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4. An Efficient Image Compression Scheme Using Wavelet Transform with Set Partitioning Embedded Block Coder Algorithm (SPECK)

Avadhesh Kumar Maurya
Assistant Professor,
Department of Electronics and Communication Engineering,
Lucknow Institute of Technology, Lucknow, U.P., India.

Vishwa Nath Maurya
Executive Vice-Chancellor and Distinguished Professor,
Chartered International Da Vinci University, Delaware, USA.

Rakesh Kumar Singh
Professor and Ex Director,
Bipin Tripathi Kumaon Institute of Technology (Autonomous),
Affiliated to Uttarakhand Technical University, Dehradun, India.

ABSTRACT

In this paper, the objective and subjective evaluation parameter generally used for image compression analysis has been presented. For the objective evaluation PSNR, CR, and variance have been discussed. These all metrics are simple to compute and shows the statistical properties of reconstructed data.

However, in some cases, this parameter may not exactly define the visual reconstruction quality. Thus, subjective evaluation parameter has also been discussed for the reconstruction quality analysis. Under our present research work we observed that trade-offs can be achieved by adjusting the parameters for compressed image against reconstructed image quality over wide a range. Moreover, besides objective performance evaluation, subjective evaluation of an image/frame has also been conducted in order to have a visual perception.

KEYWORDS:

Image compression technique, wavelet transform, SPIHT algorithm SPECK Coding method, objective and subjective performance evaluation parameters.

1. Introduction:

Image compression technique introduces some amount of distortion in the reconstructed image; therefore, evaluation of the image quality is an important issue. The quality of reconstructed images can be evaluated in terms of objective measure and subjective measure. In objective evaluation, statistical properties are considered whereas, in subjective evaluation, viewers see and investigate image directly to determine the image quality [2].

In this paper, both objective and subjective performance evaluation parameters for image compression algorithm are presented. SPECK coding method use sets in the form of blocks of contiguous coefficients to exploit similarities within the sub ands, whereas the SPIHT algorithm uses spatial trees which span and exploit the similarity across different sub bands of wavelet decomposition. SPECK comprises of three stages initialization, sorting, and refinement, and uses two linked lists: list of insignificant sets (LIS) and list of significant pixels (LSP). For more details, we refer [4,6,7, 9-13]

The objective evaluation measure includes peak signal to noise ratio (*PSNR*), compression ratio (*CR*), variance, and Structural Similarity (*SSIM*) index. Image having same *PSNR* value may have different perceptual quality in view of [5].

By adjusting the parameters, trade-offs can be achieved for compressed image against reconstructed image quality over wide a range. In order to have a visual perception, subjective evaluation of an image/frame has also been conducted for this research work and is also described in this paper.

Image compression techniques have numerous applications in the field of multimedia broadcasting channels, video conferencing, medical imaging and neural networks. If we talk about TV programs broadcasting,

Image compression technique using SPECK Coding has become essential tool. Usually, a full colour image is made up of three primary colours: red, green, and blue. In most cases, there is a strong correlation between the red, green, and blue components of the colour image.

However, this colour space is not optimal for lossless compression since the energy is distributed over these planes. Reversible RGB to LC transformations reduce the correlation between the R, G and B components and pack the energy of the colour image into one component and by using SPECK Coding we can save the cost of heavy storage device. SPECK Coding also reduces the cost of extra bandwidth used when uncompressed image is transmitted to satellite for broadcasting. SPECK Coding can also be used in compression of live video streaming in video conferencing.

In this direction we refer [14-17] for more details. In recent research work Maurya et al. [13] confined their attention to review the literature of research works of some noteworthy previous researchers [4, 6, 7, 15-17] and they succeeded to present some useful results with conclusive remarks.

2. Objective Performance Evaluation Parameters:

The objective quality metric includes the statistical analysis of an input data. There are various objective evaluation parameters. The most commonly used parameters are Peak Signal to Noise Ratio (*PSNR*), Compression ratio (*CR*), variance, and Structural Similarity (*SSIM*) index which are described in the next sub-sections.

2.1 Peak Signal to Noise Ratio (PSNR):

Peak Signal to Noise Ratio (*PSNR*) has been the most popular tool for the objective quality measurement of the compressed image and video. It is simple to compute. In view of [3] the *PSNR* in decibel is evaluated as follows:

$$\text{PSNR}=10\log_{10}\frac{I^{(2)}}{MSE} \quad (2.1)$$

Where, I am allowable image pixel intensity level. For 8 bit per pixel image,

$$\text{I}=2^{(8)}-1=255 \quad (2.2)$$

2.2 Mean Square Error (MSE):

and the Mean Square Error (MSE) is another important evaluation parameter for measuring the quality of compressed image generally used along with the *PSNR* analysis. It compares the original data and reconstructed data and results the level of distortion. The MSE between the original data and the reconstructed data is:

$$\text{MSE}=\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(Ai,j-Bi,j)^2 \quad (2.3)$$

Where, A = Original image of size M X N ,

B = Reconstructed image of size M X N.

