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Multi Object Detection Based on Deep Learning and Discrete Wavelet Transform

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Abstract

Object detection is one of the most important applications in the field of artificial intelligence, as is the case in identifying faces and license plates. As for the developed technology, work is applied with the help of wavelets to improve the results. In this work, new Discrete Hermite wavelets Transform (DHWT) were derived from Hermite polynomials (HP) so that their special role in this work is to process the input image in order to analyze the image, remove noise and compress the image in order to reach reading the most important image quality criteria, peak signal-to-noise ratio (PSNR) and average error square ratio (MSE), compression ratio (CR) and bits per pixel (BPP) to be pre-processed stage. After that, the deep learning phase begins with the creation of the convolutional neural network with the help of the new wavelets, Discrete Wavelet Convolutional Neural Network (DWCNN) in order to set the most important points of the object to be detected in order to reach the most important results.

Key words and phrases: Discrete Hermite wavelets Transform (DHWT), Discrete Wavelet Convolutional Neural Network (DWCNN), Object detection, artificial intelligence, Hermite polynomials (HP).
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1 Introduction

Artificial intelligence took a very wide role in the fields of life with the help of deep learning after the establishment of the convolutional neural network (CNN) in the fields of science and technology [1]-[5]. Applications include identifying faces, identifying parts of faces, monitoring car panels, identifying people, recognizing feelings of faces, and identifying objects [6]-[9].
Face recognition was applied with the help of deep learning by applying the use of the classification process with training the convolutional neural network with multiple layers to distinguish the face of the person, which is an important application in the security fields, state departments and airports. Basic filters are used in the convolution process, and among the most famous networks that have been trained or called is Google Net Alex Net [10]-[17].
The role of the wavelets was the auxiliary application of the face recognition task. These waves were newly derived from the polynomials and by purely mathematical laws based on the parent wavelets [18]-[20]. First and Second Discrete Chebyshev Wavelet Transforms took their role in the field of artificial intelligence to improve the results, where the latter was used in the development of the process of identifying faces, where the input image or to be identified was improved, for example, by removing noise and compressing the image, and the image resulting from the process is entered into the convolutional neural network and the use of new wavelets is a contributor Essential in the convolution process to create layers [21]. The new wavelets were also used to detect the emotions of faces [22].
Discrete Laguerre wavelet Transforms were relied upon to identify or detect vehicle number plates of violating vehicles on roads based on deep learning with a convolutional neural network with Discrete Laguerre wavelet Transform, and the results were improved to reach an accuracy of 95% [23].
The problem raised in this work is finding or detecting objects with deep learning without the use of new wavelets. In this work, the time has been clearly reduced and new DHWT wavelets were derived to be added to the MATLAB program to process the input image in order to calculate the most important quality criteria PSNR, MSE, BPP and CR. This is considered the pre-process stage, as for the stage of building the convolutional neural network with the new DWCNN filter to start the stage of deep learning, the efficiency of the proposed theory through the application of the example application to detect the object that shows the quality of the results reached with respect to the points of the detected object with accuracy 99% in 1 min and 23 seconds with MATLAB program.

2 Methodology

2.1 Wavelet Transform

Wavelet transform analysis can be defined simply as time frequency analysis suitable for many applications such as science, engineering, earthquake studies and prediction, radar, and the field of artificial intelligence. The latter is one of the most important applications in the field of image analysis with the help of wavelets, which is the use of the basis function and the generation of small wavelets, as shown in the Equation (2.1). With the help of the operators (r, s), the low frequency and the high frequency are produced through the process of increasing the value of (r). The expansion process takes place in order to take information representing the low frequency, while coefficient (s) represents the contraction in order to take the information for the high frequency.

$$\delta_{r,s}(x) = |r|^{\frac{1}{2}} \delta \left[\frac{x-s}{r} \right] \qquad r, s \in R \ , \qquad r \neq 0 \qquad (2.1)$$

Wavelet transforms are divided into two types: the continuous type (CWT) and the discrete type (DWT). The latter is used for analysis so that the filter is formed to analyze the image and signal to extract the high and low frequency such as Haar, Daube chies, Coiflet, Symlet, and Biorthogonaletc. Through the high and low frequency, two types of coefficients are obtained: the approximate coefficients and details coefficients, As a result, four bands are produced: zoom range (LL), which contains the features of the basic image (LH), vertical (HL) and diagonal (HH), as in Figure 1.

