AN OBLIVIOUS AND ROBUST MULTIPLE IMAGE WATERMARKING SCHEME USING GENETIC ALGORITHM

K. Ramanjaneyulu[1], K. Rajarajeswari[2]
[1]Department of Electronics and Communications Engineering, Bapatla Engineering College, Acharya Nagarjuna University, Andhra Pradesh, India
kongara_r@yahoo.com
[2]Department of Electronics and Communications Engineering, College of Engineering, Andhra University, Andhra Pradesh, India
krrauv@yahoo.com

ABSTRACT

A novel oblivious and robust image watermarking scheme using Multiple Descriptions Coding (MDC) and Quantization Index Modulation (QIM) is presented in this work. In the proposed scheme, watermark is embedded in two stages to increase the robustness of the watermark against many of the image processing attacks. First stage embedding is based on MDC. Using MDC, the host image is partitioned into two sub images called even description and odd description. Blocked Discrete Hadamard Transform (DHT) is applied for both descriptions. The binary watermark is embedded in the resulting DC coefficients of the odd description using DC coefficients of the even description as the reference. In the second stage, copy of the same watermark is embedded in the first stage watermarked image using QIM. Proposed scheme is characterized with parameters and Genetic Algorithm (GA) is used for parameter optimization and thereby performance improvement is achieved over the existing methods in terms of Peak Signal to Noise Ratio (PSNR) and Normalized Cross correlation (NCC). Experimental results show that, this algorithm is highly robust for many image attacks on the watermarked image.

KEYWORDS

Digital Watermarking, Discrete Hadamard Transform, Genetic Algorithm, MDC, QIM

1. INTRODUCTION

Major problem associated with digital multimedia data transfer over internet is data authentication. This is because; digital media are easy to copy and transmit. In addition to that many researchers are aware of the issues like copyright protection, proof of ownership, etc related to multimedia. As a result, many solutions have been proposed and are available in the literature. Watermarking technique is one of the popular solutions to above mentioned issues. Watermarking technique embeds specific information called watermark into the original media so that it is not easily perceptible; that is, the viewer cannot see any information embedded in the contents. In the case of dispute over the owner of the multimedia data, embedded watermark can be extracted and it can be used to identify the owner because watermark contains the required information. There are several important issues in the watermarking system. First, the embedded watermark should not degrade the quality of the image and should be perceptually invisible to maintain its protective secrecy. Second, the watermark must be robust enough to resist common image processing attacks and not be easily removable; only the owner of the image ought to be able to extract the watermark. Third, the blindness is necessary if it is difficult to obtain the original image and watermark. A watermarking technique is referred to as blind (also referred to as oblivious or public) if the original image and watermark are not needed during extraction.

The process of digital watermarking involves the modification of the original multimedia data to embed a watermark containing key information such as authentication or

DOI : 10.5121/ijma.2010.2302

copyright codes. The embedding method must leave the original data perceptually unchanged, yet should impose modifications which can be detected by using an appropriate extraction algorithm. Common types of signals to watermark are images, music clips and digital video. In this work, application of the digital watermarking to still images is considered. If the watermark survives for many image attacks and is still extractable from the watermarked media then the watermarking technique is called robust. The major technical challenge is to design a highly robust digital watermarking technique, which protects copyright of the media owner by making the process of watermark removal tedious and costly [1]. Watermarking schemes can be classified into several categories according to their applications, embedding domain and characteristics. Based on embedding domain, watermarking schemes are classified into three categories: spatial domain, transform domain and hybrid domain. Some of the algorithms based on Discrete Cosine Transform (DCT) [2], [3], [4], [5], Discrete Wavelet Transform (DWT) [6], [7], [8], [9], Discrete Hadamard Transform (DHT) [10], [11], Singular Value Decomposition (SVD) [12] and Discrete Fourier Transform (DFT) [13], Fourier–Mellin [14] are transform domain methods. This paper presents a robust and oblivious multiple watermarking scheme in the transform domain. Any two dimensional transform can be used with this scheme. Performance of the proposed scheme might change slightly from transform to transform in terms of PSNR and NCC and those changes can be analyzed experimentally with the same set of input data (host image and the watermark) for some specified value of PSNR. In this work, Discrete Hadamard Transform (DHT) is used. Watermark is embedded in two stages. Stage one uses Multiple Description Coding (MDC) [15], [16], [17] and in the second stage, Quantization Index Modulation (QIM) [18], [19] is used. In the first stage, watermark embedding is done by using Multiple Descriptions Coding (MDC). Using MDC, host image is represented using two descriptions. Discrete Hadamard Transform is applied for both the descriptions. DC coefficients of one description are modified according to watermark bits and DC coefficients of the other description. Then inverse DHT is applied for both descriptions and combined them to get the first stage watermarked image. In stage two, copy of the same watermark is embedded using QIM into the watermarked image obtained after the first stage embedding. Genetic Algorithm (GA) [20] is used for optimizing the parameters of the proposed scheme. Proposed method is compared with method in [19]. Method in [19] is also multiple watermarking scheme in which 32×32 size binary watermark (1024 bits) is embedded in two sages in the Contourlet Transform domain of the host image. But the proposed method embeds 64×64 size binary watermark (2048 bits) in stages without compromising the perceptual quality (in terms of PSNR value of the watermarked image) of the watermarked image. In addition to that the embedding schemes used in [19] were modified and significant improvement is achieved. Performance improvement of the watermarking scheme of [19] is considered and is achieved by; (i) parameterization of the two schemes using multiple embedding strength factors in stage one and multiple step size parameters in stage two for different sub-ranges of the selected coefficients and (ii) optimization of the parameters for the required performance using GA.

Remainder of the paper is organized as follows: In Section 2, Genetic Algorithm and its application to watermarking are described briefly. In section 3, Multiple Descriptions Coding (MDC) is presented. The concept of MDC based watermarking using single embedding strength factor followed by multiple embedding factors are described in Section 4. QIM based watermarking is discussed in section 5. Details of the proposed scheme are presented in Section 6. Experimental results are given in Section 7. Conclusions are presented in Section 8.

