Robust Multiple Image Watermarking Scheme using Discrete Cosine Transform with Multiple Descriptions

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***Abstract*— A novel oblivious and robust multiple image watermarking scheme using Multiple Descriptions (MD) and Quantization Index Modulation (QIM) of the host image is presented in this paper. Watermark embedding is done at two stages. In the first stage, Discrete Cosine Transform (DCT) of odd description of the host image is computed. The watermark image is embedded in the resulting DC coefficients. In the second stage, a copy of the watermark image is embedded in the watermarked image generated at the first stage. This enables us to achieve robustness to both local and global attacks. This algorithm is highly robust for different attacks on the watermarked image and superior in terms of Peak Signal to Noise Ratio (PSNR) and Normalized Cross correlation (NC).**

***Index Terms*—Digital watermarking, Discrete Cosine Transform, Multiple Descriptions, Peak Signal to Noise Ratio.**

I. Introduction

A major issue of digital multimedia data exchange over the internet is data authentication. Image attacks either intentional or unintentional try to remove ownership information (such as logo). Image watermarking algorithms using Discrete Cosine Transform (DCT) [1,2], Discrete Wavelet Transform (DWT) [3,4], Discrete Hadamard Transform (DHT) (5,6) and Singular Value Decomposition (SVD) (7,8) are available in the literature. The basic philosophy in majority of the transform domain watermarking schemes is to modify the transform coefficients based on the bits of watermark image. In an oblivious (blind or public) watermarking scheme, the presence of the host image is not required in retrieving the watermark image. In non-oblivious watermarking schemes, the presence of the host image and/or watermark image is required.

This paper presents a highly robust and oblivious multiple watermarking scheme in the DCT domain. Watermark embedding is done at two stages. Watermark is embedded at two stages, by using Multiple Description Coding (MDC) [9] and Quantization Index Modulation (QIM) [10]. Superiority of the proposed method is observed over [2], which is also a DCT based scheme.

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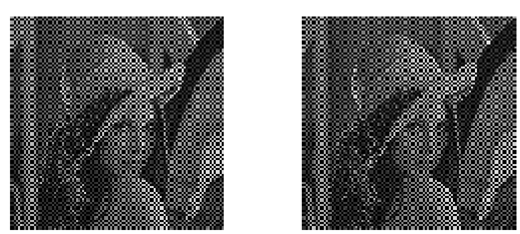
This paper is organized as follows: In Section II, Multiple Description Coding (MDC) is presented. QIM is discussed in brief in Section III. Details of the proposed image watermark embedding technique and extraction process are given in Section IV. Experimental results are given in Section V. Concluding remarks are given Section VI.

II. Multiple Description Coding

In Multiple Descriptions Coding (MDC) of an image, the image is partitioned into multiple descriptions. The receiver is able to reconstruct the original source within some prescribed distortion levels by using few of the descriptions. This concept of MDC was adapted to digital image watermarking [9]. These descriptions are selected in such a way that some correlation exists between them. For example, the image may be partitioned into two descriptions: one containing odd pixel intensities and the other even pixel intensities. One description can be used for watermark insertion and the other description can be used as a reference for watermark extraction. After watermark insertion, two descriptions are combined to get the watermarked image. In this paper, two descriptions are considered based on odd and even pixel intensities of host image. Host image LENA as shown in Fig.1, is decomposed into two descriptions odd and even as shown in Fig. 2(a) and Fig.2(b).

Fig. 1. Host image LENA



(a) (b)

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

III. Quantization Index Modulation

For the quantization of DC coefficients, dither quantization is used. Dither quantization is a variant of QIM [10]. Dither quantizers are quantizer ensembles. Each quantization cell in the ensemble is constructed from a basic quantizer. The basic quantizer may be chosen arbitrarily. The basic quantizer is shifted to get the reconstruction point. The shift depends on the watermark bit. The basic quantizer is a uniform scalar quantizer with a fixed step size. The quantized value is the center of the quantizer. Dither quantization of an image $h(i, j)$ is described as follows:

The entire range h_{min} (minimum value of $h(i, j)$) to h_{max} (maximum value of $h(i, j)$) is divided into various bins as shown in Table I. A step size of T is taken as the difference from one bin to another bin. Each element of $h(i, j)$ is checked for its position in Table I.

