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Intelligent Geometric-Distortion Resilient Watermarking Using 2D-Discrete Wavelet Transforms Domain and Genetic Algorithms

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A b s t r a c t

Watermarking has been utilized as a tool for the copyright protection of multimedia contents. Due to of their digital nature, images can be duplicated, modified, transformed, and diffused very fast and easily. In this research, it is important to develop a system for copyright protection, protection against duplication, and authentication of contents. For this, a watermark is embedded into the digital image in such a way that it is indissolubly tied to the data itself. Later on, such watermark can be extracted to prove ownership to trace the dissemination of the marked work through the multimedia contents. Watermarking simply to inform users about the identity of the rights-holder or about the allowed use of data. This research deals the developing the watermarking schemes for digital images stored in wavelet domain. In this paper we mainly focus on the 2-D Discrete Wavelet Transform (DWT) based development. The mid-frequency sub bands LH and HL are used for watermark embedding. Genetic algorithm (GA) is used to identify the position for marking. Genetic algorithm utilizes in searching appropriate locations in cover images to insert watermark. The fitness function is chosen so that optimal values are achieved for transparency and robustness in proposed algorithm. Experimental results support the potential of the proposed algorithm for resilient in geometric distortion.

Keywords:

Discrete Wavelet Transforms,
Genetic Algorithm,
Peak Signal To Noise,
Correlation Factor,
Watermarking.

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1. Introduction

Digital watermarking has become a matter of more concern over decade as the urge to find solutions to the many problems related to the widespread usage of digital image is being sought. These matters, like copyright protection, are becoming hard to protect due to adversaries, are also becoming good idea [1]. As such, two important realizations need to be considered. Firstly, brilliant search techniques are needed to find solutions to the complex issues concerning widespread usage of the digital media, which are difficult to be managed analytically. Secondly, there are few limits on the adversaries, i.e. they are free to handle highly complex attacks regularly. Therefore, there must be some adaptive technique to act against these new attacks effectively by modifying the strong watermarking algorithm.

Watermarking techniques embed imperceptible data into the multimedia content. The covertly embedded data is called the watermark and may consist of a user's unique ID, cryptographic keys, copyright ownership messages, access conditions of the content, logos, image, biometrics, or content-based information [2]. The watermark embedding and retrieval process is assisted by a secret key, in which lies information on where and to what extent has the original content been modified in order to accommodate the watermark. Imperceptibility is a strong requirement of every watermarking scheme; because the watermark should not distort the original media or interfere with its intended use or function. Robustness is necessary to assure that common signal processing, geometric operations and malicious modifications do not impact the detection or retrieval of the watermark.

The copyright objective is to facilitate content owners to prove their ownership by retrieving the watermark from a pirated media and then litigate against the offender. Figures 1 and 2 show the two components of a watermarking system; embedder and detector.

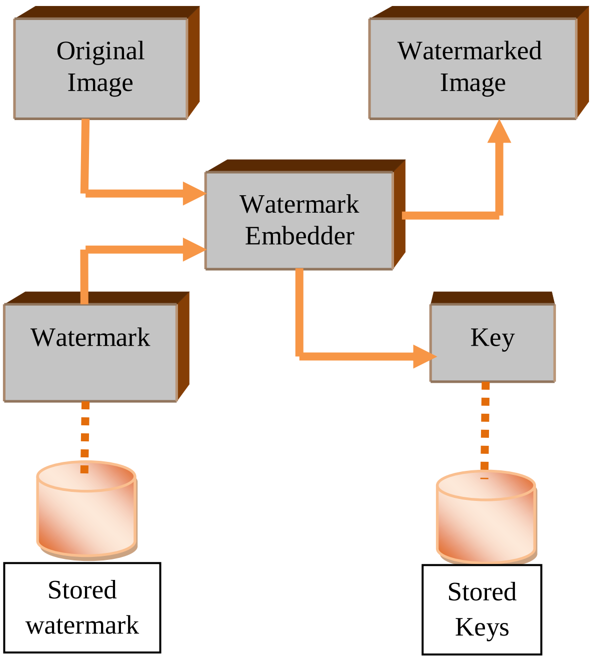

Fig. 1: Watermark insertion

The watermark detection process can be non-blind (retrieval process requires access to original image), semi-blind (detector requires access to some side information and/or the watermark but not the original image), or blind (detection is performed without access to the original image).

