A Survey on Lossless Compression for Medical Images

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ABSTRACT
Large amount of medical image sequences are available in various hospitals and medical organizations, which occupies considerable storage space. Hence to reduce the storage space there is a need for compressing medical images. There are several lossy and lossless compression techniques. Using lossy compression the original images are not recovered exactly but using lossless compression techniques the original images can be recovered exactly. This paper discusses about the various lossless compression techniques for various medical images.

General Terms
Lossless Image Compression, JPEG-2000.

Keywords
JPEG-LS, Interframe Coding, Motion Vector.

1. INTRODUCTION
Medical Image Compression is very important in the present world for efficient archiving and transmission of images. Compression is the process of coding that will effectively reduce the total number of bits needed to represent certain information.

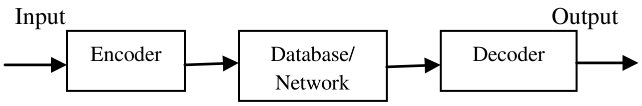

Fig 1: Simple Compression Technique

Basically two types of compression are available. (i) Lossy Compression (ii) Lossless Compression.

(i) Lossy Compression: In this compression there is loss of information and the original image is not recovered exactly. This is irreversible. Most lossy data compression formats suffer from generation loss: repeatedly compressing and decompressing the file cause it to progressively loss quality.

(ii) Lossless Compression: The goal of lossless image compression is to represent an image signed with the smallest possible number of bits without loss of any information, thereby speeding up transmission and minimizing storage requirement. This reproduces the original image without any quality loss. This is irreversible. This involves two steps.

(i) Modeling-Generates a statistical model for the input data. Statistical modeling algorithm for text include Burrow-wheeler transform, LZ77, LZW and PPM

(ii) Coding-Maps the input data to bit strings. Encoding algorithm to produce bit sequences are Huffman coding and arithmetic coding.

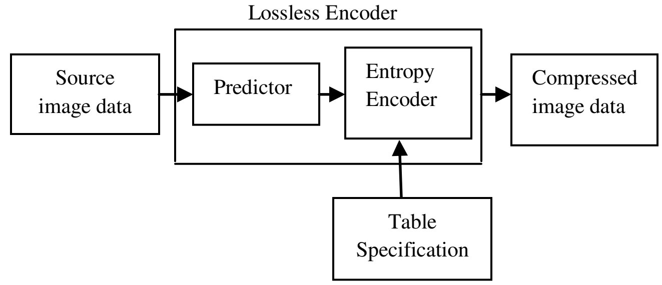

Fig 2: Lossless Compression

When large amount of data is transferred through the network the bandwidth gets wasted. To avoid that lossless compression techniques are used to reduce the storage space. [1]. This paper discusses about the lossless compression techniques that compresses the medical image sequences like Capsule Endoscopy (CE) images, Magnetic Resonance Imaging (MRI) images and Ultrasound (US) images. The following lossless compression techniques are available.

The Standard Lossless Image Compression algorithm for medical images, Lossless Interframe Coding for MR Images, Lossless Compression using JPEG-LS and Interframe coding, Image Compression with Sharing of Motion Vector.

2. LOSSLESS MEDICAL IMAGE COMPRESSION TECHNIQUES
Medical Images are captured in large amount and stored. There are several lossless image compression algorithms for the applications of compressing medical images. In this lossless JPEG, JPEG-LS, JPEG 2000, PNG and CALIC are tested as an image data set. Comparing all, JPEG-LS are the algorithm with best performance with compression ratio and compression speed. [2]. Here an image set of 382 medical images which are organized to 20 groups according to [3] is taken.

In this study we have characterized the various compression algorithm and implementation.

2.1 Lossless JPEG
This describes the predictive image compression algorithm with Huffman or arithmetic entropy coder. [4].

2.2 JPEG-LS

This describes low complexity image compression algorithm with entropy coding and the algorithm used is LOCO-I. [5]. This is developed with the aim of providing low complexity lossless and near lossless image compressions.

