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Efficient Image Compression Approach Using Discrete Wavelet Transform

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Abstract: *The huge amount of circulated images around the world need a big size of capacity in addition high speed of transmission to overcome these problems. This leading to continues need of improving the issue of image compression. This paper concentrated on the design an efficient approach for image compression using discrete wavelet transform. This approach leads to minimize the redundancies and the unwanted information in addition the original image can be presented in a good form. Wavelet transform is a multispectral analysis that can decompose image into sub-band of images. The implemented approach of image compression used the benefits of correlation operation. This based on the prediction of edges from the low-low band from the lowest resolution level to predicate edges on the other bands.*

Keywords: *Image Compression, Image Decomposition, 2D DWT, Statistical Parameters..*

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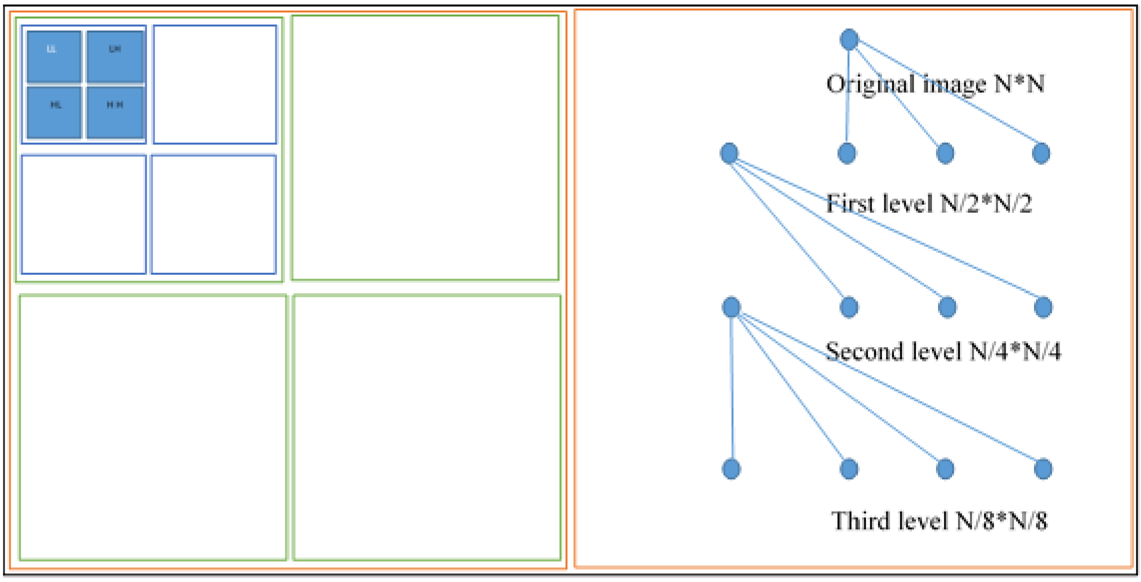
I. Introduction

Image compression minimizes the byte size of a graphic file without degrading image quality to an unacceptable level [1]. Reducing the image size allows you to store more images in a certain amount of space or memory [2]. This also reduces the time required for images to be sent over the Internet or downloaded from web pages [3]. Image compression is an important issue for their wide range of applications in various areas of our life [4]. The main categories of compression methods are lossless and lossy, and each category are divided into many methods [5]. Some of these methods for image compression are discrete cosine transform (DCT) [6,7], discrete wavelet transform (DWT) [8,9], discrete curvelet transform (DCT) [10,11], support vector machine (SVM) [12,13], principle component analysis (PCA) [14,15] and many other methods.

