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Two Level DWT-Mamdani FIS Used for Digital Image Watermarking

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ABSTRACT

Digital watermarking has been adopted to represent the newest techniques for the security of different types of images. There are many techniques of imaging watermarking and one of the effective techniques is by using fuzzy logic. In this work, a new technique of digital watermarking is proposed depending on two-level DWT to segment the cover images and partition the LH2 band into 2x2 blocks. Fuzzy inference system (FIS) Mamdani type gives the parameter to control the invisibility of the watermark according to the embedding process. The use of the two-level of DWT guaranteed a suitable choice of the positions in order for the original image to be eligible to include the watermark such that the watermark can be extracted successfully and at the same time can be achieved high measurements of the robustness and imperceptibility. The results show that the influence of the FIS increases the robustness of the algorithm. The performance measures used in the proposed technique are PSNR and NC that show the proposed technique is resistant as possible to different image attacks.

Key words: Mamdani fuzzy Inference System, Discrete Wavelet Transform, watermarked image, the Peak Signal to Noise Ratio (PSNR), normalized correlation (NC).

1. INTRODUCTION

Wavelets are separately sampled in Discrete Wavelet Transform (DWT). The principal advantage of DWT depending on Fourier transforms is the provisional decision. It can capture both the location and frequency information. For the subband decomposition of signals, DWT has been presented as a highly efficient and flexible method. Wavelet Transforms is utilized to represent nonstationary signals that have high efficiency in our real life. The image can be mutated into a series of wavelets by utilizing wavelet transform that has the ability to store more efficiently than pixel blocks.

The use of Fourier transform represented by Discrete Wavelet Transforms (DWT) provides a high watermarked image. This usage illustrated that the watermarking technique is distinct from others by precision and higher durability in transform domain than spatial domain [1].

On the other hand, several fields benefited from fuzzy logic for example but not limited to control theory, artificial intelligence and image processing. Fuzzy set theory and fuzzy logic are related to fuzzy mathematics which forms a branch of mathematics. Fuzzy logic is depending on the perception that people make decisions relying upon inaccurate and not numerical data, the fuzzy system is mathematical wherewithal of symbolizing obscurity and inaccurate data. These systems have the ability to representing, interpreting, recognizing, manipulating, and using information and data that are obscure and need sureness.

Depending on the choosing domain, the watermarking schemes can be run either in the spatial domain or the frequency domain. Since the watermark is embedded by modifying the transform coefficients then the watermarking techniques performed in the transform domain are more strong. One of the most broadly utilized is a discrete wavelet transform (DWT) [2]. A robust image watermarking scheme is proposed in [1] to the protection of type copyright relying upon a 3-level DWT. Aydin et al. in [3] used Discrete Wavelet Transform to embed partitions of the watermark to different frequency bands of the cover image in two or more level decomposition. A digital image watermarking depending on 3 levels of DWT is presented in [4] and compared with 1 and 2 levels DWT. In this method, a multibit watermark is embedded into the low-frequency subband of the host image. Through the embedding process, the watermark image is scattered within the host image according to the scaling factor used in that method.

Motivated by all of the above, this paper focus on a digital watermarking algorithm depends in parallel on 2level DWT which is taken into consideration for the first time in the watermarking techniques common side by side with the Fuzzy Inference System (FIS). The rest of this paper is divided into several sections first in order to give basic important information of DWT and FIS are covered concisely. Second to present the proposed algorithm and to explain the experimental results and discussion. Finally, the conclusion is documented in the last section.

2. DISCRETE WAVELET TRANSFORM (DWT)

During the previous period, the discrete wavelet transform (DWT) regarded an indispensable linear transformation that diffuse in most fields of science. DWT is converting an information vector to another information vector in the frequency domain of the same length. This is done by decomposes information into various frequency ingredients, therefore these ingredients are modified according to its intensities. For images that represent a two dimensional vector, DWT is performed similarly, this means that DWT operated on all the rows of the image in the first and then runs on the columns as a whole. The transformed image under DWT is represented by four bands LL, LH, HL, and HH. The forms L and H symbolized to the lowpass and highpass filtering respectively. The LL band corresponds to the lower resolution approximation image, the LH band corresponds to the horizontal features, the HL band corresponds to the vertical features and the HH band corresponds to the high-frequency point components.Lower frequency features in the image can be obtained by further levels of partition; these extra levels are implemented only to the LL band of the transformed image at the prior level [5].