2.3 JPEG-2000

This describes the algorithm based on wavelet transform image decomposition and arithmetic coding. [6].This supports both lossy and lossless compression, this produce higher quality final image.

2.4 PNG

This describes a predictive image compression algorithm using LZ77. [7] and Huffman coding.

2.5 CALIC

This describes Arithmetic Entropy codes which has high compression ratio. [8][9].

When tested with all these algorithms JPEG-LS has best Compression Speed (CS) and Compression Ratio (CR).

The speeds of JPEG 2000, PNG and CALIC are similar but CALIC is little faster than JPEG 2000 and PNG. When comparing the compression ratios JPEG-LS and CALIC are higher than JPEG2000.But JPEG 2000 is better than PNG and Lossless JPEG.Considering the compression speed and compression ratio JPEG-LS is the best algorithm for lossless compression for medical images. [2].

$$\text{Compression Ratio} = \frac{\text{Original Image Size}}{\text{Compressed Image Size}}$$

Table 1. Comparison of CS and CR for various algorithms

No of Images. [2].	Lossless JPEG		JPEG-LS		JPEG 2000		PNG		CALIC	
	CS	CR	CS	CR	CS	CR	CS	CR	CS	CR
382	11.9	3.04	19.6	4.21	4.0	3.79	3.6	3.35	4.5	4.11

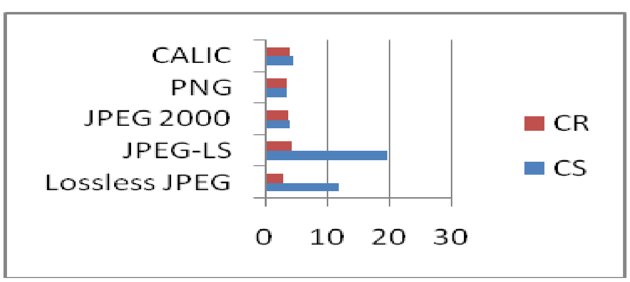

Fig 3: Comparison of CS and CR for various algorithms

3. JPEG-LS AND INTERFRAME CODING

3.1 JPEG-LS

JPEG-LS are simple and efficient baseline algorithm which consists of two independent and distinct stages called modeling and encoding. This is developed with the aim of providing a low complexity lossless and near lossless image compression. This can obtain good decor relation. The core of JPEG-LS is based on LOCO- I algorithm that relies on prediction, residual modeling and context-based coding of the residuals. [5]. Most of the low complexity of this technique comes from the assumption that prediction residuals follow a two-sided geometric distribution called Discrete Laplace Distribution and from the use of Golomb-like codes which are known to be approximately optimal for geometric distributions. [10]. Compression for JPEG-LS is generally faster than JPEG 2000. [2][11].

3.2 Interframe Coding

Interframe coding is a compression applied to a sequence of video frames rather than a single image. This exploits similarities between successive frames, known as temporal redundancy to reduce the volume of data required to describe the sequence. . Several interframe compression techniques describe sequence by reusing parts of frames to construct new frames. Sub sampling can be applied to video as an interframe compression technique by transmitting only some of the frames. Difference coding or conditional replenishment is a very simple interframe compression process during which each frame of a sequence is compared with its predecessor and only pixels that have changes are updated.Only a fraction of pixel values are transmitted.

An intercoded frame will finitely be divided into blocks known as macro blocks. After that, instead of directly encoding the raw pixel values for each block, as it would be done for an intraframe, the encoder will try to find a similar block to the one it is encoding on a previously encoded frame, referred to as reference frame. This process is done by a block matching algorithm. [12]. If the encoder succeeds on its search, the block could be directly encoded by a vector known as motion vector, which points to the position of the matching block at the reference frame. The process of motion vector determination is called motion estimation.

