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# A COMPARATIVE ANALYSIS OF IMAGE COMPRESSION BY DIFFERENT WAVELETS TECHNIQUES USING MATLAB

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## Abstract

An image generally needs considerable storage and resources, so image compression is an effective technique to overcome these requirements. This paper includes different wavelet techniques used for data compression or image compression. Image Compression generally followed in computer graphics such as in Internet, digital library, mobile and multimedia. The volume of information stored in an image or video can be compressed by using Image compression techniques. There are many image compression techniques available such as JPEG, DCT (Discrete Cosine Transform), DWT (Discrete Wavelet Transform), Wavelet, Huffman Coding, Quantization, Lossy Compression or Lossless Compression. The main objective of this paper is to select the appropriate method of wavelet towards compression of the image. Also the quality of the reconstructed image has been estimated in terms of image quality metrics such as PSNR (Peak Signal-to-Noise ratio) and CR (compression ratio). In this paper, the various wavelets methods such as Haar, Daubechies, and Biorthogonal, Coiflets and Symlet wavelet are applied to an image and then their qualitative and quantitative analysis results are compared in terms of PSNR values, MSE and compression ratios.

***Keywords:*** Image Compression, Wavelet techniques, CR (compressiond ratio), PSNR (Peak Signal-to-Noise ratio), MSE (Mean Square Error), DCT, DWT.

## INTRODUCTION

The multimedia like images, audio and video formats requires high storage capacity and transmission bandwidth. The only method which can reduce the amount of data needed for the representation of image is known as Image Compression method. This method makes the image compact in size and reduces the storage requirements. The current advancement in multimedia and internet applications generally requires this kind of technology. To achieve these requirements in the area of image compression, different useful and reliable methods have been developed. As we know the task is not only limited to compression but also to maintain or enhance the size and the pixel density of these images. Hence, efficient techniques are needed to preserve their size and reusability. The wavelets are generally considered as a mathematical tool which is used as a systematic decomposing function as they permits a function to be outlined in terms of a coarse overall shape, plus details from broad to narrow range regardless of whether the function of interest is an image wavelet. However wavelets have their own roots in approximation theory and have cubeen implemented to many problems of computer graphics. These graphics application incorporates image editing, image compression etc. [1]. The wavelets transform used in image processing has present a very flexible tool to develop innovative techniques for solving various engineering difficulties [2], Image transform provides the ideas underlying EZW have been notably modified and enhanced [3]. Wavelet allows a function to be detailed in the form of a coarse overall shape with details that ranged from broad to narrow. Nevertheless of whether the function is an image, a curve, or a surface, wavelets provides an refined technique for representing the levels of detail present [4], described an additional scheme for encoding wavelet coefficients, termed embedded zero tree coding (EZW) [5]. The compression and noise reduction of image can only be achieved by the wavelet transforms resulting improved quality of image. This is accomplished by a reversible wavelet decomposition followed by selective removal of unacceptable noise components by reconstructing the image from wavelet transform [6], Bi-orthogonal wavelets expands the family of orthogonal wavelets and found applications in signal and image processing [7]. Decomposition generally passed a signal through two complementary filters emerges as two signals known as approximation and details. Discrete Wavelet Transform (DWT) can be effectively utilized in image coding applications because of their data reduction capabilities [8]. Bahrami summarized that Huffman coding is an entropy encoding algorithm used for lossless data compression. The term refers to the use of a variable-length code table for encoding a source symbol , where the variable-length code table has been derived in a particular way based on the estimated probability of occurrence[9]. Reddy suggested that the wavelets provide good compression ratios for high resolution images and perform better than competing technologies like JPEG, in terms of signal to noise ratio and visual quality [10]. Bhawna Gupta showed that the Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable leve[11]. Sharma analyzed five different Wavelet based Image Compression techniques. The techniques involved in the comparison process are Embedded Zero tree Wavelet (EZW), Set Partitioning In Hierarchical Trees (SPIHT), Spatial-orientation Tree Wavelet (STW), Wavelet Difference Reduction (WDR) [12]. Kaur used Lossy techniques such as Quantization, Transform coding, Block Transform Coding or Lossless techniques such as Run Length Coding, Lossless Predictive Coding, Multi-resolution Coding. The performance of all these techniques have been analyzed on various parameters like MSE and PSNR [13].

A basic aim of image or data compression is to reduce the redundancies. The basic objective of the Image compression is to compress the number of bits (size) and represent an image by removing the correlation either between neighboring pixels.

## TYPES Of COMPRESSION SYSTEMS:

There are basically two types of compression systems available, such as

a. Lossy compression system b. Lossless compression system

a. Lossy Compression System

In Lossy compression techniques, some of the finer details in the image can be renunciated for the sake of saving a little more bandwidth or storage space.

b. Loss less compression system

The Lossless Compression System aims to minimize the bit rate of the compressed output without distorting the image. The decompressed bit-stream is identical to original bit-stream.

### Role of Wavelets in Image Compression

Wavelet transforms becomes one of the most promising and powerful tool for signal representation. At present, it has been used in image processing, data compression, and signal processing. In case of image compression, the wavelets tool decomposed the images into order of increasing resolutions. The wavelet transforms, specifically for orthonormal and biorthogonal wavelets have appeared as a new mathematical tool for multi-resolution decomposition purpose. The main application of the wavelet transforms are found in the compression and noise reduction of image. This improves the quality of an image.

