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IMAGE COMPRESSION BASED ON LOSSLESS WAVELET WITH HYBEID 2D_DECOMPOSIYION

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ABSTRACT:- This paper introduces a proposed method for hybrid 2D wavelet transform, and applies this method on the field of lossless image compression method. Wavelets in 2D or higher dimensions are often generated by a decomposition scheme from 1D wavelets. There are two decomposition schemes; the standard (rectangular) and the nonstandard (square) decomposition. A hybrid 2D wavelet transform is a result of mixing these two decompositions in order to improve the compression performance and compression ratio.

KEYWORD: Hybrid 2D wavelet transform, Discreet wavelet transform, Lossless compression.

1. INTRODUCTION

Wavelets and wavelet transformations have a wide variety of different applications in computer graphics including multiresolution painting , curve design, and can play some important and ubiquitous rolls in image compression.

The fundamental idea behind wavelets is to analyze according to scale. The wavelet analysis procedure is to adopt a wavelet prototype function called an analyzing wavelet or *mother* wavelet. Any signal can then be represented by a sum of translated and scaled versions of the mother wavelet.

Wavelet transforms are a new area in mathematics and have many different applications. The wavelet transform comes in two different forms, the first form is the Continuous Wavelet Transform (CWT) which deals with continuous input signal, where the time and scale parameters are continuous. The second form is the Discrete Wavelet Transform (DWT) which can be used for representing the discrete-time signals [1, 2]

2. CONTINUOUS WAVELET TRANSFORM

The continuous wavelet transform and discrete orthonormal wavelets generated by multiresolution analysis ,are the two main themes in wavelet theory. They enjoy more or less opposite properties and both have their specific field of application . The Discrete wavelet transform is a powerful technique for data compression, whereas the continuous wavelet transform is a successful tool in signal analysis [3,4].

3. DISCRETE WAVELET TRANSFORM:

The Discrete wavelet transform (DWT) provides high time resolution and low frequency resolution for high frequencies and high frequency resolution and low time resolution for low frequencies. It's a special case of the wavelet transform (WT) that it provides a compact representation of a signal in time and frequency that can be computed efficiently.
The Discrete wavelet transform (DWT) is defined by :

$$W(j,k)=\sum_{j}\sum_{k}x(k)2^{-j/2}\psi(2^{-j}n-k) \quad \text{.....................................(1)}$$

where

$\psi(t)$ is a time function with finite energy and fast decay called the mother wavelet .

In wavelet analysis, a signal can be separated into approximation (averages) and detail (high frequency coefficients), Averages are the high-scale, low frequency components of the signal, while details are the low - scale, high frequency components.

The DWT algorithm consists of forward DWT (FDWT) and inverse DWT (IDWT) which are shown in figures (1)and (2) ,respectively [1,4].

3.1. RECTANGULAR DECOMPOSITION [5,6]

The standard wavelet basis functions, in 2D also called rectangular wavelet basis functions, are generated through the Cartesian product of the 1D wavelet basis functions or the mother scaling function ϕ 00 , in every dimension. In the 2D case, the standard basis functions are:

$$\phi(x,y) = \phi_{0,0}(x)\phi_{0,0}(y) \quad \text{.......... (2)}$$

$$\left.\begin{aligned} {}^{R1}\psi_{j,k}(x,y) &= \psi_{j,k}(x)\phi_{0,0}(y) \\ {}^{R2}\psi_{j,k}(x,y) &= \phi_{0,0}(x)\psi_{j,k}(y) \\ {}^{R3}\psi_{j,m,k,n}(x,y) &= \psi_{j,k}(x)\psi_{m,n}(y) \end{aligned}\right\} \begin{aligned} &0 \le j,m < L \\ &0 \le k < 2^{j} \\ &0 \le n < 2^{m} \end{aligned}$$

