Available online at www.sciencedirect.com

ScienceDirect

Journal of Electrical Systems and Information Technology 3 (2016) 68–80

www.elsevier.com/locate/jesit

Comparison of multiple watermarking techniques using genetic algorithms

N. Mohananthini *, G. Yamuna [1]

Department of Electrical Engineering, Annamalai University, Annamalai Nagar 608002, Tamilnadu, India

Received 14 February 2015; received in revised form 31 October 2015; accepted 5 November 2015
Available online 18 March 2016

Abstract

Multiple watermarking is used to share the copyright of multiple users, increase robustness and high security. The proposed method is comparison of multiple-watermarking techniques based on Discrete Wavelet Transform and Singular Value Decomposition using Genetic algorithm. This research elaborates the three main categories of multiple watermarking techniques such as successive, segmented and composite watermarking. The experimental results show that the DWT-based watermarking algorithms possess multi-resolution description characteristics achieving imperceptibility. The SVD-based watermarking algorithms add the watermark information to the singular values of the diagonal matrix achieving robustness requirements. The optimization is to maximize the performance of peak signal to noise ratio and normalized correlation in multiple watermarking techniques using genetic algorithms.

Keywords: Multiple watermarking; Successive watermarking; Segmented watermarking; Composite watermarking; Genetic algorithms

1. Introduction

Digital Image Watermarking is an important technique in the area of information security. It is one of the important techniques which are used for safeguarding the origins of the image by protecting it against Piracy. Multiple watermarking approaches combine the advantages of single watermarking to create a sophisticated multiple watermarking techniques, which is efficient in terms of high security and robustness. Jaiswal and Patil (2012) applied text watermarking to image and text documents will detract the invisibility and robustness of embedded watermarks. This problem can be resolved by using Dual Watermarking Scheme Based on Threshold Cryptography (DWTC) for Web Document. DWTC consists of three processes that is generation of watermark in web document embedding watermark into web document, and detection of watermark from embedded web document. Based on threshold cryptography, generation

* Corresponding author. Tel.: +91 9843279541; fax: +91 4144 238080.
E-mail addresses: mohananthini@yahoo.co.in (N. Mohananthini), yamuna.sky@gmail.com (G. Yamuna).
[1] Tel.: +91 9842399987; fax: +91 4144 238080.
Peer review under responsibility of Electronics Research Institute (ERI).

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jesit.2015.11.009

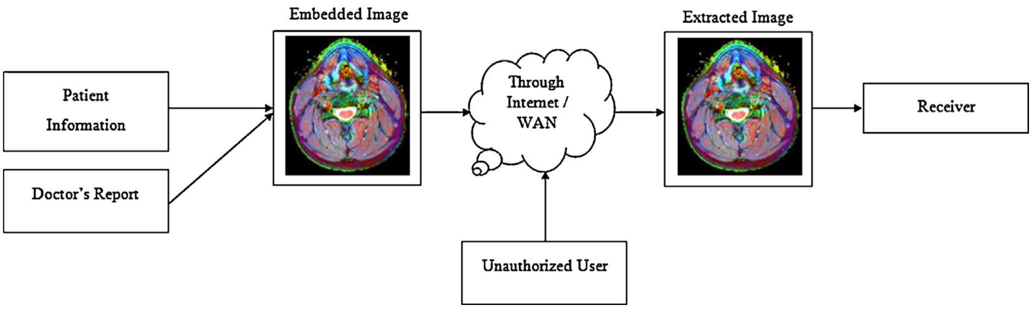


Fig. 1. Block diagram of image watermarking.

of watermark process can increase the robustness. But Dual Watermarking based on threshold cryptography has less capacity of watermarking and tamperproof performance. To resolve this problem, they can increase watermarking capacity and tamperproof performance by means of applying multiple watermarking.

Nasir et al. (2008) proposed a novel and robust colour image watermarking technique in spatial domain based on embedding four identical watermarks into the blue component of the host image. In the extraction process, the original image is available and five watermarks can be extracted from different regions of the watermarked image and only one watermark is detected or constructed from the five watermarks according to the highest value of normalized cross correlation (NCC). The experimental results show that their proposed scheme is robust for several attacks. Their proposed technique is also secure, and has the correct key to extract the watermark.

Kallel et al. (2010) applied a multiple watermarking technique in the wavelet field to preserve the traceability and the record of the medical image diagnosis made by doctors. Their technique is to hide information in the medical image and at the same time to ensure its imperceptibility. Their diagnosis made by the practitioner is the data inserted in the image. The fundamental challenge of their paper is how to hide the full diagnosis of each practitioner in the image ensuring a good quality of the image at the same time.

1.1. Problem definition

- Many digital watermarking techniques have been proposed to solve this problem by hiding an invisible watermark in an image to prove the ownership of the image. Because of most prominent applications, embedded information about the owner to prevent others from claiming copyright is adopted.
- Generally, the embedded information of medical images is exchanged from hospitals to required area through unsecured open networks. It creates a threat which results in undesirable outcome. Considering this fact the multiple watermarking techniques are used in the proposed a watermarking scheme. This is important for addressing different problems like high security of medical images, more robustness and to preserve the privacy of patients. The block diagram of medical imaging watermarking is shown in Fig. 1.
- The extraction process of a watermarking algorithm achieves transparency and robustness. The understanding between the requirements of transparency and robustness is considered as an optimization problem and is removed by applying genetic algorithms.