## MEASURE OF IMAGE QUALITY

The mean square error (MSE), peak signal to noise ratio (PSNR) between the original and compressed images is also known as Standard distortion measure [4]. PSNR parameter is not only used to determine the image quality, but also used as a standard level of similarity between reconstructed image and the original image. It has been noticed that the larger PSNR will ultimately make better image quality, expressed in decibels (db), The PSNR can be defined as,

$$PSNR = 20 * \log_{10}\left(\frac{255^2}{MSE}\right) \qquad \text{Eq. (1)}$$

The known and most frequently used objective assessments of the quality of a compressed image is mean square error (MSE) and peak signal to noise ratio and these are generally based on error measurement in the Norm, these measurements represent quality by a single number which is to be considered as aggregate measures of compression error. A least value of MSE means lower error. This can be given by the following equation.

$$MSE = \frac{1}{m,n}\sum\sum\left(X_{i,j} - Y_{i,j}\right)^2 \qquad \text{Eq. (2)}$$

Where X is original image, Y approximation of decompressed image and m, n are dimensions of the image.

**Compression Ratio (CR)**

Another quantitative parameter is the compression ratio which measures the performance of compression method. Compression ratio can be defined as –

Compression Ratio = ((original image size))/((compressed image size)) Eq. (3)

The objective of the compression ratio is to measure the capacity of image data compression, and can be determine by comparing the size of the original image against compressed image. Compression ratio (CR) can also be defined as the ratio of the number of nonzero elements in original matrix to the number of nonzero elements in updated transformed matrix.

## TYPES Of WAVELETS FAMILIES:

Following are the wavelets families which are used for the compression analysis:

**Haar Wavelets**

The base vectors of the Haar matrix are sequentially ordered. The Haar wavelet is a sequence of rescaled -square-shaped functions. The main disadvantage of Haar wavelet is that it is discontinuous type and hence not differentiable and resembles a step function. This property is generally considered to be as an advantage to inspect signals with sudden transitions, like tool failures monitoring in machines. It represents same wavelet as Daubechies 1.

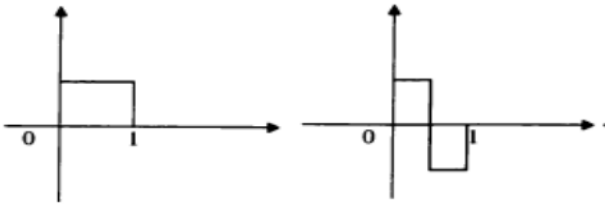


Fig 1: Scaling and Wavelet functions of HAAR

**Daubechies Wavelets**

A major challenge comes for the development of wavelets was the scaling functions that are compactly supported, orthogonal and continuous. These scaling functions were first developed by Ingrid Daubechies. The Daubechies are the low pass filter h and are equivalently comes under the Fourier series. Ingrid Daubechies developed compactly supported orthonormal wavelets and makes discrete wavelet analysis practicable [7].

**Symlet Wavelets**

Symlets are the symmetrical waveletsas proposed by Daubechies in modifications to the Db family, which selects each other set of roots to have nearer symmetry with linear complex phase. The remaining other properties of Daubechies and Symlet families are similar [4,8]. Symlets, found to be better when applied to signal and improves the Signal to Noise Ratio (SNR) of reconstructed image. It has been observed that the Symlets are efficient in denoising applications.

**Coiflet Wavelts**

The Coiflets and the Daubechies wavelets are very much similar in a certain level. Coiflets are constructed with vanishing moments for both of the wavelet function φ(x) and scaling function ø

(x). The property of symmetry in coiflets is generally needed in signal analysis work, however coiflet method is moderately rigid in visualizing any frequency of interest, its discrete form is useful for digital implementation.
Some useful features of this wavelets are as follows:
i) This method gives good approximation of polynomial functions at various resolutions, hence improves the computation efficiency of the analysis.
ii) Coiflet transform presents both frequency and time information in an integral scheme.

**Biorthogonal Wavelets**

Biorthogonal wavelets lead the family of orthogonal wavelets and have applications in man signal and image processing area. The periodic biorthogonal wavelet transforms are precieve by Matrix-vector products with sparse, structured matrices [7, 9]. An open fact in filter theory community is that when same FIR filters are used for image decomposition and reconstruction process, the symmetry phenomenon and Perfect reconstructions are totally antagonistic. To overcome this difficulty, dual scaling and wavelet functions with following properties are used:
(i)The Calculation algorithms maintained to be simple and set zero outside a segment.
ii) Symmetrical filter are used.
iii) Functions used to be for calculations are easier to build than those used in Daubechies wavelets.

**PROPOSED ALGORITHM :**

The following steps are used in compressing, decompression and reconstructed of image are:-
1. Read the image parameter form image dimension (512 × 512, 256 × 256, &128 × 128)
2. Apply 2D discrete wavelet transform (2D-DWT) using various wavelets and decompose the image from 1-level to 5 –level. ( By using 2D wavelet decomposition with respect to a dwt calculate from decomposition level with the estimate coefficients matrix CA and detail coefficient matrixes CH, CV, CD (horizontal, vertical & diagonal respectively) which is obtained by wavelet decomposition of the input matrix).
3. We have applied compression process with desired wavelets family and compressed image.
4. We can also reconstruct an estimate of the original image by applying the corresponding inverse transform process.
5. Calculate compression ratio , mean square error and peak signal noise ratio values for using different wavelets are apply for corresponding reconstructed images or original image.
6. The same process is repeated for different resolution of images and compares its parameter and result.

## IMPLEMENTATION AND RESULTS

In the proposed analysis work, different color images with varying content of details are used for two level decomposition as well as reconstruction using different wavelets families like Haar, Daubechies, Symlets, Coiflets and Biorthogonal wavelets. By using different steps of image processing a varying types of metrics PSNR, CR and MSE so obtained are noticed for analysis after simulation in matlab software.

