J Inf Process Syst, Vol.13, No.2, pp.340~347, April 2017
https://doi.org/10.3745/JIPS.03.0067

ISSN 1976-913X (Print)
ISSN 2092-805X (Electronic)

JOURNAL OF INFORMATION PROCESSING SYSTEMS JIPS

Discrete Wavelet Transform and a Singular Value Decomposition Technique for Watermarking Based on an Adaptive Fuzzy Inference System

Salima Lalani* and D. D. Doye**

Abstract
A watermark is a signal added to the original signal in order to preserve the copyright of the owner of the digital content. The basic challenge for designing a watermarking system is a dilemma between transparency and robustness. If we want a higher rate of transparency, there has to be a compromise in terms of its robustness and vice versa. Also, until now, watermarking is generalized, resulting in the need for a specialized algorithm to work for a specialized image processing application domain. Our proposed technique takes into consideration the image characteristics for watermark insertion and it optimizes transparency and robustness. It achieved a 99.98% retrieval efficiency for an image blurring attack and counterfeits other attacks. Our proposed technique counterfeits almost all of the image processing attacks.

Keywords
DWT, Fuzzy, SVD, Watermarking

1. Introduction

Watermarking is a technique of embedding a signal in a cover signal for copyright protection, authentication, or fingerprinting. Whatever the application may be, the basic requirements of the system are its transparency and robustness against various attacks. Many techniques have been proposed to date, and the problem that still remains is that even if the technique is robust against attacks it does not provide transparency. Even worse is when the technique gives good results for standard test images but a specialized algorithm is required for other applications areas since the image characteristics vary as per application area.

2. Existing Watermarking Systems

Watermarking techniques can be categorized into two types—spatial domain and frequency domain. Spatial domain techniques have lower complexity and are easy to implement, but they are fragile against

Manuscript received April 13, 2015; first revision July 23, 2015; accepted August 5, 2015.
Corresponding Author: Salima Lalani (salima_lalani@hotmail.com)
* Dept. of Computer Science and Engineering, Shri Guru Gobind Singhji Institute of Engineering and Technology, Nanded, India (salima_lalani@hotmail.com)
** Dept. of Electronics and Telecommunication Engineering, Shri Guru Gobind Singhji Institute of Engineering & Technology, Nanded, India (dddoye@yahoo.com)

image processing attacks. On the other hand, transform domain techniques embed watermarks by modulating coefficients in a transform domain, such as a discrete cosine transform (DCT), discrete wavelet transform (DWT), and singular value decomposition (SVD). Transform domain techniques have a higher computational cost but are robust against attack. In 1997, Kutter et al. [1] and in 2000, Nikolaidis and Pitas [2] proposed spatial domain techniques that modify the intensity values of the luminance in the spatial domain. On the other hand, in 2000, Hernandez et al. [3] and in 2002, Liu and Tan [4] described frequency domain methods, where the host image is transformed in a domain, such as a DCT or DWT, and then the watermark is embedded in the mid-frequency to ensure the transparency and robustness of the watermarked image. In 2010, Lui and Tsai [5] proposed a hybrid DWT and SVD-based watermarking technique.

In 2013, Sridevi and Fatima [6] implemented a robust watermarking using fuzzy logic approach based on a DWT and SVD algorithm. In 2013, Latif [7] used transform parameters to enhance robustness by tabu search and after being embedded, the watermark was adapted to the image by exploiting the masking characteristics of the human visual system with the use of a fuzzy gradient to ensure imperceptibility. In 2012, Imran and Ghafoor [8] proposed DWT-SVD-based watermarking for a color image and a principal component analysis was used to uncorrrelate the R, G, and B channels. In 2009, Bhatnagar and Raman [9] generated a reference sub-image by transforming the original image into a wavelet domain and using directive contrast and wavelet coefficients. Then they embedded the watermark in the reference image by modifying the singular values of the reference image by using the singular values of the watermark. In 2011, Lai [10] improved the SVD technique by taking into consideration human visual characteristics. In 2008, Santhi et al. [11] proposed a technique that combines the features of DWT, DCT, and SVD. In 2004, Ganic and Eskicioglu [12] modified the singular values of a DWT transformed image in all frequencies, which resulted in an increase in the robustness of an image. In 2007, Yin et al. [13] adapted different methods for embedding a watermark in each sub-band to increase robustness. In 2010, Song et al. [14] presented a semi-fragile watermark, which was robust.

