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   RESEARCH METHODOLOGY

   RESULTS & DISCUSSION

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CONTRIBUTIONS TO BOOKS

- Sharma T., Kwatra, G. (2008) Effectiveness of Social Advertising: A Study of Selected Campaigns, Corporate Social Responsibility, Edited by David Crowther & Nicholas Capaldi, Ashgate Research Companion to Corporate Social Responsibility, Chapter 15, pp 287-303.

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- Schemenner, R.W., Huber, J.C. and Cook, R.L. (1987), "Geographic Differences and the Location of New Manufacturing Facilities," Journal of Urban Economics, Vol. 21, No. 1, pp. 83-104.

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A STUDY OF WAVELET BASED IMAGE COMPRESSION ALGORITHMS

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ABSTRACT
Day by day the use of different digital devices is increases. All printed documents such as images are converted into digital form. It is necessary to compress images to make efficient transfer and storage of data. Visual data is stored in form of bits which represents pixels. An image often contains redundant and/or irrelevant data. Wavelet is the image compression algorithm. It is also known as Discrete Wavelet Transforms (DWT). It treats the image as a signal or wave. Wavelets are analyzed with respect to the scale. Wavelet algorithms can process data at different scales or resolutions. The different types of wavelets are used for image compression are Haar, Daubechies, Biorthogonal, Symlets and Coiflet. The image wavelet compression process consists of different steps such as : Wavelet Transformation, Quantization and Entropy Coding.

KEYWORDS
DWT, Entropy, Quantization, Transformation.

1. INTRODUCTION
Wavelet compression is also known as Discrete Wavelet Transforms (DWT). It treated the image as a signal or wave. The transform organizes the image information into a continuous wave, typically with many peaks and dips, and centre it on zero. The image is treated as a series of waves, one for each color channel (i.e., Red, Green, and Blue), and it may break up big images into large tiles for ease of processing. Having centered the wave, the transform records the distances from the zero line to points along the wave i.e. these distances are known as coefficients, and then takes the average between adjacent coefficients to produce a simplified version of the wave; in effect, it reduces the image's resolution or detail by one-half.
Wavelet is functions. It is used to satisfy certain mathematical requirement. It is used to representing a data or other functions. Fourier has discovered that he could superpose sins and cosines to represent other functions.

2. WAVELET IMAGE COMPRESSION
The image wavelet compression process consists of the following steps: Wavelet Transformation, Quantization and Entropy Coding. Below figure represent the block diagram of general compression and decompression process and wavelet based image compression process.

FIGURE – 1 WAVELET IMAGE COMPRESSION ROUTINES

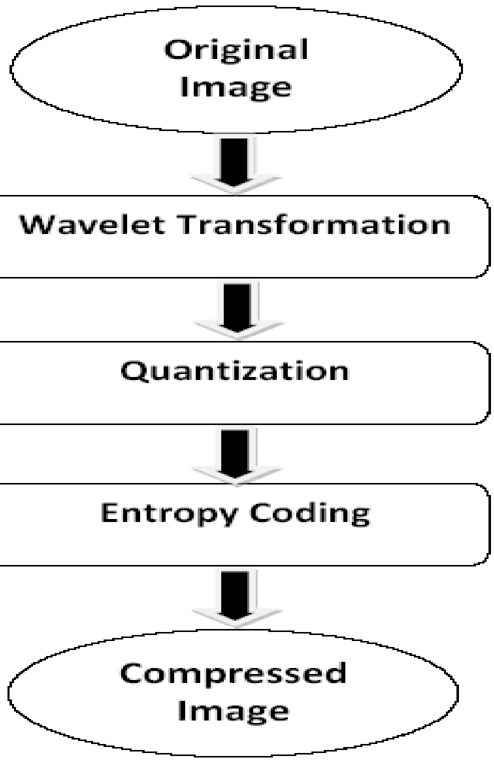
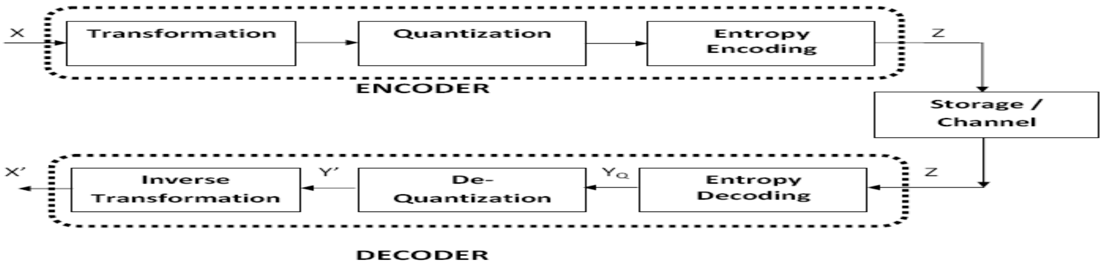


