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Image processing By Using Multi Discrete Laguerre Wavelets Transform (MDLWT)

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Abstract

In this work the new operations matrix was derived for Multi Discrete Laguerre Wavelets Transform (MDLWT) with the dimension $2^{k-1}M \times 2^{k-1}M$ and this matrix was derived by the integrals of the functions that obtained from the mother function or the mother wave. This matrix is the coefficients matrix of the developed multi wavelet and this wavelet was applied in image processing using the Matlab program, where a new program was built that applies to many of the images and examples the proposed wave efficiency. In addition, MSE and PSNR were calculated and good results were compared to the previous methods.

Keywords: Multi Discrete Laguerre Wavelet Transform (MDLWT), image processing, Peak Signal to Noise Ratio (PSNR), Mean Squared Error (MSE), Mat lab program.

1. Introduction

The wavelets took their path in many fields, such as mathematics, various sciences, engineering, meteorology and earthquakes, especially image processing. The wavelet took its large share in this field and a lot of research contains wave developments such as Haar and other wavelets.

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In the field of numerical solutions such as integral equations, integro-differential equation, variational problems [1],optimization and optimal control using four types of Chebyshev wavelet [2], a Hermite wavelet,[3-6] a Legendre wavelet [4] to the other where the wavelet functions were constructed by deriving it from the mother wavelet, which depends on the two parameters a and b of the influence of expansion and contraction and by extracting the coefficients of the wavelet by deriving the operational matrices for the integrations[7,8].

As for the field of image processing, such as improving the images, compressing the images, raising the noise from the distorted image using wavelets such as Haar wavelet, db wavelet [9-14]

in [14] used Discrete Laguerre wavelet transform of derived the operational matrix of integration used it in solved variational problems and integral equation moreover used its coefficients in image processing such as compression image by its filers and de noising image with medical applied

in this work used Laguerre polynomials in derivative new wavelet by mother wavelet with constructed multi number of functions of discrete wavelet depended of four parameters u, v, k, t explained in section 3.

2. Wavelets Transformation

The wavelets are created from expansion and contraction through the two parameters and b which are represented by the parent function from the continuous wavelets.

$$\chi_{c,d}(t) = |c|^{-\frac{1}{2}} \chi\left(\frac{x-d}{c}\right) \qquad c, d \in R, \quad c \neq 0 \qquad (1)$$

where $\chi(t) = [\chi_0(t), \chi_1(t), \ldots, \chi_{M-1}]^T$

The basis for the above function consists of the elements $\chi_0(t), \chi_1(t), ..., \chi_{M-1}(t)$ are orthogonal on the [0,1].

3. Multi Discrete Laguerre Wavelets Transform (MDLWT)

By transfer the parameters c, d to specific values, the wavelets will turn into discrete wavelets transform as, Laguerre wavelet $L_{u,v}(t) = L_{t,u,v,k}$ have four arguments; $k = 1,2,...,$ $u = 1,2,...,2^{k-1}$, v is order for Laguerre polynomials and t is normalized time.

The dilation by parameter $c = 2^{-(k+1)}$ and translation by parameter $d = 2^{-(k+1)}(2u-1)$ and use transform x , $x = 2^{-(k+1)}\left(2^k t\right)$, substituted these transfers in (1) with replace $\chi_{c,d}$ by $L_{u,v}$ will be get

$$L_{u,v}(t) = 2^{-(k+1)}\tilde{L}_{u,v}\left(\frac{2^{-(k+1)}\left(2^k t\right) - 2^{-(k+1)}(2u-1)}{2^{-(k+1)}}\right) \qquad (2)$$

$$L_{u,v}(t) = \begin{cases} 2^{k+1/2}\tilde{L}_v\left(2^k t - 2u + 1\right) & \frac{u-1}{2^{k-1}} \le t \le \frac{u}{2^{k-1}} \\ 0 & otherwise \end{cases} \qquad (3)$$

where $\tilde{L}_v = \frac{1}{v!}L_v$ v is the order of Laguerre polynomials

In [14] used k=2 gotten from (3) many functions but if used k=3 will be get multi numbers functions from (3), therefore, the wavelet in this work was called the multi wavelet

$$L_{u,v}(t) = \begin{cases} \frac{4}{v!}L_v(8t - 2u + 1) & \frac{u-1}{2^{k-1}} \le t \le \frac{u}{2^{k-1}} \\ 0 & otherwise \end{cases} \qquad (4)$$