2. GENETIC ALGORITHM

Genetic Algorithms [GA] were first developed by John Holland [20]. GA is one of the best optimization tools available in the literature. GA process can be described based on five functional units. They are a random number generator, fitness evaluation unit and genetic operators for reproduction, crossover and mutation operations. Random number generator generates a set of number strings called population. Each string represents a solution to the optimization problem. For each string, a fitness value is computed by the evaluation unit. A fitness value is a measure of the goodness of the solution .The objective of the genetic operators is to transform the set of strings into sets with higher fitness values. The reproduction operator performs a natural selection function known as "seeded selection". Individual strings are copied from one set (generation of solutions) to the next according to their fitness values. The probability of a string being selected for the next generation increases with the fitness value. The crossover operator chooses pairs of strings at random and produces new pairs. The mutation operator randomly changes the values of bits in a string. A phase of the algorithm consists of applying the evaluation, reproduction, crossover and mutation operations. A new generation of solutions is produced with each phase of the algorithm. Completion of optimization process depends on termination criterion. Termination criterion can be specified in terms of number of generations, specified time interval, etc.

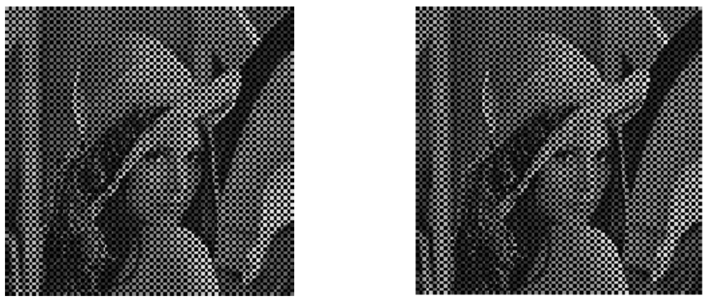
Watermarking problem can be viewed as an optimization problem. In this work, GA is used for solving the optimization problem. PSNR & NCC are the two important characteristic parameters of a watermarking system. The amount of distortion introduced to the host image during embedding process is inversely proportional to PSNR. NCC indicates the amount of similarity between original watermark and extracted watermark. Hence, both PSNR and NCC values must be as large as possible for a good watermarking system. But PSNR and NCC are related in such way that maximization of PSNR decreases the value of NCC. Hence, the watermarking scheme is characterized with parameters and GA is used to find the optimum values of parameters to obtain the specified performance of the watermarking system in terms of PSNR and NCC. But PSNR and NCC are related in such way that maximization of PSNR decreases the value of NCC. Hence, the watermarking scheme is characterized with parameters and GA is used to find the optimum values of parameters to obtain the specified performance of the watermarking system in terms of PSNR and NCC.

3. MULTIPLE DESCRIPTION CODING

Multiple descriptions coding (MDC) [15], [16] is a coding technique that fragments a single media stream into n sub streams ($n \geq 2$) referred to as descriptions. The packets of each description are routed over multiple, disjoint (partially) paths. In order to decode the media stream, any description can be used; however, the quality improves with the number of descriptions received in parallel. The idea of MDC is to provide error resilience to media streams. Since an arbitrary subset of descriptions can be used to decode the original stream, network congestion or packet loss (which is common in networking systems such as the Internet) will not interrupt the stream but only cause a loss (temporary) of quality. The quality of a stream can be expected to be roughly proportional to data rate sustained by the receiver.

Though MDC has its practical roots in media communication, it can be used for image watermarking applications as suggested by Chandramouli et al., [17]. Using MDC, host image is fragmented into two sub images referred to as descriptions. These descriptions of the host image must be in such a way that some correlation exists between them. In this work, host image is represented as a sum of two sub images called even and odd descriptions. Alternative pixels extracted from the host image are used to form the sub images. Alternative pixels (both row wise and column wise) can be collected in two ways: starting with first pixel and starting with second pixel. Sub image which contains the first pixel is identified as an odd description and other one is called even description. Host image Lena is shown in Fig.1 and is decomposed into odd and even descriptions and are shown in Fig. 2(a) and Fig. 2(b).

Fig. 1 Host image Lena



(a) (b)

Fig. 2(a) Odd description of Host Image
(b) Even description of Host Image

Watermark can be inserted in one description and the other description can be used as a reference for watermark extraction. After inserting the watermark in one description, it is combined with the other description to get the watermarked image.

4. MDC BASED WATERMARKING

Multiple descriptions coding (MDC) can be used for watermarking applications in several ways. In [19], MDC is used with single strength factor for embedding the binary watermark. In this work, MDC is used with multiple strength factors and performance improvement is achieved. In this section, both methods are described in brief.

4.1 Single Strength Factor

Based on MDC, the host image is partitioned into two sub images called odd and even descriptions respectively. Apply a block based image transform, like Discrete Hadamard Transform (DHT), to both the descriptions and obtain the coefficient matrices. Let $D_{odd}(i, j)$ and $D_{even}(i, j)$ are the DC coefficients extracted from the transforms of odd and even descriptions of the host image respectively in position (i, j). Let $w(i, j)$ denotes the watermark bit in position (i, j). Sizes of D_{odd}, D_{even} and w must be same. Watermark can be embedded in the transform domain of one of the descriptions by varying DC coefficients of the other description according to watermark bit. In this work, binary watermark is embedded in the odd description based on even description DC coefficients modulation. Each bit of the watermark can be embedded using the following equation.

$$D^{\circ}_{odd}(i,j) = D_{even}(i,j) + SF \times D_{even}(i,j), \text{ if } w(i,j)=1$$
$$= D_{even}(i,j) - SF \times D_{even}(i,j), \text{ if } w(i,j)=0$$
$$\text{For all } i \text{ and } j. \quad (1)$$

Where, SF denotes the embedding strength factor. As SF increases, the robustness of the watermark will increase where as, PSNR value of the watermarked image will decrease. After embedding all the watermark bits, inverse transform is applied to the modified transform of the odd description and is combined with the unmodified even description to obtain the watermarked image.

