A Survey On Medical Image Compression Techniques

S.Sridevi, V.R.Vijayakumar, R.Anuja

Abstract: ***Lossy compression schemes are not used in medical image compression due to possible loss of useful clinical information and as operations like enhancement may lead to further degradations in the lossy compression.***

Medical imaging poses the great challenge of having compression algorithms that reduce the loss of fidelity as much as possible so as not to contribute to diagnostic errors and yet have high compression rates for reduced storage and transmission time.

This paper outlines the comparison of compression methods such as Shape-Adaptive Wavelet Transform and Scaling Based ROI, JPEG2000 Max-Shift ROI Coding, JPEG2000 Scaling-Based ROI Coding, Discrete Wavelet Transform and Subband Block Hierarchical Partitioning on the basis of compression ratio and compression quality.

Keywords: ***Lossy Compression Ratio, Shape - Adaptive Wavelet Transform, Scaling based ROI, JPEG2000 Max – Shift ROI Coding, JPEG2000, DCT***

INTRODUCTION

Image data compression is a process applied to original image data in order to reduce the storage requirements or the transmission bandwidth. There are two categories of image data compression algorithms:

- Lossy compression
- Lossless compression.

In lossy compression approach a reconstructed image is not pixel by pixel equal to its original image. However, a high-quality lossy compression technique is capable of reconstructing images with imperceptible visual differences from the original images. A lossless compression algorithm reconstructs an image which is an exact copy of the original image.

Three performance metrics are used to evaluate algorithms and choose the most suitable one:
1) Compression ratio,
2) Computational requirements, and
3) Memory requirements.

Manuscript published on 28 February 2012.
***** Correspondence Author (s)
Mrs.S..Sridevi, Studied, B.E. Department of CSE., Thiagarajar College of Engineering, M.E. Department of CSE., RVS College of Engg. And Tech., Dindugul (Tamil Nadu), India.
Dr.V.R.Vijayakumar, M.E., Ph.D, Prof & Head, Department of Electronics and Communication Engineering, Anna University of Technology, Coimbatore (Tamil Nadu), India.
Ms.R.Anuja, M.E Student, Department of Computer Science and Engineering, Sethu Institute of Technology, Virudhunagar (Tamil Nadu), India.

Basically, the desired compression ratio is at least 2:1. The computational needs of an algorithm is expressed, in terms of how many operations (additions/multiplications, etc.) are required to encode a pixel (byte). The third metric is the amount of memory or buffer required to carry out an algorithm.

MEDICAL IMAGE COMPRESSION:

Volumetric medical images, such as magnetic resonance imaging (MRI) and computed tomography (CT) sequences, are becoming a standard in healthcare systems and an integral part of a patient's medical record [7]. Such 3-D data usually require a vast amount of resources for storage and transmission. For example, a single MRI sequence of a human brain, with slices of 512X512 pixels taken at 1 mm intervals, could easily result in over 100 MB of voxel data.

With the wide pervasiveness of medical imaging applications in healthcare settings and the increased interest in telemedicine technologies, it has become essential to reduce both storage and transmission bandwidth requirements needed for archival and communication of related data, preferably by employing lossless compression methods.

Most medical image compression algorithms are comprised of three main components, a decorrelation algorithm, a main compression engine and a formatting scheme.

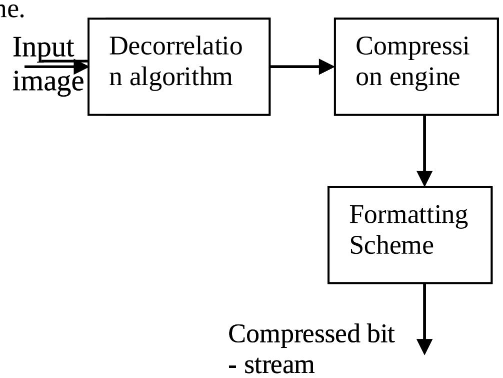

Fig. 1.1 Image Compression

Decorrelation algorithms exploit the data redundancies in medical images by employing a predictive model or a multi-resolution model. Prediction models minimize the difference between consecutive samples, slices or volumes and generate residual data by using either motion compensation and estimation or differential pulse code modulation.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

On the other hand, multi-resolution models decorrelate image data by using a transform, such as discrete wavelet transforms (DWT) or discrete cosine transforms (DCT).