FUZZY INFERENCE SYSTEM

Fuzzy inference system illustrates the procedure of deriving the mapping from a specific stimulus to a suitable result utilizing fuzzy logic. Two kinds of these systems are familiar: Mamdani-type and Sugeno-type which can be implemented through fuzzy logic Toolbox. Mamdani's method represents among the first control systems built using fuzzy set theory which is the most common method used. The procedure of fuzzy inference includes Fuzzy variables and corresponding membership functions, logic operators and if-then rules.

Fuzzy inference system is also called the rule base, which consists of the fuzzy rules. These rules combine one or more fuzzy set utilizing the fuzzy operators AND, OR, and NOT. The valuation of fuzzy rules is executed by the inference system to employ the aggregate function. This operation combines a weight parameter of the resultant part of all relevant rules in a fuzzy set to obtain the output. On output, the fuzzy inference system can not supply fuzzy values that can only operate, so it is needful to provide precise values. This stage is done using membership functions. Many values will be obtained from the degrees of membership functions. To determine the accurate value to use, one of the four methods can be applied which is: Centroid, Max, Sum, and Probor. Using one of these methods, one output value will be obtained from the total output values. In this method, we use the Centroid concept to find the weighing parameter [6].

3. METHODOLOGY

In this section, we propose a protection scheme for improving watermarking relies upon FIS applied to blocks producing out of transforming the host image by DWT. The proposed watermarking scheme can be characterized as follows:

Embedding Algorithm

The process of embedding the watermark into the cover image based on FIS and DWT is illustrated by Fig. 1, and the detailed steps are listed as follows.

1. Input the cover image which is a grayscale image of size 512×512 pixels and the watermark image is a binary image of size 64×64 pixels.
2. Partition the cover image into 8×8 blocks.
3. Implement the DCT to each block.
4. Find the edge sensitivity and contrast sensitivity of each block resulted from the DCT.
5. Input the edge and contrast sensitivity parameters to the Sugeno Fuzzy Inference System (FIS) built on 9 fuzzy rules to generate the weight factor α.
6. First level DWT, decompose the original image into 4 subbands: LL1, HL1, LH1, and HH1
7. The second level DWT is performed on the LH1 subband to get four smaller subbands LL2, HL2, LH2, and HH2.
8. Divide the band {LH2} into 2×2 blocks.
9. Embedding binary watermark bits in A sub-matrix produced from step 7

$$A\{i,j\}(1,1) = A\{i,j\}(1,1) - mod(A\{i,j\}(1,1), \alpha) + T1 \quad if \;\; w(i,j) = 1$$
$$A\{i,j\}(1,1) = A\{i,j\}(1,1) - mod(A\{i,j\}(1,1), \alpha) + T2 \quad if \;\; w(i,j) = 0$$

Where α represents the weight factor gained from the designed fuzzy inference system (FIS) and $T1 = 0.75 * \alpha$, $T2 = 0.25 * \alpha$ and mod (.) is the modulo operation.

10. Apply inverse DWT and obtain the watermarked image.

Extraction Algorithm

The process of extracting the watermark of the proposed method is illustrated in Fig. 2. As can be seen, the cover image is unrequired in the extracted process of the watermark. The detailed extraction steps are given as follows.