**Image 1: High Detailed Image**

Figures.2 to 6 and Table.1 of High detailed image clearly imply that, of all daubechies wavelets, Db2 produced high value of PSNR while the Compression ratio is more for Db10 family, Coif1 and Coif4 produced better values of PSNR and CR. In case of symlets, SYM2 and SYM4 wavelets have better PSNR, while CR values are better in SYM2 and SYM8. Bior4.4 and Bior1.3 generated large values of PSNR and also the CR values are higher in Bior2.8 and Bior4.4.

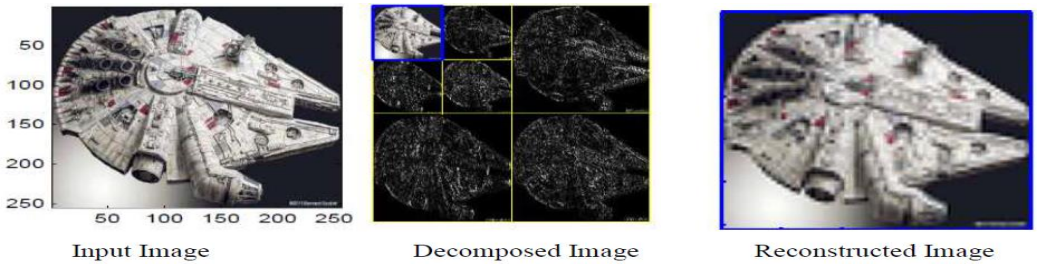


**Figure 2:** Debauchies Image (High detail)

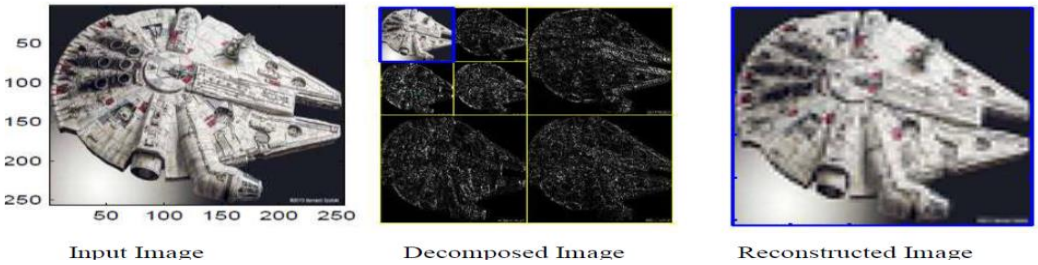


**Fig 3** Coiflet Images

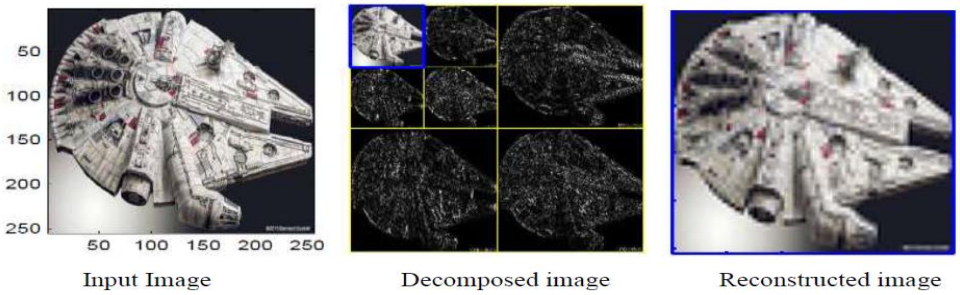


**Fig 4** Symlet Images

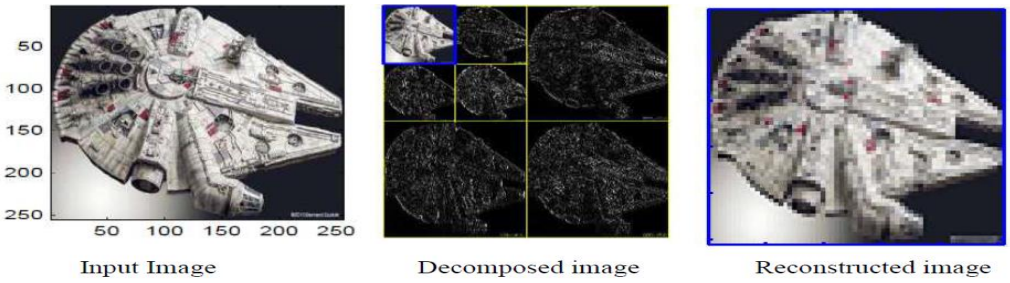


**Fig 5** Bi-orthogonal Images

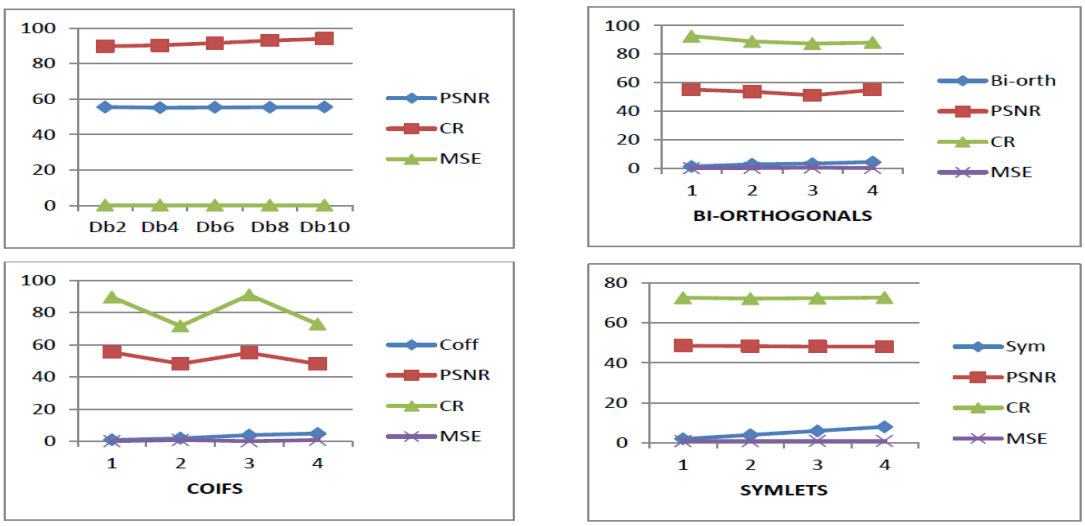


**Fig 6** Comparison of PSNR, MSE & CR of different Wavelets on high detail Image

**Table 1 (a, b,c,d).** Performance comparison between different wavelets on high detail image

**Observation Table 1 (a)**

| DbN | PSNR | CR | MSE |
|---|---|---|---|
| Db2 | 55.48 | 89.73 | 0.1841 |
| Db4 | 55.16 | 90.33 | 0.1983 |
| Db6 | 55.33 | 91.64 | 0.1905 |
| Db8 | 55.36 | 93.01 | 0.1893 |
| Db10 | 55.42 | 94.02 | 0.1866 |

**Observation Table 1 (b)**

| Bi-orth | PSNR | CR | MSE |
|---|---|---|---|
| 1.3 | 55.09 | 92.53 | 0.2014 |
| 2.8 | 53.74 | 88.83 | 0.2747 |
| 3.3 | 51.2 | 87.26 | 0.4936 |
| 4.4 | 55.01 | 88.06 | 0.2051 |

**Observation Table 1 (c)**

| Coff | PSNR | CR | MSE |
|---|---|---|---|
| 1 | 55.47 | 89.6 | 0.1843 |
| 2 | 48.23 | 71.69 | 0.9773 |
| 4 | 55.05 | 91.01 | 0.2033 |
| 5 | 48.14 | 72.81 | 0.998 |

**Observation Table 1 (d)**

| Sym | PSNR | CR | MSE |
|---|---|---|---|
| 2 | 48.6 | 72.55 | 0.8968 |
| 4 | 48.38 | 72.15 | 0.9449 |
| 6 | 48.16 | 72.35 | 0.9937 |
| 8 | 48.13 | 72.64 | 0.999 |

**Medium Image Detailed Image:**

Figures 7 to 11 and Table 2 of medium detailed image clearly imply that, Db2 and Db4 wavelets have better values of PSNR and higher CR values are observed in Db2 and Db10 while the COIF1 and COIF4 wavelet produced large values of PSNR and CR. In the case of Symlets it was observed that SYM8 family generated large values of CR and SYM2 gives higher value of PSNR, However, Bior1.3 gives higher value of CR and Bior2.8 wavelets produced large values of PSNR and CR.