Furthermore, providing random access as well as resolution and quality scalability to the compressed data has become of great utility. Random access refers to the ability to decode any section of the compressed image without having to decode the entire data set. Resolution and quality scalability, on the other hand, refers to the ability to decode the compressed image at different resolution and quality levels, respectively.

The latter is especially important in interactive telemedicine applications, where clients (e.g., radiologists or clinicians) with limited bandwidth connections using a remote image retrieval system may connect to a central server to access a specific region of a compressed 3-D data set, i.e., a volume of interest (VOI). The 3-D image is then transmitted progressively within the VOI from an initial lossy to a final lossless representation.

SHAPE-ADAPTIVE WAVELET TRANSFORM AND SCALING BASED ROI:

In [1] an ROI coding technique combining shape-adaptive wavelet transform and scaling-based ROI, which we call SA-ROI. In this method, the samples within the object are transformed with shape-adaptive wavelet transform according to the shape-information. If necessary, the background is also transformed by shape-adaptive wavelet transform independently.

Then the samples within the object are scaled up by a certain number of bit-shifts, and encoded plane by plane. In this case, the number of coefficients to be encoded does not change from the number of image samples within the object, and by scaling-up the coefficients of the object, the difference of image quality between the object and background can be controlled.

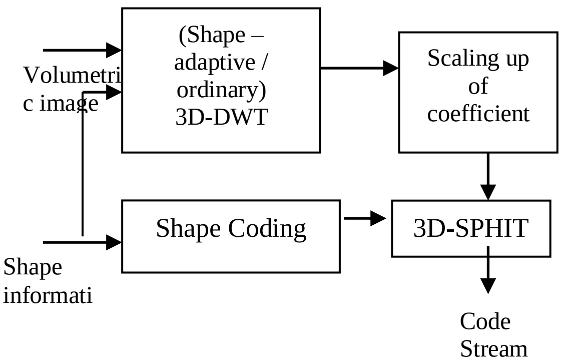

Fig. 1.2 Block Diagram

If all of the samples (both of the object and background) are transformed with shape-adaptive wavelet transform, an ROI can be specified independently of the object/background, and user-driven ROI coding can also be realized.

But computational cost of shape-adaptive wavelet transform is generally higher than conventional transform, because the length of each segment is not constant. The scaling value of the VOI coefficients is empirically assigned and the shape information of the VOI must be encoded and transmitted, which may result in an increase in computational complexity as well as bit rate

		MS – ROI	SB – ROI	SA – DWT	SA – ROI
Factors concerning compression performance	Number if coefficients needed to decode the object	More	More	Fewer	Fewer
	Number of coefficients needed to decode the entire image	Same	Same	--	Same
	Shape information transmission	Necessary	Necessary	Necessary	Necessary
ROI coding functionality	User driven ROI coding	Partly Possible	Possible	Difficult	Possible
	Decoding exactly the object	Impossible	Possible	Possible	Possible

Table 1.1 Comparison of arbitrary-shape ROI coding

JPEG2000 IMAGE COMPRESSION:

The JPEG 2000 compression engine [6] (encoder and decoder) is illustrated in block diagram