FIGURE – 2 BLOCK DIAGRAM OF GENERAL COMPRESSION AND DECOMPRESSION PROCESS



3. IMAGE QUALITY EVALUATION

The image quality can be evaluated following two different methods: Objective and Subjective.

3.1 OBJECTIVE METHOD

These methods are based on computable distortion measures. A standard objective measure of image quality is reconstruction error.

The double stimulus impairment scale method uses reference and test conditions which are arranged in pairs such that the first in the pair is the unimpaired reference and the second is the same sequence impaired. The method uses the five grade impairment scale with proper description for each grade:

TABLE – 1 GRADE OF IMAGE QUALITY EVALUATION

Grade	Meaning
5	imperceptible
4	perceptible, but not annoying
3	slightly annoying
2	annoying
1	very annoying

3.2 SUBJECTIVE METHOD

Subjective assessments methods of image quality are experimentally difficult and lengthy, and the results may vary depending on the test conditions.

4. TYPES OF WAVELETS

Several families of wavelets that have proven to be especially useful are included in the wavelet toolbox. Here five different types of wavelets are used for image compression such as Haar, Daubechies, Biorthogonal, Symlets and Coiflet. The details of these wavelet families have been shown below:

4.1. HAAR WAVELET

The first DWT was invented by the Hungarian mathematician Alfred Haar in 1909. Haar wavelet is the first and simplest method. It is the simplest of all wavelets and its operation is easy to understand. It have its own their limitations also. They are piecewise constant and hence produce irregular, blocky approximations.

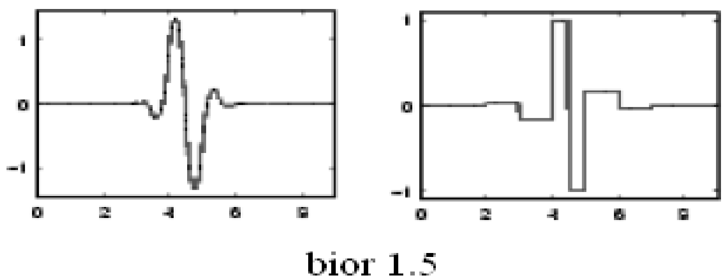
4.2. DAUBECHIES (DB4) WAVELET

It is a family of orthogonal wavelets. It defines the discrete wavelet transform. It can be characterized by a maximum number of vanishing moments for some given support. Each wavelet type of this class, it has a scaling function which is known as father wavelet also. It generates an orthogonal multi resolution analysis.

4.3. BIORTHOGONAL WAVELET

The biorthogonal family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. By using two wavelets, one for decomposition and the other for reconstruction instead of the same single one, interesting properties are derived. Below figure on left side represent decomposition and on right side represent reconstruction.

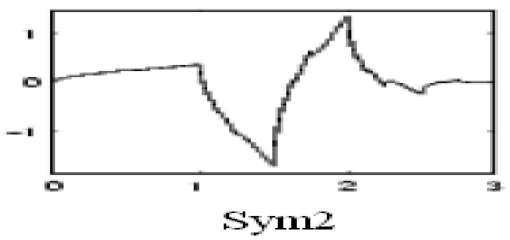
FIGURE – 3 BIOR 1.5 WAVELET FUNCTION WAVEFORM



4.4. SYMLETS WAVELET

The Symlets are nearly symmetrical wavelets proposed by Daubechies as modifications to the db family. The properties of the two wavelet families are similar. There are 7 different Symlets functions from sym2 to sym8. Below figure shows the sym2 function.