During the watermark extraction process, even description of the host image is used as a reference. Based on MDC, the possibly attacked watermarked image is partitioned into two sub images called odd and even descriptions respectively. Apply block based DHT to both descriptions and get the DC coefficients. Let $D^{\circ}_{odd}(i,j)$ and $D^{\circ}_{even}(i,j)$ denote the DC coefficients of odd and even descriptions respectively in position (i,j). Watermark bits can be extracted as follows:

$$w(i,j)=1, \text{ if } D^{\circ}_{odd}(i,j) \geq D^{\circ}_{even}(i,j)$$
$$w(i,j)=0, \text{ if } D^{\circ}_{odd}(i,j) < D^{\circ}_{even}(i,j)$$
$$\text{For all } i \text{ and } j. \quad (2)$$

4.2 Multiple Strength Factors

Performance of the scheme using single strength factor can be improved by characterizing with multiple strength factors (SFs).The entire range of selected coefficients is divided into 'n' number of non-overlapping sub ranges. For each sub range of coefficients, a different SF is used during the embedding. Then 'n' number of SFs is required for the completion of embedding process. Advantage of using multiple SFs is that perceptual difference between the host image and the watermarked image can be minimized by choosing the optimum values for SFs. MDC based watermarking with multiple SFs can be characterized with two sets of factors; Strength Factors (SFs) and Range Factors (RFs). Number of RFs is one less than the numbers of SFs. Range Factors (RFs) are used to divide the entire range (over which the selected coefficients are spreading) into number of non-overlapping sub ranges equal to the number of SFs.Each sub range is characterized by one strength factor. In this work, MDC is characterized with three SFs and two RFs. Let d_{max} denotes the maximum value of selected coefficients for modification. Then SF_1 is the strength factor for the sub range 0 to $RF_1 \times d_{max}$, SF_2 is the strength factor for the sub range $RF_1 \times d_{max}$ to $RF_2 \times d_{max}$ and the strength factor for the sub range $RF_2 \times d_{max}$ to d_{max} is SF_3. After identifying the sub range, the coefficient value is modified with the corresponding strength factor value and according to watermark bit as per equation (1) with SF defined in the following equation (3).

$$SF = SF_1, \text{ for } 0 < D_{odd}(i,j) \leq RF_1 \times d_{max}$$
$$= SF_2, \text{ for } RF_1 \times d_{max} < D_{odd}(i,j) \leq RF_2 \times d_{max}$$
$$= SF_3, \text{ for } RF_2 \times d_{max} < D_{odd}(i,j) \leq d_{max} \quad (3)$$

In (3), $D_{even}(i,j)$, for all i and j; refers to DC coefficients of even description and $SF < 1$ is a strength factor which can be varied for different sub ranges of the coefficients to control robustness and perceptual quality. After embedding all the watermark bits, inverse transform is applied to the modified transform of the odd description and is combined with the unmodified even description to obtain the watermarked image. Watermark extraction process does not require any parameter and can be done based on equation (2). It is difficult to find the required parameters for the optimum performance of the scheme. Parameter selection can be viewed as the optimization problem and it can be solved using the optimization tools available in the literature. In this work, Genetic Algorithm (GA) is used for parameters (Three strength factors and three non-overlapping sub ranges) optimization.

5. QUANTIZATION INDEX MODULATION

Index Modulation (QIM) [18], [19], is used for watermarking applications in the past. For the special case of binary watermark embedding, QIM is equivalent to designing two quantizers. One quantizer is to embed watermark bit 1 and the other quantizer is for embedding watermark bit 0. In this section, two different ways of using QIM for watermarking is considered. One is QIM based on uniform quantization with one step size parameter which is used in [19] and the other is QIM based on non uniform quantization with multiple step size parameters which is proposed in this work. Advantage of the proposed QIM method is the flexibility in obtaining the required performance. GA is used for parameter optimization.

5.1 QIM based on uniform quantization

QIM is used to quantize the host image transform coefficients according to watermark bits. The entire range of coefficients is divided into sub ranges of equal width. Number of sub ranges depends on the value of quantization step size. As the step size increases, robustness of the watermark increases and the quality of the watermarked image decreases. Hence, one has to choose the step size value optimally depending on the robustness and perceptibility requirement.

QIM based on uniform quantization can be characterized with one quantization step size parameter. Let $C(i,j)$ denotes the transform coefficient in the $(i,j)^{th}$ position of the selected transform coefficients matrix for watermark embedding. Similarly $W(i,j)$ represents the watermark bit in the $(i,j)^{th}$ position of the watermark to be embedded. Let Δ represents the quantization step size parameter. Consider the arithmetic division of $C(i,j)$ with Δ. That division operation produces the quotient q and the remainder r. Let $C^{\circ}(i,j)$ represents the modified value of $C(i,j)$. For the special case of binary watermark, the embedding is as follows:

(i) If $W(i,j)=1$,

$$\begin{aligned} C^{\circ}(i,j) &= (\mathrm{q}\times\Delta)+(0.75\times\Delta), \quad \textit{if} \quad r \geq 0.25\times\Delta \\ &= (\mathrm{q}-1)\times\Delta)+(0.75\times\Delta), \quad \textit{otherwise} \end{aligned} \tag{4}$$

(i) If $W(i,j)=0$,

$$\begin{aligned} C^{\circ}(i,j) &= (\mathrm{q}\times\Delta)+(0.25\times\Delta), \quad \textit{if} \quad r \leq 0.75\times\Delta \\ &= (\mathrm{q}+1)\ \Delta+(0.25\times\Delta), \quad \textit{otherwise} \end{aligned} \tag{5}$$

After embedding all the watermark bits, inverse transform is applied to the modified transform to obtain the watermarked image. Above scheme introduces minimum distortion into the host image in embedding the watermark and allows a simple decoding rule. Modified coefficient $C^{\circ}(i,j)$ contains the information about the watermark bit. Following is the watermark bit decoding rule:

$$W(i,j) = 1,\ if\ \ (C^{\circ}(i,j) \bmod \Delta) \geq \Delta/2$$
$$= 0,\ otherwise \qquad (6)$$

Where, mod operation produces the remainder of the division operation: $C^{\circ}(i,j)/\Delta$.

