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The Algebraic LUD Method Combined with the Two Folds FIS to Build Digital Image Watermarking Scheme

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ABSTRACT: Recently digital image watermarking techniques becomes broadly dependent on mathematics. This paper introduced a proposed scheme using the algebraic matrix decomposition method LU along with two folds Mamdani fuzzy inference system (FIS). The proposed scheme to embedding the watermark into the original image involves two separate cases, one of them splits the original image into 8×8 blocks in order to apply the LUD method on each block and collect the resulted matrices U of each block in one matrix to be ready to the embedding process. Independently, the second case includes computing two values of the FIS according to the two inputs edge sensitivity and contrast sensitivity. The sum of these two values used as a control parameter that decided the robustness of the scheme. The evaluation of the results done by the PSNR and NC which shows that this scheme is robust against various attacks.

Keywords -Fuzzy Inference System**,** LU decomposition**,** watermarked image**,** the Peak Signal to Noise Ratio(PSNR), normalized correlation(NC).

I. INTRODUCTION

Linear algebra used in many applications of mathematics. Linear algebra is centric to most whole scopes of mathematics and it is a very important field to study. A perfect understanding of linear algebra is substantial for comprehending and dealing with numerous algorithms, in particular, image processing algorithms.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.

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].

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 and applya worthy tool in numerical linear algebra named SVD to the HL band obtained from the 3rd level of DWT to get 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 LUD 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 LUD. 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 basic important information of LUD 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. BACKGROUND

In this section needed data is provided that used in the rest of the paper.

2.1 LU decomposition

In linear algebra and numerical analysis, lower–upper decomposition (LU) (or LU factorization) operators a matrix A as the product of a lower triangular matrix (L) and an upper triangular matrix(U), as well as sometimes the product includes a permutation matrix. In 1948 [10]Turing gives LU decomposition which is the basic modified way of Gaussian elimination. LU decomposition is often adopted in solving square systems of linear equations. It is a necessary process when calculating the determinant of a matrix or inverting a matrix. For example, for a 3×3 matrix A, its LU decomposition can be presented as:

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} = LU = \begin{pmatrix} 1 & 0 & 0 \\ l_{21} & 1 & 0 \\ l_{31} & l_{32} & 1 \end{pmatrix} \begin{pmatrix} u_{11} & u_{12} & u_{13} \\ 0 & u_{22} & u_{23} \\ 0 & 0 & u_{33} \end{pmatrix}$$

$$= \begin{pmatrix} u_{11} & u_{12} & u_{13} \\ l_{21}u_{11} & l_{21}u_{12} + u_{22} & l_{21}u_{13} + u_{23} \\ l_{31}u_{11} & l_{31}u_{12} + l_{32}u_{22} & l_{31}u_{13} + l_{32}u_{23} + u_{33} \end{pmatrix}$$

2.2 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:

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

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

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[11, 12].

2.3Fuzzy 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 [11].

2.4Fuzzy Variables and Membership Functions

One of the steps or stages of 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].

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

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[11].

III. METHODOLOGY

In this section, we propose a protection scheme for improving watermarking relies on FIS and LUD 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 LUD is illustrated by Fig. 1, and the detailed steps are listed as follows.

1. Input the cover image which is a grayscale imageof size 512×512 pixels and the watermark image is a binary image of size 64×64pixels.
2. Partition the cover image into 8×8 blocks.

3. Implementthe DCT to each block.
4. Find the edge sensitivity and contrast sensitivity of each block resulted from the DCT.
5. Provide edge sensitivity as input to the Mamdani Fuzzy Inference System1 (FIS1) and contrast sensitivity as input to the Mamdani Fuzzy Inference System2 (FIS2)
6. Total output for both FIS1 and FIS2 is used as weighing factor.
7. Divide the original image(grayscale) into 8×8 blocks.
8. Apply LU matrix decompositionto each block.
9. Embedding binary watermark bits in U submatrix

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

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:

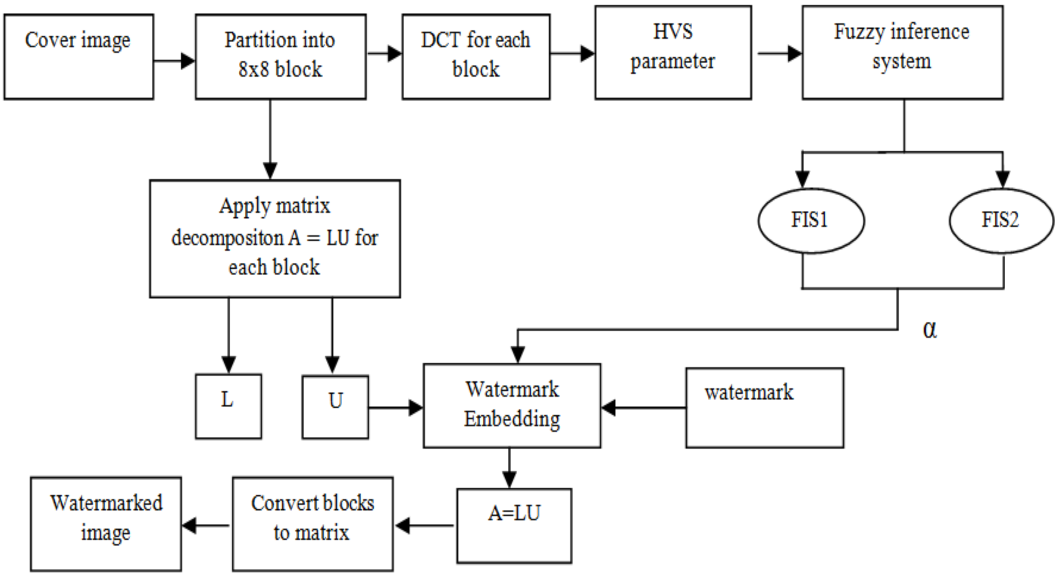


Fig. 1: Block Diagram of The Embedding Algorithm

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.
4. Provide edge sensitivity as inputs to the Mamdani Fuzzy Inference System1 (FIS1) and contrast sensitivity as inputs to the Mamdani Fuzzy Inference System2 (FIS2)
5. Total output for both FIS1 and FIS2 is used as weighing factor.
6.Divide the watermarked image (grayscale) into 8×8 blocks.
7. Apply LU matrix decompositionto each block.
8. The watermark bit is extracted as follows:

$$w(i,j) = 0 \quad if \;\; mod(U1\{i,j\}(1,1),\beta) < ave$$
$$w(i,j) = 1 \quad if \;\; mod(U1\{i,j\}(1,1),\beta) > ave$$

where β represents the weight factor gained from the designed fuzzy inference system (FIS1) and (FIS2) and $ave = (T1 + T2)/2$ represents the average.

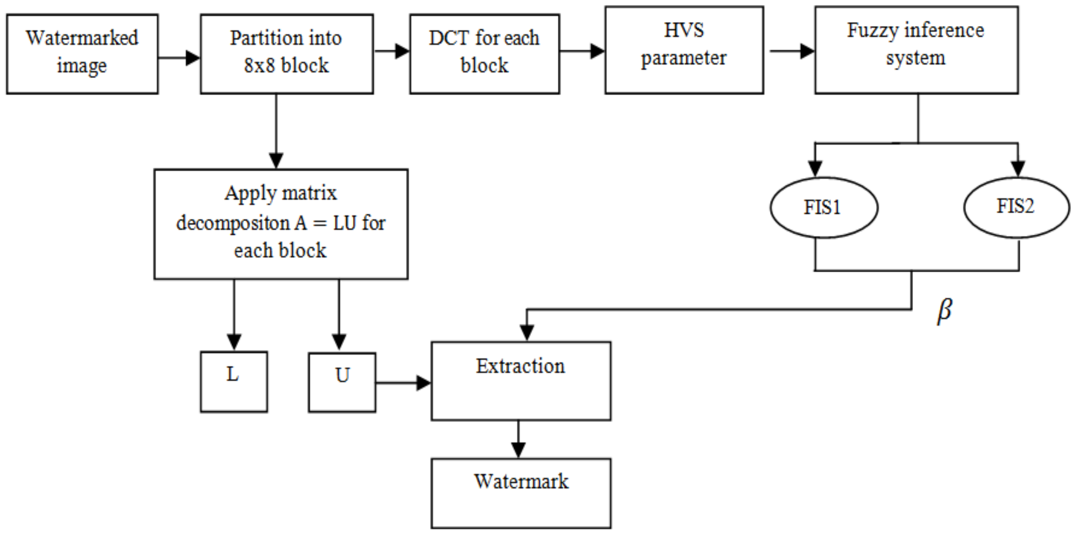
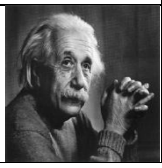