FIGURE – 4 SYM2 WAVELET FUNCTION WAVEFORM



4.5. COIFLET WAVELET

Coiflets are discrete wavelets designed by Ingrid Daubechies, at the request of Ronald Coifman, to have scaling functions with vanishing moments. This looks like

$B_k=(-1)^k C_{N-1-k}$

Where k is the coefficient index

B is a wavelet coefficient

C is a scaling function coefficient and

N is the wavelet index

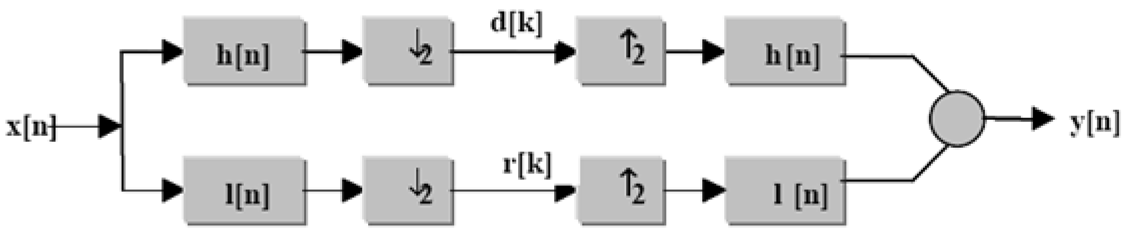
5. TRANSFORMATION

There are two dimensional wavelet transformations such as one dimensional wavelet transform and Multilevel Decomposition Wavelet Transform.

5.1. ONE-DIMENSIONAL WAVELET TRANSFORM

The one-dimensional discrete wavelet transform can be described in terms of a filter band as shown in below figure:

FIGURE – 5 ONE DIMENSIONAL WAVELET TRANSFORM



An input signal x[n] is applied to the low pass filter l[n] and to the analysis high pass filter h[n]. The odd samples of the outputs of these filters are then discarded, corresponding to a decimation factor of two. The decimated outputs of these filters constitute the reference signal r[k] and the detail signal d[k] for a new-level of decomposition. During reconstruction, interpolation by a factor of two is performed, followed by filtering using the low pass and high pass synthesis filters l[n] and h[n]. Finally, the outputs of the two synthesis filters are added together.

The above procedure can be expressed mathematically as the following equations.

$$d[k] = \sum_n x[n] \bullet h[2k-n]$$

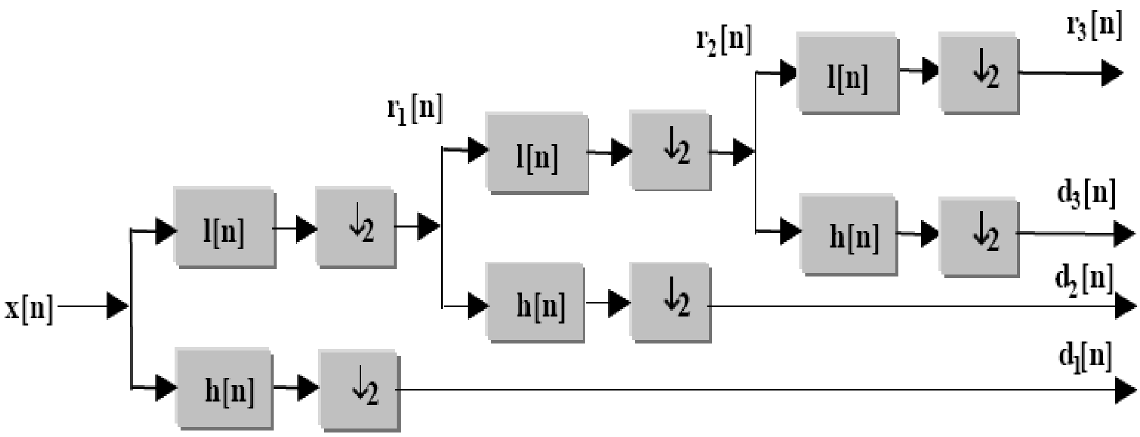
$$r[k] = \sum_n x[n] \bullet l[2k-n]$$

$$x[n] = \sum_n (d[k] \bullet g[-n+2k]) + (r[k] \bullet h[-n+2k])$$

5.2. MULTILEVEL DECOMPOSITION WAVELET TRANSFORM

In a multilevel decomposition, the above process is repeated. The previous level's lower resolution reference signal ri[n] becomes the next level sub-sampling input, and its associated detail signal di[n] is obtained after each level filtering. Below figure shows this procedure.