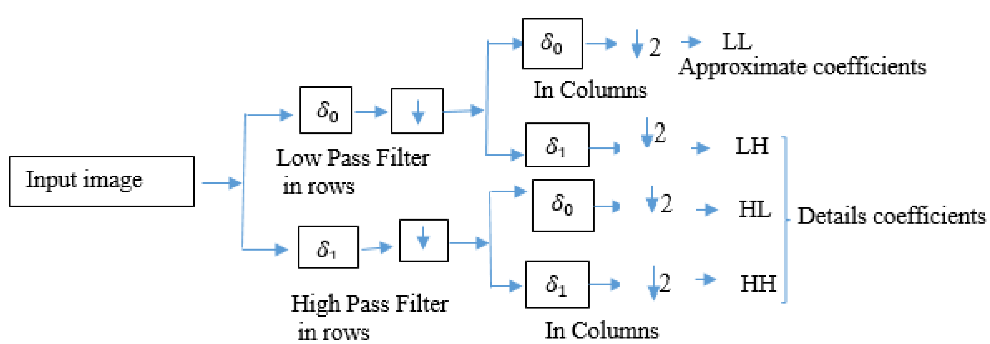

Figure 1: Image analysis using the new filter DHWT with MATLAB program.

2.2 Discrete Hermite Wavelet Transform (DHWT)

New wavelets are formed in the Hilbert Space field depending on the mother wavelets in which the process of contraction and expansion takes place, which is responsible for the operators r, s. The orthogonal vector obtained belongs to the Hilbert space containing the function wavelets in $[0,1]$

$$\delta\left(x\right)=\left[\delta_{0}\left(x\right),\delta_{1}\left(x\right),\ldots,\delta_{M-1}(x)\right]^{T}$$

Efficient algorithms exist for constructing new Hermite wavelets. The property of expansion and contraction in the construction of new Hermite wavelets are the two factors (l,m), and, $l=1,2,\ldots,2^{n}$, n is the positive number, the degree of Hermite polynomials represented of m and the normalized time will be t. the new Hermite wavelets depend on four parameters: l,m,n,k and $t\in[0,1]$. Consider $r=2^{-(n+1)}$ in dilation wave and $s=2^{-(n+1)}(2l-1)$ with translate$x$ in Equation (2.1) being $x=2^{-(n+1)}\left(2^{n}t\right)$. Then Equation (2.2) represent the new Hermite wavelets,

$$\gamma_{l,m}\left(t\right)=\begin{cases}2^{\frac{n}{2}}H_{m}^{*}\left(2^{n+1}t-2l+1\right) & t\in\left[\frac{l-1}{2^{n}},\frac{l}{2^{n}}\right]\\ 0 & o.w\end{cases}\tag{2.2}$$

where

$$H_{m}^{*}=\frac{1}{2^{m}m!\sqrt{\pi}}H_{m}\tag{2.3}$$

$m=0,1,2,...,m-1$ $\qquad$ $l=0,1,2,\ldots,2^{n}$ the approximate function of defined by Equation (2.4)

$$f\left(t\right)=\sum_{l=1}^{\infty}\sum_{m=0}^{\infty}\partial_{l,m}\gamma_{l,m}(t)\tag{2.4}$$

$\langle f\left(t\right),\gamma_{l,m}(t)\rangle$ is the inner product in Hilbert space and $\partial_{l,m}$ is the vector of Discrete Hermite Wavelet Transform in $L_{w_{l}}^{2}$ belong to $[0,1]$ $\partial_{l,m}=\langle f\left(t\right),\gamma_{l,m}(t)\rangle=\int_{0}^{1}w_{l}\left(t\right)\gamma_{l,m}\left(t\right)f\left(t\right)dt$. The finite function:

$$f\left(t\right)\cong f_{2^{n},M-1}=\sum_{l=1}^{2^{n}}\sum_{m=0}^{M-1}\partial_{l,m}\gamma_{l,m}(t)=\partial^{T}\gamma(t)\tag{2.5}$$

Obtained the two vectors of Hermite wavelets functions and confections respectively $2^n M \times 1$ matrices given by:

$$\gamma = [\gamma_{1,0}, \gamma_{1,1}, \ldots, \gamma_{1,M-1}, \gamma_{2,0}, \ldots, \gamma_{2,M-1}, \ldots, \gamma_{2^n,0}, \ldots, \gamma_{2^n,M-1}]$$

$$\partial = \left[\partial_{10}, \partial_{11}, \ldots, \partial_{1(M-1)}, \partial_{20}, \ldots, \partial_{2(M-1)}, \ldots, \partial_{2^{n-1}}, \ldots, \partial_{2^{n-1}M-1}\right]^T$$