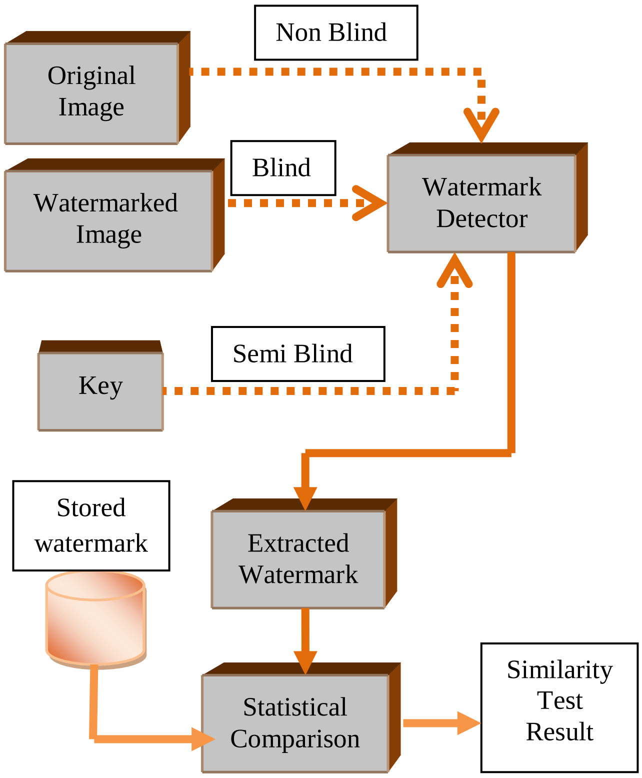

Fig. 2: Watermark detection

Non-blind detection methods are more robust but impractical for use in Digital Rights Management (DRM) systems. Since non-blind techniques require that the original image is available to the detector that necessitates access ability to the original image from the consumer's end of the DRM system software, which creates a security hole in the system. Semi-blind techniques are most appropriate for use in this context as blind techniques compromise the robustness requirement.

A watermarked image could tolerate different attacks before the watermark is retrieved, where; the attack is defined as any processing of the watermarked image that can damage the image and watermark [3].

Resistance against attacks is thus, a fundamental issue while designing a watermarking system. With the exception of fragile watermarking systems, almost all watermarking systems need to be resistant against any intentional or unintentional processing of the watermarked image. This originating of a watermarking algorithm is usually called robustness.

These attacks and their effects are deliberated in the context of the watermark applications, as different applications are mostly concerned with a different set of attacks [4]. Therefore, while designing a watermarking system, its intended application and thus the corresponding set of conceivable attacks are of main importance.

In this work, we have proposed an intelligent image watermarking algorithm in the 2D-Discrete Wavelet Transform (DWT) domain which is robust against geometric attacks. Then, we are going to increase the performance of 2D-DWT system using Genetic Algorithms (GA). The embedding positions are simulated as chromosomes in the evolution process. Then the nearly optimal embedding positions are obtained by evolution of chromosomes using natural selection and GA operators. Thus, the whole evolution of GA can efficiently achieve high transparency. Images from South Florida University database are used for algorithm implantation.

This watermarking method would be such that it is transparent to the end user. The watermarked content would be consumable at the intended user device without giving annoyance to the user.

The rest of this paper is organized as follows. Section 2 discusses some useful related preliminaries. Section 3 gives an overview of the proposed watermarking system. Section 4 presents some details about the simulation of the algorithm and provides various experimental results for test of the proposed approach, and finally, Section 5 concludes the paper.

