AN EXQUISITE APPROACH FOR IMAGE COMPRESSION TECHNIQUE USING LOSSLESS COMPRESSION ALGORITHM FOR ROI & NON-ROI REGIONS

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ABSTRACT

The imminent evolution in the field of medical imaging, telehealth and teleradiology services has been on a significant rise with a dire need for a proficient structure for the compression of a DICOM (Digital Imaging and Communications in Medicine) standard medical image obtained through various modalities, with clinical relevance and digitized clinical data, and various other diagnostic phenomena and the progressive transmission of such a medical image over varying bandwidths. The data loss redundancy during the process of compression is to be maintained below the alarming level, meaning it is to be under scanner without the loss of data/information. In this paper we present an efficient time bound algorithm that utilizes a process flow wherein multiple ROI sectors as well as the Non-ROI sector of the DICOM image are considered in the algorithmic machine and the compression is done based upon a hybrid compression algorithm by LZW & SPIHT encoder & decoder machines. The paper provides a magnitude of the overall compression ratio involved in thus compressing the DICOM standard image. It also provides a brief description about the PSNR values obtained after suitably compressing the image. We analyze the various encoder scenarios and have projected a suitable hybrid lossless compression algorithm that helps in the retrieval of the data/information related to the image.

This paper also discusses around the Integer Wavelet Transforms used in order to encode the image and thus parameterize various metrics related to the transform function provided by IWT. It is seen that we could achieve a compression ratio value specific to 92% thereby swaying with a large deviation in the considered metric.

KEYWORDS

Wavelet Transform, Hybrid Encoder, IWT (Integer Wavelet Transforms), ROI (Region of Interest) & Non-ROI (Non-Region Of Interest), PSNR, Compression Ratio

1. INTRODUCTION

The image compression has evolved into one of the imminent and necessary dynamic field in today's research and the needful areas of medical imaging, telehealth, and telemedicine services. Thus care needs to be taken while the data/information pertaining to a DICOM standard image is being compressed for transmission across a suitable medium between various health inspectors or health institutions for various diagnostic purposes. Lossless image compression has proven to be a well established approach in reducing the image data without compromising the quality of the same. Medical Imaging is been in use for various diagnostic as well as surgical processes. It sometimes may need a long-term storage for profiling the patient's data as well as the transmission of the same over to long distances. One of the most proven and valuable tools supporting the Picture Archiving and Communication System (PACS), a key successor facilitating the exchange of the structured medical imaging data to PACS is, Digital Imaging and Communications in Medicine (DICOM) standard. This DICOM file consists of a header, containing the information about the patient's name, type of scan, position & dimension of the scan, and other image data. While all the image information will be contained in the image data. The very motivating aim of image compression is to maintain a very squat but rate representation with respect to the image data of a patient. Reduction in the storage and potency with its limitations as such, without any loss in the entropy of an image and the transmission of the raw information pertaining to the image reducing the ubiquitous redundancy is the major aspects that needs to be addressed during an image compression and by its underlying algorithm. With such an approach we have two different types of compression techniques;

- *Lossy Compression Techniques* – some of the data pertaining to the image data may be lost or some identified changes or loss may be incurred, in the reconstructed image.
- *Lossless Compression Technique* – the reconstructed image will be exactly the same as the original image, without loss of data in the image.

The proven task is to obtain better compression ratios during multimedia and image compression, without any as such compromise in the data of the multimedia file or an image file, during the loss in the communication field or during compression.

A well constructed as such approach is discussed and highlighted in this paper, which focuses on the potential gains which are achieved in archiving and compressing a medical image like a DICOM image using a lossless compression technique which is an hybrid with the dictionary based approach of LZW lossless image compression algorithm & SPIHT, with the amount of data being minimal for the transmission of data with a high quality of the image and IWT (Integer Wavelet Transforms) algorithms across a region of importance termed as the Region Of Interest (ROI) and the Non-ROI (Non Region Of Interest) sections of the medical image and applying suitable compression algorithms and differentiating a metric among various lossless compression algorithms and their deviations from each other, in terms of the compression ratios and the data redundancy.

