

A New Wavelet Based Bio-Medical Data Compression Scheme Using FPGA

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ABSTRACT: In today's telemedicine applications, the amount of data generated utilize more memory for storing the data and require more bandwidth for transmitting this type of data from one end to the other end. To overcome certain limitations and retain high image quality, data compression is considered as a necessary tool. The most advanced method for image compression is Discrete Wavelet Transform (DWT), because there are less blocking artifacts, which in turn leads to energy compaction with high quality of reconstructed data. The purpose for image compression is to decrease the bit-rate of the actual image, at the same time preserving high quality of the image. In this paper, we present the wavelet based medical data compression system using fpga (Field Programmable Gate Array). The prime idea behind this approach is *to dissolve the medical image first then insert the bio-signal and then consider the mixture data as an image for compression*. However, hardware implementing medical image compression using an adequate codec is proposed with respect to compression ratio, peak signal to noise ratio and root mean square error in order to appraise the compression system.

KEYWORDS: Discrete Wavelet Transforms (DWT), Field Programmable Gate Array (FPGA), Image Compression, Medical Data Compression.

I. INTRODUCTION

Data compression [7] is the procedure of removing the amount of data necessary in order to decrease the actual size of the data, by eliminating the unnecessary and irrelevant information. The image can be one dimension or two dimensions. Two dimensional image is described as a two dimensional signal, represented by the mathematical function $f(x, y)$ where x and y represents the horizontal and vertical coordinates respectively. The signal can also be defined as a mathematical function that conveys some information. There are two types of image compression system. They are lossy and lossless image compression. In lossy compression, there is a disappearance of information but the productiveness of compression ratio is high. In lossless image compression, there is no disappearance of information but the productiveness of compression ratio is less when compared to lossy compression. First let us know the fundamentals behind Image Compression system [6, 9]. The most unique feature of an image is that adjacent coordinates are linked between them and thus leaving an unnecessary information. Unnecessary removing of coordinates aims at producing only the exact facsimile of the image. In particular, there are three types of superfluous present in an image. First, Spatial Superfluous indicates the link between adjacent coordinates. Second, Spectral Superfluous indicates the link between color frames or spectral quadrant. Third, Temporal superfluous indicates the link between neighbor planes in accordance of an image. The main goal of image compression is to decrease the number of bits required to present an image by discarding the spatial and spectral superfluous at the most in order to give a productive compression system. The choice of image compression depends on the type of applications. In today's telemedicine applications, biomedical data compression [1, 2, 4, 7, 10, 13, and 14] system plays a vital role. In such systems, there should be no disappearance of information.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 8, August 2017

A. Wavelet Transform

The Wavelet Transform [3, 5, 8, 11, 12] can be considered as a useful approach in solving the problem of analyzing the signal/image processing both in time and frequency. The term *wavelet* is a function that can be expressed in both time and frequency. Wavelets can also be used as an alternate to the term *multiresolution analysis*. Initially the data (i.e., image/signal) is in spatial domain and transformed into frequency domain in order to extract the features or meaningful information of the data. Thus before compressing any data (image/signal), we need to transform the data from time domain (also known as spatial domain) to frequency domain. For this purpose, the discrete wavelet transform is employed in order to achieve high quality of the data and also the better compression efficiency. Before DWT, there were many previous methods such Fourier transforms, discrete cosine transform and so on, having certain limitations like low compression ratio, low PSNR etc [7, 8]. In Fourier transforms, the image dissolved in such a manner where we can obtain the initial image using Inverse Fourier transform, but Fourier transforms are not suitable for dynamic signals i.e., the signals which changes over time. Discrete cosine transform and discrete wavelet transform are used to dissolve noisy images. However, wavelets transforms has defeated the cosine transform in order to attain the productive compression system. Fig1 shows the basic elements of the image compression system. In this system, the image is first transformed from spatial domain to frequency domain using discrete wavelet transform, in order to extract the features for the analysis of image compression system. In the first step of transformation, were the image is divided into rows and columns, we first consider the rows and then the columns of the image. Thus the image can be dissolved into four portions. The first portion is the upper left portion, which consists of all the coordinates of the image. In the second portion, the horizontal edges of the image reside. In the third portion, the vertical edge of the image resides and finally in the fourth portion which is the lower right portion, the edges of the original image in the diagonal direction resides. Thus, the transformed image is quantized using some quantization values and finally encoded using various coding techniques.