2. Preliminaries

2.1 Discrete Wavelet Transform on Images

Discrete wavelet transform (DWT) is one of the excellence transformation algorithms for digital image watermarking in frequency domain. DWT stipulates both spatial and frequency domain description of an image. It is an effective mathematical tool for decomposing an image hierarchically [5]. DWT decomposes the image into three spatial directions: diagonal, horizontal and vertical.

The multi-resolution of wavelet allows representing an image at more than one resolution level. It divides the image into four sub-bands which are lower resolution approximation image (LL), diagonal (HH), vertical (LH) and horizontal (HL) detail sub-bands [6], [7]. This process of separation can be repeated many times to compute multi-level wavelet decomposition .The LL sub band is not suitable for the watermark embedding, due to it contains more essential data about the image and causes image distortion. In addition, embedding a watermark in the HH sub-band is not suitable, because this sub-band is less robust against some image processing operations. Thus, the suitable areas for watermark embedding are the mid-frequency sub-bands LH and HL, where moderate performance of imperceptibility and robustness could be achieved.

Figure 3 shows the sub-band decomposition of an image using 2D wavelet transform after 3 levels of decomposition. Where, H be a symbol of high-pass filter and L represents low-pass filter. An original image can be decomposed of frequency areas of LH1, HL1, and HH1.

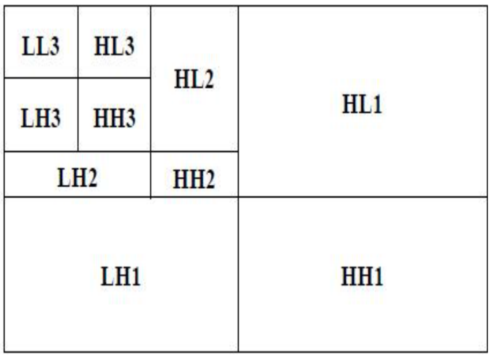

Fig. 3: Wavelet decomposition of an image

The low-frequency area data also can be decomposed into sub-level frequency district information of HH2, LL2, LH2 and HL2. By doing this, the original image can be decomposed for n-level wavelet transformation. Figures 4 shows second level wavelet transform of on image from university of California database.

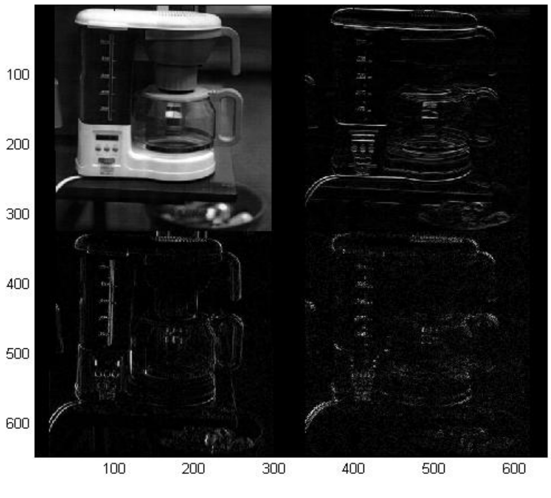

Fig. 4: Wavelet decomposition of an image

2.2 Genetic Algorithms

Genetic Algorithm (GA) is a heuristic search technique for finding the global minimum/ maximum solutions for problems in the area of evolutionary computation [8]. Any optimization problem is modeled in GA by defining the chromosomal representation, fitness function, and application of the GA operators. The GA algorithm starts with a few randomly selected genes in the first generation, called population. Each individual in the population corresponding to solution in the problem is called chromosome, which include finite length strings. The objective of the problem, named fitness function, is utilized to evaluate the quality of each chromosome in the population [9].

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, crossover, selection, and mutation, are applied to the chromosomes repeatedly to determine the best solution over consecutive generations [14]. In digital image watermarking using the DWT domain, the value of the watermark correlation factor (ρ) and PSNR, balances the imperceptibility and the robustness. This balance is obtained though the optimization process, accomplish through GA.