2. IMAGE COMPRESSION

The compression of digital medical images is of great demand nowadays. The compression of such images may involve a single image or a sequence of images. With the days the medical community has been reluctant on the compression techniques by adopting to lossy over lossless compression techniques in clinical practices. With a geometric increase in the diagnostic data and images produced by the medical organizations, a suitable compression technique is needed to compress large amounts of data resulting in greater data reductions and transmission speeds over a bandwidth. The preference to lossy compression techniques is provided in these cases for the perseverance of the diagnostic information. Lossy compression techniques involve deliberate discarding of information for the image that is not visually or diagnostically important. Modest compression metrics can be achieved in lossy compression techniques with a significant loss of data. But on a contrary note greater compression rates are achievable in lossy compression techniques with an acceptance of visible loss of data for the clinical task. For particular applications, there is still a controversial role with lossy compression techniques. This due course of compression techniques can be overcome by an appropriate lossless compression technique and the performance of traditional and state-of-art metrics involved in the compression techniques are evaluated.

The lossless compression techniques involve some of the crude classifiers such as;

- Statistical Modelling involving predictive schemes, with the differences between the underlying and the neighbouring pixels of an image are computed before the coding of compression algorithm with Context Modelling.
- Each pixel or a cluster of pixels being transformed into frequency or wavelet domain prior to modelling and coding, as in Transform Based Coding.
- Ad-Hoc Schemes (as such in Run-Length Encoding)
- Replacing strings of symbols with code snippets, as in Dictionary Based Schemes.

Dictionary Based Schemes are widely used for text data compression. Advantage of data redundancy occurs in image compression techniques. Each one of these redundancies will be exploited by each of the compression methodologies. The various redundancies are;

- *Spatial*
- *Temporal*
- *Spectral*

The underlying idea behind most of the compression algorithms is to transform an image suitable for storage and transmission and also to represent the image in the form of an orthogonal function so as to distribute the energy signal components among the various de-correlated components.

3. RELATED WORKS

Compression of DICOM images for different entities on SPIHT (Set Partitioning in Hierarchical Trees) with progressive transmission qualities for telemedical applications, wherein the header of the DICOM file is transmitted first followed by the image data in various stages. It works on the principle of spatial relationship among the various wavelet co-efficient at different levels and frequency sub-bands in the pyramid like structure of the wavelet decomposition, producing streams of embedded bits for an image. This work was proposed as a methodology by Ramakrishnan et al. (2006) for the compression of wavelets and splints for telemedicine applications. Various compression metrics were evaluated with other standard lossless image compression techniques and were concluded that they produce the best results with less consumption of bandwidth and lesser execution time as well as transmission time. In another methodology proposed by Kumar et al. (2008), they considered DCT (Discrete Cosine Transforms), SVD and BTC (Block Truncation Code), SD (Standard Deviation) depending upon the properties of the image and the requirements. The evaluation of such a kind of a methodology yielded quite reliable results with respect to the performance metrics in terms of PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error). Limitations with respect to the SPIHT techniques as proposed by Ramakrishnan et al. (2006), involving the non specification of the types of wavelets for image compression lead to the evolution of a new methodology proposed and worked around by Bairagi et al., wherein they made as selection of wavelets for medical image compression. Analysis over all the 'db' wavelet series and the comparison of the results over several metrics such as PSNR, MSE, NAE (Normalized Absolute Error), Structural Contents etc, showed up an improvement with their proposed methodology. A revival over various implemented image compression techniques and algorithms involved in this compression techniques were discussed by Dhawan et al. (2011). They also proposed a low bit compression and fractal approach utilizing resolution free decoding property for a low bit compression. Verification approach by correlation using the wavelet compression of pre-processing digital images was presented by Morales et al. (2012). A biometric system was implemented that used a recognition pattern for digital finger-print which satisfies the characteristics of uniqueness, universally, performance and collectability. They used a specific Fourier Transform and wavelet transform to perform the function of correlation, compression, compressed filter implementation, transformation and GUI implementation. An advanced approach using DCT in DCM to improve the performance of the image compression and its underlying metrics such as performace , minimum data loss, and reconstructed image clarity with HAAR process, using orthogonal combination on unit interval was proposed by Alka Sharma et al. (2013). There was also a proposal of such a work involving the multiple ROI sections over a suitable medical image and an efficient lossless compression algorithm to compress the ROI section of the medical image while the Non-ROI section being done with a lossy compression algorithm was subdued with an ideology proposed by Shivaputra et al. (2014). They proposed a workflow that rather utilizes an efficient lossless image compression algorithm for both ROI and Non-ROI section of a DICOM standard medical image.

Before the discussion of the actual methodology involved in this proposed work we considered the very basic workflow or the idea of implementing the lossless image compression algorithm for both ROI and Non-ROI sections and evaluation of the various performance metrics such as PSNR, MSE, NAE, and energy distribution within the compressed image and the need for a suitable lossless image compression algorithm for a suitable transmission over a bandwidth.

