Chapter

# A Robust and Oblivious Watermarking Method Using Maximum Wavelet Coefficient Modulation and Genetic Algorithm

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## Abstract

An image watermarking method using Discrete Wavelet Transform (DWT) and Genetic Algorithm (GA) is presented for applications like content authentication and copyright protection. This method is robust to various image attacks. For watermark detection/extraction, the cover image is not essential. Gray scale images of size 512 × 512 as cover image and binary images of size 64 × 64 as watermark are used in the simulation of the proposed method. Watermark embedding is done in the DWT domain. 3rd and 2nd level detail sub-band coefficients are selected for further processing. Selected coefficients are arranged in different blocks. The size of the block and the number blocks depends on the size of the watermark. One watermark bit is embedded in each block. Then, inverse DWT operation is performed to get the required watermarked image. This watermarked image is used for transmission and distribution purposes. In case of any dispute over the ownership, the hidden watermark is decoded to solve the problem. Threshold-based method is used for watermark extraction. Control parameters are identified and optimized based on GA for targeted performance in terms of PSNR and NCC. Performance comparison is done with the existing works and substantial improvement is witnessed.

**Keywords:** image watermarking, discrete wavelet transform, genetic algorithm, PSNR and NCC

## 1. Introduction

In today's world, digital media storage and its security are of the highest importance for any multimedia application. Copyright protection, proof of ownership and image authentication are some of the applications in the protection of the digital data. Watermarking Technique is one of the methods used in these applications. In the watermarking process, specific information called watermark is embedded imperceptibly into the original media object. The Watermarking algorithm is referred to as an oblivious (also called as public/blind) if the extraction can be done, just with the knowledge of watermarked image.

Quality, robustness and blindness are the three key aspects in a watermarking system. The degradation in the quality of a watermarked image should be minimal and invisible. The watermarking system should be robust enough to withstand various image watermark attacks. In applications where the original image is not available at the time of extraction, blindness is essential.

In this chapter, a robust and oblivious image watermarking scheme based on the maximum wavelet coefficient modulation is proposed.

## 2. Review of the related works

Watermarking process can be implemented both in spatial and transform domains. In Spatial domain, the process is simple but it is hard to achieve robustness. In transform domain, the watermarking is very secure and robust but the process is complex. Discrete Wavelet Transform (DWT), Fourier Transform (FT), Singular Value Decomposition (SVD) and Discrete Cosine Transform (DCT) are some of the popular Image transformation methods used in the watermarking algorithms. DWT based image watermarking is easy and effective when compared with the other approaches [1]. Transform coefficient selection is the most important aspect in DWT based implementation. In [2], significant wavelet coefficients are selected to embed the watermark. Wang et al. [3] proposed a watermarking method where the significant coefficients are selected based on multi-threshold wavelet coding (MTWC) and successive sub-band quantization (SSQ). Significant coefficients are selected and quantized to embed the watermark. In [4], two different watermarking algorithms were proposed. In the first method, the triplets of significant coefficients are modified based on a sequence of bits to embed the watermark. In the second method, the coefficients are divided into rectangular blocks. In each block, one watermark bit is embedded.

In [2, 5, 6], the significant coefficients which are selected from global coefficients are used and showed robustness to many image attacks. The problem is that the order of extracting the significant coefficients in the extraction process should be exactly the same as those in the embedding process. Hence, they are not suitable for blind watermarking.

W.H. Lin et al. [7] used DWT for watermarking a $512 \times 512$ grayscale image. They quantized the maximum wavelet coefficient of a variable-sized block of a selected sub-band. The watermark is a $32 \times 16$ binary image. Low embedding capacity and adjustment of the scheme parameters to satisfy some specified watermarking requirements (PSNR and NCC with attacks) are the limitations of their method.

This chapter focuses on a robust and oblivious watermarking method. In this method, local maximum coefficient in the wavelet transform domain is used for embedding a binary watermark into a grayscale original image. Third level DWT is applied to the original image and watermark is embedded in the LH sub-band. Sub-band coefficients are grouped into equal sized blocks and a watermark bit is embedded in every block. In each block, the coefficient with maximum value is either increased or decreased based on the corresponding watermarking bit. The coefficient value (maximum) is increased if the bit is 1 and it is reduced to a value slightly higher than second maximum coefficient if the bit is 0. In the extraction process, the energy of the coefficient with maximum value in every block is decreased. After the decrement, if it is still the maximum coefficient in the block, the watermark bit is 1, or else the bit is 0.

The scheme is characterized by parameters to get control over the embedding and extraction process. Then, the Genetic Algorithm (GA) is used for parameter optimization. Optimization is required to satisfy the conflicting requirements of the Peak Signal to Noise Ratio (PSNR) and the Normalized Cross-correlation (NCC). Experimental results show that the proposed method is better than the existing methods [8] in terms of both PSNR and NCC.