According to Figure 5, the evolution process starts by random creation of a population of chromosomes as the initial population. At the next step, the fitness value of each chromosome is calculated using a pre-defined fitness function. Then the chromosomes compete with each other to be selected as parents to produce off springs. Fitter chromosomes have the greater chance to be selected and survive during the evolution process. The off springs are then generated from the selected parents by using genetic operations, crossover and mutation. In crossover, a crossover point is selected between the first and last genes of the parents.

Then, the fractions of two parents after the crossover point are exchanged, and two new off springs are produced. In mutation, genes of the chromosomes are randomly changed based on predefined mutation rate.

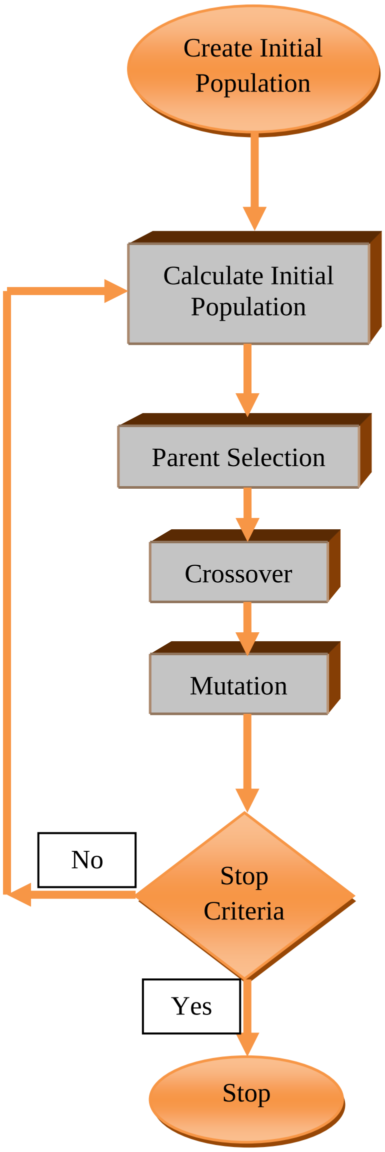

Fig. 5: The flowchart of a typical GA

The process will reiterate until a predefined condition is satisfied, or a constant number of iterations are obtained.

3. Proposed Method

First applies multi-level 2D-DWT to the host image to provide the wavelet coefficients pyramid. To have a multi resolution representation of the binary watermark, a multi level 2D-DWT is applied to the watermark. Figure 6shows selected watermark and 2D-DWT of this mark.

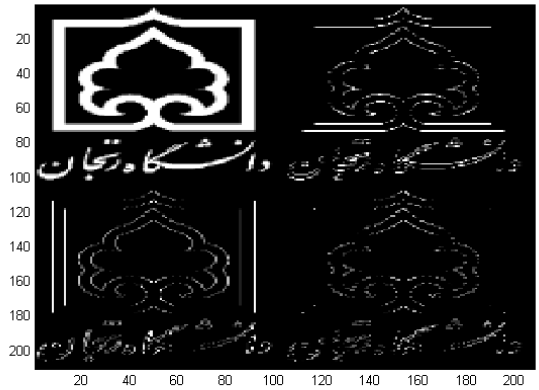

Fig. 6: selected watermark and 2D-DWT of this mark.

Notice that selected watermark is contained our university name and logo.

In proposed watermarking algorithm, the population is started by selecting a set of random positions in the cover image and inserting the watermark image into the selected positions. The best solutions for digital watermarking using DWT are obtained based on two key factors: the DWT sub-band and the value of the watermark details [10].

The GA algorithm searches its population for the appropriate solution with all possible combinations of the DWT sub-bands and watermark details. The genetic algorithm procedure will attempt to find the specific sub-band that will provide simultaneous perceptual transparency and robustness. In order to increase the robustness of the algorithm against attacks, the watermark strength or the amplification factor α should be optimized.