$\phi(x,y)$ Denotes the 2D scaling function and the different types of wavelet functions are defined as

$${}^{R1}\psi_{j,k}(x,y),\ {}^{R2}\psi_{j,k}(x,y) \text{ and } {}^{R3}\psi_{j,m,k,n}(x,y)$$

The fast wavelet transformation with the standard basis wavelets, also known as standard decomposition, is computed by successively applying the 1D wavelet transformation to the data in every dimension. In the 2D case, all the rows are transformed first, then a 1D wavelet transformation is applied on all columns of the intermediate result. The wavelet coefficients of the 1D transformation steps are stored in the right (row transform) or lower (column transform) part, while the scaling coefficients are stored in the left or upper part.

3.2. SQUARE DECOMPOSITION [5,6]

The nonstandard wavelet basis functions, in 2D also called square wavelet basis functions. They are generated through the Cartesian product of 1D wavelets and 1D scaling functions. In contrast to the standard basis functions, the nonstandard basis functions always use tensor products of wavelet and/or scaling functions of the same resolution level. In the 2D case, the nonstandard basis functions are:

$$\phi(x,y)=\phi_{0,0}(x)\phi_{0,0}(y)$$

$$\left.\begin{aligned} {}^{h}\psi^{j}_{k,m}(x,y)&=\psi_{j,k}(x)\phi_{j,m}(y)\\ {}^{v}\psi^{j}_{k,m}(x,y)&=\phi_{j,k}(x)\psi_{j,m}(y)\\ {}^{d}\psi^{j}_{k,m}(x,y)&=\psi_{j,k}(x)\psi_{j,m}(y)\end{aligned}\right\} \begin{aligned}&0\le j<L\\ &0\le k,m<2^{j}\end{aligned} \quad \text{.....(3)}$$

Like in the standard decomposition, it contains one 2D scaling function and three different types of 2D wavelet functions. Note that the wavelet functions ${}^{d}\psi^{j}_{k,m}(x,y)$ are a subset of the wavelet functions ${}^{R3}\psi^{j}_{j,m,k,n}(x,y)$ in the rectangular decomposition.

3.3. A HYBRID 2D WAVELET DECOMPOSITION[7,8]

2D wavelets are usually generated from 1D wavelets through rectangular or square decomposition schemes.
In this paper a new hybrid 2D decomposition scheme for compression related applications will be introduced. Results for lossless image compression have shown improvements in the compression rate between 1% and 10% compared to the square decomposition. . In one decomposition step of the square decomposition three wavelet sub bands and one scaling sub band are generated, and the wavelet sub bands are not altered in the following decomposition steps. The first wavelet sub band in the upper right part of the transformed image consists of the coefficients of the wavelet functions ***hψ*** as defined in equation (2) the second sub band in the lower left part has coefficients of ***vψ*** and the third sub band in the lower right part has the coefficients of ***dψ***. All the wavelet functions in ***dψ*** are also contained in R^3 of the rectangular decomposition, therefore the coefficients in this part of the transformed image are the same for both decompositions. The upper right part of the square transformed image contains coefficients of the wavelet functions

$${}^{h}\psi^{L}(x,y)=\psi^{L}(x)\phi^{L}(y) \quad \text{..........(4)}$$

Where L is the maximum resolution level. The corresponding rectangular decomposition holds the coefficients of the wavelet functions

$$\{R^{1}\psi_{L}(x,y);\mathrm{R}^{3}\psi_{L}(x,y)\quad \backslash\, 0\le \mathrm{i}\le \mathrm{L}\}$$

It can be seen from the definition of these wavelet functions in equations (2 & 3), that the part of the transformed image in the rectangular decomposition can be generated from the square decomposition with a 1D wavelet transformation within, every column of this part . In analogy the lower left part of the rectangular decomposition can be generated from the square decomposition with a 1D wavelet transformation within every row. A hybrid 2D wavelet decomposition can include both rectangular and square decompositions. If the square decomposition has the best compression of the coefficients the hybrid 2D decomposition, the square decomposition wavelet functions are selected, and the same is true for the rectangular decomposition. In a general case, the hybrid 2D decomposition selects some wavelet functions from the square decomposition, and some from the rectangular decomposition.

