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An advanced image compression technique by using a coupled compression algorithm depend on different wavelet methods

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ABSTRACT

Digital images need a large storage capacity, and as a result they need a large bandwidth for data transmission to deliver to the desired destination over the network. Image compression technologies not only reduce the size of stored data, but also maintain as much as possible the output image quality. In the proposed research we review a technique for image compression that uses a distinct two-stage image encoding method using different compression algorithms and wavelet transform methods, which combines two types of effective compression algorithms that give more ability to compress image data.

The proposed compression technique which coupled two image compression algorithms that put to use premium characteristics from each algorithm. The wavelet transform methods contribute effectively to finding suitable solutions to supply better compression ratios for images with high resolution. The complete series of compression includes repeated stages of encoding and decoding, in addition to the wavelet processing itself.

This study will have carried out an advanced compression technique that contain a coupled compression algorithm relying on the preferred wavelets to this work from practical experiments they are, biorthogonal and Haar wavelet transform, the performance metrics for tested true HD color image will be studied. The challenge for image compression algorithms is to detect a best solution between a low compression ratio and good visual perception results. An essential measure of achieved image compression process is taken by compression ratio CR and the ratio of bit-per-pixel BPP. The CR and BPP metrics are important components in image compression techniques.

Through the results of the image compression metrics in two stages, the best practical results were obtained when the compression ratio metric CR was equal to 2.3%, and this metric indicates that the compressed image can be stored using 2.3% of the original image data size. While the BPP which represent the bit number that used to store one pixel of true color image is equal to 0.575.

Keywords: Coupled compression, image compression, SPHIT and STW.

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1. Introduction

One of the results of the rapid growth in modern technology, especially in the areas of the development of smart phones and the use of software applications in various fields of communication, is the great use of the transmission of images and videos. Where the images transmission is one of the most popular processes among users of IT applications. The transfer of the image and its data size faced many problems. Researchers in the fields of IT and data transmission have provided various and advanced solutions aimed to reducing the transferred data size while preserving the important information of the files within the communication network. [1]. Uncompressed images require large storage capacity and high bandwidth in order to transfer their data. Among the solutions put forward to reduce the volume of multimedia data transmitted over communication

networks, is to reduce the size of transferred files by utilizing the update technologies for data compression, including reducing the size of the images transferred over the communication network [2].
The suitable solution for image compression will based on the diminish of the needed volume of redundancy bits, which has an effect on the transferred data size without losing its contents or changing the type of information. The digital image data is arranged from pixels in a matrix that represent a set of specified rows and columns through which the width and height of the image are determined Each pixel in the image has an intensity value that is indicated through a fixed bit number. Image compression technology based on the implementation of data redundancy, that covers all kinds of duplication or similarity, and unnecessary or unwanted values of the image pixel. In general, there are two main categories of redundancy in images:
(1) statistical redundancy and (2) psych-visual redundancy [3].
Image compression essentially minimize the image size by representing important image data in smaller number of bits, by takeout unimportant image information [4] [5]. The most important goal of image compression techniques is how to manage the data of digital image by increasing the degree of compression, depending on important metrics such as the percentage of compression ratio CR between the images before and after the compression process, as well as the size of data per pixel or bit per pixel BPP of the compressed image during data transfer and storage. The problems mentioned above are among the matters of concern by researchers that work in the image compression field. One of the solutions put forward is a couple compression technique to attain high compression ratio. [6]. This technique will merge the best features from each compression method. So, the main goal of this paper is to recognize how to improve a coupled compression technique that being used to enhance the image compression performance metrics. This enhancement was done through the reduction of number of bits that needed to perform input image as far as possible, while preserving the quality of the obtained image after the compression process as close to the original image as possible.
This modality is depending on utilizing two parts of progressive compression techniques. First compression stage used one of the different algorithms of compression based on one of the wavelets transforms (Biorthogonal or Haar), and the produced file will be compressed again in the second stage with one of selected compression algorithms depend on one of the above wavelet methods. The output compressed file after the two compression stages should be well compressed while retaining the quality of the transferred file, with significant proportions in improving performance.
This work focuses primarily on the comparison and evaluation of compression metrics for tested image which take out from the application of different compression algorithms based on wavelet transform.

2. Image compression

Data compression technique is the art of how-to representing image data in a compact form. The main aim is to minimize the number of bits that required representing a series of data. Therefore, the storing and transmission of data image must be performed with efficient manner. Decreasing data redundancy is the main topic in compression process. Image compression technique, is the process of encode the original data image with at least as possible number of bits, and will reduce the size of data storage. The original image will retrieve by decoding the compressed image. The decoding image must be similar to original image as much as possible [7].
Normally, the capture images from camera will be in analog form. But in order to transmit, process, and store data images must be in transform to digital form [8]**.**
The adjacent pixels in digital image are correlated, thus these pixels comprise from redundant bits [9]. The compression technique will remove the redundant bits from the data of image, which reduce the image size accordingly [8].
The advantages that gained from image compression techniques basically are to eliminate redundant information from the proposed image [9]. The main types of data redundancy can be counted in three kinds [8]:

- Inter pixel redundancy.
- Psychovisual redundancy.

- Coding redundancy.

Image compression not only reduces storage capability, but also minimizes the transmission time [10] [11]. There are many types of image compression techniques, but more common of these techniques will be split in two categories. ***Lossless*** compression and ***Lossy*** compression techniques.

3. Wavelet transform

Over the past few years, wavelet transform has accomplished by widespread acceptance, especially in science of image compression. Wavelets allow complex information like the speech, music, images, and patterns to be decomposed at different scales and positions into elementary forms and then reconstructed with a high accuracy degree [12]. Wavelets supply better compression ratios for images with high resolution.
The wavelet transformation's core principle is the representation of some arbitrary function as a set of wavelets or simple functions, these simple functions are obtained by shifts and scaling from a single prototype wavelet, called a mother wavelet. this helps very large wavelets to distinguish coarse details, whereas very small wavelets can be used in a signal to separate very fine details [12]. There are many reasons for the advancement of wavelet transformations, and one of the most important reasons is clearly that in many implementations, the wavelet coding scheme (often called sub-band coding) achieves greater efficiency than other coding schemes such as the one based on DCT. Since the input picture does not need to be blocked and its basic functions have variable length, wavelet-based coding schemes may prevent artifact blocking. Wavelet-based coding also encourages progressive image transmission because it enables an image to be reconstructed beginning with coarse quality and eventually progressing to a higher quality. [11], The signal is broken down into many sub bands of high and low frequencies at varying wavelet sizes. [13].
Furthermore, wavelet transformations have strong spatial and time localization, frequency domain are resilient against errors in transmission and decoding, beside that conform well to the HVS characteristics [12].

3.1 The families of wavelet transform

Various of wavelet transform families have been improved for DWT which are strongly support the orthogonal and bi-orthogonal wavelet, that are described by the analysis filters of low pass and high pass, in addition to composition filters. The following are some available families' wavelet transform:
(i) Haar. (ii) Daubechies (iii) Symlets, (iv) Coiflets, (v) Meyer, (vi) Mexicanhat and (vii) Morlet. etc.
Some of these families are corroborative through orthogonal wavelets, like Coiflets Symlets Haar and Daubechies, while the other families like Morlet, Mexicanhat and Meyer wavelets are symmetrical in their shapes. Depending on the significant features of wavelet such as scaling function and capability of signal analyzation, these wavelets are chosen for any specific application [14]. In this paper, we will focus on two types of wavelets that have been selecting from the well-known group of wavelets families, due to the practical ability of these two types to obtain distinct results through image compression processes. Which are Haar and biorthogonal wavelets.

(i) Haar wavelets

Haar is one of the simplest types of wavelets and it has a high transform speed. The Haar matrix basic vectors are arranged sequentially.
the Haar wavelet transform can be regarding for joining an input values, conserve the difference and passes the sum. This procedure is repeated frequently, joining up the sums to confirm the following scale, that provide a route to display style 2^n-1 difference and the final summation.
The Haar wavelet in mathematics describe as a series of down-scaled the square shape functions, as seen in figure 1. Because the wave is not continuous, it is considered as a disadvantage and therefore indistinguishable and identify the step function. This feature is considering as advantage for signals analyze with unexpected transitions, such as observation of failures tool in machines [14].

