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A Review On Medical Image Compression Techniques

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ABSTRACT

Medical Images are the digital representation of the body images. The medical imaging technology has a tremendous growth in past few decades. The amount of diagnostic data produced in a medical image is vast and this could create several problems when sending the medical data through a network. To overcome this problem there is a great need for compression of medical images for communication and storage purposes. Now a day's medical image compression plays a key role as hospitals to have high image quality with relevant diagnostic information and with less storage requirements so that it can be easily transmitted over a network and can be accessed within a limited time. Current compression schemes provide a high rate of compression with a considerable loss of quality. This paper discusses a survey and analysis of different image compression schemes for the medical images.

Keywords:*Compression; CR (Compression Ratio); Lossy; Lossless; Medical Images; PSNR (Peak Signal To Noise Ratio)*

1. INTRODUCTION

Data compression is the term which is used for compressing data files so that they could be stored in much less memory space rather than in their original form. Image compression is the technique of minimizing the size of any image files without lowering the quality of the images to an unacceptable level. Due to this distinctive property, Image compression techniques are extensively used in many applications, especially in telemedicine field in order to minimize the cost of storage .It is also used to increase the transmission speed of medical images and data at available bandwidth [1]. In medical image compression, diagnosis will be effective only when compression techniques preserves all the most significant information needed without any significant information loss [2]. Maintaining the quality of the image after compression is very essential and it must be within the acceptable limits and which can be varied from image to image and the method to method [3]. More over nowadays most hospitals store medical image data in digital form for picture archiving and communication systems .Due to digitization of data and increasing telemedicine use, medical image compression is necessary in all the related fields including image database, image communications, image storage etc.

The main aim of the Image compression is the reduction of number of bits required to represent an image by removing different redundancies present in it. In many fields, digitized images are used rather than analog images. The volume of data needed for symbolizing such images are high [4]. Hence the transmission rate is slow and the cost of operation is high. Therefore the information contained in images should be compressed by extracting only visible elements, which has to be encoded. To increase the compression rate of the data to represent an image, the quantity of data has to be reduced. The essential goal of image compression is the reduction of bit rate for transmission and storage while maintaining an acceptable reliability or image quality.

2. MEDICAL IMAGE COMPRESSION

A. Image

An image is a matrix which consists of arrangement of square pixels in different rows and columns. Images may be black and white colour, 2-D, 3- D, high pixel, low pixel, etc. An image is composed of rectangular array of dots called pixels. The size of an image is given as width X height, in numbers of pixels. Resolution of an image is usually measured in terms of DPI [5]. Though the images which are taken from a camera is in the analog form, for processing, transmitting and storage, images are to be converted in to digital form. Different types of images are used in various fields like remote sensing, video processing, medical fields, biometric, satellite imaging techniques which require compression for transmission across or within networks and storage [6].

B. Medical *Images*

In modern medicine, medical imaging had undergone major advancements. Today, the information about the human body is used for many diagnostic and practical purposes in clinical applications. Over the years, different medical imaging techniques have been developed, each with their own specific features [7].They are X-ray, Magnetic Resonance Imaging (MRI), Ultrasound scans etc. X-ray based methods of medical imaging includes conventional X-ray. MRI uses strong magnetic fields radiations. Diagnostic ultrasound systems uses high-frequency sound waves to produce images of soft tissue and internal body organs.

3. DIFFERENT TYPES OF MEDICAL IMAGES

There are different methods of medical imaging – each uses different technology to create different type of images. The types of images differ in how well they could represent the changes in certain body tissues (Ex. bone, soft tissue, tumours)

A. X-rays

In radiography, the X-ray generator produces a beam of X-rays which is transmitted through the part of the body to be scanned.

X-rays which are not absorbed passes through the object and are recorded on sensitive X-ray film. High density bones absorbs X-rays, while soft tissues which has a lower density than bone, absorbs fewer X-rays. This results in the different contrast seen in X-ray images, with bones highlighted as white areas and tissues as darker areas (Fig.1).

Fig.1. X-rays

B. Computed Tomography (CT)

CT scans provides more detailed images than conventional X-rays. When the X -rays passes through the body parts, the energy of the X-ray beam is absorbed. Similar to an X-ray film, the attenuation depends on the tissues. Bones appears white as the attenuation of bones are very high. For tissues the attenuation is low, hence they are represented by various shades of black and grey in Fig. 2.