Example 2.1: PSNR Comparison:

The pioneer research work of [3] depicted in Figure 2.1 shows the standard image ‘pepper’ of size 512 X 512. The image is compressed using DCT1 with two different compression levels to obtain different *PSNR* values. The reconstructed images are shown in Figure 2.1-(b) and (c). The *PSNR* for the image (b) is 26.75 dB, and (c) is 28.55 dB. It is observed that *PSNR* difference between figures (b) and (c) is 1.8 dB. However, when we visualize the reconstructed image, we can observe a reconstruction quality difference between the two reconstructed images. Blocking artifacts is clearly visible in figure (b). This proves that, *PSNR* is not the sufficient measurement criterion as image is previewed as visual perception.

Visual perception at the end level user has been a crucial issue and is growing demand especially in telemedicine, and teleconferencing areas.

Hence, it is necessary to take account of both objective measure and subjective measure in order to evaluate the reconstruction quality of compressed data.

(a) Original image (b) *PSNR* = 26.75 dB (c) *PSNR* = 28.55 dB

Figure 2.1: PSNR comparison (a) original image[2] and reconstructed image using DCT (b), (c).

2.3 Compression Ratio (CR):

In the process of image compression, it is important to know how much detail (important) coefficient one can discard from the input data in order to preserve critical information of the original data.

Compression ratio (*CR*) is a measure of the reduction of the detail coefficient of the data. It can be defined as,

$$CR = \frac{Discarded\ Data}{Original\ Data} \tag{2..4}$$

The *CR* can be varied to get different image quality. The more the details coefficients are discarded, the higher the *CR* can be achieved. Higher compression ratio means lower reconstruction quality of the image.

The quantization table (Q) and the scaling factor (*SF*) are the main controlling parameters of the compression ratio. Each element of the transformed data is divided by corresponding element in the quantization table (Q) and rounded to the nearest integer value. This process makes some of the coefficients to be zero which can be discarded.

Furthermore, in order to achieve higher compression ratio, quantizes output is then divide by some scalar constant (*SF*) and rounded to nearest integer value. This process produces more zero coefficients which can be discarded during compression.

Example 2.2: Compression Ratio Comparison

(a) Original image (b) $CR = 85.81$ % (c) $CR = 96.12$ %

Figure 2.2: *CR* comparison (a) original image[3] and (b), (c) reconstructed image using 2-D DCT

In the research study of [3] illustrated as in Figure 2.2, the original image of monarch of size 256 x 256 is presented. Figure 2.2-(a) is original image and Figure 2.2(b) and Figure 2.2(c) are reconstructed image using DCT[4]at two different compression ratios. When the image is compressed at 85.81 % of compression ratio as shown in Figure 4.2(b), the reconstruction looks visually similar to the original one. However, when the compression ratio is increased to 96.12 % as shown in Figure 2.2-(c), the visible distortion is evident. This clearly shows that the overall quality of reconstruction depends on the compression ratio.

2.4 Variance:

Variance is another tool to calculate the performance of image compression algorithm. Variance describes how far certain value deviates from the mean. It's the measure of variability from an average. In signal processing, the variances□ for k=1, 2…N, are represented by the Eigen values of the transformed coefficient [1]. N is the size of input data block. The lower the variance, higher will be the energy compaction property. The energy compaction property defines that most of the information signal tends to concentrate in the low frequency component. Higher the energy compaction property, the better is the compression algorithm.

Example 2.3: Variance Calculation

Any random sequence *u(n)* is called Markov -*p*, or p^{th}€ order Markov, if the conditional probability of *u(n)* given the entire past is equal to the conditional probability of *u(n)*given only *u(n-1)………u(n-p)* , we refer [8].

The covariance function of first order stationary Markov sequence *u(n)* is given as

$$Prob\ [u(n) \mid u(n-1), u(n-2), \ldots\ldots] = Prob\ [u(n) \mid u(n-1), u(n-2), \ldots\ldots\ u(n-p)] \quad (2.5)$$

For first order Markov sequence having the correlation matrix of size N and correlation Coefficient. Thus, the variance of the transformed coefficient can be obtained as the Eigen value of the transformed correlation coefficient.

