DOI: 10.21917/ijsc.2011.0038

IMPLEMENTATION OF GENETIC ALGORITHM FOR A DWT BASED IMAGE WATERMARKING SCHEME

P. Surekha[1] and S. Sumathi[2]
[1,2]*Department of Electrical and Electronics Engineering, PSG College of Technology, Tamil Nadu, India*
E-mail: [1]surekha_3000@yahoo.com

Abstract
This paper proposes a new optimization method for digital images in the Discrete Wavelet Transform (DWT) domain. Digital image watermarking has proved its efficiency in protecting illegal authentication of data. The amplification factor of the watermark is the significant parameter that helps in improving the perceptual transparency and robustness against attacks. The tradeoff between the transparency and robustness is considered as an optimization problem and is solved by applying Genetic Algorithm. The experimental results of this approach prove to be secure and robust to filtering attacks, additive noise, rotation, scaling, cropping and JPEG compression. The Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), and computational time are evaluated for a set of images obtained from the Tampere University of Technology, Finland using the MATLAB R2008b software.

Keywords:
DWT, Genetic Algorithm, Robustness, Transparency, PSNR, MSE, Computational Time

1. INTRODUCTION

The need for digital image copyright protection methods has become a fundamental essence in multimedia applications due to the rapid growth of unauthorized access and reproduction of original digital objects like audio, video and images. Thus multimedia data protection is one of the major challenges and has drawn the attention of several researchers towards the development of protection approaches. Digital watermarking is one among the several protection methods which embeds a secret message or valuable information (watermark) within a host image, [3] video or an audio to prevent from unauthorized access. The watermark can either be a random signal, an organization's trademark symbol, or a copyright message for copy control and authentication [2].

Embedding information in a robust and reliable way has lead to the application of frequency domain techniques like discrete cosine or the discrete wavelet transforms. The watermarks are added to the transform coefficients of the image instead of modifying the pixels, thus making it difficult to remove the embedded watermark. Nevertheless, robust watermarking in spatial domain can be achieved at the cost of explicitily modeling the local image characteristics. However, these features can be obtained with much ease in the frequency domain.

The two major properties – robustness and imperceptibility are essential in preserving the security of images from unauthorized usage. The ability to detect the watermark image after application of common signal processing distortions is known as robustness. The embedded watermarks are imperceptible both perceptually as well as statistically and do not alter the aesthetics of the multimedia content that is watermarked. While embedding the watermark into the host image, the strength is maintained without considering the local distribution of the host image. Due to this, certain unnecessary perceptible objects appear in the smooth regions. These deformations decrease as the watermark strength or the amplification factor is reduced. During this process, however, the robustness cannot be achieved. Hence the watermark has to be perceptually shaped with suitable amplification values for DWT sub-bands. The choice of amplification factors can be viewed as an optimization problem and solved using Genetic Algorithm.

M. Ketcham et al., [9] have proposed an innovative DWT watermarking scheme based on Genetic Algorithms for audio signals. The optimal localization and intensity were obtained using GA and the method was found robust against cropping, low pass filter and additive noise. Ali Al-Haj et al. [11] described an imperceptible and robust digital image watermarking scheme based on a combination of DWT and DCT. Similarly, Franco et al.[5], provided a DWT based technique for evaluation of fidelity and robustness. These algorithms were capable of extracting the watermark but suffered from the problems of unsatisfactory values of fidelity and robustness to various attacks concentrated in these papers. Zhicheng Wei et al [17] proposed an algorithm that yielded a watermark that is invisible to human eyes and robust to various image manipulation, and the results showed that only some specific positions were the best choices for embedding the watermark. The authors applied GA to train the frequency set for embedding the watermark and compared their approach with the Cox's method [10] to prove robustness. The analysis of GA was restricted to JPEG compression attack in this method. In [18], Jin Cong et al proposed a scheme that does not require the original image because the informations from the shape specific points of the original image were been memorized by the neural network. This scheme applies the shape specific points technique and features point matching method by genetic algorithm for resisting geometric attacks. G. Boato [19] et al. proposed a new flexible and effective evaluation tool based on genetic algorithms to test the robustness of digital image watermarking techniques. Given a set of possible attacks, the method finds the best possible un-watermarked image in terms of Weighted Peak Signal to Noise Ratio (WPSNR). Chin-Shiuh Shieh [14] proposed an innovative watermarking scheme based on genetic algorithms (GA) in the transform domain considering the watermarked image quality.

In this paper, Genetic Algorithm is used to adaptively optimize the watermark amplification factor at every chosen DWT sub-band that will improve the imperceptibility and robustness of the watermark against attacks. The proposed technique uses the normalized correlation of the cover image and the watermarked images as the basis for evaluating the fitness function. The fitness function serves as the objective function that is to be optimized and searches the population consisting of appropriate embedding locations of the watermark within the cover image.

2. DIGITAL IMAGE WATERMARKING

The concept of digital image watermarking is to add a watermark image into the host image to be watermarked such that the watermark image is unobtrusive and secure, which is capable of recovering partially or completely using appropriate cryptographical measures. A perceptibility criteria is applied to ensure the imperceptibility of the changes caused due to the watermark embedding, which may be either implicit or explicit, fixed or adaptive to the host data. As a result of this, the samples such as the pixels or the transform coefficients responsible for the watermarking can only be customized by a relatively small amplitude [9].

The novelty of the Discrete Wavelet Transform (DWT) algorithm resides in the manner the robustness and the invisibility are improved on the watermark image [5]. The major objective of the wavelet transform is to decompose the input image in a hierarchical manner into a series of successive low frequency sub bands and their associated detailed sub bands. The low frequency sub band and the detailed sub bands contain the information required to reconstruct the low frequency approximation at the next higher resolution level [9]. Such kind of an excellent space and frequency energy compaction is provided by wavelet techniques and hence DWT has received an incredible interest in several signal and image processing applications.