Once all the chromosomes are encoded the fitness function is calculated. The function is a combination of the correlation factor ρ and the

Peak Signal to Noise Ratio (PSNR). It is given as equation (1).

$$\text{Fitness function} = \text{PSNR} + 100 * \rho \quad (1)$$

where PSNR is computed as equation (2).

$$\text{PSNR} = 10\log\frac{255 \times 255}{\frac{1}{M\times N}\sum\sum[h(x,y) - h'(x,y)]^2} \quad (2)$$

Where, N and M are the width and height of the image, respectively, h(x, y) and h' (x, y) are the values located at coordinates (x, y) of the host image, and the watermarked image, respectively.
The Correlation factor (ρ) is computed as equation (3).

$$\rho = \frac{\sum_{j=1}^{M}\sum_{i=1}^{N} w(i,j) \times w'(i,j)}{\sqrt{\sum_{j=1}^{M}\sum_{i=1}^{N} w(i,j)^2}\sqrt{\sum_{j=1}^{M}\sum_{i=1}^{N} w'(i,j)^2}} \quad (3)$$

where, $w(i,j)$ and $w'(i,j)$ represent the original and the extracted watermarks respectively. Correlation factor (ρ) determines the similarity between the original watermark and the extracted watermark from the attacked watermarked image (robustness).

The fitness function improves proportionately with the PSNR value, but (ρ) is the critical 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 calculated for all the individuals in the population and the best fit individual along with the corresponding fitness value are procured. Genetic operators like mutation and crossover are performed on the selected parents to make 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 procedure for proposed intelligent watermarking using GA is depicted in figure 7.

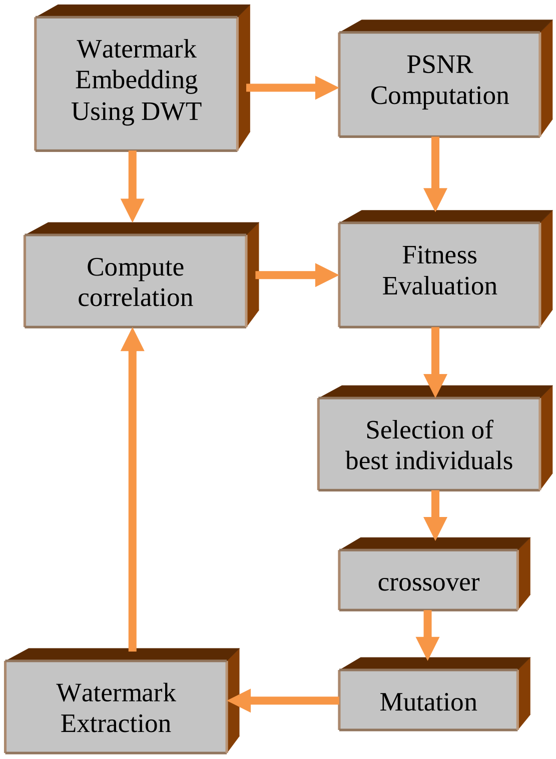

Fig. 7: proposed algorithm watermarking using GA

3.1 Procedure of Proposed Algorithm

- Sets the population size randomly, number of iterations, crossover rate, and mutation rate.

- Produce the first generation of GA individuals based on the parameters specified by performing the watermark embedding procedure. A different watermarked image is produced for each individual.

- **While** max iterations have not obtained **do**

- Calculate the perceptual transparency of each watermarked image by computing the corresponding PSNR value.

- Execute the watermark extraction procedure on each attacked watermark image.

- Calculate 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

4. Experimental Results

Extensive experiments were conducted to prove the validity of the GA algorithm and 2D-DWT to digital image watermarking. Experiments aimed at evaluating 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 geometric attacks.

A series of experiments were performed by varying several parameters in GA, like number of generations. The analysis was performed on database images from university of California's. The PSNR, Correlation factor (ρ) and Mean Square Error (MSE) are evaluated.