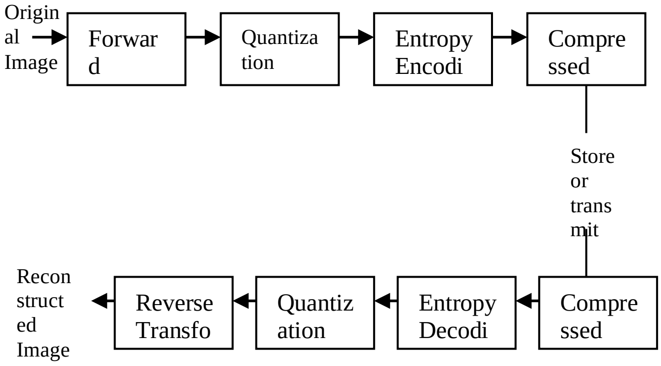

Fig 1.3 JPEG 2000 Block Diagram

At the encoder, the discrete transform is first applied on the source image data. The transform coefficients are then quantized and entropy coded before forming the output code stream (bit stream).The decoder is the reverse of the encoder. The code stream is first entropy decoded, de-quantized, and inverse discrete transformed, thus resulting in the reconstructed

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

image data. Although this general block diagram looks like the one for the conventional JPEG, there are radical differences in all of the processes of each block of the diagram.

For the clarity of presentation we have decomposed the whole compression engine into three parts: the preprocessing, the core processing, and the bit-stream formation part, although there exist high interrelation between them. In the preprocessing part the image tiling, the dc-level shifting and the component transformations are included. The core processing part consists of the discrete transform, the quantization and the entropy coding processes. Finally, the concepts of the precincts, code blocks, layers, and packets are included in the bit-stream formation part.

JPEG2000 MAX-SHIFT ROI CODING:

In [2] the max-shift ROI coding adopted in JPEG2000, which we call MS-ROI, an entire volumetric image is transformed and only the coefficients associated with the ROI are scaled up through a given number of bit-shifts, where the number of bit-shifts, which is called scaling value *s*, is given by the largest number of non-empty magnitude bit-planes of the coefficients.

The bit -planes of coefficients are encoded plane by plane to let the ROI have higher fidelity than the rest of the image. The same concept can be applied to coefficients produced with three-dimensional wavelet transform.

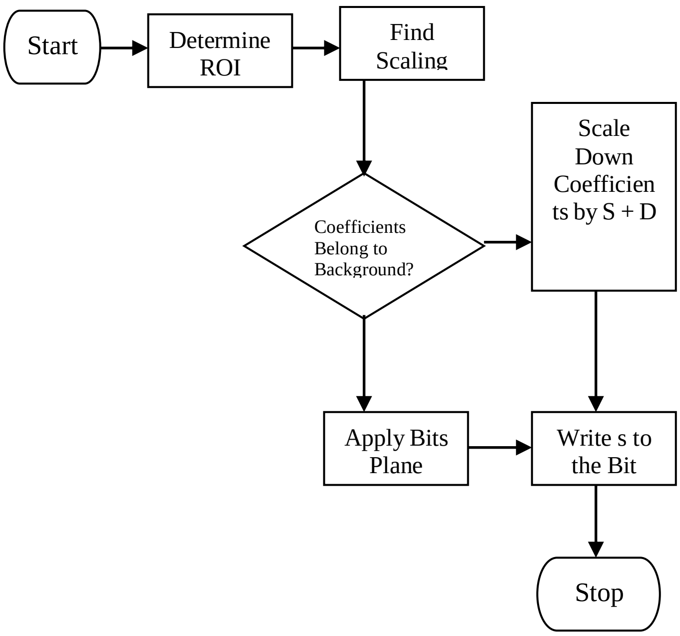

Fig 1.4 Flow Chart of MAXSHIFT ROI Coding

Note that not only the coefficients within the ROI but also coefficients surrounding the ROI that affect the image samples within the ROI need to be encoded to realize lossless coding of the ROI.

One of the advantages of this method is that it does not need to transmit the shape information as additional information and just send the scaling value *s*, because the decoder can identify coefficients scaled up just by comparing each coefficient with a threshold 2s.