4. THE COMPRESSION SYSTEM COMPONENTS

The image compression scheme using Hybrid 2D wavelet transform consists of several stages. Figure (3. a and b) shows the block diagram for the stages of compression and decompression systems, respectively.

4.1 . THE PROPOSED COMPRESSION ALGORITHM (HYBRID 2D DECOMPOSITION)

The proposed algorithm implies the following steps :

First- Apply square decomposition step on the image:

In this stage the image will be divided into four equal parts as shown in the following steps:

- **a.** Low pass filer (LPF) (scaling function) is applied for each row of data, to get the frequency components of the row then the result is sub sampled by two so that the output data now contains only half the original number of samples. And we denote (L) (Low Sub band).
- **b.** High pass filter (wavelet function) is applied for the same row of the original data and then apply sub sampling by two to get high frequency components denote (H) high sub band.
- **c.** Apply LPF for each column in the (L) low sub band and then apply sub sampling to get LL sub band.
- **d.** Apply HPF for each column in the (L) low sub band to get LH sub band.
- **e.** Apply LPF for each column in the H high sub band resulting in step (b) to get HL (sub band).
- **f.** Apply HPF for each column in the H high sub band resulting in step (b) to get HH (sub band).

Now the LL band resulting in step (c) can be decomposed once again in the same manner producing even more sub bands. This can be done up to many levels.

Second - for every column in the upper right part of the result image in the first level of the square decomposition. The following step is done:

- Apply all ID wavelet decomposition steps in the Y-dimension.

Third- for every row in the low left part of the result image in the first level of the square decomposition the following step is done:

- Apply all ID wavelet decomposition steps in the X-dimension.

Fourth- apply this scheme recursively on the upper left part of the transformed image.

4.2. RUN LENGTH CODING (RLC)

After converting the gray level value to binary number the run length coding it's used. The run length coding is based on counting the repetitions of both 0's and 1's where each sequence of similar bits is replaced by a single number representing the run length of these repeated bits, the result of this coding method is a sequence of numbers, the first number represent the length of 0's sequence while the next number is the length of 1's sequence, and so on. Applying this method (RLC) on the result of the hybrid 2D wavelet, the output of this coding process is the compression data, and thus it's size represents the size of the compression file. Table (1) presents the output of the RLC.

4.3. DECOMPRESSION SYSTEM COMPONENTS

The decompression system has many components including:

4.3.1. RUN LENGTH DECODING (RLD):

The inverse process of RLC will be applied to reconstruct the Run length decoding sequence. The code of the RLC can be decoded to produce sequences of 0's and 1's.

4.3.2. INVERSE WAVELET TRANSFORM

This process is applied on the result of RLD that results the previous step, the procedure of the inverse process goes like the following steps:-

First - for every row in the upper right part (HL) sub band the inverse ID WT will apply.

Second - for every column in the lower left part inverse ID WT will apply. This process is apply at all levels of wavelet decomposition from the top most level until we reach the first level.

Third - now the inverse square wavelet transform (WT) will apply to reconstruct the original. The following steps discuss the process of inverse square wavelet transform:-

1. The columns of LL sub band will up sampled by 2 then the result is passed through the LPF.
2. The columns of LH sub band will up sampled by 2 then the result is passed through the HPF .
3. Apply the summation operation between the result from step1& step2 to get L sub band.
4. Repeat step1 but on the HL sub band.
5. Repeat step2 but on the HH sub band.
6. Apply the summation operation on the result from step 4& step5 to get H sub band.
7. The rows of L sub band will up sampled by 2 then the result will passed through LPF.
8. The rows of H sub band will up sampled by 2 then the result will passed through the HPF.
9. Apply the summation operation to get the reconstructed image.

