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ENHANCING AN IMAGE'S COMPRESSION WHILE KEEPING QUALITY STANDARDS UTILIZING NEW MATHEMATICAL TECHNOLOGY

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Abstract

The rapid development of technology led to the need to keep pace with it, especially in the field of image processing, because of its importance in the need to get better results. In this paper, new discrete Chebyshev wavelet transforms (DChWT) derived from Chebyshev polynomials (ChP) were proposed and characterized. In terms of orthogonality and approximation (convergence) in the field of mathematics, (ChP) were qualified to transform into discrete wavelets called (DChWT), depending on the mother function with operators (*s*, *r*), and were used in image processing to analyze them in the low filter and the high filter so that the image is analyzed into coefficients. Proximity and detail coefficients, which lead to dividing the image into four parts, low left (LL), in which the proximity coefficients are concentrated while the rest of the parts are centered on the detail coefficients, which are high left (HL), low right (LR), and high right (HR), and image compression through the new filter, which has proven its efficiency at level (8) in our results. The results of the proposed wavelets in this work were reached in calculating quality standards in the image obtained after the compression process after comparing them with the results obtained using the standard wavelet used in HaarSymlet 2, Conflict 2, and Daubecheis 2. The most important of these standards is a mean square error (MSE), peak signal-to-noise ratio (PSNR), bit per pixel (BPP), compression ratio (CR), and table one. In this paper, the efficiency of the proposed new wavelets is explained after adding it to MATLAB and according to a specific program to drop in with the basic wavelets to take on their role in important tasks in the image processing area, like artificial intelligence.

Keywords: image processing, new transform, proximity coefficients, Discrete, Chebyshev Wavelet Transform (DChWT).

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1. Introduction

Mechanical analysis and the engineering field cause many problems called diversification problems. These problems are avoided by using the wavelet technique, which is derived from polynomials that are orthogonal and approximate, for example, Chebyshev, Laguerre, Legendre, etc [1, 2], which have been used in solving numerical problems and differential equations [3]. In order to reach the exact solution, the error rate must be very close to zero. In addition, the wavelets made their way into the field of signal approximation [4]. In addition, it made its way into the field of image processing after adding wavelets to the MATLAB program after following a certain algorithm [5, 6]. Image processing has found its way into many fields of engineering, science, and medicine, and discrete wavelets have been used in many works [7]. Discrete wavelets are constrained depending on the parent wavelets to be the (*s*, *r*) effectors affecting expansion and contraction, [8], where the resulting separate wavelets are to be used in digital image processing [9, 10]. Because the image has two dimensions, which are called pixels. In this paper, new transforms derived from Chebyshev polynomials [11], depending on the mother wave, with operators (*s*, *r*), are proposed and used in image processing to analyze the low filter and high filter so that the image is analyzed into proximity coefficients [12], and detail coefficients [13], After dividing the coefficients, the image is divided into four parts: LL, HL, LH, and HH [14]. After the image analysis process, the inverse of the separated wavelets is projected to reconstruct the decomposed image [13, 15]. With the new DWT [16], the color image will be compressed, and the efficiency has been proven through the results reached in this work in calculating the image quality standards obtained after the compression [17]. One of the most important criteria for image quality that has been calculated is the mean square error (MSE), peak signal-to-noise ratio (PSNR), bit per pixel (BPP), and compression ratio (CR) [18], In this work, the discrete Chebyshev wavelet transform (DChWT) will be suggested to be used in color image analysis and image compression to achieve the best results compared to other basic wavelets found within the MATLAB program such as Symlet 2, Conflict 2, and Daubeche 2 in **Table 1**. The most important results that show the efficiency of the new filter compared to other filters are the MSE, PSNR, and BPP. The proposed algorithm in this work uses the new wavelets derived from Chebyshev polynomials in dealing with images. The filter derived from the Discrete Chebyshev Wavelet Transform (DChWT) was used in MATLAB, and then the new inverse transformation was used to return to the original image after compressing it without losing the image's original properties.

2. Material and Methods

The discrete wavelet transformation (DWT) coefficients, the based wavelet:

$$W_{s,r}(t)=|s|^{\frac{-1}{2}}W\left(\frac{t-r}{s}\right)s,\ r\in R,\ s\neq 0. \tag{1}$$

The vector $W(t)=\left[W_0(t),W_1(t),\ldots,W_{M-1}(t)\right]^T$.