2. Material and methods

2.1. Discrete wavelet transform

In recent years, several digital image watermarking algorithms have been proposed based on discrete wavelet transform (DWT) and Singular Value Decomposition (SVD). The wavelet transform which is based on small waves has gained widespread acceptance in signal processing and image compression. Anoop Suraj et al. (2014) reviewed discrete wavelet transform based image fusion and denoising in FPGA. They effectively fused the MRI images of a patient suffering from sarcoma using Daubechies mother wavelet. Their approach is focused on the FPGA implementation of algorithm and the scaling-up of the algorithm to perform real time operations. Wavelet-coding is especially suitable for the applications of tolerable degradation and scalability. The wavelet analysis is the heart of multi-resolution analysis decomposition of an image into sub images of different size resolution levels. The proposed method is two level wavelet decomposition of original image and the watermark is applied on a low frequency sub-band (LL_2).

2.2. Singular value decomposition

Singular value decomposition is a mathematical approach with several applications in watermarking, image compression, and other signal processing areas. In SVD-based watermarking algorithms add the watermark information to the singular values of the diagonal matrix S in such a way to meet the robustness and imperceptibility requirements. If the watermark is added in the orthogonal matrices of SVD then the imperceptibility of the original image is improved and it is not robust to many attacks because the matrix elements of orthogonal matrices are very small. The SVD of an $m \times n$ image matrix F has a decomposition form, where m number of rows and n number of columns

$$F = U \times S \times V^T \tag{1}$$

where, U is the left singular values is an $m \times m$ orthogonal matrix; V is the right singular values is an $n \times n$ orthogonal matrix and $S = m \times n$ diagonal matrix with singular values on the diagonal. An enhanced semi-blind SVD–DWT-based image watermarking technique has been introduced (Sleit et al., 2012). Experimental results also showed that their proposed scheme outperformed in terms of robustness with respect to various attacks.

2.3. Genetic algorithms

Genetic algorithms are a powerful adaptive method to solve, search and optimization problems. It is one of the artificial intelligent techniques for optimization. Genetic algorithms are more robust and better than conventional algorithms. In genetic algorithms each individual is coded as a finite length vector of variables and these individuals are linked with chromosomes, then a set of chromosomes form a population. Genetic algorithms start with some randomly selected population is called the first generation and then each individual in the population corresponding with a solution is to the problem domain. The fitness function is also known as the objective functions are formed by combining two metrics are peak signal to noise ratio and normalized correlation. The fitness function is used to evaluate all the individuals in the population and the best individual along with the corresponding fitness value are evaluated. The three main operators in genetic algorithms are: selection, crossover and mutation operator applied to the chromosomes repeatedly. The flowchart of a genetic algorithm is shown in Fig. 2. Kumsawat and Attakitmongcol (2004) developed a technique for optimizing the image watermarking using genetic algorithms. Their method is applied to improve the quality of the watermarked image and the robustness of the watermark.

2.4. Multiple watermarking

In multiple watermarking techniques more than one watermark are embedded into the original image. Sheppard et al. (2001) introduced three multiple watermarking algorithms with some properties. Such algorithms describe some potential security problems in multiple watermarking applications that are not applicable for single watermark applications. The multiple watermarking techniques are discussed as follows,

2.4.1. Successive watermarking

In the embedding process, the multiple watermarks are embedded one after the other to get watermarked images. In the extraction process, the multiple watermarks are extracted from one after the other from the watermarked images. This approach is also denoted as Re-watermarking technique. Mark et al. (2007) demonstrated that the watermark interface is a threat to reliable detection in multiple re-watermarking scenarios. In re-watermarking the watermarks are embedded one after the other. Employing disjoint frequency bands for embedding different watermarks turn out to be more effective and capable of maintaining reasonable detection correlation in multiple embedding applications. The classical robust watermarking technique for multiple re-watermarking is discussed (Kampfer et al., 2006). Their method found that non-blind as well as blind algorithms may be employed for that purpose provided that correct reference image data is recorded and stored for the non-blind algorithms. A surprisingly large number of different watermarks may be detected and also robustness is maintained to a certain extent using their approach.