5.2 QIM based on non uniform quantization

QIM based on non uniform quantization is characterized with specific number of quantization step size parameters. The entire range of selected transform coefficients must be divided into 'n' (≥2) number of sub ranges and for each sub range a different quantization step size parameter must be selected. The choice of 'n', beginning and ending of each sub range depend on various issues like sensitivity of selected transform coefficients to various image attacks, specific watermark embedding and extraction strategy, etc. QIM based watermarking using non-uniform quantization can be characterized with two sets of parameters; step size parameters (Δs) and Range Factors (RFs). Number of RFs is one less than the number of Δs. Range Factors (RFs) are used to divide the entire range (over which the selected coefficients are spreading) into number of non-overlapping sub ranges equal to the number of Δs. Each sub range is characterized by one step size parameter. In this work, QIM is characterized with three Δs and two RFs. Let $d_{\max}$ denotes the maximum value of selected coefficients for modification. Then Δ_1 is the step size parameter for the sub range 0 to $RF_1 \times d_{\max}$, Δ_2 is the step size parameter for the sub range $RF_1 \times d_{\max}$ to $RF_2 \times d_{\max}$ and the step size parameter for the sub range $RF_2 \times d_{\max}$ to $d_{\max}$ is Δ_3. After identifying the sub range, the coefficient value is modified with the corresponding step size parameter value and according to watermark bit as per equations (4) and (5) but with Δ specified in equation (7).

$$\Delta = \Delta_1,\ \text{for}\ \ 0 < C(i,j) \leq RF_1 \times d_{\max},$$
$$= \Delta_2,\ \text{for}\ \ RF_1 \times d_{\max} < C(i,j) \leq RF_2 \times d_{\max},$$
$$= \Delta_3,\ \text{for}\ \ RF_2 \times d_{\max} < C(i,j) \leq d_{\max}. \qquad (7)$$

Similarly, watermark extraction can be done based on equation (6) with Δ defined in equation (7). In this work, GA is used to determine the optimum values of step size parameters and optimum widths of non overlapping sub ranges. Optimization is with respect to two important conflicting requirements (PSNR and NCC) of watermarking.

6. PROPOSED SCHEME

In this section, proposed scheme is described in there sub sections. Sub section 6.1 deals with watermark embedding procedure, watermark extraction is explained in sub section 6.2 and the application of GA for determining the optimum parameters is given in sub section 6.3.

6.1 Watermark Embedding Technique

Let the size of a binary watermark is $\left(N/K \; x \; N/K\right)$ and the size of the grey level host image is NxN. Proposed GA based scheme embeds the watermark into the host image in two stages. The first stage is based on MDC with multiple strength factors (section 4.2) and the second stage is based on QIM with non uniform quantization (section 5.2).

Steps of embedding algorithm are as follows:

1. The host image $h(i, j)$ of size NxN is partitioned into two descriptions called odd and even descriptions respectively. Block based DHT with a block size of $K \times K$ is applied to both the descriptions. DC coefficients of all the blocks of odd description are selected for watermark embedding.
2. All the DC coefficients of odd description, $D_{odd}(i, j)$, for all $\left(1 \leq, i, j \leq (N/K)\right)$, are modified according watermark bits $w(i, j)$ using equations (1) and (3) given in sub section 4.2 with multiple strength factors and range factors. Use the GA based procedure given in sub section 6.3 to find the optimum values of three strength factors and two range factors.
3. Block based Inverse Discrete Hadamard Transform (IDHT) is applied to the modified transform of the odd description. The outcome of the inverse transformation is combined with the unmodified even description to get the stage one watermarked image.
4. Block based DHT is applied to the watermarked image obtained in Step 3. DC coefficients of all the blocks of the watermarked image are modified according to the watermark bits. This modification is based on non uniform QIM described in sub section 5.2 and using equations (4), (5) and (7). Use the GA based procedure given in sub section 6.3 to find the optimum values of three quantization step size parameters and two range factors.
5. IDHT is applied to the modified DC coefficients to get the second stage watermarked image and is also representing the final watermarked image.

6.2 Watermark Extraction Process

Watermark extraction is done in two stages. Quality of the extracted watermark in stage one is extremely good for some set of image attacks whereas, extracted watermark using stage two is outstanding for some other set of attacks. No parameters are required for stage one extraction. But for second stage extraction, the parameters (three step size parameters and two range factors) used in embedding are required. First stage extraction is based on MDC and the second stage extraction is based on QIM.

Extraction of watermark is as follows:

1. Possibly attacked watermarked image of size NxN is partitioned into two descriptions. Apply $K \times K$ block based DHT to both the descriptions and get the DC coefficients.
2. First stage watermark extraction is based on comparison between the DC coefficients of odd description and the DC coefficients of even description and is according to the equation (2) given in section 4.
3. For second stage extraction, apply $K \times K$ block based DHT to the received watermarked image and get the DC coefficients of all the blocks.

4. Then extract the second stage watermark from DC coefficients obtained from step 3 and using the equation (6) with Δ defined in equation (7).

Advantage of the proposed two-stage watermarking scheme is that watermark survival capability is very high for many of the image attacks. This is because, for global attacks like histogram equalization, sharpening and gamma correction; watermark embedded based on MDC (stage one) survives and for local attacks like JPEG compression, median filtering etc; watermark embedded based on QIM (stage two) survives. Hence, the performance of this two-stage embedding scheme is better than conventional single stage embedding schemes.

6.3 Optimization of parameters using GA

Optimization of parameters using GA requires initial values for the parameters of the embedding process and the fitness function. Fitness function is a user defined function and it must be a function of PSNR, NCC and the parameters of the scheme. Optimization process starts with initialization. Hence, initial values for the parameters must be supplied before running the GA algorithm. Supplied initial values must be within the solution space and they need not represent the correct solution. GA will maximize the value of the fitness function and this maximization process will terminate according to one or one of several specified termination criteria. After the termination of GA, it gives the optimum values of parameters. Those parameters must be used in the embedding and/or extraction process. The error metrics used to test the proposed algorithm are Normalized Cross correlation (NCC) and peak signal to noise ratio (PSNR) and are defined in section 7.

Optimization of parameters is as follows:

1. Set the suitable values for the parameters.
2. Embed a binary watermark in the gray level host image following the steps in section 6.1 and based on MDC (section 4.2). Get the corresponding watermarked image.
3. Extract the watermark from the attacked watermarked images for the specified number; say p, of attacks as per the procedure explained in section 6.2 for stage one extraction.
4. Define a fitness function fit_l as follows:

$$fit_l = PSNR_l + \frac{1}{p} \sum_{k=1}^{p} (NCC_{k,l} \times \lambda_{k,l}) \tag{8}$$

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 $\lambda_{k,l}$ represents weighting factor for NCC.

5. Use GA to maximize the above fitness function and get the optimum parameters for MDC based watermark embedding.
6. Repeat the above procedure using QIM (section 5.2) and get the optimum parameters for that method.