Then $W_0(t),W_1(t),\ldots,W_{M-1}(t)$ orthogonal and basic on the [0,1].

$W_{n,m}(t)=W_{t,n,m,k}(t)$ they are $k=1,2,\ldots,n=1,2,\ldots,2^{k-1}$ where $r=2^{-(k+1)}(2n-1)$ and $x=2^{-(k+1)}(2^k t)$ then equation (2):

$$W_{n,m}(t)=\begin{cases}\dfrac{c_m 2^{\frac{k}{2}}}{\sqrt{\pi}}\widetilde{Ch}_m\left(2^{k+1}t-2n+1\right), & \dfrac{n-1}{2^{k-1}}\leq t<\dfrac{n}{2^{k-1}};\\ 0, & o.w,\end{cases} \tag{2}$$

$$c_m=\begin{cases}\sqrt{2}, & m=0;\\ 2, & m=1,2,\ldots.\end{cases}$$

2. 1. New wavelet gatherings

The proposed wavelets are orthogonal to help smooth analysis. The set of functions $W_{j,n}=(W_m)_{j,n}(t)$; *m* in *Z* includes (*j*, *n*) new wavelet gatherings.

The resulting new wavelets will be the output of the decision tree from 0 to 2^{j-1}, $W_{j,n}$ Which refers to the nucleus of the composition of the tree.

$W_{j,n}$ as $\bar{W}_{j,n}$ space is generated $\forall j$ $\bar{W}_{j,0}=V$ and $\bar{W}_{j,1}=W$, DChWT be their gatherings with $V_0=W_{0,0}$. $\omega_{r,1}$; $r\geq 1$ orthogonal in $V_0\left(W_{N,0},\left(W_{j,1};j\in[1,N)\right)\right)$ is an orthogonal base of the tree of DChWT in **Fig. 1**.

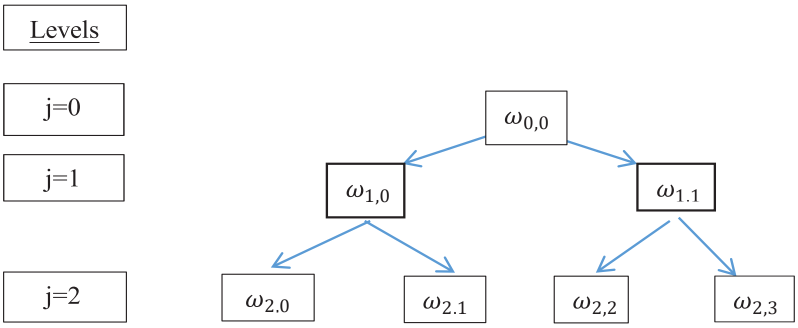

Fig. 1. The tree of DChWT

Place the tree of the generic model in **Fig. 2**.

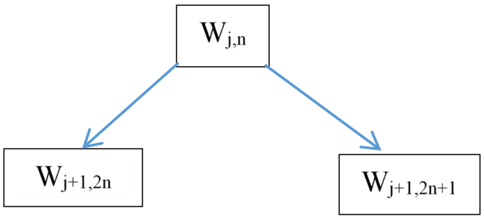

Fig. 2. The tree of the generic model

If take $j=0$, 1, 2 in equation (2):

$$\boldsymbol{j}=0, \vartheta_{0,0}(\boldsymbol{t})=\omega_0(\boldsymbol{t})=1 \text{ in } \boldsymbol{V}_0,\ \boldsymbol{j}=1,\ \boldsymbol{W}_{1,0}(\boldsymbol{t})=\frac{1}{\sqrt{2}}\boldsymbol{W}_0(2\boldsymbol{t})=\frac{1}{\sqrt{2}},$$

$$\boldsymbol{W}_{1,1}(\boldsymbol{t})=\frac{1}{\sqrt{2}}\boldsymbol{Ch}_1(2\boldsymbol{t}-1)=\frac{1}{\sqrt{2}}\left[1-(2\boldsymbol{t}-1)\right],$$