3.3 Motion Vector

Motion vector is the key element in motion estimation process. It is used to represent a macro block in a picture based on the position of this macro block in another picture called the reference picture. In video editing, motion vectors are used to compress video by storing the changes to an image from one frame to next. When motion vector is applied to an image, we can synthesize the next image called motion compensation.[13][14]. This is used to compress video by storing the changes to an image from one frame to next frame. To improve the quality of the compressed medical image sequence, motion vector sharing is used. [15].

4. COMPARISON AND DISCUSSION

Fig. 3 has demonstrated that JPEG-LS perform better than Lossless JPEG, JPEG 2000, PNG and CALIC. Next we examine the average CR for CE image sequences and MRI sequence. The results are discussed in Table 2 and 3. Fig.4 and Fig.5 demonstrates that the compression ratio is higher for JPEG-LS+VAR+MV than JPEG-LS and JPEG 2000. Time for compressing 100 image sequence is 29.83±0.47, 24.75±2.61 and 4.93±0.33 S when JPEG-LS+MV, JPEG-LS+VAR+MV and JPEG-LS respectively. Coding gain for CR image is 13.3% and 26.3%.Similarly coding gain for MRI image is 77.5% and 86.5%.[11].

Table 2. Average CR for CE Image Sequence

Method.[11]	#1	#2	#3	#4	#5	#6
JPEG 2000	3.03	2.90	2.97	2.88	2.87	2.30
JPEG-LS	3.48	3.34	3.47	3.32	3.37	2.56
JPEG-LS+VAR+MV	3.74	3.78	3.61	4.37	3.88	2.77

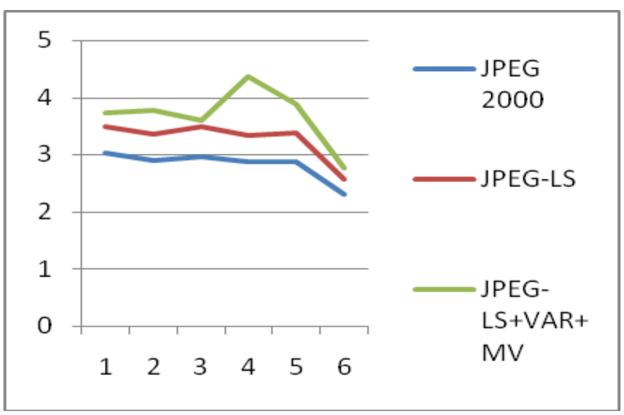

Fig 4: Comparison of CR for CE Image Sequence

Table 3. Average CR for MRI Image Sequence

Method.[11]	CR
JPEG 2000	2.59
JPEG-LS	2.72
JPEG-LS+VAR+MV	4.84

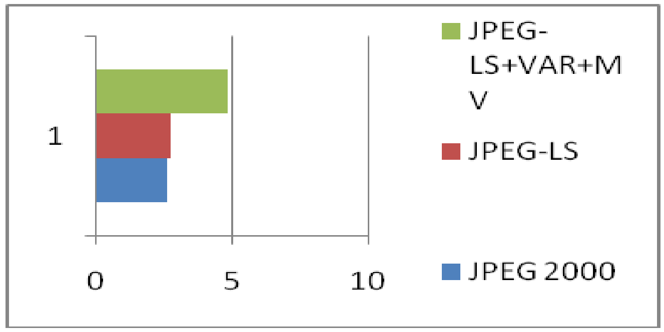

Fig 5: Comparison of CR for MRI Image Sequence

5. CONCLUSION

In this paper we performed a survey on various lossless compressing techniques. For medical images[2] various compression algorithm like Lossless JPEG, JPEG-LS, JPEG 2000, PNG and CALIC are used and JPEG-LS is found to be the best algorithm based on compression speed and compression ratio. For medical image sequences[11] using JPEG-LS and Interframe coding, the quality can be improved and to avoid the coding loss and significant increase of computational cost like[5][16], correlation estimation approach is used.

6. ACKNOWLEDGEMENT

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