Sugeno FIS-QRD for Digital Image Watermarking

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ABSTRACT: *The presence of several types of fuzzy inference system allows us to control the expected results of a problem that to be resolved. Image processing is the most interesting science that concern with fuzzy theory and linear algebra. In this paper, the Sugeno Fuzzy Inference System is adopted with the QR matrix decomposition method to propose a watermarking algorithm using the parameter generated by FIS to control the choice of the location to embed the information of the watermark into the R matrix obtained from the QR matrix decomposition method. Some attacks are applied to test the robustness represented by NC and the imperceptibility represented by PSNR of the proposed scheme.*

Keywords -Sugeno fuzzy Inference System, QR matrix decomposition,watermarked image, the Peak Signal to Noise Ratio(PSNR), normalized correlation(NC).

I. INTRODUCTION

Fuzzy Inference System (FIS) is one of the factors used to control the decision in fuzzy logic. The fundamental of fuzzy logic is analogous to human attitude. It is based on the linguistic variables concerning the human language. Moreover, these variables are specified by some tentative experiments. 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. The FIS helps to embed the bits of the watermark depending on the goal to be achieved [1]. Linear algebra plays an important role in image processing, particularly in watermarking. Furthermore, linear algebra is a subfield of mathematics interested with matrices, vectors, and linear transforms. It is a fundamental key to the field of image processing, from symbols used to describe the approach of algorithms to the enforcement of algorithms in code. The idea of the digital image watermarking is summarised by hiding the information represented by the watermark into the digital data. In other words, to affirm the originality of the data; the embedded secret image can be specified or extracted later.

The definition of digital image watermarking is summarised by hiding the information (the watermark) 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].

Sakr et al. [3] exploited the Sugeno type of the FIS along with DWT in order to propose a nonblind digital image watermarking technique. The embedding process uses the result of applying DWT to the original image first to generate the watermark weighting function using FIS and second to embed the watermark (which consists of a binary pseudo-random sequence) into the lowest level subbands of the DWT.

In [4] Imran and Harvey proposed a blind adaptive color image watermarking technique depending on the two algebraic methods PCA, SVD and HVS. To improve the perceptual quality of the watermarked image PCA is used to decorrelate the three color channels of the cover image. While the HVS and FIS worked to further improve both robustness and imperceptibility by choosing a suitable running scale, for this reason, regions more susceptible to noise can be added with additional information as compared to fewer susceptible regions.

The goodness of the watermarked image is typically handled in [5] by locating the adaptable running factor for every demarcation pixel intensity. The HVS (texture masking) and FIS were used in order to set the adaptable scaling factor. To enhance the security grade and robustness DWT has been used. This improvement

is owing to the irregular apportionment of the watermark within the image through the transform converse. The algorithm of using (SVD) in order to decompose LH; and HL sub-bands is given.

Kumar and Rao in [6] implemented a novel robust watermarking scheme relying on DWT and SVD using Fuzzy Logic and Genetic Algorithm. Fuzzy logic system is used to find the strength of watermark that has to be added to the original image while embedding.

Lalani and Doye [7] proposed a technique tries to solve this problem by designing a fuzzy inference system (FIS) based on just-noticeable distortion (JND) that takes into consideration the image characteristics for deciding the transparency of the cover signal. apply a worthy tool in numerical linear algebra named SVD to the HL band obtained from the 3rd level of DWT to obtain the modified component.

The DWT is used and then develops a DWT-SVD path using the band LL obtained from the 2-level DWT in [8]. Even if DWT has a broad scope of implementation but when combined both SVD and DWT it will boost the robustness of the extracted watermark.

An authentication technique has been developed in the wavelet domain of a medical image by Jayanthi and Sridevi in [9]. The authentication message is embedded in the singular values of Region of Non-Interest (RONI) pixels. The watermark strength of the pixels in the RONI portion is predicted using fuzzy inference rules, Singular Value Decomposition (SVD)is applied to the HL details of the RONI.

Fan and Wu in [10] decompose the cover image using the complex wavelet transform. Secondly, the selection of the singular value of the low-frequency coefficients is made as an embedded factor, which hides the watermark perfectly. Ultimately, as a fuzzy clustering feature vectors, image high frequency texture features and low frequency background, that are regarding human visual masking, are utilized in order to set the different embedding strength.

In this paper, a Sugeno FIS is adopted along with QR factorization which is taken into consideration for the first time in the watermarking techniques to introduce a digital watermarking algorithm. This work investigates the robustness and the imperceptibility in the frequency domain of QR. Moreover, in this paper, various attacks are given to explain the advantages of the proposed digital image watermarking.

