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IMAGE WATERMARKING ALGORITHM BASED ON A COMBINATION OF TEXTURE MAPPING AND BIT SUBSTITUTION METHOD

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ABSTRACT

Watermarking algorithms can be implemented using simple and direct calculations in time domain embedding as replacing the least significant bit (LSB) of the original image pixels, it also can be implemented using more complex but more robust transform domain based embedding by changing coefficients values. In this paper, a new method of using a combination between the transform domain and time domain watermarking is presented by embedding the watermark within the approximation band coefficients of LWT transform. This method will combine the simplicity of time domain watermarking and the high performance of transform domain watermarking. The choice of the coefficient bit in certain image block is based on the amount of texture in that block. The texture amount is calculated using a low complexity texture mapping model. The experimental results shows high quality watermarked images since a small portion of image is used for the embedding process.
Keywords: *Image Processing, ALD, Non-Blind Watermarking, Texture Masking, Copyrights protection.*

1. INTRODUCTION

Watermarking is similar to steganography which is a process of hiding secret messages within another data cover, using certain algorithms [1]. The difference between watermarking and steganography is that, in steganography, the existence of the hidden message is not known, while in watermarking, the existence of the watermark is known, but it shouldn't be extracted, removed or distorted unless the original image is distorted. Watermarking process involves embedding and extracting of the watermark in which the watermark is embedded and recovered, respectively. Different watermark applications, as copyright protection, authentication, and tamper detection made the developing of watermarking algorithms an interest for many researchers. The copyright protection needs a watermark that is robust against different attacks that aims to remove it, while in the tamper detection applications the watermark needs to be fragile to detect any malicious attempts. A semi fragile watermark is considered as a level between robust and fragile watermark, as it acts as robust when a malicious alterations occurred, for example, cropping the watermarked image, while the common image processing operations as compression doesn't affect the watermark.

Proof of ownership and copyright protection are the two major issues that watermarking algorithm solves [2] especially after the widespread of internet applications. To initiate a watermarking algorithm, two basic factors must be taken into consideration, first is to keep the perceptual quality of the watermarked images high, second is to create a robust watermark which resist different attacks that try to distort or remove the watermark. The basic issue in designing a watermarking algorithm is the trade-off between imperceptibility and robustness, as embedding the watermark with high intensity will produce a robust watermark but degrades the quality of the image. On the other hand, embedding the watermark with low intensity will produce high quality images but low robustness, accordingly, different methods have been used to get the best robustness and imperceptibility.

There are basically two approaches to embed a watermark: spatial domain and transform domain watermarking. In the spatial domain, the watermark is embedded by modifying the pixel values in the original image, a simple examples of spatial domain is to change the least significant bit (LSB) with the watermark value, this method is fast and simple and produces high quality watermarked images but the robustness of the watermark is limited. In transform domain watermarking, the coefficients of transforms such as discrete cosine transform DCT [3], discrete wavelet transform DWT [4], singular value decomposition SVD [5] or a hybrid of two or more transformation coefficients are modified [6]. The transform domain watermarking is more robust and it allows to apply more changes in frequency component where the HVS can tolerate the changes. However; transform domain embedding is more complicated than time domain attempts for the calculations involved in the transform steps. In the trade off between time domain simplicity and transform domain performance, there is a need for combining the features of the two methods.

In this paper, a combination of both domains is used, the complexity of the transform domain is simplified by using lifting wavelet transform (LWT), because all the computations involved in LWT computations are integer. Then the embedding is done using one bit exchange in each coefficient. The algorithm is supported by employing a texture masking model to find the amount of texture in each block and embed the watermark within the correspondent bit that is relative to HVS sensitivity to noise.

The paper is organized as follow, in the next section a literature of different watermarking attempts is presented. Texture masking is explained in section three, while in section four the methodology of the proposed model is explained followed by experimental results and comparison in sections five. The paper is concluded in section six.

2. REVIEW OF LITERATURE

Generally, watermarking literature studies can be classified according to the technique that is used in watermarking detection. Non-blind (informed) detectors relies on the original image and the watermarked image to extract the watermark. In the blind (non-informed) extraction, the original image is not necessary for watermark recovery [7]. In this paper the non-blind watermarking is used.