3. Subjective Evaluation Parameters:

For the end user, the visual perception of the reconstructed image is essential. In some cases, the objective quality assessment does not give proper information about the quality of the reconstructed image. In such scenarios, it is important to analyses the reconstructed image using subjective analysis. When the subjective measure is considered, viewers focus on the difference between reconstructed and original image and correlates the differences.

4. Results and Discussion:

This section evaluates the performance of the proposed SPECK algorithm. The proposed SPECK algorithm is applied on several types of images: natural images, tool's images, painting captured images such that the performance of proposed algorithm can be verified for various applications.

4.1 Simulation Tool:

The algorithm was implemented in MATLAB simulation tool. The evaluation parameters (PSNR, CR, and Variance), sub-sampling, quantization and scaling routines were manually programmed in MATLAB.

For a better assessment, the following approach has been adopted:

- The *PSNR* is evaluated for a constant *CR*. While evaluating the *PSNR*, highest *CR* is intended to achieve by using the scaling factor without visually distorting the reconstructed image.
- The average *PSNR* is determined and the *CR* is computed for that particular *PSNR*.
- The *SSIM* is computed for the initial constant average *CR*.
- The proposed algorithm is compared with general, DWT and gray images.

4.2 Result and Analysis:

In this section, the performance evaluation parameters for image, these images taken for the experiment were, 'Ship', 'Tools', 'Mandrill', 'Lena' of size (256 X 256).

We compare the performance of PSNR value of different images and different level of decomposition. The basis phenomena applied of image compression to use as SPECK algorithm. We showed the performance based on evaluation parameters such as Compression Ratio (CR), Peck Signal to Noise Ratio (PSNR), Variance (difference) and Mean to Error. For compression to take as firstly originally image.

These images captured by a camera. Further, we applied an algorithm to change as Gray, DWT and SPECK.

4.3 SPECK Compression of 'Ship' Image:

We compared a five level of compassion of original image. These levels implemented in MATLAB simulation tool as per evaluation parameters. These evaluation parameters changed as per as different level of image decomposition. These summarized parameters of different level are shown in Table 4.1.

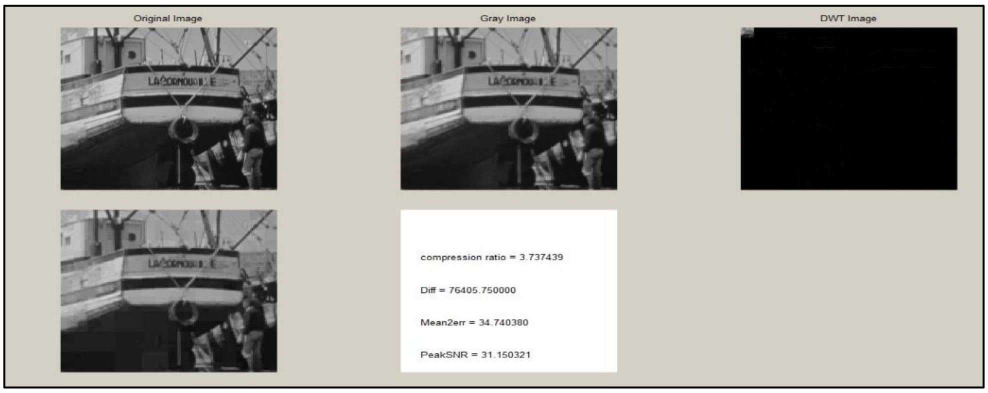

Figure 4.1: SPECK compressions of 'ship' image level 1.