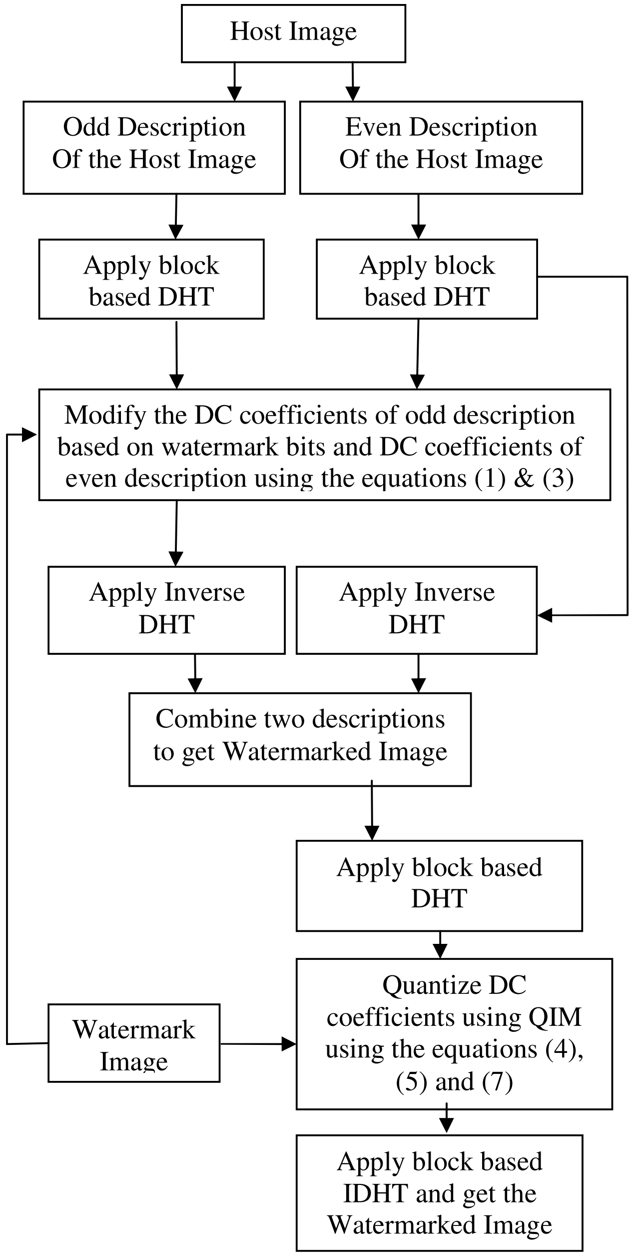


Fig. 3 Embedding Algorithm

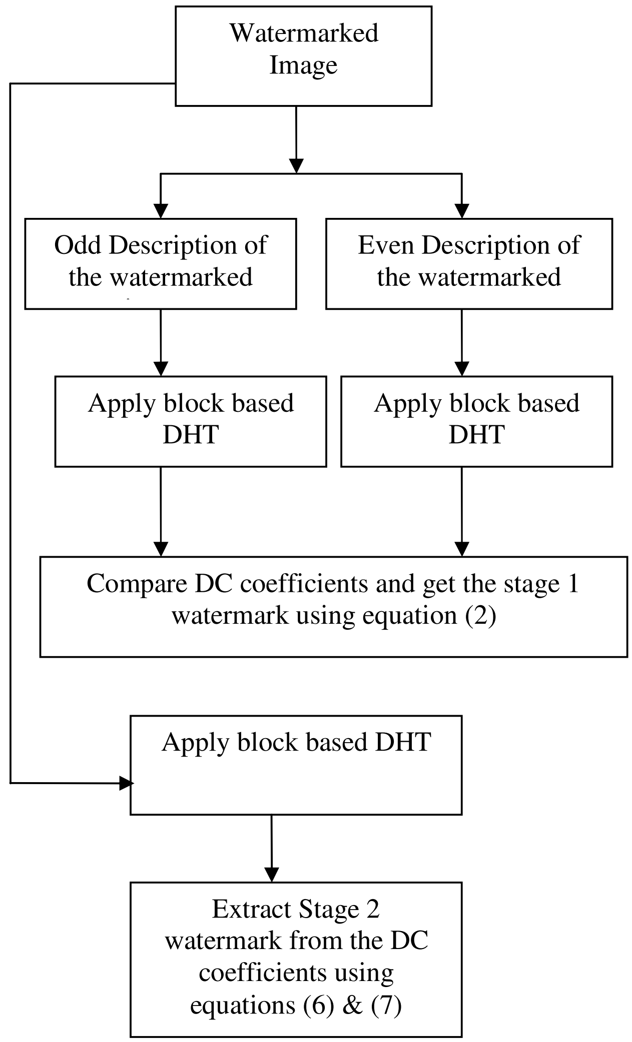


Fig. 4 Extraction Algorithm

Note:

- Refer Fig. 3, Fig. 4 and Fig. 5 for flow charts of Embedding Algorithm, Extraction Algorithm, and optimization of parameters respectively.
- Fitness function fit_l of equation (8) is the most generalized one and it can be changed according to the watermarking requirements for some intended application.
- Fitness functions used in this work are given in the experimental results section.

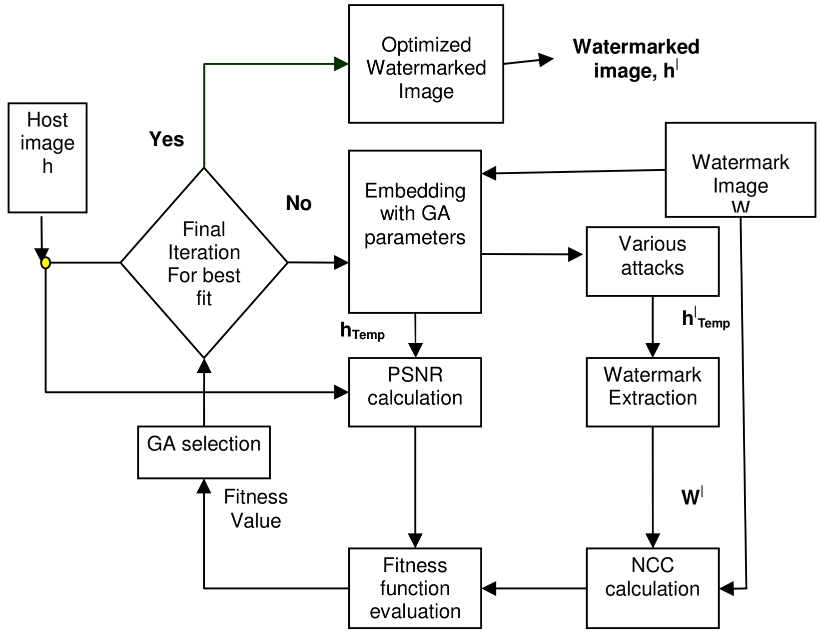


Fig. 5 Flow chart for GA based watermark embedding

8. EXPERIMENTAL RESULTS

The peak signal-to-noise ratio ($PSNR$) is used to evaluate the quality of the watermarked image in comparison with the host image. $PSNR$ Formula is as follows:

$$PSNR = 10\log_{10}\frac{255\times 255}{\frac{1}{M\times N}\sum_{x=1}^{M}\sum_{y=1}^{N}\left[h(x,y)-h^{\circ}(x,y)\right]^2}dB \tag{9}$$

Where, M and N are the height and width of the image, respectively. $h(x,y)$ and $h^{\circ}(x,y)$ are the values located at coordinates (x,y) of the host image, and the watermarked image, respectively. After extracting the watermark, the normalized correlation coefficient (NCC) is computed using the original watermark and the extracted watermark to judge the existence of the watermark and to measure the correctness of an extracted watermark. It is defined as

$$NCC = \frac{1}{m\times n}\sum_{i=1}^{m}\sum_{j=1}^{n} w(i,j)\times w^{\circ}(i,j) \tag{10}$$

Where, m and n are the height and width of the watermark, respectively. $w(i,j)$ and $w^{\circ}(i,j)$ are the watermark bits located at coordinates (i,j) of the original watermark and the extracted watermark.

Lena image of size 512×512 is used as the host image and is shown in Fig.1. The watermark image is of 64×64 size, which is a binary logo as shown in Fig. 6. Watermarked image is shown in Fig. 7. Block size used in block based DHT is 8×8. Parameters of the MDC based watermarking (used in stage 1) with multiple factors are Strength Factors (SFs) and Range Factors (RFs). As explained section IV, three SFs and two RFs are used in this work. GA is used to find the optimum values of these parameters for some target values for PSNR, NCC, and one or more specific image attacks. When GA algorithm is executed to minimize the value of a fitness function, 10×abs (1-NCC) + abs (43-PSNR) for high pass filtering attack only, GA has produced the following optimum values for SFs, RFs, PSNR and NCC after GA is terminated.

SFs = (0.0700, 0.0302, and 0.0376), RFs = (0.4068, 0.7760), PSNR= 43.05 dB, and NCC= 1.

Parameters of the QIM based watermarking (used in stage 2) with multiple parameters are three Δs and two RFs. When GA algorithm is executed to minimize the value of a fitness function, 10×abs (1-NCC) + abs (43-PSNR) for JPEG attack with QF=50, GA has produced the following optimum values for Δs, RFs, PSNR and NCC after GA is terminated.

SFs = (6.7206, 5.8009, 6.0463), RFs = (0.3768 0.6674), PSNR= 42.71 dB, and NCC= 0.9948.

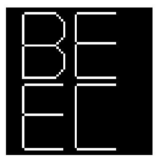


Fig. 6 Watermark Image

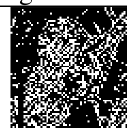
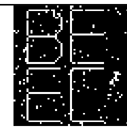
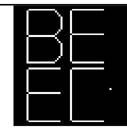
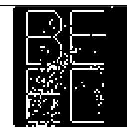
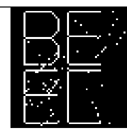
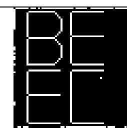
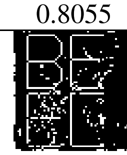
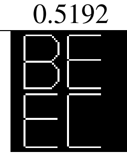
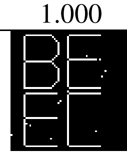
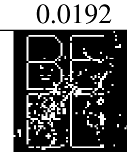
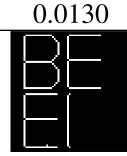
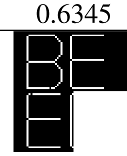
Fig. 7 Watermarked Lena (PSNR=39.90 dB)

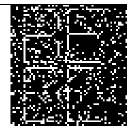
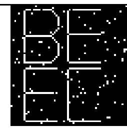
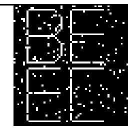
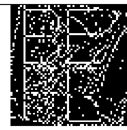
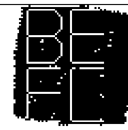
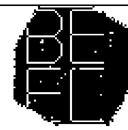
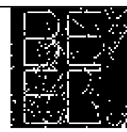
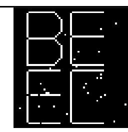
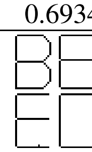
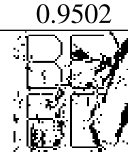
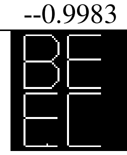
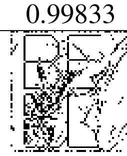
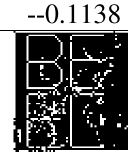
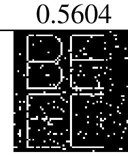
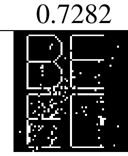
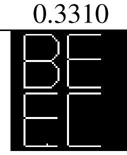
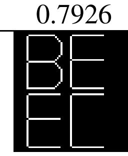
For testing the robustness of the proposed scheme MATLAB 7.0 and Checkmark 1.2 [21] are used. For all the attacks of Checkmark 1.2 and MATLAB 7.0, a window size of 3x3 is taken. Various attacks used to test the robustness of the proposed watermark are JPEG Compression, Median Filter, Gaussian filter, Average filter, Image Sharpening, Histogram Equalization, Resizing, Cropping, Gaussian noise, Salt & Pepper Noise, Rotation, Wiener Filter, Grey Scale Inversion, Gamma Correction, Soft Thresholding, Template Removal, Trimmed Mean Alpha, Bit plane Removal, Row & Column Copying, Row & column Blanking, and Linear Motion of camera. Performance of the proposed method is compared with [19] and is shown in TABLE 1. Extracted watermarks, after applying various attacks are summarized in TABLE 2. TABLES 3 to 6 show the results of the two methods in fixing the parameters for various requirements.

