Improved Sugeno FIS-2Level DWT Digital Image Watermarking Technique

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Abstract *- In this paper, Sugeno Fuzzy inference system (FIS) has adopted depending on 2level DWT in order to ensure finding the best locations to embed the watermark data in the host image in the frequency domain of DWT and hence to increase the robustness of the proposed technique. First of all, apply DWT on the host image twice, then decompose the LH2 band into 2x2 blocks to assure the superior hiding of the bits of the watermark in a chosen places. On the other hand, FIS is performed to obtain a parameter that controls the embedding robustness. The algorithm leads to achieving robustness and imperceptibility criterion. The results for PSNR and NC with and without attacks are better for the proposed algorithm. Experimental results show the efficiency of the proposed technique. The experimental results show that the proposed technique has perfect robustness against image processing attacks.*

Keywords — *Sugeno fuzzy Inference System; Discrete Wavelet Transform; watermarked image; the Peak Signal to Noise Ratio(PSNR); normalized correlation(NC).*

I. INTRODUCTION

Fuzzy theory has become the cornerstone of many important sciences today. With the gradual transition of science into the digital world, fuzzy logic has become one of the most important influences in the development of the rest of science, including image processing. Digital watermarking techniques depends on many factors to insert the information of the watermark into the cover image. Fuzzy Inference System (FIS) [1] is one of these factors that used to control the decision of how to embed bits of the watermark depending on the goal to be achieved.

Digital image watermarking is information (the watermark) hiding into the digital data. In other words, to affirm the originality of the data; the embedded secret image can be specified or extracted later. Digital watermarking is the first kind of mechanisms to better the impartiality and reliability of digital data. Lately, authentication is one of the major watermarking requirements in image processing applications [2].

Depending on the choosing domain, the watermarking schemes can be performed 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 robust. One of the most broadly utilized is a discrete wavelet transform (DWT) [3].

Aydin et al. in [4] 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 based on 3 levels of discrete wavelet transform (DWT) is presented in [5] 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 the above, this paper focus on a digital watermarking algorithm depends on 2level DWTin parallel with the FIS. This algorithm is taken into consideration for the first time in the watermarking techniques. This work investigates the robustness and the imperceptibility in the frequency domain of the DWT in the second level. Moreover, in this paper, various attacks are adopted to explain the advantages of the given digital image watermarking.

The rest of this paper is ordered as follows. In Section II and III basic important information of DWT and FIS are covered concisely. Section IV devoted to present the proposed algorithm. Section V of this paper particularized to explain the experimental results and discussion. Finally, the conclusion is documented in Section VI.

II. 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 converted image at the prior level [7].

III. DISCRETE COSINE TRANSFORM

DCT represents a technique for converting the signal from time domain representation to frequency band form. For a given image A of size $n \times n$, in digital image processing, the two-dimensional DCT is given as:

$$C_{nm} = \alpha n\, \alpha m \sum_{i=0}^{I-1} \sum_{j=0}^{J-1} Z_{ij} \left(\frac{\cos(2\pi i + 1)\, n}{2I}\right)\left(\frac{\cos(2\pi j + 1)\, m}{2J}\right)$$

$$\text{for} 0 \leq n \leq I - 1 \quad \text{and} \quad 0 \leq m \leq J - 1$$

$$\alpha n = \begin{cases} \frac{1}{\sqrt{J}}, & n = 0 \\ \frac{2}{\sqrt{J}}, & 1 \leq n \leq J - 1 \end{cases},$$

$$\alpha m = \begin{cases} \frac{1}{\sqrt{I}}, & m = 0 \\ \frac{2}{\sqrt{I}}, & 1 \leq m \leq I - 1 \end{cases}$$

Dct is characterized by the property that most of the important optical functions are concentrated around the image in a few DCT parameters and therefore we observe the use of DCT frequently in image compression applications[8][9].

IV. 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. These 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 [10]. It is worth to mention that Multi Wavelet Transform and fuzzy inference system can be used for several purposes as in [11].

A. Fuzzy Variables and Membership Functions

One of the steps or stages of implementing a fuzzy inference system is processed the given information and classify the grade of results to which they belong utilizing membership functions. One of the mathematical functions used in the FIS is a membership function which takes the given information to a grade of membership between [0,1]. There are several shapes of membership functions, they are not limited to triangular and trapezoidal functions. Any form for membership functions can be adopted mathematically defined according to the demands of the case. The input variables used in our system are Edge sensitivity and contrast sensitivity while the membership functions used are triangular functions[12].

$$\mu_A(x) = \begin{cases} 0, & x \leq a \\ \frac{x - a}{m - a}, & a < x \leq m \\ \frac{b - x}{b - m}, & b < x < m \\ 0, & x \geq b \end{cases}$$

B. Rules of Inference and Logic Operators

Rules of inference represent all fuzzy rules aggregating the various variables of a fuzzy inference system. These rules take the following form:

- If (condition 1) and / or condition (N) then (action on the outputs)

The logic operators AND or OR is utilized in the fuzzy logic to craft the inference rules. therefore the output magnitude is obtained using the maximum or minimum inputs respectively[10].