The watermark amplification factor is modulated based on the local image characteristics, in a pixel by pixel manner. Most of the DWT based watermarking concepts concentrate on the sub-bands or block based techniques, whereas, here the watermark amplification factor is adjusted pixelwise. As a consequence, the grey-level sensibility, isofrequency masking, non-isofrequency masking, noise sensibility etc., are taken into account [5]. Due to the excellent spatial-frequency localization property of DWT, it is easier to identify the image areas in which a disturb can be hidden more likely [2]. In contrast to the DFT/DCT watermarking techniques, if a DWT coefficient is modified, only the region of the image corresponding to that coefficient will be modified.

2.1 WATERMARK EMBEDDING

Let the image to be watermarked be initially decomposed through DWT into four levels. Let B_l^x denote the sub-band at level l = 0,1,2,3 and the orientation $x \in \{0, 1, 2,3\}$ as shown in Fig.1.

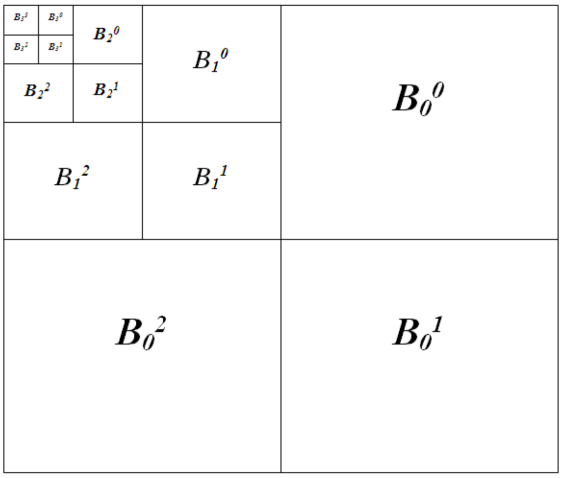


Fig.1. Decomposition of an image into four levels through DWT technique

The watermark is inserted into the three detail bands at level 0 by modifying the wavelet coefficients. The choice of inserting the watermark into this level was based on experimental tests such that the robustness and invisibility are compromised. The result of insertion is poor, resulting in a low robustness, but given the low visibitly of disturbs added, a higher watermark amplification factor is allowed thus compensating for the high fragility.

The watermark information of dimension M_1 x M_2 is transformed into a unidimensional antipodal sequence $d(i,j) \in \{+1,-1\}$, where M_1 and M_2 indicate the number of rows and columns. The input image is decomposed into four levels and all the obtained wavelet coefficients at the chosen sub band are divided into n segments such that $n = M_1M_2$. The average value of each segment is computed and removed from all of the wavelet coefficients to facilitate the embedding process. The sub band coefficients are then modified according to,

$$\tilde{B}_l^x(i,j) = B_l^x(i,j) + \alpha\, w^x(i,j) d^x(i,j)$$

where, α is the global parameter accounting for the watermark amplification and $w^x(i, j)$ is the weighting function that considers the local sensitivity of the image to noise. The weighing function is chosen such that, $w^x(i, j) = q^x{}_l(i,j)/2$, where $q^x{}_l(i,j)$ is the quantization step for a DWT coefficient at location (i,j). Disturbs having a greater value than $q^x{}_l(i,j)/2$ are assumed perceivable and those below are not. This kind of an approach allows to add each DWT coefficient to the maximum unperceivable watermark level [5]. The IDWT process is then applied to the DWT transformed image including the modified sub bands to generate the watermarked host image.

2.2 WATERMARK DETECTION

The DWT approach applied is a blind process and hence does not require the original image for watermark detection. The DWT is applied to the watermarked image and the sub band to which the watermark was embedded is chosen. The correlation between the original watermark and the extracted watermark is then computed as

$$\rho = \frac{\sum_{i=1}^{N} I.I'}{\sqrt{\sum_{i=1}^{N} I.^2}\sqrt{\sum_{i=1}^{N} .I'^2}}$$

where, I and I' represent the original and the extracted watermarks respectively. Each of the computed correlation value is then compared with a mean correlation. If the computed value is greater than the mean then the extracted watermark bit is considered as 0, else if the computed value is lesser then it is taken as 1 [11]. Finally the watermark image is reconstructed using the extracted bits and the similarity between the original and the watermarked image is determined.

3. GENETIC ALGORITHM

Genetic Algorithm (GA) is a heuristic search technique for determining the global maximum/minimum solutions for problems in the area of evolutionary computation [19]. Any optimization problem is modeled in GA by defining the chromosomal representation, fitness function, and application of the GA operators. The GA process begins with a few randomly selected genes in the first generation, called population. Each individual in the population corresponding to a solution in the problem is called chromosome, which consists of finite length strings. The objective of the problem, called fitness function, is used to evaluate the quality of each chromosome in the population. Chromosomes that possess good quality are said to be fit and they survive and form a new population of the next generation. The three GA operators, selection, crossover, and mutation, are applied to the chromosomes repeatedly to determine the best solution over successive generations [14]. In digital image watermarking using the DWT domain, the value of the watermark amplification factor α, balances the imperceptibility and the robustness. This balance is obtained though the optimization process, achieved through Genetic Algorithm.