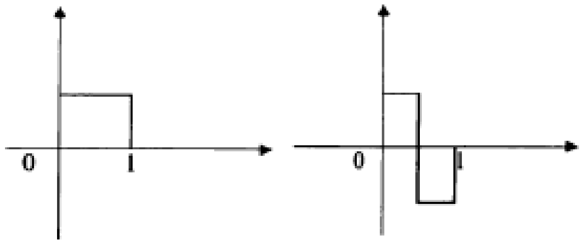


Figure 1. The HAAR scaling and wavelet functions [14]

(ii) Biorthogonal wavelet transform (Tap 9/7)

Biorthogonal wavelet transformation is a section of the biorthogonal wavelet CDF, symmetric family (encoding time is equal to decoding time), have got up to a specific occurrence in order to chosen for being the transform seed in JPEG2000 standard [12].

In certain cases, there are floating point coefficients for the filters used in this type of wavelet transformation. Since the input images have integer entries, integers are no longer included in the filtered output, and losses are generated by rounding.

Symmetric extension is used to control image boundary filtering by adding mirror pixels to the outside of the boundaries so that large errors are not registered at the boundaries [12].

By implementing lifting steps, followed by scaling steps, the biorthogonal wavelet transformation is determined, the lifting scheme is utilized through a series of phases, we can have represented the proposed phases by three types: split phase, predict phase and update phase, as shown in figure 2.

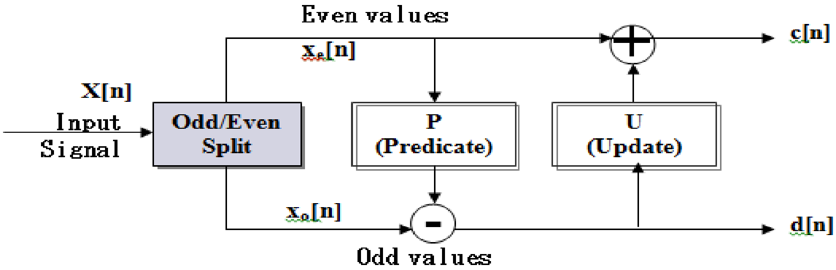


Figure 2. Lifting scheme transform [12]

In the ***Split*** phase, the initial data is split into two sub-bands: the first sub-band contain the odd indices elements and the second contain the even indices elements. The ***Predict*** phase ***(P)*** is used to obtain the high frequency sub-bands details coefficients (these coefficients are called wavelet coefficients), and The goal of this phase is to predict even indices values based on odd indices values. The ***Update*** phase ***(U)*** is applied after the predict phase to obtain the low frequency sub-band coefficients by making the average output value of low-pass coefficients equal to the average output value of the initial input data. So, the aim of update phase ***U*** is to upgrade the even samples through utilizing the detail of the wavelet coefficients that have been previously calculated [12].

4. The proposed compression system

This study is offers the advancement of compression technique which based on using coupled assembled compression techniques depend on three styles selected from wavelet methods (Bior 4.4, Bior 5.5, Bior 6.8 and Haar), These wavelet methods were chosen because their results in terms of performance metrics or images obtained after the compression and processes were completely convincing. Choosing the best way to compress image has a strong advantage to achieve a significant reduction in image data size, provided that this does not effect on image quality after the compression process. To utilize the proposed coupled assembled image compression technique, the following steps must be taken into consideration:

Step 1: Upload any test true color HD image, analyze it with MATLAB software, and then save it in a file.

Step 2: Compress the component of primary image through utilizing one of the compression image means, this procedure based on using two separate progressive compression schemes with a wavelet filter (we used the following filters Bior 4.4, Bior 5.5, Bior 6.8 and Haar).
Step 3: Upload the saved compressed image and use the method to decompress it.
Step 4: Decompress the image obtained from step 2, then compare the image result with the primary one.
Step 5: Compute the popular compressed image performance metrics: CR, MSE, BPP, and PSNR. Then use these procedures to find the differences between compressed and primary images.
Step 6: Further compression algorithm should be utilized to enhance the results of data reduction; By compressing acquired components from an image that is decoded.
Step 7: The second compression process for the gained decoded image from step 4, through utilizing an extra compression algorithm with the help of one wavelet methods filter (Bior 4.4, Bior 5.5 and Haar).
Step 8: Load the obtained coupled compressed image and then moving towards the next step of an additional coupled decompression process.
Step 9: Decompress the recover image file from step 7, as, at this stage, the results of the extracted decompressed image in terms of visual perception and the size, are compared with the original image.
Step 10: Compute the compressed image performance metrics: CR, MSE, BPP and PSNR. Accordingly, these performance metrics are used to decide the dissimilarity between the original and the resultant image after coupled compression processes.
The acquired image should be useful from several considerations, while preserving the original image visual perception, the missing features from the resulting image are so insignificant that they have no discernible effect on the basic characteristics of the original image.

5. System performance measures

There are some image compression performance metrics against which to measure the performance of a compression system. Among these metrics commonly used are [15]:

(i) Compression ratio (CR)

This is an important metric for measuring the extent to which the resulting data is reduced after using the image compression algorithm. CR also names as a compression power is calculated as the ratio of the data file size of the original image (before compression) to the size of the file after the compression process [16]. The target of compression methods is to find the best equalization between a low compression ratio and a good visual perception result.

$$CR = \frac{Uncompressed\ File\ Size}{Compressed\ File\ Size} \tag{1}$$

(ii) Mean square error (MSE)

A further metric is used to determine the performance of image compression algorithms by using a dynamic grading parameter to calculate the quality of the compressed image. The computation is done by compare the primary data image with the image after decompression, and after that present the deformation level [17]. In general, the deformation is calculated by the dissimilarity between the primary and the compressed image. The error role Er is calculated by the disparity between the primary image (input G(x,y)) and the reshaped image (output G'(x,y)) [18]:

$$Er = G(x,y) - G'(x,y) \tag{2}$$

The MSE can be located as:

$$MSE = \frac{1}{W \times H} \sum_{x=0}^{W-1} \sum_{y=0}^{H-1} Er^2 \tag{3}$$

The Mean Square Error (MSE) is computed in dB. Where the variables W and H represent the width and height of the proposed image.

(iii) Peak signal to noise ratio (PSNR)

PSNR is a powerful factor in evaluate the compressed image. This scale is better than the MSE scale, and can be computed easily. This metric shows the similarity between the primary image and the reconstruct one. The PSNR is defined as in the following formula, and can be measured in decibels (dB) [19]:

$$PSNR(dB) = 10log_{10}\left[\frac{(R-1)^2}{MSE}\right] \quad (4)$$

Where; R is the number of the image intensity level.

(iv) Compression gain (CG)

This metric is defined as:

$$CG = 100\log_e \frac{Reference\ Size}{Compressed\ Size} \quad (5)$$

Where, the reference size is offer the size of input stream. The compression gains (CG) unit is present as a log ratio, that can be determined by % [20].

(v) Data compression rate

Is one of the important metrics and can be computed by divide the rate bits' number which required to perform a single element [21]. Bits per Pixel (bpp) is the bit's number that can be used to store one pixel of the image. So, for a true color image the initial value of bpp is 24 bits, because we need 8 bits to encode every one of the three basic colors in RGB color space.

$$\text{Bits per pixel (bpp)} = \left(\frac{Number\ of\ bits}{Number\ of\ pixels}\right) \Rightarrow \left(\frac{8 * Number\ of\ bytes}{N * N}\right) \quad (6)$$

(vi) Speed of compression

Image compression speed depends mainly on the technology used for this procedure, in addition to the nature of the host system that includes the compression process. The compression speed is affected by the size of the memory and the complexity of the calculation [22].

(vii) Power consumption

Is one of the significant metrics. Multimedia inherently requires large storage capacity and high bandwidth, which leads to rapid energy consumption. The power required to transmit the streaming data, and the methods required to compress the transmitted image data, are important in reducing the transmission time, and decrease the consumed energy. Therefore, organizing the processing complexity will decrement the size of the transmitted data and as a result, it will save the energy which can be consumed for data transfer [21].

6. Discussions of experimental results

This paper presents coupled compression algorithms to enhance the data reduction of still true color images, while preserving the visual quality of the reconstructed image closer to the original image as much as possible. By using the progressive compression methods with different number of encoding loops. The resultant image must be a satisfactory while remaining a good visual observation.

The test image, which utilizes in this work are selected from a dataset of true color HD images.