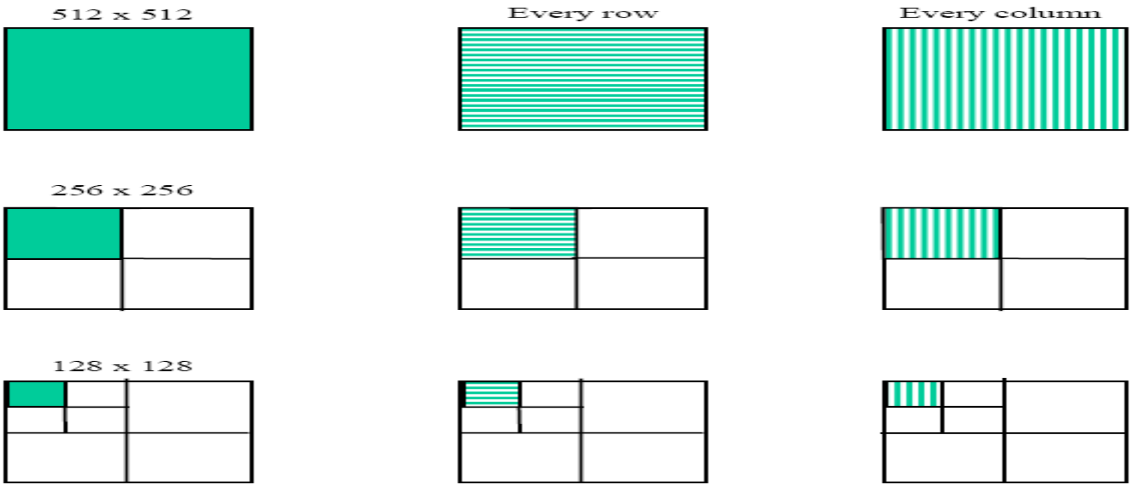
FIGURE – 6 THREE LEVEL DECOMPOSITION FOR WAVELET TRANSFORM



The original signal x[n] is input into the low-pass filter l[n] and the high pass filter h[n]. After three levels of decomposition, a reference signal r3[n] with the resolution reduced by a factor of 23 and detail signals d3[n], d2[n], d1[n] are obtained. These signals can be used for signal reconstruction.

The three levels of wavelet transform implementation are shown in below figure:

FIGURE – 7 WAVELET TRANSFORM IMPLEMENTATION



6. EXPERIMENTAL STUDY

Wavelet based image compression algorithm experiment is performed on Cameraman image. This experiment was performing in different algorithms such as Haar, Daubechies, Biorthogonal, Symlets and Coiflet at different level. In our experiment we perform this study up to five level. Below images represent the different algorithm at different decomposition level and compressed image.

FIGURE – 8 ORIGINAL CAMERAMAN IMAGE

FIGURE – 9 HISTOGRAM OF CAMERAMAN IMAGE

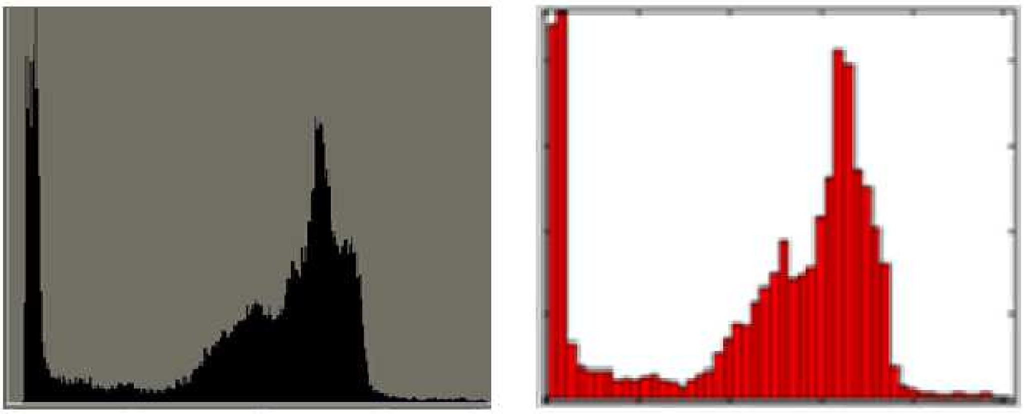


TABLE – 1 STATISTICS OF CAMERAMAN IMAGE

Mean	115.5
Median	141
Mode	8.56
Standard Deviation	64.01
Median Absolute Deviation	30
Mean Absolute Deviation	54.26

Below table shows the different wavelet based image compression algorithm at different decomposition level on cameraman image.