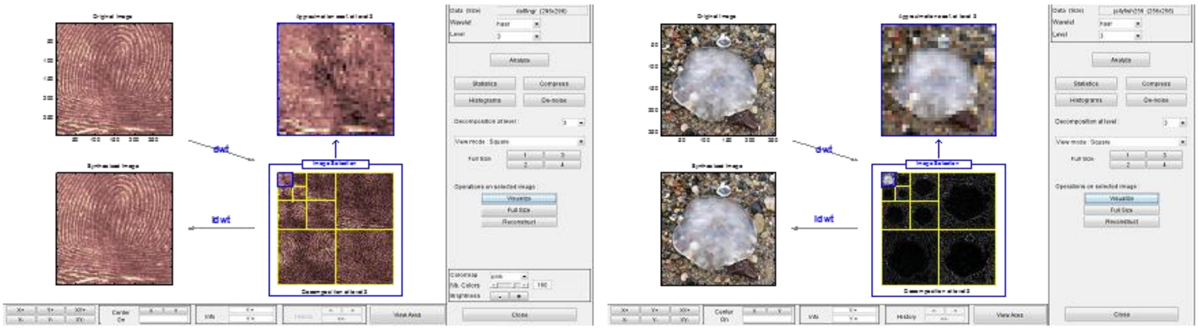
One of the important method used for image compression is discrete wavelet transform (DWT) that divides the original image into four sub-bands: low-low (LL) band, low-high (LH) band, high-low (HL) band, and high-high (HH) band [16,17]. These bands are demonstrated in figure 1 in which the first level divides the original image into four images with size equal to ¼ of the original image for each level [18,19]. Part a of Fig.1 shows the sub-band decomposition and part b shows the tree structure [20,21].



(a) sub-band decomposition (b) tree structure

Figure 1 discrete wavelet transform

Fig.2 indicated a real example of image decomposition applying DWT. Part (a) indicates the indexed image that applied to three levels and part (b) indicates the color image that applied to three levels. It is clear from both images that the details of image is concentrated in low-low level.



Part (a) indicates the indexed image part (b) indicates the color image

Figure 2 image decomposition applying DWT

II. Literature Review

DWT have various applications in different areas, so many works are published in this field and this paragraph will be concentrated on the recent works.

N. Vijaya Bala, Dr. R. Shanmughalakshmi (2010), studied several aspects of very large scale integration architectures that have emerged to meet the real-time demands of online application processing. This article discusses several techniques that help to achieve the fast operation of the transformation stage of the image compression processes. Different parameters involved in high-speed optimizations such as calculation time, silicon area, memory size, etc. are considered in the survey [22].

Mohammad-Reza Keyvanpour, Farnoosh Merrikh-Bayat (2011), presented a new technique to embed the watermark based on the discrete wavelet transformation to hide small but important information in images. In order to adapt to the characteristics of human perception, this approach uses three discrete wavelet transformation sub-bands. The main purpose of the proposed scheme is to apply a dynamic lock rather than being static to select the positions of the embedded filigree bits. Dynamic blocking applies to pixels that are attached to strong edges where these pixels are obtained from the discrete wavelet transformation HL and LH subbands [23].

P Karthigaikumar et al (2012), used a watermarking technique for images. A watermark is embedded in the host signal for authentication. The complete algorithm is designed and simulated using a simulink block in MATLAB, and then the algorithm is converted to the hardware description language using the Xilinx system generator tool. The algorithm was prototype in virtex-6 FPGA. The results show that the proposed design can operate at a maximum frequency of 344 MHz in Vertex 6 FPGA consuming only 1.1% of the available device [24].

Mohammad Reza Keyvanpour, Farnoosh Merrikh Bayat (2012), proposed an algorithm is based on chaotic mapping and dynamic blocking, operating in the DWT domain. The framework of the proposed integration algorithm consists of a special coding process that uses a chaotic map to produce the integration key (first key) (in LW (3) of the DWT domain). Due to the use of the Arnold Cat Map, the key can be produced in the extraction phase without the presence of the original or transmitted information. This phase used the special dynamic blocking method and the quantification of the wavelet coefficient high-low or low-high [25].