$$\boldsymbol{j}=2,\ \boldsymbol{W}_{2,0}(\boldsymbol{t})=\frac{1}{2}\boldsymbol{W}_0(4\boldsymbol{t})=\frac{1}{2},\ \boldsymbol{W}_{2,1}(\boldsymbol{t})=\frac{1}{2}\boldsymbol{W}_1(4\boldsymbol{t}-1)=\frac{1}{2}\left[1-(4\boldsymbol{t}-1)\right],$$

$$\boldsymbol{W}_{2,2}(\boldsymbol{t})=\frac{1}{2}\boldsymbol{W}_2(4\boldsymbol{t}-2)=\frac{1}{2}\left[(4\boldsymbol{t}-2)^2-(4\boldsymbol{t}-2)+2\right],$$

$$\boldsymbol{W}_{2,3}(\boldsymbol{t})=\frac{1}{2}\boldsymbol{W}_3(4\boldsymbol{t}-3)=\frac{1}{2}\left[6-18(4\boldsymbol{t}-3)+9(4\boldsymbol{t}-3)^2-(4\boldsymbol{t}-3)^3\right],$$

$$\boldsymbol{n}=0,1,2,\ldots,2^j-1 \text{ and } \boldsymbol{j}=0,1,2,$$

scale function of DChWT in equation (3):

$$\vartheta_{j,n}(t)=\begin{cases}1, & t\in[0,1);\\ 0, & o.w,\end{cases} \quad (3)$$

$$f(t)=C_0+\sum_{j=0}^{\infty}\sum_{n=0}^{2^j-1}C_{j,n}\omega_{j,n}(t). \quad (4)$$

3. The results and their discussion

In this work, by relying on wavelets for image processing based on Laguerre polynomials and through the new filter, which proved the efficiency of the results that were reached after analyzing the color image and compressing it after adding the new wavelets to the MATLAB program with an appropriate algorithm, wavelet analysis of the image into four parts: LL, LH, HL, HH, proximity coefficients and AC detail coefficients centered in the LL quadrant in which the compression and noise lifting process takes place , Wavelet analysis of the image DChWT divided to Low pass filter and high pass filter after take inverse Discrete Chebyshev Wavelet Transform (IDChWT) to re constructed image one sample was taken from the color image, so that the processing process was carried out using the new technique in **Fig. 3, 4**, the difference between this work and the previous work is explained by the results that were presented in **Table 1**.