4. Proposed Methodology

In this paper we have proposed an efficient approach for the lossless image compression using the IWT transformations for both ROI and the Non-ROI sections of the DICOM standard medical image. This approach has provided an improvement in the performance, redundant loss in the image data and reconstructed image. The process involved in this approach is as given below;

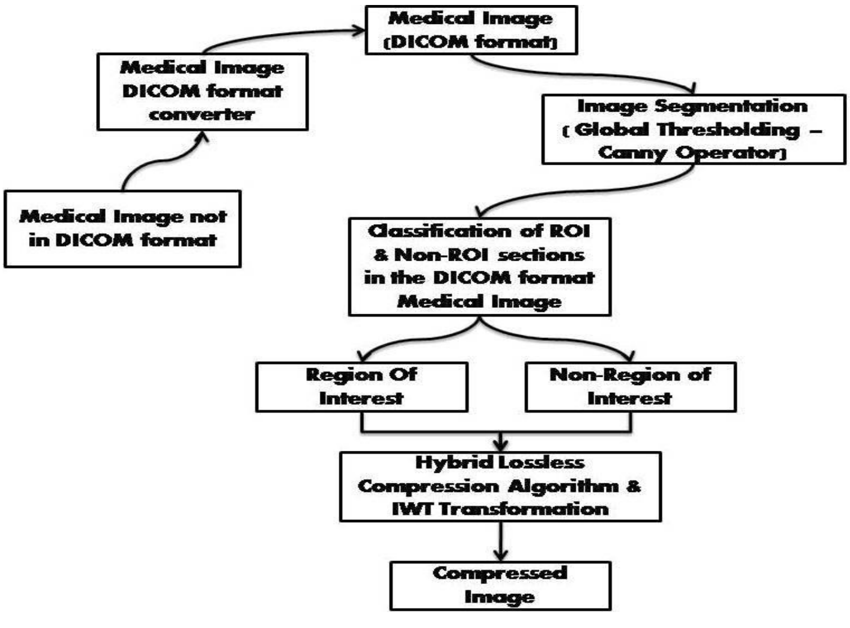

Figure 1. Proposed Methodology Flow Diagram

A suitable medical image obtained from the varsity of the modalities is obtained in the prescribed DICOM standard, which can be in any of the acceptable formats such as bitmap (.bmp), tiff or jpeg. Here for the justification of our methodology we have used a Nose Fracture X-ray image of the format .bmp and the resolution 256X256. Thou image is subjected to the Image Segmentation (Global Thresholding) to segment the complex image file into simpler structure to be input to the compression algorithm. The values specific in this proposed work is considered as, 0.44 as the Global Threshold (Graythresh) and a threshold value of 0.55. We also implement the Canny operator to segment the complex DICOM standard medical image. The below figure justifies the segmented image and its histogram analysis of the Graythresh value.

Figure 2. Original Nose Fracture Image

Figure 3. Canny operator segmented image

The segmentation procedure can be done using the normal gray threshold as it yields much better analysis results [3]. The previous works involving segmentation of the image before subjecting it to the compression phenomena has proven to be back bone for the same in our work, with their values revolving around the scenarios as 1.0 as the Threshold values. But in our work we are considering a value much lesser than these values as it has proven to provide with a better metrics like CR, MSE and PSNR evolving from the compression of the image. The histogram and the Gray threshold segmented image is as shown below. The other metrics that correlates with the segmentation of the image by thresholding are as;

- Sensitivity Threshold = 0.047
- Sigma operator = 1 (default)
- Overlay Opacity = 0.4
- Image Opacity = 1
- Overlay Color = Black