5. EXPERIMENTAL ANALYSIS

This section is devoted to study the compression performance of the proposed compression system with the proposed algorithm (i.e., Hybrid 2D wavelet decomposition). Two images are used as test material. They are different in size, and the type of these images is a bitmap with (8 bits / pixel) format. Figure (4) shows these two images; lena with (512 *512 pixels) and hand with (256 * 256 pixels).

5.1. ENCODING MODULE

In this stage the proposed methods, Hybrid 2D wavelet decomposition will applied as illustrated in section (4.1). The result of this stage is shown in figure (5) the number of levels of wavelet that will be applied is 3 levels and the type of filter used is Haar filters (LPF $=1/\sqrt{2}, 1/\sqrt{2}$) and (HPF$=1/\sqrt{2}, -1/\sqrt{2}$)

5.2. DECODING MODULE

In order to reconstruct the original images, the inverse algorithm will be applied on the result images from the encoding stage while it will be checked to evaluate the system performance. Figure (6) shows the reconstructed images.

6. KEY PARAMETERS

Although a lot of key parameters are utilized in the literature for performance evaluation of the various compression methods, this work will utilize four key parameters.

6.1. COMPRESSION RATIO (CR)

This parameter is used to calculate how much that the size of the tested image files was compressed; the compression ratio is defined as:

$$\text{Compression ratio (Cr)} = \frac{\text{size of original image}}{\text{Size of compressed data image}} \quad \ldots\ldots\ldots\ldots\ (5)$$

Cr > 1 means positive compression, while
Cr < 1 means the output stream (negative compression).
Whenever this factor is big it indicates that the compression is better, otherwise the compression is weak.

6.2. THE MEAN SQUARE ERROR (MSE)

This parameter is a fidelity parameter which is used to measure the error level caused by the compression system; mean square error and root mean square error(RMSE) can be defined as:

$$MSE = \frac{1}{H * W} \sum_{y=0}^{H-1} \sum_{x=0}^{W-1} \left(f(x,y) - f'(x,y) \right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ (6)$$

and

$$\text{RMSE} = \sqrt{MSE} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ \mathbf{(7)}$$

where:
f(x,y) is the value of the original image at row (y) and column(x).
f′(x,y) is the corresponding values of the reconstructed image.
H is the height of the image.
W is the width of the image

The small results of (MSE) means that there is a small overall error in the reconstructed version of image caused by the compression system, this indicates that the objective quality of the reconstructed data is acceptable, when the value of MSE is high it will indicate that the compression system may cause a significant error.

6.3. PEAK SIGNAL TO NOISE RATIO (PSNR)

It is also a fidelity parameter used to measure the distortion level caused by the compression system. Peak signal to Noise ratio (PSNR) can be defined as:

$$PSNR = 10\log_{10}\left(\frac{(L-1)^2}{MSE} \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (8)$$

Where:
MSE is the mean square error.
L is a number of the used gray levels.
The large results of (PSNR) means that there is a small noise in the compression system and the quality of the reconstructed image is better. When the value of this parameter is small it means that the compression performance is weak.
Table (2) shows the values of key parameter (CR, MSE, RMSE, PSNR) after applying the algorithms on the images.
As seen in Ttable(2), the values of Cr (compression ratio) highlights the good performance . The small results of MSE means that there is a small overall error in the reconstructed version of image caused by the compression system, also the large values of PSNR mean that there is a small noise in the compression system and the quality of the reconstructed image is better.

Table (3) shows a comparison between the proposed method and some other methods of the" Lena" image, as seen from the values, the value of(Cr) of the proposed method is better than the LZW , square and rectangular method .

Figure (7) shows that the difference operation between the reconstructed image and the original image gives a black image. that means the difference value between the pixels is zero, this will show that the reconstructed image is approximately similar to the original image according to the following equation.

$D = f'(x, y) - f(x, y)$ ………………………………..(9)

D: is the value of the difference.