4. IMPLEMENTATION

In digital image watermarking, the population is initialized by choosing a set of random positions in the cover image and inserting the watermark image into the selected positions. The optimal solutions for digital watermarking using DWT are obtained based on two key factors: the DWT sub-band and the value of the watermark amplification factor [11]. The GA algorithm searches its population for the best solution with all possible combinations of the DWT sub-bands and watermark amplification factors. The genetic algorithm procedure will attempt to find the specific sub-band that will provide simultaneous perceptual transparency and robustness. In order to improve the robustness of the algorithm against attacks, the watermark strength or the amplification factor α should be optimized, but this factor varies on each sub-band.

The input image is first encoded through a binary string encoding scheme. The ones in the string indicate the position of the watermarks. Once all the chromosomes are encoded the objective function is evaluated. The objective function also known as the fitness function is a combination of the Peak Signal to Noise Ratio (PSNR) and the correlation factor ρ (α * NC) and is given as,

$$\text{Fitness function} = \text{PSNR} + 100 * \rho$$

where, PSNR is computed as,

$$PSNR = 10\log\left(\frac{MAX_i^2}{MSE}\right)$$

where, MSE denotes the mean square error between the original and watermarked image and MAX_i = the maximum pixel value of the image which is generally 255 in the experiment since pixels were represented using 8 bits per sample.

Here, the correlation factor is the product of Normal Correlation (NC) and the watermark strength factor α. The fitness function increases proportionately with the PSNR value, but NC is the key factor contributing to the robustness and ultimately, the fitness value increases with the robustness measure. The correlation factor ρ has been multiplied by 100 since its normal values fall in the range 0 ~ 1, where as PSNR values may reach the value of 100.

The fitness function is evaluated for all the individuals in the population and the best fit individual along with the corresponding fitness value are obtained. Genetic operators like crossover and mutation are performed on the selected parents to produce new offspring which are included in the population to form the next generation. The entire process is repeated for several generations until the best solutions are obtained. The correlation factor ρ measures the similarity between the original watermark and the watermark extracted from the attacked watermarked image (robustness). The procedure for implementing digital image watermarking using GA is shown below. The flow chart of the procedure is also illustrated in Fig.2.

Procedure:

- Initialize watermark amplification factor α between 0 and 1, initialize the population size, number of iterations, crossover rate, mutation rate.
- Generate the first generation of GA individuals based on the parameters specified by performing the watermark embedding procedure. A different watermarked image is generated for each individual.
- ***While*** max iterations have not reached ***do***
    - Evaluate the perceptual transparency of each watermarked image by computing the corresponding PSNR value
    - Apply a common attack on the watermarked image.
    - Perform the watermark extraction procedure on each attacked watermark image.
    - Evaluate robustness by computing the correlation between the original and extracted watermarks
    - Evaluate the fitness function for the PSNR and ρ values
    - Select the individuals with the best fitness values.
    - Generate new population by performing the crossover and mutation functions on the selected individuals.
- ***End While***

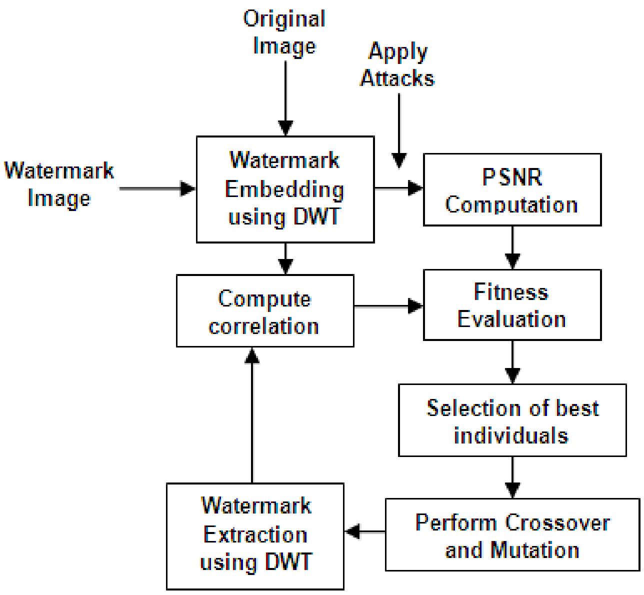


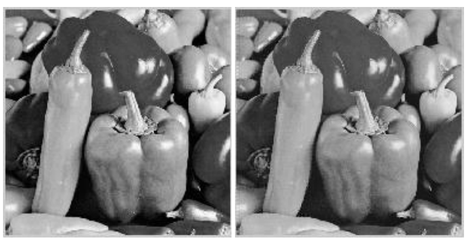
Fig.2. GA based Optimization Procedure

5. EXPERIMENTAL RESULTS

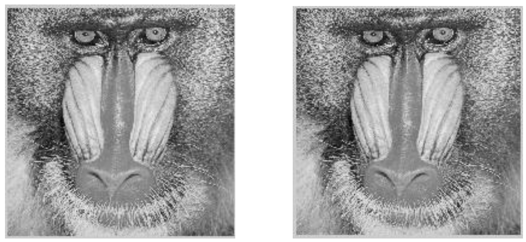
Extensive experiments were conducted to prove the validity of the Genetic Algorithm approach to digital image watermarking. Experiments aimed at assessing the performance system both from the point of view of watermark imperceptibility and from the point of view of robustness; in particular the system has demonstrated to be resistant to several attacks like JPEG compression, median filtering, average filtering, Gaussian noise addition, rotation, rotation plus scaling, rotation plus scaling plus cropping and rotation plus scaling plus JPEG compression. The watermark amplification factor α was optimized in the interval [0,1]. A series of experiments were performed by varying several parameters in GA, like number of generations, population size, crossover probability, and mutation probability. The analysis was performed on six images i.e. Peppers, Mandrill, Lena, Barbara, Boat and Cameraman and the PSNR, MSE, Robustness measure, computational time are evaluated. These images were taken as the cover images and best.bmp (Fig. 3) of size 60 x 24 was taken as the watermark. Fig. 4 shows the set of original and the corresponding watermarked images.