Ming-Sheng Wu (2014), proposed a genetic algorithm based on a discrete wavelet transform to overcome the time disadvantage required for the fractal encoder. In this approach two wave coefficients for each range block are used to find the most appropriate dihedral block of the domain block. Similar mapping occurs only with the strongest block to record seven-eighth redundant mean square error calculations. Then, the genetic algorithm based on discrete wavelet transform is designed to accelerate the exchange rate and maintain good quality reclaimed. The experiments show that, in the same number of mean square error calculations, the peak signal to noise ratio of the proposed method is reduced from 0.29 to 0.47 dB compared to the genetic algorithm method [26].

Divjot Kaur Thind, Sonika Jindal (2015), introduced digital watermark due to the rapid advancement of networked multimedia systems. It has been developed to apply copyright technologies for the protection of copyright ownership. This approach is mainly used for still images, but recently they have been developed for other multimedia objects like audio, video, etc. The proposed approach related to a new digital video watermarking scheme that combines the discrete wavelet transform and the singular value decomposition in which the watermark occurs in the high frequency subband and then several attacks have been applied. Tests were performed to verify the proposed scheme of robustness and imperceptibility [27].

NST Saia et al. (2016), proposed two different approaches to calculate the feature vector for the content-based image retrieval system (CBIR). Singular Value Decomposition of the successively truncated discrete cosine transform image and the decomposed discrete wavelet transform image calculated for the grayscale image, the RGB image and the YCbCrcolor image. Truncated discrete cosine transform and discrete wavelet transform and decomposition of singular value decomposition image characteristics calculated up to the fifth level to compare performance. The proposed methods are integrated with the vector of multidimensional characteristics calculated using singular value decomposition of low frequency coefficients of discrete cosine transform and discrete wavelet transform image. The similarity between the query image and the database image is measured using simple Euclidean distance and Bray Curtis distance [28].

Bae-Muu Chang et al. (2016), presented a new image classification technique that first extracts the rotational invariant image texture characteristics in the singular value decomposition and discrete wavelet transform domains. Subsequently, it operates a vector support machine to perform an image texture classification. For convenience, the SRITCSD method is called here. First, the method applies the singular value decomposition to improve the image textures of an image. It then integrates the texture functions into the discrete wavelet transform domain of the singular value decomposition version of the image [29].

Guiqiang Hu et al. (2017), implemented an efficient image coding scheme that combines compression and encryption in a parallel compression detection frame, where sampling and reconstruction are performed in parallel. In this way, efficiency can be guaranteed. In the security aspect, the selected clear text attack resistance is achieved by cooperation between a non-linear chaotic detection matrix building process and a counter mode operation. In addition, the lack of leakage of energy information in the compressive sensing -based cryptosystem is also overcome by a diffusion procedure. The experimental and analytical results show that the scheme achieves effective, efficiency and high security [30].

Miao Zhang, Xiaojun Tong (2017), proposed an image encryption and compression scheme based on integer wavelet transform and partitioning defined in hierarchical trees to obtain encryption and lossless compression of the data, simultaneously. Using the properties of integer wavelet transform and hierarchical trees, encryption and compression are combined. Then, the secure set shared in hierarchical trees by adding encryption in the encoding process has no effect on compression performance. A hyper-chaotic system, a non-linear inverse operation, a secure hash algorithm, and a clear text-based key stream are all used to improve the security. The test results indicated that the proposed methods have high safety and good lossless compression performance [31].

The above literature review demonstrated the image compression methods and technologies. This work will concentrated on Efficient Image Compression Approach Using Discrete Wavelet Transform.

III. Methodology

Mean and Standard Deviation

Edge detection based on the variation of intensity between pixels, and generally tracking the maximum variation of image intensity [32]. This idea can be achieved via the measurement of standard deviation of the block of transform coefficients for edge detection [33].

Consider x(n) is the input 1D digital signal then the mean value of 1D signal is given as below [34,35]:

$$\mu 1 = \frac{1}{N} \sum x(n) \qquad (1)$$

Where N is the number of values and n is the index value that varied from 0 to N-1.