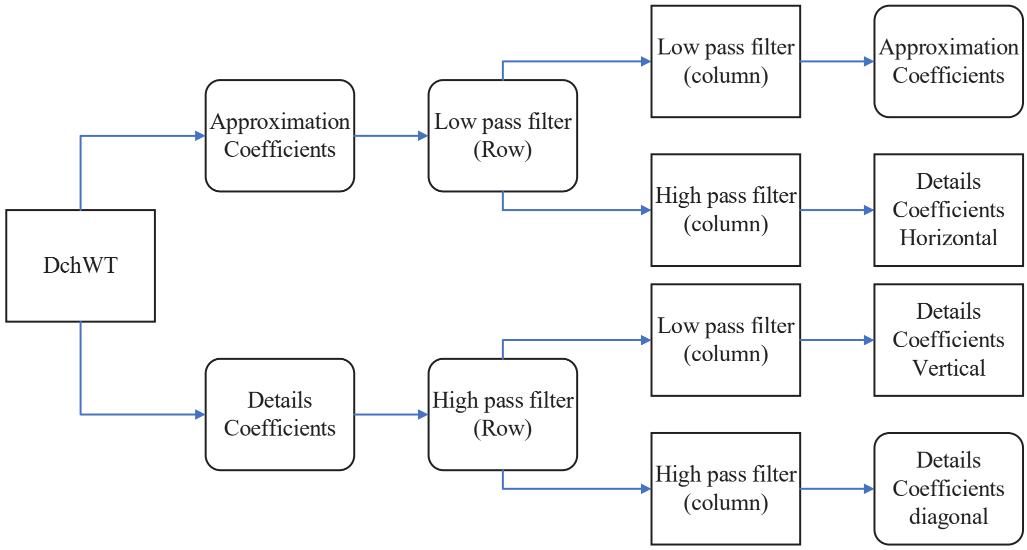

Fig. 3. Wavelet analysis of the image

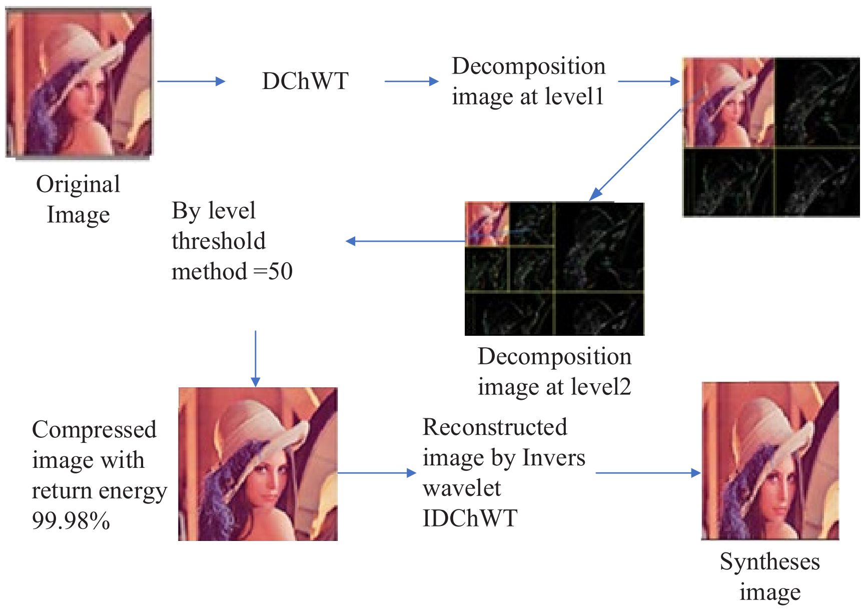

Fig. 4. Wavelet analysis of the image DChWT and Inverse Discrete Chebyshev Wavelet Transform (IDChWT) to reconstructed image

Table 1 at level 8 The proposed wavelets were compared with the basic wavelets that were used in the MATLAB program, including Symlet 2, Coiflet 2, and standard Daubechies 2. Calculation of quality standards for color images.

Table 1
Comparison results between DChWT and Smelt 2, Coiflet 2 and Daubecheis 2

Level	MSE	PSNR	BPP	CR
DChWT				
1	10.0	38.1	22.5	93.8 %
2	9.5	38.3	8.1	34.0 %
3	8.3	38.9	11.2	46.8 %
4	4.5	41.5	7.1	29.7 %
5	4.5	41.5	7.1	30.6 %
6	4.8	41.2	7.3	30.6 %
7	2.2	44.5	13.2	55.0 %
8	2.2	44.5	13.2	55.0 %
SYM 2				
1	8.8	38.66	24.1	100 %
2	6.4	40.02	13.6	56.7 %
3	4.9	41.2	10.7	44.6 %
4	4.2	41.83	6.9	28.8 %
5	4.3	41.79	6.7	27.9 %
6	4.3	41.79	6.6	27.7 %
7	4.3	41.8	6.6	27.2 %
8	2.6	42.89	12.9	53.8 %
COIF 2				
1	9.8	38.1	24.0	100 %
2	7.7	39.2	13.3	55.5 %
3	8.5	38.8	7.5	31.44 %
4	3.9	42.1	6.7	28.1 %
5	4.0	42.1	6.5	27.1 %
6	4.0	42.1	6.4	26.9 %
7	4.0	42.1	6.4	26.8 %
8	2.4	40.51	12.5	52.4 %
db2				
1	10.0	38.1	22.5	93.8 %
2	8.3	33.9	11.2	46.8 %
3	9.5	38.3	8.1	34.0 %
4	4.5	41.5	7.3	30.6 %
5	4.5	41.5	7.1	29.7 %
6	4.8	41.2	7.0	29.4 %
7	4.8	41.2	7.0	29.4 %
8	2.7	43.7	9.9	41.4 %

In **Table 1** The image quality parameters MSE, PSNR, BPP, CR with DChWT were recorded in level 8 and compared with the most basic discrete wavelets, for example Symlet2 (SYM2), coiflet2 (COIF2) and daubecheis2 (db2) with good results were obtained better than those achieved with fundamental wavelets **Fig. 5–7** the charts the qualities standards with DChWT. MSE = 2.2, PSNR = 44.5, BPP = 13.2, CR = 55.0 %.