Figure 4. Gray Threshold segmentation of the image

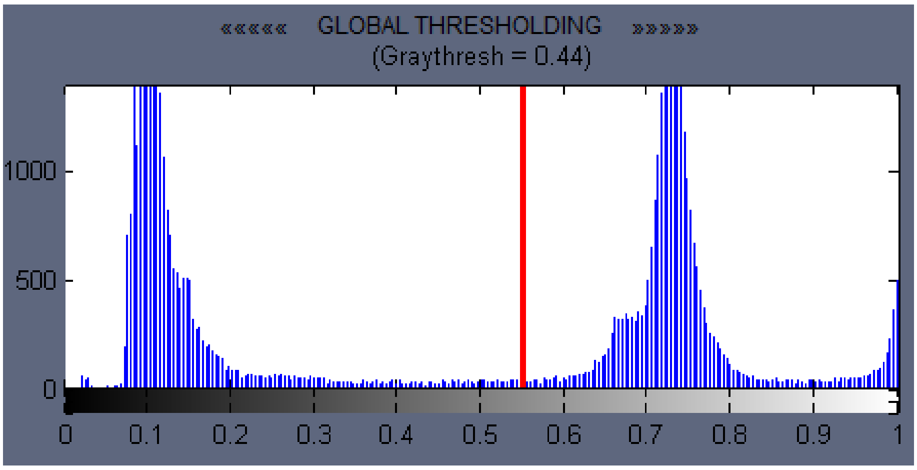

Figure 5. Global Gray Threshold Value

The considered image if not in a DICOM standard then a mechanism for the conversion of the same to a standard DICOM medical image format has to be done (usually a grayscale image format). The image is input to the ROI tool to classify the ROI and the Non-ROI sections. Figure 5 & Figure 6 provides a substantial proof for the classification.

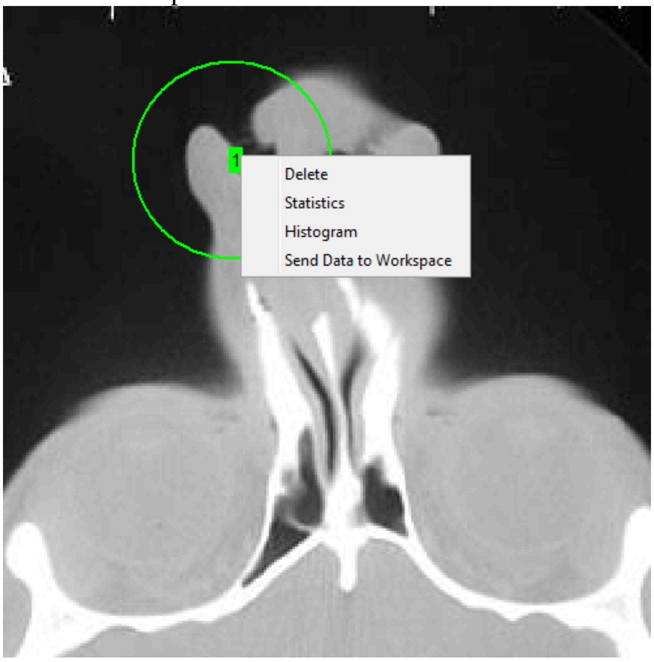

Figure 6. Classification of the ROI and the Non-ROI from the segmented image

A selection is made with respect to the multiple ROI sections in a DICOM standard medical image. We analyze various parameters such as Statistics, Histogram with reference to the ROI section selected and the Data related to the ROI selected, which is imported to the Workspace of the MATLAB environment. Multiple ROI sections may be recorded or classified from a DICOM standard medical image. We have considered 2 ROI sections within this image considered for our work.

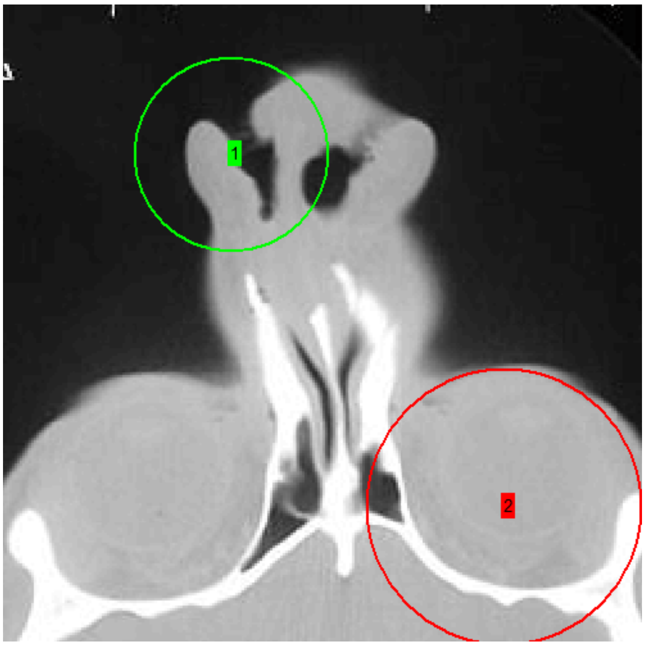

Figure 7. Multiple ROI selections within the segmented image

The Histogram feature set of the ROI section 1 being selected from the DICOM standard medical image provides details about the data features of the ROI section placed in the Workspace environment of the MATLAB tool. The given data is in the form of a structure 1X1, with the metrics such as Mean, Standard Deviation, Mask, Minimum and the Maximum pixel values of the image. The selected ROI will be expressed in the double format while the mask is also in the double format to classify between the ROI and the Non ROI sections in an image.