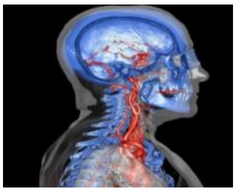

Fig. 2. Modern CT scans

C. Ultra Sound Images

In Ultrasound imaging dynamic visual images of organs are displayed using high-frequency sound waves. The sound waves are transmitted to the area to be examined and the returning echoes are captured and processed to provide the physician with ‘live’ images of the area. Many parts of the body, such as the abdomen, heart and blood vessels, muscles, breasts, carotid arteries, and female reproductive system including pregnancy diagnostics can be examined using ultrasound imaging technique as in Fig.3.

Fig.3. Prenatal 3D ultrasound showing baby's head, arms and hand

D. Magnetic Resonance Imaging (MRI)

MRI systems radio frequency pulses and magnetic field to produce detailed images of the body’s. During MRI scan, the patient should not be exposed to ionizing radiation (X-rays). High quality images are produced during MRI with good contrast details of soft tissues and other anatomic structures in the brain. Many abnormalities in human body can be visualized using MRI because of a high contrast definition. Fig.4

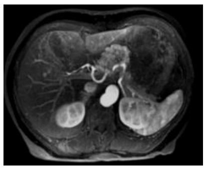

Fig. 4. MRI Images

E. Positron Emission Tomography (PET)

A brain positron emission tomography (PET) scan in Fig.5 is an imaging test of the brain. PET scan shows how the brain and its tissues works .It is used to look for disease or injury in the brain using a radioactive substance called a tracer.

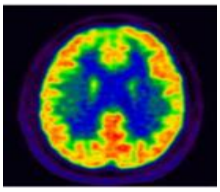

Fig.5. PET Image

4. NEED FOR COMPRESSION OF MEDICAL IMAGES

Large amount of RAM storage space is required for uncompressed images and it takes a long time for its transmission across network devices. Image compression is the technique used for reducing the data required to represent a digital image [8]. It is one of the novel technique to yield a compact representation of an image. Thus it helps in reducing the image storage space and transmission requirements [9]. In medical image compression the compression techniques should preserve all the relevant information received after the diagnosis. Then only the diagnosis will become effective. Examples given in Table 1 clearly show need for sufficient storage space and more bandwidth because long transmission time is required for uncompressed image. The only solution is to compress the image.

Table 1 Different Uncompressed Images and its storage space

	Storage Space of Uncompressed Images				
	Image Size	***Bits/ Pixels***	***Uncompressed Size***	***Transmission Bandwidth***	***Transmission Time***
Page	11"x8.5"	Depends on Resolution	5.8KB	32.55BPS	1.4-3.4SEC
Camera Image	800x600	8BPS	1.3MB	100 MBPS	50MIN
Colour Image	512x512	24BPP	786KB	6.30 MBPS	5MIN
Medical Image	2048x1680	12BPP	5.16KB	41.3MBPS	32MIN

Image compression is applied to reduce the number of bits which represent the image. Different lossless and loss-compression algorithms [10] are employed on the different medical images to obtain the desired result.

A. Elements of Image compression

1) Redundancy reduction –In redundancy reduction the extra bits of repeated bits are removed so that the required information is obtained [11], [12]. There are 3 types of redundancies, they are as follows:

a) Coding redundancy –Coding redundancy is present when less number of code words required instead of larger symbol.

b) Inter pixel redundancy –Correlated pixels of an image leads to Inter pixel redundancy

c) Psycho visual Redundancy –In psycho visual redundancy data is ignored by the normal visual system

2) Irrelevant data reduction –In irrelevant data reduction the less important or the irrelevant data is removed.