- The proposed true color HD image is shown in figure 3.
- Table 1 presents the results of compression procedure for tested image by using different coupled of compression algorithms depend on (Bior 4.4 + Haar) wavelet methods in order to calculate the tested image performance metrics after each compression. The key parameter is the number of loops. Increasing it, leads to better recovery but worse compression ratio. Fine practical results were obtained with number of coding loop equal to 12.

To discuss the results of table 1 in terms of performance metrics, the following inference can be drawn from the results of compression. The best compression methods are when utilizing the compression methods (spiht

+ spiht) and (spiht and stw) for first and second compression respectively. But the results of the first coupled compression mode are better and the utilizing of spiht compression method will have higher heels than stw, especially with the use of the Haar wavelet. The compression results can be slightly improved by using a more recent algorithm spiht. Which gave good compression results while preserving the visual perception of the original image. While a worse result of the performance metrics is obtained through utilizing wdr and aswdr methods, even with Haar wavelet, noting that the image view after compression was relatively convincing. Whereas, the results of the performance metrics for ezw compression method are better than the previous two methods (wdr and aswdr).

- Table 2 submits the results of compression procedure for tested image by using the more recently compression algorithm spiht depend on (Bior 4.4 + Haar) wavelet methods, to compute the metric features. With number of coding loop equal to 10, 14 and 16.

Because the spiht compression method gave the best performance metrics as seen in table 1, it was adopted for the first and second compression stages. By utilizing the same wavelet methods that is applied in Table 1 (Bior 4.4 and Haar). However, new practical experiments have been implemented by using Matlab program with several numbers of encoding loops to determine the effect of increasing or decreasing of this number on image characteristics and performance metrics. The practical experiments have already been done with number of coding loops equal to 10, 14 and 16. The best performance metrics results were when using the number of loops equal to 10 but produces a very coarse resulting image, and the worst performance metrics results in the case of the number of coding loops equal to 16 but produce a satisfactory resulting image. If the number of coding loop equal to 14 it gives a little better result. As seen in figures (4,5 and 6).

- Table 3 submits the results of compression procedure for tested image by using different coupled of compression algorithms depend on (Bior 5.5 + Haar) wavelet methods based on metric features. With choosing the best number of coding loop which equal to 12.

To get the best compression results, we decided to change the wavelet method for the first compression process from Bior 4.4 to Bior 5.5 while keeping the Haar wavelet method for the second compression due to the effectiveness of this method in image compression. From the practical results that obtained by utilizing different compression methods to examine the performance metrics and the visual inspection of the resultant images after correlated compression processes, we can list the following.

1- The number of coding levels equal to 12 was chosen, because it gave fine results as seen in previous practical experiments.

2- The focus in this table was on using the preferable compression algorithm spiht for the first compression stage, and choosing different algorithms for the second compression stage, except for the last case, where the wdr and ezw compression algorithm were used for the second stage.

3- Experimental results were done by utilizing the compression methods spith and ezw with wavelet methods (Bior 5.5 and Haar) and in using the same compression methods with wavelet methods (Bior 4.4 and Haar). The result of the gained performance metrics for the two cases are close to each other.

a. As for the first compression process by using spiht algorithm, in the case of using Bior 5.5 wavelet method, the results are relatively better than using Bior 4.4 wavelet method.

b. The experimental results for the second compression process by using the ezw algorithm were opposite to those of the previous case but the visual inspection of the compressed image is close in both cases.

c. Also, the execution time by using Matlab program for the first case which utilize the Bior 5.5 wavelet transform is relatively higher than the execution time for the second case when utilizing Bior 4.4 method.

d. In order to reach a complete contentment by choosing a suitable wavelet method among the Biorthogonal wavelet methods, a practical experiment was conducted using the Bior 6.8 and Haar wavelet methods with the use of the same previous compression algorithms (spiht and ezw). The results obtained showed that the performance metrics are very close to the results of the case which utilized the Bior 4.4 and Haar wavelet methods. Also, the execution time by using Matlab program for the case which utilize the Bior 6.8 wavelet transform is higher than the execution time when utilizing Bior 4.4 method.

4- Even the images produced after the two compressions stages are similar in appearance in all cases. Figures 7 and 8 shows the results of compression the proposed image by using spiht compression algorithm

with Bior 5.5 and Bior 6.8 Biorthogonal wavelet methods for first compression stage, and ezw compression algorithm with Bior 5.5 and Bior 6.8 Biorthogonal wavelet methods for second compression stage respectively.
5- Also, it can be said from the practical results that utilizing the compression wdr and aswdr compression algorithms produce a worse result as compared with other compression algorithms.

- Table 4 submits the results of metric features for compression procedure to tested image by using different coupled of compression algorithms depend on (Haar + Haar) wavelet methods. With number of coding loop equal to 12.

In order to obtain convincing results regarding image compression, we will continue to make all possible options in practical trials. In this case, the Haar wavelet method was used as a wavelet method for the two stages of compression, because it proved highly effective in the previous practical experiments results. So, the Haar wavelet method was used for the first and second compression stages with different compression algorithms, as shown in table 4. Also the number of maximum coding loop for two compression stages was fixed at 12, because it gave satisfactory results in practical experiments, and the result images have visually convenient. From the gained practical results, it can be confirmed that spith algorithm is the best compression scheme, followed by stw, and this mode is close to the results of ezw.

- From the above practical results, it becomes clear to us that the process of obtaining better compression performance depends on the following basic parameters: choosing the appropriate wavelet method, compression algorithm and in addition selecting the best adapted number of coding loops. In this case, we would like to proceed to an effective change by choosing a type of wavelet transform that gives higher ability to compress the image data and will improve the compression performance. By selecting the Bior4.4 instead of Haar wavelet**,** for the two compression stages.

Table 5 submits the results of compression procedure for tested image by using different coupled of compression algorithms depend on (Bior 4.4 + Bior 4.4) wavelet methods for the two compression stages, the results can be compared through the performance metrics for each compression stage. With number of encoding loop equal to 12.

The practical experiment results that are obtained in this table containing performance metrics of the compressed image. From the practical results it can be said that the compression algorithm spiht is the best, followed by stw algorithm, then ezw.

- Through the previous practical experimental results that obtained from different methods of wavelet transform, the best and worst performance metrics results were taken into consideration. The algorithms of image compression spiht and stw were chosen that gave the best results with different wavelet methods. On the other hand, the selection of images compression algorithms wdr and ezw, will gave a worse performance metrics result.

Table 6 submits the results of compression procedure for tested image by using (wdr + ezw) and (spiht +stw) coupled compression algorithms depend on different wavelet methods. Figure 22 shows the clear difference in the performance metrics values for the first and second image compression stages.

- From what has been listed above, the practical results have been summarized in the following figures, explaining the different choices of compression algorithms and wavelet methods in addition to the number of coding loop chosen for each case.