Command Window | Variables - ROI_2

ROI_2 ×

ROI_2 <1x1 struct>

Field	Value	Min	Max
Mean	189.7737	189.7737	189.7737
StdDev	28.0586	28.0586	28.0586
Min	43.8281	43.8281	43.8281
Max	255	255	255
NPixels	9465	9465	9465
Mask	<256x256 double>	0	1
I	<9465x1 double>	37421	65089
Z	<9465x1 double>	2805	16320
X	<9465x1 double>	1	109
Y	<9465x1 double>	147	255

Figure 8. ROI Data in the workspace environment

The image is compressed using the hybrid compression algorithm involving both LZW & SPIHT, and the image is obtained after the algorithm is run with a maximum loop structure for about 16 iterations. The minimum number of loops encountered will be 12 as the variation in the compression ratios in the order 3:1 is achievable only from the loop value ranging from 12. The Bit-Per-Pixel (bpp), MSE (Mean Square Error) and the (Peak Signal-to-Noise Ratio) PSNR is recorded for the same and the deviation with the metrics are evaluated.

Thus obtained image with the classification of ROI and NON-ROI sections is input to the transformation algorithm machine, based on IWT (Integer Wavelet Transforms). High fidelity images like the medical images require an efficient lossless encoding procedure for its preservation.

The set of transforms are governed by the following equations in IWT;

$$d_{1,l}^{(1)} = s_{0,2l} + 1 - s_{0,2l}$$

$$s_{1,l} = s_{0,2l} + \left\lfloor d_{1,l}^{(1)} / 2 \right\rfloor$$

$$d_{1,l} = d_{1,l}^{(1)} + \left\lfloor \alpha_{-1}(s_{1,l-2} - s_{1,l-1}) + \alpha_0(s_{1,l-1} - s_{1,l}) + \alpha_1(s_{1,l} - s_{1,l+1}) - \beta_1 d_{1,l+1}^{(1)} \right\rfloor$$

The IWT engine takes in the DICOM standard medical image and the effectiveness of this transformation algorithm is done by substantially measuring the first order entropy relate to the medical image. The magnitude of these entropies with respect to various quadrants of the ROI sections and the Non-ROPI sections varies relatively, while their mean is calculated. The wavelet filter is attached to the coding algorithm in order to obtain the higher entropies to compute the actual bit rate. Higher order filters can be used in order to produce a better compressed image. We could achieve a comprehensive compression ratio rate of about 11.039 with the S-filter and the efficiency was improved with higher order filters like (4,2) and (2,2+2). Bit Rates in the range 3.56, 4.89, 6.81, 4.77, and 3.14 were obtained with S-random, SPB, SPC, 2/6, and 2/10 random filters. Among the different flavours of approaches we calculate with the spatial domain approach using the equation;

$$d_j = s_j - \left\lfloor g\,(s_{j-J}, \dots \dots \dots, s_{j-3}, s_{j-2}, s_{j-1}) \right\rfloor$$

Table 1. Bit Rates with respect to various filters

Filters	**Bit Rate**
S-transform	3.42
SPB	4.89
SPC	6.81
2/6	4.77
2/10	3.14

Now the ROI and Non-ROI classified image is compressed using the hybrid compression algorithm which has a dictionary based approach as in LZW Lossless Image Compression algorithm as well as the pyramid like structure approach with the 4 different filters used in the SPIHT (Set Partitioning in Hierarchial Trees). The procedure of the proposed work / algorithm is as follows;

Step1: Select the segmented image X;

Step2: Initialize the vectors in the dictionary table for the hybrid algorithm with uint16 & double format;

Step3: The grayscale pixel values are imposed onto the segmented pixels;

Step4: Filters such as LL, HH, LH & HL as in SPIHT are used to move up the pyramid to provide with different values to have a high quality compressed image with the classified ROI & Non-ROI sections with the data from the classification;

Step5: The compressed image is transformed using the IWT with 5 high order filters; as shown in the figure below.