The atoms obtained in equation (4) from Laguerre polynomials with weight function e^{-x^2} on the interval $[0,\infty]$ are as follows Initial values

$$L_0(x) = 1$$
$$L_1(x) = 1 - x$$

$L_{v+1}(x)=(2v+1-x)L_v(x)-v^2L_{v-1}(x)$ (5)

$v=0,1,2,....$

3.1 Function Approximate

The function approximate with dilation and translation the weight function $e^{-(8t-2u+1)^2}$ By expansion of the period $[0,1)$ it is obtained $f(t)$,

$$f(t)=\sum_{u=1}^{\infty}\sum_{v=0}^{\infty}C_{u,v}L_{u,u}(t) \quad (6)$$

where $C_{u,v}=\langle f(t),L_{u,v}(t)\rangle e^{-(8t-2u+1)^2}=\int_0^1 e^{-(8t-2u+1)^2}L_{u,v}(t)\,f(t)dt$ (7)

$\langle .,. \rangle$ denoted the inner product with weight function $w_u(8t-2u-1)$ on the Hilbert Space $[1,0)$, if finite equation(6) obtained

$$f(t)=\sum_{u=1}^{2^k-1}\sum_{v=0}^{M-1}C_{u,v}L_{u,u}(t) \quad (8)$$

From the above equations will be get two vectors $A_{u,v}$, $L_{u,v}$ $k=3$ with dimension $2^{k-1}M\times 1$

$$C=\left[C_{1,0},C_{1,1},...C_{1,M-1},C_{2,0},...,C_{2,(M-1)},C_{3,0},C_{3,1},...,C_{3,M-1},.....C_{2^{k-1},0},...,C_{2^{k-1},M-1}\right]^T$$

$$L=\left[L_{1,0},L_{1,1},...L_{1,M-1},L_{2,0},...,L_{2,(M-1)},L_{3,0},L_{3,1},...,L_{3,M-1},.....L_{2^{k-1},0},...,L_{2^{k-1},M-1}\right]^T \quad (9)$$

3.2 Operation matrix of coefficient for MDLWT

In this section an operational matrix obtained from wavelet coefficients will be built, by use equation (4) which have a major role in this work, where it was taken $M=4$ will be get

$$Z = T_L W \ , \ T_L = \begin{bmatrix} \frac{1}{4} & 0 & 0 & 0 \\ \frac{1}{16} & -\frac{1}{32} & 0 & 0 \\ \frac{5}{256} & -\frac{3}{128} & \frac{1}{128} & 0 \\ \frac{24}{1024} & -\frac{33}{2048} & \frac{12}{1024} & -\frac{3}{1024} \end{bmatrix} , \ t \in [0, 0.25) \ ,$$

$$T_L = \begin{bmatrix} \frac{1}{4} & 0 & 0 & 0 \\ \frac{1}{8} & -\frac{1}{32} & 0 & 0 \\ \frac{17}{256} & -\frac{5}{128} & \frac{1}{128} & 0 \\ \frac{39}{1024} & -\frac{81}{2048} & \frac{18}{1024} & -\frac{3}{1024} \end{bmatrix} , \ t \in [0.25, 0.5)$$

$$T_L = \begin{bmatrix} \frac{1}{4} & 0 & 0 & 0 \\ \frac{6}{32} & -\frac{1}{32} & 0 & 0 \\ \frac{37}{256} & -\frac{7}{128} & \frac{1}{128} & 0 \\ -\frac{118}{1024} & -\frac{153}{2048} & \frac{24}{1024} & -\frac{3}{1024} \end{bmatrix} t \in [0.5, 0.75)$$

$$T_L = \begin{bmatrix} \frac{1}{4} & 0 & 0 & 0 \\ \frac{8}{32} & -\frac{1}{32} & 0 & 0 \\ \frac{65}{256} & -\frac{9}{128} & \frac{1}{128} & 0 \\ \frac{683}{1024} & -\frac{249}{2048} & \frac{30}{1024} & -\frac{3}{1024} \end{bmatrix} t \in [0.75, 1)$$