As a non-blind study, [8] used a hybrid method to embed the watermark into colored images, the watermark was embedded into the singular values of discrete wavelet transform sub-band. The embedding is performed after the color components are uncorrelated using principle component analysis. In [9] DWT was used with DWT to achieve better trade-off between robustness and invisibility. The combination of SVD and DWT was used in [10] and [11] for the same purpose.

The hybrid studies may have high robustness and accepted perceptual quality, but the combination of multiple transformations with all involved calculations produces a high complexity operations that is considered as a drawback [12] in many cases as in real time and embedded systems. In many cases the single transformation is also considered as a complex operation for using floating point calculations. The time domain attempts has low complexity overhead as using leas significant (LSB) bit embedding.

One of the earliest time domain image watermarking studies was achieved by using the time domain and specifically the LSB by [13], this attempt is followed by different attempts as [14] in using the LSB in watermark embedding. However, time domain attempts has limited performance in compare to frequency domain watermarking. Accordingly, LSB was used in combination with other techniques as [15] which used LSB spatial embedding with Discrete Cosine transform (DCT) in the watermarking process. Researchers in [16] embed the watermark into the LSB of the cover after combining the MSBs of the watermarks, in the aim of improvement the watermark's invisibility.

Other attempts used the perceptual factors for embedding the watermark in places where the watermark can be embedded with high intensity in places that the human eye cannot observe it so it is embedded without affecting the perceptual quality of the image. [17] and [18] proposed a DCT based watermarking algorithm. The texture is used in [17] with the luminance masking within DCT components in an adaptive watermarking algorithm, to incorporate the human visual system into watermarking. A similar usage is done in [18] where the algorithm utilized the luminance masking and texture masking to simulate the HVS. The embedding process is done by modifying the DCT blocks in the DC component of the DCT transform. But the combination has complex calculations that needs to be reduced.

To solve the complexity issue, a mix between the transform domain embedding and the utilization of bit substitution in a single algorithm is used with the support of a texture masking model . The feature of the algorithm is that, all the calculations are based on integer numbers using LWT [19], and the texture masking model that is proposed in [20] are also relied on integer calculation.

3. TEXTURE MASKING

To find the highest watermark embedding intensity that cannot perceived by human eyes, a texture masking model is utilized. The texture masking model is used to find the highest texture areas and use it for watermarking embedding. The existing of texture estimation in watermarking algorithms is important because the human eye cannot perceive the changes in highly textured areas (except edges), in the same time, low textured areas causes change impact [21]. Accumulative Lifting Differences (ALD) as texture masking model that was proposed by [20] is employed in this paper for texture estimation based on LWT that will be used for watermark embedding and extracting processes. The model is basically relied on LWT and it is based on the fact that details band coefficients of LWT are used to implement the difference between linear change and actual change in image pixels intensities, i.e. higher details band coefficients indicates higher non-linearity change in image pixels. Hence, finding the divergence of the non-linearity in details band coefficients in certain region is represent the amount of texture in that region.

Accordingly, the details band is portioned into 5×5 blocks, and the absolute of the difference between each two coefficients in each row is summarized and the calculated values are accumulated to obtain a single value for each block that represents the amount of texture. ALD equation is given as follows:

$$\text{ALD (I, J)} = \sum_{i=I-2}^{I+2} \sum_{j=J-1}^{J+2} |D2(i, j-1) - D2(i, j)| \quad (1)$$

where I,J are the coordinates center coefficients of each block in details band.

4. PROPOSED WATERMARKING MODEL

The watermarking algorithm consists of two parts, watermark embedding and watermark extracting.

A. Watermark Embedding

To embed the watermark, texture masking is applied on the image to assign the relative texture value for each 5×5 block. Then the texture blocks are sorted to find the largest 1024 block. A 32×32 watermark is embedded by inserting one bit in each of the choosen blocks. These blocks are classified into four levels of textures, level 1 to level 4. Level one is the least of texture amount while level 4 is the largest, levels 2 and 3 have the middle amount of texture.