TABLE – 2 CAMERAMAN IMAGE COMPRESSION RESULT

Compression Algorithm	Decomposition Level				
	1	2	3	4	5
Haar	25	11	9	10	10
Daubechies	26	12	10	10	9
Biorthogonal	61	54	50	49	50
Symlets	62	55	51	52	52
Coiflet	62	55	50	49	49

FIGURE – 10 HAAR WAVELET IMAGE COMPRESSION CHART

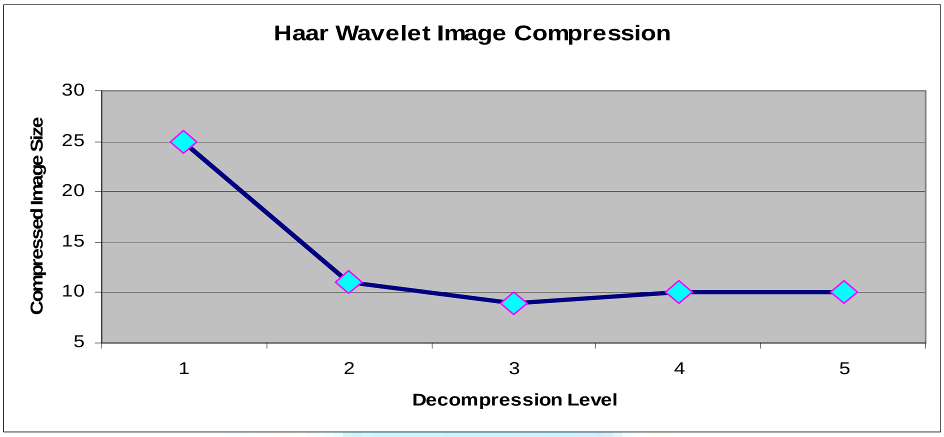


FIGURE – 11 DAUBECHIES WAVELET IMAGE COMPRESSION CHART

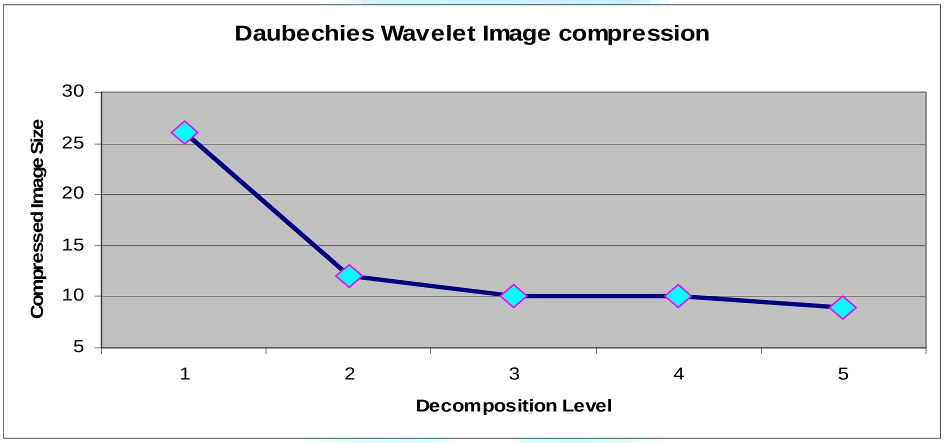


FIGURE – 12 BIORTHOGONAL WAVELET IMAGE COMPRESSION CHART

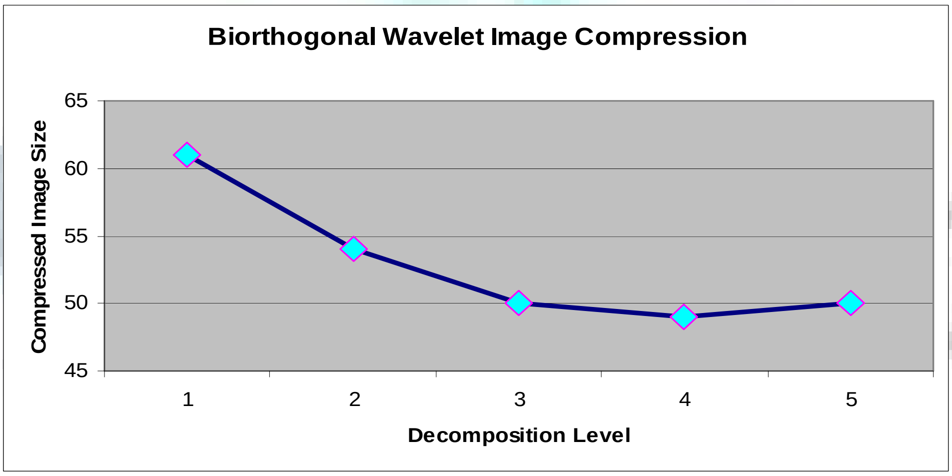


FIGURE – 13 SYMLETS WAVELET IMAGE COMPRESSION CHART

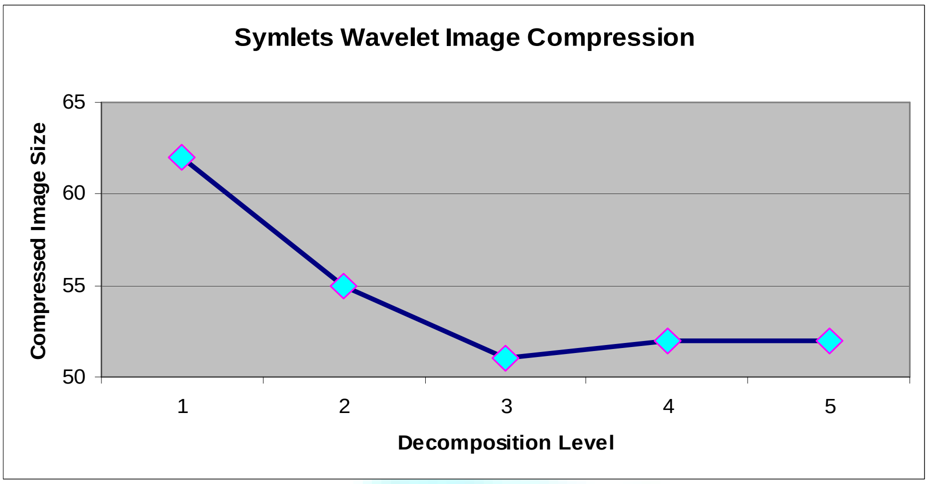