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

II. PRELIMINARIES

This section presents some concepts and notions that are used throughout the paper.

2.1 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.

2.2Fuzzy Variables and Membership Functions

One of the steps or stages of 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 [11].

implementing a fuzzy inference system is processed the given informationand 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].

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

2.3 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)

Inference rules are crafted using a fuzzy logical operator such as AND or OR. After we apply the rules using the "AND" or "OR" operator, the output value is obtained with the minimum or maximum input values respectively[11].

2.4 QR Decomposition

The QR decomposition, also known as QR factorization in linear algebra is a linear operation that factors a real square matrix A into two matrices: an orthogonalmatrix Q and an upper triangular matrix R. The uses of QR decomposition are varied and the best uses are solving the linear least squares problem. Additional uses involve the QR method and calculatingthe SVD of a matrix. Numerous ways for finding the QR matrix decomposition exist; in particular the (Gram Schmidt) method, Givens rotations, and Householder transformations. QR factorization for a 3x3 matrix can be presented as[13]:

$$A = QR = [Q_1, Q_2, Q_3] \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ 0 & R_{22} & R_{23} \\ 0 & 0 & R_{33} \end{bmatrix}$$

2.5 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:

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

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

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[14][15].

3   METHODOLOGY

In this section, we propose a protection scheme for improving watermarking relies on FIS and QR Matrix Decomposition. The proposed watermarking scheme can be characterized as follows:

3.1 Embedding Algorithm
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. Implement the QR matrix decomposition methodto each 8×8 blocks obtain in step 2 of the cover image.
7. Embedding binary watermark bits in R submatrix

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

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.

8- Convert block to the matrix and obtain Watermarked image.

The following figure illustrates the above steps:
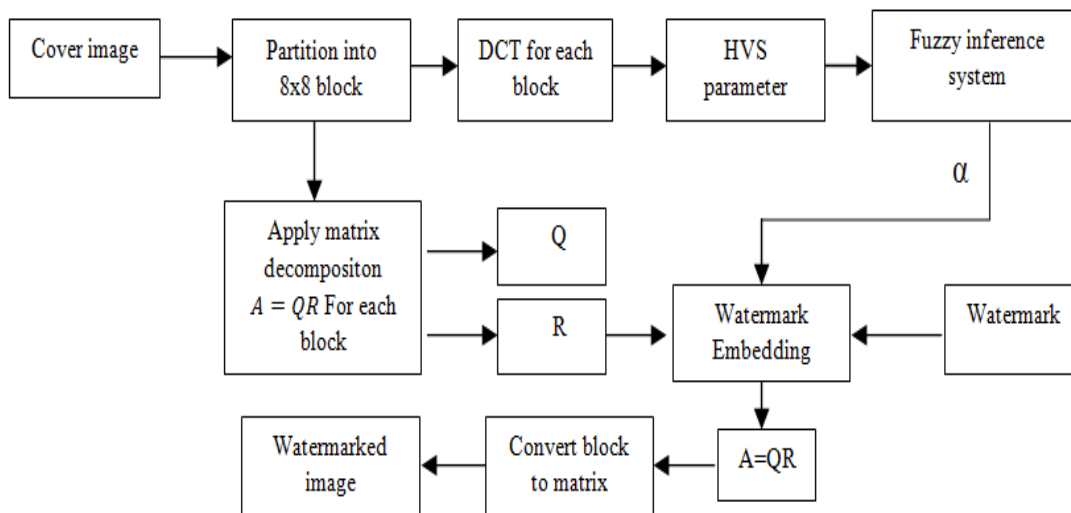
Fig. 1: Block Diagram of The Embedding Algorithm

3.2 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 ofthe watermark. The detailedextraction 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. Implement the QR matrix decomposition method to each 8×8 blocks obtain in step 2 of the cover image.
7. The watermark bit is extracted as follows:

$$w(i,j) = 0 \quad if \; mod(R1\{i,j\}(1,1), \beta) < ave$$
$$w(i,j) = 1 \quad if \; mod(R1\{i,j\}(1,1), \beta) > ave$$