The embedding is done on the approximation band of LWT by replacing one bit in each center block. And According to the level of texture, the LSB embedding is taken place, in level 1, where the changes in less textured area is visible to the HVS, the embedding is done by replacing the 5^{th} bit (All texture levels are within blocks with largest texture amount). In level 2, the 4^{th} bit is replaced, in level 3 the 3^{rd} bit is used, and in level 4 the 2^{nd} bit is used for embedding. After replacing the correspondent bit, the ILWT is applied to obtain the watermarked image. Figure (1) shows the flowchart of the embedding process.

B. Watermark Extracting

The watermark extracting process is non blind, as the original image is needed to apply the texture masking and find the largest textured blocks without being modified by the watermark bits.
LWT is applied on both original and watermarked images, ALD texture masking model is applied on the original image and the blocks are classified to levels in the same process of embedding. The correspondent blocks are selected from the watermarked image, and the correspondent bit according to each level of texture is extracted by subtracting to obtain the watermark vector that is converted to a two dimensional binary watermark. Figure (2) shown a flowchart of the extracting process.

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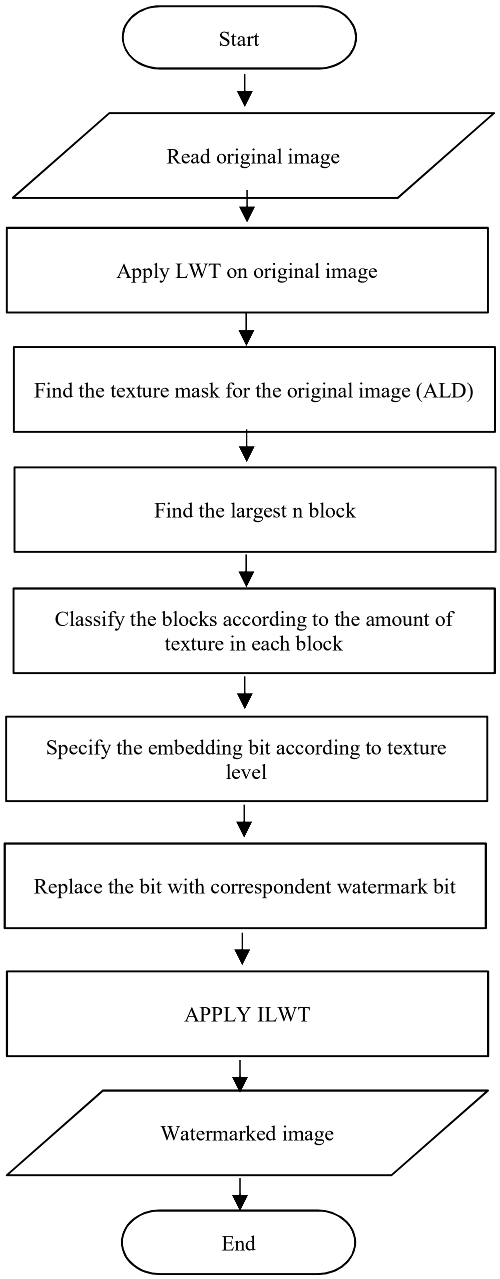