## 3. Genetic algorithm

Genetic Algorithms (GAs) [9, 10] are computer-based problem-solving systems that use computational models of some of the known mechanisms in evolution as key elements in their design and implementation. GA can be described as a search heuristic that mimics the process of natural evolution. Heuristic means discovery. Heuristic methods are based on experience, rational ideas, and rules of thumb. Heuristics are based more on common sense than on mathematics. This heuristic is habitually used to generate useful solutions to improvement and search problems. Genetic algorithms belong to the larger class of organic process algorithms (EA), which generate solutions to improvement problems using techniques inspired by uncolored evolution, such as selection, crossover, acquisition, and mutation.

In a genetic algorithm, a accumulation of strings or chromosomes which encode several solutions to an optimization problem develop towards better solutions. In general, solutions are described in binary as strings of 0 s and 1 s, but other encryptions are also possible. Evolution usually originates from a group of randomly produced individuals and takes place in generations. In each generation, the suitability of every individual in the population is evaluated, aggregate individuals are randomly selected from the current grouping based on their suitableness, and adapted (with recombination and possibly random mutation) to form a new grouping. The new grouping is then used in the next process of the algorithm. The algorithm modify according to the specified resultant criteria. If the algorithm has concluded due to a extreme number of generations, an adequate solution may or may not have been reached.

A typical genetic algorithmic program requires the following:

1. Genetic creation of the solution domain

2. A fitness function to measure the solution domain

A standard delegacy of the result is as an array of bits. Arrays of other types and composition can also be used. The main attribute that makes these genetic mean favorable is that their surroundings are easily allied due to their rigid size, which serve simple crossover dealings. Variable-dimension representations may also be utilized, but crossover execution is more involved in this case. Tree-like representations are explored in genetic planning and graph-form mean are explored in organic process programming.

The fitness utility is defined over the heritable representation and explores the choice of the represented result. The fitness usefulness is always job dependent. For example, in the backpack problem, one wants to increase the total value of target that can be put in a backpack of some fixed volume. A representation of a result might be an array of fragment, where each bit represents a contrary object, and the value of the bit (0 or 1) represents whether or not the aim is in the backpack. Not all such representation is effectual, as the size of target may surpass the capacity of the knapsack. The fitness of the result is the sum of belief of all objects in the knapsack if the content is valid or 0 otherwise. In some job, it is hard or even impracticable to define the fittingness expression; in these causes, synergistic genetic algorithms are used.

Once we have got the genetic representation and the suitability function outlined, GA yield to initialize a grouping of solutions randomly, and then amend it through insistent application of the causal agent; selection, crossover, organism, and fitness evaluation. Although recollection methods that are based on the use of two rear are more "biology-inspired", some inquiry [11, 12] suggests more than two "parents" are improved to be used to re-create a good quality chromosome. Crossover and Alteration are known as the main genetic operators. It is possible to use other operators such as regrouping, colonization-extinction, or migration in genetic algorithms [13].

## 4. Proposed watermarking scheme

In this section, the planned scheme is represented in three sub-sections. The next piece of writing deals with the watermark embedding state, watermark dilatation is explained in advance section and the utilization of GA for determining the optimal parameters of the strategy is given in further section.

**Watermark Embedding:**

In the projected algorithm, a double star watermark image is integrated in a grayscale covering image. The transform in use is DWT. The embedding scheme is supported on the local maximal wavelet constant modulation.

The steps of the proposed embedding algorithm are as follows.

1. Decompose the cover image using third level DWT and obtain the sub-bands ($LL_3$, $LH_3$, $HL_3$, and $HH_3$).

2. Represent the binary watermark as a vector. Let the number of watermark bits is $N_w$.

3. Divide the $LH_3$ sub-band into $N_w$ number of blocks.

4. Compute mean value of the maximum wavelet coefficient ($MWC_{mean}$) and adaptive embedding parameter ($a_j$) as follows:

$$\text{(a) } MWC_{mean} = \frac{1}{N_w}\sum_{j=1}^{N_w} M_j \quad (1)$$

Where,

$M_j = \max_{j,}$ if the watermark bit is '1'.

$= \max_j \times t_{1,}$ otherwise

$\max_j$ = maximum wavelet coefficient of the $j^{th}$ block.

$t_1$ = scaling factor

$$\text{(b) } a_j = t_2 \times \text{maximum}\left\{|avg_j|, |MWC_{mean} \times t_3|\right\} \text{ for all j} = 1 \text{ to } N_w \quad (2)$$

Where,

$avg_j$ = average coefficient value of the $j^{th}$ block

$t_2, t_3$ are the scaling parameters

5. Modulate $\max_j$ according to the Watermark bit

for all $j = 1$ to $N_w$ as follows:

$$\max_j^{new} = \max_j + a_j, \text{if the watermark bit is‘1’}$$

$$= \sec_j + a_j \text{ otherwise} \quad (3)$$

Where,
$\sec_j$ denotes the second maximum coefficient value of the $j^{th}$ block.
$t_3$ is the scaling factor (less than 1)

6. Get the modified $LH_3$ sub-band by combining the modulated blocks.

7. Obtain the three-level inverse DWT using a modified $LH_3$ sub-band to get the watermarked image.

The parameters/scaling factors; $t_1$, $t_2$, and $t_3$; are used to control the value of the PSNR.

