An Oblivious Image Watermarking Scheme Using Multiple Description Coding and Genetic Algorithm

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Abstract
A novel oblivious and robust image watermarking scheme using Multiple Descriptions coding (MDC) is presented in this work. Based on MDC, the host image is partitioned into two sub images called even description and odd description. Discrete Hadamard Transform (DHT) is applied for both descriptions. The watermark image is embedded in the resulting DC coefficients of the odd description using DC coefficients of the even description as the reference. 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). This algorithm is highly robust for different attacks on the watermarked image.
Index Terms: *Digital watermarking, Discrete Hadamard Transform, Genetic Algorithm, MDC, PSNR.*

1. Introduction

With the rapid development of computer networks and Internet, multimedia security and digital rights management (DRM) are becoming increasingly important issues [1, 2]. Watermarking technology is one possible solution to control the unauthorized copying and redistribution of multimedia data like digital images, audio and video. Digital watermarking is the process of embedding some information called watermark into an original multimedia object so that the watermark may be detected or extracted later to make a claim about the object. The original media object is also called as cover object or host object.

A variety of watermarking techniques have been proposed for multimedia protection, and in particular for digital images [3, 4, 5]. These techniques can be divided into two main categories according to the embedding domain of the cover image: spatial domain methods and transform domain methods [5]. The spatial domain methods are the earliest and simplest watermarking techniques. But the watermark can easily be erased by lossy image compression. On the other hand, the transform domain approaches embed the watermark into the transform coefficients of the host image, yielding more robustness against watermarking attacks. Transform domain methods include the discrete cosine transform (DCT) [6, 7], the discrete Fourier transform (DFT) and the discrete wavelet transform (DWT) [8, 9]. Many different ideas have been presented, most of them originating from Cox et al [3]. Barni et al [10] have improved the idea by providing a blind detection system. Watermarking methods can also be divided into three categories based on the inputs required for extraction other than the watermarked image. They are oblivious, semi-oblivious and non-oblivious. In oblivious watermarking systems, original image or watermark is not required for its extraction and designing these systems is challenging. Oblivious watermarking has been accepted as the state of the art solution for most of the applications.

This paper presents a robust and oblivious watermarking scheme in the transform domain. Any two dimensional transform can be used. In this work, Discrete Hadamard Transform (DHT) is used. Watermark embedding is done by using Multiple Descriptions Coding (MDC) [11]. In this work, 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 watermarked image. Genetic Algorithm (GA) is used for optimizing the parameters of MDC based watermarking. Superiority of the proposed method is observed over [12]. In [12], watermark is embedded twice in the Contourlet Transform domain of the host image. In the first stage, binary watermark is embedded with one embedding strength factor for the entire range of selected coefficients using MDC based watermarking. A copy of the same watermark is embedded in the second stage using QIM [13]. In this work, performance improvement of MDC based watermarking is considered and is achieved by; (i) parameterization of the scheme using multiple embedding strength factors for different sub-ranges of the selected coefficients and (ii) optimization of the parameters for the required performance. Remainder of the paper is organized as follows: Multiple Description Coding (MDC) is presented in Section II. The concept of MDC based watermarking using one embedding strength factor is described in Section III. Basic structure of GA is presented in section IV. Details of the proposed

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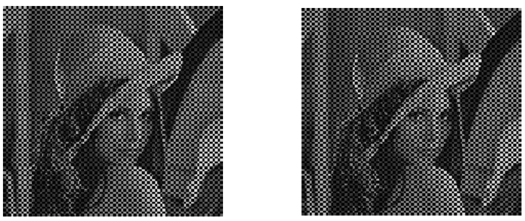
scheme are presented in Section V. Experimental results are given in Section VI. Conclusions are presented in Section VII.

2. Multiple Descriptions Coding

In Multiple Descriptions Coding (MDC) [11] of an image, the image is partitioned into multiple descriptions. Partitioning must be done in such way that the receiver is able to reconstruct the original image within some prescribed distortion levels by using few of the descriptions.

This concept of MDC was adapted to digital image watermarking. 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). 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 form the watermarked image.