If we take $n = 1$ and $l = 1, 2$, the we obtain the basis functions up tol $M = 3$:

$$\left.\begin{array}{l} \gamma_{1,0}(t) = \frac{\sqrt{2}}{\sqrt{\pi}} \\ \gamma_{1,1}(t) = \frac{\sqrt{2}}{2\sqrt{\pi}}(8t-2) \\ \gamma_{1,2}(t) = \frac{\sqrt{2}}{8\sqrt{\pi}}\ (64t^2-32\text{t}+2) \end{array}\right\} \quad 0 \le t < \frac{1}{2} \tag{2.6}$$

$$\left.\begin{array}{l} \gamma_{2,0}(t) = \frac{\sqrt{2}}{\sqrt{\pi}} \\ \gamma_{2,1}(t) = \frac{\sqrt{2}}{2\sqrt{\pi}}(8t-6) \\ \gamma_{2,2}(t) = \frac{\sqrt{2}}{8\sqrt{\pi}}\ (64t^2-96\text{t}+34) \end{array}\right\} \quad \frac{1}{2} \le t < 1 \tag{2.7}$$

2.3 Deep Learning Wavelet Object Detection (DLWOD)

Identifying objects with wave transforms is a new developed and unique technique that analyzes image data to object detection based on deep learning discrete wavelet convolutional neural networks (DWCNN) object detection through the following stages.

1. The stage of converting the image into a Discrete Wavelet Transform (DWT) field.

2. Within the discovery process features that are relevant to the desired objects in the image are extracted.

3. Determine the threshold to remove the noise from the image while keeping the important parameters and ignoring the unimportant things.

4. The implementation is done in determining the location of the object to be detected based on the wavelets.

5. Deep learning stage to train the Discrete Wavelets Convolutional Neural Network (DWCNN) to classify objects.

The role of discrete wavelets for object detection with deep learning is very important because the image data will be hierarchically represented for deep learning.
Figure 2 shows the efficiency and design of the technique proposed in this work:

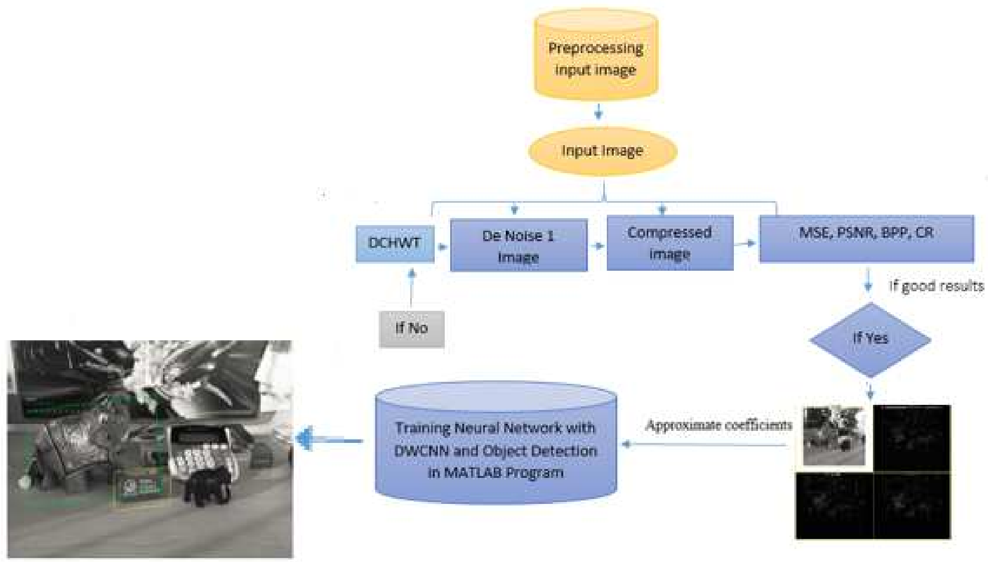

Figure 2: Stages of Methodology design with the proposed technique.