However with code stream associated with the object (most significant *s* bit-planes) the object cannot be exactly decoded, since the decoder cannot distinguish coefficients within the object from coefficients surrounding the object.

JPEG2000 SCALING-BASED ROI CODING:

In [2] the scaling-based ROI coding adopted in JPEG2000, which we call SB-ROI, an entire volumetric image is transformed, and the coefficients associated with the ROI (within and around the ROI) are scaled up by a certain number of bit-shifts.

Then the bit-planes of coefficients are encoded plane by plane. The difference of image quality between the ROI and non-ROI can be controlled by specifying the scaling value. Although JPEG2000 specifies scaling-based ROI coding only for rectangular or elliptic areas of a two-dimensional image, the concept of scaling-based ROI coding can be easily extended to arbitrary-shape ROI coding for volumetric imagery. In the scaling-based ROI coding, shape information has to be transmitted to the decoder unlike the max-shift ROI coding.

Therefore, in scaling-based ROI coding, the object can be exactly decoded by discarding all of the background, but looking at the background near the object, the additional coefficients still might cause unwanted effect at an early stage of progressive coding.

DISCRETE WAVELET TRANSFORM:

In [3] JPEG2000 employs the 2-D discrete wavelet transform (DWT). DWT decomposes its input into four spatial frequency subbands. Each level of DWT decomposes an image into 3 subbands. This paper, deal with medical volumes, which are typically acquired as a sequence of axial slices.

Depending on the slice thickness, there can be significant correlation in the slice direction. We exploit this correlation by applying a DWT in the direction as specified in JPEG2000 prior to the DWT.

We refer to the “slices” that result from the direction transform as transformed components. These transformed components are further decomposed (by DWT) to form subbands. JPEG2000 can support up to 16384 slices in this fashion.

A smaller code-block size gives finer granularity, and consequently the need for less data transmission for a given desired spatial region. However, in this paper these smaller code-block dimensions gives reduced compression performance and can result in increased packet signaling overhead and increased disk thrashing.

As expected, smaller code-block sizes result in increased decoding times due to increased fetches and the increased overhead of decoding smaller code-blocks.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

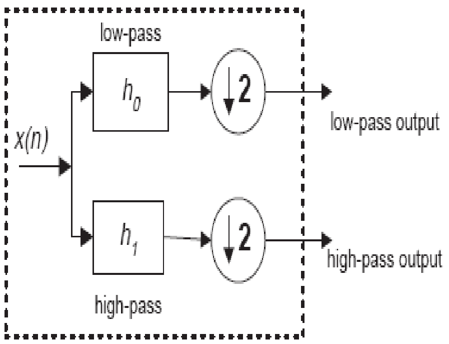

Fig1.5 DWT Structure

MESH BASED CODING SCHEME:

This [4] paper propose and evaluate a number of novel improvements to the mesh-based coding scheme for 3-D brain magnetic resonance images.

This includes: 1) elimination of the clinically irrelevant background leading to meshing of only the brain part of the image; 2) content-based (adaptive) mesh generation using spatial edges and optical flow between two consecutive slices; 3) a simple solution for the aperture problem at the edges, where an accurate estimation of motion vectors is not possible; and 4) context based entropy coding of the residues after motion compensation using affine transformations.

In the case of adaptive mesh, the nodes should be selected in such a way that the entire foreground region is meshed. The minimum distance between two nodes and the maximum number of nodes are chosen as 12 and 200, respectively.

Number of Nodes	Bit-Rate(bpp)
64	2.39
256	2.31
1024	2.35

Table 1.2: Performance of uniform Mesh-Based scheme with context for different number of nodes

Adaptive mesh-based schemes perform marginally better than the uniform mesh-based methods, at the expense of increased complexity.

This paper considered typical MR image consists of two parts:
1) Air part (background)
2) Flesh part (foreground)

The flesh part contains the useful clinical information to be compressed without any loss. The air part does not contain any clinical information; it is only noise and consumes unnecessary bits that impair the performance of a compression scheme. This paper addresses only lossless coding of the images.