Figure 1. Watermark embedding process

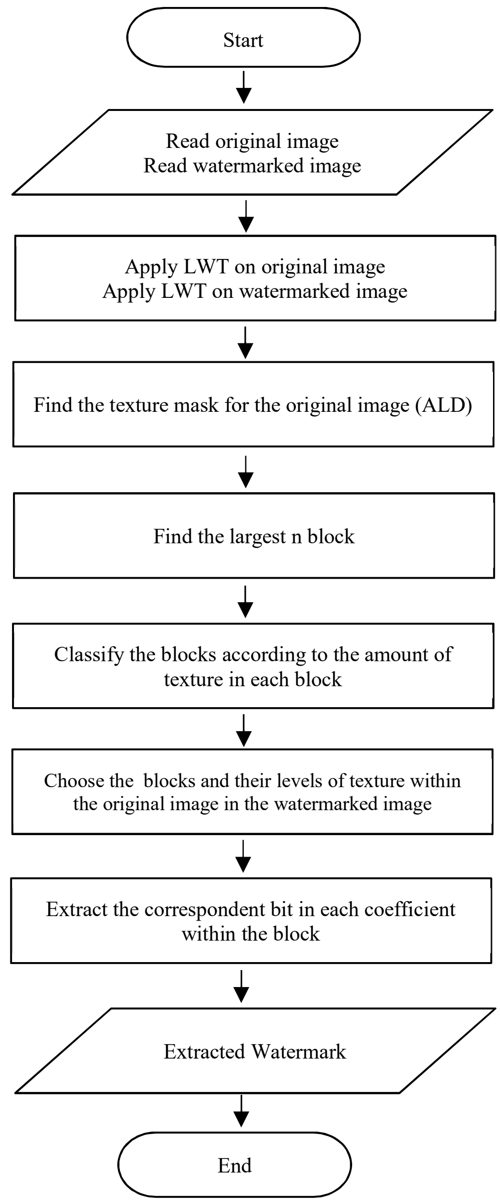

Figure 2. Watermark Extracting process

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5. RESULTS AND DISCUSSION

The performance of a watermarking algorithm is mainly measured by perceptual quality of the watermarked images and the robustness of the watermark. Below are the experimental results for both of them.

A. Perceptual Quality Evaluation

Ten different images were used to embed the binary watermark that is shown in Figure (3) .

Figure 3. Binary watermark

Two universal metrics are used for objective evaluation, peak signal to noise ratio (PSNR) and Structural similarity index SSIM [22].

PSNR as a quantitative measurement can be defined according to the following equation:

$$\mathrm{PSNR} = 20\log_{10}\left(\frac{\mathrm{MAX}}{\sqrt{\mathrm{MSE}}}\right) \qquad (2)$$

and

$$\mathrm{MSE} = \frac{1}{m \times n}\sum_{i=1}^{m}\sum_{j=1}^{n} \| X(i,j) - Y(i,j) \|^{2} \qquad (3)$$

On the other hand, SSIM has more realistic values in compare with PSNR [23][24], since it takes into consideration three components, luminance, contrast and structural information. The SSIM simulate human eye observations better than simple intensity differences used in PSNR. SSIM is given as:

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2+\mu_y^2 + C_1)(\sigma_x^2+\sigma_y^2 + C_2)} \qquad (4)$$

Where x and y are two non-negative image signals. μx, μy, are the mean intensity, σx, σy are the standard deviations for the original and distorted images respectively, C1, and C2 are constants.

PSNR and SSIM values for different tested images are depicted in Table 1, and the tested images with the watermarked images are shown in Figure (4a) and (4b)

Table 1. PSNR and SSIM for watermarked images

Image	PSNR (dB)	SSIM
1	44.6906	0.9984
2	35.6495	0.9902
3	42.0005	0.9883
4	44.7820	0.9980
5	38.3059	0.9904
6	42.8679	0.9948
7	41.1680	0.9885
8	35.3962	0.9800
9	47.9984	0.9946
10	40.9432	0.9957