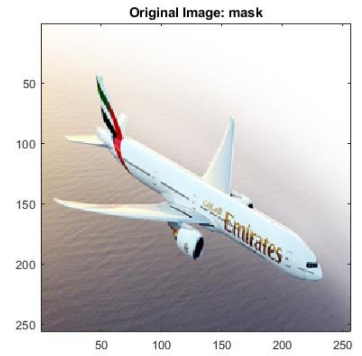
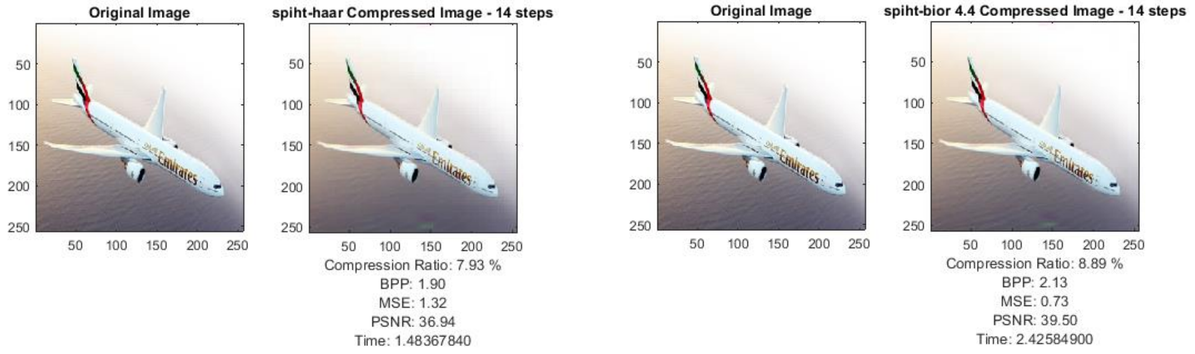
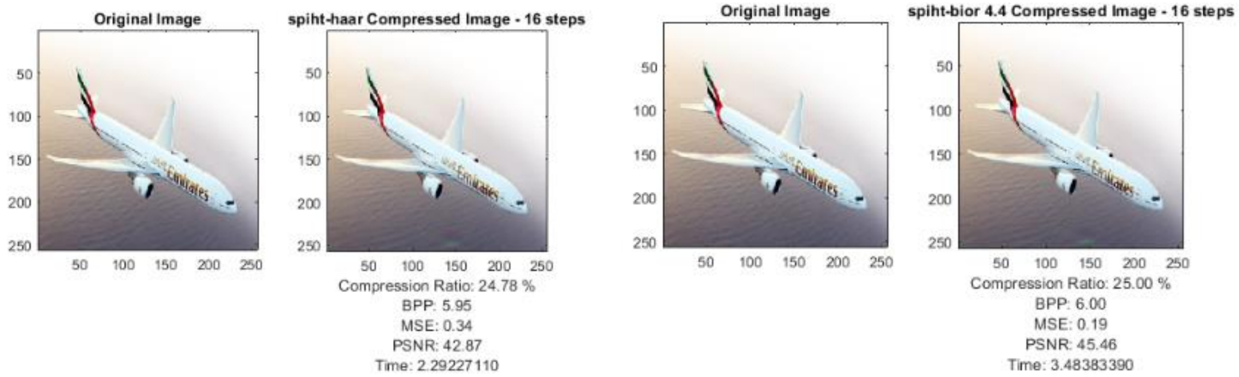


Figure 3. The true color test image



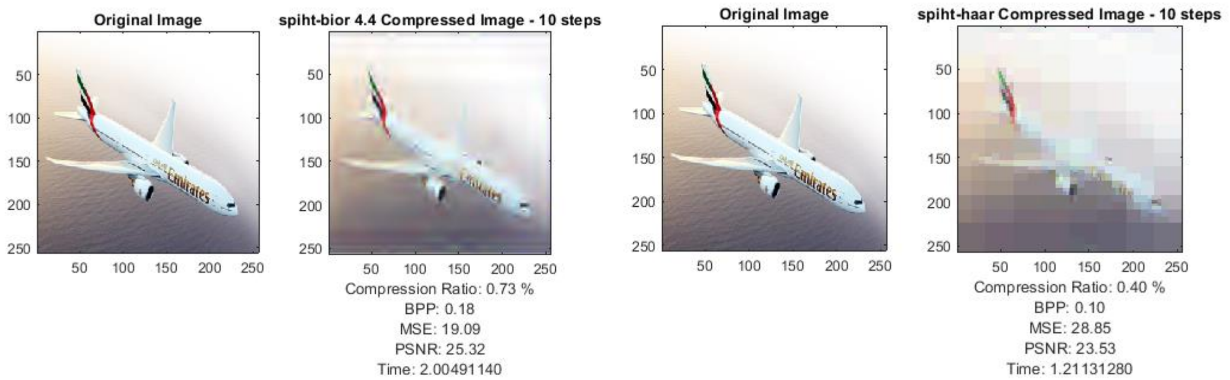
(a) (b)

Figure 4. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using spiht compression algorithm based on Haar wavelet method. With number of coding = 14 loop



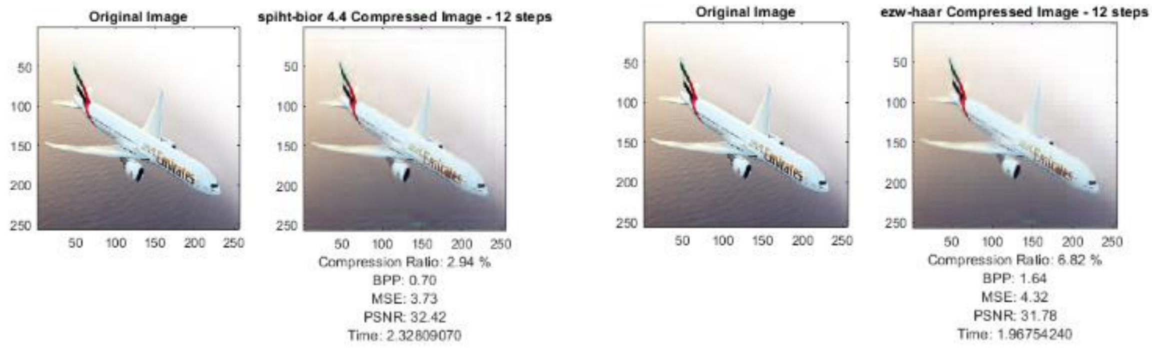
(a) (b)

Figure 5. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using spiht compression algorithm based on Haar wavelet method. With number of coding = 16 loop



(a) (b)

Figure 6. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using spiht compression algorithm based on Haar wavelet method. With number of coding = 10 loop



(a) (b)

Figure 7. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using ezw compression algorithm based on Haar wavelet method. With number of coding = 12 loop

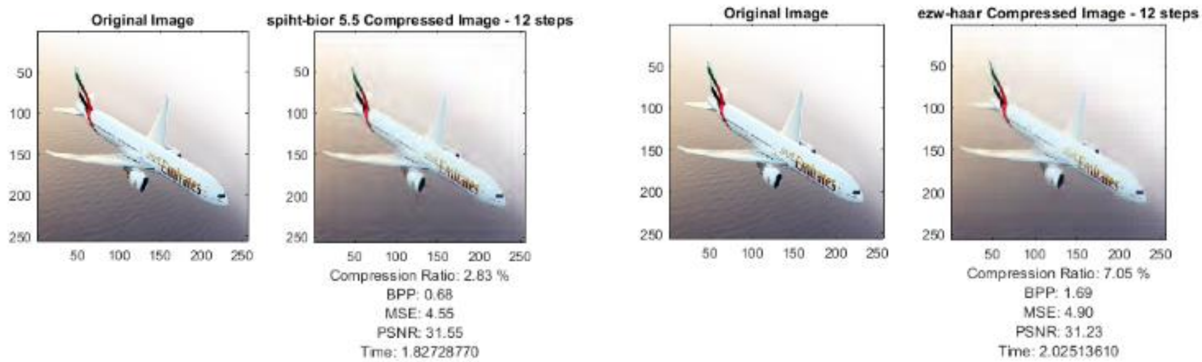
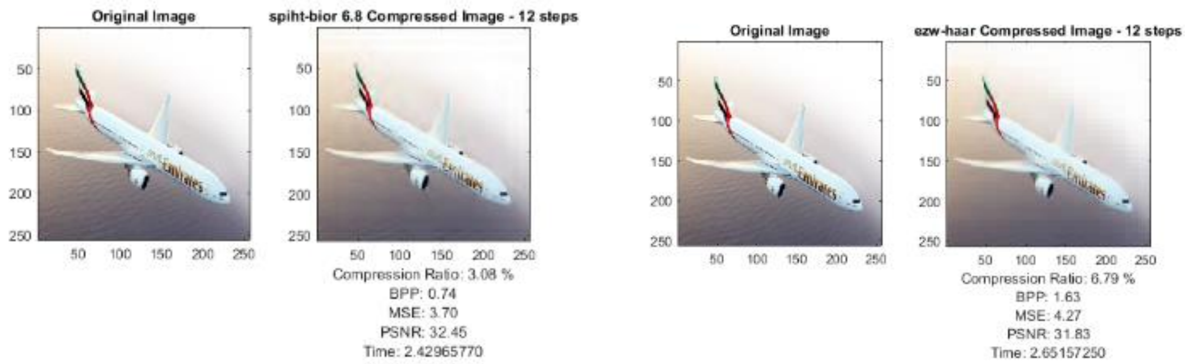
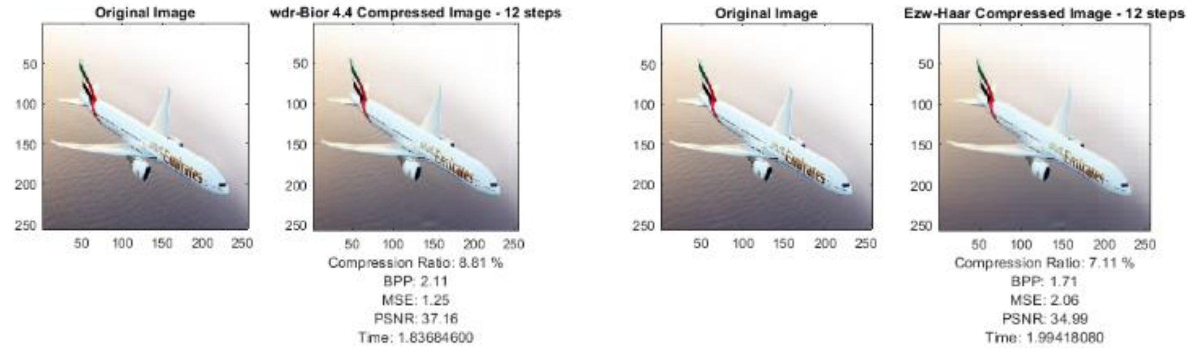