These above images have four sub image blocks

- Original Image
- Gray Image
- DWT image
- SPECK compress image

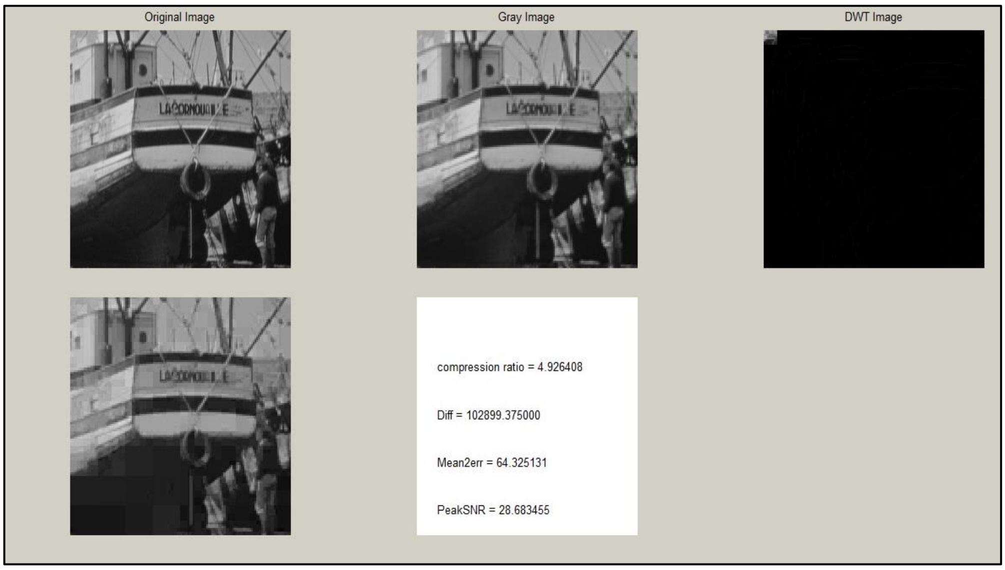

Figure 4.2: SPECK Compressions of 'Ship' Image Level 2

Figure 4.3: SPECK Compressions of 'Ship' Image Level 3

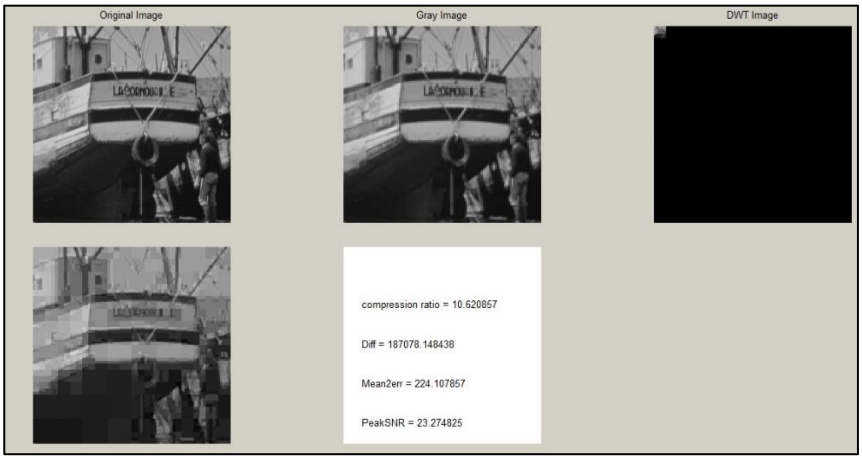

Figure 4.4: SPECK Compressions of 'Ship' Image Level 4

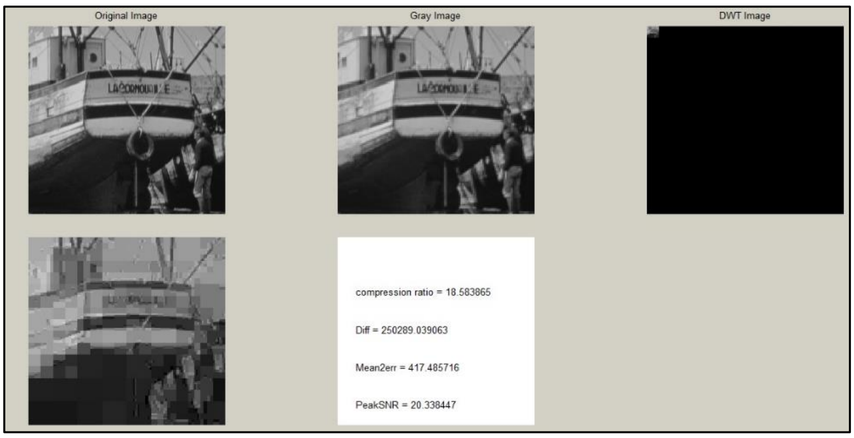

Figure 4.5; SPECK Compressions of 'Ship' Image Level 5

Table 4.1: Compression of all the performance evaluation parameters for 'ship' image

Levels	Compression Ratio	Mean to error	PSNR (db)
1	3.737	34.740	31.150
2	4.926	64.320	28.683
3	6.950	123.968	25.799
4	10.620	224.107	23.274
5	18.583	417.485	20.338

4.4 SPECK Compression of 'Tools' Image:

These evaluation parameters changed as per as different level of image decomposition. These summarized parameters of different level are shown in Table 4.2.