B. Different Image compression techniques

The image compression techniques are broadly classified into two categories depending whether or not an exact replica of the original image could be reconstructed using the compressed image [13], [14]. These are:

1) Lossy image compression technique

In Lossy compression, there is some amount of loss and the compressed image is different from the input image. It provides higher compression ratio in comparison with lossless compression [15]. Some amount of information is lost as a result there is difference between compressed image and original image [16].

a) Transform Coding: In this original image is portioned into small blocks of smaller size based on the transformation used coefficients are obtained for each block examples are wavelet and curvelet. The output is obtained by computing resulting coefficients by using quantization technique, the final output is taken from quantize which uses symbol encoding technique then image is reconstructed by reverse process at the decoder [17], [18].

b) Block Truncation coding: The input image is portioned into non overlapping blocks of pixels. The mean of pixel value is calculated by quantize for all non-overlapping blocks [19]. The process of threshold sets the image pixels to zero or one. The reconstructed value is obtained for each segment in the bit map [20]. Greater compression ratio can be obtained for larger block size but at cost of image quality [21].

c) Sub–band Coding: Finds application in speech and image coding. The frequency bands of the signal are split and the coding of sub band is done by encoder. The sub band signals are decoded and passed through synthesis filter at the decoder. The compressed image is obtained by properly summing the sub band coefficients [22].

d) Vector quantization: Scalar quantization technique when extended in multiple dimensions resulted in vector quantization. It consists of dictionary of fixed size vectors called code vectors. Non overlapping blocks called image vectors are formed by partitioning of given image [23]. Closest matching vector in dictionary is determined and its index in dictionary is determined and is used as encoding of original image vector for each input image vector. Vector quantization technique finds its application in multimedia as it has fast lookup capability at decoder side.

2) Lossless image compression technique

In the loss less compression the compressed image is totally replica of the original input image, there is not any amount of loss present in the image [24]. The reconstructed image is same to the input image in lossless compression scheme. In this scheme the image is first converted into image pixels each single pixel is then processed [25]. Next image pixel value is predicted from the neighbourhood pixel .the final step is using different encoding method coding of the difference between the predicted value and actual intensity of next pixel is performed [26]. Lossless compression encoding and decoding methods are as below

a) RLE (run length encoding): In this simple image compression technique in which sequence of identical symbols are replaced by a pair containing the symbol and length at which the number is repeated [27], [28]. For fax standardization it is used.

b) Statistical Coding: The techniques are included in Statistical Coding.

i) Huffman Encoding - By removing irrelevant information the file size is reduced from 10-50%the pixel values which occur frequently is given a smaller bit code and repeated pixel value is given to higher bit code [29],[30]. The encoding procedure using Huffman coding is as follows. The input images are first divided into 8x8 blocks, and then a particular symbol is given to each block. Each block is then applied with Huffman code to encode all block is done.

ii) Arithmetic Encoding - Rissanen introduced this encoding technique .In this technique encoding and decoding of last symbol is first done [31]. The principle of arithmetic encoding is infinite value for symbol alphabet is not acceptable the finite value for all possible symbol sequence of given length is not accepted, for any given input sequence of symbols, the real number in the interval [1,0]can assign a unique subinterval.

iii) LZW coding: Coding is based on a dictionary and dictionary is fixed during encoding and decoding for static dictionary coding. Better compression ratio can be achieved using area coding [32], [33].It is highly effective and can be limited to application of nonlinear transformation.

iv) Area coding: RLE's enhanced version is area coding .Better compression ratio can be achieved using area coding [34].It is highly effective and can be limited to application of nonlinear transformation.

C. Major Performance Parameters of Compression

In order to measure the performance of the image compression algorithms two performance parameters are used [35].

- PSNR (peak signal to noise ratio)
- Mean square error (MSE)
- Compression Ratio (CR)

The peak error between the compressed image and original image is measured in terms of PSNR. The higher value of PSNR indicates higher quality of image [36], [37]. To calculate PSNR, MSE is first computed. Cumulative difference between the compressed image and original image is MSE.

1) Mean square error (MSE)

Mean Squared Error (MSE) [38], [39] is defined as the square of differences in the pixel values between the corresponding pixels of the two images. The mean square error (MSE) of N * M size image is given by.

$$MSE= \Sigma_{M,N} [I_1 (m, n) - I_2 (m, n)]^2 / (M*N) \qquad (1)$$

M &*N* - number of rows and columns in the input images.