TABLE I. QUANTIZATION TABLE

bin no. (n)	*dlow*	*dhigh*
1	h_{min} - T	h_{min}
2	h_{min}	h_{min} + T
3	h_{min} +T	h_{min} + 2 T
. .	. .	. .
b_{n-1}	h_{max} - T	h_{max}
b_n	h_{max}	h_{max} + T

After identifying the bin number *n*, $h(i, j)$ is modified as follows:

(i)If watermark bit is '1' then it belongs to Range 1 where Range 1 is defined as

Range 1 = *dlow (n)* to $\frac{dlow(n) + dhigh(n)}{2}$

Modification of $h(i, j)$ is

$$h(i, j) = \left(\frac{(dlow(n) + (dlow(n) + dhigh(n))/2}{2} \right)$$

(ii)If watermark bit is '0' then it belongs to Range 2 where Range 2 is defined as

Range 2= $\frac{dlow(n) + dhigh(n)}{2}$ to *dhigh (n)*

Modification of $h(i, j)$ is

$$h(i, j) = \left(\frac{(dhigh(n) + (dlow(n) + dhigh(n))/2}{2} \right)$$

The proposed watermarking scheme is as follows.

IV. Proposed Scheme

A. Watermark Embedding Technique

A binary watermark of size $\left(N/_K \, x \, N/_K\right)$, is embedded twice in the grey level host image of size NxN at two stages. In the first stage, host image is decomposed into two descriptions, one with odd pixel intensities and the other with even pixel intensities. Block based DCT (block size kxk) coefficients of odd and even description are calculated. DC coefficients of all the blocks of odd description are modified as per watermark bits. This permits us to use second description as a reference, while extracting watermark at the receiver.

In the second stage also a block based DCT with a block size of KxK is applied to the watermarked image obtained in the first stage. Once again a block based DCT is applied to the resultant watermarked image. By using QIM, all the DC coefficients are modified according to the watermark bits. Various steps involved in watermark embedding are shown in Fig. 3.

Steps of embedding algorithm are as follows:

1. The host image $f(i, j)$ of size NxN is partitioned into two descriptions. Block based DCT 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:

$$D_{odd}(i, j) = D_{odd}(i, j) + \alpha_1 * D_{even}(i, j) \text{ if } w(i, j) = 1$$

$$D_{odd}(i, j) = D_{odd}(i, j) - \alpha_1 * D_{even}(i, j) \text{ if } w(i, j) = 0 \qquad (1)$$

In (1), $D_{even}(i, j)$, $\left(1 \le, i, j \le (N/_K)\right)$ refers to DC coefficients of even description and $\alpha_1 < 1$ is a strength factor which can be varied to control robustness and perceptual quality. Block based Inverse Discrete Cosine Transform (IDCT) is applied by considering the modified DC coefficients.

3. Block based DCT is applied to the watermarked image obtained in Step 2. DC coefficients of all the blocks of the watermarked image are modified according to the watermark bits. This modification is based on scalar quantization as specified in QIM.
4. IDCT is applied to the modified DC coefficients and the final watermarked image is obtained.

B. Watermark Extraction Process

Parameter required for watermark extraction is only step size used in the quantization process. This is required for the generation of quantization table at the receiver. Watermark extraction process is summarized in Fig.4.

Extraction of watermark is as follows:

1. Partition the watermarked image of size NxN into odd and even descriptions. Block based DCT is applied to both the descriptions.

2. DC coefficients of odd description are compared with the DC coefficients of even description. Watermark at stage 1 is generated as follows.

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

$$w(i, j) = 0 \quad \text{if } D_{odd}(i, j) < D_{even}(i, j) \qquad (2)$$

3. DCT is applied to the received watermarked image.
4. A quantization table similar to the one generated at the embedding process is generated at the receiver. The position of DC coefficients is identified and accordingly watermark bits are generated from the quantization table.

The error metrics used to test the proposed algorithm are Normalized Cross correlation (NC) and peak signal to noise ratio (PSNR). They are defined in [7].

Benefits of embedding the watermark at two stages in two different ways are two fold: If faithful watermark extraction is not achieved at the first stage, there exists a fair amount of probability that it survives at the second stage. In first stage, DC coefficients of odd description are modified for watermark embedding. This is comparison based embedding.

Many global attacks like histogram equalization, sharpening, gamma correction and blurring change the pixel intensity values. Change in DC coefficients is same for both the descriptions and hence error free extraction is possible. To resist local attacks like JPEG compression and resizing operation, quantization of DC coefficients is considered in the second stage embedding. In this way, watermark can survive to both local and global attacks so that robustness of the watermark system can be improved.