MSE is defined average squared difference between to reference image pixels and distorted image pixels. It is calculated by the equation (4).

$$\mathrm{MSE} = [\sum_{i=0}^{x}\sum_{j=0}^{y}\left(\mathrm{I}(i,j) - \mathrm{I}'(i,j)\right)^2] \qquad (4)$$

Where x and y are coordinate of pixel, I(i, j) is the pixel value of the original image and I'(i, j) is the pixel value of the attacked image.

Images from university of California's database were taken as the original images and Fig. 6 image was taken as the watermark.Figure8 shows the set of original and the corresponding watermarked images for some images. It is clear that not any obvious changes are occurred after watermark embedded. In other words, GA makes the watermarking technique adaptive with respect to the cover image.

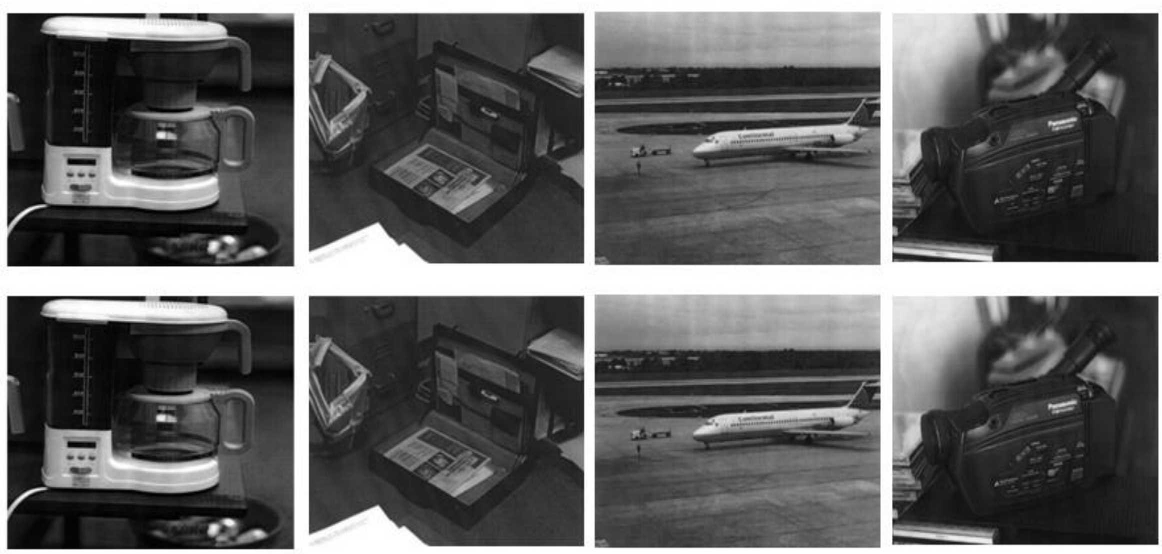

Fig. 8: set of original (up) and the corresponding watermarked images (down)

Figure 9 shows Lena's original image, watermarked image and difference image of these images.

(a)

(b)

(c)

Fig. 9: Lena's image, (a) original image (b) watermarked image, (c) difference image

As it is shown in Figure 9(c); the whole evolution of 2D-DWT and GA can efficiently achieve high transparency.

In this algorithm, "bior3.7" wave is used for wavelet transformation. In GA, with a population size of 100, the number of generations was varied starting from 5 to 30 with the interval of 5, to optimize the watermark amplification factor and thus compute the PSNR, MSE and Correlation factor (ρ). The crossover probability was chosen to be 0.8 and the mutation probability was chosen as 0.02.

Effect of number of generations on watermarking algorithm parameters is briefed in Table 1. From this Table, it is observed that the maximum PSNR and efficient fitness is obtained at 5 generations.

Table 1. Effect of number of generations on images

No. of Gen.	PSNR	MSE	ρ
30	41.567	7.49	0.9578
25	41.875	7.43	0.9632
20	42.567	6.98	0.9745
15	42.897	6.34	0.9798
10	43.556	6.01	0.9865
5	44.013	4.56	0.9966

Figure 10 illustrates the fitness function value of GA simulation result. It is observed that as generations pass by, improvement in fitness of the best individual obtained. That is, with increase in fitness of the best perceptual shaping function of a generation, its genome's total number of nodes as well as its average tree depth increases.