Figure 8. The result of (a) 1st compression by using spiht compression algorithm based on Bior 5.5 wavelet method, and (b) 2nd compression by using ezw compression algorithm based on Haar wavelet method. With number of coding = 12 loop



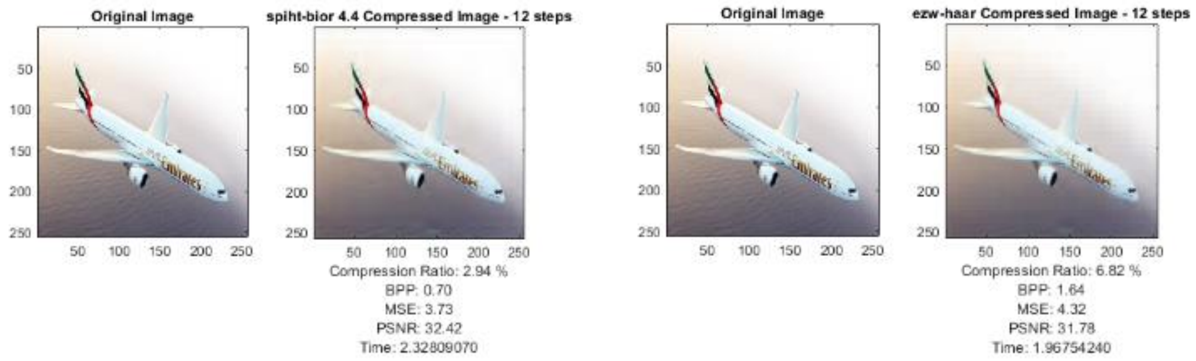
(a) (b)

Figure 9. The result of (a) 1st compression by using spiht compression algorithm based on Bior 6.8 wavelet method, and (b) 2nd compression by using ezw compression algorithm based on Haar wavelet method. With number of coding = 12 loop



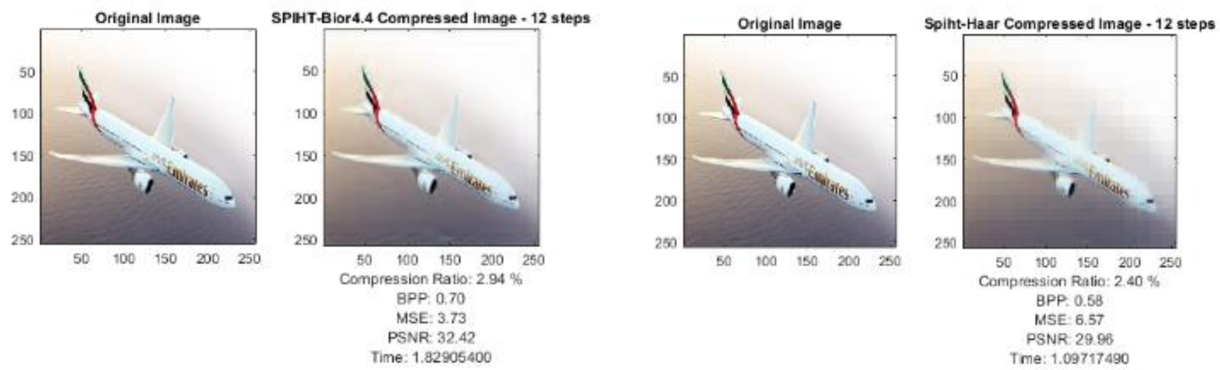
(a) (b)

Figure 10. The result of (a) 1st compression by using wdr compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using ezw compression algorithm based on Haar wavelet method. With 12 loop



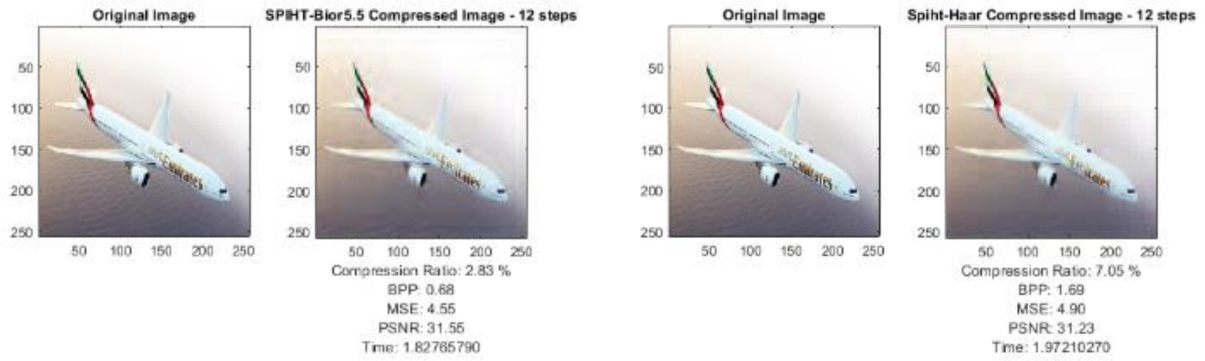
(a) (b)

Figure 11. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using ezw compression algorithm based on Haar wavelet method. With 12 loop



(a) (b)

Figure. 12. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using spiht compression algorithm based on Haar wavelet method. With number of coding = 12 loop



(a) (b)

Figure 13. The result of (a) 1st compression by using spiht compression algorithm based on Bior 5.5 wavelet method, and (b) 2nd compression by using spiht compression algorithm based on Haar wavelet method. With number of coding = 12 loop

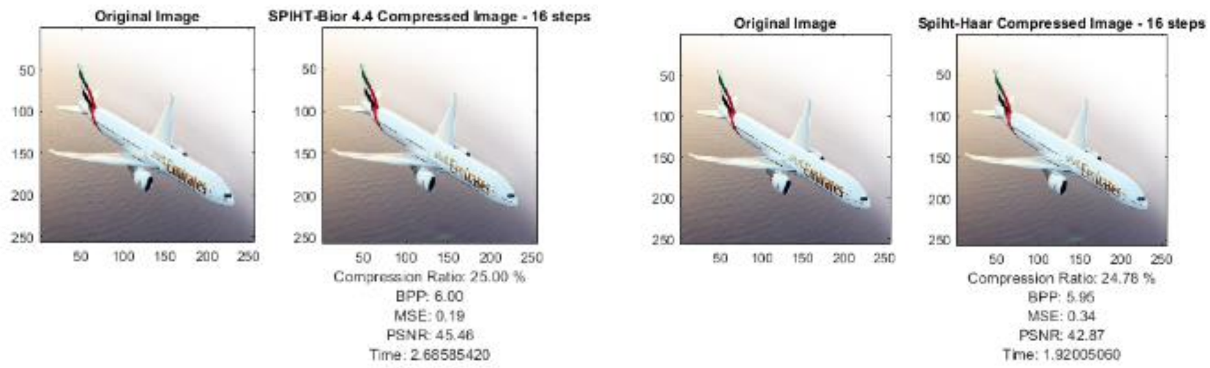
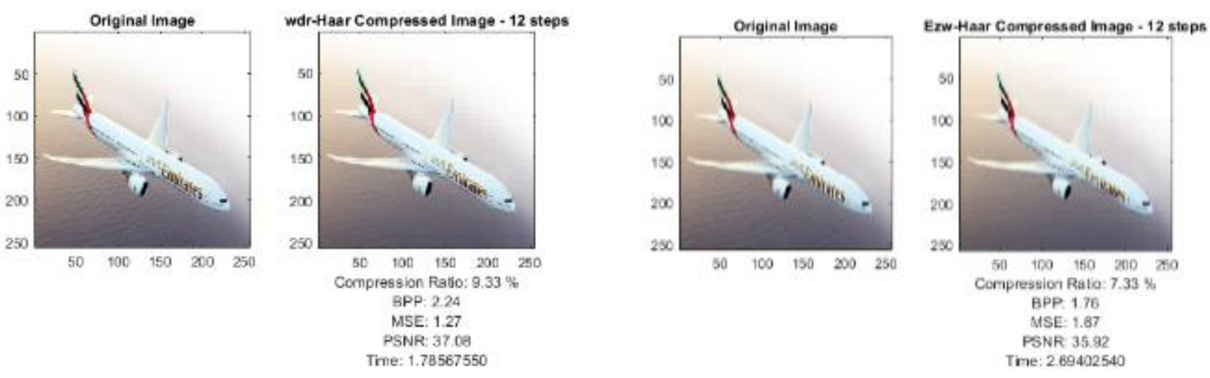