In general, we can refer to the matrices above

$$\begin{pmatrix} t^0 \\ t^1 \\ t^2 \\ t^3 \end{pmatrix} = C^T \begin{pmatrix} L_{u,0} \\ L_{u,1} \\ L_{u,2} \\ L_{u,3} \end{pmatrix} \qquad (10)$$

the above 16 functions are integrated from 0 to 1 by used equation (7)

$$\int_0^t L_{1,0}(t)dt = \frac{1}{4}L_{1,0}(t) - \frac{1}{8}L_{1,1}(t) + \frac{1}{4}L_{2,0}$$

(11)

$$\int_0^t L_{1.1}(t)dt = -\frac{3}{16}L_{1,0}(t) + \frac{1}{8}L_{1,1}(t) - \frac{1}{8}L_{1,2}(t) + \frac{1}{4}L_{2,0}(t) \quad (12)$$

$$\int_0^t L_{1,2}(t) = \frac{15}{16}L_{1,0}(t) + \frac{1}{8}L_{1,2}(t) + \frac{7}{6}L_{2,0}(t)$$

(13)

$$\int_0^t L_{1,3}(t)dt = \frac{325}{96}L_{1,0}(t) - \frac{98}{96}L_{1,1}(t) + \frac{19}{16}L_{1,2}(t) - \frac{1}{2}L_{1,3}(t) + \frac{11}{6}L_{2,0}(t) \quad (14)$$

$$\int_0^t L_{2,0}(t)dt = \frac{1}{4}L_{2,0}(t) - \frac{1}{8}L_{2,1}(t) + \frac{1}{4}L_{3,0}$$

(15)

$$\int_0^t L_{2.1}(t)dt = -\frac{3}{16}L_{2,0}(t) + \frac{1}{8}L_{2,1}(t) - \frac{1}{8}L_{2,2}(t) + \frac{1}{4}L_{3,0}(t)$$

(16)

$$\int_0^t L_{2,2}(t) = \frac{15}{16}L_{2,0}(t) + \frac{1}{8}L_{2,2}(t) + \frac{7}{6}L_{3,0}(t)$$

(17)

$$\int_0^t L_{2,3}(t)dt = \frac{325}{96}L_{2,0}(t) - \frac{98}{96}L_{2,1}(t) + \frac{19}{16}L_{2,2}(t) - \frac{1}{2}L_{2,3}(t) + \frac{11}{6}L_{3,0}(t) \quad (18)$$

$$\int_0^t L_{3,0}(t)dt = \frac{1}{4}L_{3,0}(t) - \frac{1}{8}L_{3,1}(t) + \frac{1}{4}L_{4,0}$$

(19)

$$\int_0^t L_{3.1}(t)dt = -\frac{3}{16}L_{3,0}(t) + \frac{1}{8}L_{3,1}(t) - \frac{1}{8}L_{3,2}(t) + \frac{1}{4}L_{40}(t) \quad (20)$$

$$\int_0^t L_{3,2}(t) = \frac{15}{16} L_{3,0}(t) + \frac{1}{8} L_{3,2}(t) + \frac{7}{6} L_{4,0}(t)$$

(21)

$$\int_0^t L_{3,3}(t)dt = \frac{325}{96} L_{3,0}(t) - \frac{98}{96} L_{3,1}(t) + \frac{19}{16} L_{3,2}(t) - \frac{1}{2} L_{3,3}(t) + \frac{11}{6} L_{4,0}(t) \quad (22)$$

$$\int_0^t L_{4,0}(t)dt = \frac{1}{4} L_{4,0}(t) - \frac{1}{8} L_{4,1}(t)$$

(23)

$$\int_0^t L_{4.1}(t)dt = -\frac{3}{16} L_{4,0}(t) + \frac{1}{8} L_{4,1}(t) - \frac{1}{8} L_{4,2}(t)$$

(24)

$$\int_0^t L_{4,2}(t) = \frac{15}{16} L_{4,0}(t) + \frac{1}{8} L_{4,2}(t)$$

(25)

$$\int_0^t L_{4,3}(t)dt = \frac{325}{96} L_{4,0}(t) - \frac{98}{96} L_{4,1}(t) + \frac{19}{16} L_{4,2}(t) - \frac{1}{2} L_{1,3}(t)$$

(26)

Then $$\int_0^t L_{16}(t)dt = Q_{16\times16} L(t)$$

(27)