The standard deviation of 1D signal is given as below [36,37]:

$$\sigma 1 = \frac{1}{N} \sqrt{\sum [x(n) - \mu 1]^2} \qquad (2)$$

Consider x(n1,n2) is the input 2D digital signal then the mean value of 2D signal (image) is given as below [38]:

$$\mu 2 = \frac{1}{N1 * N2} \sum \sum x(n1, n2) \qquad (3)$$

Where N1 and N2 are the number of rows and columns, and n1 an n2 are varied from 0 to N1-1 and 0 to N2-1 respectively.

The standard deviation of 2D signal (image) is given as below [39]:

$$\sigma 2 = \frac{1}{N1 * N2} \sqrt{\sum \sum [x(n1, n2) - \mu 2]^2} \qquad (4)$$

The Implemented Discrete Wavelet Transform Approach

The implemented approach is concentrated on DWT which is a lossy method. DWT is applied via three steps; transformation, quantization, and coding. The input image is passed through multispectral discrete wavelet transform to produce the coefficient matrix in which a set of sub-band matrix are generated: LL-band, LH-band, HL-band and HH-band. Then these sub-bands are quantized by a scalar quantizer to generate a stream

of symbols. The quantized values is a transform coefficients with the small value entropy of as possible that the symbol can be coded at low bit rate. There is an estimated threshold for each sub-band that indicates the image intensity variation which is the indication of edge detection.
The steps of the implemented approach are sated in Fig. 3 and explained below:

- First: The encoder transmits the sub-band 8 to the receiver.
- Second: According to the standard deviation of a 2*2 block in the sub-band 8, the encoder decides whether to send the block of 2*2 at LH, HL, and HH bands of level3 or not.
- Third: if the block is rejected then it is indicated in the encoder and is filled by zeros in the encoder.
- Fourth: otherwise, the block is transmitted and unindicated.
- Fifth: when the transmission for all bands in level3 is finished, then the standard deviation at the other three bands in level3 (block 2*2) is used to predicate the edges of the corresponding bands of level2 (block 4*4).
- Sixth: According to the standard deviation of a 2*2 block in every band of level2, the encoder decides whether to send the block of 4*4 at the corresponding bands in level1 or not, if it will fill by zeros.
- Seventh: when no edge is detected in a 2*2 block in the LL-band, then the corresponding 2*2, 4*4 and 8*8 blocks in all other bands are discarded.
- Eighth: when an edge is detected in 2*2 block in LL-band, then the corresponding 4*4 and 8*8 blocks may be not detected.