Figure 14. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using spiht compression algorithm based on Haar wavelet method. With number of coding = 16 loop



(a) (b)

Figure. 15. The result of (a) 1st compression by using wdr compression algorithm based on Haar wavelet method, and (b) 2nd compression by using ezw compression algorithm based on Haar wavelet method. With number of coding = 12 loop

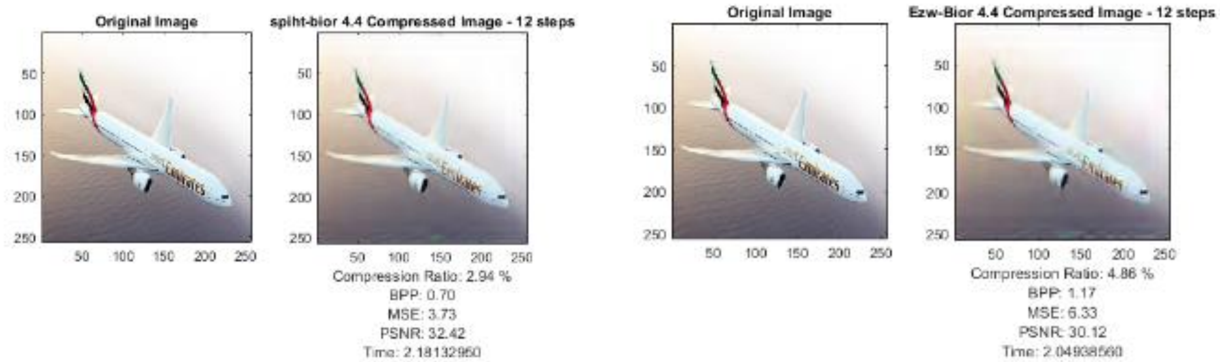


Figure. 16. The result of (a) 1st compression by using spiht compression algorithm based on Bior 4.4 wavelet method, and (b) 2nd compression by using ezw compression algorithm based on Haar wavelet method. With number of coding = 12 loop

Table 1. The results of compression test image by using different coupled of compression algorithms based on (Bior 4.4 + Haar) wavelet methods depend on metric features. With number of coding loops =12

Image title Airplane T1	Performance Measures	compression algorithms							
		stw + ezw	wdr+ ezw	Aswdr + ezw	spiht + ezw	Sphit + stw	wdr + sphit	aswdr + sphit	sphit + sphit
1st compression	CR	3.858	8.812	8.657	2.935	2.935	8.812	8.657	2.935
	BPP	0.926	2.115	2.077	0.704	0.704	2.115	2.077	0.704
	MSE	2.789	1.252	1.252	3.727	3.727	1.252	1.252	3.727
	PSNR	33.675	37.155	37.155	32.416	32.416	37.155	37.155	32.416
2nd compression	CR	7.010	7.110	7.110	6.817	3.456	2.695	2.695	2.396
	BPP	1.682	1.706	1.706	1.636	0.829	0.647	0.647	0.575
	MSE	3.304	2.058	2.058	4.315	5.542	4.163	4.163	6.568
	PSNR	32.940	34.995	34.995	31.780	30.694	31.936	31.936	29.956

Table 2. The results of compression test image by using different coupled of compression algorithms based on (Bior 4.4 + Haar) wavelet methods depend on metric features

Image title Airplane T2	Performance Measures	compression algorithms			
		Loop=14	Loop=16	Loop=10	Loop=10
		sphit + sphit	sphit + sphit	sphit + sphit	sphit + sphit_3d
1st compression	CR	8.890	24.995	0.729	0.544
	BPP	2.134	5.999	0.175	0.131
	MSE	0.729	0.185	19.088	19.088
	PSNR	39.499	45.455	25.323	25.323
2nd compression	CR	7.929	2.852	2.059	2.059
	BPP	1.903	0.684	0.494	0.494
	MSE	1.315	3.511	20.332	20.332
	PSNR	32.122	32.676	25.049	25.049

Table 3. The results of compression test image by using different coupled of compression algorithms based on (Bior 5.5 + Haar) wavelet methods depend on metric features

Image title Airplane T3	Performance Measures	compression algorithms					
		Loop=12	Loop=12	Loop=12	Loop=12	Loop=12	Loop=12
		sphit + sphit	sphit + ezw	sphit + wdr	sphit + aswdr	sphit + stw	Wdr + ezw
1st compression	CR	2.832	2.832	2.832	2.832	2.832	8.772
	BPP	0.679	0.679	0.679	0.679	0.679	2.105
	MSE	4.546	4.546	4.546	4.546	4.546	1.481
	PSNR	31.554	31.554	31.554	31.554	31.554	36.424
2nd compression	CR	2.416	7.046	8.230	7.847	3.482	7.107
	BPP	0.579	1.691	1.975	1.883	0.836	1.706
	MSE	7.103	4.897	4.897	4.897	6.146	2.153
	PSNR	29.616	31.232	31.232	31.232	30.245	34.800

Table 4. The results of compression test image by using different coupled of compression algorithms based on (Haar + Haar) wavelet methods depend on metric features. With number of coding = 12 loop

Image title Airplane T4	Performance Measures	Compression Algorithms					
		Loop=12	Loop=12	Loop=12	Loop=12	Loop=12	Loop=12
		sphit + ezw	sphit + wdr	sphit + aswdr	sphit + stw	ezw + sphit	wdr + ezw
1st compression	CR	2.901	2.901	2.900	2.901	7.888	9.326
	BPP	0.696	0.696	0.696	0.696	1.893	2.238
	MSE	3.368	3.368	3.368	3.368	1.252	1.274
	PSNR	32.856	32.856	32.856	32.856	37.155	37.079
2nd compression	CR	4.733	5.053	4.865	3.910	2.779	7.334
	BPP	1.136	1.213	1.167	0.938	0.667	1.760
	MSE	4.266	4.2665	4.266	3.425	4.638	1.665
	PSNR	31.830	31.829	31.829	32.784	31.467	35.916

Table 5. The results of compression test image by using different coupled of compression algorithms based on (Bior 4.4 + Bior 4.4) wavelet methods depend on metric features. With number of coding = 12 loop

Image title Airplane T5	Performance Measures	Compression Algorithms			
		Loop=12	Loop=12	Loop=12	Loop=1
		sphit + ezw	wdr + ezw	sphit + stw	ezw + stw
1st compression	CR	2.935	8.812	2.935	7.888
	BPP	0.704	2.115	0.704	1.893
	MSE	3.727	1.252	3.727	1.252
	PSNR	32.416	37.155	32.416	37.155
2nd compression	CR	4.856	7.150	3.469	3.754
	BPP	1.165	1.716	0.833	0.901
	MSE	6.330	2.132	4.246	3.081
	PSNR	30.116	34.842	31.850	33.243

Table 6. The results of compression test image by using (wdr + ezw) and (ezw + spiht) coupled compression algorithms based on different wavelet methods

Image title Airplane T6	Performance Measures	Compression algorithm	Bior 4.4 + Haar	Haar + Haar	Bior 4.4 + Bior 4.4
1st compression	CR	wdr + ezw	8.812	9.326	8.812
	CR	sphit + ezw	2.935	2.901	2.935
2nd compression	CR	wdr + ezw	7.110	7.334	7.150
	CR	sphit + ezw	6.817	4.733	4.856