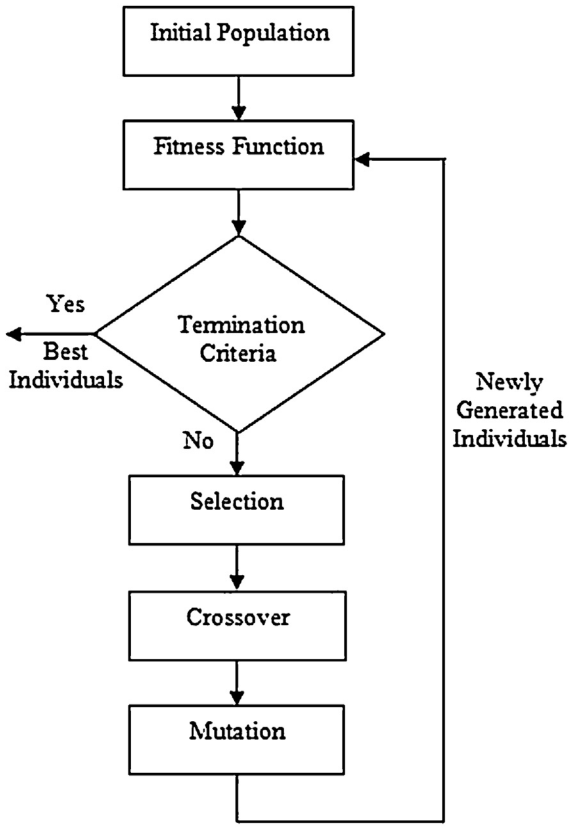


Fig. 2. Flowchart for genetic algorithms.

2.4.2. Segmented watermarking

The segmented watermarking method performs segmentation of the original image so that each watermark has its own separate embedding area. In the proposed work, one watermark is embedded into odd-numbered rows and columns and another watermark is embedded into even-numbered rows and columns in colour image of Lena. A new rotation and scaling invariant image watermarking scheme is proposed (Nantha Priya and Lenty Stuwart, 2010). The image is segmented into a number of homogeneous regions and the feature points are extracted. Based on the image normalization and orientation assignment, the translation, scaling and rotation invariant regions can be used for watermark embedding and extraction. The segmented image is modelled as mixture generalized Gaussian distribution and this model is the basis of mathematical analysis of various aspects of the watermarking processes such as probability of error, embedding strength adjustment. The effectiveness and accuracy of their proposed scheme is established through experimental results.

Wheeler et al. (2004) introduced the notion of weighted segmented digital watermarking, and generalized work on cropping-resistance in segmented watermarking to provide performance measures for the weighted case. Segmented watermarking of still images in which segments are formed by dividing the image into square blocks, each of which contains one contributor's watermark. If a watermark is present in one or more segments of their work, the owner of that watermark is reported to be an owner of the work as a whole by an arbiter. Their work compared performance measurement of watermark embedding patterns in the presence of cropping attacks.

A set of schemes and their analysis for multiple watermark placements that maximize resilience to cropping attack is presented (Frikken and Atallah, 2003). Watermarking is a tool for digital rights management, and inserting multiple watermarks into the same data is an important application. Dehghan and Ebrahim Safavi (2010) presented a new wavelet-based image watermarking technique which is suitable for image copyright protection. Their method the host image was segmented to small blocks and the watermark data is embedded in the low pass wavelet coefficients of each block with one of two methods. Due to low computational complexity of the proposed approach, their algorithm can be implemented in real time. Experimental results demonstrated the imperceptibility of their proposed method and its high robustness against various attacks.

2.4.3. Composite watermarking

Composite watermarking is the process of mixing information of two images of a scene in to a single composite image that is certainly more beneficial and is also far better with regard to visible conception or computer finalizing. The objective of composite watermarking is to combine supporting multi-sensor, multi-temporal and multi-view facts directly into one particular new image. The aim should be to decrease the uncertainty and to limit redundancy in the productivity while maximizing applicable facts. A new singular value decomposition-discrete wavelet transform (SVD-DWT) based composite image watermarking algorithm is presented (Liang, 2006). Watermark is embedded in a high frequency image by singular value decomposition and this is unlike traditional viewpoint that assumes watermarking should be embeds watermarking in low or middle frequency to have good robustness. Experimental evaluation demonstrated that their proposed algorithm is able to withstand a variety of attacks including common geometric attacks.

3. Proposed multiple watermarking techniques

The proposed scheme, DWT-SVD based multiple watermarking techniques using genetic algorithms are adopted. The watermark embedding, extraction and genetic algorithm process are discussed below.

3.1. Successive watermarking

a. The original image and the first watermark are decomposed by two levels using discrete wavelet transforms.
b. The SVD is applied to LL_2 sub-bands of decomposing the original and watermark images.
c. The singular value of watermark image is embedded into singular value of original image by the following equation

$$I_{W1}(i, j) = SI(i, j) + \alpha \times SWI(i, j) \tag{2}$$

   where $SI(i,j)$ is the singular value of original image, $SWI(i,j)$ is the singular value of first watermark image, α is the scaling factor which establish the watermark strength and $I_{WI}(i,j)$ is the singular value of watermarked Image 1
d. The inverse SVD is applied and inverse wavelet transform is performed to get the watermarked Image 1.
e. Similarly, the second watermark is embedded into the watermarked Images 1, to get the watermarked Image 2.
f. The watermarked Image 1 and watermarked Image 2 are decomposed by two levels by using discrete wavelet transforms.
g. The SVD is applied to LL_2 sub-band of watermarked Image 1 and 2.
h. The singular values of second watermark can be extracted as,

$$SW_2(i, j) = \frac{I_{W1}(i, j) - SI(i, j)}{\alpha} \tag{3}$$

i. The inverse SVD is applied to get the second watermark.
j. The first watermark is extracted from the watermarked Image 1 and original image by repeating the above steps.