2) PSNR (peak signal to noise ratio)

PSNR Peak signal-to-noise ratio often abbreviated PSNR, is an engineering name, for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity. The peak error between the compressed image and original image is measured in terms of PSNR [40], [41]. The higher value of PSNR indicates higher quality of image. To calculate PSNR, MSE is first computed. Cumulative difference between the compressed image and original image is MSE. Small value of MSE improves image quality and reduces the error [42].

$$PSNR = 10 \log_{10} (R^2/ MSE) \qquad (2)$$

3) Compression Ratio (CR)

Data redundancy is the centric release in digital image compression [43], [44]. If n1 and n2 denote the number of information carrying units in original and encoded image respectively, then the compression ratio, CR can be specify as

$$CR= N_1/ N_2 \qquad (3)$$

And data redundancy of the original image can be specify as

$$RD= 1- (1/CR) \qquad (4)$$

I. VARIOUS MEDICAL IMAGE COMPRESSION ALGORITHMS

A. JPEG2000 Image Compression

The JPEG 2000 compression engine consists of an encoder as well as decoder [45]. The discrete transform is first applied to the source image data at the encoder side. The entropy coded quantized transform co efficient forms the output code stream [bit stream].The decoder is the reverse of an encoder. The code stream is entropy decoded first and de-quantized, and inverse discrete transformed, hence resulting in the reconstructed image data. The overall JPEG 2000 image compression engine is decomposed into three parts:
1) Pre-processing
2) Core processing
3) Bit-stream formation

In the pre-processing part the image tiling, the dc-level shifting and component transformations is carried out. The core processing part does the discrete transform, the quantization and the entropy coding processes. Finally in the bit stream formation part, the precincts, code blocks, layers, and packets are send to bit stream.

B. JPEG2000 Scaling-Based ROI Coding

In this method the transformed image and the coefficients associated with in and around the ROI are scaled up by an established number of bit-shifts. The bit-planes of coefficients are then encoded plane by plane. The difference in the image quality between the ROI and non-ROI can be varied by specifying the scaling value [46]. In scaling-based ROI coding method the object can be exactly decoded by rejecting all of the background.

A. JPEG2000 MAX-SHIFT ROI Coding

The max-shift ROI coding adopted in JPEG2000, which is also called as MS-ROI. Here the coefficients associated with ROI are scaled up through a given number of bit-shifts. The number of bit-shifts are called as scaling values. It is given by the largest number of non-empty magnitude bit-planes of coefficients. These bit -planes of coefficients are encoded plane by plane to allow the ROI have higher fidelity than the rest of the image [47]. One of the pros of this method is that it does not need to transmit the shape of the information as additional information and just to send the scaling values, because the decoder can identify coefficients scaled up just by comparing each coefficient with a threshold value.

B. 1.5-D Multi-Channel EEG Compression Algorithm Based on NLSPIHT

This is a novel 1.5-D algorithm for a multichannel Electroencephalogram (EEG) compression. In this algorithm, a new 2-D arranging method that exploits correlations between different sub-bands are developed to concentrate the energy, which causes more efficient compression using No List Set Partitioning in Hierarchical Trees (NLSPIHT) algorithm. This method is slightly inferior to 2-D SPIHT algorithm in the near-lossless compression regime, but it can provide a better fidelity with respect to higher Compression Ratios [48].

C. *Decimation And Interpolation Algorithm*

In this method a novel decimation and interpolation scheme which is used for evolving a new lossless compression technique for images. This falls widely under the spatial hierarchy schemes. This procedure has a better compression efficiency than procedures like lossless JPEG .The empirical results show that ZIP, PNG and TIFF are 27%, 57% and 42% poorer in terms of compression efficiency respectively [49]. This method can produce images of high quality. However, this comes at the cost of higher computational complexity.

D. *ROI Based Medical Image Compression for Telemedicine Using IWT & SPIHT*

In this method ROI part is compressed through Integer wavelet transform in a lossless manner and SPIHT is used for efficient lossy compression for all other regions [50]. The results shows that ROI based compression have better performance in terms of image quality, PSNR and bandwidth requirement to maintaining the critical information as compared to the compression result on the whole image.

E. *Block-Based Spatial Prediction and Transforms Based on 2D Markov Processes*

This is an approach which uses transformation of the intra prediction residuals .The transformation used odd type-3 discrete sine transform in the prediction direction and the DCT in the perpendicular direction [51]. This method utilizes Markov processes to enhance the transform or the prediction step. Here both the intra prediction and the transform steps are obtained based on 2D Markov processes. This method provides improved coding gains and produce less blocking effects at low bit rates.