The basic challenge for designing a watermarking system is the dilemma between transparency and robustness. Our proposed technique tries to solve this problem by designing a fuzzy inference system (FIS) based on just-noticeable distortion (JND) that takes into consideration the image characteristics for deciding the transparency of the cover signal. Also, the system is can be changed per the application's requirements, in order to give the best results. To provide robustness against attacks, especially in the transform domain, a DWT combined with a SVD is used.

3. Proposed Technique

3.1 Fuzzy Inference System

The only problem with existing watermarking techniques is that if the transparency is improved its robustness is reduced, whereas if we improve the robustness then it affects the transparency. The FIS that we designed is the primary contribution of this paper and it is designed in such a manner that it takes into consideration the image's characteristics, in order to achieve maximum transparency and robustness. The fuzzy system is based on two inputs, which are the JND matrix of the original image and the actual watermark matrix. The algorithm used for the design of FIS is as follows:

If (JND of original image < watermark signal)
Then alpha should be low
Else if (JND of original image = watermark signal)
Then alpha should be medium
Else
Alpha should be high.

The advantage of the system is that the value of JND and the watermark signal may vary according to the input signal. The method gives the optimal results for standard test images. The embedding technique and extraction technique for watermarking are described below.

3.2 Watermark Embedding Algorithm

Three levels of DWT is used to divide the image into LL3, LH3, HL3, and HH3 components, respectively. The LL3 and HH3 sub-bands are prone to filtering attacks, which makes them unsecure against watermark insertion. As such, LH3 and HL3 can be used for watermark embedding. The LH3 band introduces redundancy and reduces PSNR. So the HL3 component matrixis decomposed into orthogonal and singular matrices, as given below:

$$A=USV^T \tag{1}$$

where, the columns of U and V are orthonormal and the matrix S is a singular diagonal matrix with positive real entries. Compute the JND matrix of the original image to determine the image characteristics.

The FIS takes the JND and watermarked image as inputs to the system, and the output is the variable value of alpha depending on the image characteristics. The watermarked image is decomposed into a singular matrix, shown in Eq. (2) as:

$$W=Uw\ Sw\ Vw^T \tag{2}$$

Modify the singular values of the HL3 components and then apply SVD to them to obtain the modified HL3 component as follows:

$$S=S+\alpha Sw \tag{3}$$

$$HL3\_modified=USV^T \tag{4}$$

The embedding process is shown in Fig. 1.

3.3 Watermark Extraction Algorithm

Apply three levels of DWT to divide the original watermarked image in order to divide the image into LLw3, LHw3, HLw3, and HHw3 components, respectively. Decompose the HLw3 component matrix into orthogonal and singular matrices, as given below:

$$A=UwmSwmVwm^T \tag{5}$$

Compute the JND matrix of the original image to determine the image characteristics.

The FIS takes the JND and watermarked image as inputs to the system and the output is the variable value of alpha depending on the image's characteristics

The singular values of the watermark can be extracted as:

$$Sw=(Swm\text{-}S)/\alpha \quad (6)$$

The original watermark can be extracted as:

$$W=UwSwVw^T \quad (7)$$

The extraction process is shown in Fig. 2.

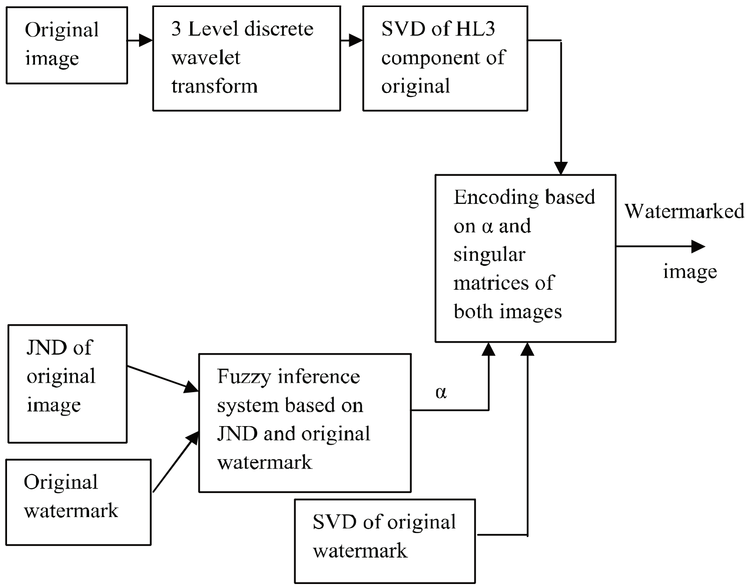

Fig. 1. Fuzzy based DWT-SVD watermark embedding process.