Where

$$\int_0^t L_{16}(t)dt = [L_{1,0}(t), L_{1,1}(t), L_{1,2}(t), L_{1,3}(t), L_{2,0}(t), L_{2,1}(t), L_{2,2}(t), L_{2,3}(t), L_{3,0}(t), L_{3,1}(t), L_{3,2}(t), L_{3,3}(t), L_{4,0}(t), L_{4,1}(t), L_{4,2}(t), L_{4,3}(t)]^T$$

the operation matrix of integration by using equations (11)-(26) L is

$$Q_{16\times16}=\begin{bmatrix}
\frac{1}{4} & -\frac{1}{8} & 0 & 0 & \frac{1}{4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
-\frac{3}{16} & \frac{1}{8} & -\frac{1}{8} & 0 & \frac{1}{4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
\frac{15}{16} & 0 & \frac{1}{8} & 0 & \frac{7}{6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
\frac{325}{96} & -\frac{98}{96} & \frac{19}{16} & -\frac{1}{2} & \frac{11}{6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & \frac{1}{4} & -\frac{1}{8} & 0 & 0 & \frac{1}{4} & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & -\frac{3}{16} & \frac{1}{8} & -\frac{1}{8} & 0 & \frac{1}{4} & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & \frac{15}{16} & 0 & \frac{1}{8} & 0 & \frac{7}{6} & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & \frac{325}{96} & -\frac{98}{96} & \frac{19}{16} & -\frac{1}{2} & \frac{11}{6} & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{4} & -\frac{1}{8} & 0 & 0 & \frac{1}{4} & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\frac{3}{16} & \frac{1}{8} & -\frac{1}{8} & 0 & \frac{1}{4} & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{15}{16} & 0 & \frac{1}{8} & 0 & \frac{7}{6} & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{325}{96} & -\frac{98}{96} & \frac{19}{16} & -\frac{1}{2} & \frac{11}{6} & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{4} & -\frac{1}{8} & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\frac{3}{16} & \frac{1}{8} & -\frac{1}{8} & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{15}{16} & 0 & \frac{1}{8} & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{325}{96} & -\frac{98}{96} & \frac{19}{16} & -\frac{1}{2}
\end{bmatrix}$$