F. Shape-Adaptive Wavelet Transform and Scaling Based ROI

The ROI coding technique joins shape-adaptive wavelet transform and scaling-based ROI, which is called as SA-ROI. In this method, the samples within the objects are being modified with shape-adaptive wavelet transform according to the shape-information. The background is also transformed by shape-adaptive wavelet transform independently if needed. Along with that, the samples within the object are scaled up by a certain number of bit-shifts, and encoded plane by plane [52]. This method provides high compression ratio. Here the computational complexity increases with bit rates.

G. Fuzzy Logic with Huffman coding Algorithm

This technique combines the fuzzy logic with that of Huffman coding algorithm. This method consists of following steps

1) Normalization of image pixel

2) Approximation of pixel pair sets

Huffman coding algorithm (RFHA) is used for encoding and rough fuzzy logic is used to reconstruct the pixel of the image [53]. The procedure employed here is rough fuzzy logic with a Huffman coding algorithm (RFHA). The result shows that high compression rates are achieved and there are only visually negligible difference between compressed images and original images.

H. JPEG Image Compression

In this method the following steps are followed

1) An image to be compressed is divided into 32x32 pixel blocks

2) DCT and quantization of DCT coefficients for pixel values of each block is computed

3) Division of quantized DCT coefficients into bit-planes is carried out

4) Bit-planes so obtained are coded in the order starting from higher bits to lower ones

5) For each group of bits, individual probability model is used for dynamic arithmetic coding.

High degree of compression and picture quality is achieved [54].

I. *Quantum-Accelerated Fractal Image Compression*

In the proposed technique, the intrinsic computational complexity of Fractal image compression (FIC) is minimised by using Grover's QSA algorithm [55], without reducing compression ratio. Experimental results show that the execution time of the proposed method is much less than that of the FIC. Moreover the CR and the quality of retrieved images from this proposal is much better than that of other state-of-the-art FIC approaches.

J. *Fuzzy-logic-based route selection technique*

Here an optimization based medical data compression technique is proposed, which is robust to transmission errors [56]. A fuzzy-logic-based route selection technique is proposed to deliver the compressed data that increase the lifetime of WANETs. The technique is fully distributed and does not use any geographical and location information. The utility of the proposed work is demonstrated by simulation results. The results are shown that the proposed work effectively maintains connectivity of WANETs and prolongs network lifetime.

K. Gray-Scale Image Compression Using DWT-SPIHT Algorithm

SPIHT is one of the computationally fastest image compression algorithms identified. In this method, the output binary stream of SPIHT encoding is combined with Huffman encoding [57]. This is one of the effective method for gray scale image compression.

L. Mesh Based Coding Scheme

This method is used for the compression of 3D MRI images

1) Rejection of the clinically irrelevant background

2) Content-based (adaptive) mesh generation

3) Solution for the aperture problem at the edges

4) Context based entropy coding of the residues after the motion compensation using an affine transformation.

Here the nodes are chosen in such a way that the entire foreground region is collapsed [58]. This scheme uses two source models, one for the background and the other in the foreground. High CR and improvement in performance is achieved.

M. Compression Based On Dipole Fitting

This lossless technique is basically used for the compression of electroencephalogram (EEG) [59]. This method comprises of 2 stages

1) The source dipoles are approximated based on forward model

2) Residual compression

The number of dipoles is directly proportional to the Compression Ratio (CR). If the number of dipoles is increased, the CR increases and vice versa. Also if the number of dipoles is increased, the overhead will increase and accuracy gets reduced.

N. 3D Subband Block Hierarchical Partitioning

The highly scalable Sub band Block Hierarchical Partitioning (SBHP) algorithm is modified and spread to three dimensions [60]. The proposed algorithm 3D-SBHP is having an effective mechanism to compress 3D images efficiently without compromising the quality of images.