1. Input the watermarked image with size 512×512 and convert this image to grayscale image.
2. Partition the watermarked image into 8 × 8 blocks.
3. Implement the DCT to each block.
4. Find the edge sensitivity and contrast sensitivity of each block resulted from the DCT.
5. Input the edge and contrast sensitivity parameters to the Fuzzy Inference System (FIS) to generate the weight factor β.
6. First level DWT, decompose the watermarked image into 4 subbands: LL1, HL1, LH1, and HH1
7. The second level DWT is performed on the LH1 subband to get four smaller subbands LL2, HL2, LH2, and HH2.
8. Divide the band {LH2} into 2×2 blocks.
9. The watermark bit is extracted as follows:

$$w = 0 \ \ if \ \ A1\{i,j\}(1,1) \ \ mod\, \beta < \ ave$$
$$w = 1 \ \ if \ \ A1\{i,j\}(1,1) \ \ mod\, \beta > ave$$

where β represents the weight factor gained from the designed fuzzy inference system (FIS) and $ave \ = (T1 + T2)/2$ represents the average.

The following two figures illustrate the above two algorithms:

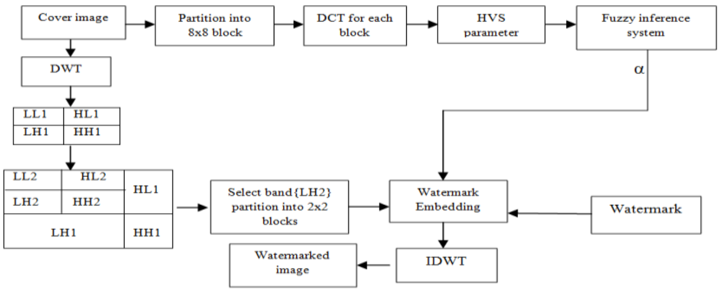


Fig. 1 Block Diagram of the Embedding Algorithm

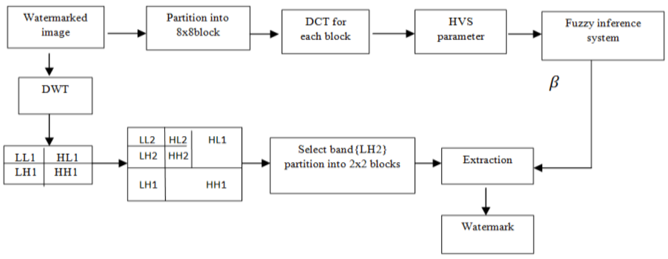
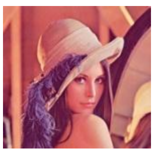
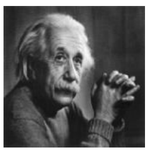


Fig. 2: Block Diagram of Extraction Algorithm

4. EXPERIMENTAL RESULTS

In this section, some attacks are performed to assess the robustness and imperceptibility of the suggested algorithm. This image watermarking technique is examined with different grayscale cover images of size 512×512. A binary image of size 64×64 is utilized as a watermark image. Table 1 shows the watermark and the images used to test the proposed algorithm.

Table -1 The Watermark and the Images used to Test the Proposed Algorithm

Image 1	Image 2	Image 3	Image 4	Watermark Image
				

To evidence the soundness of the proposed watermarking algorithm, some results are clarified. Five sorts of attacks were utilized to test the robustness of the proposed watermarking algorithm.

In general, the performances of image watermarking techniques are measured by the robustness, invisibility, computation complexity, etc.

PSNR as a good tester for the watermark visibility assess and it is given by the following equation:

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{\mathrm{MAX}^{2}}{\mathrm{MSE}}\right). \quad (1)$$

where

$$\mathrm{MES} = \frac{1}{pq}\sum_{i=0}^{p-1}\sum_{j=0}^{q-1}[I(i,j) - K(i,j)]^{2}. \quad (2)$$

and MAX is the maximum greyscale value which here is equal to 256.

The matching between the extracted watermark W' and the authentic watermark W is computed based on NC (a normalized correlation) between W and W'.

$$\mathrm{NC} = \frac{\sum_i \sum_j w(i,j).w'(i,j)}{\sqrt{\sum_i \sum_j w(i,j)}\sqrt{\sum_i \sum_j w'(i,j)}}. \quad (3)$$

To show the robustness of the proposed mechanism, diverse attacks are implemented on the watermarked image to assess the robustness of the proposed mechanism as shown in Table 2, Table 3 respectively. Salt and pepper attack is added with the rate of 1% density to the watermarked image. Another important attack is JPEG compression attack. It is one of the common attacks that our proposed method has a good performance against it.