V. Experimental Results

Lena image of size 512x512 is considered as host image. This is shown in Fig.1. The watermark image is of 64x64 size, which is a binary logo as shown in Fig. 5. Watermarked image is shown in Fig. 6. The parameters used in the work are strength factor α_1=0.55, block size used is 8x8, and the step size used in the quantization process is 50. MATLAB 7.0 and Checkmark 1.2 [11] are used for testing the robustness of the proposed scheme. JPEG2000 attack is tested using MORGAN JPEG2000 tool box [12]. For all the attacks of Checkmark 1.2, a window size of 3x3 is taken. Various attacks used to test the robustness of the proposed watermark are resizing, JPEG, JPEG2000, soft thresholding, median filtering, template removal, trimmed mean alpha, wiener filtering, gray scale inversion, salt &pepper noise, gaussian low pass filtering, cropping, row column copying, gamma correction, bit plane removal, image sharpening, histogram equalization, frequency mode laplacian removal, image tampering, row-column blanking and rotation.

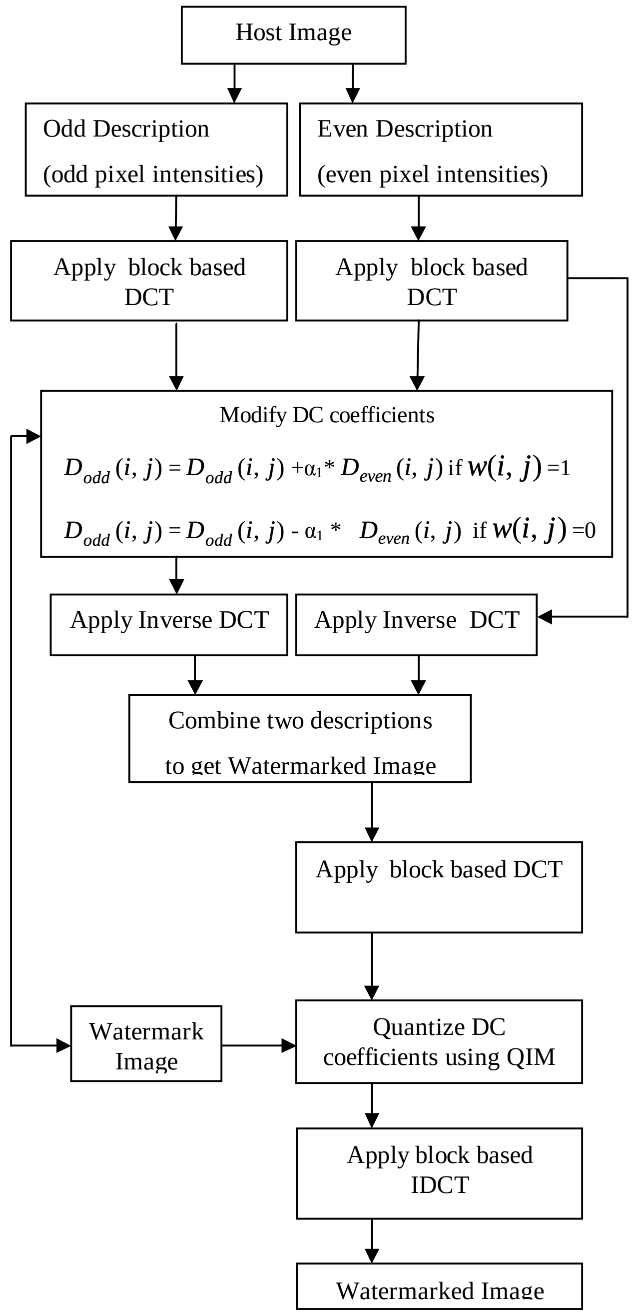


Fig. 3. Embedding Algorithm

Image tampering is done with Microsoft Paint Brush software and the tampered image is shown in Fig.7. Extracted watermarks, after applying various attacks are summarized in TABLE II. Performance of the proposed method is compared with [2] and is shown in TABLE III.