where β represents the weight factor gained from the designed fuzzy inference system (FIS) and $ave = (T1 + T2)/2$ represents the average.
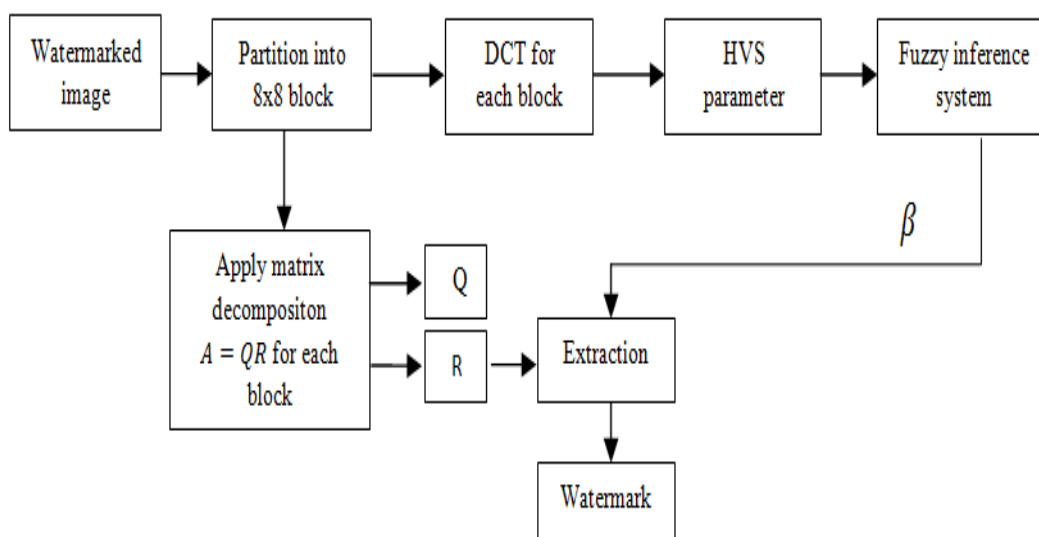
Fig. 2: Block Diagram of Extraction Algorithm

4   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 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:

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

where

$$\text{MES} = \frac{1}{pq}\sum_{i=0}^{p-1}\sum_{j=0}^{q-1}[I(i,j) - K(i,j)]^2. \tag{3}$$

and MAX 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′.

$$\text{NC} = \frac{\sum_i \sum_j w(i,j).w'(i,j)}{\sqrt{\sum_i \sum_j w(i,j)}\sqrt{\sum_i \sum_j w'(i,j)}}. \tag{4}$$

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. In salt and pepper noise attack, noise is added to the watermarked image at 1 % density. Another important attack is JPEG compression attack. It is one of the common attacks that our proposed method has a good performance against it.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.
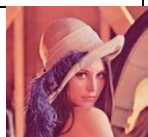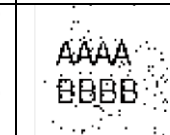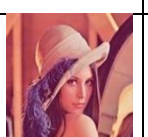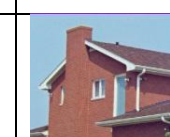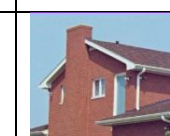
Table 2:The PSNR and NC Values for Watermarked Images with Attacks

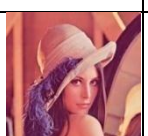| Attacks	Images	Image1	Image2	Image3	Image4
No attack	PSNR	45.2417	44.9709	44.8205	43.9888
	NC	1	1	1	1
Salt and Pepper %1	PSNR	27.2917	26.719	26.1766	27.0816
	NC	0.98687	0.98860	0.98727	0.98607
JPEG Compression	PSNR	59.4708	59.3599	59.6057	59.9072
	NC	1	1	1	1
Gaussian noise	PSNR	37.6495	37.6835	37.6813	37.6362
	NC	0.98446	0.98326	0.98339	0.98406
Winer	PSNR	38.989	38.5309	42.0224	40.6159
	NC	0.78944	0.81588	0.84931	0.79197
Specklenoise	PSNR	35.6599	35.5983	41.0816	3.881
	NC	0.95237	0.94248	0.99233	0.943356

Our method usedSugeno-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:

Table 3: 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

This work focus on the impact of the Sugeno FIS using the algebraic method QR matrix decomposition. The aim of the proposed algorithm is to introduce a combination of the linear algebra decomposition method QRD and the Sugeno Fuzzy inference system (FIS). It is concluded that the embedding and extraction of the proposed algorithm are well optimized. In order to achieve the determined goal, HVS, FIS, and QR are used together. The watermarking technique given in this paper involves two basic parameters of the HVS model namely Edge and Contrast Sensitivity computed using block threshold value and block variance. These HVS parameters are modeled using fuzzy inference system to implement the watermarking algorithm using four different gray-scale images. So, imperceptibility is then enhanced and can be seen from the results that the imperceptibility of the proposed scheme is good or acceptable comparing with existing methods. The robustness is achieved using QR depending on the properties of the R 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.

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