Analysis of performance of a DWT-DFT-SVD based Digital Watermarking Scheme on the Basis of Scaling Factor

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Abstract - In this paper, effects of variations of scaling factor on a digital watermarking scheme are analyzed. The scheme makes use of discrete wavelet transform, discrete Fourier transform and singular values decomposition in YCbCr color space. Robustness of the scheme is tested in terms of correlation coefficients between the original and extracted watermark. Peak signal to noise ratio between the original and watermarked image is used as a measure of imperceptibility. The performance of the scheme for varying scaling factors is evaluated in the presence of four attacks, i.e., motions blur, average, Gaussian blur and crop.

Keywords - Digital watermarking, Discrete wavelet transform (DWT), Discrete Fourier transform (DFT), Singular value decomposition (SVD), YCbCr color space.

I. INTRODUCTION

The growth of high speed computer networks and World Wide Web (WWW) have explored means of new business, scientific, entertainment and social opportunities in the form of electronic publishing and advertising, messaging, real-time information delivery, data sharing, collaboration among computers, product ordering, transaction processing, digital repositories and libraries, web newspapers and magazines, network video and audio, personal communication and lots more. Information security is one of the most important issues in modern computerized society. For this purpose, digital watermarking has received considerable attention. Digital watermark is the process of embedding digital watermark information into digital content such as message/data/information (audio, video, images or text) that can be detected or extracted later. Such message/data/information mostly carries the copyright or ownership information of the content [1]. The embedded watermark should not degrade the original image & must be invariant to various attacks, such as cropping, compression, scaling, etc. Complete process of watermarking is represented in Fig. 1.

Digital watermarking is mostly addressed in either spatial or frequency domain. Spatial domain methods involve the embedding of data directly by manipulation of pixel values, code values of the host image/signal or bit stream. Inspite of being straightforward and simple, these methods are not robust in the presence of attacks [2]. To improve the robustness, most of the present work in this area is inspired by the manipulation of the frequency domain of the multimedia objects. In frequency domain, researchers have selected different transformation methods for embedding and extracting watermark objects. These includes discrete cosine trans-form (DCT) [3], discrete Fourier transform (DFT) [4, 5, 6] and discrete wavelet transform [7, 8] etc. Use of DCT results in a robust scheme (with respect to JPEG compression), but, it is sensitive to geometrical distortions [6]. This disadvantage is overcome by the use of DFT, which is rotation invariant and translation resistant [6].

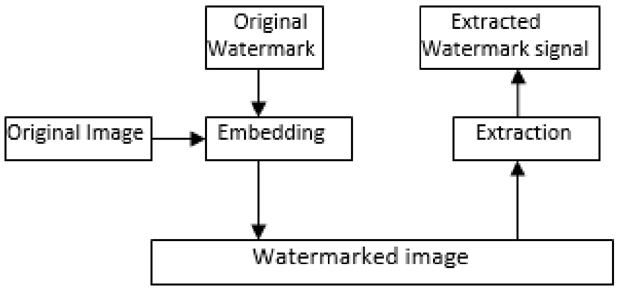


Fig. 1. Block diagram of watermarking scheme

Many hybrid image watermarking schemes have been developed by the researchers to get the benefit of two or more techniques. In a hybrid scheme based on DWT and SVD, the watermark is embedded on the elements of singular values of the DWT sub-bands of cover image [9]. This technique is further enhanced by adding the concept of discrete cosine transform (DCT) [2]. To further improve the robustness and efficiency of watermarking scheme, DWT-DFT-SVD based scheme is used [10] and is extended to YCbCr colour space [6].

In this paper,the performance of a DWT-DFT-SVD based digital watermarking scheme in YCbCr colour space [6] is analyzed for different values of scaling factors. Rest of the paper is organized as follows:A brief introduction to the watermarking scheme is given in the next section. Performance measures are elaborated in section III, Simulation results are presented in section IV followed by conclusion & list of references.

II. DWT-DFT-SVD BASED WATER MARKING SCHEME

Following steps are involved in the embedding and extraction of watermark for the DWT-DFT-SVD based water marking scheme [6] analyzed in this paper:

Embedding of watermark [6]:

1. Host image is changed to YCbCr color space. . 2D–discrete wavelet transform is applied to one of the channel and HL wavelet is chosen. Again, 2D–DWT is applied to the selected wavelet & now LH wavelet is selected. 2D–discrete fourier transform is applied to the selected LH wavelet.