2.4 Discrete Wavelet convolutional neural network (DWCNN)

Deep learning that is concentrated in the artificial neural network when information is entered between the two cells so that the weight is the function that connects between the two cells to generate layers. The process of distinguishing objects is one of the important applications in artificial intelligence, especially deep learning. In this work, a new technology was used, which is the use of DHWT in this process that was mentioned with high accuracy to speed up the detection process because it depends on frequency and time. Consequently, the noise is lifted from the input image to be compressed and after recording the most important criteria for image quality, the image is entered into the convolutional neural network of the new discrete wavelets DWCNN. Its role there is as a filter so that the convolution process takes place to generate hidden layers, and when selecting objects in the input image. The efficiency of the proposed theory has been proven by applying an example to identify the objects to be distinguished. An efficient and fast algorithm will be proposed to implement the proposed theory. The mathematical concept in network training DWCNN to be considered as kernel-coded K with the new filter proposed in this work, DHWT= (R, R, n_c) in Equation (2.8). The convolution process startsg from $K = 1$

$$C\left(I, M\right)_{r,s} = \sum_{i=1}^{n_H}\sum_{j=1}^{n_W}\sum_{M=1}^{n_c} M_{i,j-M} I_{r+i-1}, M \tag{2.8}$$

The merging process begins to distinguish the image with the dimensions above to maintain the number of channels:

$$dim\left(C\left(I, M\right)\right) = \left(\left[\frac{n_H + 2P - R}{S} + 1\right], \left[\frac{n_W + 2P - R}{S} + 1\right]\right) \quad S > 0 \tag{2.9}$$

Let $S = 1$. Then Equation (2.9) will be $(n_H + 2P - R, n_W + 2P - R)$, $p = \frac{R-1}{2}$.

2.5 Algorithm Object Detection with DWCNN

The proposed algorithm is an advanced and developed technique for detecting the object using the MATLAB program after proposing the new filter DHWT derived from the Hermite polynomials responsible for improving the input image to obtain better results so that certain objects are detected from among a group of objects in the field of deep learning where in the proposed example certains parts of the image such as the elephant and the box were detected among other undesirable objects Input Image:

Step 1: Using the suggested filter, the input image is analyzed so that the image parameters are analyzed into the approximate coefficients and details coefficients.

Step 2: Raise the noise from the input image to complete the compression process and read the most important results of the image quality standards MSE, PSNR, BPP, CR.

Step 3: The deep learning process starts from this step. The convolutional neural network is created with the help of the proposed new filter to form a

new network DWCNN.
Step 4: With the new filter and the network resulting from the convolution process, the most important points are identified in the part to be identified, so that the features that define the part to be exposed are identified.
Step 5: At this point the focus is on the features you define with the points that are mapped in the Image.
Step 6: With the directive estgeotform2d, the points of the part to be selected are calculated, neglecting the values that are not needed to select the object in the image. line(newBoxPolygon(:, 1), newBoxPolygon(:, 2), Color='y'); title('Detected Box'); output image detection Box with point 1: (408,462), point 2: (592,444), point 3:(405,595), point 4: (590,576). Either the body, the second object, or any other object, the previous steps are followed. Table (1) and Table (2) show the steps of the algorithm above, with the distinctive points and the perimeter points that distinguish the two shapes, the box and the elephant, and in work space elephantImage = imread('elephant.jpg'); figure; imshow(elephantImage); title('Image of an Elephant');

Figure 3 shows the steps of the algorithm using the new filter DHWT with deep learning DWCNN in MATLAB program:

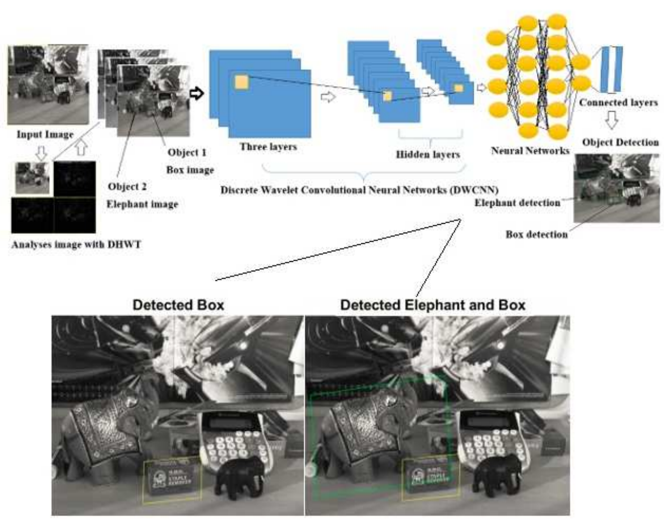

Figure 3: Deep Learning Object Detection theory with the help of the new filter DWCNN.

Table 1: Points revealed for the two sprites, the box and the elephant, before and after their separation.

Matched Points of Box detection					Matched Points of Elephant detection			
Points	New		Old		New		Old	
	x	y	x	y	x	y	x	y
1	384	338	1563	511	473	390	1313	396
2	411	448	1496	545	363	386	1324	398
3	564	357	1487	507	131	460	1282	467
4	473	395	1496	545	447	540	1304	534

Table 2: Points revealed for the two sprites, the box and the elephant, before and after their separation in work space MATLAB program.