Table-2 PSNR Values for the Attacks Implemented on Images

Types of attacks	PSNR values for watermarked images			
	Image 1	Image 2	Image 3	Image 4
No attacks	44.537	46.1777	46.1239	45.8389
Salt and Pepper %1	26.9052	26.2816	26.9908	27.0898
JPEG Compression	59.0451	58.8306	58.9171	58.7901
Gaussian noise	37.6718	37.6892	37.6442	37.679
Winer	38.738	40.4168	39.3336	40.5825
Specklenoise	35.6429	39.0642	35.7209	34.7062

In Table3, results of the NC values are shown against different attacks. High NC values show the robustness of this method against Salt and Pepper, JPEG Compression and Gaussian attack while Our method does not perform well under the Winer attack.

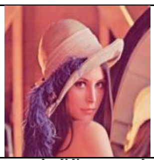
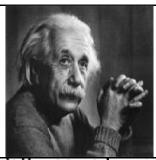
Table -3The NC Values for the Attacks Implemented on Images

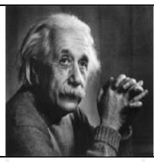
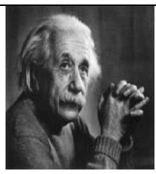
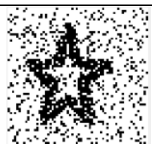
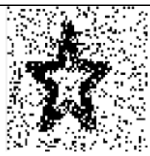
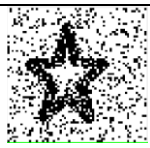
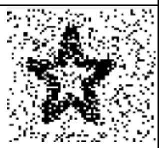
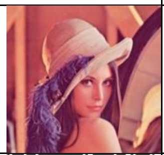
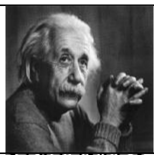
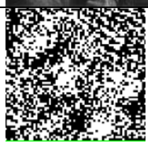
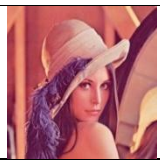
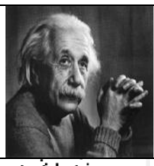
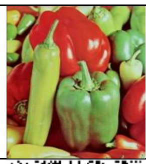
Types of attacks	NC values for watermarked images			
	Image1	Image2	Image3	Image4
No attack	1	1	1	1
Salt and Pepper %1	0.9665	0.9634	0.9715	0.9661
JPEG Compression	1	1	1	1
Gaussian noise	0.8999	0.9041	0.8953	0.9012
Winer	0.5949	0.6778	0.6568	0.6667
Specklenoise	0.8568	0.9462	0.8616	0.8196

Our method used Mamdani -fuzzy inference system to obtain the weighting factor for controlling the embedding of the watermark in order to control balance achieved between robustness and imperceptibility and that the values of the robustness and imperceptibility vary by the value of weighting factor.

The following are the watermarked images and the extracted watermark image from each one respectively after attacks implementation:

Table -4 Test Original Images and Watermarked Images after Attacks

Attack / **Extracted watermark**	**Image1**	**Image2**	**Image3**	**Image4**
Salt and Pepper %1				
Extracted watermark				

JPEG Compression				
Extracted watermark				
Gaussian noise				
Extracted watermark				
Winer				
Extracted watermark				
Specklenoise				
Extracted watermark				

5. CONCLUSION

The goal of the method proposed in this work is to introduce a combination of 2level DWT and the Fuzzy inference system (FIS). In order to achieve the determined goal, HVS, FIS, and DWT are used in parallel. The HVS parameters are modeled using fuzzy inference system to implement the watermarking algorithm using four different gray-scale images. So, the results show that the imperceptibility of the proposed scheme is enhanced comparing with existing methods. The robustness is achieved using DWT depending on the properties of the LH2 matrix. The perceptible quality is good as indicated by the PSNR values and the watermark extraction is also found to be good as indicated by good values of the NC between the embedded and the extracted watermark. It is concluded that the embedding and extraction of the proposed algorithm are well optimized.

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