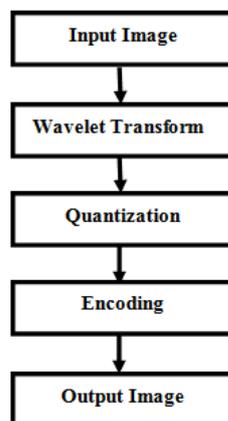


Fig1: The basic elements of image compression system

FPGA is a semiconductor device. The term *Field Programmable* means the device is programmed by the user and not by the manufacturer. An FPGA (Field Programmable Gate Array) is a reprogrammable chip containing thousands of logic gates that are internally connected together to build a complex digital circuitry. In this paper, we are going to carry out an adequate image compression algorithm with the help of *Field Programmable* in order to increase the productiveness and performance speed of the compression system. Field Programmable Gate Array (FPGA) is applied in several embedded applications such as mechanization, conversations, industrial computerization, motor supervision, medical imaging and many more. FPGA has been selected because of its *reform* ability, where we have the liberty to reshape or reform the hardware layout. Without the need of hardware layout, the application of FPGA devices extends the life of the system by changing data files. FPGA is grown to such an extent so that the whole system can be held on a single chip, thus allowing software testing and correction of errors if any in the system. Also, it attempts to take the advantage of hardware/software co-design in order to establish a high productive system for several applications.

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Vol. 6, Issue 8, August 2017

This paper contains introduction, related work where various methodologies used are explained in section II, Section III describes proposed system architecture. Section IV explains the analysis of system, section V shows the mathematical model, section VI gives the software requirement specification, section VII describes the Performance measures used with the success definition of the system and section VIII will conclude the paper.

II. RELATED WORK

In Earlier days of research work which took place in the field of medical imaging were focused on image filtering, image segmentation, and image registration and image compression. Many methods were used and discrete wavelet transform [3, 5, 8, 11, 12] is the most advanced method that needs to be considered for image compression. From the review of literature, we observed that the wavelet transform has been employed in various applications, apart from image compression. Some of them are as follows: signal denoising by wavelets, signal compression, fingerprint compression, image filtering and also in wireless communication systems.

Tahar Brahimi et.al in [1] has introduced the new concept of image compression called as multimodal signal-image compression scheme. In this paper, the decomposed signal is inserted into the image using insertion function or the mixing function. The insertion phase is performed in three different versions: spatial into spatial, spatial into wavelet, and wavelet into wavelet. This inserted data is now compressed using SPIHT encoder. In the decoding phase, the compressed image is reconstructed using the separation function in order to obtain the original image and the signal. This process is performed both on natural images and medical images and compared the results in terms of PSNR and PRD for both image and signal. The future work involves using other encoding technique and transform methods such as curvelets, contourlets and bandlets.

Alessandro Adamo et.al in [2] has discussed about electro-cardiogram (ECG) signals compression. An efficient algorithm is presented to show the sparsest between the signals. In this algorithm, the ECG signal is divided into uniform patterns in order to show the sparse between the signals. This signal is then quantized and encoded using various techniques like Huffman coding, arithmetic coding and so on. This experiment is carried out on various signal recordings which were already stored in the database and measured in terms of compression ratio, PRD and PSNR values. However because of the favorable results, the future study is to perform the experiment on portable devices so that the medical service is made easily available to all the people.

Boubchir L et.al in [3] has showed one of the applications of wavelet transform. According to this method, the medical image decomposition is done at various levels in order to obtain the coefficients of the image. These coefficients are known as frequency components. Once the coefficients are extracted, now divide the image in smaller blocks. On each block, the encoding is performed using different function. The encoding process is defined in such a way that the most significant pixels will be remained over the image and the low significant pixel will be removed from the image. After this stage, the image information and the compressed one will be obtained effectively from the image. These coefficient blocks are then combined using inverse DWT approach. Once the image is constructed, the compressed form of image is obtained. The future work involves performing the wavelet transform method on time frequency images.