2. Singular value decomposition is applied to the transformed wavelet M_1 to break it into U_1, S_1 and V_1 components as shown in eqn.1.

$$M_1 = U_1 S_1 V_1^T \quad (1)$$

Here, U_1 & V_1 are real or complex unitary matrices and S_1 is a rectangular diagonal matrix whose diagonal entries are singular values of M_1 in decreasing order.

3. 2D–discrete wavelet transform is applied to watermark and HL wavelet is chosen. 2D– discrete wavelet transform is applied to the selected wavelet and, LH wavelet is selected in the second level DWT & 2D–discrete Fourier transform is applied to it.

4. Singular value decomposition is applied to the transformed wavelet to break it into U_2, S_2 and V_2 components as shown in eqn. 2.

$$M_1 = U_2 S_2 V_2^T \quad (2)$$

5. Weighted singular values of the watermark are added to the host image by using eqn. 3.

$$S = S_1 + \alpha S_2 \quad (3)$$

here, α is scaling factor and is used to control strength of the embedded watermark.

6. Modified value of S is used with U_1 and V_1 matrices of the host image to get C as shown in eqn. 4.

$$C = U_1 S V_1^T \quad (4)$$

7. Second level wavelet is derived by application of 2D–inverse discrete fourier transform to C. Then, first level wavelet is derived by applying 2D–IDWT to the second level wavelet. Modified channel is obtained by combining IDWT of the first level wavelet. Watermarked channel is combined with non modified channels to obtain the watermarked image.

a. Extraction of the watermark [6]:

1. 2D–discrete wavelet transform is applied to the channel in which watermark is embedded and HL wavelet is chosen. 2D–DWT is applied to the selected wavelet & now LH wavelet is selected. Then, 2D– discrete fourier transform is applied to the selected LH wavelet.

2. Singular value decomposition is applied to the transformed wavelet M_3 to break it into U_1, S_1 and V_1 components as shown in eqn.4. & singular values of watermark are retrieved by use of eqn.5

$$M_3 = U_3 S_3 V_3^T \quad (4)$$

$$S_4 = \frac{S_3 - S_1}{\alpha} \quad (5)$$

3. Matrix M_4 is obtained by using eqn.6.

$$M_4 = U_2 S_4 V_2^T \quad (6)$$

4. Second level wavelet is obtained by 2D inverse Fourier transformation of M4. 2 D inverse wavelet transform of second level wavelet is taken to derive first level wavelet & 2 D inverse wavelet transform of first level wavelet is taken to retrieve the watermark.

III. PERFORMANCE MEASURES

The imperceptibility and robustness of the watermarking scheme given in section II is tested in this paper for different values of the scaling factor α (used in eqn.3 & eqn.5). Peak signal to noise ratio (PSNR) (calculated by using eqn.7) between the cover image & watermarked image is used to test the imperceptibility of scheme.

$$PSNR = 20 \log_{10} \frac{255}{RMSE} \text{ dB} \quad (7)$$

Here, RMSE stands for root mean square error and is calculated by using eqn.8.

$$RMSE = \sqrt{\frac{1}{X \times Y} \sum_{i=1}^{X} \sum_{j=1}^{Y} (A_{ij} - B_{ij})^2} \quad (8)$$

A_{ij} is a pixel of the host image of size $X \times Y$ and B_{ij} is a pixel of watermarked image of size $X \times Y$.

Correlation coefficient (as calculated by eqn.9) between the original and extracted watermark is used as a measure of robustness of the scheme. It's ideal value is one, yet, 0.7 is acceptable [11]

$$CF = \frac{\sum_{i=1}^{X} \sum_{j=1}^{Y} (W_{orgij} - W_{extij})}{\sum_{i=1}^{X} \sum_{j=1}^{Y} (W_{orgij})^2} \quad (9)$$

W_{orgij} is a pixel of the host image of size $X \times Y$ and W_{extij} is a pixel of recovered watermarked image of size $X \times Y$.