Fig. 1 Host image LENA



(a) (b)

Fig. 2(a) LENA odd description (b) LENA even description

3. Mdc Based Watemarking

MDC described in section II can be used for watermarking. Based on MDC, the host image is partitioned into two sub images called odd and even descriptions respectively. Let $h(i,j)$ represents the pixel value of the host image in position (i,j). Similarly $h_{odd}(i,j)$ and $h_{even}(i,j)$ represent the pixel values of odd and even descriptions respectively. Let $H(i,j)$, $H_{odd}(i,j)$ and $H_{even}(i,j)$ are the transform coefficients of the host image, odd description and even description respectively. The transform can be a block based DHT, Discrete Cosine Transform (DCT) or a multi-resolution transform like Discrete Wavelet Transform (DWT). 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. 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 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.

$$D_{odd}(i,j) = D_{even}(i,j) + SF * D_{even}(i,j) \text{ if } w(i,j) = 1$$

$$D_{odd}(i,j) = D_{even}(i,j) - SF * D_{even}(i,j) \text{ if } w(i,j) = 0$$

For all i and j. (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. Even description of the host image is used as a reference during the watermark extraction process. Partition the possibly attacked watermarked image into two descriptions based on MDC. Apply block based DHT to both descriptions and get the DC coefficients. Let D_{odd} and D_{even} denote the DC coefficients of odd and even descriptions respectively. Watermark bits can be extracted as follows:

$$w(i,j) = 1 \text{ if } D_{odd}(i,j) > D_{even}(i,j)$$

$$w(i,j) = 0 \text{ if } D_{odd}(i,j) < D_{even}(i,j)$$

For all i and j. (2)

4. Genetic Algorithm

Genetic Algorithms were first developed by John Holland [14]. 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.

5. Proposed Scheme

Performance of the existing scheme described in section III can be improved by characterizing MDC based watermarking 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 (3). Watermark extraction process does not require any parameter and can be done based on equation (4).

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 parameter optimization. Summary of the proposed method is as follows.

A. 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 . Based on MDC, the host image is divided into two sub images called even and odd descriptions (refer section II). A block based DHT with a block size of $K \times K$ is applied to both descriptions. Based on MDC and using multiple strength factors, all the DC coefficients of odd description are modified using DC components of even description and according to the watermark bits. Required parameters for watermark embedding may be obtained using GA (refer part C of this section). The flow chart for GA based watermark embedding procedure is shown in Fig. 1.

Steps of embedding algorithm are as follows

1. The host image $h(i, j)$ of size NxN is partitioned into two descriptions. Block based DHT is applied to both the descriptions. DC coefficients of all the blocks of odd description are selected for watermark embedding.

2. DC coefficients of odd description $D_{odd}(i, j)$ $\left(1 \le i, j \le (N/K)\right)$ are modified as follows:

$$D_{odd}(i, j) = D_{even}(i, j) + SF * D_{even}(i, j) \quad \text{if } w(i, j) = 1$$

$$D_{odd}(i, j) = D_{even}(i, j) - SF * D_{even}(i, j) \quad \text{if } w(i, j) = 0$$

Where,

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

(3)

In (3), $D_{even}(i, j)$, $\left(1 \le i, j \le (N/K)\right)$ 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. In this work three strength factors are used for three non-overlapping sub ranges of the selected coefficients. GA is used for optimizing the values of strength factors and range factors which are used for embedding the watermark in the host image.

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 watermarked image.

B. Watermark Extraction Process

Parameters (SFs and RFs) used in embedding are not required for watermark extraction. Possibly attacked watermarked image is partitioned into two sub images called even and odd descriptions based on MDC (refer section II). A block based DHT with a block size of $K \times K$ is applied to both descriptions. Watermark bits are extracted by comparing DC coefficients of the two descriptions.