$f'(x, y)$: is the compressed image .

$f(x, y)$: is the original image.

7. CONCLUSIONS

1-Applying this method on some images offers good compression rates and small mean square error; also the value of (PSNR) shows good results.

2- In the case of applying this method on lossless image compression of medical images, the results are also good and this is very important for doctors in diagnosing accurately because the original image can be reconstructed from the compressed image with very small error.

3- The compression ratio is increased as the image size increase, this because the value of any pixel in the image will be within the range (0-255), so large image size will lead to an opportunity to have more similar values.

4- The implementation of adaptive 2D wavelet transform adds some power to the compression performance because it divides the image domain into different wavelet part (according to the number of levels) each part can be processed independently so an efficient compression can be gained.

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Table (1): The process of Run length coding.

Binary Bit-Plane	The Output of Adaptive RLE							
000001111111110000111111111111111111	5	9	4	19				
000111111111111100000000000111111111111111	3	13	11	15				
00111111000001111111110000000011111111111	2	6	5	9	8	11		
0000000000000000000011111111111111111	20	17						
0000000111111110000001111000011111110011111	7	8	6	4	4	7	2	4
00000111111110000000111111111 1	5	8	7	10				
000111111111111100111111111111111101111111	3	13	2	16	1	7		
00110011001100000000000111111111111111111	2	2	2	2	2	2	11	19

Table (2): Results of CR, PSNR, RMSE, MSE.

Type of image	Size	MSE	RMSE	PSNR	CR
Lena (512 x 512)	256 KB	0.11	0.32	133.36	1.57
Hand (256x256)	64 KB	0.10	0.31	134.11	1.55

Table (3): The result of Cr of the proposed method and some other methods.

Compr. Rate LZW	Compr. Rate Square	Compr. Rate Rectangular	Compr. Rate Hybrid
0.95	1.28	1.23	1.57