O. SPIHT and RLE for medical Image compression

This approach is implemented by modifying Haar Wavelet Transform. Here 2 the following compression techniques are used

1) The Set Partitioning in Hierarchical Trees (SPIHT)

2) Run Length Encoding (RLE)

This method will increase the compression ratio without compromising the image quality [61]. Also the number of computations and the processing time in Haar transform is reduced. The experimental results shown that the compression ratio increases without affecting the PSNR and the results are comparable to SPIHT algorithm.

P. Medical Image Compression Using Variable Order Wavelets Transforms And HVS Characteristics

This method is a progressive compression scheme for medical images. The approach followed is based on a quantification method based on the human vision along with sub band coding by wavelet filters [62]. The proposed wavelet transform based image compression scheme yields high compression ratio.

Q. 3-D Scalable Medical Image Compression With Optimized Volume of Interest Coding

Here 3-D scalable compression with optimized volume of interest (VOI) coding is proposed for medical image compression. In this method, the scalable bit-stream is created by combining 3-D integer wavelet transform and modified EBCOT [63]. The compressed image obtained by this lossless method has very high reconstruction quality and high peak signal-to-noise ratio at a variety of bit rates comparable to JPEG 2000.

R. Wavelet-Based Image and Volumetric Coding Approach for medical Image compression

The proposed algorithm is designed based on the principle of “lossy plus residual coding”, it consists of 2 stages [64]

1) Wavelet-based lossy coding

2) Arithmetic coding on the residual. This approach ensures a specifiable high number of error between original and reconstructed signal. In this method, high compression ratios are achieved for low error values.

S. *Optimized decomposition basis using Lanczos filters*

This method introduces Lanczos interpolation filters for wavelet decomposition of biomedical images. The decomposed Lanczos parameters segregated and optimized in a generic packet structure having different biomedical imaging modalities [65]. The experimental results shows that this approach will improve the compression by more than 10% on lesser noise images and up to 30% on more noisy datasets like 3D-MRI when compared to bi-orthogonal wavelets.

T. Adaptive Arithmetic Coding Model

During segmentation process of an image, data regions can be separated from background and that can be added at the reconstruction stage. This will yield a normal compression ratio of 3:1.When adaptive arithmetic coding model is used along with this segmentation process, high compression ratios up to 9:1 can be achieved [66].

U. Integer Wavelet Transform Function and PSO Algorithm

It has been observed that the duplicated structure of medical images reduces the compression ratio and PSNR .Hence the quality of medical images after compression will be reduced. In the proposed method, the duplicate frame of a structure for compression is selected using a structure reference selection process [67]. Particle swarm optimization (PSO) searching technique is used for the collection of redundant frame structures. Integer Wavelet Transform (IWT) is used for creating the structure of the frame. This method provides high compression ratios.

V. Evolutionary clustering based vector quantization and SPIHT coding

The new Vector Quantization (VQ) technology overcome the drawbacks of classical clustering algorithm by exploiting the global searching capability of OSGD-GA. The contextual constraints are determined by using weighted average method of the significance, and hence it overcomes the drawbacks of classical clustering algorithm [68]. This method has 2 stages

1) Vector quantization

2) SPIHT coding algorithm

The results show that this proposed method yields an improvement of PSNR to the greatest 0.66dB over SPIHT algorithm.

W. Genetic Algorithm Based K-Means

For compressing medical images, a new Genetic algorithm is proposed to find the initial seeds of K-means [69]. This method shows an improved performance when applied to medical images in terms of image quality and high compression ratio.

X. Image Compression And Fusion Based On Wavelet Transform

In this method, the images are fused using wavelet transform of different resolution sub image, which is based on energy and correlation coefficient [70]. The simulation experiments of fusion method shows that the image is compressed with high image fusion speed and high quality fast fusion image is obtained.

Y. Combined Wavelet and Self Organizing Maps

This method is a combination of 2 stages

1) Discrete Wavelet Transform (DWT) decomposition

2) Incremental Self-Organizing Map (ISOM) image compression.

The experimental results show that this method yields high performances in terms of compression ratio and reconstruction quality [71].

Z. 3-D Adaptive Sparsity Based Image Compression

The correlations among adjacent optical coherence tomography (OCT) images is exploited in 3D-ASRC algorithm to improve compression performance [72]. This method yields high quality compressed images with high compression ratio.