Fig.1 shows the surf of $Q_{16\times16}$

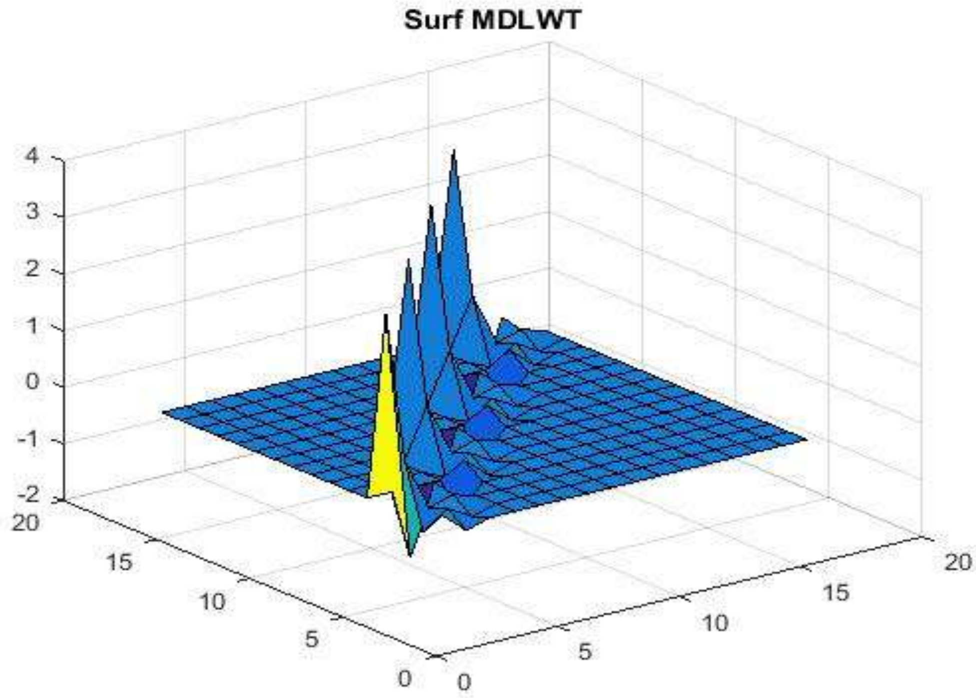


Fig.1 shows the surf of $Q_{16\times16}$

In general the matrix $Q_{16\times16}$ will be written

$$Q_{16\times16}=\begin{bmatrix} C_{4\times4} & F_{4\times4} & O_{4\times4} & O_{4\times4} \\ O_{4\times4} & C_{4\times4} & F_{4\times4} & O_{4\times4} \\ O_{4\times4} & O_{4\times4} & C_{4\times4} & F_{4\times4} \\ O_{4\times4} & O_{4\times4} & O_{4\times4} & C_{4\times4} \end{bmatrix}$$ then $\int_0^t L(t)dt \cong QL(t)$, Q is $2^{k-1}M\times 2^{k-1}M$ matrix

, C,F are $M\times M$ matrices

4. Image processing by using Operation matrix of coefficient for MDLWT

In this section the images will be processed by using $Q\ 16\times16$, the four parameters u,v,k,t are called the scaling and shifting parameters, represents the intermittent wavelets filter.

Where the wavelet DMLWT used is two-dimensional the first is called standard decomposition, the role of which is the passage of the wave on the rows and then on the columns.

The second is called reconstructed, which alternates between rows and columns. The wave is decomposed into four parts of the original size. This process, using the suggested wave, is fast and effective. The process is performed on the matrix that is formulated as follows.

$$P=I\times Q$$
$$P=\left((IQ)^T Q\right)^T$$

(27)

$$P=\left(Q^{-1}\right)^T PQ^{-1}$$

(28)

I is 16×16 input matrix Q is the coefficients of MDLWT P is the output matrix, equations (27), (28) show the decomposition and reconstructed matrices respectively .

Fig.2 shows the above processed

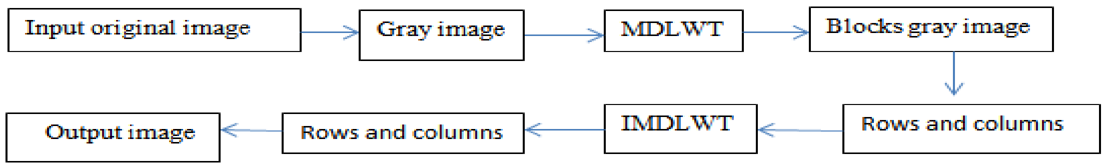


Fig.2 shows the stages of the wavelet form using image processing

4.1 Algorithm

The stages of image processing by using MDLWT

Input color image

1- Download the image using the Matlab program
2- Convert color image to gray image
3- Decomposition step by dividing the gray image into blocks, each block 16×16 same size of $Q_{16\times 16}$ matrix to processed each block to facilitate processing using two equations (27) and (28).
4- Processed all blocks in level1 and level2 without normalized
5- Processed all blocks in level1 and level2 with normalized $\frac{1}{4}$
6- Reconstructed step by using invers multi Discrete Laguerre wavelet Transform (IMDLWT)
7- Calculated Peak Signal to Noise Ratio (PSNR) and Mean Squared Error (MSE)

$$mse = \frac{1}{M * N} \sum_{M=0}^{M-1} \sum_{N=0}^{N-1} \left(I_{N,M} - O_{N,M} \right)^2 \tag{29}$$

$$psnr = \frac{10 \log 10(255)^2}{mse} \tag{30}$$

Output processed gray image in level1 and level2

4.2 Examples

In this section the algorithm will be applied to some color images and clarify the effect of the proposed wavelet these images after converted to gray images and divided into blocks. Each block has a dimension equal to the matrix dimension of coefficients for MDLWT, with calculated PSNR and MSE Fig.3 will be illustrated algorithm steps in section 4.1