Fig.3. Watermark to be hidden

Peppers.png

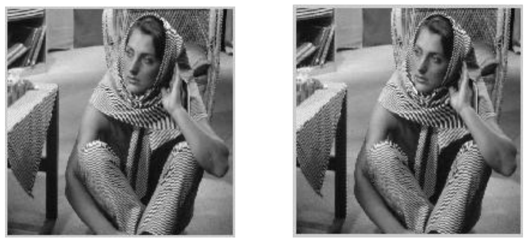


Mandrill.png



Lena.png

Barb.png



Boat.png

Cameraman.jpg

Fig.4. Original (left) and Watermarked (right) Images

5.1 VARIATION IN THE NUMBER OF GENERATIONS

With a population size of 120, the number of generations were varied starting from 10 to 40 with the interval of 10 to optimize the watermark amplification factor and thus compute the PSNR, MSE, Robustness (Normalized Cross Correlation (NCC)) and computational time. The crossover probability was chosen to be 0.7 and the mutation probability was chosen as 0.02 based on previous experiments [14], and maintained constant for variation in the number of generations. From Table.1, it is observed that the maximum PSNR and efficient fitness is obtained at 10 generations for peppers, mandrill, and lena images, while for Barbara and boat it is obtained at 20 generations and for cameraman at 30 generations. The watermark amplification factor was set to 0.12 which was found the optimal during the GA runs.

Table.1. Effect of number of generations on images

Images	No. of Gen	MSE	PSNR	NCC	Fitness	Comp Time
Peppers	10	**5.9415**	**40.39184**	0.9965	**52.34984**	14.12
	20	6.1214	40.2623	0.9982	52.2407	15.76
	30	6.9732	39.69648	0.9971	51.66168	16.92
	40	7.4712	39.3969	0.9952	51.3393	18.01
Mandrill	10	**5.1172**	**41.04048**	0.9892	**52.91088**	13.9
	20	5.3783	40.82435	0.991	52.71635	14.56
	30	5.6125	40.63924	0.9987	52.62364	15.25
	40	5.9372	40.39499	0.9954	52.33979	15.98
Lena	10	**3.3476**	**42.88347**	0.9978	**54.85707**	13.5
	20	3.9899	42.12118	0.9895	53.99518	13.98
	30	4.1024	42.00042	0.9864	53.83722	14.22
	40	4.2921	41.80411	0.9778	53.53771	15.02
Barbara	10	4.052	42.05411	0.9912	53.94851	13.87
	20	**3.9866**	**42.12478**	0.9945	**54.05878**	14.06
	30	4.0256	42.0825	0.989	53.9505	14.67
	40	4.1244	41.9772	0.9856	53.8044	15.15
Boat	10	4.2378	41.8594	0.9376	53.1106	14.18
	20	**4.0267**	**42.08131**	0.9634	**53.64211**	15.04
	30	4.6432	41.46263	0.9912	53.35703	15.79
	40	4.5433	41.55709	0.9875	53.40709	16.13
Camera-man	10	5.1245	41.03429	0.9877	52.88669	15.45
	20	5.1156	41.04184	0.9823	52.82944	16.66
	30	**5.0123**	**41.13043**	0.9912	**53.02483**	17.13
	40	5.2366	40.94031	0.9891	52.80951	17.99

5.2 VARIATION IN THE POPULATION SIZE

The major issue while applying genetic algorithm for optimization is choosing the correct size for the population of the encoded chromosomes. The choice of population size (PS) is a tradeoff between the quality of the solution and the computational cost. A larger population size will maintain a high genetic diversity, thus leading to a higher possibility of locating the global optimum, however at a high computational cost. In this experiment, the population size was varied in multiples of 4 and the number of generations for the images corresponds to the optimum results obtained from Table.1. The crossover rate was maintained constant with 0.7 and mutation rate as 0.02, and the PSNR, MSE, Robustness and Computational Time are evaluated as shown in Table.2. The maximum number of generations for peppers, Mandrill, and Lena were set to 10, for Barbara and Boat it was set to 20 and for Cameraman set to 30. The best values were obtained for different images at different population sizes and these values were carried over for the next set of experiments.

Table.2. Population sizes and its impact on images

Images	Pop. Size	MSE	PSNR	NCC	Fitness	Comp Time
Peppers (# gen = 10)	64	6.1425	40.24735	0.9961	52.20055	13.98
	128	**5.3214**	**40.87054**	**0.9987**	**52.85494**	14.47
	256	6.1712	40.22711	0.9968	52.18871	15.82
	512	7.1112	39.61137	0.9949	51.55017	17.11
Mandrill (# gen= 10)	64	5.1342	41.02608	0.9791	52.77528	14.12
	128	5.4534	40.76413	0.9892	52.63453	14.75
	256	**5.0322**	**41.11322**	**0.9987**	**53.09762**	15.17
	512	5.9657	40.37419	0.9945	52.30819	15.88
Lena (# gen= 10)	64	**3.1486**	**43.14963**	**0.9965**	**55.10763**	13.05
	128	3.9724	42.14027	0.9812	53.91467	13.68
	256	4.1128	41.98943	0.9826	53.78063	13.98
	512	4.2821	41.81424	0.9833	53.61384	14.19
Barbara (# gen = 20)	64	4.154	41.94614	0.9944	53.87894	13.56
	128	**3.924**	**42.19351**	**0.9965**	**54.15151**	14.12
	256	4.011	42.09828	0.9823	53.88588	14.34
	512	4.128	41.97341	0.9876	53.82461	15.11
Boat (# gen =20)	64	4.2251	41.87243	0.9265	52.99043	14.22
	128	4.3412	41.75471	0.9576	53.24591	14.78
	256	4.0211	42.08735	0.9867	53.92775	15.08
	512	**4.0045**	**42.10532**	**0.9943**	**54.03692**	16.02
Camera man (# gen= 30)	64	5.3423	40.85352	0.9827	52.64592	15.12
	128	5.1216	41.03675	0.9809	52.80755	16.72
	256	5.1477	41.01467	0.9897	52.89107	16.99
	512	**5.0366**	**41.10943**	**0.9991**	**53.09863**	17.49