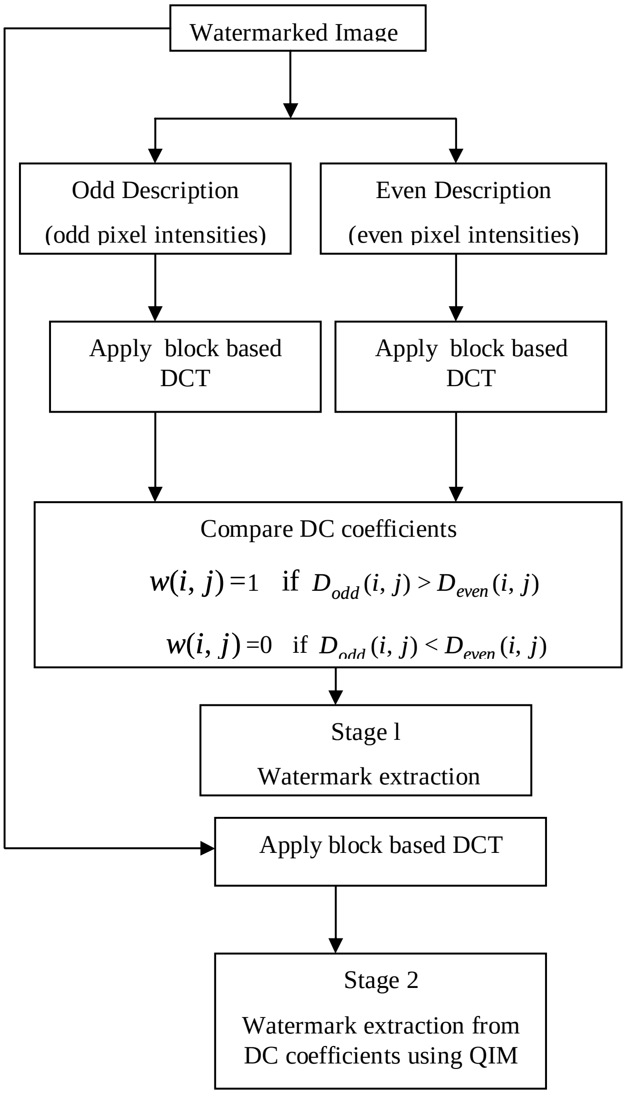
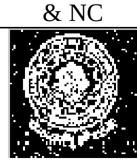
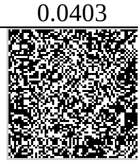
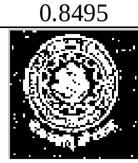
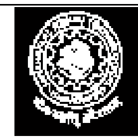
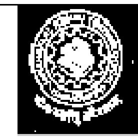
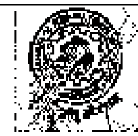
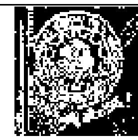
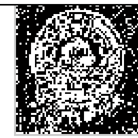
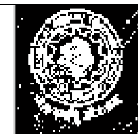
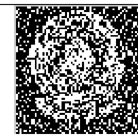
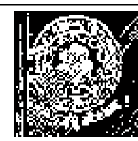
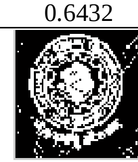
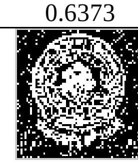
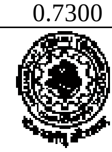
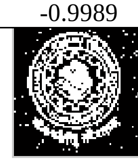
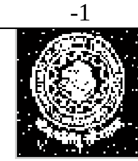
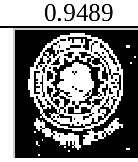
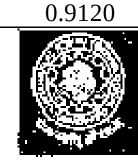
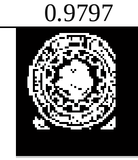
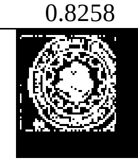
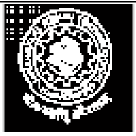
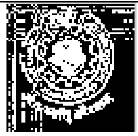
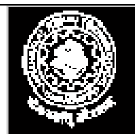
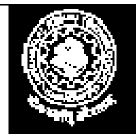
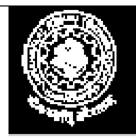
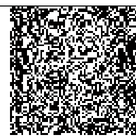
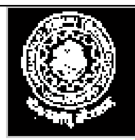
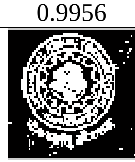
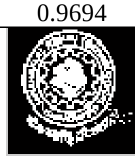
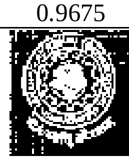
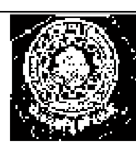


Fig. 4. Extraction Algorithm

TABLE II. EXTRACTED WATERMARKS

Attack	Retrieved Watermark Stage 1 & NC	Retrieved Watermark at Stage 2 & NC
Resizing (50%)	 0.0403	 0.8495
JPEG Compression (QF=80%)	 0.1573	 0.9384
JPEG 2000 Compression (QF=50%)	 0.9994	 0.9956
Soft Thresholding (3x3)	 -0.6814	 0.5861
Median Filtering (3x3)	 0.6208	 0.5678
Template Removal	 0.8853	 0.5101
Trimmed Mean Alpha	 0.6432	 0.6373
Wiener Filtering	 0.8920	 0.7300
Grey Scale Inversion	 -0.9989	 -1
Salt & Pepper Noise (0.001 density)	 0.9489	 0.9120
Gaussian LPF	 0.9797	 0.8258
Cropping (30:404,30:404)	 0.9030	 0.8566