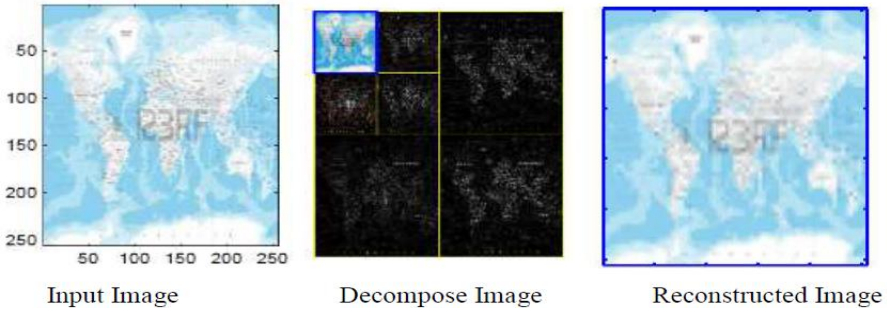


**Fig 7**: Medium detail images Debauchies

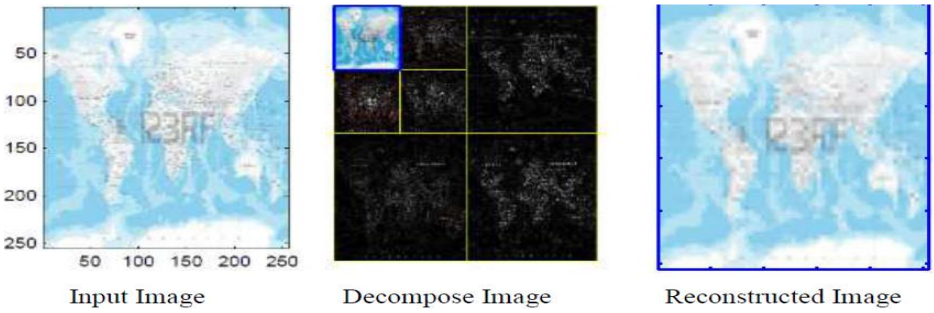


**Fig 8** Medium detail images Symlets

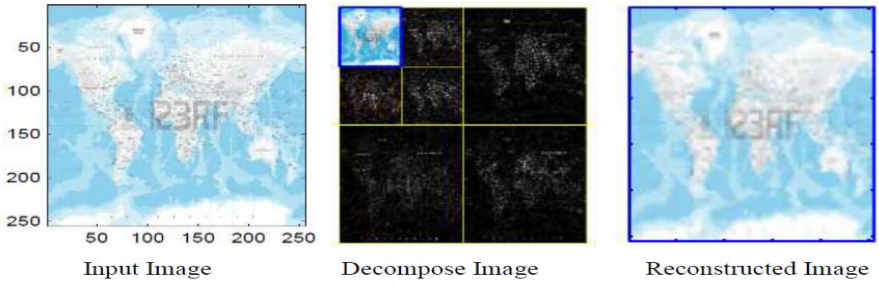


**Fig 9** Medium detail images coif

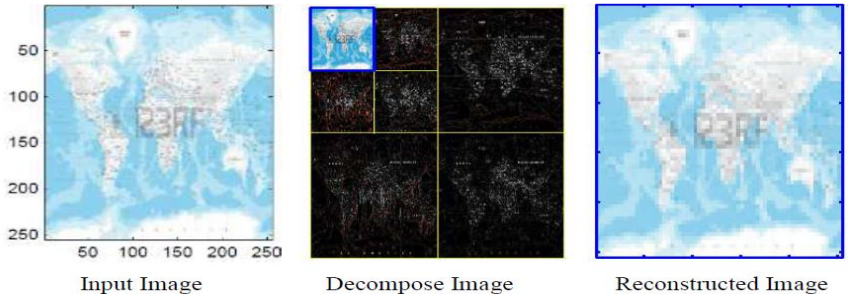


**Fig 10** Medium detail images Bi-orthogonal

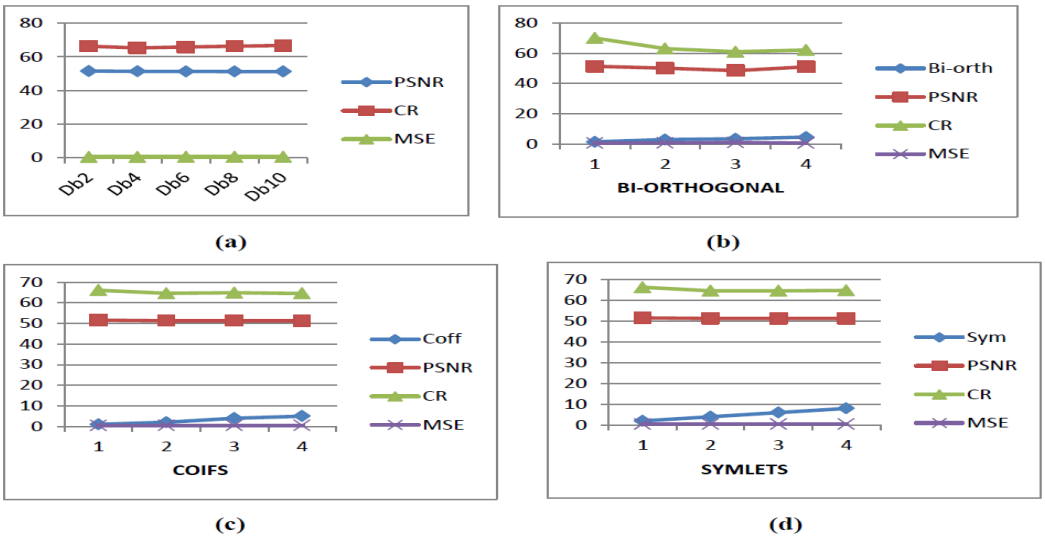


**Fig 11 (a, b, c, d):** Comparison of PSNR, MSE & CR of different Wavelets on medium Image.

The following **Table 2 (a, b, c, d)** summarizes performance comparison between suggested wavelet families .

**Observation Table 2 (a)**

| DbN | PSNR | CR | MSE |
|---|---|---|---|
| Db2 | 51.58 | 66.37 | 0.4519 |
| Db4 | 51.39 | 65.36 | 0.4727 |
| Db6 | 51.33 | 65.86 | 0.4786 |
| Db8 | 51.28 | 66.33 | 0.4846 |
| Db10 | 51.25 | 66.74 | 0.4971 |

**Observation Table 2 (b)**

| Bi-orth | PSNR | CR | MSE |
|---|---|---|---|
| 1.3 | 51.39 | 70.18 | 0.4721 |
| 2.8 | 50.17 | 63.17 | 0.6258 |
| 3.3 | 48.55 | 61.07 | 0.9082 |
| 4.4 | 51.11 | 62.18 | 0.5032 |

**Observation Table 2 (c)**

| Coif | PSNR | CR | MSE |
|---|---|---|---|
| 1 | 51.54 | 66.12 | 0.456 |
| 2 | 51.34 | 64.61 | 0.4772 |
| 4 | 51.33 | 64.87 | 0.4792 |
| 5 | 51.28 | 64.54 | 0.4838 |

**Observation Table 2 (d)**

| Sym | PSNR | CR | MSE |
|---|---|---|---|
| 2 | 51.58 | 66.37 | 0.4519 |
| 4 | 51.35 | 64.69 | 0.4764 |
| 6 | 51.34 | 64.68 | 0.4778 |
| 8 | 51.35 | 64.85 | 0.4763 |

**Image 3: Group Image**

Figures. 12 to 16 and Table 3 of staff group image imply that, Db8 and Db10 wavelets produced high values of PSNR and CR value, on the other hand Coif5 and Coif1 wavelets resulted in better values of CR however better values of PSNR can be achieved in Coif1 and Coif2, In case of Symlets, Sym2 wavelet generated better PSNR and CR values as well. While Bior1.3 wavelet produced better values of PSNR and CR of all bi-orthogonal family wavelets in contrast Bior3.3 wavelet produced the least value of CR.