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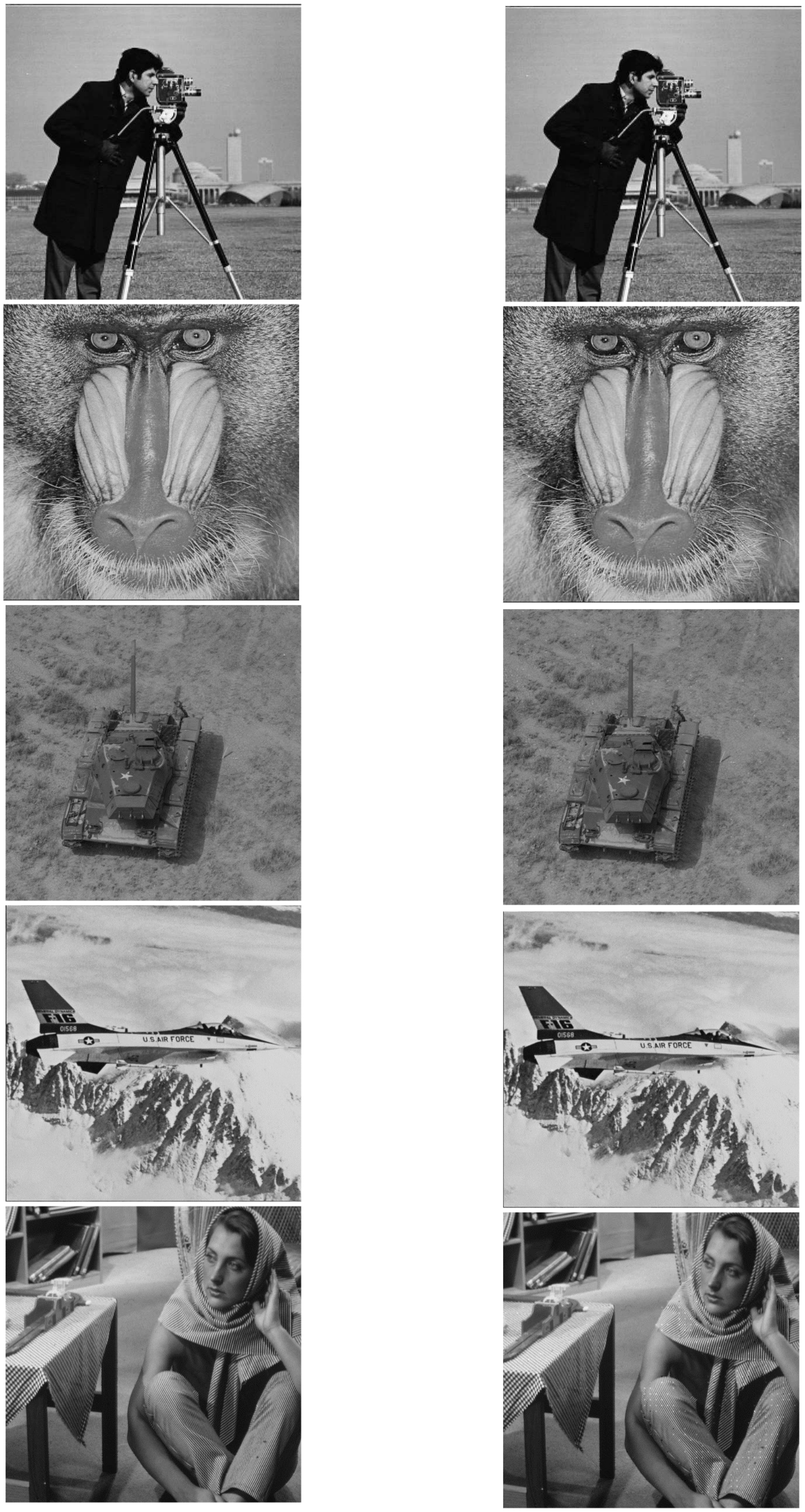

Figure 4a. Original images (left), watermarked images (right) (Images 1 to 5, up to bottom)