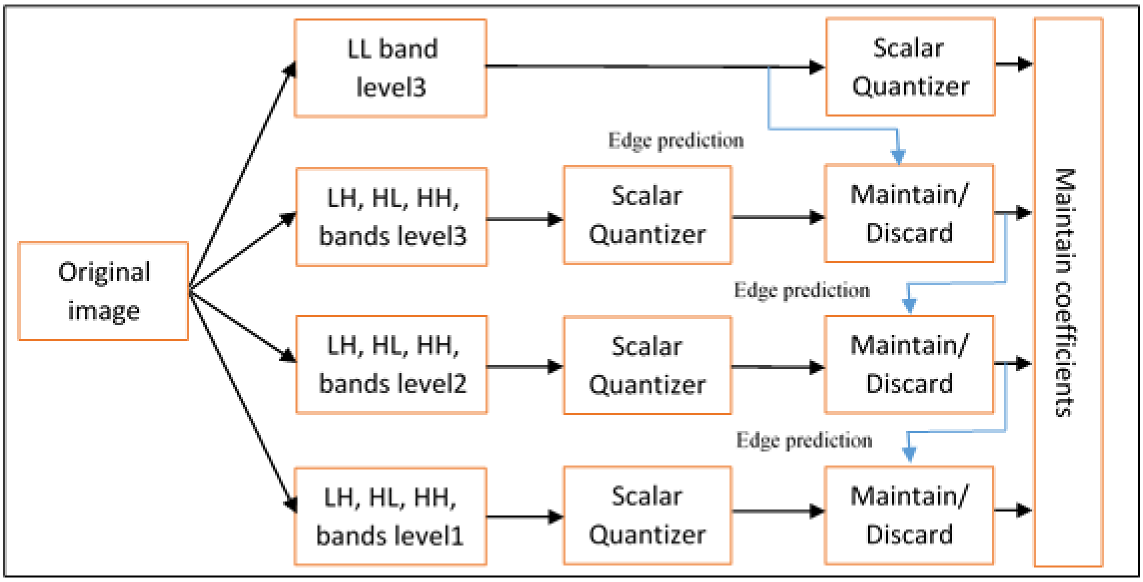


Figure 3 the implemented approach via DWT

IV. Results and Discussions

Wavelet have many families such as Harr, Daubechies, Symlets, Coiflets, Biorthogonal … etc. Daubechies are an important family and have more than 20 sub families. Fig.4 shows the decomposition of images into 10 sub-bands according to the third level of two dimensional discrete wavelet transform (2D-DWT). The vision of these bands is used to quantize the coefficients in higher frequency bands coarsely and the coefficients in the middle level and lower level bands smoothly to prevent the degradation. Each band is quantized (with optimal work) and encoded with variable length coding. Each band (except sub-band 8) is quantized with various bit-rate based on its standard deviation.

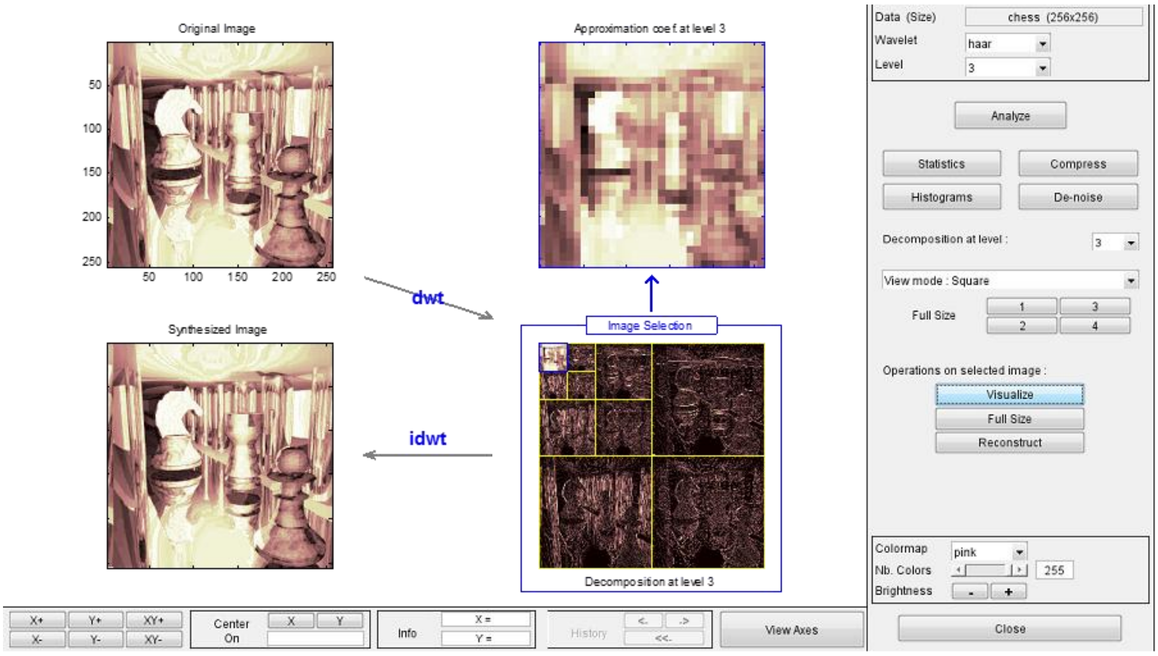


Figure 4 decomposition of images into 10 sub-bands

The edge detection is applied in each sub-bands applying this approach as shown in Fig.5 for third level and Fig.6 for sixth level. The white dots in the sub-bands are represent the coefficients which are predicted as edges and these are maintained, on other hand the coefficients which are not represented edges and these are discarded. Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are measured for different types of images. Fig.7 shows different values of MSE and PSNR generated from many images, at this figure you can see that the values of MSE, MAX ERROR, PSNR, BIT Per Pixel (BPP) and Compression Ratio (CR) corresponding to the level of image compression. This figure started from first level DWT and ended to eighth level.