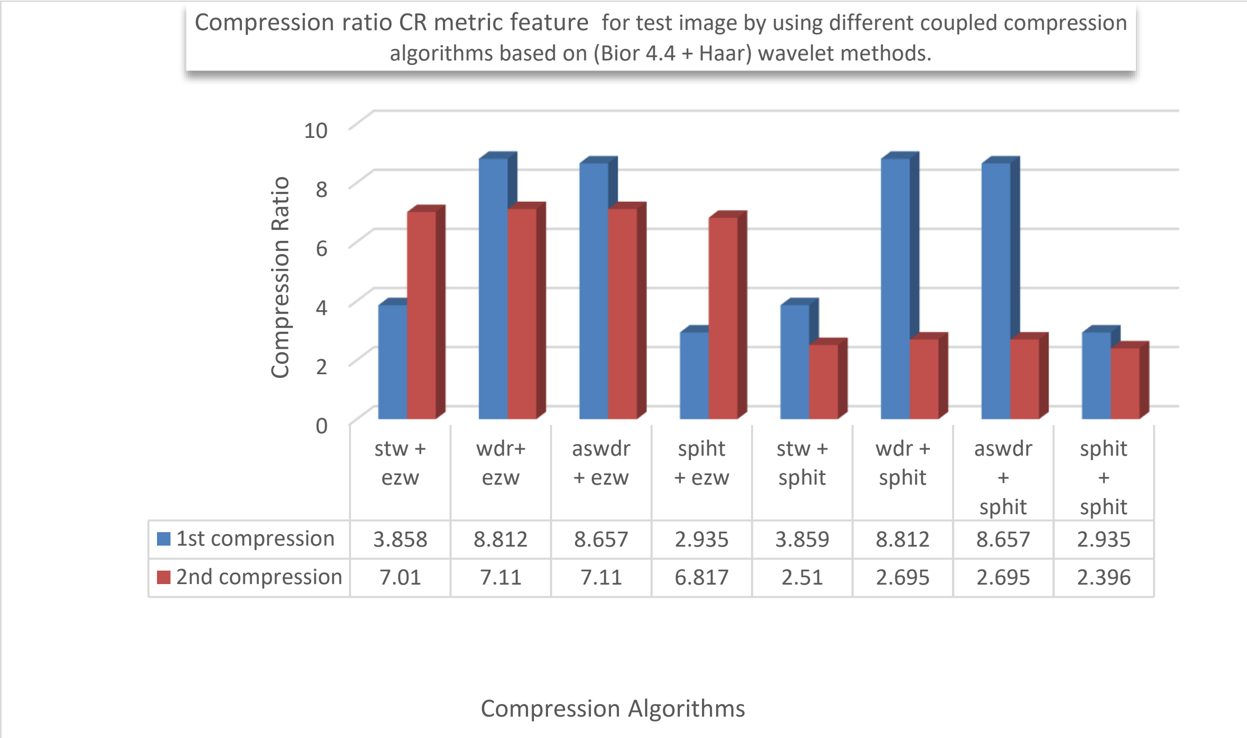


Figure 17. The bar chart of the compression ratio for test image by using different coupled compression algorithms based on (Bior 4.4 + Haar) wavelet methods

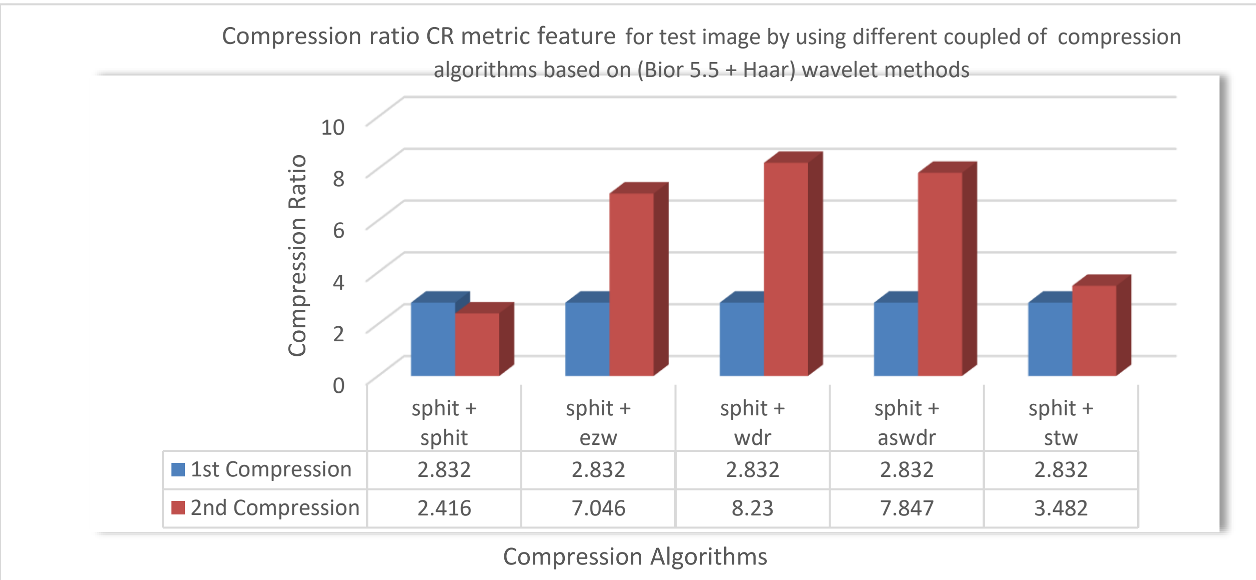


Figure 18. The bar chart of the compression ratio for test image by using different coupled compression algorithms based on (Bior 5.5 + Haar) wavelet methods

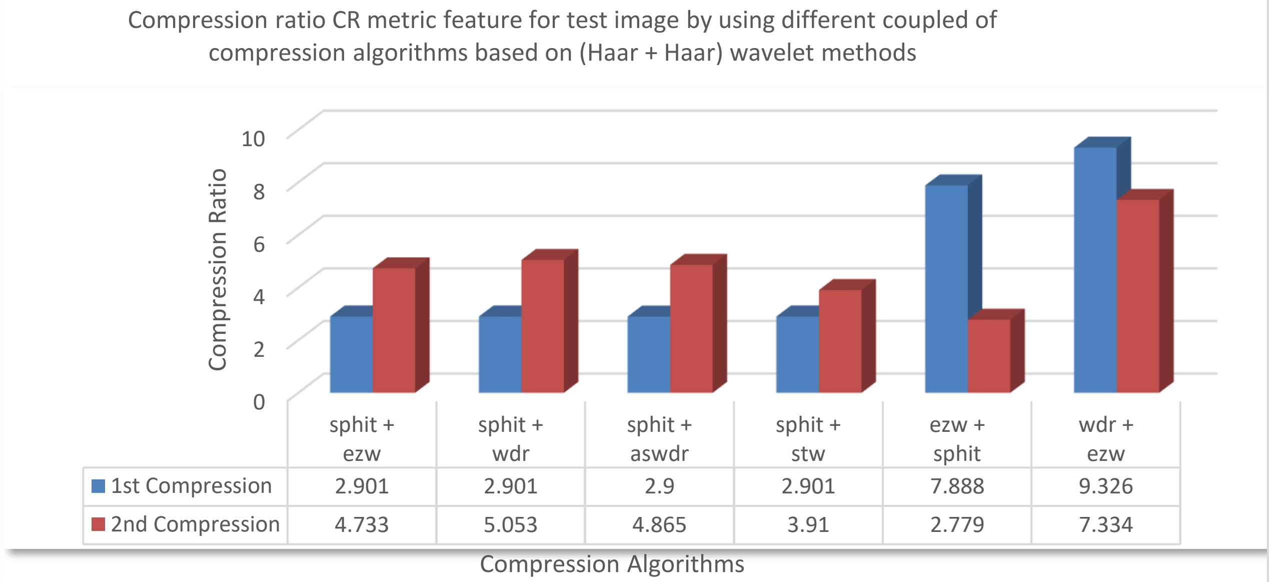


Figure 19. The bar chart of the compression ratio for test image by using different coupled compression algorithms based on (Haar + Haar) wavelet methods