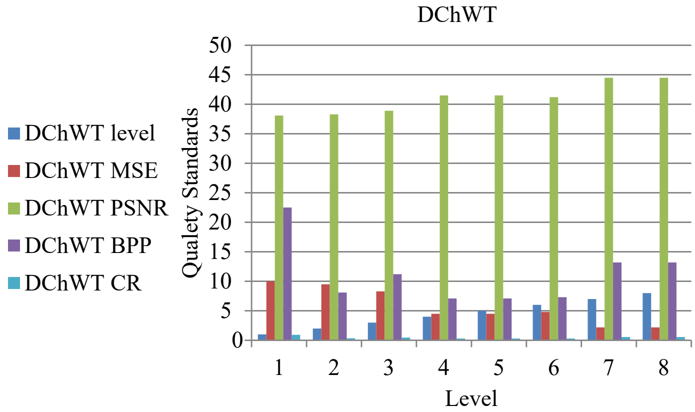

Fig. 5. The quality standards image with DChWT

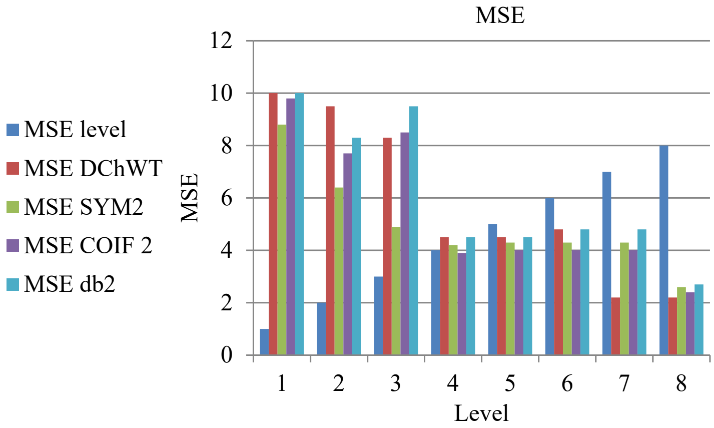

Fig. 6. Compare results of MSE

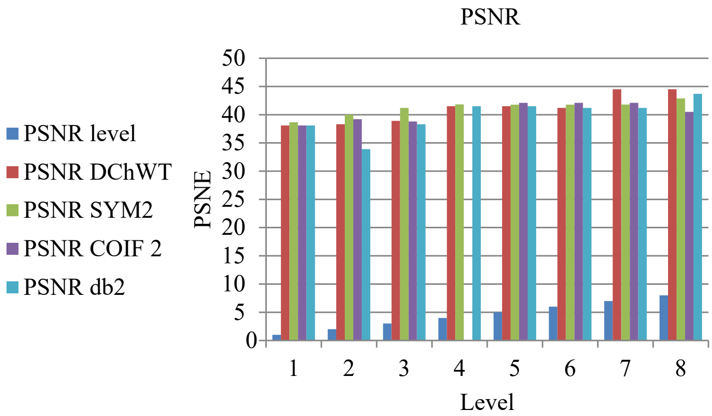

Fig. 7. Compare results of PSNR

4. Conclusions

In this work, new wavelets based on polynomials are discovered, depending on the parent function and through many calculations, and show many theories and important features that this wave possesses, such as the orthogonal property and the approach that qualifies these new waves in image processing, for instance, compression noise and image analysis, by searching for a filter. For the results of the scaling function and the wavelet function, it is appropriate and novel to implement analysis and reconstruction using high-pass and low-pass filters.

Four samples were subjected to colour images, and the compression process was performed with use of MATLAB. The use of new waves is the Discrete Chebyshev Wavelet Transform (DChWT), where the standards resulting from the compression process were calculated, and the most efficient results were obtained without losing the image of the original information compared to the standard wavelets.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship, or otherwise, that could affect the research and its results presented in this paper.

Data availability

Data will be made available on reasonable request.

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