Extraction of watermark is as follows:

1. Possibly attacked watermarked image of size NxN is partitioned into two descriptions. Apply block based DHT to both descriptions and get the DC coefficients.
2. DC coefficients of odd description are compared with the DC coefficients of even description to extract watermark bits according to the following rule.

$$w(i, j) = 1 \quad \text{if } D_{odd}(i, j) > D_{even}(i, j)$$

$$w(i, j) = 0 \quad \text{if } D_{odd}(i, j) < D_{even}(i, j) \quad (4)$$

C. Optimization of parameters using GA

Optimization of parameters using GA requires initial values for SFs and RFs used in the embedding process. Hence the optimization process starts with initialization. The error metrics used to test the proposed algorithm are Normalized Cross correlation (NCC) and peak signal to noise ratio (PSNR). They are defined in section VI.

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 part A and obtain the 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 part B.

4. Define a fitness function fit_l as follows:

$$fit_l = PSNR_l + \frac{1}{P}\sum_{h=1}^{p}\left(NCC_{h,l} \times \lambda_{h,l}\right) \quad (5)$$

Where, l denotes GA generation number, p denotes the total number of attacks used in the optimization process, $NCC_{h,l}$ represents NCC value with attack h and GA generation number l, and $\lambda_{h,l}$ represents weighting factor for NCC.

5. Use GA to maximize the above fitness function and get the parameters for the optimum performance of the proposed scheme.

Flow chart for GA based watermarking is shown in Fig. 3.

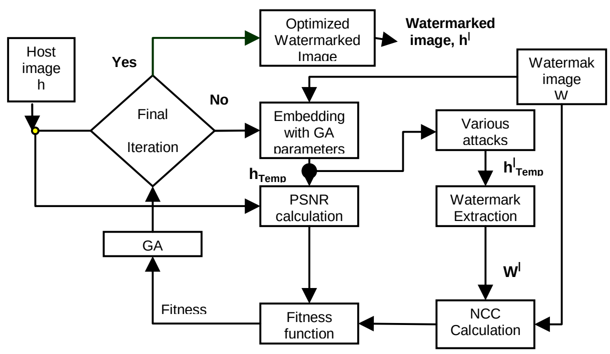


Fig. 3 Flow chart for GA based watermark embedding

6. 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:

$$PSNR = 10\log_{10} \frac{255 \times 255}{\frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} \left[h(x,y) - h^{\circ}(x,y) \right]^2} dB \quad (6)$$

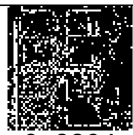
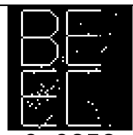
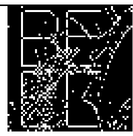
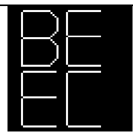
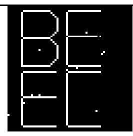
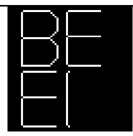
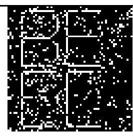
Where, M and N are the height and width of the image, respectively. $h(x,y)$ and $h^{\circ}(x,y)$ are the values located at coordinates (x,y) of the host image, and the watermarked image, respectively. After extracting the watermark, the normalized correlation coefficient (NCC) is computed using the 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

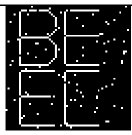
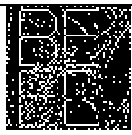
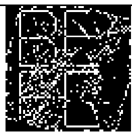
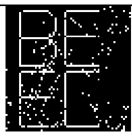
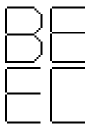
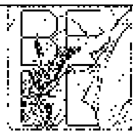
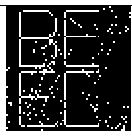
$$NCC = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} w(i,j) \times w'(i,j) \quad (7)$$