In [4], a scheme is proposed which uses two source models, one for background and the other for foreground. An improvement in performance is reported. However, there is no need to code the air part. This fact has been confirmed by the neuro-radiologist with whom we are collaborating. Thus, in this paper, the air part is ignored. We generate image masks in such a way that the flesh part is totally included and the pixel values in the air part are set to zero.

However, the recent 3-D compression schemes for medical images provide important functionalities like region of interest coding and progressive transmission of images and additional functionality of decoding 2-D images or any objects of interest from the 3-D encoded images. The current implementation does not provide these important functionalities.

SUBBAND BLOCK HIERARCHICAL PARTITIONING:

The [5] Subband Block Hierarchial Partitioning (SBHP) algorithm is modified and extended to three dimensions, and applied to every code block independently. The resultant algorithm, 3D-SBHP, efficiently encodes 3D image data by the exploitation of the dependencies in all dimensions, while enabling progressive SNR and resolution decompression and Region-of-Interest (ROI) access from the same bit stream. The code-block selection method by which random access decoding can be achieved is outlined.

The 2-D SBHP algorithm is a SPECK variant which was originally designed as a low complexity alternative to JPEG2000. 3-D SBHP is a modification and extension of 2-D SBHP to three-dimensions. In 3-D SBHP, each subband is partitioned into code-blocks. All code-blocks have the same size. 3-D SBHP is applied to every code-block independently and generates a highly scalable bit-stream for each code-block by using the same form of progressive bitplane coding as in SPIHT.

But in this scheme the background information is only decoded after the VOI is fully decoded, which prevents observing the position of the VOI within the original 3-D image.

Coding Techniques	Shape information incorporated in coding	Arbitrary ROI coding	Exact decoding of the object	PSNR in db(bits per pixel)
General Scaling Method	Required	Supported	-	44.91 (0.08 bpp)
MAXSHIFT	-	Supported	-	44.90 (0.08 bpp)
SA-DWT	-	-	Possible	52.5 (0.50 bpp)
3D-SPIHT	-	-	-	38.78(0.52 bpp)

Table 1.3: Comparison of coding techniques

CONCLUSION

In this paper, various medical image compression techniques are reviewed. Though there are many techniques technique proposed unique characteristics, researches has to be done to enhance

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

the reconstructed quality of an image with high compression rate for 3D medical image.

REFERENCE:

1. I.Ueno and W.Pearlman, “Region of interest coding in volumetric images with shape-adaptive wavelet transform”, in Proc. SPIE, 2003, vol.5022.

2. C.Doukas and I.Maglogiannis, “Region of interest coding techniques for medical image compression”, IEEE Eng. Med. Biol. Mag.,vol.25, no.5, Sep-Oct.2007.

3. K.Krishnan, M.Marcellin, A.Bilgin, and M.Nadar, “Efficient transmission of comressed data for remote volume visualization”, IEEE Trans. Med. Imag., vol.25, no.9, Sep.2006.

4. R. Srikanth and A. G. Ramakrishnan, “Contextual encoding in uniform and adaptive mesh-based lossless compression of MR images,” IEEE Trans. Med. Imag., vol. 24, no. 9, Sep. 2005.

5. Y.Liu and W.A.Pearlman,” Resolution Scalable Coding and Region of Interest Access with Three-Dimensional SBHP Algorithm”, Third International symposium on 3D Data Processing, Jun 2006.

6. Ram Singh, Ramesh Verma and Sushil Kumar “JPEG2000: Wavelet Based Image Compression” EE678 wavelets application assignment 1.

7. P. Schelkens, A. Munteanu, J. Barbarien, M. Galca, X. Giro-Nieto, and J. Cornelis, “Wavelet coding of volumetric medical datasets,” IEEE Trans. Med. Imag., vol. 22, no. 3, pp. 441–458, Mar. 2003.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)