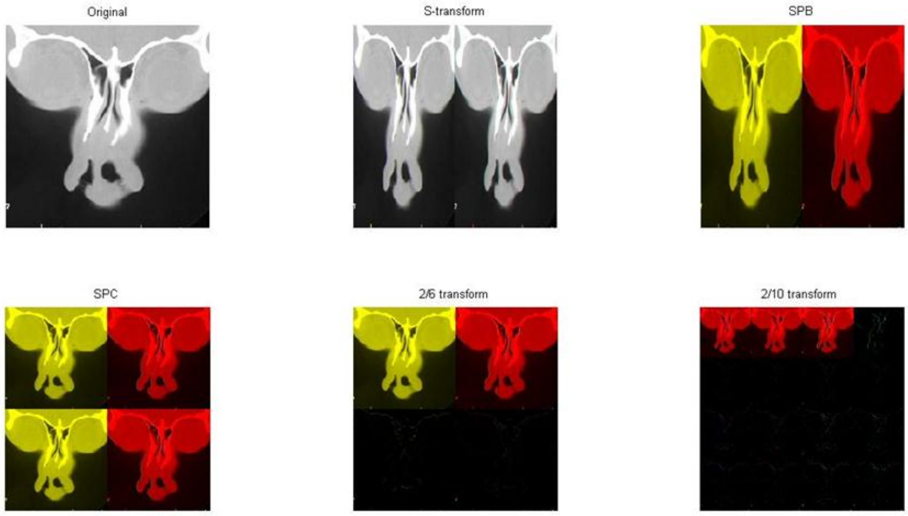

Figure 9. IWT Transformation of the compressed image using Hybrid Lossless Compression Techniques involving both ROI & Non-ROI sections

5. PERFORMANCE METRICS

Appraisal of the performance of the image compression algorithm is performed by using the following metrics obtained as the Compression Ratio (CR) and PSNR (Peak Signal-to-Noise Ratio), determining the quality of the reconstructed image. The rate of distortion is also gauged with the metric MSE (Mean Square Error) for the image pixels A sheer measure of the image compression, Bit Rate (BR) is also analyzed as against the various relative quotas. The amount of information encoded in the image as the encoded bit rate gives a measure to assess the effectiveness of the scheduled compression algorithm. The Compression Ratio metric is a reliable aspect for the analyses of the performance in the "real world".

(i) Compression Ratio:

The ratio being specifically with a value, between the original image and the actual compressed image by a suitable image compression algorithm, governed by the equation as;

$$CR = \frac{n_1}{n_2}$$

(ii) Peak Signal-to-Noise Ratio:

Human perception approximation being made with regards to the quality of the reconstructed image, given as;

$$PSNR = 10\log_{10}\frac{(MAX)^2}{MSE}$$

(iii) Mean Square Error:

Quota of the scale of distortion in a reconstructed image obtained from a decoder is MSE, monitored by the mathematical formulae;

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]$$

Higher the deterministic values output with respect to PSNR and higher CR values, yield a high quality of the reconstructed image.

The values for the above mentioned metrics are recorded after the compression of the DICOM standard medical image. The table given below gives the details about the Maximum loops the iterations have entered for the compression of the image, CR, BPP, MSE and PSNR.

Table 2. Table representing various metrics with respect to the maximum number of loops of iterations

Maximum Loop	**CR**	**BPP**	**MSE**	**PSNR (dB)**
12	3.4261	0.8223	6.9835	39.6901
13	5.7938	1.3905	3.4397	42.7656
14	9.9747	2.3939	1.9047	45.3324
15	16.4083	3.9380	1.3057	46.9722
16	25.1424	6.0342	1.1157	47.6552

6. CONCLUSION

In this work, we have worked around the compression techniques using the lossless compression algorithms with IWT. DICOM standard medical images from various medical diagnosis phenomena are obtained and are used for telemedical applications and diagnostic purposes. The recommended format of medical images providing the information about the patients in the header of the DICOM file while the information about the image in the image data file. Here we have considered the metrics such as PSNR, MSE and CR between various transforms using various high order filters. Thus obtained results are compared with the various images and their compression techniques and were found that the proposed algorithm depicts that the value of PSNR, CR, MSE for the DICOM standard medical image, proving to be more reliable and efficient. The performance of our proposed method of IWT using Lossless Image Compression techniques (Hybrid Compression technique) is measured over the DICOM medical image and observed the results for decomposition levels. The proposed algorithm scheme has given superior image compression results for DICOM images.

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