3.2. Segmented watermarking

a. The original image is segmented into odd-numbered and even-numbered rows & columns images.
b. The odd-numbered and even-numbered rows & columns images are decomposed into two levels by using discrete wavelet transform.
c. The SVD is applied to LL_2 sub-bands of decomposing the odd-numbered rows & columns, even-numbered rows & columns and watermark images.

d. The singular value of first watermark image is embedded into singular value of odd-numbered rows & columns image and the singular value of second watermark image is embedded into singular value of even-numbered rows & columns image by the following equation

$$I_{W1}(i, j) = SI_{odd}(i, j) + \alpha \times SW1(i, j) \tag{4}$$

$$I_{W2}(i, j) = SI_{even}(i, j) + \alpha \times SW2(i, j) \tag{5}$$

where $SI_{odd}(i,j)$ is the singular value of odd-numbered rows & columns image, $SW1(i,j)$ is the singular value of first watermark image, $I_{W1}(i,j)$ is the singular value of odd-numbered rows & columns watermarked image, $SI_{even}(i,j)$ is the singular value of even-numbered rows & columns image, $SW2(i,j)$ is the singular value of second watermark image, $I_{W2}(i,j)$ is the singular value of even-numbered rows & columns watermarked image.

e. The inverse SVD is applied and inverse wavelet transform is performed to get the odd-numbered and even-numbered rows & columns watermarked images.
f. The odd-numbered and even-numbered rows & columns watermarked images are combined to get the final watermarked image.
g. The watermarked image is segmented into two images such as odd-numbered and even-numbered rows & columns watermarked images.
h. The odd-numbered and even-numbered rows & columns watermarked images are decomposed into two levels by using discrete wavelet transform.
i. The SVD process is applied to LL_2 sub band of decomposing the odd-numbered and even-numbered rows & columns watermarked images.
j. The singular values of first and second watermark image can be extracted as follows:-

$$SW1(i, j) = \frac{I_{W1}(i, j) - SI_{odd}(i, j)}{\alpha} \tag{6}$$

$$SW2(i, j) = \frac{I_{W1}(i, j) - SI_{even}(i, j)}{\alpha} \tag{7}$$

k. The inverse SVD is applied to get the first and second watermarks.

3.3. Composite watermarking

a. Mix information of first and second watermark image into a single composite watermark image.
b. The original image and the composite watermark image are decomposed into two levels using discrete wavelet transforms.
c. The SVD is applied to LL_2 sub-bands of decomposing the original and composite watermark image.
d. The singular value of composite watermark image is embedded into singular value of the original image by the following equation

$$I_W(i, j) = SI(i, j) + \alpha \times SW(i, j) \tag{8}$$

where $SI(i,j)$ is the singular value of the original image, $SW(i,j)$ is the singular value of composite watermark image, $I_W(i,j)$ is the singular value of watermarked image.

e. The inverse SVD is applied and inverse wavelet transform is performed to get the watermarked image.
f. The watermarked image and original image are decomposed into two levels by using the discrete wavelet transforms.
g. The SVD is applied to LL_2 sub-band of watermarked image and original image.
h. The singular values of composite watermark can be extracted as,

$$SW(i, j) = \frac{I_W(i, j) - SI(i, j)}{\alpha} \tag{9}$$

i. The inverse SVD is applied to get the composite watermark.
j. From the composite watermarking image, the first and second watermark images are obtained.

3.4. Genetic algorithms process

The objective of genetic algorithm process is the optimization of imperceptibility and robustness. The steps involved in the genetic algorithms process in the current work are briefly mentioned as follows:-

a. Initialize the parameters: crossover rate, mutation rate, initial population size and number of iterations.
b. Generate randomly the initial population specified by performing the watermark embedding and extraction process, as the attacked watermarked image and extracted watermark is generated for each individual.
c. The selection of the fitness function is based on the magnitude of imperceptibility and robustness as follows:

$$Fitness\ Function = PSNR + (100 \times NC1) \tag{10}$$

$$Fitness\ Function = PSNR + (100 \times NC2) \tag{11}$$

where *PSNR* is the peak signal to noise ratio, *NC1* is the normalized correlation1, *NC2* is the normalized correlation2. In Eqs. (10) and (11), if the value of 100 is multiplied with NC, the fitness value increases more by increasing the value of NC rather than PSNR. So, optimization of robustness takes place for a given value of imperceptibility. The robustness value has a positive correlation with the fitness function.

$$Fitness\ Function = NC + (100 \times PSNR) \tag{12}$$

Here, the NC value is the average value of two watermarks. In Eq. (12), if the value of 100 is multiplied with PSNR, the fitness value increases more by increasing the value of PSNR rather than NC. So, optimization of imperceptibility takes place for a given value of robustness. The imperceptibility value has a positive peak signal to noise ratio with the fitness function.

d. Select the best fitness value and the best individuals
e. Generate randomly the new population specified by performing the crossover, mutation functions on the selected individuals.
f. Repeat the above steps until a predefined iteration is reached.

4. Results

In this paper, a multiple image watermarking technique is proposed based on wavelet domain and singular value decomposition using genetic algorithms for colour images. Fig. 3(a)–(c) shows the 512×512 original sizes of Lena, medical and military images respectively. Moreover, 48×48 size colour logo is used as watermark images that are shown in Fig. 3(d) and (e).