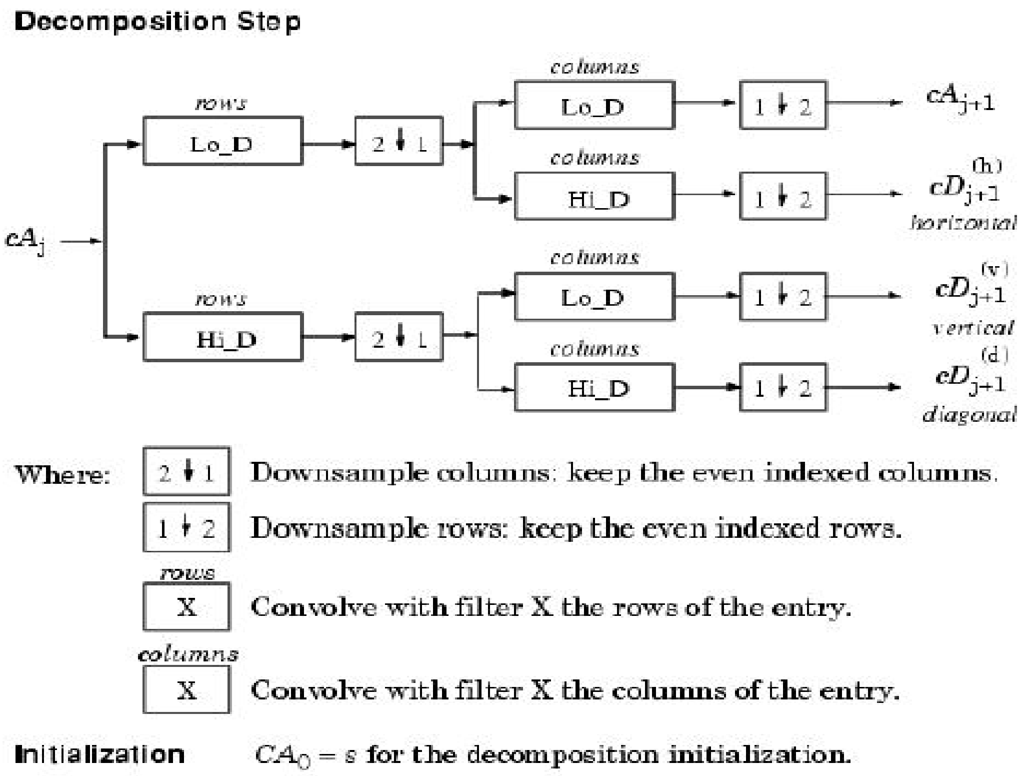


Fig.(1): Block diagram of FDWT.