TABLE 1 Comparison of proposed method with Mohan et al. Method [19]

Characteristic	Mohan et al Method [19]	Proposed Method
No of Watermark Bits embedded	1024 (32x32 logo)	4096 (64x64 logo)
PSNR in dB	39.37	39.90
Method used for determining parameters of scheme	Trail and error method	GA based optimization method
Distinct number of attacks used to test the robustness of the proposed scheme	20	22
Type of embedding	Oblivious	Oblivious

TABLE 2 Extracted Watermarks

Attack	Retrieved Watermark at Stage 1 & NCC	Retrieved Watermark at Stage 2 & NCC
JPEG Compression (QF=40%)	 0.0340	 0.7880
JPEG Compression (QF=60%)	 0.0216	 0.9983
Median Filtering (3x3)	 0.2422	 0.7466
Gaussian filter (3x3)	 0.8886	 0.8055
Average filter (3x3)	 0.5192	 0.6688
Image Sharpening	 1.000	 0.1381
Histogram Equalization	 0.9795	 0.0192
Resizing (50%)	 0.0130	 0.6345
Cropping (257:512,257:512)	 0.9412	 0.4157

Gaussian noise (0.001 density)	 0.4626	 0.4616
Salt & Pepper Noise (0.001 density)	 0.8458	 0.7575
Rotation 10^0	 0.4614	 0.6016
Rotation 30^0	 0.3511	 0.4783
Wiener Filtering	 0.6934	 0.9502
Grey Scale Inversion	 --0.9983	 --0.4564
Gamma Correction (Gamma=0.9)	 0.99833	 --0.1138
Soft Threshold (3x3)	 --0.4519	 0.5604
Template Removal	 0.6855	 0.7282
Trimmed Mean Alpha	 0.3310	 0.7926
Bit plane Removal (LSB)	 0.9983	 1.000

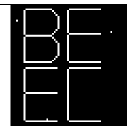
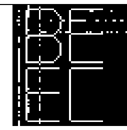
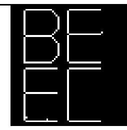
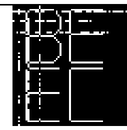
Row & Column copying (10-30,40-70,100-120)	 0.9931	 0.8248
Row column Blanking 30,70,120	 0.9948	 0.7488
Linear Motion of camera (9 pixels, zero degrees)	 0.5043	 0.1984

TABLE 3 DHT-MDC RESULTS

Type: single strength parameter (Uniform Embedding) Attack: Sharpening Filter			
S.NO	PSNR	NCC	Parameter (SF)
1	44.5870	0.9502	0.0305
2	43.8609	0.9645	0.0330
3	42.6338	0.9879	0.0380
4	42.4509	0.9914	0.0390
5	42.2582	0.9914	0.0400
6	42.0841	0.9931	0.0410
7	41.8499	0.9948	0.0420
8	41.4492	0.9948	0.0440
9	40.5445	1.0000	0.0490

TABLE 4 DHT-MDC-GA RESULTS

Type: Three Strength Parameters and Two Range Factors (Non Uniform Embedding) Attack: Sharpening Filter Fitness Function: PSNR+20*NCC (p=1 and λ=20)				
No. of Gen	Fitness value	PSNR In dB	NCC	Parameters [SF_1, SF_2, SF_3, RF_1, RF_2]
1 (20 Iterations)	64.116	44.1851	0.9965	[0.0421, 0.0302, 0.0305, 0.4800, 0.7914]
2 (40 Iterations)	63.808	43.8427	0.9983	[0.0522, 0.0342, 0.0257, 0.2870, 0.7978]

3 (60 Iterations)	64.304	44.3388	0.9983	[0.0465, 0.0327, 0.0305, 0.3457, 0.4908]
4 (80 Iterations)	64.58	44.5802	1.0000	[0.0475, 0.0377, 0.0253, 0.3028, 0.6116]
5 (100 Iterations)	66.333	47.4942	0.9419	[0.0303, 0.0371, 0.0144, 0.5462, 0.5940]

TABLE 5 DHT-QIM RESULTS

Type: single strength parameter (Uniform Embedding) Attack: Jpeg (QF=40)			
S.NO	PSNR	NCC	Parameter (Δ)
1	44.6801	0.9429	5.0
2	43.5695	0.6568	5.5
3	42.6787	0.6189	6.0
4	42.1405	0.8066	6.5
5	41.7681	0.9094	7.0
6	40.7919	1.0000	7.5
7	40.1387	0.9465	8.0
8	39.4632	0.9948	9.0
9	38.6486	1.0000	10

TABLE 6 DHT-QIM-GA RESULTS

Type: Three Step Size Parameters and Two Range Factors (Non Uniform Quantization) Attack: Jpeg (QF=40) Fitness Function: PSNR+20*NCC (p=1 and λ=20)				
No. of Generations	Fitness value	PSNR In dB	NCC	Parameters [Δ_1, Δ_2, Δ_3, RF_1, RF_2]
1 (20 Iterations)	59.485	40.5247	0.9480	[6.8521, 7.5416, 10.7905, 0.4109, 0.7966]
2 (40 Iterations)	60.072	41.0199	0.9526	[5.8904, 7.3384, 9.8794, 0.3978, 0.7634]

3 (60 Iterations)	60.989	41.4653	0.9762	[7.2956 , 7.3600, 6.3043, 0.4049 0.7564]
4 (80 Iterations)	60.405	40.4046	1.0000	[8.0304, 9.4453, 7.1510 , 0.4983, 0.6428]
5 (100 Iterations)	62.763	42.9029	0.9930	[7.2059, 5.0724, 7.7731, 0.3185, 0.7300]

TABLE 3 shows the values of PSNR and NCC of a MDC based watermarking scheme with single embedding strength parameter for different values of the parameter. The attack used in obtaining the values is image sharpening. TABLE 4 shows the results of MDC based and with multiple strength parameters using GA. For 100% watermark extraction (NCC=1), the required PSNR is 40.5445 dB with single parameter. But under similar conditions, proposed GA based MDC with multiple factors performs well and watermark can be completely extracted from a watermarked image with PSNR equal to 44.5802. This clearly indicates the superiority of the proposed scheme in comparison with the existing scheme. Similarly, from TABLES 5 & 6, one can conclude that GA based QIM with multiple step size parameters is the better scheme in comparison with QIM based on single step size parameter.