AA. High-Efficiency Video Coding-HEVC Compression

The medical images and videos with respect to quality is addressed via quality metrics is evaluated. Here the performance quality metrics analysis is carried out with respect to compressed medical ultrasound video sequences. The correlation results indicate that the universal quality index metrics shows good correlation with the reference scores [73]. The results show that the quantization parameter up to 35 can be achieved using HEVC. This method is one of the diagnostically reliable ultrasound video compression technique. It also enables the bit reduction of 50% for perpetual video quality.

BB. *Compression using curvelet transform and differential pulse code modulation (DPCM)*

The proposed method is used to compress images in a lossless manner. This method has 3 stages

1) The medical image is partitioned into 2 different regions i.e. region of importance (ROI) and region of non-importance (RNOI) using K-Means algorithm.

2) The region of importance (ROI) is compressed using curvelet transform and differential pulse code modulation (DPCM)

3) Non region of importance (NROI) is compressed using integer wavelet transform (IWT) technique and Set Partitioning in Hierarchical Tree (SPIHT) followed by adaptive arithmetic encoder.

Both the compressed ROI and non ROI outputs are fused together to give the final output compressed image [74].

CC. Cohen-Daubechies-Feauveau biorthoganal wavelet method and SPIHT Algorithm

The proposed algorithm is divided into two stages:

1) Generalized Cohen-Daubechies-Feauveau biorthogonal wavelet is used for decomposing DICOM images.

2) Set Partitioning in Hierarchical Trees (SPIHT) is used for encoding the wavelet coefficients.

In this method consistent quality images are generated at a lower bit rate compared to JPEG [75]. This method provide high compression ratio and high resolution images.

DD. COMPARISON OF SOME MEDICAL IMAGE COMPRESSION TECHNIQUES

Compression Method	Advantages	Disadvantages
[6] Fusion of DWT-DCT Algorithm	High CR Higher PSNR value than the traditional DCT and DWT	Computationally complex
[9]3-D Hartley transform	Preserves image quality and details	Slow system
[10] Integer 3D Wavelet Transform	Fast System	High Cost
[17]SPIHT	Reserve quality of data better Improve efficiency of encoding Encoding/Decoding Speed	At high threshold bit rates decreases to greater extent and the quality of the image is degraded
[26] Variable Threshold and Adaptive Block Size	High compression ratios with no appreciable degradation of image quality Less complexity	Increasing the block size leads to Information loss
[28]EZW	High CR High PSNR Low MSE	As threshold increases the bit rate goes on decreasing ,at the same time the PSNR values decreases with Compression Ratio (CR)
[36] Arithmetic Encoding	High CR Speed is high Redundancy is reduced	Cost of computation is high
[39] Huffman Image Compression	High Performance Computation cost is low Easy to implement	Redundancy is high
[43] Integer Wavelet Transform	Computationally very fast Compress or de-noise a signal without appreciable degradation	Low Hiding Capacity
[45] JPEG2000 Image Compression	JPEG2000 has very high CR. It has mainly been developed for use on the internet. JPEG2000 is said to produce as much as a 20% improvement in compression efficiency over the current JPEG format. It also offers an optional lossless compression mode. Lossless JPEG2000 files are about half	JPEG2000 is a resource hog: compressing data requires lots of CPU-horsepower At compression ratio’s below 25:1, the wavelet-based algorithm produces less blocky but somewhat less detailed images compared to regular JPEG compression. Too much compression is never a good idea

	the size of the original	
[46]JPEG2000 Scaling-Based ROI Coding	High Compression Ratio ROI coding preserves image quality in diagnostically critical regions by performing advanced image compression, enabling better image examination and addressing issues regarding image handling and transmission in telemedicine systems	Requires lots of CPU-horsepower
[47] JPEG2000 MAX-SHIFT ROI Coding	High Compression Ratio	Increases the algorithm complexity Decreases the overall coding efficiency Increases decoder complexity and processing overhead
[48] 1.5-D Multi-Channel Compression Algorithm Based on NLSPIHT	High Compression Ratio Low complexity Low power dissipation	Slower than 2-D SPIHT
[49] Decimation and Interpolation Algorithm	High CR	High computational complexity High power dissipation
[50] ROI Based Compression Using IWT & SPIHT	High CR Better performance in terms of image quality, PSNR and bandwidth requirement	High computational complexity Large and complex system
[51] Block-Based Spatial Prediction and Transforms Based on 2D Markov Processes	Improved coding gains Less blocking effects at low bit rates Appropriate for the real time broadcasting	Computationally complex
[52] Shape Adaptive wavelet Transform and	Easy parallelism High speed processing systems	Increase in computational complexity as well as bit rate