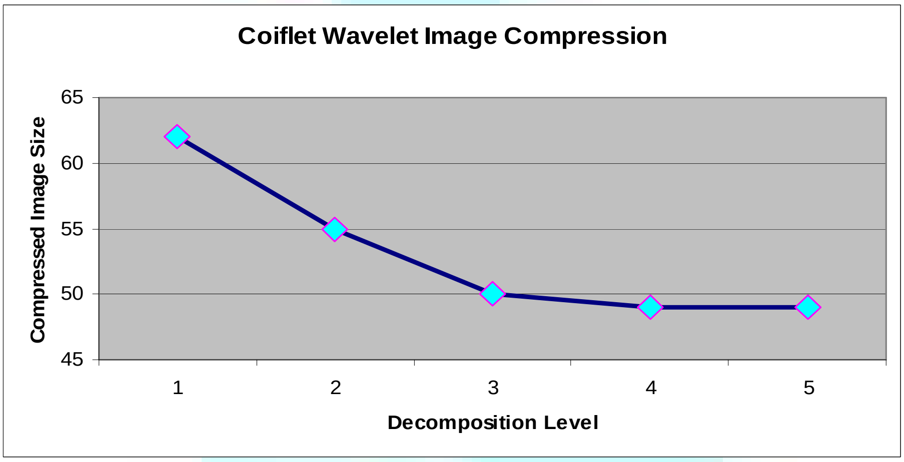


FIGURE – 14 COIFLET WAVELET IMAGE COMPRESSION CHART



7. CONCLUSION

From the experimental study of cameraman image of different algorithms at different level, it concludes that when you increase the decomposition level, the compressed image size is decrease which is shown in above table. This experimental study concludes that the best compression is performed by Haar and Daubechies wavelet image compression algorithm. Symlets, Biorthogonal and Coiflet wavelet image compression algorithms are also compressed the image at good level.

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