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Unification of 2-FIS Values for Digital Image Watermarking Based on QRD

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Abstract: 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) 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. In this paper, the Mamdani type of FIS is introduced in two parallel cases utilizing two deferent inputs named contrast sensitivity and edge sensitivity respectively to achieve high robustness and acceptable imperceptibility relying on appropriate places obtained by the algebraic matrix decomposition method QR. Experimental results show that the proposed method has a promising behaver to increase the normalized correlation (NC) and the peak signal to noise ratio (PSNR).

Keywords: Fuzzy Inference System**;** QR decomposition**;** watermarked image**;** the Peak Signal to Noise Ratio(PSNR); normalized correlation(NC).

I. INTRODUCTION

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. 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) 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 [1].

On the other hand, 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. Furthermore, linear algebra plays an important role in image processing, particularly in watermarking.

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].

Imran and Harvey proposed in [3] a blind adaptive color image watermarking technique depending on 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.

Typically the goodness of the watermarked image is handled in [4] 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.

A novel robust watermarking scheme is implemented 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 [5].

The essential difficulty for creating a new watermarking scheme is typically the stalemate between impressionability plus robustness. Lalani and Doye [6] 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 which applies 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.

Authors in [7] used the DWT and then develops a DWT-SVD path using the band LL obtained from the 2-level DWT. 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.

In the proposed work in [8], an authentication technique has been developed in the wavelet domain of a medical image. 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.

Firstly in [9] Fan and Wu 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.

Motivated by the above, this paper focus on a digital watermarking algorithm depends primarily on QRD factorization which is taken into consideration for the first time in the watermarking techniques common side by side with the Fuzzy Inference System (FIS). This work investigates the robustness and the imperceptibility in the frequency domain of QRD. 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 2,3 and 4 basic important information of QRD and FIS are covered concisely. Section 5 devoted to present the proposed algorithm. Section 5 of this paper particularized to explain the experimental results and discussion. Finally, the conclusion is documented in Section 7.

II. BACKGROUND

In this section, some needed information is given that will be used in the next sections.

2.1 QR Decomposition

The QRD decomposition, also known as QRD 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 QRD decomposition are varied and the best uses are solving the linear least squares problem. Additional uses involve the QRD method and calculating the SVD of a matrix. Numerous ways for finding the QRD matrix decomposition exist; in particular the (Gram Schmidt) method, Givens rotations, and Householder transformations. QRD factorization for a 3x3 matrix can be presented as[10]:

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

2.2Discrete 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:

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

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

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[12, 13].

2.3 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 [14].

2.4 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[15].

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

2.5 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[14].

III. 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

The process of embedding the watermark into the cover image based on FIS and QRD 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. Provide edge sensitivity as inputs to the Mamdani Fuzzy Inference System1 (FIS1) and contrast sensitivity as inputs to the Mamdani Fuzzy Inference System2 (FIS2)
6. Total output for both FIS1 and FIS2 is used as a weighing factor.
7. Divide the original image(grayscale) into 8×8 blocks.

8. Apply QR matrix decompositionto each block.
9. 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 (FIS1) and (FIS2) 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:

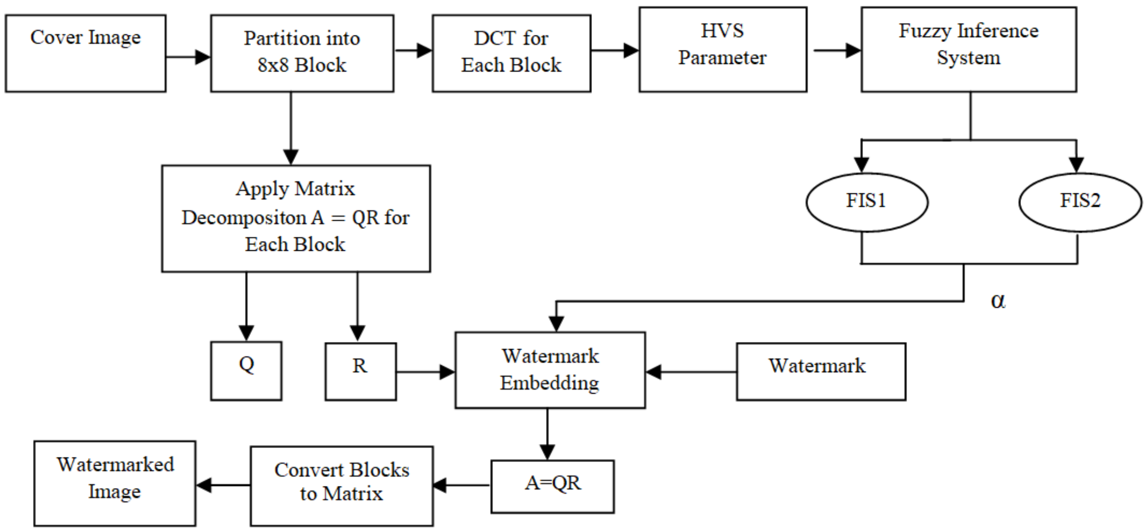


Fig. 1: Block Diagram of The Embedding Algorithm

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 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. Provide edge sensitivity as inputs to the Mamdani Fuzzy Inference System1 (FIS1) and contrast sensitivity as inputs to the Mamdani Fuzzy Inference System2 (FIS2)
6. Total output for both FIS1 and FIS2 is used as weighing factor.
7. Divide the watermarked image (grayscale) into 8×8 blocks.
   Apply QR matrix decompositionto each block.
   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 (FIS1) and (FIS2) and $ave \; = (T1 + T2)/2$ represents the average.