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

Lena image of size 512x512 is used as the host image for conducting experiments. Lena image is shown in Fig.4. The watermark image is of size 64x64, which is a binary logo as shown in Fig. 5. Watermarked image is shown in Fig. 6. The parameters used in the work are: block size is 8×8 , $p = 1$ and $\lambda_{h,l} = 10$ with the high pass filter attack. In equation (5), $PSNR$ changes from one generation to next generation until GA terminates. Similarly, NCC changes with generation and also with attack. MATLAB 7.0 and Checkmark 1.2 [15] are used for testing the robustness of the proposed scheme. The parameter set (three SFs and two RFs) obtained using GA (after GA termination) is [0.0677 0.0404 0.0316 0.3578 0.7633]. Various attacks used to test the robustness of the proposed watermark are median filtering, high pass filtering, histogram equalization, wiener filtering, salt &pepper noise, Gaussian low pass filtering, cropping, rotation, etc. Extracted watermarks, after applying various attacks are summarized in TABLE I. Performance of the proposed method are compared with one of the method used in [12] and are shown in TABLE II. In [12], MDC based watermarking with one scaling factor for the entire range of selected coefficients is used. The advantage of MDC watermarking with multiple scaling factors for different ranges of the selected coefficients is that its improved performance over MDC with one strength factor in terms of the parameter NCC . Parameters of both methods are adjusted to almost same value of $PSNR$, same watermark of size 64×64 and the same transform (DHT) is used for comparing the NCC values. For comparison purpose, same watermark (64x64 size) is embedded in the same host image (512x512 size Lena) using each method separately. Strength factor used with the method of [12] is 0.042. From TABLE II, the superiority of the proposed method over the existing method [12] can be observed in terms NCC .

TABLE I EXTRACTED WATERMARKS

Attack Details	***Retrieved Watermark & NCC***
Median filer (3x3)	 0.2804
Gaussian filer (3x3)	 0.9252
Image Averaging (3x3)	 0.5553
High-pass filter (3x3)	 1.000
Histogram equalization	 0.9795
Cropping (257:512, 257:512)	 0.9430
Gaussian noise (0.001 density)	 0.5528

Salt & Pepper noise (0.001 density)	 0.8601
Rotation 5 degrees	 0.5093
Rotation 15 degrees	 0.4918
Wiener filter (3x3)	 0.7594
Gray Scale Inversion	 -1.000
Gamma Correction (0.9)	 1.000
Soft Threshold	 -0.4623
Template Removal	 0.7584
Trimmed mean alpha	 0.3555
Bit plane Removal (LSB)	 1.000

Row & Column copying (10-30,40-70100-120)	 0.9965
Row & Column blanking (10-30,40-70100-120)	 0.9983
Linear motion of camera (9 pixels, 0 degrees)	 0.5781

Fig. 4 Original / host Image LENA

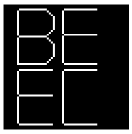


Fig. 5 Watermark

Fig. 6 Watermarked LENA (PSNR =41.86 dB)

TABLE II COMPARISON OF PROPOSED METHOD WITH MOHAN AND KUMAR METHOD [12]

Characteristic	***Mohan & Kumar Method [12]***	***Proposeed Method***
No of Watermark Bits embedded	2048 (32x32 logo)	4096 (64x64 logo)
PSNR in dB	41.85	41.87
NCC with no attack	0.9930	1.000
NCC with Gaussian filter attack (0.5 variance)	0.8687	0.9252
NCC with high pass filter attack	0.9948	1.000
NCC with histogram equalization attack	0.9520	0.9795
NCC with cropping (1/4) attack	0.9375	0.9430
NCC with Gaussian noise attack (0.001 variance)	0.5149	0.5528
NCC with 5 degrees rotation attack	0.4807	0.5093
NCC with template removal attack	0.7150	0.7584
NCC with bit plane (LSB) removal attack	0.9896	1.000
NCC with row & column blanking (10-30, 40-70, 100,120) attack	0.9861	0.9983
NCC Wiener fitter attack	0.7065	0.7594

7. Conclusions

In this paper, a novel and oblivious watermarking scheme based on DHT and MDC is proposed. Watermark is embedded in the DC coefficients of block based DHT of odd description of the host image. For embedding the watermark, MDC with multiple strength factors using GA is proposed. MDC scheme in this work is characterized using five parameters and GA is used for parameter optimization. Performance of the proposed scheme against the attacks like high pass filtering, histogram equalization and rotation is extremely good. Compared to [12], the proposed method is superior in terms of NCC and allows flexibility in designing optimum watermarking system for certain specified image processing attacks.

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