5.3 VARIATION IN CROSSOVER RATE

Higher the crossover rate, new offsprings are added to the population more quickly. If the crossover rate is too high, high performance strings are eliminated faster that selection can produce improvements. A low crossover rate may cause stagnation due to the lower exploration rate. Here the crossover rate was varied between [0.45, 0.95] according to Grefenstette [22].

The no. of generations and the population size were chosen from the best values obtained from Table.1 and Table.2. The mutation rate was maintained constant at 0.02 and the evaluations were performed. For peppers, Lena and cameraman, the optimal values were obtained for a crossover rate of 0.7, for Mandrill with 0.8, and for Barbara and Boat with 0.6. Evaluation results are shown in Table.3.

Table.3. Performance evaluation of images based on various crossover rates

Images	Cr	MSE	PSNR	NCC	Fitness	Comp Time
Peppers (# gen = 10 PS = 128)	0.5	6.0102	40.34191	0.9788	52.08751	14.55
	0.6	5.4532	40.76429	0.9823	52.55189	14.72
	0.7	**5.1255**	**41.03344**	**0.9982**	**53.01184**	14.98
	0.8	6.1121	40.2689	0.9856	52.0961	15.12
	0.9	6.4239	40.05282	0.9821	51.83802	15.65
Mandrill (# gen = 10 PS = 256)	0.5	5.3985	40.80807	0.9734	52.48887	14.67
	0.6	5.6623	40.60087	0.9822	52.38727	14.98
	0.7	5.2785	40.9057	0.9991	52.8949	15.98
	0.8	**5.3932**	**40.81234**	**0.9901**	**52.69354**	16.01
	0.9	5.8723	40.44272	0.9828	52.23632	16.55
Lena (# gen= 10 PS = 64)	0.5	4.0254	42.08271	0.9821	53.86791	14.15
	0.6	3.9876	42.12369	0.9856	53.95089	14.21
	0.7	**3.7834**	**42.35198**	**0.9967**	**54.31238**	14.22
	0.8	4.0909	42.01261	0.9837	53.81701	14.08
	0.9	4.3726	41.72341	0.9784	53.46421	14.27
Barbara (# gen= 20 PS = 128)	0.5	4.1276	41.97383	0.9912	53.86823	14.76
	0.6	**3.8769**	**42.24596**	**0.9959**	**54.19676**	14.92
	0.7	4.0986	42.00445	0.9926	53.91565	15.23
	0.8	4.5329	41.56704	0.9892	53.43744	14.12
	0.9	4.8934	41.2347	0.9826	53.0259	14.33
Boat (# gen= 20 PS = 512)	0.5	4.3415	41.75441	0.9758	53.46401	15.21
	0.6	**4.1249**	**41.97667**	**0.9983**	**53.95627**	15.02
	0.7	4.3289	41.76703	0.9856	53.59423	15.62
	0.8	4.7834	41.33344	0.9784	53.07424	15.72
	0.9	4.9167	41.21407	0.9711	52.86727	15.19
Cameraman (# gen= 30 PS = 512)	0.5	5.2278	40.94761	0.9781	52.68481	17.49
	0.6	5.1916	40.97779	0.9856	52.80499	17.12
	0.7	**5.1256**	**41.03336**	**0.9981**	**53.01056**	16.98
	0.8	5.2784	40.90578	0.9897	52.78218	17.16
	0.9	5.3329	40.86117	0.9798	52.61877	17.05

5.4 VARIATION IN MUTATION RATE

Mutation probability (Pm) is a very important parameter in mutation process that decides the rate at which the genes in the chromosome get swapped.

A low mutation rate helps to prevent any bit positions from getting stuck to single values, where as a high mutation rate results in essentially random search. With the best values of population size, no. of generations (# gen) and crossover rate (Cr) obtained in the previous experiments, the mutation rate is varied and the parameters are evaluated as in Table.4. The mutation rate was varied between the range [0.01, 0.2] and the GA was run to compute the optimized values of PSNR, NCC, and Fitness. From the table, it can be observed that the mutation rate of 0.02 produced best results for peppers, Mandrill, Lena, Barbara, and cameraman, and a rate of 0.01 for Boat image.