**Watermark extraction:**

Possibly attacked watermarked image is the only input image required for the extraction process as the scheme is an oblivious watermarking method. Parameter $t_4$ value is required. Even if the value of $t_4$ is not available, GA may be used to find its value.

Extraction of the watermark is as follows:

1. Decompose the possibly attacked watermarked image using third-level DWT and obtain the sub-bands ($LL_3$, $LH_3$, $HL_3$, and $HH_3$).

2. Divide the $LH_3$ sub-band into $N_w$ a number of blocks.

3. Compute the following

$$\text{(a) } MWC^{\circ}_{mean} = \frac{1}{N_w}\sum_{j=1}^{N_w} \max^{\circ}_j \quad (4)$$

Where $\max^{\circ}_j$ denotes the maximum coefficient of $j^{th}$ the block.

$$\text{(b) } Mean_{block} = \frac{1}{N_w}\sum_{j=1}^{N_w} |avg^{\circ}_j| \quad (5)$$

Where, $avg^{\circ}_j$ is the average coefficient value of the $j^{th}$ block excluding $\max^{\circ}_j$.

4. Detect the watermark bit using the following detection rule for all $j = 1$ to $N_w$

$$\text{Watermark bit} = 1, \text{if } \left(\max^{\circ}_j - t_4 \times a^{\circ}_j\right) >= \sec^{\circ}_j$$

$$= 0, \text{otherwise} \quad (6)$$

Where,
$t_4$ is the scaling factor,

$$a^{\circ}_{j} = \text{maximum}\left(|avg^{\circ}_{j}|, |Mean_{block}|, \mathrm{k}_1, \mathrm{k}_2\right) \tag{7}$$

$$\mathrm{k}_1 = \max{}^{\circ}_{j}/MWC^{\circ}_{mean} \tag{8}$$

$$\mathrm{k}_2 = avg^{\circ}_{j}/Mean_{block} \tag{9}$$

$sec^{\circ}_{j}$ = secondary maximum value of the $j^{th}$ block.
The parameter/scaling factor, $t_4$, is used to control the value of the NCC.

## 5. Optimization of parameters using GA

As spoke to in area 2, GA can be used for watermarking concern [14] dependent on the way that amazing watermarking has two opposing interest, PSNR and NCC. These two hypothesize are identified with one another and consequently the watermarking algorithmic standard spoke to above must be streamlined. Advancement movement space and the appropriateness work are spoken to as follows.

Search space: The conviction of the four estimating factors (t1, t2, t3 and t4) are the base that, if most loved appropriately, will bring about ideal unaware and lashing watermarking. It is the job of the GA to knowledge such qualities, where the GA's research space must consider all conceivable conviction for the four evaluating factors. The GA is an iterative method that accomplishes advancement in a given pursuit space utilizing the hereditary administrators (choice, multiplication, hybrid and transformation) and a wellness work as portrayed in segment 2.

**The fitness function:** Two common performance evaluation metrics are combined to form the fitness function, PSNR and NCC. The fitness function is formed by combining the two metrics as follows.

$$fit_l = PSNR_l + \frac{1}{P}\sum_{k=1}^{p}(NCC_{k,l} \times \alpha_k) \tag{10}$$

Where $l$ denotes GA generation number, $p$ denotes the total number of attacks used in the optimization process, $NCC_{k,l}$ represents $NCC$ value with attack $k$ and $\alpha_k$ represents the weighting factor for NCC. PSNR and NCC are defined by Eqs. (12) and (13).

**Figure 1** shows the flow chart for the performance optimization of the watermarking scheme.

Optimization of parameters is described as follows: mutation.

Note: Steps 1 to 3 speaks to the introduction of the GA-preparing factors.

1. Define an underlying reach for all the variables (or scaling factors) utilized in the plan.

2. Specify the assortment size, hybrid rate, change rate, and various cycles.

3. Specify the end standards.

4. Write a capacity to insert a twofold watermark into the dark level spread picture following the means given in the above area. The capacity should restore the PSNR estimation of the got watermarked picture.