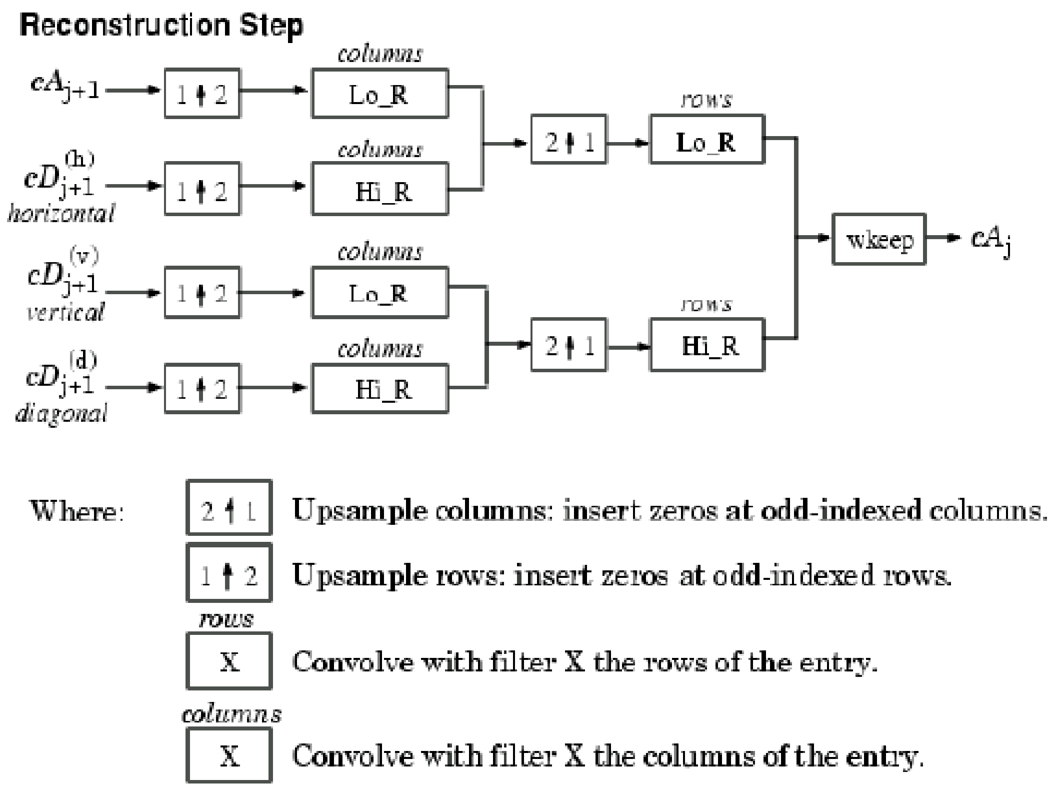
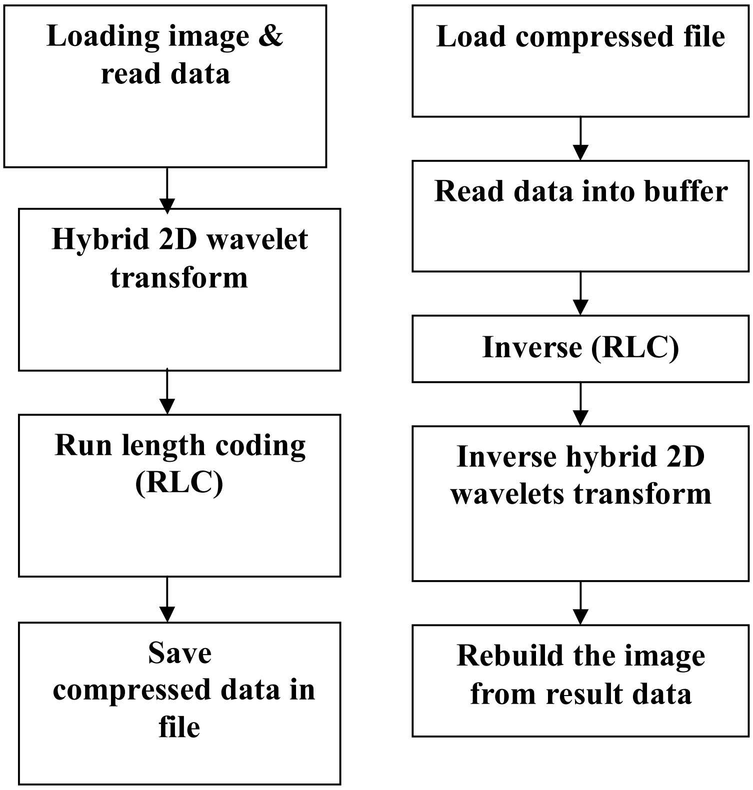


