MSE for R, G, B channels for HL3 subband)

An extracted result of the proposed method using normalized correlation is shown in fig. 10.
Fig. 10: Extracted results of the DWT-SVD using normalized correlation

5. Conclusion

In this paper, a comparative performance analysis by DWT-SVD based robust color image watermarking technique in RGB color space is presented. The SVD is an efficient tool for watermarking in the DWT domain. The maximum PSNR for R, G & B channels is 74.1073 dB, 72.4670 dB & 69.5147 dB respectively without any attack. Correlation factor equals to 1. The PSNR values for R channel are better than PSNR values for G & B channels. NC values of approx. 0.99 are showing best recovery of watermark from speckle noise and median filtering attack. The technique is robust for different attacks like noise addition, image sharpening and others. Imperceptibility and robustness are the measure for quality of watermark. The results show that this scheme satisfies both quality measures.

References