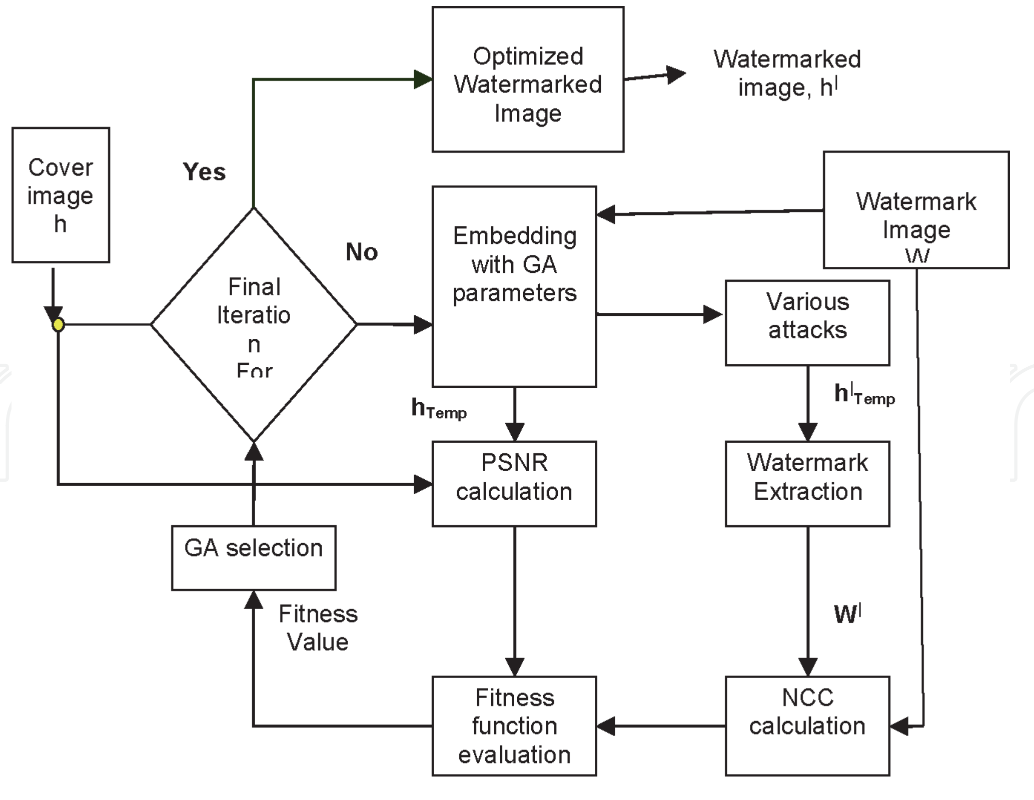


**Figure 1.**
*Flow chart for GA based watermark embedding.*

5. Write a capacity to extricate the watermark from the assaulted watermarked picture (with at least one explicit assaults) according to the technique clarified in the above segment. The capacity should restore the NCC esteem for the removed watermark.

6. Write another capacity by utilizing the boundaries of the plan, install, and separate capacities depicted in the past two stages for computing the wellness esteem. The wellness work is characterized in Eq. (10).

7. Run GA to augment the wellness work. After the end of GA, we get the ideal qualities for the boundaries.

8. Using the boundary esteems got from the past advance, ascertain the ideal estimation of PSNR for an unattacked watermarked picture and NCC values for the separated watermarks with different assaults.

9. Use the acquired ideal estimations of PSNR and NCCs with different assaults to depict the presentation of the plan.

## 6. Experimental results

Three different cover images are used for experimentation. They are Lena, Peppers, and Barbara (512 × 512 pixels, 8 bits/pixel) which are shown in **Figure 2** (a), (b), and (c) respectively. MATLAB 7.0 and Checkmark 1.2 [15] are used for testing the robustness of the proposed scheme. Two dimensional DWT with 'Haar' wavelet filters is used. Genetic Algorithm (GA) with a population size of 20 chromosomes, a crossover rate of 0.8, and a Gaussian mutation function (with a scale 1.0 and shrink 1.0) are used.

(a) (b) (c)

**Figure 2.**
*Cover images of size 512 × 512 (a) Lena, (b) Peppers, and (c) Barbara.*

The peak signal-to-noise ratio (PSNR) is used to evaluate the quality between an attacked image and the original image. PSNR is defined as follows:

$$PSNR = 10\log_{10}\frac{255\times 255}{\frac{1}{M\times N}\sum_{x=1}^{M}\sum_{y=1}^{N}\left[f(i,j)-g(i,j)\right]^2}dB \tag{11}$$

Where, M and N are the tallness and width of the picture, individually. f(i, j) and g(i, j) are the pixel esteems situated at facilitates (I, j) of the first picture, and the assaulted picture, separately. Subsequent to extricating the watermark, the standardized connection coefficient (NCC) is registered utilizing the first watermark and the separated watermark to pass judgment on the presence of the watermark and to quantify the rightness of a removed watermark.

It is characterized as

$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[w(i,j)-w_{mean}\right]\left[w^{\circ}(i,j)-w^{\circ}_{mean}\right]}{\sqrt{\left(\sum_{i=1}^{m}\sum_{j=1}^{n}\left[w(i,j)-w_{mean}\right]^2\right)\left(\sum_{i=1}^{m}\sum_{j=1}^{n}\left[w^{\circ}(i,j)-w^{\circ}_{mean}\right]^2\right)}} \tag{12}$$

Where, m and n are the stature and width of the watermark, individually. The images are the pieces situated at the directions of the first watermark and the separated watermark individually. The images are the mean estimations of the first watermark and the extricated watermark individually. Genetic Algorithm is executed to find the optimum values for the scaling factors of the proposed scheme. Scaling factors used in the proposed algorithm are $t_1$, $t_2$, $t_3$ and $t_4$. Scaling factors can be adjusted according to PSNR and NCC requirements. The required values (target values for GA process) must be included in the fitness function written for GA. Let the required values for PSNR and NCC are 42 and 1 respectively. PSNR depends upon the scheme parameters $t_1$, $t_2$, and $t_3$. NCC depends on $t_4$. But, PSNR and NCC are not independent. Hence, it is not possible to fix the values for both PSNR and NCC. In addition, one can specify the weights for requirements. As the required value of NCC is very small in comparison with the required PSNR, a weight 20 is used for NCC. Refer the expression shown for fitness function in the first row of **Table 1**. GA will optimize the whole process according to the requirements specified in the fitness function and produces the optimum values for PSNR, NCC, and scaling factors. We can also specify one or more image attacks against which robustness is required for the watermark. In these experiments, a JPEG attack with quality factor 40 is specified for GA.