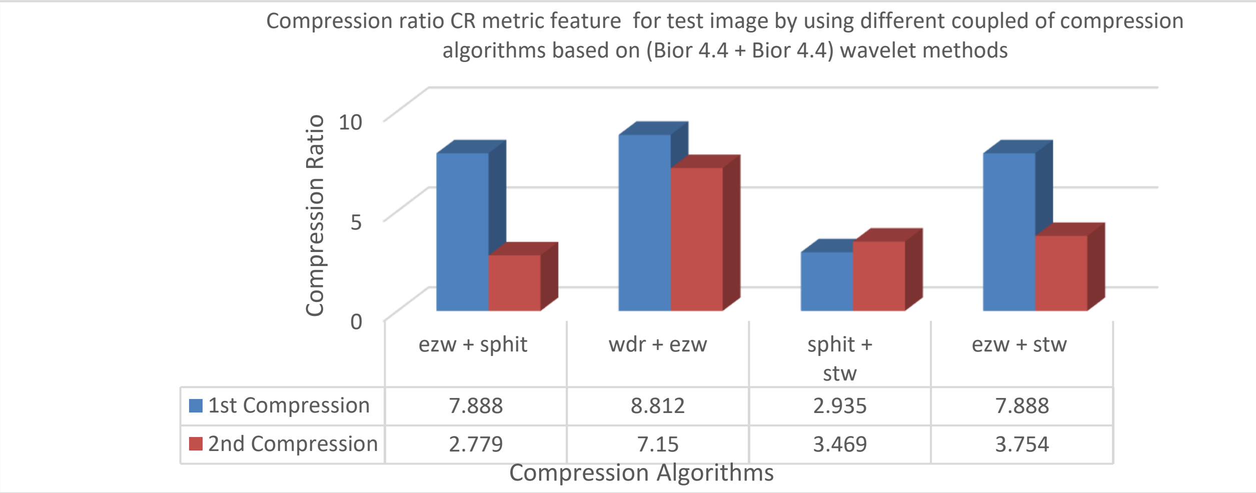


Figure 20. The bar chart of the compression ratio for test image by using different coupled compression algorithms based on (Bior 4.4 + Bior 4.4) wavelet methods

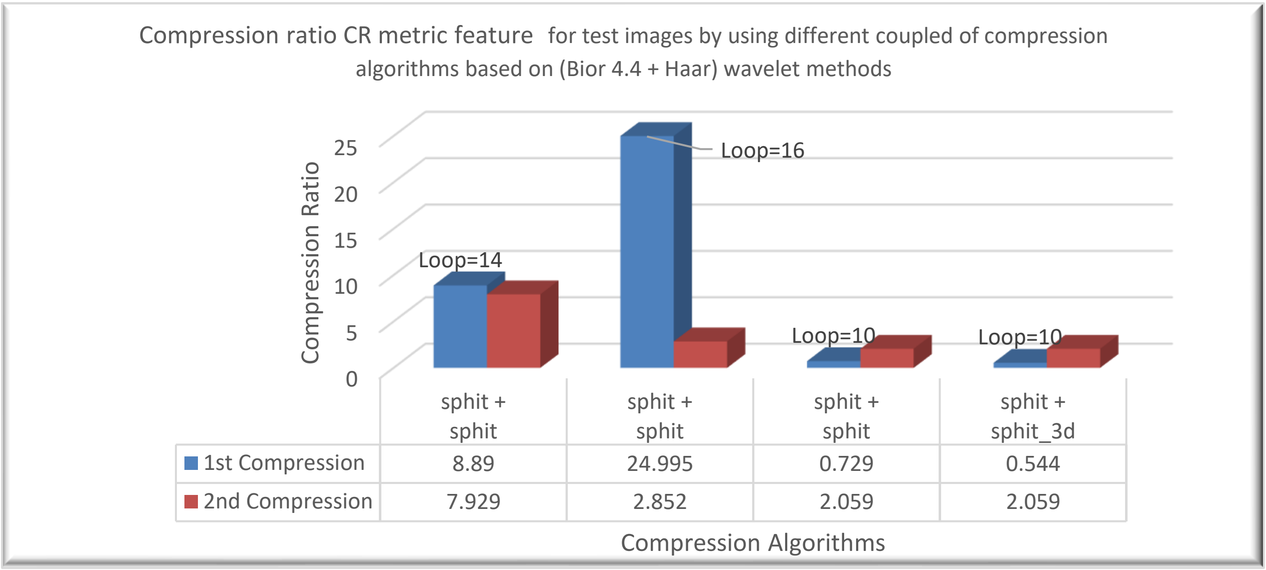


Figure 21. The bar chart of the compression ratio for test image by using different coupled compression algorithms based on (Bior 4.4 + Haar) wavelet methods. With different number of coding loops

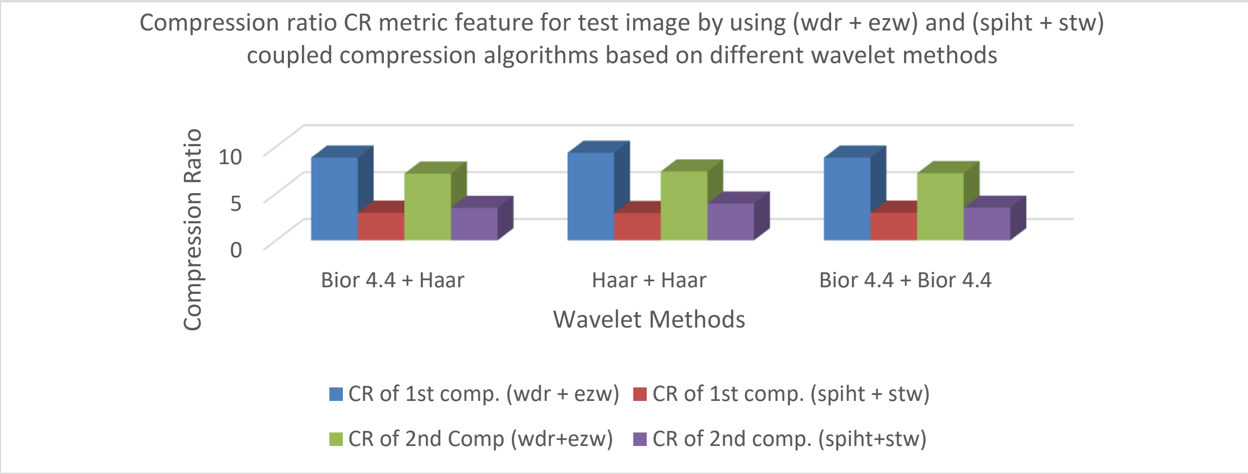


Figure 22. The bar chart of the compression ratio for test image by using (wdr + ezw) and (spiht + stw) coupled compression algorithms based on different wavelet methods

7. Conclusion

This study will have carried out an advanced compression technique that contain a coupled algorithms of image compression by utilizing different algorithms which based on biorthogonal and Haar wavelet transform, the performance metrics for tested true HD color image will be studied. Among the various wavelet families, there are two types that have been focused on in this paper, namely, Haar and Bior wavelets, which gave convincing results for performance metrics. Many compression algorithms will be experimentally tested on elected HD true color image. From practice results that gained, we show that the using of more sophisticated actual compression algorithms like (spiht + stw) coupled compression algorithms, will offer a good performance on various estimation measurements if matching with other coupled compression methods that used for still true color image, while preserving the visual perception of the original image. Through the practical results, we can conclude that the following main parameters have a great influence on image compression process according to the required metrics. Which are the selection of compression algorithms, wavelet methods and in addition the number of coding loop chosen for each case. By increasing the number of coding loops parameter; it leads to better recovery, but a worse compression ratio, fine practical results were obtained with number of coding loop equal to 12.

In this study, the distinction was made by taking several types of image compression algorithms, depending on a selection of wavelet methods, and knowing the effect of these methods on image compression parameters. Hence, the best pair of these methods was determined.

An essential measure of achieved image compression process is taken by compression ratio CR and the ratio of bit-per-pixel BPP. The CR and BPP metrics are an important component of image compression. Keep in mind that an image with high color contrast has a high CR, while the image with low color contrast has a low CR.

Through the results of the image compression metrics in two stages, the best result was obtained when the compression ratio metric CR was equal to 2.3%, and this metric indicates that the compressed image can be stored using 2.3% of the original image data size. While the BPP which represent the bit number that used to store one pixel of true color image is equal to 0.575.

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