Matched Points of Box detection					Matched Points of Elephant detection			
Points	New		Old		New		Old	
	x	y	x	y	x	y	x	y
1	408	462	1	1	111	256	1	1
2	592	444	504	1	544	192	389	1
3	405	595	504	383	565	520	389	357
4	408	462	1	383	132	584	1	357

3 Results and Discussion

The proposed wavelets in this work have a major role in building the process of convolution with the new filter, where the image was processed in the preliminary stage by removing noise and compressing the input image before selecting the object with the MATLAB program and calculating the most important image quality criteria PSNR=43.74, MSE=0.07, BPP=8.634 and CR=36.98% where the results were good so that the image is ready for the process of deep learning to be the new network DWCNN and by selecting the object, the best results were reached. This is shown in the Table (1) points before using wavelets and after using wavelets. Through the MATLAB program, the most important points for the two selected objects were obtained.

The figure shows the quality of the training process to reach the ideal accuracy=99% in 1 min and 23 sec, through Figure 4 as the optimization process in this work is the use of the new filter DHWT in Table (3) shows pairs of points in MATLAB program box pairs $= 17 \times 2$ uint 32 and elephant pairs $= 12 \times 2$ uint 32 in work space.

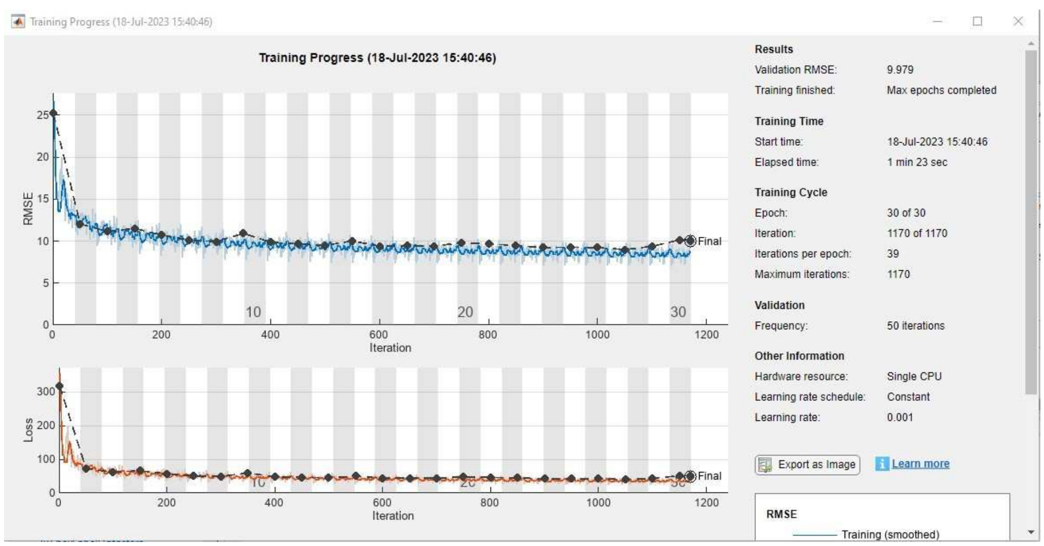

Figure 4: The optimal accuracy reached after training the convolutional neural network DWCNN with the new filter DHWT.

Table 3: Important pairs points for box and elephant.

box pairs = 17 × 2 uint 32			pairs = 12 × 2 uint 32	
	x	y	x	y
1	5	51	6	313
2	21	28	31	214
3	67	182	43	338
4	101	349	71	252
5	120	342	92	646
6	148	452	89	655
7	152	423	106	259
8	156	840	114	785
9	178	581	123	337
10	221	629	163	689
11	244	553	193	178
12	258	740	238	248
13	291	672		
14	292	740		
15	303	1014		
16	356	1129		
17	384	868		

4 Conclusion

The proposed application in this work is an advanced technology in the field of artificial intelligence and deep learning, which is the identification of objects, and it is a very important application in the fields of life and its development, such as traffic in identifying vehicles on public roads, identifying garbage objects such as separating plastic, iron and waste. In this work, an example of identifying objects was tested, which is distinguishing two objects among a group of objects, where the box and the elephant were distinguished among a group of objects. Started this work with building a new filter DHWT from polynomials to be used in image analysis, noise removal and image compression to create a convolutional neural network using the new filter DWCNN. The proposed example demonstrates the efficiency of the proposed technique by reaching the ideal accuracy.

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