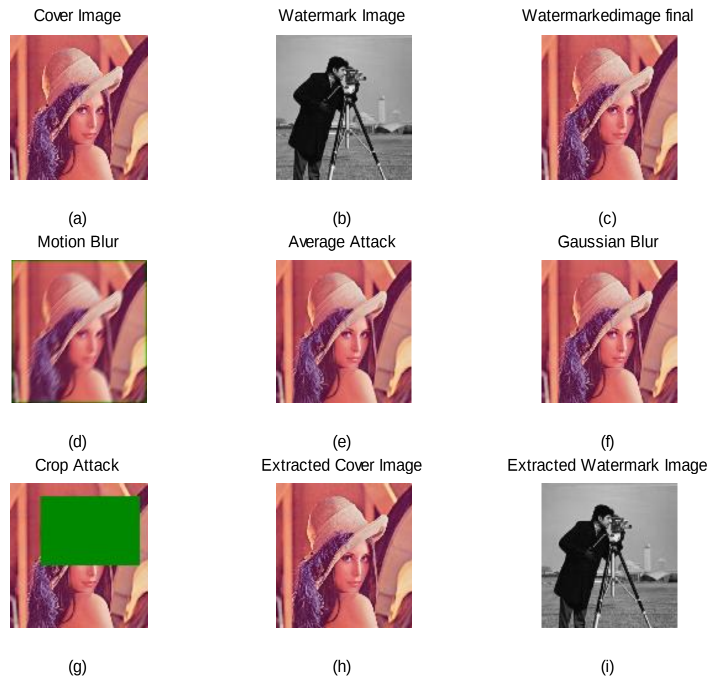
IV. SIMULATION RESULTS

The performance of the proposed watermarking scheme for different values of scaling factor α is tested by simulation in MATLAB. Images of Lena512 and Cameraman of size 512×512 are used as cover & watermark images respectively. The perceptual quality of the scheme is tested by calculation of peak signal to noise ratio (PSNR) between cover image and watermarked image. As shown in Table 1, as the value of scaling factor increases, PSNR reduces, i.e., the imperceptibility becomes poorer.

Table 1: Imperceptibility (PSNR) for different values of α

S. no.	Scaling factor	PSNR (in dB)
1.	0.05	56.9806
2.	0.1	56.8682
3.	0.3	54.7173
4.	0.5	51.9402
5.	0.7	49.7808
6.	0.9	48.0398

Fig. 2. Cover and watermark image during different phases of watermarking scheme



To test the robustness, performance of the watermarking scheme is tested against four types of attacks, i.e., motion blur, average, Gaussian blur and cropping. For different values of scaling factor, the similarity between original and extracted watermark in the presence of these four attacks is expressed in terms of correlation coefficient (defined by eqn. 9) as shown in Tables 2, 3, 4 & 5. It can be observed that as the scaling factor increases, the values of the correlation coefficients or similarity between original and extracted watermark image increases, i.e., the robustness increases

Table 2: Correlation coefficients for different values of scaling factor, Name of the attack: Motion Blur

S. no.	Scaling factor	Channel used for watermarking		
		Y	Cb	Cr
1.	0.05	0.9998	0.9998	0.9998
2.	0.1	0.9998	0.9998	0.9998
3.	0.3	0.9998	0.9999	0.9999
4.	0.5	0.9998	0.9999	0.9999
5.	0.7	0.9998	0.9999	0.9999
6.	0.9	0.9998	0.9999	0.9999

Table 3: Correlation coefficients for different values of scaling factor, Name of the attack: Average

S. no.	Scaling factor	Channel used for watermarking		
		Y	Cb	Cr
1.	0.05	0.9998	0.9998	0.9998
2.	0.1	0.9998	0.9999	0.9998
3.	0.3	0.9998	0.9999	0.9999
4.	0.5	0.9998	0.9999	0.9999
5.	0.7	0.9998	0.9999	0.9999
6.	0.9	0.9999	0.9999	0.9999

Table 4: Correlation coefficients for different values of scaling factor, Name of the attack: Gaussian

S. no.	Scaling factor	Channel used for watermarking		
		Y	Cb	Cr
1.	0.05	0.9998	0.9999	0.9999
2.	0.1	0.9998	0.9999	0.9999
3.	0.3	0.9998	0.9999	0.9999
4.	0.5	0.9998	0.9999	0.9999
5.	0.7	0.9998	0.9999	0.9999
6.	0.9	0.9999	0.9999	0.9999

Table 5: Correlation coefficients for different values of scaling factor, Name of the attack: Crop

S. no.	Scaling factor	Channel used for watermarking		
		Y	Cb	Cr
1.	0.05	0.9998	0.9998	0.9998
2.	0.1	0.9998	0.9998	0.9998
3.	0.3	0.9998	0.9999	0.9999
4.	0.5	0.9998	0.9999	0.9999
5.	0.7	0.9998	0.9999	0.9999
6.	0.9	0.9999	0.9999	0.9999

V. CONCLUSION

Simulation results show that larger is the value of scaling factor α, more is the robustness of watermarking scheme, but lesser is the perceptual quality of watermarked image.

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