Fournier R et.al in [4] has introduced a new kind of multimodal compression scheme on hyperspectral images. In this scheme, a mixing function, separation function, and the 3D-SPIHT algorithm is used. The mixing function is used to insert the signals into the image and then compress jointly. The separation function is used to reconstruct the original image and the signal. The SPIHT algorithm is used for encoding and decoding the signals. The main benefit of this multimodal compression scheme is to decrease this kind of encoding and decoding time, thus enhancing compression rate of the system.

According to Guo J in [5] there are various applications of wavelet transforms including signal processing and digital watermark for ensuring security purpose. In this paper the author introduces wavelet based watermarking with the Human Visual System (HVS), in which the watermarks are inserted into the portions of the image coordinates which

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Vol. 6, Issue 8, August 2017

were already decomposed by the wavelet transform. The experiment results is analyzed using PSNR values based on the quality of the image and also helps in managing copyright issues.

In [6] Khan Et.al has shown that the compression efficiency can be calculated using various methodologies and coding techniques. The author proposed Bi-level Burrows Wheeler Compression Algorithm (BBWCA) coding technique on various images such as raster map images, Color Filter Array (CFA) images and 2-D ElectroEncephaloGraphy (EEG) image data. This method obtained better compression efficiency and execution speed when compared with the other coding techniques.

Ranjeet Kumar et.al in [7] have presented an algorithm which is based on singular value decomposition (SVD) and wavelet difference reduction (WDR) techniques for ECG signal compression with large amount of data present in the system. SVD based compression technique have good reconstruction quality but with low compression ratio and WDR have exactly opposite characteristics. Both of these techniques have used in order to calculate the efficiency of the system.

Kumar et.al in [8] have proposed SVD and Embedded Zero tree wavelet (EZW) coding techniques for ECG signal compression with large amount of data present in the system. Again in this system also the most important parameters have been used for calculation of performance efficiency. As the compression rate increases the PRD value also increases. The processing speed decreases when there is large amount of data in the system.

III. SYSTEM ARCHITECTURE

The system architecture is as shown in fig2. In this system, the input file is written into the software. The input file consisting of medical data such as an image or the bio-signal, this input file is stored in the SRAM memory. The first processing of the input file is to decompose the image using the wavelet transforms for feature extraction of the image. Once the image is decomposed, we are going to insert the signal pixels in place of the redundant pixels of the original image. In this way, we are going to compress both the image and the signal together which in turn saves the processing speed or the execution speed of the compression system. The processor and the controller play a key role in this compression system. Once the image is compressed the output file is stored in the DRAM memory which will be necessary for future reference. The output file is readout from the software and is displayed to the output screen, where we can see the compressed output file.

A. Preprocessing Module

In the first module that is the preprocessing module, the input medical MRI image and the bio-signal (ECG) [1, 2, 4, 7, 10, 13, 14] is mixed using mixing or insertion function with the help of MATLAB software. The output of this module is the mixed data which consists of both image and signal in one image file. This image file is in terms of bit file which is then given as input to the FPGA.

B. Compression Module

In the second module, the Discrete Wavelet Transform (DWT) method is applied using FPGA implementation for image compression. The output of this module is the compressed image. In order to reconstruct the original image and signal we should apply inverse discrete wavelet transform and also use separation function to get back the initial image and signal.

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Vol. 6, Issue 8, August 2017

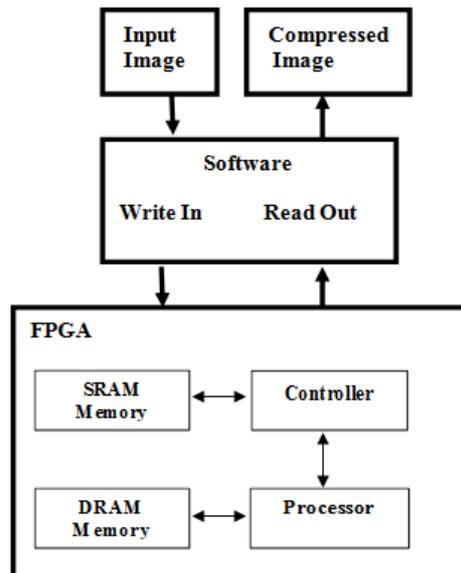


Fig2: The Proposed System Architecture

IV. SYSTEM ANALYSIS

The flow diagram of the system is as shown below. In fig3 the original image and the original signal is combined together by applying the insertion function [1, 14]. The inserted data is now encoded using encoding scheme and the resulting compressed file is preserved.