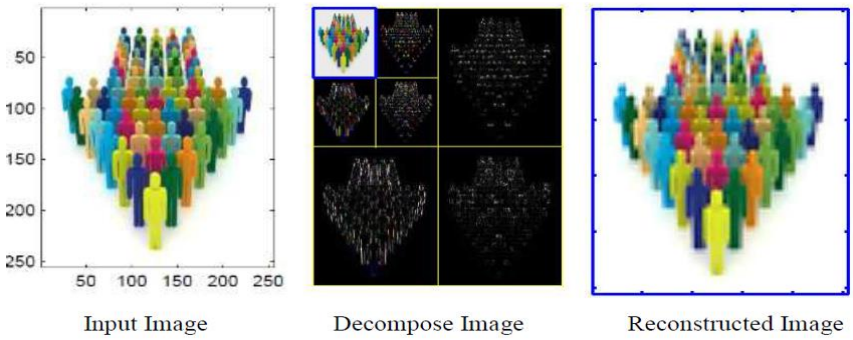


**Fig 12** Group images Debauchies

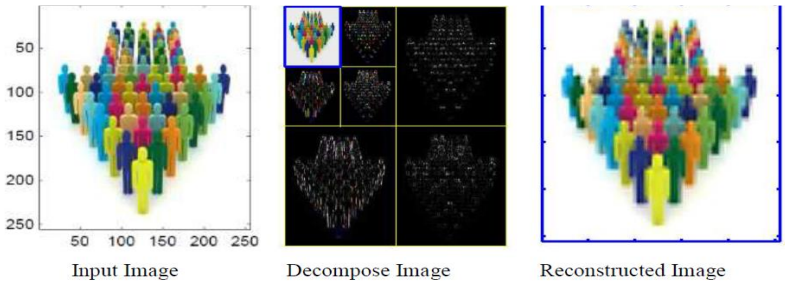


**Fig 13** Group images Symlets

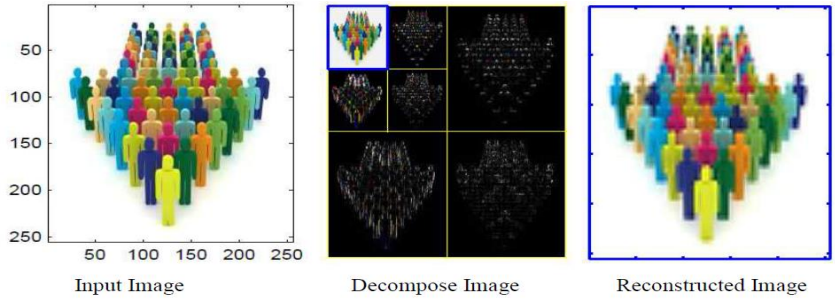


**Fig 14** Group images coif

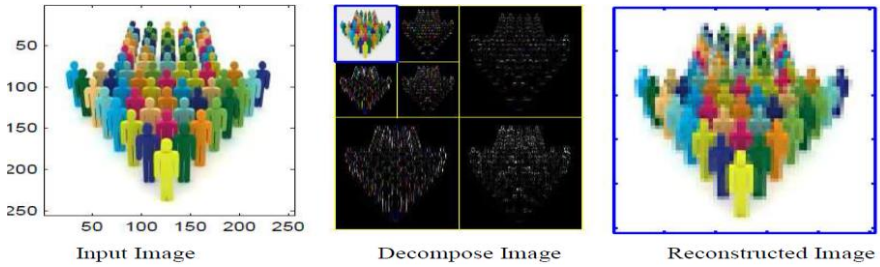


**Fig 15** Group images Bi-orthogonal

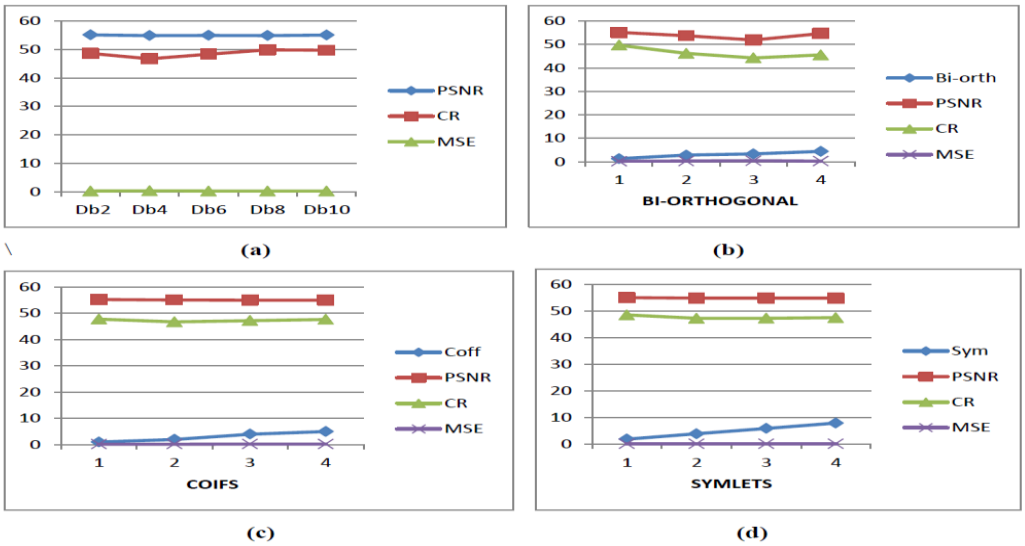


**Fig 16 (a, b, c, d):** Comparison of PSNR, MSE & CR of different Wavelets on group Image.

The following **Table 3 (a, b, c, d)** summarizes performance comparison between suggested wavelet families.