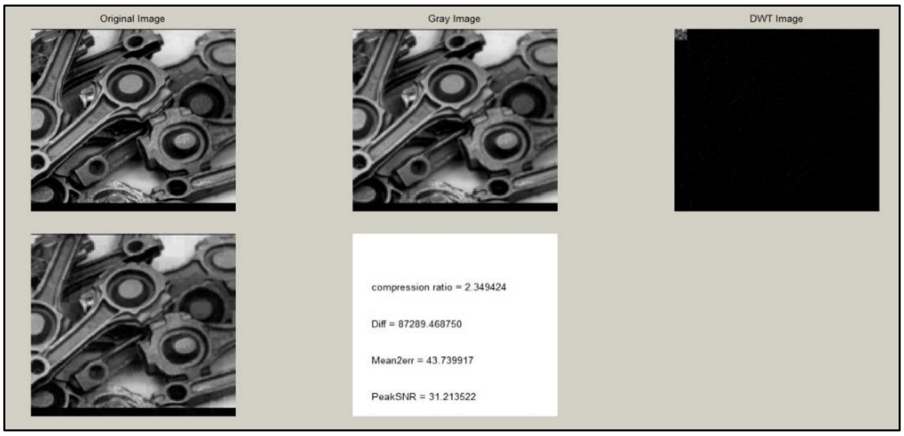

Figure 4.6: SPECK Compressions of 'Tools' Image Level 1

Figure 4.7: SPECK Compressions of 'Tools' Image Level 2

Figure 4.8: SPECK Compressions of 'Tools' Image Level 3

Figure 4.9: SPECK Compressions of 'Tools' Image Level 4

Figure 4.10: SPECK Compressions of 'Tools' Image Level 5

Table 4.2: Compression of all the performance evaluation parameters for 'tools' image

Levels	Compression Ratio	Mean to Error	PSNR (db)
1	2.343	43.739	31.213
2	2.931	86.897	28.403
3	3.901	181.346	25.148
4	5.499	361.423	22.018
5	8.988	683.226	19.998

4.5 SPECK Compression of 'Mandrill' Image:

These evaluation parameters changed as per as different level of image decomposition. These summarized parameters of different level to show as Table 4.3.