Fig. 2: Block Diagram of Extraction Algorithm

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	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:

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

where

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

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. 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.

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

Types of attacks	PSNR values for watermarked images			
	Image1	Image2	Image3	Image4
No attacks	39.454	38.9748	36.8179	39.6121
Salt and Pepper %1	26.67778	26.4798	26.654	27.1416
JPEG Compression	59.5266	59.009	59.6525	58.6055
Gaussian noise	37.679	37.6641	37.662	37.6465
Winer	36.8391	39.6122	41.2925	34.6133
Specklenoise	33.5843	39.0409	38.564	35.4773

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 and Specklenoise attack.

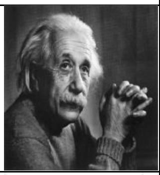
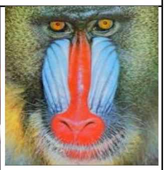
Table 3: The NC Values for Different Attacks Applied to Test Images

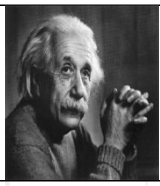
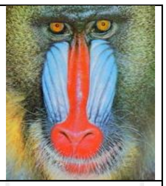
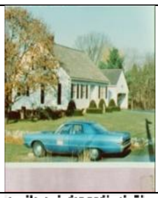
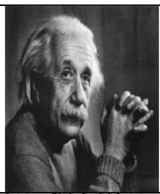
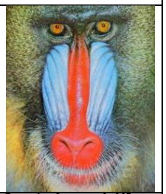
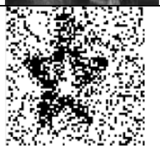
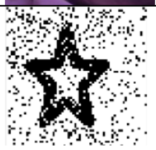
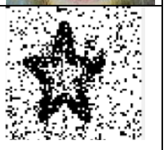
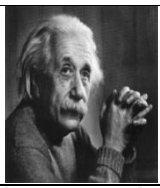
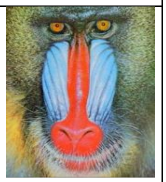
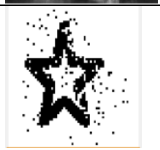
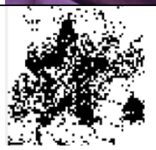
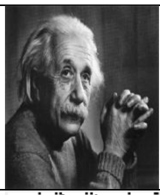
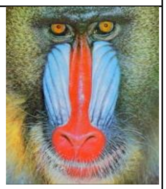
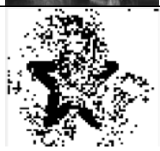
Types of attacks	NC values for watermarked images			
	Image1	Image2	Image3	Image4
No attack	1	1	1	1
Salt and Pepper %1	0.5873	0.9967	0.3701	0.9965
JPEGCompression	1	0.9982	1	1
Gaussian noise	0.8666	0.8363	0.9246	0.9008
Winer	0.8844	0.9780	0.8539	0.7536
Specklenoise	0.7281	0.8855	0.9603	0.8156

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.

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				

V. CONCLUSION

This work focus on the impact of the two-fold FIS using the algebraic method LU matrix decomposition. The aim of the proposed algorithm is to introduce a hybrid between two values obtained from the FIS and linear algebra decomposition method LU matrix decomposition. 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 LU matrix decomposition method.

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