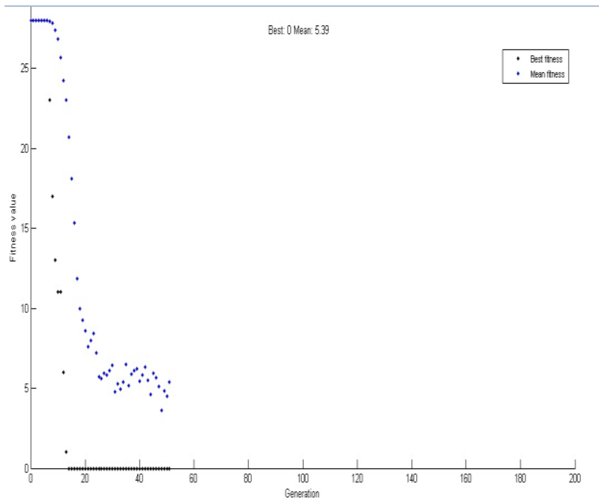

Fig. 10: fitness function value versus generation

Number of children versus individual is shown in Figure 11.

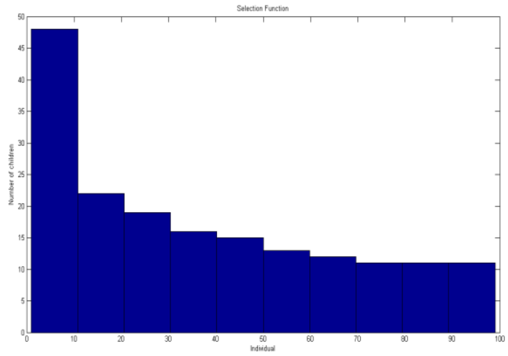

Fig. 11: Number of children versus individual

4.1 Attacks

The common attacks employed to the watermarked image in this experiment are; translate image, symmetry mapping, 20% row and column cropping, 0.5 and 0.75 scaling.

Figure 12 depicts extracted watermark from some attacked images. Slightly change is observed in these outputs.

(a)

(b)

(c)

(d)

(e)

Fig. 12: Extracted watermark from, (a) translated image (b) symmetry changed image, (c) cropped image (d) scaled image (0.5), (e) scaled image (0.75).

Table 2 summarizes our watermarking algorithm result; PSNR, Correlation factor and MSE results under this geometric attacks.

As a result in table2, we claim that our proposed watermarking algorithm is resistant to all geometric attacks in the range of PSNR factor 39 to 42, correlation factor0.951 to 0.995 and MSE factor 0.97 to 5.75.In other words it works extremely well on the s images with good performance.

Table 2: PSNR, Correlation factor and MSE value for geometric attacks

Attack	PSNR	Correlation factor	MSE
Spatial transformation	41.54	0.981	2.43
Symmetry mapping	42.14	0.995	0.97
20% cropping	41.35	0.965	2.77
Scaling (0.75)	41.54	0.976	5.75
Scaling (0.5)	39.87	0.951	3.49

5. Conclusions

An intelligent, scalable, robust watermarking approach for scalable wavelet-based image compression was introduced. A multi resolution decomposition of the binary watermark image was performed by applying of 2D-DWT. The decomposed watermark sub-bands were inserted into their counterpart sub-bands of the wavelet decomposed image.

A GA was used to find the nearly optimal positions to insert watermark into the coefficients of the wavelet pyramid. The embedding positions were coded as GA chromosomes and the GA operators were used to evolve a population of chromosomes. The PSNR and Correlation factor results obtained for test images proved the transparency of the approach.

Inserting watermark into nearly optimal positions, high transparency and robustness against geometric attack, make it attractive for digital image watermarking.

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