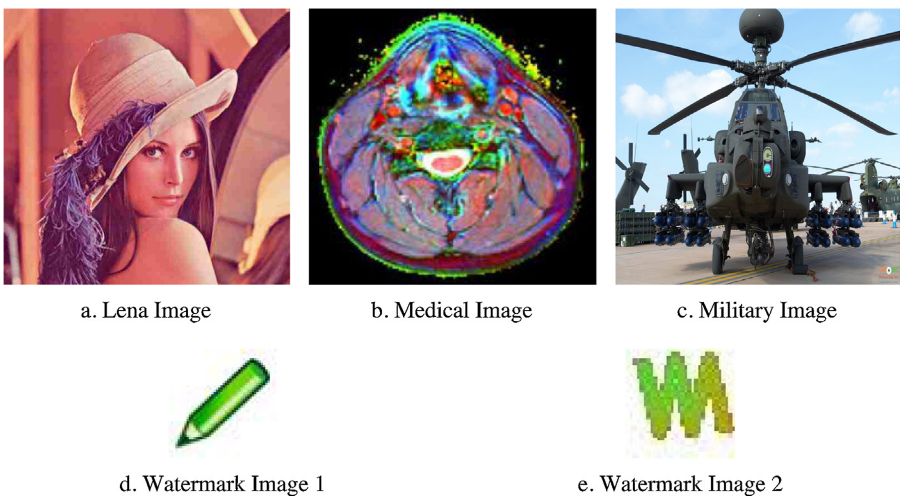


Fig. 3. Test images. (a) Lena image, (b) Medical image, (c) military image, (d) watermark Image 1 and (e) watermark Image 2.

4.1. Performance evaluation

The performance of watermarking technique can be evaluated by considering the peak signal to noise Ratio (PSNR). The PSNR is used to measure the quality of watermarked image, which is given by

$$PSNR(dB) = \frac{10\log_{10} 255^2}{MSE} \tag{13}$$

where MSE is the Mean Square Error. Normalized correlation (NC) is used to measure the quality of watermarks after extraction. The NC between the extracted watermark $W'(i,j)$ and the embedded watermark $W(i,j)$ is defined as

$$NC = \frac{\sum_{i=1}^{H}\sum_{j=1}^{L} W(i,j) \times W'(i,j)}{\sum_{i=1}^{H}\sum_{j=1}^{L}[W(i,j)]^2} \tag{14}$$

where, $W(i, j)$ is the embedded watermark, $W'(i, j)$ is the extracted watermark.

4.2. Single watermarking techniques against attacks

To prove the robustness, the watermarked image is tested with selected attacks such as geometric attacks (rotation, translation, cropping, row–column blanking and row–column copying), removal attacks (median filtering, wiener filtering, JPEG compression) and common image processing attacks (salt & pepper noise, Gaussian noise, speckle noise, sharpening, smoothing). Table 1 shows the watermarked images and extracted watermarks on different image watermarking methods. Table 2 shows the PSNR and NC of single watermarking techniques for Lena image.

4.3. Multiple watermarking techniques against attacks

To prove the robustness, the watermarked images are tested with selected attacks on multiple watermarking techniques. Tables 3 and 4 show the performance of PSNR and NC values on multiple watermarking techniques (successive, segmented and composite) for Lena colour image.

4.4. Optimization on single watermarking techniques against attacks

A multiple watermarking technique is proposed based on DWT and SVD using genetic algorithms. Table 5 shows optimization of PSNR and NC values on single watermarking techniques for Lena colour image. The parameters are chosen by trial and error, from that the parameters which have furnished the best results are presented in the paper. The related parameters for the experiments using a genetic tool are as follows: the population size is 20, the number of variables is 2, the maximum number of generation is 5, the probability of crossover is 0.8, and the probability of mutation is 0.2.

4.5. Optimization on multiple watermarking techniques against attacks

Tables 6 and 7 show the optimization of PSNR and NC values on multiple watermarking techniques for Lena colour image.

5. Discussion

A digital image multiple successive watermarking scheme based on the wavelet transform is proposed (Mohananthini and Yamuna, 2013). The successive watermarking method is useful in the applications, where extraction of one watermark should depend on the extract of other watermark. The experimental results show that their proposed method has good imperceptibility on watermarked images and against attacks. Comparison of multiple watermarking techniques (successive and segmented) using discrete wavelet transforms is proposed (Mohananthini et al., 2013). Their proposed scheme shows good performance on original colour images in terms of imperceptibility and the segmented watermarking has better visual quality on watermarked image when compared with successive watermarking.

Table 1
PSNR and NC values for watermarked images and extracted watermarks on different image watermarking methods.