V. METHODOLOGY

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

A. Embedding Phase

The process of this phasethat 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.

The following figure illustrates the above steps:

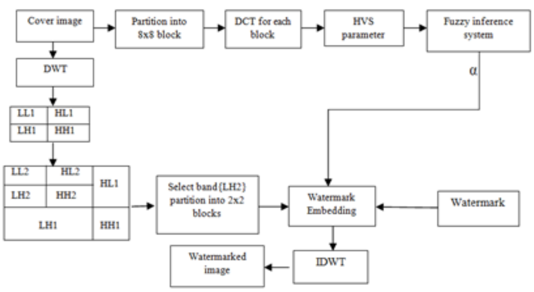


Fig. 1: Block Diagram of The Embedding Algorithm

B. Extraction Phase

The process of the extraction 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:

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

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

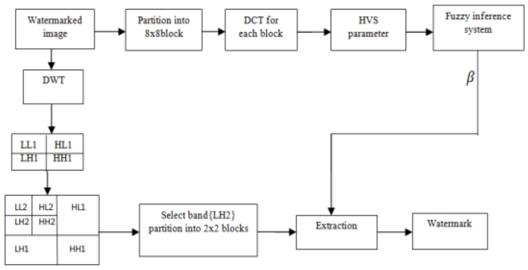


Fig. 2: Block Diagram of The Extraction Algorithm

VI. EXPERIMENTAL RESULTS

In this section, some experiments are performed to assess the imperceptibility and robustness of the proposed watermarking algorithm. The proposed 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 utilized to test the designedtechnique.

Image 1	**Image 2**	**Image 3**	**Image 4**	**Water mark Image**
				

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

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:

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

where

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

andMAX is the maximum greyscale value which here is equal to 256.

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

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

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.

Types of attacks	**PSNR values for watermarked images**			
	Image 1	**Image 2**	**Image 3**	**Image 4**
No attack	1	1	1	1
Salt and Pepper %1	0.9666	0.9592	0.9692	0.9676
JPEG Compression	1	1	1	1
Gaussian noise	0.9782	0.9793	0.9799	0.9782
Winer	0.6737	0.6421	0.5708	0.6709
Speckle noise	0.9229	0.9279	0.9292	0.8919

Table 2: PSNR Values for Different Attacks Implemented to Test Images for the QRD-FIS Algorithm

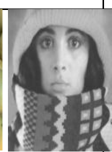
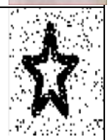
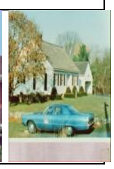
In Table3, results of the NC values are shown against different attacks. High NC values show the robustness of this method against Salt and Pepper, JPEG Compression and Gaussian attack while Our method does not perform well under the Winer attack.

Types of attacks	**PSNR values for watermarked images**			
	Image 1	Image 2	Image 3	Image 4
No attacks	42.086	41.425	40.521	43.38
Salt and Pepper %1	27.022	26.964	27.131	26.547
JPEG Compression	58.843	59.037	59.656	59.338
Gaussian noise	37.664	37.654	37.670	37.663
Winer	39.807	39.791	39.328	36.829
Specklenoise	34.696	34.799	34.852	33.601

Table 3: The NC Values for Different Attacks Implemented to Test Images for the QRD-FIS Algorithm

Our method used Sugeno -fuzzy inference system to generate the weighting factor for embedding 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:

Attack Extracted watermark	**Image 1**	**Image 2**	**Image3**	**Image 4**
Salt and Pepper %1				
Extracted watermark				
JPEG Compression				

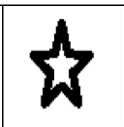
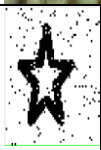
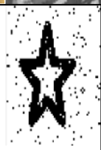
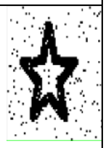
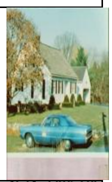
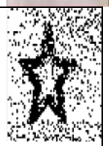
Extracted watermark				
Gaussian noise				
Extracted watermark				
Winer				
Extracted watermark				
Specklenoise				
Extracted watermark				

Table 4: Test OriginalImages and Watermarked Images after Attacks

VII. CONCLUSION

The aim of the proposed algorithm 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 presentthat the imperceptibility of the designed scheme is enhanced comparing with known 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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