**Observation Table 3 (a)**

| DbN | PSNR | CR | MSE |
|---|---|---|---|
| Db2 | 55.16 | 48.62 | 0.1983 |
| Db4 | 54.92 | 46.76 | 0.3096 |
| Db6 | 54.97 | 48.36 | 0.2072 |
| Db8 | 54.91 | 49.92 | 0.2098 |
| Db10 | 55.11 | 49.75 | 0.2004 |

**Observation Table 3 (b)**

| Bi-orth | PSNR | CR | MSE |
|---|---|---|---|
| 1.3 | 55.16 | 49.72 | 0.1981 |
| 2.8 | 53.76 | 46.22 | 0.2737 |
| 3.3 | 51.97 | 44.29 | 0.4129 |
| 4.4 | 54.72 | 45.56 | 0.2195 |

**Observation Table 3 (c)**

| Coif | PSNR | CR | MSE |
|---|---|---|---|
| 1 | 55.18 | 47.7 | 0.1971 |
| 2 | 55.01 | 46.67 | 0.2053 |
| 4 | 54.93 | 47.16 | 0.2088 |
| 5 | 54.97 | 47.62 | 0.2072 |

**Observation Table 3 (d)**

| Sym | PSNR | CR | MSE |
|---|---|---|---|
| 2 | 55.16 | 48.62 | 0.1983 |
| 4 | 54.95 | 47.36 | 0.2081 |
| 6 | 54.94 | 47.37 | 0.2083 |
| 8 | 54.93 | 47.59 | 0.209 |

**Single Image:**

Figures 17 to 21 and Table 4 of medium detailed image clearly imply that, Db8 and Db10 wavelets have better values of PSNR and CR, while the COIF1 wavelet produced large values of PSNR and CR. In the case of symlets it was observed that SYM2 family generated large values of PSNR and CR, However, Bior1.3 wavelets produced large values of PSNR and CR, and Bior2.8 gives second higher value of CR, second PSNR value is higher in Bior4.4.

