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Image Watermarking Based on DWT-SVD

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ABSTRACT

Image watermark is one of the interesting fields of image processing which hide information within a digital image. The main purpose of this paper is to propose a combination technique of discrete wavelet transform and singular value decomposition to achieve a good image watermarking. Colour images are here utilized for image watermarking. In the proposed method, the main image is first transformed into the wavelet domain and then the watermark is embedded into the reference image after modifying by the singular values of reference image using the singular values of the watermark. Experimental results are then applied by the proposed method for illustrating the system efficiency.

KEYWORDS: Digital watermarking; color image; DWT; SVD.

1 INTRODUCTION

By developing the multimedia technologies, digital multimedia systems moved to utilize on a large scale of applications (Moallem & Razmjooy, 2012). Among different applications, information security and the authentication, because of the necessity of the multimedia securities as one of the most important discussions which is currently much attention is being paid (Dang-Pham, Pittayachawan, & Bruno, 2017; Teal, 2017; Tuna et al., 2017).

Digital watermarking as a multimedia protections method is a process in which hide or embed digital information (watermark) into an image (Al-Haj & Barouqa, 2017; Falkenstern, Reed, Holub, & Rodriguez, 2017). The resulted embedded image can be then extracted from the watermarked product for security purposes like ensuring tamper-resistance and resolving copyright ownership (Kaur & Kaur, 2018). Generally, a good digital watermark system should be secure, robust, difficult to remove, non-perceptible and Fidel (Singh, 2017). Nonetheless, during the practical applications, the watermark is facing different kinds of problems like security, capability, authentication, etc. and limits the process of watermarking technology application (Rasti, Anbarjafari, & Demirel, 2017).

Great deals of watermarking embedding methods are applied to the gray level images. Hence, recently the researchers' interest has turned into image watermarking on color images.

Currently, watermarking techniques can be divided into two main categories including the spacial domain and the transform domain schemes. Special domain embeds data by modifying the pixel values of the main image in the normal image space, but, the transform domain does this job in transform domain coefficients.

In an image watermarking method, the invisibility and the robustness are considered as two most basic requirements. The main advantage of the transform domain methods is that has superiority than the spacial domain when facing the common image distortions; i.e. they are quite robust that watermarking information cannot be easily damaged by filters and geometry distortions etc. (Jia, Zhou, & Zhou, 2017; Rana & Pareek, 2017). Discrete wavelet transform (DWT) is one of the popular transform methods which can be utilized for transform domain watermarking. It decomposes the input image into four bands and can be used for watermarking purposes by embedding data at all frequencies.

This method may not make an optimal representation of the given image; in the recent years, a new transform representation called singular value decomposition (SVD) is introduced for watermarking (Cherian & Mereena, 2016).

SVD is an optimal matrix decomposition method in the least square sense. It comprises the maximum energy into some coefficients. Since the ability of SVD can adapt to variations in local statistics of an image, watermarking schemes with this method has typically of large capacity (Fazli & Moeini, 2016).

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2 BACKGROUND REVIEW AND THEORY

2.1 Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) is one of the popular methods in image processing which can be utilized in different applications like compression and de-noising. Indeed, DWT is a discrete sampling of the wavelet transform.

Since DWT techniques have a temporal resolution, they have superiority than the Fourier transforms: This technique captures both location and frequency information. The main structure of DWT is based on a multi-resolution analysis which decomposes the image in frequency channels and constant bandwidth on a logarithmic scale.

By using the DWT, an input image can be decomposed into four sub-bands called LL, LH, HL, and HH at level 1 in the DWT domain. Here, LH, HL, and HH stand the finest scale wavelet coefficients and LL represents for the coarse-level coefficients. In addition, different level of decomposition can be decomposed for LL sub-band. In this situation, decomposition will continue since the considered number of levels get reached by the application.

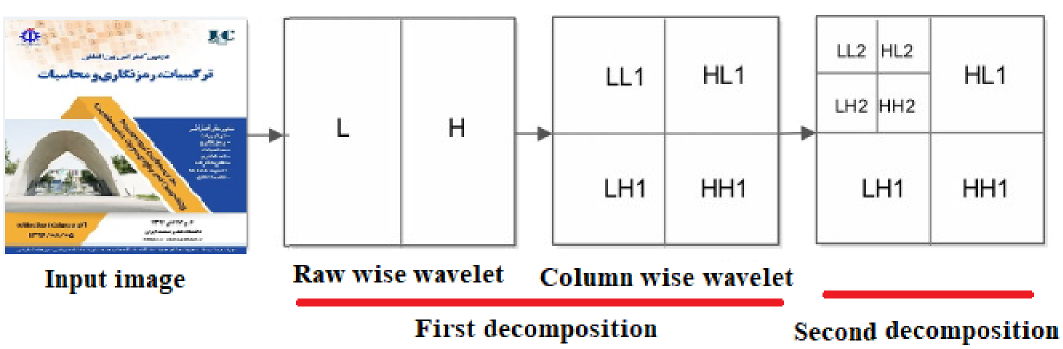

Figure 1: Two levels of decomposition flow chart

2.2 Singular Value Decomposition

Singular value decomposition (SVD) describes a general and popular method which has different applications from solving most linear least-squares problems, multivariate analysis to computing pseudo-inverse of a matrix. Images are in fact a matrix with nonnegative scalar entries. Consider an image with the size *m*×*m*; the SVD for this image can be achieved by:

$$A = USV^T \tag{1}$$
$$S = diag(\lambda_i)$$
$$i = 1,...,n$$

where *S* is a diagonal matrix of singular values λ_i which are arranged in decreasing order and *U* and *V* describes the orthogonal matrices. The columns of *V* are the right singular vectors whereas the columns of *U* are the left singular vectors of the input image *A*.