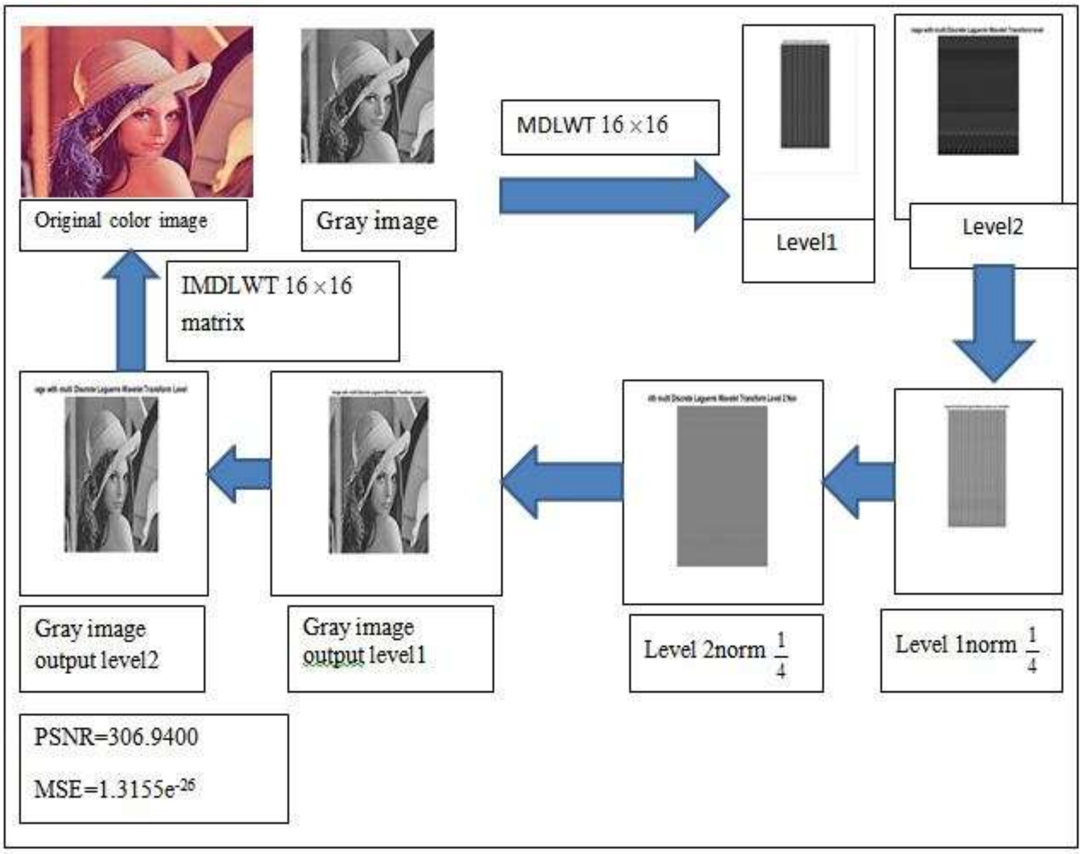
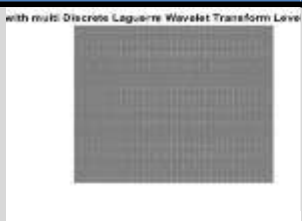
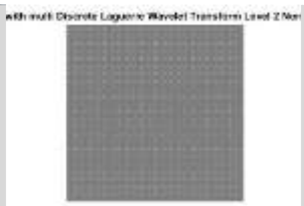


Fig.3. Shows algorithm steps

Same processed for another examples calculated PSNR and MSE the table1 shows these results

Table.1: Shows the results of three samples using MDHWT in level 2

image	Original image	In Process image	Process image	PSNR	MSE
Image 1				306.8805	1.3336 e^{-26}
Image 2				306.8557	1.3412 e^{-26}
Image 3				312.4146	3.7293 e^{-27}

4.3 Discussed Results

In this section we will discuss the results obtained from using the coefficient matrix for MDLWT 16×16, the method used to process images using the Matlab program after building a program with arranged steps starting with the matrix $Q_{16\times16}$ and invoking an image of size 256×256 and dividing it into blocks. Each block is treated in an isolated way.

Upon reverting the inverse of the used matrix, the image is processed and a gray image is obtained without losses. This is indicated by the examples used and excellent results were obtained, where the error was calculated and was equal to zero.