Table.4. Effect of mutation rate on images

Images	Pm	MSE	PSNR	NCC	Fitness	Comp Time
Peppers (# gen= 10 PS = 128 Cr = 0.7)	0.01	5.3465	40.85011	0.9879	52.70491	14.95
	0.02	**5.1289**	**41.03056**	**0.9984**	**53.01136**	14.87
	0.1	5.1782	40.98902	0.9892	52.85942	14.99
	0.15	5.3549	40.84329	0.9823	52.63089	14.76
	0.2	5.8971	40.42442	0.9809	52.19522	15.12
Mandrill (# gen= 10 PS = 256 Cr = 0.8)	0.01	5.4976	40.72907	0.9854	52.55387	14.87
	0.02	**5.1287**	**41.03073**	**0.9991**	**53.01993**	14.34
	0.1	5.2267	40.94853	0.9987	52.93293	14.81
	0.15	5.9734	40.36859	0.9789	52.11539	14.92
	0.2	5.8623	40.45012	0.9693	52.08172	14.23
Lena (# gen= 10 PS = 64 Cr = 0.7)	0.01	3.1274	43.17897	0.9972	55.14537	14.11
	0.02	**3.0106**	**43.34427**	**0.9991**	**55.33347**	14.94
	0.1	3.2216	43.05009	0.9964	55.00689	14.76
	0.15	3.1415	43.15943	0.9944	55.09223	14.93
	0.2	3.3969	42.81998	0.9895	54.69398	14.11
Barbara (# gen= 20 PS = 128 Cr = 0.6)	0.01	3.9781	42.13405	0.9873	53.98165	14.19
	0.02	**3.6742**	**42.47918**	**0.9982**	**54.45758**	14.45
	0.1	3.8862	42.23555	0.9913	54.13115	14.23
	0.15	4.0151	42.09384	0.9876	53.94504	14.82
	0.2	4.1214	41.98036	0.9894	53.85316	14.15
Boat (# gen= 20 PS = 512 Cr = 0.6)	0.01	**4.0124**	**42.09676**	**0.9992**	**54.08716**	15.43
	0.02	4.1214	41.98036	0.9976	53.95156	15.87
	0.1	4.2146	41.88324	0.9961	53.83644	15.12
	0.15	4.3421	41.75381	0.9943	53.68541	15.87
	0.2	4.3989	41.69736	0.9952	53.63976	15.32
Cameraman (# gen= 30 PS = 512 Cr = 0.7)	0.01	5.2165	40.95701	0.9981	52.93421	16.76
	0.02	**5.1413**	**41.02007**	**0.9993**	**53.01167**	17.02
	0.1	5.2247	40.95019	0.9976	52.92139	16.22
	0.15	5.2989	40.88895	0.9955	52.83495	16.43
	0.2	5.4012	40.8059	0.9947	52.7423	16.94

5.5 ATTACKS

The common attacks employed to the watermarked image in this experiment are filtering, addition of Gaussian noise, rotation, scaling, cropping and JPEG compression. Different filtering techniques with varying mask sizes were applied to analyze the performance of the watermarked image. Average filtering removes the high frequency components present in the image acting like a low pass filter. The average filter with a 5 x 5 mask was applied to the watermark image during the optimization process of GA to evaluate the robustness measure. The Gaussian filter attack with a window size of 3 x 3 was applied with zero mean and unit variance.

Median filter is a non-linear spatial filter most commonly used to remove the noise spikes from the image. The median filter with a mask size of 3 x 3, and 2 x 2 were applied on the chosen set of images and this seemed to preserve the edges in a better way while recovering the watermark. From Table.5, comparing the filtering attacks and their robustness measure, it can be inferred that the proposed digital image watermarking technique is robust against Median filter attacks.

The watermarked images were subject to Gaussian noise attacks with various noise density ranges, which indicate the percentage of gray levels added into the image. The results from the Table.5 prove that the images are more resilient to Gaussian noise attacks for low density ranges. The watermarked images are compressed using lossy JPEG compression, whose index of compression or the quality factor ranges from 0 to 100. Low values of quality factor indicate high compression ratio and while high values indicate poor compression ratios. Higher the quality factor, better the robustness of the watermarked image.

Rotation and Scale invariance is also tested by rotating the image in counter-clockwise direction and then back to the original position through bilinear interpolation. Higher the angles, higher the padded black pixels in order to maintain the shape and size of the image, resulting in a lower correlation factor.

Table.5. Robustness measure for images against attacks

Type of attack	**Peppers**	**Mandrill**	**Lena**	**Barbara**	**Boat**	**Cameraman**
Average Filtering 5x5	0.974	0.9723	0.9806	0.9745	0.9822	0.9718
Gaussian Filtering 3x3	0.9826	0.9891	0.9875	0.9816	0.9796	0.9879
Median Filtering 2x2	0.9896	0.9934	0.9927	0.9889	0.9963	0.9911
Median Filtering 3x3	0.9894	0.9926	0.9918	0.9884	0.9956	0.9906
Gaussian Noise $\sigma = 0.001$	0.8753	0.8896	0.8934	0.8799	0.8902	0.8967
Gaussian Noise $\sigma = 0.01$	0.8742	0.8886	0.8923	0.8789	0.8891	0.8959
Gaussian Noise $\sigma = 0.1$	0.8617	0.8746	0.8856	0.8701	0.8806	0.8895
JPEG QF=20%	0.8467	0.8534	0.8662	0.8589	0.8622	0.8563
JPEG QF=40%	0.8573	0.8587	0.8679	0.8645	0.8744	0.8656
JPEG QF=70%	0.8856	0.8916	0.8835	0.8897	0.8959	0.8933
JPEG QF=95%	0.9270	0.9378	0.9543	0.9129	0.9334	0.9452
Rotation 5^o	0.8934	0.9120	0.9025	0.8993	0.8978	0.8933
Rotation 15^o	0.8659	0.8854	0.8786	0.8911	0.8897	0.8887
Rotation 30^o	0.7943	0.8268	0.8215	0.8137	0.8187	0.8115
Rotation 40^o	0.7157	0.7839	0.7546	0.7298	0.7745	0.7489
Rotation 5^o + Scaling 0.5	0.7955	0.8210	0.8105	0.7986	0.8182	0.8056
Rotation 5^o + Scaling 1.1	0.8836	0.9098	0.8976	0.8895	0.8874	0.8901
Rotation 5^o + Scaling 1.1 + Cropping (Block size = 10)	0.8765	0.8967	0.8806	0.8745	0.8769	0.8840
Rotation 5^o + Scaling 1.1 + Cropping (Block size = 100)	0.6543	0.7145	0.6982	0.6580	0.6659	0.7108
Rotation 5^o + Scaling 1.1 + JPEG 95%	0.8821	0.9085	0.8945	0.8833	0.8859	0.8896
Rotation 5^o + Scaling 1.1 + JPEG 60%	0.8701	0.8971	0.8821	0.8740	0.8724	0.8698

The scaling factors are selected such that the robustness, invisibility and quality of the extracted watermark is maintained, usually higher in the low frequency band and lower in the high frequency band. In this experiment, scaling attacks are combined with rotation and the correlation is computed as shown in Table.5. Cropping is a lossy operation, which was also used with block sizes of 10 and 100 to attack the watermarked image. For large block sizes, the correlation factor was found to be very low.