By using the SVD technique for image watermarking, it finds the SVD of each block or the cover image of the cover image, and then it develops the singular values to embed the watermark.

3 WATERMARKING BASED ON HYBRID DWT-SVD

In this study, there is two-step for image watermarking: embedding and extraction which are explained respectively in the following:

3.1 Image watermark embedding

First, one-level Haar DWT is utilized for decomposing the cover image A into four sub-bands (i.e., LL, LH, HL, and HH). After that, SVD technique is applied to the LH and HL sub-bands as follows:

$$A^K = U^K S^K V^{KT} \tag{2}$$

where $k = 1,2$ describes the sub-bonds.

Afterwards, the watermark is divided into two sections, i.e. $W = W^1 + W^2$ where W^k describes the half of the watermark image. Here, using W^1 and W^2, the singular values of HL and LH get modified and then SVD is applied to them as follows:

$$S^K + \alpha W^K = U_W^K S_W^K V_W^{KT} \tag{3}$$

where α describes the *scale factor*. The scale factor can be employed for controlling the watermark strength to be inserted. In the following, the modified DWT coefficients are obtained by:

$$A^{*K} = U^K S_W^K V_W^{KT} \tag{4}$$

And finally, the watermarked image can be achieved by applying the inverse DWT with the modified DWT coefficients and non-modified DWT coefficients.

3.2 Image watermark extraction

First, one level Haar DWT is utilized for decomposing the watermarked image into four sub-bands (i.e., LL, LH, HL, and HH). Afterwards, SVD is applied to the LH and HL sub-bands:

$$A_W^{*K} = U^{*K} S_W^{*K} V^{*KT} \tag{5}$$

After that, the following formula is applied:

$$D^{*K} = U_W^K S_W^{*K} V_W^{KT} \tag{6}$$

The watermarked image can be then extracted from the sub-band by the following equation:

$$D^{*K} = U_W^K S_W^{*K} V_W^{KT} \tag{7}$$

Afterwards, the half of the watermark image can be extracted from

$$W^{*K} = \frac{(D^{*K} - S^{K})}{\alpha} \tag{8}$$

Finally, by combining the results of W^{*K}, the embedded watermark can be achieved by $W^{*} = W^{1*} + W^{2*}$.

4 EXPERIMENTAL RESULTS

The performance of the proposed method is tested on color images with different sizes. There are different metrics to verify the presence of the watermark and to show the similarity between the original and the extracted singular values. In this study, the correlation coefficient is employed as follows:

$$\rho(w, \overline{w}) = \frac{\sum_{i=1}^{r} w(i)\overline{w}(i)}{\sqrt{\sum_{i=1}^{r} \overline{w}^{2}(i)}\sqrt{\sum_{i=1}^{r} w^{2}(i)}} \tag{9}$$

where w and $\overline{w}$ describe the of the original watermark and the extracted singular values respectively, r=max(M1, N1). ρ defines the lied number in the interval [-1, 1].

Extracted singular values will be equal to the original Image if ρ=1 otherwise if ρ=-1 then the difference is negative for the largest singular values. This situation constructs a watermark image look like a negative thin film. The correlation coefficients for all extracted watermarks are given in the following Table.

Table 1 Correlation coefficient of the extracted image

Image	Pepper	Text
Average Filtering (13×13)	-0.3654	-0.5137
Median Filtering (13×13)	-0.3183	-0.6248
Additive Gaussian Noise (75%)	0.2747	0.4835
Histogram Equalization	0.8841	0.6852

From the results, it is observed that the proposed method is somewhat resilient against Histogram Equalization. Fig.2 and Fig.3 show the watermarked image for the analyzed case studies. Thus it can be seen that this method has good invisibility. From the simulation of the experiment results, it can be observed that the proposed method is robust to attacks.

5 CONCLUSION

In this paper, a new kind of image watermarking is proposed based on discrete time wavelet transform and singular value decomposition techniques embedding a watermark into an input color original image. In the proposed method, like ordinary watermarking methods using DWT, the main image is first decomposed into four bands. Afterwards, singular value decomposition is computed for each band and finally, singular values of the watermarked images are minimized and added to the bands. The method has advantages of robustness for its embedding data because of SVD. The experimental results indicate that the proposed method is robust to Histogram equalization.

Figure 2: (A) 1st input image, (B) 2nd input image, (C) Watermarked image and (D) Extracted image

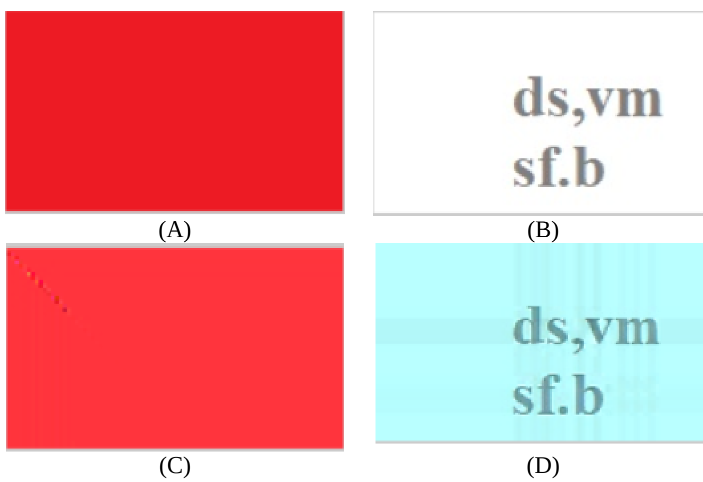

Figure 3: (A) 1st input image, (B) 2nd input image, (C) Watermarked image and (D) Extracted image

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