The table.2 shows compare results in section 4.2 with results by using another methods for example Haar wavelet and DLWT

Table.2: Shows Comparison of results for Haar wavelet & MDLWT in level 2

NO	PSNR (Haar)	PSNR(DLWT)	PSNR(MDLWT)	MSE(Haar)	MSE(DLWT)	MSE(MDLWT)
Image 1	326.1410	271.7864	306.9400	$9.9766e^{-29}$	$4.3096e^{-23}$	$1.3155e^{-26}$
Image 2	326.4202	188.7577	306.8805	$1.4827e^{-28}$	$8.6559e^{-15}$	$1.3336e^{-26}$
Image 3	327.8732	188.4143	306.8557	$1.0611e^{-28}$	$9.3680e^{-15}$	$1.3412e^{-23}$
Image 4	333.0736	193.8867	312.4146	$3.0747e^{-29}$	$2.6571e^{-15}$	$3.7293e^{-27}$

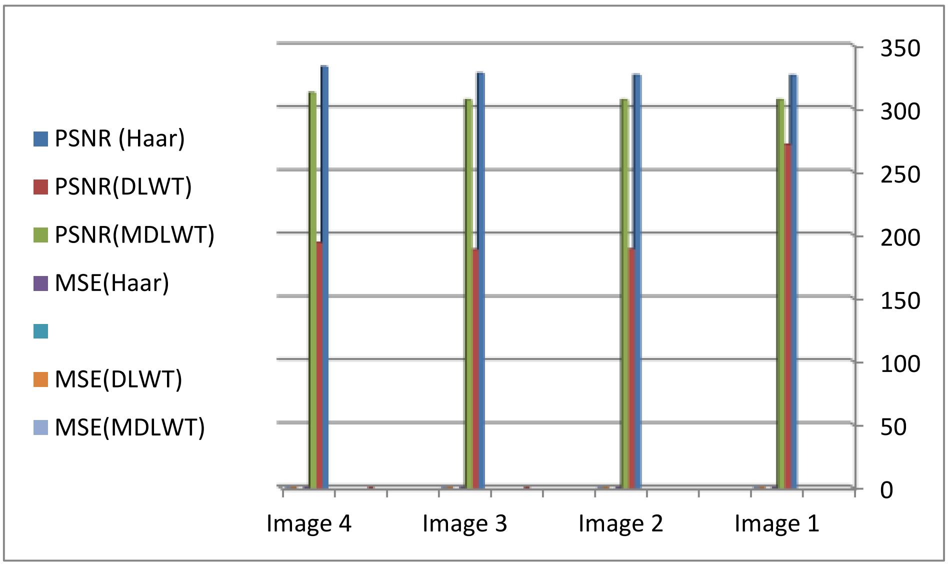


Chart.1 shows comparing between results

Through the table.2 and the chart.1 it turns out that the Haar wavelet is equipped in the Matlab program it is standard wavelet, the proposed method reached the mean square error near the mean square error with Haar wavelet

5. Conclusion

In this work, a new and developed wavelet was constructed by using the mother wavelet and relying on the two effects c and d those responsible for expansion and contraction. When using Laguerre polynomials, obtained MDLWT by integration it derivative the coefficients $2^{k-1}M \times 2^{k-1}M$ matrix
And it is used to process images using the Matlab program and to create a program for image analysis and calculation PSNR and MSE, and good results were obtained, as the method used proved its efficiency in this field.
Moreover , the proposed method can be used to solve many mathematical problems numerically, for example, Variational problems, Optimal Control problems, differential and integral equations of all kinds, etc.
Finally, can say that the method used has proven to be effective.

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معالجة الصور باستخدام تحويل موجة لاكير المضاعفة منفصلة

علي مالك هادي

اسماء عبدالاله عبدالرحمن

المستخلص:

في هذا العمل، تم اشتقاق مصفوفة العمليات الجديدة للتحويل متعدد الموجات للاكير المتقطعة والمضاعفة والتي كان بعدها $2^{k-1}M \times 2^{k-1}M$ وقد استمدت هذه المصفوفة من خلال تكامل الوظائف التي تم الحصول عليها من الوظيفة الأم أو الموجة الأم. هذه المصفوفة هي مصفوفة معاملات المويجات المتعددة المطورة، وقد طبقت هذه المويجة في معالجة الصور باستخدام برنامج ماتلاب ، حيث تم بناء برنامج جديد ينطبق على العديد من الصور والأمثلة على كفاءة الموجة المقترحة. بالإضافة إلى ذلك ، تم حساب MSE و PSNR وتمت مقارنة النتائج الجيدة بالطرق السابقة.