**Table 1** shows the results of GA with Lena as the cover (cover) image. Optimum values for PSNR, NCC and scaling factors (scheme parameters) after each GA generation are shown. Results are shown up to five GA generations. Hence, five sets of optimum values are available for use. The set that is more close to the requirement for the specified application can be selected. In terms of both PSNR and NCC, parameter values obtained after the fifth generation are good. Similarly, **Tables 2** and **3** show the GA results with Peppers and Barbara cover images respectively. In **Tables 2** and **3**, parameter values obtained after fourth-generation are optimum in terms of both PSNR and NCC.

Original watermark image is shown in **Figure 3(a)** and **(b)** shows the unattacked watermarked Lena. **Figure 3(c)** shows the attacked (JPEG, quality factor 40) watermarked Lena. The extracted watermark is shown in **Figure 3(d)**. Scaling factors used for watermarking are $t_1$ = 0.3140, $t_2$ = 0.7962, $t_3$ = 0.8903 and $t_4$ = 0.6206 (Refer the last row of **Table 1**).

JPEG is one of the most much of the time utilized configurations regarding the Internet and advanced cameras. The JPEG quality factor is a number somewhere in the range of 0 and 100 and partners a numerical incentive with a specific pressure level. At the point when the quality factor is diminished from 100, the picture pressure is improved, however the nature of the subsequent picture is fundamentally decreased. Changed quality variables are applied in the analyses, and the

**Attack: JPEG-40**
**Fitness function:** (42-PSNR) + 20(1-NCC)
**Initial range for parameters:** [0.1-1.0, 0.5-1.0, 0.1-1.0, 0.05-1.0]
**Cover image:** Lena

| No. of generations (no. of iterations) | Fitness value | PSNR in dB | NCC | Scaling factors [t1, t2, t3, t4] |
|---|---|---|---|---|
| 1 (20) | 1.7512 | 41.7425 | 0.9253 | [0.8344, 0.8784, 0.7205, 0.6015] |
| 2 (40) | 1.6931 | 41.4934 | 0.9407 | [0.3313, 0.9540, 0.8266, 0.7660] |
| 3 (60) | 1.9825 | 42.3381 | 0.9178 | [0.3754, 0.6596, 1.0127, 0.5832] |
| 4 (80) | 1.756 | 41.7370 | 0.9253 | [0.7596, 0.8797, 0.8687, 0.6403] |
| 5 (100) | 1.5023 | 41.9914 | 0.9253 | [0.3140, 0.7962, 0.8903, 0.6206] |

**Table 1.**
*Results of GA based optimization against the JPEG attack with QF = 40 (the cover image is Lena).*

**Attack: JPEG-40**
**Fitness function:** (42-PSNR) + 20(1-NCC)
**Initial range for parameters:** [0.1-1.0, 0.1-0.6, 0.1-1.0, 0.05-1.0]
**Cover image:** Peppers

| No. of generations (no. of iterations) | Fitness value | PSNR in dB | NCC | Scaling factors [t1, t2, t3, t4] |
|---|---|---|---|---|
| 1 (20) | 3.1412 | 41.8024 | 0.8528 | [0.4017, 0.5404, 0.8020, 0.3730] |
| 2 (40) | 3.5756 | 42.2452 | 0.8371 | [0.7123, 0.4546, 0.9787, 0.4052] |
| 3 (60) | 3.8528 | 42.1525 | 0.8258 | [0.6213, 0.4676, 0.6829, 0.4343] |
| 4 (80) | 3.2263 | 41.7069 | 0.8493 | [0.7654, 0.5576, 0.5172, 0.4459] |
| 5 (100) | 2.8405 | 40.8038 | 0.9178 | [−0.8038, 0.5743, 1.0763, 0.4824] |

**Table 2.**
*Results of GA based optimization against the JPEG attack with QF = 40 (cover image is Peppers).*

| **Attack: JPEG-40**<br>**Fitness function: (42-PSNR) + 20(1-NCC)**<br>**Parameter value ranges: [0.1-1.0, 0.4-1.0, 0.1-1.0, 0.05-1.0]**<br>**Cover image: Barbara** | | | | |
|---|---|---|---|---|
| **No. of generations (no. of iterations)** | **Fitness value** | **PSNR in dB** | **NCC** | **Scaling factors[t1, t2, t3, t4]** |
| 1 (20) | 2.7381 | 41.4453 | 0.8908 | [0.1757, 0.5391, 0.9408, 0.4877] |
| 2 (40) | 2.9209 | 41.7110 | 0.8684 | [0.8335, 0.6549, 0.4174, 0.4410] |
| 3 (60) | 2.5027 | 41.6835 | 0.8907 | [0.4936, 0.4699, 0.9824, 0.4374] |
| 4 (80) | 2.4459 | 41.5814 | 0.8986 | [0.7015, 0.4967, 0.8835, 0.4220] |
| 5 (100) | 2.6055 | 41.6519 | 0.8871 | [1.0284, 0.4783, 0.9497, 0.3963] |