Fig.(2): Block diagram of IDWT.



a ***b***

Fig.(3): a- block diagram for the stages of the compression system.

b- block diagram for the stages of the decompression system.

(Lena) (Hand)

Fig.(4): Tow images to be compressed by the algorithm.

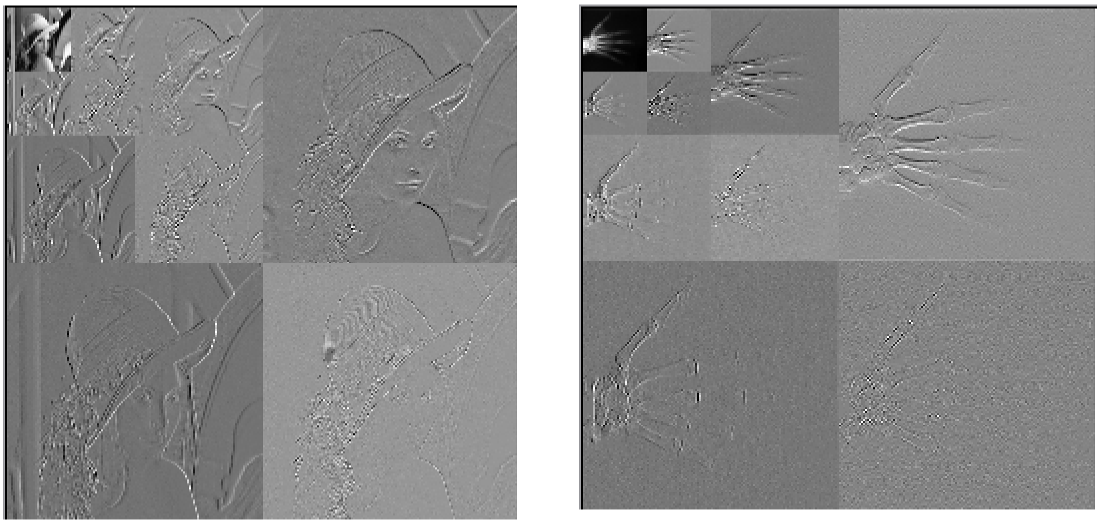


Fig. (5): Adaptive 2D wavelet Decomposition applied on Lena and Hand images

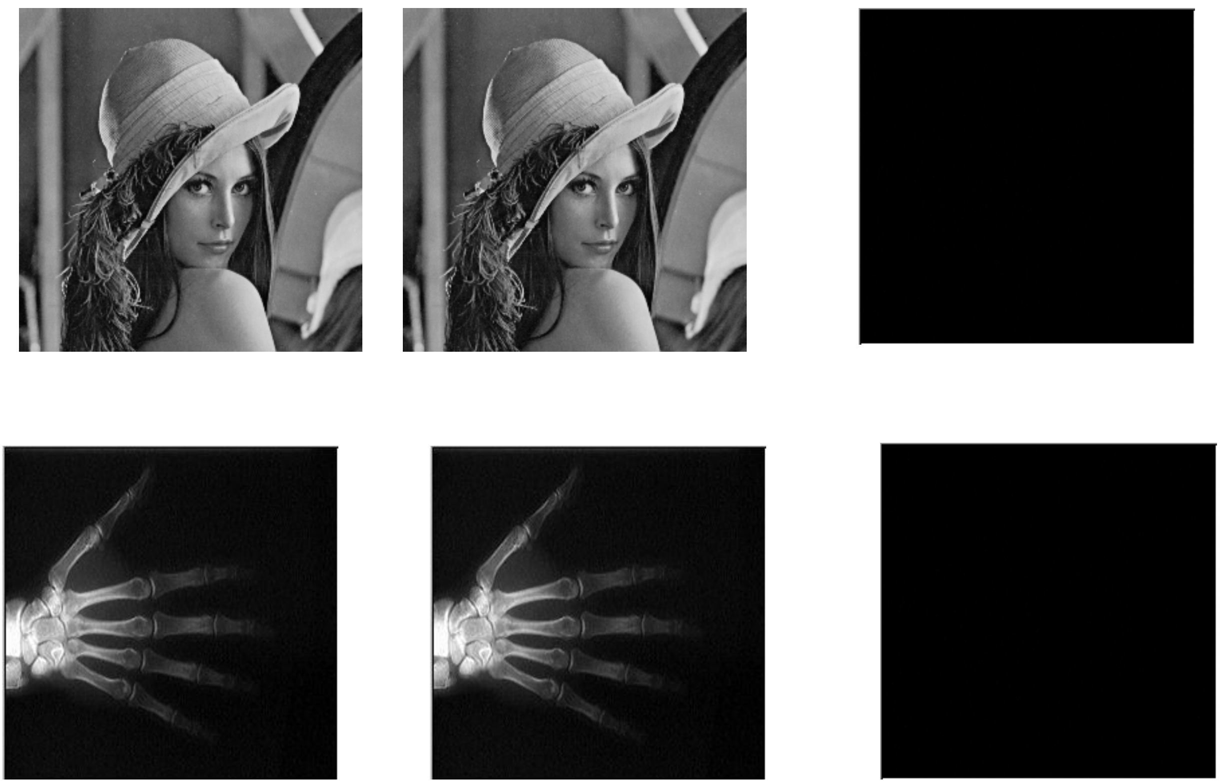


Fig.(7): The difference operation between the reconstructed image and the original image.

ضغط الصور بالاعتماد على التحويلات الموجية الهجينة

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الخلاصة

إن هذا البحث يقدم طريقة مقترحة(التحويل المويجي ذو البعدين الهجين)وتطبيقه في حقل ضغط الصور المحكم. التحويلات الموجية ذات البعدين أو أعلى تتولد عادة بواسطة النسق التحليلي من التحويلات الموجية ذات البعد الواحد.هناك نوعان من النسق التحليلية هي التحليلات الرباعية الشكل والتحليلات المستطيلة الشكل والتحويلات الموجية الهجينة والتي استخدمت في هذا البحث هي ناتجة عن دمج هذين النوعين من التحليلات .وبعد تطبيق هذه الطريقة المقترحة على عدة صور ذات أحجام مختلقه ومن نتائج العمل تبين انه هناك تحسن في كفاءة الضغط نسبته.