9. CONCLUSIONS

In this paper, a novel and oblivious watermarking scheme based on multiple description of host image and quantization of DC coefficients in the DHT domain is proposed. Watermark is embedded in two stages. In the first stage, watermark is embedded in the DC coefficients of blocked DHT of odd description of host image. In the second stage, copy of the same watermark is embedded in the DC coefficients of blocked DHT of the first stage watermarked image using quantization. Watermark extraction is also done in two stages. Stage one extraction is based on MDC where as second stage extraction is based on quantization. It has been observed experimentally that for image sharpening and histogram equalization, quality of the extracted watermark based on second stage extraction is very poor. But, quality of the extracted watermark using stage one extraction is good for those attacks. For JPEG Compression, Median filtering, Resizing and Rotation, second stage watermark extraction is much better to stage one extraction. GA is used for parameter optimization. Compared to [19], proposed method based on GA is superior in terms of, amount of embedded information, PSNR and survival to number of image attacks. In addition that flexibility of the proposed GA based scheme is demonstrated in fixing the parameters of the scheme.

REFERENCES

1. *J. Zhao, "Look, it's not there," Byte, January 1997.*
2. *I. J. Cox, J. Killian, T. Leighton, T. Shamoon. "Secure spread spectrum watermarking for multimedia," IEEE Transactions on Image Processing 6, 1997, pp. 1673-1687.*
3. C. I. Podilchuk, W. Zeng, "Image adaptive watermarking using visual models," IEEE Journal on Selected Areas in Communications 1998; 16: 525–39.
4. *Chu, W.C., 2003, "DCT based image watermarking using sub sampling," IEEE Transactions Multimedia, pp.34-38.*
5. *Wang, Y., Alan Pearmain., 2004. "Blind image data hiding based on self reference," Pattern Recognition Letters 25, pp. 1681-1689.*
6. *Barni, M., Bartolini, M., Piva, F.V., 2001. "Improved wavelet based watermarking through pixel-wise masking," IEEE Transactions on Image Processing, 10, pp. 783-791.*
7. *Lee, C., Lee, H., 2005. "Geometric attack resistant watermarking in wavelet transform domain," Optics Express vol.13, no.4, and pp.1307-1321.*
8. C. I. Podilchuk, W. Zeng, "Image adaptive watermarking using visual models," IEEE Journal on Selected Areas in Communications 1998; 16: 525–39.
9. A. H. Paquet, R. K. Ward, I. Pitas, "Wavelet packet-based digital watermarking for image verification and authentication," Signal Processing 2003; 83: 2117–32.
10. Chandra Mohan B, Srinivas Kumar S, Chatterjee B.N., "Digital Image watermarking in dual domains," at *IET Visual Information Engineering*, *VIE* 2006 at Leela Palace, Bangalore, 26-28th September 2006.
11. Santi P.Maity, Malay K. Kundu, "DHT domain digital watermarking with low loss in image informations," *International Journal of Electronics and Communications*, 2009
12. Yongdong, Wu, "On the Security of an SVD based ownership watermarking," *IEEE transactions on Multimedia*, 2005, vol. 7, No. 4.
13. O. Ruanaidh, T. Pun, "Rotation, scale and translation invariant digital image watermarking," in Proceedings of IEEE ICIP, Atlanta, GA, 1997 p. 536–9.
14. O. Ruanaidh, T. Pun, "Rotation, scale and translation invariant spread spectrum digital image watermarking," Signal Processing 1998; 66:303–17.
15. V. K. Goyal, "Multiple Description Coding: Compression Meets the Network," IEEE Signal Processing Magazine, vol. 18, no. 5, pp. 74–94, Sept. 2001.
16. K. Ramanjaneyulu and K. Rajarajeswari, "An Oblivious Image Watermarking Scheme Using Multiple Description Coding and Genetic Algorithm," is published in the International Journal of Computer Science and Network Security (IJCSNS), Vol. 10 No. 5, May 2010.
17. Chandramouli R, Graubard Benjamin and Richard Collin R, "A multiple description framework for oblivious watermarking," in *Proceedings of Security, Watermarking and Multimedia,* 2001.
18. B. Chen and G. W. Wornell, "Quantization index modulation: a class of provably good methods for digital watermarking and information embedding," *IEEE Transactions on Information Theory*, Vol. 47, 2001, pp. 1423-1443.
19. B. C. Mohan and S. S. Kumar, "Robust Digital Watermarking Scheme using Contourlet Transform," IJCSNS International Journal of Computer Science and Network Security, VOL.8 No.2, PP. 43-51, February 2008.
20. Holland JH. "Adaptation in natural and artificial systems: an introductory analysis with applications to biology, control and artificial intelligence". Cambridge, MA: MIT Press; 1992.
21. www.http://watermarking.unige.ch/Checkmark/

AUTHORS

K. Ramanjaneyulu is currently working as a Professor in ECE Department, Bapatla Engineering College, Bapatla, India. He is working towards his Ph.D.at AU College of Engineering, Vishakhapatnam, India. He received his M.Tech. from Pondicherry Engineering college, Pondicherry, India. He has seventeen years of experience in teaching undergraduate students and post graduate students. His research interests are in the areas of image watermarking, and wireless communications

K. Raja Rajeswari obtained her BE ME and PhD degrees from Andhra University, Visakhapatnam, India in 1976, 1978 and 1992 respectively. Presently she is working as a professor in the Department of Electronics and Communication Engineering, Andhra University. She has published over 100 papers in various National, International Journals and conferences. She is Author of the textbook *Signals and Systems* published by PHI. She is co-author of the textbook *Electronics Devices and Circuits* published by Pearson Education. Her research interests include Radar and Sonar Signal Processing, Wireless CDMA communication technologies etc. She has guided *ten* PhDs and presently she is guiding *twelve* students for Doctoral degree. She is current chairperson of IETE, Visakhapatnam Centre. She is recipient of prestigious IETE Prof SVC Aiya Memorial National Award for the year 2009, Best Researcher Award by Andhra University for the year 2004 and Dr. Sarvepalli Radhakrishnan Best Academician Award of the year by Andhra University for the year 2009. She is expert member for various national level academic and research committees and reviewer for various national/international journals.