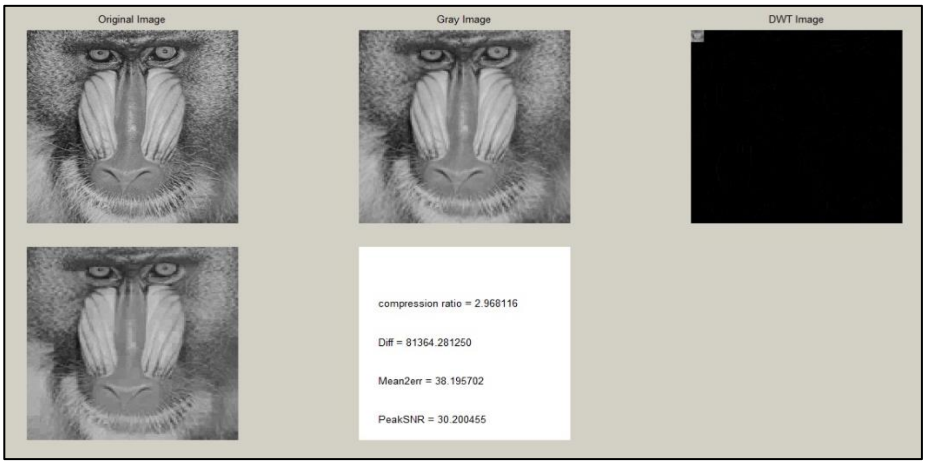

Figure 4.11: SPECK Compressions of 'Mandrill' Image Level 1

Figure 4.12: SPECK Compressions of 'Mandrill' Image Level 2

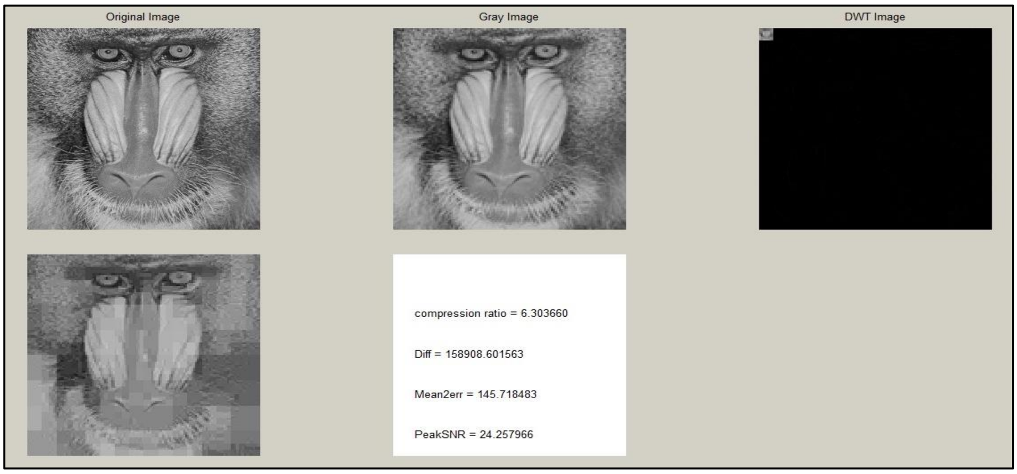

Figure 4.13: SPECK Compressions of 'Mandrill' Image Level 3

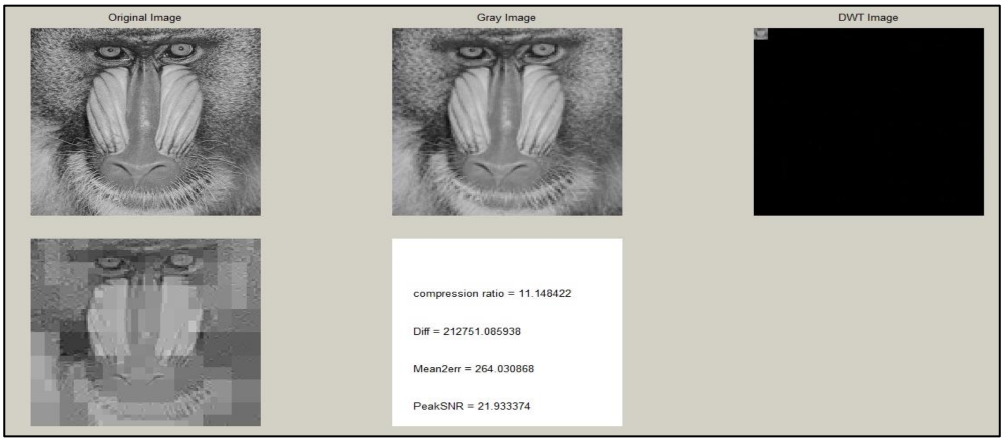

Figure 4.14: SPECK Compressions of 'Mandrill' Image Level 4

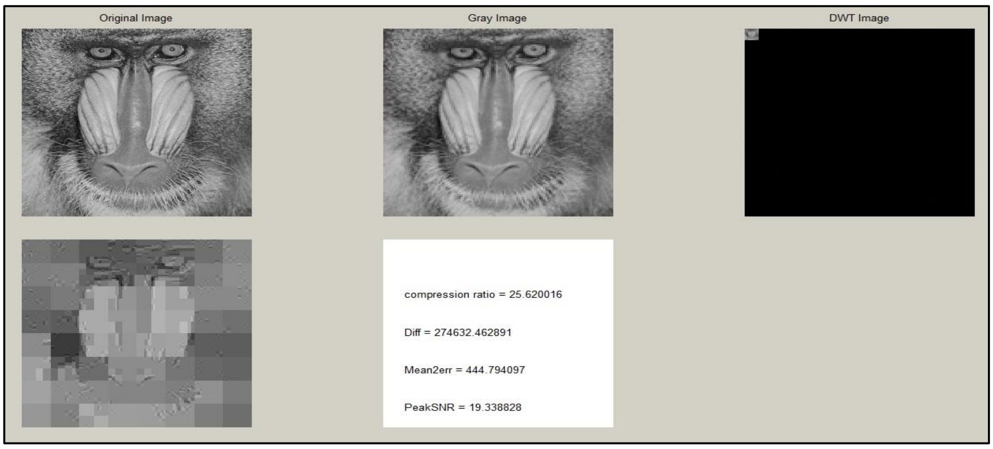

Figure 4.15: SPECK Compressions of 'Mandrill' Image Level 5

Table 4.3: Compression of All the Performance Evaluation Parameters for 'Mandrill' Image

Levels	Compression Ratio	Mean to error	PSNR (db)
1	2.968	38.195	30.200
2	4.059	77.170	27.232
3	6.303	145.718	24.257
4	11.148	264.030	21.933
5	25.620	444.794	19.338

4.6 SPECK Compression of 'Lena' Image:

These evaluation parameters changed as per as different level of image decomposition. These summarized parameters of different level to show as Table 4.4.