Scaling Based ROI		
[53] Fuzzy Logic with Huffman coding Algorithm	High CR Significantly decreases the computational difficulty of clinical image dispensation for instance production of functional images	High power dissipation
[54] JPEG Image compression	High CR	Complex System
[55] Quantum-Accelerated Fractal Image Compression	Can handle variety of images with different ranges of frequency and intensity Preserves frequency content	Comparatively slow system
[56] Fuzzy-logic-based route selection technique	Preserves image quality and details	Complex system
[57] Gray-Scale Image Compression using DWT-SPIHT Algorithm	Noise removal	Quality of image is affected Involves too many processes
[58] Mesh Based Coding Scheme	Image quality is preserved	Quality of image is affected
[59] Compression Based On Dipole Fitting	Has better performance than JPEG with low and high bit rates.	Expensive system
[60] 3D Sub band Block Hierarchical Partitioning	Fast system	Computationally complex
[61] SPIHT and RLE for medical Image compression	The particulars of the real image are protected in there built image and are conserved High compression rate is achieved with minimum utilization of SNR	Problems of empty cells in the image do exist
[62] Medical Image Compression Using Variable Order Wavelets Transforms And HVS Characteristics	Preserves image quality Obtained acceptable compression	Large and complex system
[63] 3-D Scalable Medical Image Compression With Optimized	Preserves image quality and details Handles 3D data	Complex system Image storage requirements are high

Volume of Interest Coding		
[64] Wavelet-Based Image and Volumetric Coding Approach for medical Image compression	High CR High PSNR Less error prone Encoding time is relatively less	Complex system
[65] Optimized decomposition basis using Lanczos filters	High PSNR Less Execution time	Computationally complex
[66] Adaptive Arithmetic Coding Model	Image quality is preserved Noise removal	Slow System
[67] Integer Wavelet Transform Function and PSO Algorithm	Increase of both reliability and coding efficiency Has smallest entropy and very easy to implement on hardware	Comparably complex system
[68] Evolutionary clustering based vector quantization and SPIHT coding	Minimizes power requirements	Computationally complex
[69] Genetic Algorithm Based K-Means	High CR High speed processing systems	Sensitive to quality of image
[70] Image Compression and Fusion Based On Wavelet Transform	Increase of both reliability and coding efficiency	Computationally expensive Applicable to a specific type of images
[71] Combined Wavelet and Self Organizing Maps	Has smallest entropy and very easy to implement on hardware	Computationally expensive
[72]3-D Adaptive Sparsity Based Image Compression	High speed processing systems Applicable for 3D data	Computationally expensive Comparably a slow system
[73]High-Efficiency Video Coding-HEVC Compression	Effective and efficient method for compression Adequate image quality is obtained High speed processing systems	Computationally complex
[74] Compression using curvelet transform and differential pulse code	Image quality is not affected Increase of both reliability and coding efficiency	Yields far smaller reconstruction errors

modulation (DPCM)		
[75] Cohen-Daubechies-Feauveau biorthogonal wavelet method and SPIHT Algorithm	Computational efficiency and noise removal Uses small number of data Fast and reliable in case of preservation of image details	Computationally complex Quality of reconstructed signals is bit affected

5. CONCLUSION

This review paper gives clear idea about image types and various compression techniques that are frequently used for the medical image compression. After considering image quality, amount of compression and speed of compression new techniques are being developed day by day to achieve the desired results for compression. Based on the study we found that lossy compression techniques provides high compression ratio than lossless compression scheme. But in medical image compression lossless compression is used since the original image and reconstructed image are to be identical. Also the selection of compression algorithm depends on the quality of image, amount of compression and speed of compression. The objective of developing new or modifying previously developed image compression techniques is to improve the quantitative performance such as the compression and the signal to noise ratios, to reduce computational time and to explore new data and applications.

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