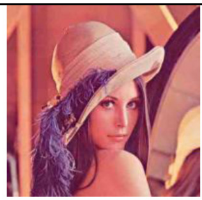
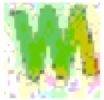
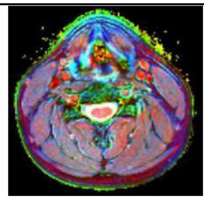
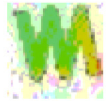
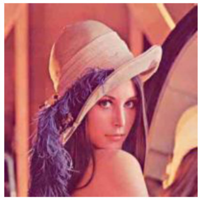
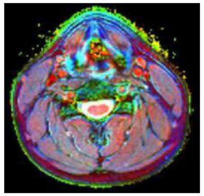
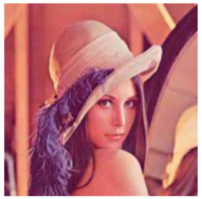
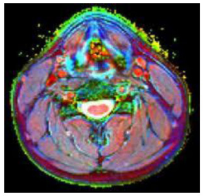
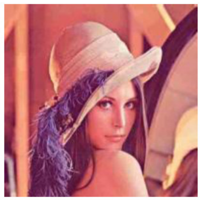
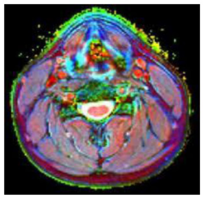
Methods	Single Watermarking					
	Lena Image		Medical Image		Military Image	
	PSNR (dB)	NC	PSNR (dB)	NC	PSNR (dB)	NC
original image + watermark	 41.7268	 0.9675	 41.7166	 0.9675	 41.7528	 0.9674
(original image with DWT) + watermark	 50.9085	 0.6586	 50.9005	 0.6586	 50.9096	 0.6586
(original image with SVD) + (watermark with SVD)	 42.1390	 1.00	 42.0294	 1	 42.1618	 1
(original image with DWT and SVD) + (watermark with SVD)	 44.3211	 1	 44.3427	 1	 44.6307	 1

Table 2
PSNR and NC values on single watermarking techniques against attacks.

Attacks	Single watermarking (PSNR)	Extracted watermark
Salt & pepper noise at the density of 3%	20.3472	0.8081
Gaussian noise of variance 1%	19.2428	0.9089
Speckle noise of variance 0.005	27.9465	0.9968
Median filtering for 3 × 3 filter size	34.9266	0.9928
wiener filtering for 3 × 3 filter size	20.5902	0.6731
Gaussian blur	29.2428	0.9089
Translation	16.9247	0.5150
Cropping	11.1938	0.3354
Rotation at 60°	10.1057	0.1351
JPEG compression with quality of 20	36.3849	0.8469
Sharpening	25.6618	0.8101
Smoothing	41.1692	0.9989
Row–column blanking	11.9599	0.6670
Row–column copying	18.7932	0.8358

In our previous work the successive and segmented watermarking algorithm was analyzed (Mohananthini and Yamuna, 2013; Mohananthini et al., 2013). The present work is added with SVD-based method, composite watermarking, and optimization.

The combination of original image with DWT and SVD along with watermark displays high imperceptibility and robustness. While they are treated alone, the original image with DWT or original image with SVD with watermark shows varying high and low values in either cases. Thus, demonstrating the importance of taking DWT and SVD in the original image for watermarking is important.

Regarding the analysis of multiple watermarking techniques, the composite watermarking achieves high PSNR when compared with successive and segmented watermarking technique. The successive watermarking technique achieves more robustness for wiener filtering, rotation, row–column blanking and row–column copying. The segmented watermarking technique achieves more robustness for salt & pepper noise, median filtering, translation, JPEG compression and smoothing. The composite watermarking technique achieves more robustness for sharpening, speckle noise, cropping, JPEG compression and smoothing. From the results, it is observed that the multiple watermarking techniques achieve more robustness when compared with the single watermarking. In multiple watermarking algorithms, the image quality is degraded with embedding a new watermarking into the image. For solving this problem, multiple watermarking is tested using the genetic algorithms (Gas).

Table 3
PSNR values on multiple watermarking techniques against attacks.

Attacks	Successive watermarking (PSNR)	Segmented watermarking (PSNR)	Composite watermarking (PSNR)
Without attacks	37.9677	38.0639	43.8860
Salt & pepper noise at the density of 3%	20.2435	20.2656	20.3467
Gaussian noise of variance 1%	20.2283	20.2222	20.2497
Speckle noise of variance 0.005	27.6204	27.6107	27.9337
Median filtering for 3 × 3 filter size	33.4053	33.4168	34.8667
Wiener filtering for 3 × 3 filter size	20.5546	20.5544	20.5721
Translation	16.7352	15.8991	16.7675
Cropping	10.8597	10.6319	10.9140
Rotation at 60°	9.8067	8.5919	9.8319
JPEG compression with quality of 20	35.3364	35.2048	36.3708
Sharpening	25.3802	23.9824	25.5756
Smoothing	37.0359	36.4034	40.9839
Row–column blanking	11.9525	11.9524	11.9596
Row–column copying	18.6990	18.7024	18.7836

Table 4
NC values on multiple watermarking techniques against attacks.