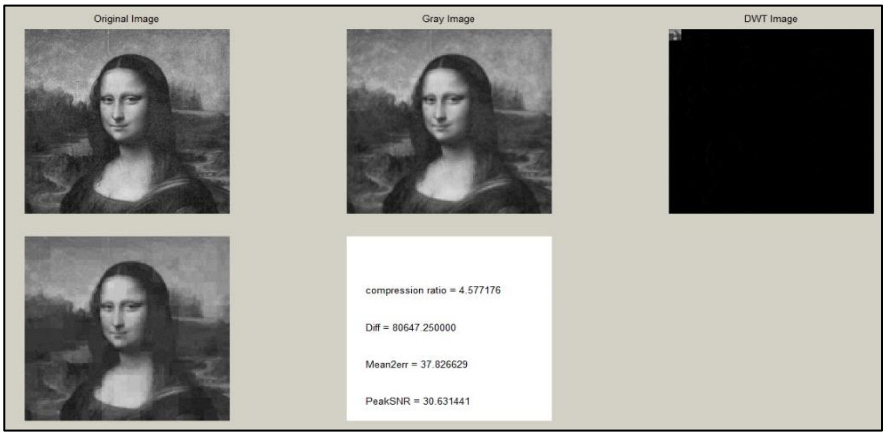

Figure 4.16: SPECK Compressions of 'Lena' Image Level 1

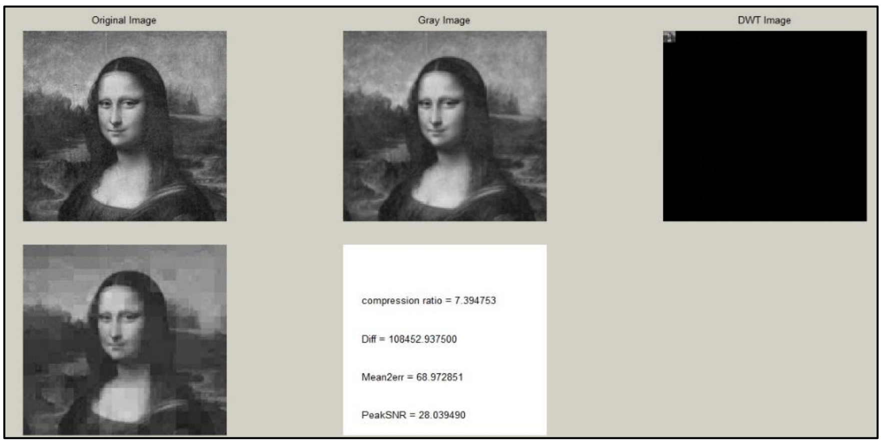

Figure 4.17: SPECK Compressions of 'Lena' Image Level 2

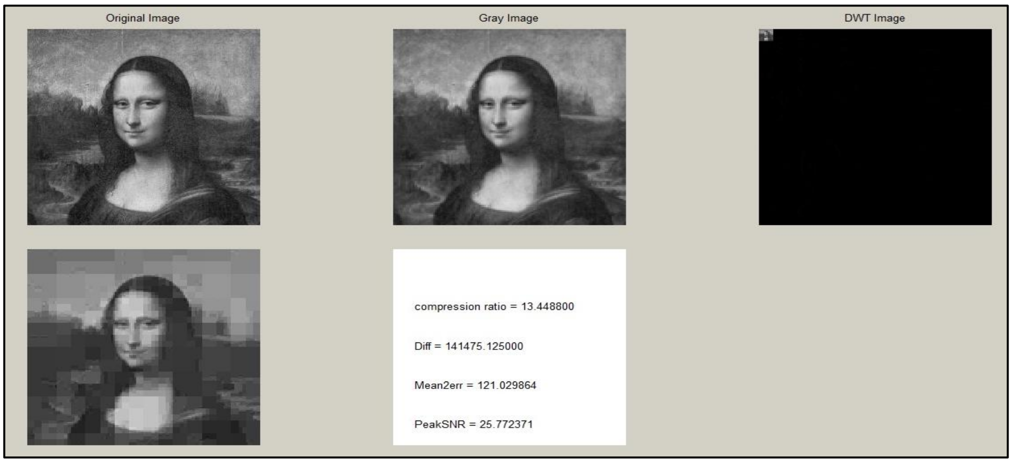

Figure 4.18: SPECK Compressions of 'Lena' Image Level 3

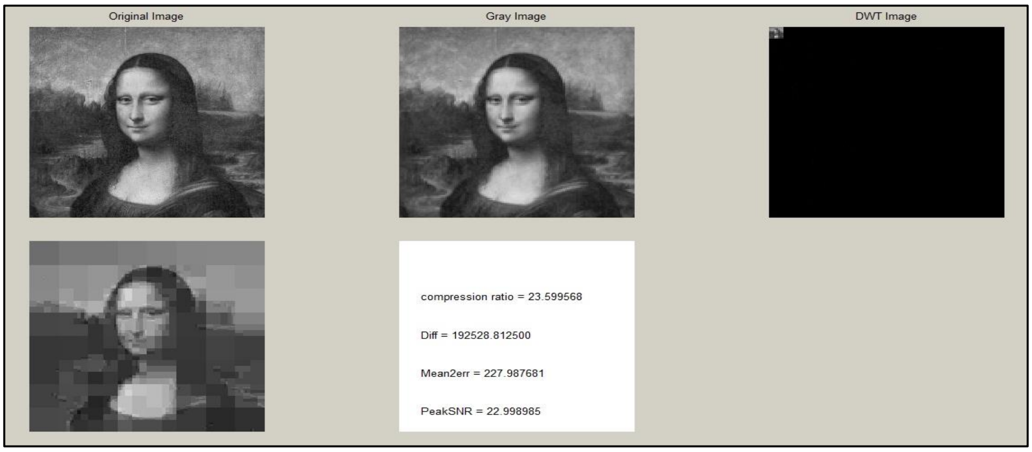

Figure 4.19: SPECK Compressions of 'Lena' Image Level 4

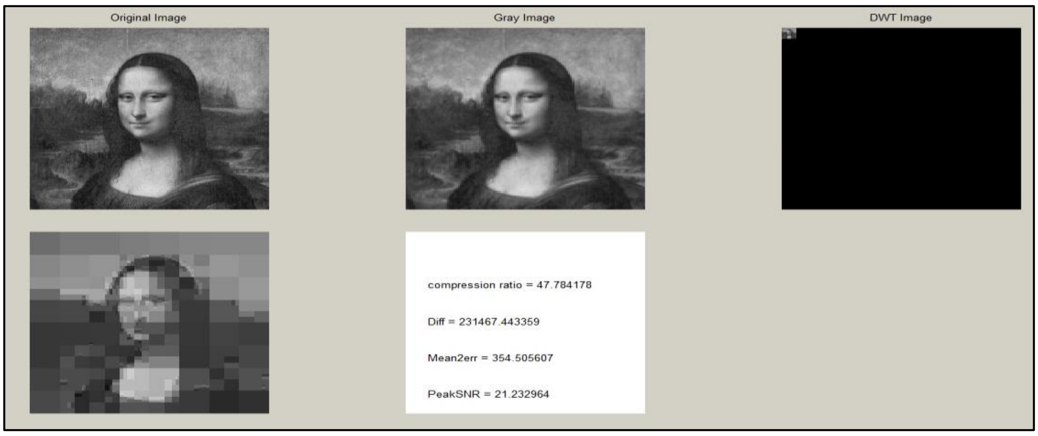

Figure 4.20: SPECK compressions of 'Lena' image level 5

Table 4.4: Compression of all the performance evaluation parameters for 'Lena' image

Levels	Compression Ratio	Mean to error	PSNR (db)
1	4.577	37.826	30.631
2	7.394	68.972	28.039
3	13.448	121.029	25.772
4	23.599	227.987	22.998
5	47.784	354.505	21.232

These tabulation formations have showed that PSNR values decreases level 1 to level 5. A set-partitioning block-based embedded image coding scheme, the SPECK algorithm is show to properly and efficiently evaluation parameters. The SPECK image compression algorithm is more efficient and less complex to other compression techniques.

4.7 Average PSNR (In Db) For SPECK with JPGE 2000:

Here we refer that an average PSNR was calculated by [16]. Hence, following procedure of [16], we present following table 4.5 to show the average PSNR.

Table 4.5: Average PSNR (in dB) for SPECK with JPGE 2000

Sr. No	Algorithm ('lena' image)	PSNR (db) (0.5 bpp)
1	JPGE 2000	38.992
2	SPECK	25.772

5. Conclusion:

In this paper, the objective and subjective evaluation parameter generally used for image compression analysis has been presented. For the objective evaluation *PSNR*, *CR*, and variance have been discussed. These all metrics are simple to compute and shows the statistical properties of reconstructed data.

However, in some cases, this parameter may not exactly define the visual reconstruction quality. Thus, subjective evaluation parameter has also been discussed for the reconstruction quality analysis.

In this research work, we have successfully analysed an efficient compression scheme to obtain better quality and higher compression ratio using wavelet transform with Set Partitioned Embedded block coder algorithm (SPECK).

The performance of the SPECK, is compared with JPEG2000.The SPECK algorithm has some important features which are low complexity, embeddedness, progressive coding, exploits clustering of energy to zoom into high energy areas within a region (block) to code them with minimum significance maps, better visual perception.

6. Future Scope of Research Work:

The present research work has contributed in development of low memory wavelet based embedded coders. The significant contribution is SPECK algorithm. Following the results and analysis described in this thesis, a number of future works could be taken up as follows;

- The concept behind the low memory coders can be extended for color images, and volumetric images and videos.
- The coding efficiency of low memory coder suffers slight degradation than SPECK at some points. The improvement of coding efficiency can be attempted possibly by context formations.
- All of the analysis presented in this thesis work involved exhaustive simulations. The algorithm can be realized in hardware implementation as a future work.
- The proposed algorithm can also be a good option for the image processor of the wireless capsule endoscopic system.

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