The PSNR values (Table.6) are computed for the chosen images and this metric is used to evaluate the imperceptibility of the watermarked images. For several combination of attacks the PSNR for the images were found to be more than 30dB with the exception of the cropping combination of attack. Experimental results in Table.7 shows that the correlation values of the proposed method outperforms the method proposed in [4] and [23], especially for median filtering, Gaussian filtering, Salt and Pepper noise, scaling, cropping and rotation attacks. Similarly, the results obtained from the proposed method were compared with [24] interms of PSNR values and the correlation due to Gaussian noise, median filtering and JPEG compression. Table.8 shows that the results of the proposed method are much better (bolded) when compared with the results in [24], specifically while extracting the watermark under median filtering attack and JPEG compression attack

Table.6. PSNR vales for images against attacks

Type of attack	Peppers	Mandrill	Lena	Barbara	Boat	Cameraman
Average Filtering 5x5	35.07	34.98	36.92	34.76	36.21	36.13
Gaussian Filtering 3x3	35.15	35.26	37.24	35.17	36.47	36.77
Median Filtering 2x2	36.24	35.74	37.81	35.51	36.81	36.99
Median Filtering 3x3	36.17	35.67	37.76	35.46	36.72	36.92
Gaussian Noise σ = 0.001	42.56	43.17	44.47	43.77	43.89	41.78
Gaussian Noise σ = 0.01	42.25	42.96	44.36	44.64	43.71	41.56
Gaussian Noise σ = 0.1	42.07	42.83	44.24	44.15	43.48	41.32
JPEG QF=20%	39.97	39.04	41.75	41.02	41.23	39.44
JPEG QF=40%	40.01	39.17	41.89	41.16	41.36	39.56
JPEG QF=70%	40.15	39.34	42.09	41.33	41.65	39.78
JPEG QF=95%	40.30	39.67	42.35	41.62	41.88	39.97
Rotation 5°	31.54	32.25	33.35	31.65	32.91	31.33
Rotation 15°	31.02	31.82	32.94	31.12	32.75	31.16
Rotation 30°	30.89	31.34	32.26	30.88	32.60	30.89
Rotation 40°	30.62	31.02	32.05	30.75	32.23	30.77
Rotation 5° + Scaling 0.5	31.06	32.01	33.09	31.21	32.72	31.10
Rotation 5° + Scaling 1.1	31.23	32.18	33.17	31.43	32.82	31.21
Rotation 5° + Scaling 1.1 + Cropping (Block size = 10)	30.85	31.56	32.13	30.32	31.29	30.23
Rotation 5° + Scaling 1.1 + Cropping (Block size = 100)	26.14	27.98	28.55	27.76	26.12	27.52
Rotation 5° + Scaling 1.1 + JPEG 95%	31.02	32.01	33.11	31.32	32.75	31.16
Rotation 5° + Scaling 1.1 + JPEG 60%	30.89	31.94	33.03	31.29	32.71	31.02

Table.7. Comparison of the correlation values for Lena image between the proposed method and methods in [4] and [23]

Parameters	NC using [4]	NC using [23]	NC using Proposed method
Median Filtering 3x3	0.8549	NA	**0.9918**
Gaussian Noise σ=0.001	NA	**0.94**	0.8934
Scaling 0.5	NA	0.91	**0.9113**
Salt and Pepper Noise	0.8278	NA	**0.9214**
JPEG Compression 40%	**0.9581**	NA	0.8679
Cropping 1/4	0.8516	0.76	**0.8913**
Gaussian Filtering 3x3	0.6918	NA	**0.9875**
Rotation 30°	NA	0.68	**0.8215**

Table.8. Performance comparison between the proposed method and method proposed in [24]

Images	Methods	PSNR[a]	WI[1]	GN[2]	MF[3]	JC[4]
Peppers	Proposed	41.03	**0.9984**	0.8753	**0.9894**	**0.927**
	[24]	**41.8**	0.986	**0.975**	0.413	0.478
Lena	Proposed	**43.34**	**0.9991**	0.8934	**0.9918**	**0.9543**
	[24]	42.5	0.982	**0.971**	0.384	0.404
Barbara	Proposed	**42.47**	**0.9982**	0.8799	**0.9884**	**0.9129**
	[24]	42.2	0.987	**0.971**	0.501	0.671
Mandrill	Proposed	41.04	**0.999**	0.8896	**0.9926**	**0.9378**
	[24]	**41.9**	0.988	**0.974**	0.367	0.661

[a]PSNR – PSNR of watermarked image
[1]WI – NCC of watermarked image
[2]GN – NCC due to Gaussian Noise
[3]MF – NCC due to Median Filtering
[4]JC – NCC due to JPEG compression

6. CONCLUSION

In this paper, the digital image watermarking based on Genetic Algorithm is proposed. The watermark amplification factor is optimized and the quality of the watermarked images for a set of six images is found to be good in terms of PSNR and Correlation factor. The images like peppers, mandrill, Lena, Barbara, boat and cameraman are shown robust to attacks like average filtering, Gaussian filtering, Median filtering, Gaussian Noise, JPEG compression, rotation, scaling, and cropping. In future, approaches like Swarm Intelligence, and Multi-objective optimization can be investigated and compared with the obtained GA results.