Attacks	Successive watermarking		Segmented watermarking		Composite watermarking	
	Extracted watermark		Extracted watermark		Extracted watermark	
	1	2	1	2	1	2
Without attacks	1	1	1	1	1	1
Salt & pepper noise at the density of 3%	0.8120	0.9918	0.8856	0.9978	0.8291	0.7959
Gaussian noise of variance 1%	0.7891	0.9906	0.8769	0.9743	0.8468	0.8306
Speckle noise of variance 0.005	0.9980	1	0.9965	0.9992	0.9998	0.9999
Median filtering for 3 × 3 filter size	0.9916	1	0.9993	1	0.9982	1
Wiener filtering for 3 × 3 filter size	0.6766	0.9987	0.8142	0.7679	0.7060	0.7476
Translation	1	0.4717	0.9586	0.9359	0.5970	0.6367
Cropping	0.8410	0.9427	0.3374	0.3600	0.9412	0.8839
Rotation at 60°	0.1364	0.9736	0.1240	0.1187	0.1235	0.1883
JPEG compression with quality of 20	1	0.9652	1	1	1	1
Sharpening	0.8000	1	0.9078	0.9655	0.9334	0.9648
Smoothing	0.9989	1	1	1	1	1
Row–column blanking	0.6670	0.9835	0.6686	0.6705	0.6673	0.6707
Row–column copying	0.8358	0.9956	0.9211	0.9323	0.9433	0.9046

Table 5
Optimization of PSNR and NC values on single watermarking techniques against attacks.

Attacks	Single watermarking (PSNR)	Extracted watermark
Salt & pepper noise at the density of 3%	21.4387	0.8158
Gaussian noise of variance 1%	21.2736	0.9149
Speckle noise of variance 0.005	28.9667	1
Median filtering for 3 × 3 filter size	35.9287	0.9932
wiener filtering for 3 × 3 filter size	21.6475	0.6864
JPEG compression with quality of 20	38.2576	0.9162

In this present work, the following are the outcomes of the chosen parameters in the genetic algorithm which has displayed best results. The genetic algorithm is utilized for solving the optimization problem in watermarking. In the watermarking algorithm PSNR and NC are the two important characteristics parameters. These two parameters must be as large as possible for a superior watermarking algorithm. However PSNR and NC are associated in such way that maximization of PSNR reduces the value of NC. Hence, the watermarking algorithm is described with parameters and genetic algorithm are used to find the best values of parameters to obtain a specified performance of the watermarking system in terms of PSNR and NC.

Simulation results show that the proposed scheme is effective by checking the fitness function in GA. This includes both factors related to the robustness under attacks (salt & pepper noise, Gaussian noise, speckle noise, JPEG

Table 6
PSNR values on optimization of multiple watermarking techniques against attacks.

Attacks	Successive watermarking (PSNR)	Segmented watermarking (PSNR)	Composite watermarking (PSNR)
Salt & pepper noise at the density of 3%	21.3882	21.3710	21.4216
Gaussian noise of variance 1%	21.2456	21.2425	21.2750
Speckle noise of variance 0.005	28.6274	28.9107	28.9469
Median filtering for 3 × 3 filter size	34.5579	34.5685	35.9431
Wiener filtering for 3 × 3 filter size	21.5912	21.5878	21.6498
JPEG compression with quality of 20	37.4234	37.7035	38.2083

Table 7
NC values on optimization of multiple watermarking techniques against attacks.

Attacks	Successive watermarking (NC)		Segmented watermarking (NC)		Composite watermarking (NC)	
	Extracted watermark1	Extracted watermark2	Extracted watermark1	Extracted watermark2	Extracted watermark1	Extracted watermark2
Salt & pepper noise at the density of 3%	0.8123	1	0.9073	1	0.8503	0.8063
Gaussian noise of variance 1%	0.8104	1	0.8864	0.9873	0.8920	0.8716
Speckle noise of variance 0.005	0.9998	1	0.9985	0.9998	1	1
Median filtering for 3 × 3 filter size	0.9932	1	0.9997	1	1	1
Wiener filtering for 3 × 3 filter size	0.6901	1	0.8346	0.7803	0.7266	0.7596
JPEG compression with quality of 20	1	1	1	1	1	1

Table 8
Comparison to existing scheme (Ghafoor and Imran, 2012).

Attacks	Existing method (Ghafoor and Imran, 2012)	Proposed method
Salt & pepper noise	0.400	0.8081
Gaussian noise	0.417	0.9089
Cropping	0.273	0.3354
Sharpening	0.263	0.8101
Median filtering	0.612	0.9932

compression, median filtering and wiener filtering) and the improvement in the watermarked image quality with genetic algorithms.

5.1. Comparison to existing scheme

To prove the effectiveness of the proposed scheme, the robustness (NC) value is compared with the SVD-based single watermarking schemes (Ghafoor and Imran, 2012). The authors proposed the watermark which is embedded into the singular values of the discrete wavelet transform sub-band in the original image. The NC values are listed in Table 8, and it is evident that the robustness performance of the proposed scheme is superior to the existing one for Lena image (scaling factor value is 0.03).

To prove the effectiveness of multiple watermarking techniques, the robustness is compared with existing method (Jagadeesh et al., 2012). An Image watermarking scheme based on Singular Value Decomposition, Quantization and Genetic algorithm are presented in Jagadeesh et al. (2012). In their SVD based single watermarking algorithm has a drawback of robustness. For resolving this problem, the DWT–SVD based multiple watermarking techniques using genetic algorithm is presented. The values are listed in Table 9, it is evident that the robustness of multiple watermarking techniques is superior to existing method for the number of generation 5.