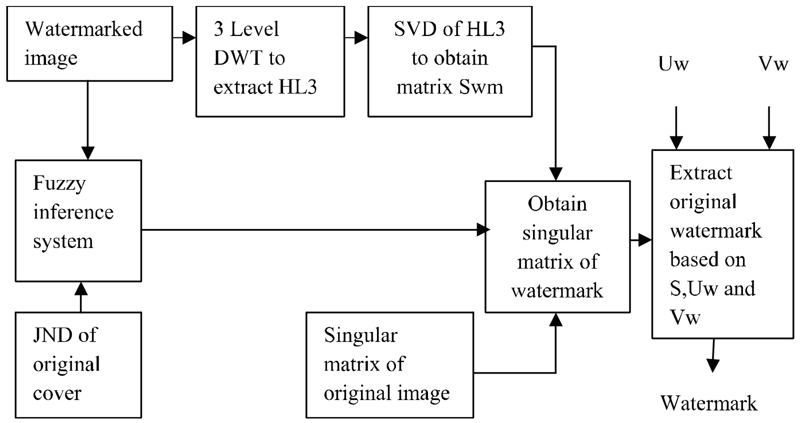

Fig. 2. Fuzzy based DWT-SVD watermark extraction process.

4. Experimental Results

Proposed approach is used on various 512×512 cover images and on a 64×64 cameraman image as watermark image. Fig. 3 shows the original and watermarked images for four different images. We tested our proposed system on standard images as well as a biomedical image.

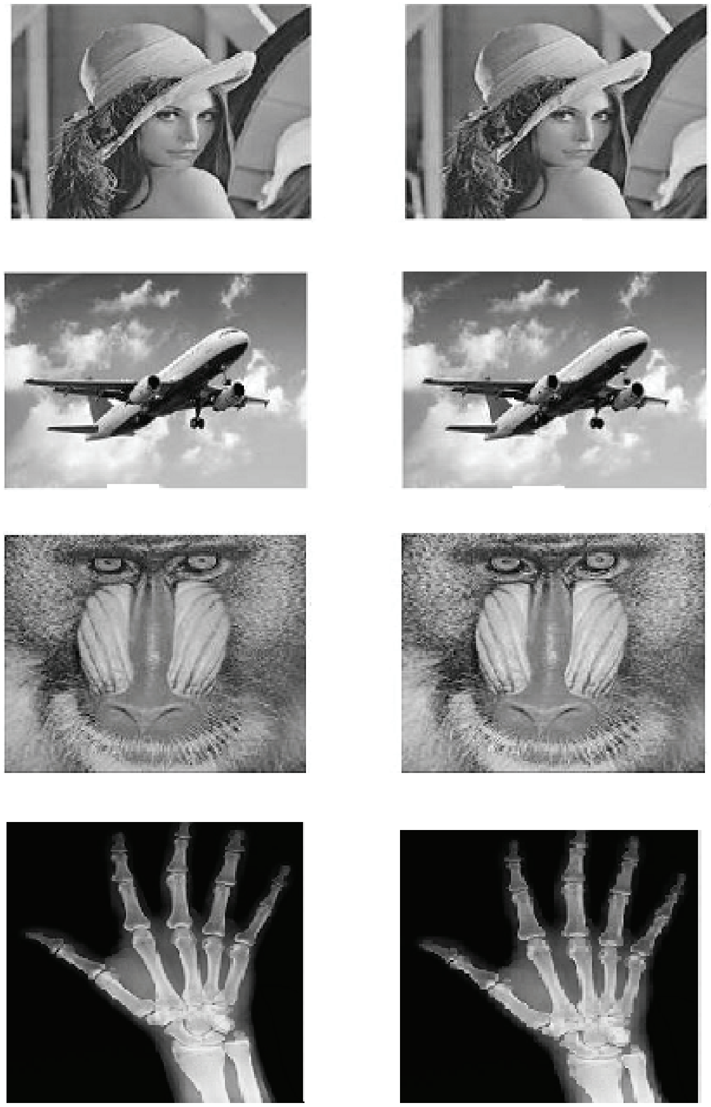

Fig. 3. Original images (left) and watermarked images (right).