REFERENCES

[1] Dong Zheng, Sha Wang, and Jiying Zhao, "RST invariant Image Watermarking Algorithm With Mathematical Modeling and Analysis of the Watermarking Processes" *IEEE Transactions on Image Processing*, Vol. 18, No. 5, 2009.

[2] A. Piva, M. Barni, F. Bartolini, and V. Cappellini, "Mask building for perceptually hiding frequency embedded watermarks", *Proceedings of 5th IEEE International Conference on Image Processing,* Vol. 1, pp. 450–454, 1998.

[3] B. Sikander, M. Ishtiaq, M.A. Jaffar, M. Tariq, A.M. Mirza, "Adaptive Digital Watermarking of Images Using Genetic Algorithm", *IEEE International Conference on Information Science and Applications*, pp. 1-8, April 2010.

[4] B. Jagadeesh, S.S. Kumar and K.R. Rajeswari, "A Genetic Algorithm based oblivious image watermarking scheme using Singular Value Decomposition", *IEEE International Conference on Networks and Communications*, pp. 224-229, 2009.

[5] Mauro Barni, Franco Bartolini, and Alessandro Piva, "Improved Wavelet-Based Watermarking Through Pixel-Wise Masking", *IEEE Transactions on Image Processing*, Vol. 10, No. 5, pp. 783-791, 2001.

[6] C. Lin, M. Wu, J. Bloom, I. Cox, M. Miller, and Y. Lui, "Rotation, scale, and translation resilient watermarking for images," *IEEE Transactions on Image Processing*, Vol. 10, No. 5, pp.767–782, 2001.

[7] C. W. Tang and H. M. Hang, "A feature-based robust digital image watermarking scheme," *IEEE Transactions on Signal Processing*, Vol. 51, No. 4, pp. 950–959, 2003.

[8] Sachin Goyal, Roopam Gupta and Ashish Bansal, "Application of Genetic Algorithm to Optimize Robustness and Fidelity of Watermarked Images", *International Journal on Computer Science and Engineering*, Vol. 1, No. 3, pp. 239-242, 2009.

[9] M. Ketcham, and S. Vongpradhip, "Intelligent Audio Watermarking using Genetic Algorithm in DWT Domain", *World Academy of Science, Engineering and Technology*, pp. 336-341, 2007.

[10] I. Cox, M. Miller, and J. Bloom, "*Digital Watermarking: Principles and Practice*", San Mateo, CA: Morgan Kaufmann, 2001.

[11] Abu-Errub, Ali Al-Haj and Aymen, "Performance Optimization of Discrete Wavelets Transform Based Image Watermarking Using Genetic Algorithms", *Journal of Computer Science*, pp. 834-841, 2008.

[12] V.H. Vallabha, "Multiresolution Watermark Based on Wavelet Transform for Digital images", *Cranes Software International Ltd*, 2003.

[13] J.R. Hernández, and F. Pérez-González, "A tutorial on digital watermarking", *Proceedings of the 33rd IEEE Annual Carnahan Conference on Security Technology*, pp. 286-292, 1999.

[14] Chin-Shiuh Shieh, Hsiang-Cheh Huan, Feng-Hsing Wang and Jeng-Shyang Pan, "Genetic watermarking based on transform-domain techniques", *Pattern Recognitio*n, Vol. 37, No. 3, pp. 555-565, 2004.

[15] Yi-leh Wu, Divyakant Agrawal,Amr El Abbadi, "A comparison of DFT and DWT based similarity search in time-series databases", *Proceedings of Ninth international conference on Information and knowledge management, United States of America*, pp. 488 – 495, 2000.

[16] J.-S. Pan, H.-C. Huang, L.C. Jain, "*Intelligent Watermarking Techniques (Innovative Intelligence)*", World Scientific Press, 2004.

[17] Zhicheng Wei, Hao Li and Jufeng Dai, "Image Watermarking Based On Genetic Algorithm", *Proceedings of International Conference on Multimedia and Expo*, pp.1117-1120, 2006.

[18] Cong Jin, "Affine invariant watermarking algorithm using feature matching", *Digital Signal Processing*, Vol. 16, No.3, pp. 247-254, 2006.

[19] G. Boato, V. Conotter and F. G. B. De Natale, "GA-based Robustness Evaluation Method for Digital Image Watermarking", *Proceedings of International Workshop on Digital* Watermarking, pp. 294-307, 2007.

[20] C.-S. Shieh, H.-C. Huang, F.-H. Wang and J.-S. Pan, "Genetic watermarking based on transform domain techniques", *Pattern Recognition*, Vol. 37, No. 3, pp. 555-565, 2004.

[21] John J. Grefenstette, "Optimization of Control Parameters for Genetic Algorithms", *IEEE Transactions on Systems, Man and Cybernetics*, Vol. 16, No. 1, pp. 122-128, 1986.

[22] www.cs.tut.fi/~foi/GCF-BM3D/images

[23] Yuh-Rau Wang, Wei-Hung Lin and Ling Yang, "An Intelligent Pso Watermarking", Proceedings of *International Conference on Machine Learning and Cybernetics*, pp. 2555-2558, 2010.

[24] Y. Wang, J.F. Doherty and R.E. Van Dyck, "A wavelet-based watermarking algorithm for ownership verification of digital images", *IEEE Transactions on Image Processing*, Vol. 11, No. 2, pp. 77 – 88, 2002.