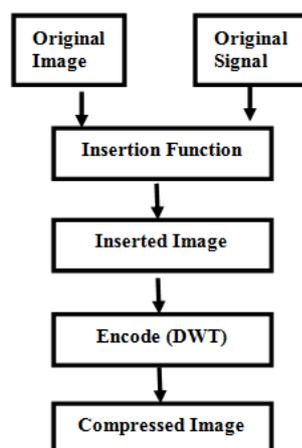


Fig3: Flow diagram for Encoding Process

The compression system can be analyzed by using various parameters like compression ratio, peak signal to noise ratio and the Percent of root mean square error as the important metrics for analyzing the compression system. The compression ratio is described as the proportion of the number of coordinates present in the original image to the number of coordinates present in the compressed image. The other two metrics that is the PSNR and PRD are used to estimate the image quality and bias present in an image. Without these important parameters it is difficult to analyze the

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

size, quality and misinterpretation if any present in the compressed image. Therefore, these are the essential metrics which are always used in the performance evaluation of compression system.

A. DWT Algorithm

The step for DWT Algorithm for Image Compression is as follows:

INPUT: Original MRI image with ECG signal

OUTPUT: Compressed Image

Step 1: Digitize the source image to a signal s , which is a string of numbers.

Step 2: Decompose the signal into a sequence of wavelet coefficients.

Step 3: Use Thresholding to modify the wavelet compression from w , to another sequence w .

Step 4: Use Quantization to convert w to a sequence q .

Step 5: Apply Entropy coding to compress q into a sequence of e .

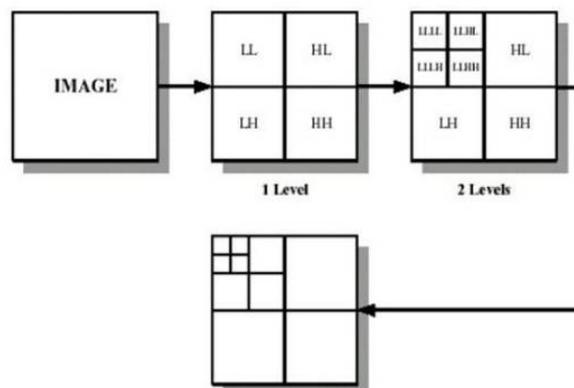
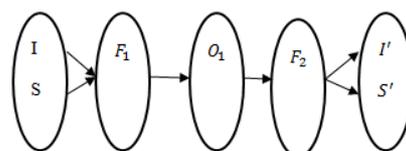


Fig4: Image Compression Levels

V. MATHEMATICAL MODEL AND DESIGN

The mathematical model is used to know the definitions of the functions and also the relationship between these functions used. With this mathematical model we can easily measure the significant behavior of the system and match with the present system in order to find out vitality and deficiency. The image compression system in terms of mathematical model is explained as follows.

A. Mapping Diagram



The mapping diagram is as shown above where

I = Image

S = Signal

F_1 = Insertion Function

O_1 = Compressed Image

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

F_2 = Separation Function
 I' = Reconstructed Image
 S' = Reconstructed Signal

The insertion function used in the encoding phase is defined as follows:

$$s'(t) = \frac{s(t)}{\max(s(t))} \times (2^B - 1) \quad \dots\dots (1)$$

The separation function used in the decoding phase is defined as follows:

$$s(t) = \frac{s'(t)}{(2^B - 1)} \times \max(s(t)) \quad \dots\dots (2)$$

where B is the bit-depth of the host image, s(t) is the original signal and max(s(t)) is the maximum value of the original signal s(t).

B. Set Theory

$$S = \{I, F_1, O_1, F_2, O_2\}$$

I = {Medical Image, Bio-Signal}
 F_1 = {Insertion or Mixing Function}
 O_1 = {Compressed Image}
 F_2 = {Separation Function}
 O_2 = {Reconstructed Image and signal}

where S is the image compression system, I is the input, F_1 is the insertion function, O_1 is the compressed output image, F_2 is the separation function, O_2 is the reconstructed output image.

Space Complexity: The space complexity depends on the size of the medical data (image and signal) stored in the database. More the storage of data more is the space complexity.