To evaluate the robustness of the techniques, five types of attacks were performed on the image, which were as follows: 1) a geometrical attack: cropping and rotation; 2) a noising attack: Gaussian noise; 3) a de-noising attack: average filtering; 4) a format-compression attack: JPEG compression; and 5) an image processing attack: histogram equalization, blurring, and gamma correction. Fig. 4 shows the recovered watermark after the watermarked image was attacked by various kinds of attacks. The transparency of the watermark was determined mathematically by using PSNR, and robustness was determined by computing the Pearson correlation coefficient.

It can be seen that the maximum PSNR obtained was 63.7404, but that the robustness was comparatively compromised, whereas when the PSNR obtained was 44.6556, robustness was better. The FIS provides optimization between transparency and robustness. PSNR was 50.9563, which retained the robustness of system. Our proposed system gave optimal robustness and transparency concurrently for all five attacks. The correlation for different values of the DWT-SVD-based method for different values of alpha and also proposed FIS-based method. As shown in Table 1, for image processing attacks, the robustness was best compared to existing techniques. For cropping and rotation attacks, the results were comparable for noising and de-noising attacks. The JPEG compression attack also gave optimal results for transparency and robustness.

Table 1. Comparison between DWT-SVD for various values of alpha and DWT-SVD based on FIS using Pearson correlation

Attacks	α=0.01 PSNR=63.7404	α=0.03 PSNR=54.1980	α=0.05 PSNR=49.7610	α=0.07 PSNR=46.8385	α=0.09 PSNR=44.6556	FIS-based α PSNR=50.95
Cropping	0.7761	0.7340	0.7660	0.7456	0.7222	0.6939
Rotation	0.8901	0.8638	0.8572	0.8520	0.8161	0.6179
Gauss. noise	0.8799	0.7589	0.8346	0.7907	0.8052	0.7256
Avg. Filt.	0.9485	0.9196	0.9309	0.8820	0.8914	0.7105
Hist. Eq.	0.9450	0.9218	0.9320	0.8839	0.8962	0.7610
JPEG comp.	0.8234	0.9634	0.9634	0.9805	0.9813	0.9751
GC	0.6785	0.6450	0.6467	0.5336	0.6646	0.9362
Blurring	0.8913	0.9207	0.9154	0.9041	0.9108	0.9998

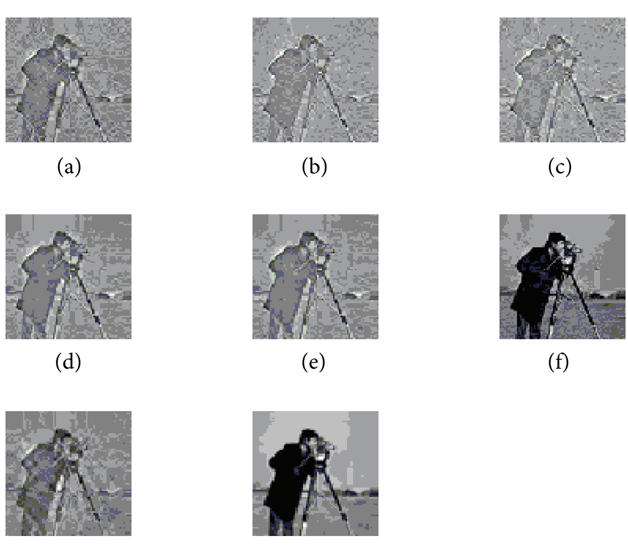

Fig. 4. Recovered watermark obtained from (a) cropping, (b) rotation, (c) Gaussian noise, (d) averaging, (e) histogram equalization, (f) JPEG compression, (g) gamma correction, and (h) blurring.

5. Discussion and Conclusions

Our proposed approach is an optimal solution for the dilemma between robustness and transparency. The PSNR value obtained was 50.9563, and it is robust against all five attacks. It gave excellent results against a blurring attack, for which the Pearson correlation was 0.9998, as compared to other values of alpha. The FIS adapts the system to variable image characteristics and, hence, improves the transparency of the system.