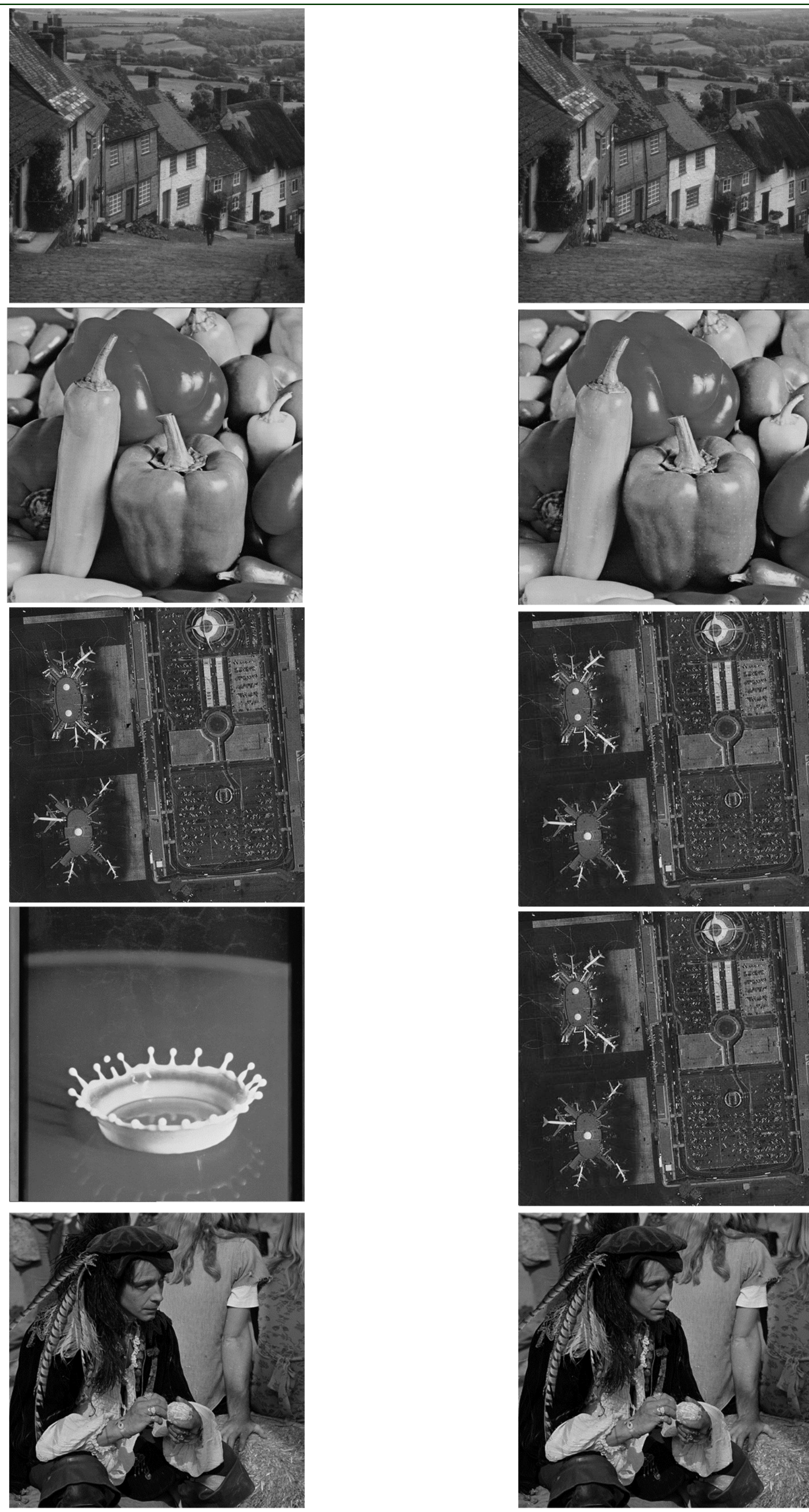

Figure 4b. Original images (left), watermarked images (right) (Images 6 to 10, up to bottom)

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From table 1, it is noticed that the watermarked images has high values for both metrics. This is because of using a minimum number of embedding coefficients and modifying only a single bit in each of them, that also enhance the subjective evaluation of the image as shown in Figure 4.

B. Robustness Evaluation

For all tested images, different attacks have been applied and the watermark is extracted with different qualities. First the watermark is extracted without any attack, then the watermark is extracted after applying different attacks as compression where JPG compression of qualities 90 and 70 is applied, additive noise where salt & pepper with intensity 0.01 is added and cropping attack where the image is cropped from all sides. Sample of applied attack is shown in figure (5).

JPG compression QF=90

JPG compression QF=70

Salt & Pepper (0.01)

Cropping

Figure 5, Sample of applied attacks

The results of applying these attacks on the extracted watermark is assessed using two metrics, the normalized correlation coefficient (NCC) and the bit error rate (BER). The NCC is give according to the following equation :

$$NCC = \frac{\sum_i^m \sum_j^n [W_{ij} W'_{ij}]}{\sqrt{\sum_i^m \sum_j^n (Wm_{ij})^2}\ \sqrt{\sum_i^m \sum_j^n (Wm'_{ij})^2}} \quad (4)$$

Where Wm, Wm' are original and recovered watermark, respectively each of size m×n.

Table 2 shows the NCC for different attack that are applied on tested images.