**Table 3.**
*Results of GA based optimization against the JPEG attack with QF = 40 (cover image is Barbara).*


(a) (b) (c) (d)

**Figure 3.**
*(a) Original watermark image. (b) Watermarked Lena, PSNR = 41.9914 dB. (c) Attacked watermarked Lena with JPEG-40 attack, PSNR = 34.9652 dB. (d) Extracted watermark, NCC = 0.9253.*

outcomes are appeared in **Table 4** for the three test pictures. Optimum parameter values (Fifth generation parameters for Lena, fourth-generation parameters for both Peppers and Barbara) are used for evaluation. The proposed method can detect the existence of a watermark through quality factors greater than 15. The results show that the value of NCC is greater than 0.50 for any of the three test images with JPEG quality factor greater than or equal to 15.

Other attacks like a median filter, Gaussian filter, average filter (low pass filter), sharpening filter, histogram equalization scaling, cropping, rotation, Gaussian noise, row-column blanking, row-column copying, salt and pepper noise, bit plane removal, and gamma correction etc. are also applied to the watermarked images obtained with the optimum parameters and the corresponding results are shown in **Table 5**. The proposed method can effectively resist all those attacks.

The watermarked image is rotated by some degrees to the right and then rotated back to their original position using the bilinear transformation. This is a lossy operation. In this experiment; 5, 10, 15, and 30 degrees rotations are used to test the robustness of the watermark.

The resizing operation initially reduces or increases the size of the image and then generates the image with the original size by using an interpolation technique. With this operation, the watermarked image loses some watermark information. In this experiment, initially, the watermarked image size is reduced from 512 $\times$ 512 to

| JPEG quality factor (QF) | (a) Lena PSNR = 41.9914 dB $t_1$ = 0.3140, $t_2$ = 0.7962, $t_3$ = 0.8903, $t_4$ = 0.6206 | (b) Peppers PSNR = 41.7069 dB $t_1$ = 0.7654, $t_2$ = 0.5576, $t_3$ = 0.5172, $t_4$ = 0.4459 | (c) Barbara PSNR = 41.5814 dB $t_1$ = 0.7015, $t_2$ = 0.4967, $t_3$ = 0.8835, $t_4$ = 0.4220 |
|---|---|---|---|
| | NCC | NCC | NCC |
| 10 | 0.4405 | 0.3813 | 0.4767 |
| 15 | 0.7443 | 0.5087 | 0. 6414 |
| 20 | 0.8157 | 0. 6392 | 0. 7653 |
| 25 | 0.8781 | 0. 7413 | 0. 8441 |
| 30 | 0.8910 | 0. 8209 | 0. 8633 |
| 35 | 0.9256 | 0. 8363 | 0. 8594 |
| 40 | 0.9253 | 0. 8493 | 0.8986 |
| 50 | 0.9177 | 0. 9142 | 0. 9254 |
| 60 | 0.8870 | 0. 9219 | 0. 9293 |
| 70 | 0.9594 | 0. 9816 | 0. 9556 |
| 80 | 0.9890 | 1. 0000 | 0. 9853 |
| 90 | 1.0000 | 1.0000 | 1.0000 |
| 100 | 1.0000 | 1.0000 | 1.0000 |

**Table 4.**
*NCC of the watermark images extracted from different watermarked images with JPEG attack [(a) Lena, (b) Peppers and (c) Barbara].*

256 × 256. Later, its dimensions are increased to 512 × 512 by using bilinear interpolation.

For a low pass separating assault, a 3 × 3 veil is utilized. The middle channel is a nonlinear spatial channel which is generally used to expel commotion spikes from a picture. The watermarked picture is assaulted by middle separating with a 3 × 3 veil.

The trimming activity erases some bit of the picture. The separated watermark is as yet conspicuous significantly after 25% of trimming. In line section blanking assault, a lot of lines and segments are erased. In this examination 10,30,40,70,100,120 and 140 of lines and sections are expelled. The removed watermark indicated great comparability with the first watermark.

In succession section duplicate assault, a lot of lines and segments are replicated to the nearby or irregular areas. In this test, tenth line is duplicated to 30th column, 40 to 70, 100 to 120 and 140th line is replicated to 160th line. The separated watermark is unmistakably obvious. In bit plane evacuation assault, the least critical pieces of the watermarked picture pixel power esteems are made '0'. In gamma adjustment, the power of the watermarked picture is changed by a predefined force change. The proposed calculation is tough to bit plane expulsion and gamma rectification. The watermarked image is attacked by salt and pepper noise with a noise density of 0.001. The extracted watermark is still recognizable.