References

[1] M. Kutter, F. D. Jordan, and F. Bossen, "Digital signature of color images using amplitude modulation," in *Proceedings of SPIE 3022: Storage and Retrieval for Image and Video Databases V.* Bellingham, WA: International Society for Optics and Photonics, 1997, pp. 518-526.

[2] A. Nikolaidis and I. Pitas, "A region-based technique for chaotic image watermarking," in *Proceedings of 10th European Signal Processing Conference (EUSIPCO2000)*, Tampere, Finland, 2000, pp. 1-4.

[3] J. R. Hernandez, M. Amado, and F. Perez-Gonzalez, "DCT-domain watermarking techniques for still images: detector performance analysis and a new structure," *IEEE Transactions on Image Processing*, vol. 9, no. 1, pp. 55-68, 2000.

[4] R. Liu and T. Tan, "An SVD-based watermarking scheme for protecting rightful ownership," *IEEE Transactions on Multimedia*, vol. 4, no. 1, pp. 121-128, 2002.

[5] C. Lui and C. C. Tsai, "Digital image watermarking using discrete wavelet transform and singular value decomposition," *IEEE Transactions on Instrumentation and Measurement*, vol. 59, no. 11, pp. 3060-3063, 2010.

[6] T. Sridevi and S. S. Fatima, "Digital image watermarking using fuzzy logic approach based on DWT and SVD," *International Journal of Computer Applications*, vol. 74, no. 13, pp. 16-20, 2013.

[7] A. Latif, "An adaptive digital image watermarking scheme using fuzzy logic and tabu search," *Journal of Information Hiding and Multimedia Signal Processing*, vol. 4, no. 4, pp. 250-271, 2013.

[8] M. Imran and A. Ghafoor, "A PCA-DWT-SVD based color image watermarking," in *Proceedings of IEEE International Conference on Systems, Man, and Cybernetics*, Seoul, Korea, 2012, pp. 1147-1152.

[9] G. Bhatnagar and B. Raman, "A new robust reference watermarking scheme based on DWT-SVD," *Computer Standards & Interfaces*, vol. 31, no. 5, pp. 1002-1013, 2009.

[10] C. Lai, "An improved SVD-based watermarking scheme using human visual characteristics," *Optics Communications*, vol. 284, no. 4, pp. 938-944, 2011.

[11] V. Santhi, N. Rekha, and S. Tharini, "A hybrid block based watermarking algorithm using DWT-DCT-SVD techniques for color images," in *Proceedings of International Conference on Computing, Communication and Networking*, Karur, India, 2008, pp. 1-7.

[12] E. Ganic and A. M. Eskicioglu, "Robust DWT-SVD domain image watermarking: embedding data in all frequencies," in *Proceedings of the 2004 Workshop on Multimedia and Security*, Magdeburg, Germany, 2004, pp. 166-174.

[13] C. Q. Yin, L. Li, A. Q. Lv, and L. Qu, "Color image watermarking algorithm based on DWT-SVD," in *Proceedings of IEEE International Conference on Automation and Logistics*, Jinan, China, 2007, pp. 2607-2611.

[14] H. Song, Z. Qiu, and J. Gu, "A novel semi-fragile image watermarking scheme based on wavelet," in *Proceedings of IEEE International Conference on Audio Language and Image Processing (ICALIP)*, Shanghai, China, 2010, pp. 1504-1510.

Salima Lalani

She was a gold medalist in the degrees of B.E. and M.E. in Computer Science and Engineering from Swami Ramanand Teerth Marathwada University in 2008 and 2011, respectively. Since November 2011, she is with the SGGS IE&T, Computer Science and Engineering Department from SRTM University as a PhD candidate.

D. D. Doye

He received B.E. and M.E. degrees in Electronics from Marathwada University Aurangabad in 1988 and 1993, respectively. He received Ph.D. in 2003 from Swami Ramanand Teerth Marathwada University, Nanded. Presently, working as Professor since 2003 in Department of Electronics and Telecommunication Engineering, SGGS Institute of Engineering and Technology, Nanded (MS), India. His research field includes speech processing, image processing and pattern recognition.