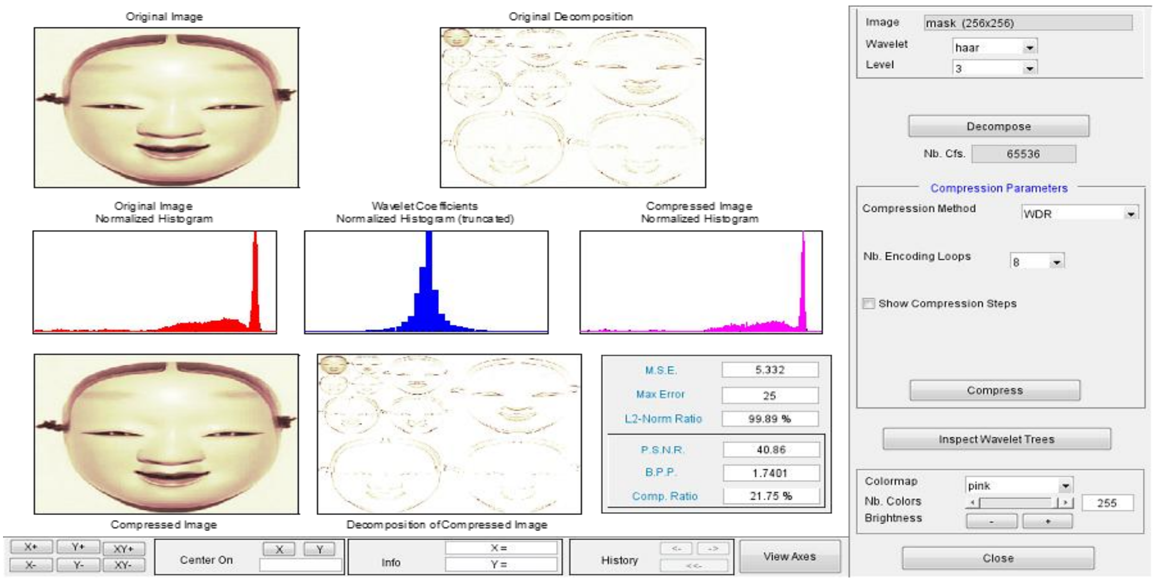


Figure 5 third level Haar DWT

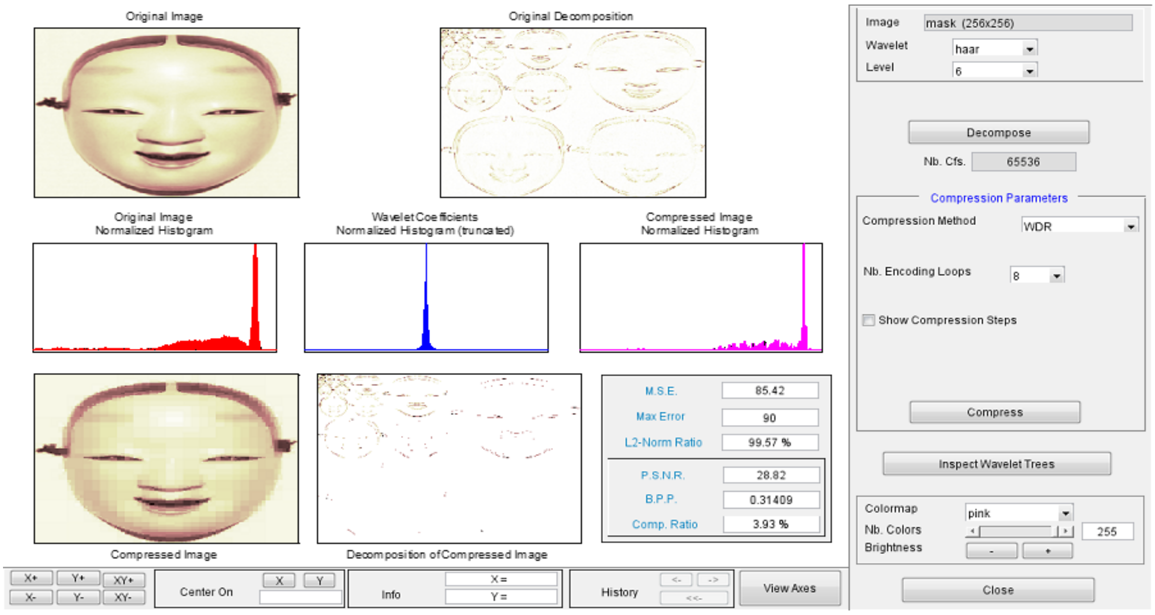


Figure 6 sixth level Haar DWT

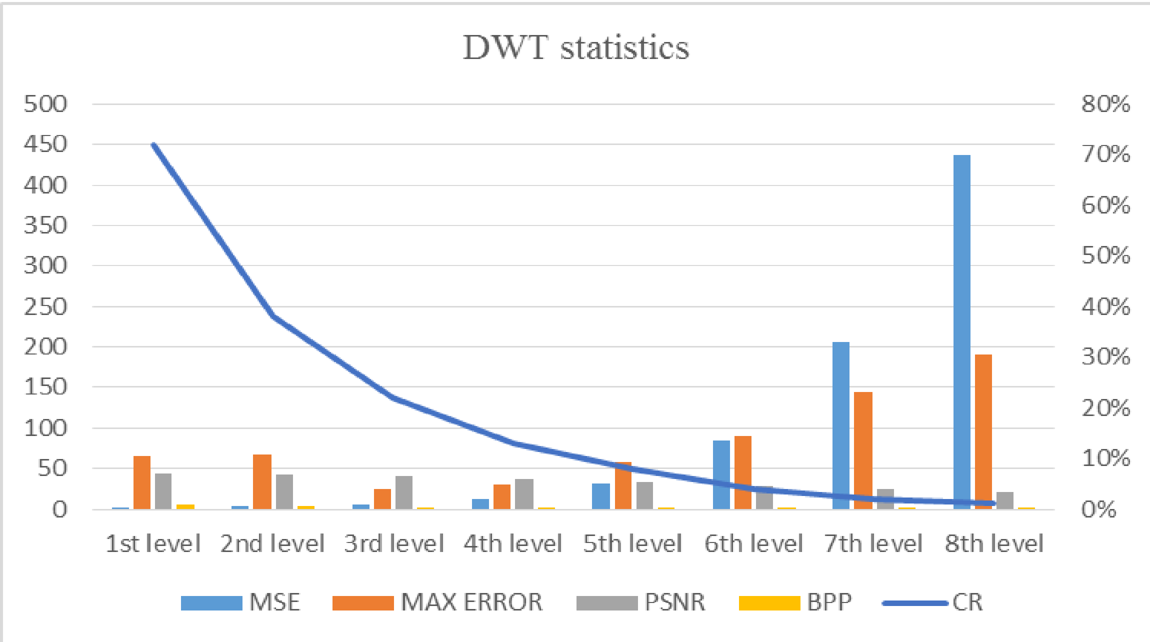


Figure 7 different values of MSE and PSNR generated from many images

V. Conclusion and recommendation

Two dimensional discrete wavelet transform is an important method for image compression. The main aspect of 2D-DWT is a multispectral resolution method that generate four band for each level. The implemented approach based on estimated threshold for each sub-band that indicates the image intensity variation which is the indication of edge detection. The applied images are of 256*256 size. In this approach, many statistical parameters including MSE, PSNR, BPP and CR are measured to compare the efficiency of the implemented approach.

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