The proposed method is compared with Wang and Lin's [8], Li et al.'s [16], Lien and Lin's [17] and Lin et al. [7] methods in terms of PSNR and NCC (using the Lena as the cover image). The results of those existing methods are found in [16]. Size of the watermark image (Logo) is 32 × 16 in those methods. For comparison purposes, a watermark with the same size is embedded using GA based proposed method and obtained the results. Comparison results are shown in **Table 6** and in **Figure 4** in the graphical form. The performance of the proposed method is better than the other methods against JPEG compression and Gaussian filter attacks. But, this

| Type of attack | | (a) Lena<br>PSNR = 41.9914 dB<br>$t_1$ = 0.3140,<br>$t_2$ = 0.7962,<br>$t_3$ = 0.8903,<br>$t_4$ = 0.6206 | (b) Peppers<br>PSNR = 41.7069 dB<br>$t_1$ = 0.7654,<br>$t_2$ = 0.5576,<br>$t_3$ = 0.5172,<br>$t_4$ = 0.459 | (c) Barbara<br>PSNR =41. 5814 dB<br>$t_1$ = 0.7015,<br>$t_2$ = 0.4967,<br>$t_3$ = 0.8835,<br>$t_4$ = 0.4220 |
|---|---|---|---|---|
| | | NCC | NCC | NCC |
| Median filter (3 × 3) | | 0.8751 | 0. 7833 | 0.7059 |
| Gaussian filter (3 × 3)<br>Variance = 0.5 | | 0.9062 | 0. 9299 | 0.9296 |
| Average filter (3 × 3) | | 0.7156 | 0. 7170 | 0.6830 |
| Sharpening filter | | 0.8204 | 0. 7657 | 0.7018 |
| Histogram Equalization | | 0.8432 | 0. 7702 | 0.9193 |
| Scaling 50% | | 0.8299 | 0. 7300 | 0. 7475 |
| Cropping 25% | | 0.5751 | 0. 5751 | 0. 5751 |
| Gamma correction (gamma = 0.9) | | 1.0000 | 0. 8775 | 0. 9890 |
| Bit plane removal (LSB) | | 1.0000 | 1.0000 | 1.0000 |
| Row and column copying | | 0. 9443 | 0. 8861 | 0. 8900 |
| Row column blanking | | 0. 6236 | 0. 6439 | 0. 6592 |
| Gaussian noise (0.001 variance) | | 0.7242 | 0. 6124 | 0.7479 |
| Salt and pepper noise (0.001) | | 0.9222 | 0. 8714 | 0.9130 |
| Rotation | 5 degrees | 0.7074 | 0. 7732 | 0.7502 |
| | 10 degrees | 0.6505 | 0. 7073 | 0.6726 |
| | 15 degrees | 0.5940 | 0. 6591 | 0.6279 |
| | 30 degrees | 0.5413 | 0. 5959 | 0.5759 |

**Table 5.**
*NCC of the watermark images extracted from different watermarked images with various other attacks ((a) Lena, (b) Peppers and (c) Barbara).*

method is slightly inferior in comparison with the methods in [7, 17] against sharpening and scaling attacks. The proposed method can detect the existence of a watermark through JPEG quality factors greater than 10. NCC value obtained against JPEG (Quality factor 10) attack with the proposed method is 0.78. But, the NCC value against the same attack for the existing methods is less than or equal to 0.34. Similarly, the proposed method is better in terms of perceptual quality (PSNR) of the watermarked image. The optimum value obtained for PSNR with the proposed scheme is 42.92 dB when 32 × 16 size watermark is embedded. Optimization is performed against JPEG, average filter, and high pass filters. The obtained parameter values are $t_1$ = 1.1710, $t_2$ = 1.1879, $t_3$ = 0.6047 and $t_4$ = 1.0058.

## 7. Conclusions

In this chapter, a novel and an oblivious watermarking method is proposed based on GA and using maximum wavelet coefficient modulation. A binary watermark is embedded in the third level LH sub-band of the cover image. The perceptual quality of the watermarked image is good and the watermark can effectively resist JPEG compression and various other attacks like Gaussian filter, median filter,

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| **Attacks** | **Wang and Lin [8] (PSNR = 38.2 dB) NCC** | **Li et al. [16] (PSNR = 40.6 dB) NCC** | **Lien and Lin [17] (PSNR = 41.54 dB) NCC** | **Lin et al. [7] (PSNR = 42.02 dB) NCC** | **Proposed method (PSNR = 42.92 dB) NCC** |
|---|---|---|---|---|---|
| JPEG (QF = 10) | NA | 0.15 | 0.17 | 0.34 | 0.78 |
| JPEG (QF = 20) | NA | 0.34 | 0.61 | 0.67 | 0.90 |
| JPEG (QF = 30) | 0.15 | 0.52 | 0.79 | 0.82 | 0.83 |
| JPEG (QF = 70) | 0.57 | 0.63 | 0.97 | 0.97 | 0.99 |
| JPEG (QF = 90) | 1.00 | 0.78 | 1.00 | 0.99 | 1.00 |
| Gaussian filter | 0.64 | 0.70 | 0.84 | 0.88 | 0.93 |
| Median filter (3 × 3) | 0.51 | 0.35 | 0.79 | 0.90 | 0.87 |
| Sharpening filter | 0.46 | 0.38 | 0.88 | 0.97 | 0.83 |
| Scaling (50%) | NA | 0.35 | 0.79 | 0.88 | 0.81 |