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Table 2. NCC for the extracted watermark

Image	No attack	JPG 90	JPG 70	Salt & pepper	Crop
1	1	0.8893	0.7952	0.9211	0.7875
2	1	0.9796	0.9453	0.9567	0.7239
3	1	0.9542	0.8575	0.9288	0.7723
4	1	0.9440	0.8422	0.9186	0.8397
5	1	0.9567	0.9249	0.9478	0.8359
6	1	0.9478	0.8499	0.9415	0.8868
7	1	0.9656	0.8728	0.9249	0.8486
8	1	0.9746	0.9529	0.9567	0.8969
9	1	0.9071	0.7799	0.9059	0.8270
10	1	0.9440	0.8601	0.9300	0.8753

Table 3. BER for different attacks.

Image	No attack	JPG 90	JPG 70	Salt & pepper	Crop
1	0	0.1113	0.2148	0.0801	0.1631
2	0	0.0195	0.0479	0.0381	0.2119
3	0	0.0498	0.1572	0.0713	0.1748
4	0	0.0684	0.1650	0.0840	0.1230
5	0	0.0449	0.0879	0.0557	0.1260
6	0	0.0527	0.1523	0.0605	0.0869
7	0	0.0332	0.1172	0.0771	0.1162
8	0	0.0225	0.0400	0.0400	0.0791
9	0	0.0938	0.2090	0.0928	0.1328
10	0	0.0518	0.1309	0.0635	0.0957

BER, on the other hand is given as follows:

$$BER = \frac{1}{m \times n} \sum_{i}^{m} \sum_{j}^{n} [\, W_{ij} \otimes W'_{ij} \,] \times 100\% \qquad (6)$$

Wm, Wm' are original and recovered watermark, respectively each of size m×n. Table 3 shows the BER for the extracted watermark after applying the same attacks.

The extracted watermarks after different attacks are shown in Table 4. From Tables 2,3 and 4, it is noticed that the proposed algorithm has accepted robustness that tolerated several attacks, the watermark is completely recovered when no attacks applied. In JPG compression, the watermark is recovered with some distortions. After applying the salt and peper noise the watermark was recovered with good quality. The cropping from sides distorts the watermark but it still can be recognized.

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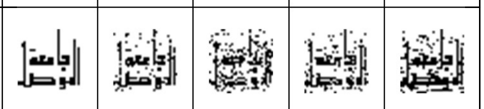
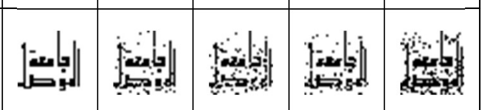
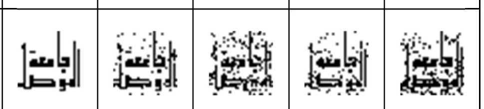
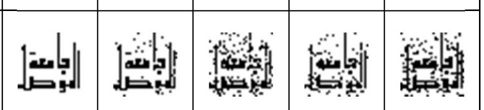
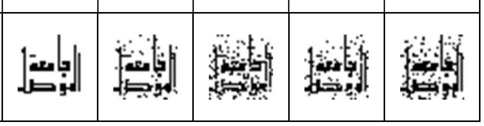
Table 4. Extracted watermark after different attacks.

Image	No attack	JPG 90	JPG 70	Salt & pepper	Crop
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

The usage of LWT reduced the computation involved with frequency domain watermarking schemes, for instance the LWT is faster and simpler than traditional DWT [19]; Hence the proposed watermarking algorithm is fast and it can be implemented in real time and embedded systems.

6. CONCLUSION

In this paper, bit exchange embedding is combined with texture masking for a new image watermarking algorithm. The embedding is achieved by replacing one bit from the coefficients of the LWT approximation band. The choice of coefficients is based on the texture masking model. The blocks of highest texture are selected and classified into four level of texture density. According to the level of texture, the significance of the exchanged bit is selected, where higher order bits were used when the area is highly textured, and lower bit are chosen when the texture is less. Experimental results shows that the proposed algorithm produces high quality watermarked images in terms subjective and objective evaluations, and accepted robustness that tolerate traditional attacks as JPG compression and cropping. Current work is to enhance the algorithm to work as non-blind algorithm so that the existing of the original image is not required in order to meet the requirements of limited embedded systems memories. The proposed algorithm can also be used in steganography systems.

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