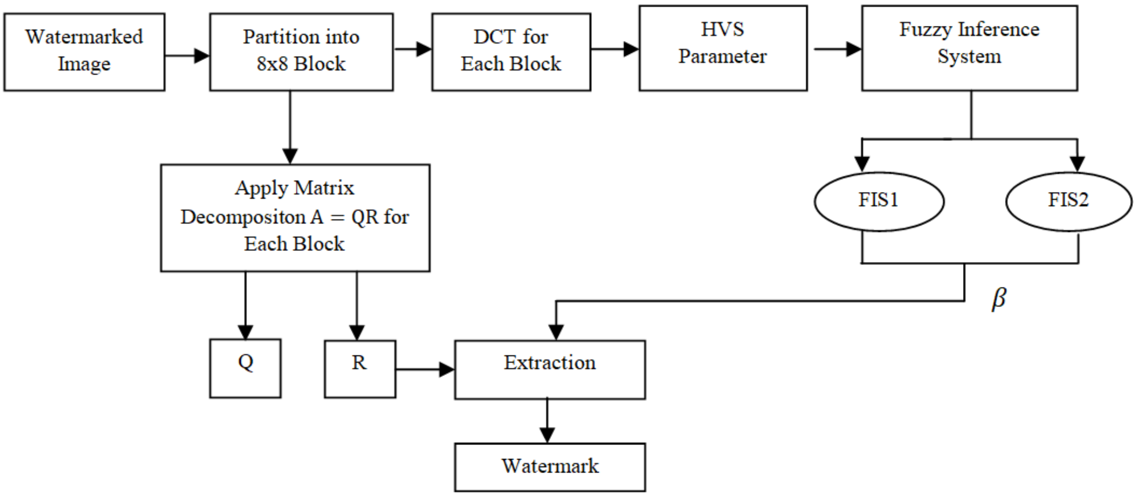
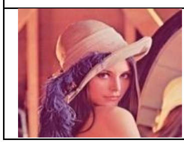


Fig. 2: Block Diagram of Extraction Algorithm

IV. 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	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:

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

where

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

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' .

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

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, Table 3 respectively**.**

Table 2: PSNR Values for Different Attacks Applied to Test Images

Types of attacks	**Image1**	**Image2**	**Image3**
No attacks	46.9593	47.1716	47.8213
Salt and Pepper %1	27.0212	27.2729	26.0384
JPEG Compression	59.5118	58.6492	59.6148
Gaussian noise	37.6638	37.6426	37.7078
Winer	39.1601	35.0736	42.3447
Specklenoise	35.6524	35.5127	41.0828

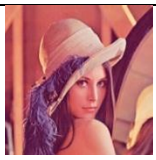
Our method used Mamdani -fuzzy inference system to generate the weighting factor for embedding the watermark in order to control balance achieved between robustness and imperceptibility and that the values of the robustness and imperceptibility vary by the value of weighting factor.

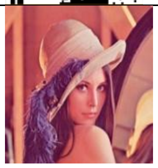
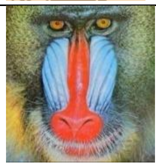
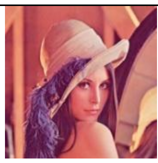
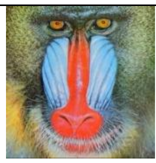
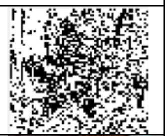
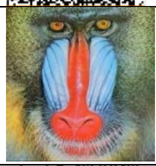
Table 3: The NC Values for Different Attacks Applied to Test Images

Types of attacks	**Image1**	**Image2**	**Image3**
No attack	1	1	1
Salt and Pepper %1	0.9809	0.9838	0.9805
JPEG Compression	0.5732	0.6504	0.8556
Gaussian noise	0.6694	0.7984	0.8432
Winer	0.7023	0.6649	0.7818
Specklenoise	0.7700	0.8285	0.9233

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**
Salt and Pepper %1			
Extracted watermark			
JPEG Compression			

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

V. CONCLUSION

In order to achieve the determined goal, 2-FIS, and QRD are used together. The aim of the proposed algorithm is to introduce a hybrid between two values obtained from the FIS and linear algebra decomposition method QRD. The watermarking technique given in this paper involves two basic parameters of the HVS model namely Edge and Contrast Sensitivity computed to give two values for FIS. These values are used to implement the watermarking algorithm using four different gray-scale images. So, imperceptibility is then enhanced comparing with existing methods. 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. The robustness is achieved using 2-FIS depending on the properties of the R matrix obtained by QRD method.

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