**Table 6.**
*Performance comparison of the proposed method with the methods of Wang and Lin's [8], Li et al.'s [16], Lien and Lin's [17], and Lin et al. [7] (using Lena as the cover image and 32 × 16 logo).*

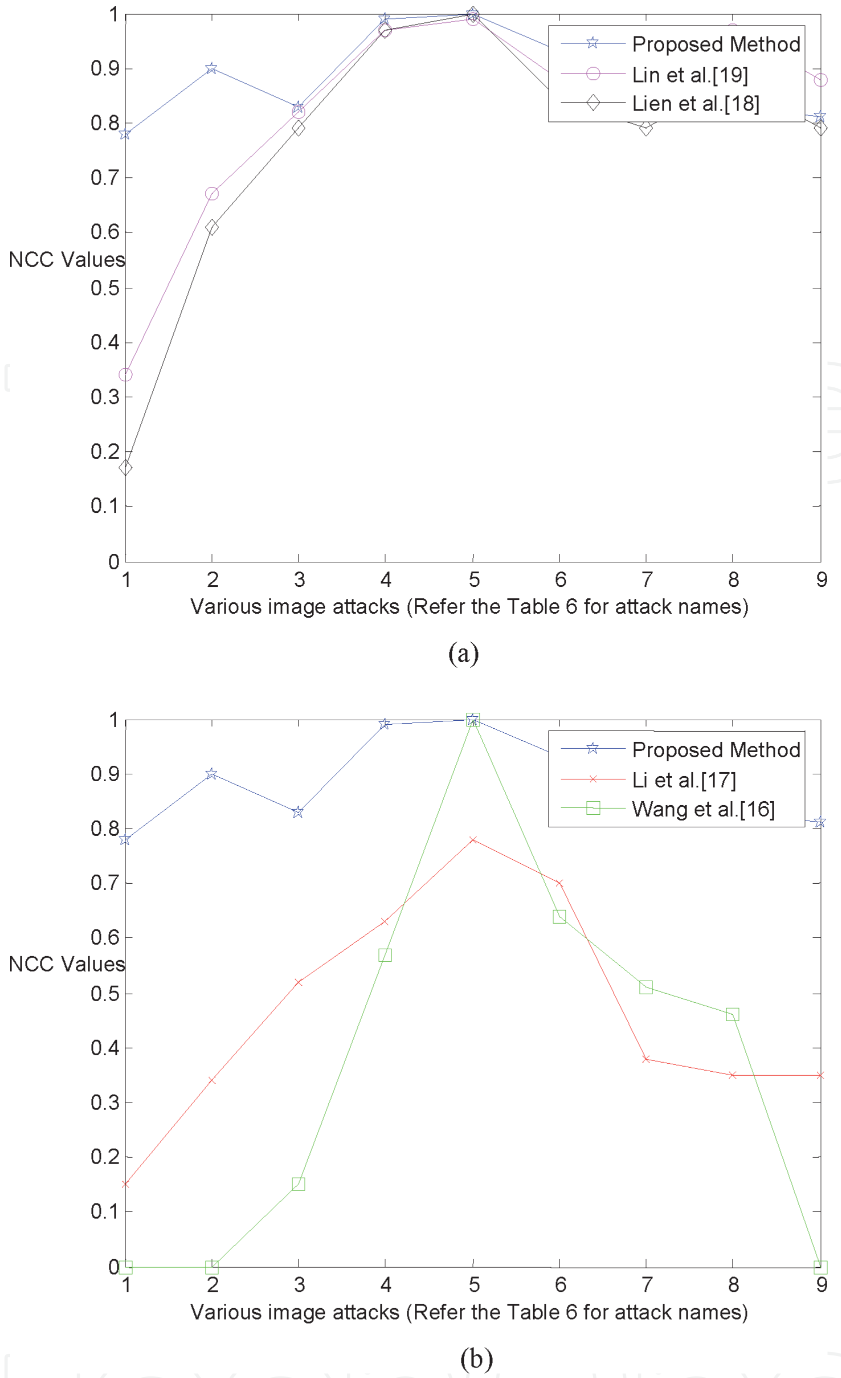


**Figure 4.**
*Performance comparison of the proposed method with the existing methods. (a) With Lin et al. [7] & Lien et al. [17]. (b) With Li et al. [16] and Wang et al. [8].*

and average filter, etc. The advantage of the proposed scheme is the effective use of GA to obtain the optimum response in terms of both PSNR and NCC. Experimental results show that the performance of the scheme is better than the existing schemes in terms of the embedding capacity, PSNR and NCC. In addition to copyright protection, the proposed scheme can also be applied to data hiding and image authentication. The flexibility of the proposed GA based scheme is also demonstrated in fixing the parameters of the scheme. Here, flexibility refers to the fixation of scheme parameters for satisfying the requirements in terms of PSNR and NCC when the input images (cover and/or watermark images) are changed.

For the scheme proposed in this chapter, watermark embedding capacity is medium. It can effectively embed $32 \times 32$ size watermark into $512 \times 512$ cover image. Hence, embedding capacity improvement is considered in the next chapter.

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