Time Complexity: Check No. of images available in the database = n. If (n>1) then retrieving of information can be time consuming. So the time complexity of this algorithm is $O(n^n)$.

Φ = Failures and Success conditions.

Failures:

1. Huge database can lead to more time consumption to get the information.
2. Hardware failure.
3. Software failure.

Success:

1. Search the required information from available in Database.
2. User gets result very fast according to their needs.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

VI. SOFTWARE REQUIREMENT SPECIFICATION

The requirement specification table is as shown below which consists of hardware and software requirements used in order to develop the project. This is very essential to evaluate the results of the experiment in order to determine the efficiency of the system.

Table I: Software Requirement Specification

Hardware Requirement	Software Requirement
FPGA Spartan 3	Xilinx ISE 14.5
Arduino	MATLAB 2013
	Windows 7 OS

- A. **Functional requirements:** Functional requirements deal with what the system should do or provide for users. They include description of the required functions, outlines of associated reports or online queries, and details of data to be held in the system.
- B. **Non-Functional requirements:** A non-functional requirement is a requirement that specifies criteria that can be used to judge the operation of a system, rather than specific behaviors. Non-functional requirements are often called "quality attributes" of a system. Our System fulfils the following non-functional requirement:
- **Runtime System Qualities:** Runtime System Qualities can be measured as the system executes.
 - **Functionality:** The ability of the system to do the work for which it was intended.
 - **Performance:** The response time, utilization, and throughput behavior of the system. Not to be confused with human performance or system delivery time.
 - **Security:** A measure of systems ability to resist unauthorized attempts at usage or behavior modification, while still providing service to legitimate users.
 - **Availability:** (Reliability quality attributes falls under this category) the measure of time that the system is up and running correctly; the length of time between failures and the length of time needed to resume operation after a failure.
 - **Reusability:** The degree to which existing applications can be reused in new applications.
 - **Testability:** The ease with which software can be made to demonstrate its faults.

VII. PERFORMANCE MEASURES USED

The performance metrics used in order to evaluate the compression system is the compression ratio [7, 8]. The compression ratio is described as the proportion of the number of coordinates present in the original image to the number of coordinates present in the compressed image. The compression ratio is as shown below in equation (3).

$$CR = \frac{\text{Number of Bits in original image}}{\text{Number of Bits in compressed image}} \dots\dots\dots (3)$$

A. Implementation

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

The implementation of the image compression system is as follows: the figure below shows how to run arduino program in order to generate ECG signal. The arduino sensor is connected to the laptop using USB cable and once the person comes in contact with the sensor, the ECG signal is displayed on the screen.

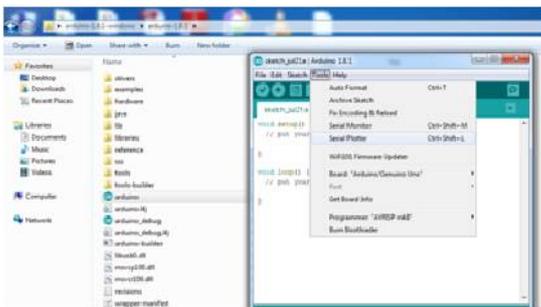


Fig 5: Running Arduino program to generate ECG signal



Fig6: Generating ECG signal from sensor

This signal is saved as a text file in MATLAB. The medical images are downloaded from the physionetbank database. Now the ECG signal is inserted into the MRI image using MATLAB functions.