Row & Column copying 10-30,40-70, 100-120,40-160 rows and columns are copied	 0.9740	 0.7648
Gamma Correction (Gamma=0.6)	 0.9989	 -0.0051
Bit plane Removal (LSB)	 0.9989	 0.1698
Image Sharpening	 0.9994	 0.1995
Histogram Equalization	 0.9956	 -0.0431
Frequency mode Laplacian removal	 0.9694	 0.7809
Tampered Lena	 0.9769	 0.9675
Row column Blanking 10,30,40,70, 100, 120 columns and rows blanked.	 0.9956	 0.8953
Rotation 30^0	 0.7253	 0.8058

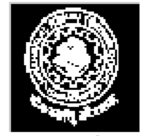


Fig. 5. Watermark Image

Fig. 6. Watermarked LENA (PSNR=39.37 dB)

Fig. 7. Tampered LENA

TABLE III. COMPARISON OF PROPOSED METHOD WITH WANG AND PEARMAIN METHOD [2]

Characteristic	Proposed Method	Wang & Pearmain Method [2]
No of Watermark Bits embedded	4096 (64x64 logo)	910
PSNR in dB	39.37	39.21
No of attacks reported	20	4
Type of embedding	Oblivious	Oblivious

VI. CONCLUSIONS

In this paper, a novel and oblivious watermarking scheme based on multiple description of host image and scalar quantization of DC coefficients in DCT domain is proposed. Embedding of watermark is done at two stages. At the first stage, watermark is embedded in the DC coefficients of DCT of odd description of host image. In the second stage, watermark is embedded in the DC coefficients of DCT of the watermarked image. So even if watermark extraction at one stage is not possible at the second stage it can be extracted. For example for gamma correction, bit plane removal, image sharpening and histogram equalization watermark at stage 2 is completely destroyed. But, it survived well at stage 1. For JPEG Compression, resizing and rotation watermark extraction at stage 2 is much superior to stage 1 extraction. Compared to [2], the proposed method is superior in terms of embedding capacity, PSNR and survival to number of image attacks.

REFERENCES

[1] Chu, W.C., 2003. DCT based image watermarking using sub sampling, IEEE Transactions Multimedia, pp.34-38.

IACSIT International Association of Computer Science and Information Technology WWW.IACSIT.ORG

[2] Wang, Y., Alan Pearmain., 2004. Blind image data hiding based on self reference. Pattern Recognition Letters 25, pp. 1681-1689.
[3] 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.
[4] Lee, C., Lee, H., 2005. Geometric attack resistant watermarking in wavelet transform domain, Optics Express vol.13, no.4, pp.1307-1321.
[5] Chandra Mohan B, Srinivas Kumar S, Chatterjee B.N.,2006. Digital Image watermarking in dual domains at IET Visual Information Engineering, VIE 2006 at Leela Palace, Bangalore, 26-28th September 2006.
[6] Santi P.Maity, Malay K Kundu, 2009. DHT domain digital watermarking with low loss in image informations, International Journal of Electronics and Communications, 2009. in press.
[7] Srinivas Kumar S, Chandra Mohan B, Chatterjee B.N., 2007. An oblivious image watermarking scheme using singular value decomposition. IASTED, International conference on Signal and Image Processing, at Honolulu, Hawaii, USA, August 20-22.
[8] Yongdong, Wu, 2005. On the Security of an SVD based ownership watermarking. IEEE transactions on Multimedia, vol 7. no.4.
[9] Chandramouli,R.,Graubard Benjamin, M., Richmond Colin, R., 2001. A multiple description framework for oblivious watermarking. Proceeding of Security and Watermarking and Multimedia contents III, SPIE vol. 4314.
[10] Chen, B., Wornell, G.W., 1998. Digital watermarking and information embedding using dither modulation. Proceedings of the IEEE workshop on Multimedia Signal Processing (MMSP-98), Redondo Beach, CA, December.
[11] www.http://watermarking.unige.ch/Checkmark/
[12] Morgan JPEG 2000 Tool Box, http://Morgan-Multimedia.com.

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