Table 9
Comparison to existing method (Jagadeesh et al., 2012).

Attacks	Existing method (Jagadeesh et al., 2012)	Proposed method					
		Successive watermarking Extracted watermarks		Segmented watermarking Extracted watermarks		Composite watermarking Extracted watermarks	
		1	2	1	2	1	2
Salt & pepper noise	0.6578	0.8121	0.9925	0.8896	0.9989	0.8437	0.8060
Median filtering	0.6578	0.8121	0.9925	0.8896	0.9989	0.8437	0.8060
JPEG compression	0.7499	1	0.9870	1	1	1	1

6. Conclusion

In this paper, the optimization of multiple watermarking techniques using genetic algorithms has been presented. The embedding and extraction process uses the multi resolution analysis of wavelet transform and singular value decomposition. In multiple watermarking techniques, the composite watermarking achieves high imperceptibility when compared with the successive and segmented watermarking technique. The experimental result shows that the multiple watermarking techniques achieve more robustness when compared with the single watermarking technique. The optimization is to maximize the performance of peak signal to noise ratio (PSNR) and normalized correlation (NC). The experimental result demonstrates the presented work achieves good imperceptibility and robustness against attacks using genetic algorithms. The performance of the proposed scheme is analyzed by comparing it with the existing scheme.

Acknowledgements

The authors wish to record the sincere thanks to the Department of Electrical Engineering, Annamalai University for their support to carry out this investigation.

References

Anoop Suraj, A., Mathew Francis, Kavya, T.S., Nirmal, T.M., 2014. Discrete wavelet transform-based image fusion and de-noising in FPGA. J. Elect. Sys. Infor. Tech. 1 (1), 72–81.

Dehghan, H., Ebrahim Safavi, S., 2010. Robust image watermarking in the wavelet domain for copyright protection. ICEE, Jan 4, Submitted.

Frikken, K., Atallah, M., 2003. Cropping-resilient segmented multiple watermarking, algorithms and data structure. Lect. Notes Comput. Sci. 2748, 231–242.

Ghafoor, A., Imran, M., 2012. A non-blind color image watermarking scheme resistant against geometric attacks. Radio Engg. 21 (4), 1246–1251.

Jagadeesh, B., Rajesh Kumar, P., Chenna Reddy, P., 2012. Genetic algorithm approach for singular value decomposition and quantization based digital image watermarking. Int. J. Eng. Res. App. 2 (2), 1229–1235.

Jaiswal, R.J., Patil, N.N., 2012. Multiple watermarking for text documents: a review. Wor. J. Sci. Tech. 2 (3), 176–179.

Kallel, M., Bouhlel, M.S., Lapayre, J.C., 2010. Use of multi-watermarking schema to maintain awareness in a teleneurology diagnosis platform. Radio Engg. 19 (1), 68–73.

Kampfer, A.M., Stogner, H., Uhl, A., 2006. Multiple re-watermarking scenarios. In: Proceedings of the 13th International Conference on Systems, Signals, and Image Processing (IWSSIP), London, United Kingdom, pp. 53–56.

Kumsawat, P., Attakitmongcol, K., 2004. Wavelet-based image watermarking using genetic algorithm. In: International Conference on Knowledge-Based Intelligent Information and Engineering Systems, Wellington, New Zealand, pp. 40–46.

Liang, Liu, 2006. A new SVD-DWT composite watermarking. In: Eighth International Conference on Signal Processing, Beijing (4).

Mark, D., Uhl, A., Wernisch, H., 2007. Experimental study on watermark interference in multiple re-watermarking,. In: Proc. SPIE 6505, Security, Steganography, and Watermarking of Multimedia Contents IX, p. 6505.

Mohananthini, N., Yamuna, G., 2013. Multiple successive watermarking scheme based on wavelet transform. Int. J. Emer. Tren. Tech. Comp. Sci. 2 (2), 416–420.

Mohananthini, N., Yamuna, G., Vivek, R., 2013. Comparison of successive and segmented watermarking techniques for colour images. In: National Conference on Emerging Trends in Information & Communication Technology, Rajkot, Gujarat, pp. 13–16.

Nantha Priya, N.R., Lenty Stuwart, S., 2010. Robust feature-based image watermarking process. Int. J. Comp. Appl. 4 (5), 13–16.

Nasir, I., Weng, Y., Jiang, J., 2008. Novel multiple spatial watermarking technique in color images. In: IEEE Fifth International Conference on Information Technology: New Generations, Las Vegas, NV, pp. 777–782.

Sheppard, N.P., Shafavi Naini, R., Ogunbona, P., 2001. On multiple watermarking. In: Proceedings of the ACM Multimedia and Security Workshop (MMSW), New York, NY, USA, pp. 3–6.

Sleit, A., Abusharkh, S., Etoom, R., Khero, Y., 2012. An enhanced semi-blind DWT–SVD-based watermarking technique for digital images. The Imag. Sci. J. 60 (1), 29–38.

Wheeler, G.E., Sheppard, N.P., Safavi-Naini, R., 2004. Weighted segmented digital watermarking. In: Third International Workshop on Digital Watermarking, Seoul, South Korea, pp. 89–100.