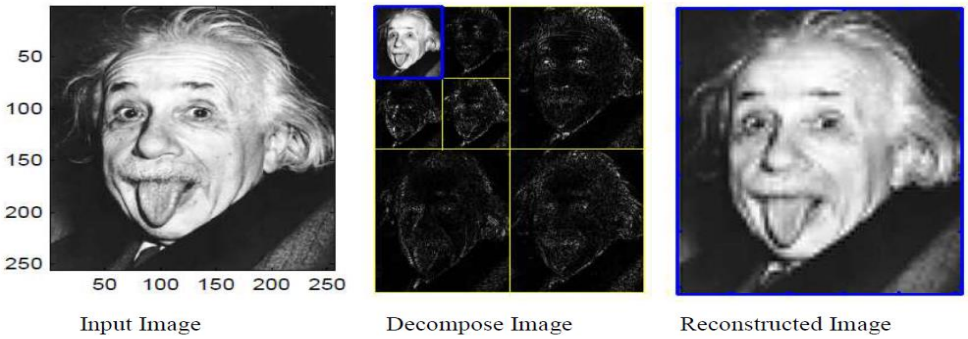


**Fig 17**: Single image Debauchies

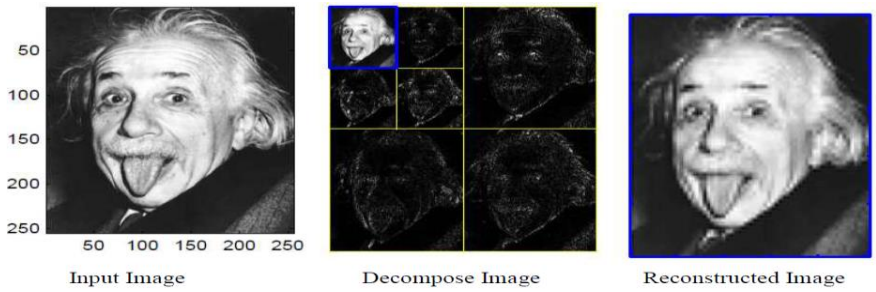


**Fig 18**: Single image Symlets

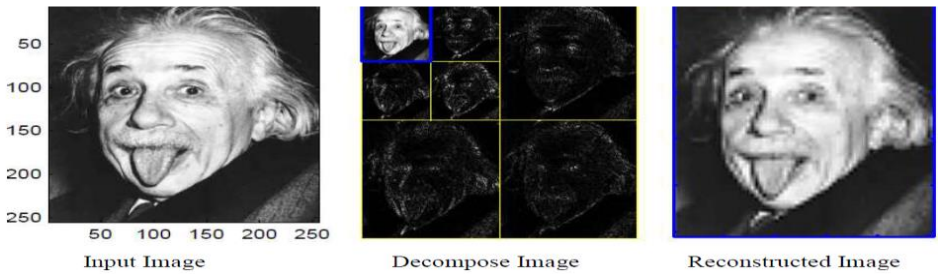


**Fig 19:** Single image Coif

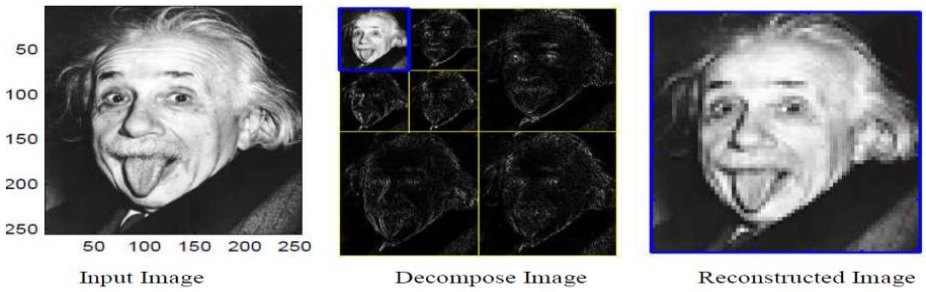


**Fig 20** Single image Bi-orthogonal

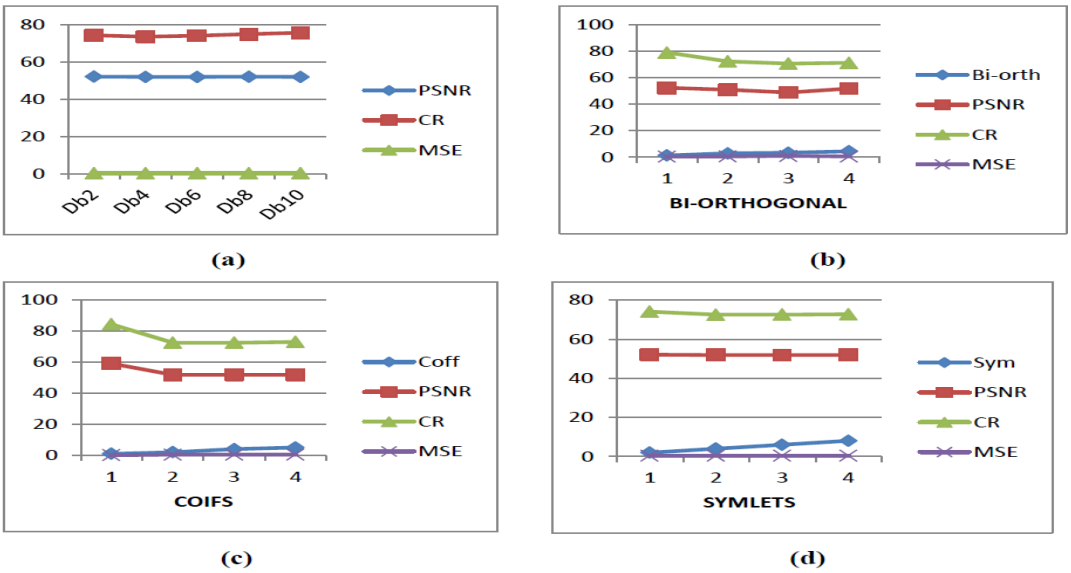


**Fig 21 (a, b, c, d):** Comparison of PSNR, MSE & CR of different Wavelets on single Image.

The following **Table 4 (a, b, c, d)** summarizes performance comparison between suggested wavelet families.

**Observation Table 4 (a)**

| DbN | PSNR | CR | MSE |
|---|---|---|---|
| Db2 | 52.06 | 74.11 | 0.4043 |
| Db4 | 51.91 | 73.36 | 0.419 |
| Db6 | 51.9 | 73.97 | 0.4195 |
| Db8 | 51.97 | 74.73 | 0.4128 |
| Db10 | 51.91 | 75.55 | 0.4189 |

**Observation Table 4 (b)**

| Bi-orth | PSNR | CR | MSE |
|---|---|---|---|
| 1.3 | 52.2 | 78.75 | 0.3921 |
| 2.8 | 50.73 | 72.05 | 0.55 |
| 3.3 | 48.66 | 70.47 | 0.8853 |
| 4.4 | 51.65 | 70.96 | 0.445 |

**Observation Table 4 (c)**

| Coif | PSNR | CR | MSE |
|---|---|---|---|
| 1 | 59.18 | 84.42 | 0.07857 |
| 2 | 51.88 | 72.58 | 0.4214 |
| 4 | 51.91 | 72.57 | 0.4193 |
| 5 | 51.82 | 73.05 | 0.4275 |

**Observation Table 4 (d)**

| Sym | PSNR | CR | MSE |
|---|---|---|---|
| 2 | 52.06 | 74.11 | 0.4047 |
| 4 | 51.94 | 72.54 | 0.4156 |
| 6 | 51.86 | 72.6 | 0.4235 |
| 8 | 51.91 | 72.72 | 0.4188 |

## CONCLUSION AND FUTURE SCOPE:

This work is mainly focused upon the comparison and analysis of image compression derived by applying different available wavelets methods. In this paper we noticed that the high detail image provides better image compression ratio specifically by using debauchies db10. On the other hand on the same image format, symlets 2.8 provides lower PSNR values, whereas coif 1 gives higher PSNR values. However lowest MSE value is observed by coif wavelet method. Group image showed better results on the application of Db10, in terms of PSNR, CR, MSE as compared to other available wavelet parameters. For single image, the debauchies Db8 and Db10 gives high CR but the better PSNR value was achieved by bi-orthogonal wavelet method. However coif

provides better MSE values for the same class of image i.e. single image. In case of medium image, the debauchies Db10 gives better PSNR, CR but better MSE is achieved by symlet wavelet method. Though from all above discussions we can say that the debauchies wavelet method is superior one from the other above mentioned/ suggested wavelet methods as we have got better CR, MSE, PSNR values in comparison to other available wavelet methods in all given images formats.

For the future work, the above algorithms can be studied for video compression real time video compression also. Parallel model may be enhanced and modeled with in some combination of mathematical transformation or wavelet transform used.

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