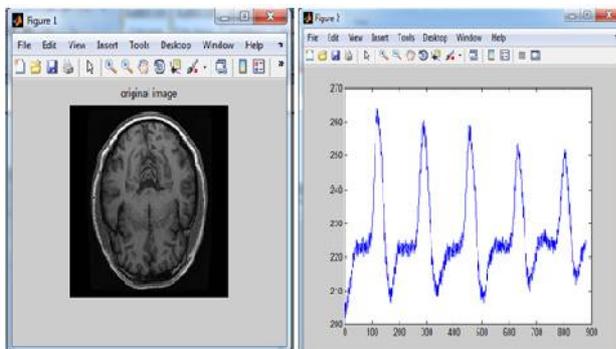


Fig7: The input MRI image and the ECG signal

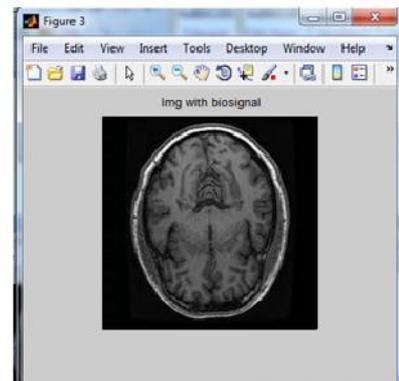


Fig8: MRI image with the ECG signal

The image thus obtained is converted to .coe file and sent to the Xilinx software for FPGA implementation. The DWT algorithm is implemented in Spartan FPGA board using Xilinx software.



Fig9: Spartan FPGA board

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

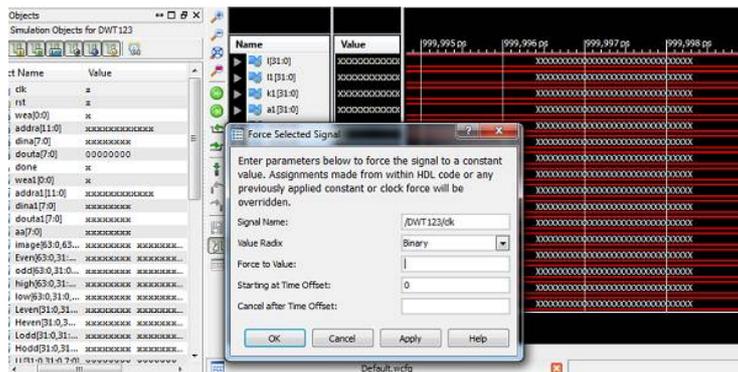


Fig10: Simulation objects for DWT



Fig11: Simulation Result

The figure shows the simulation results using DWT for image compression. The DWT decomposes the input image into LL,LH,HL and HH coefficients. The LL coefficient indicates the compressed image with low frequency values in which most of the information resides and the HL,LH and HH are the high frequency values.

Compression Ratio = 36.3354
Original Image FileSize: 24246
Compressed Image FileSize: 4513
Decompressed Image FileSize: 3713

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

B. Result Analysis and Discussion

Table II: Test case

Input Data	DWT Levels	Original size	Compressed size	CR
MRI with ECG	Level 1	24246	4293	23.228
MRI with ECG	Level 2	24246	4513	36.335
MRI with ECG	Level 3	24246	5345	41.718
MRI with ECG	Level 4	24246	5741	43.458
MRI with ECG	Level 5	24246	4785	44.146

The table shows the result of the image compression algorithm. As the levels of the decomposition increases, the compression ratio also increases. The same is represented in graph below.

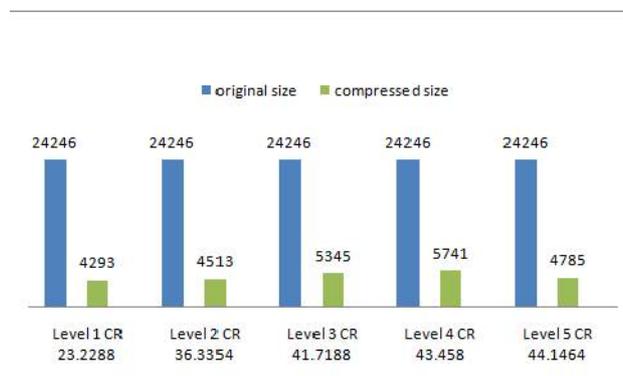


Fig12: Result Analysis

C. Outcome and Success Definition

The outcome of our system is to save the storage space and fast processing performance will be obtained with hardware implementation as compared to state of art systems.

VIII. CONCLUSION

We implemented a new wavelet based [3, 5, 8] data compression scheme. It is recommended to compress image and a bio-signal together applying an efficient codec. Here we also discussed about various methods available for the image compression. Among these methods we select the most appropriate one for our compression system. Through hardware implementation the complexity and cost reduction can be easily done and also we try to achieve the maximum best

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

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Vol. 6, Issue 8, August 2017

results by using an efficient coder. This technique is very essentially used in medical database system. With this kind of FPGA implementation the memory saving and fast processing is achieved in the medical database system.

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