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Lossless medical image compression by IWT

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ABSTRACT

Image compression has become an important process in today's world of information exchange. Image compression helps in effective utilization of high speed network resources. Medical Image Compression is very important in the present world for efficient archiving and transmission of images. Integer wavelet Transform (IWT) show the effectiveness of the methodology used, different image quality parameters are measured and observed the increased higher PSNR values. Homogeneous data in radiological image databases consumes an extraordinary amount of storage space. Lossless compression algorithms are imperative for efficient storage and transmission of volumetric data sets. The proposed work is to compress the medical data without any loss (i.e. lossless). Medical information is either in multidimensional or multi-resolution form, this creates enormous amount of data. Retrieval, Efficient storage, management and transmission of this voluminous data are highly complex. This technique combines integer transforms and JPEGLS Prediction to enhance the performance of lossless compression.

Key words: IWT, PACS, DICOM GAP and GED.

INTRODUCTION

Applications involve image transmission within and among health care organizations using public networks. In addition to compressing the data, this requires handling of security issues when dealing with sensitive medical information system. Compressing medical data includes high compression ratio and the ability to decode the compressed data at various resolutions (1). In order to provide a reliable and efficient means for storing and managing medical data computer based archiving systems such as Picture Archiving and Communication Systems (PACS) and Digital-Imaging and Communications in Medicine (DICOM) standards were developed With the explosion in the number of images acquired for diagnostic purposes, the importance of compression has become invaluable in developing standards for maintaining and protecting medical images and health records (2).

Compression offers a means to reduce the cost of storage and increase the speed of transmission. Thus medical images have attained lot of attention towards compression. These images are very large in size and require lot of storage space. Image compression can be lossless and lossy. In lossless compression, the recovered data is identical to the original, whereas in the case of lossy compression the recovered data is a close replica of the original with minimal loss of data (3).

Various predictive based coding techniques with their effectiveness are shown in table below:

Table: Predictive based coding techniques

Predictive based Coding methods	Comments
LJPEG	1. Predictive algorithm used. 2. Huffman or arithmetic entropy algorithm. 3. Highest compression ratio.
JPEG LS	1. Near lossless 2. High speed and compression ratio, mostly used 3. JPEG-LS algorithm is more scalable than JPEG and JPEG 2000
JPEG 2000	1. Wavelet based method. 2. High noise compensation ratio. 3. JPEG 2000 delivers a typical compression gain in the range of 20%, depending on the image characteristics. 4. Higher-resolution images tend to benefit more, where JPEG-2000's spatial-redundancy prediction can contribute more to the compression process. 5. JPEG 2000 has quality advantage over JPEG
MED	1. Belongs to the group of switching Predictors. 2. MMSE performs the adaptation prediction coefficient on the basis of a training set of causal pixels. This approach can achieve better results. 3. Redundancy between frames is reduced by the prediction of each pixel based.
GAP	1. Gradient estimation around The current pixel. 2. Gradient estimation is estimated by the context of current pixel.
GED	1. GED predictor is a simple combination of gradient and median Predictors. 2. Pixel in context of horizontal edge, vertical edge or smooth region
CALIC	1. Poor performance 2. High compression ratio 3. More complex algorithm with more resources
Blending predictor(model based)	1. Models for particular pixel designed by combination of linear sub predictors 2. Bayesion model averaging used(BMA), risk associated with this model 3. Better performance

Motivation: The future of healthcare delivery systems and telemedical applications will undergo a radical change due to the developments in wearable technologies, medical sensors, mobile computing and communication techniques. When dealing with applications of collecting, sorting and transferring medical data from distant locations for performing remote medical collaborations and diagnosis (4, 5). E-health was born with the integration of networks and telecommunications. In recent years healthcare systems rely on images acquired in two dimensional domains in the case of still images, or three dimensional domains for volumetric video sequences and images. Images are acquired with many modalities including X-ray, magnetic resonance imaging, ultrasound, positron emission tomography, computed axial tomography. Medical information is either in multidimensional or multi-resolution form, this creates enormous amount of data. Retrieval, Efficient storage, management and transmission of this voluminous data are highly complex. One of the solutions to reduce this complex problem is to compress the medical data without any loss (6-8).

Proposed System: The objective of the proposed system is to perform lossless compression using Huffman encoding and JPEGLS algorithms (7).

IWT Followed by JPEGLS: Figure shows, Method integer wavelet transform is applied on the image which divides the image into four sub bands ss, sd, ds and dd. Now JPEGLS is applied on the four different bands separately giving outputs d1, d2, d3 and d4. To verify the perfect reconstruction the original and the reconstructed images are subtracted and the output is a dark image with maximum values as zero (9, 10).

Implementation of Integer Wavelet Transform
In integer wavelet transform there is a mapping between integers to integers (1, 4).

Implementation Using Filter Bank
In signal processing, a filter bank is an array of band-pass filters that separates the input signal into multiple components each one carrying a single frequency sub band of this original signal. In process of decomposition performed by the filter bank is called analysis and the output of analysis is referred to as a sub band signal with as many sub bands as there are filters in the filter bank. The reconstruction process is called synthesis (11). After performing decomposition, the important frequencies can be coded with a fine resolution. The minimum requirement of the filters both the analysis filters and the synthesis filters are achieved by using the analysis filters.

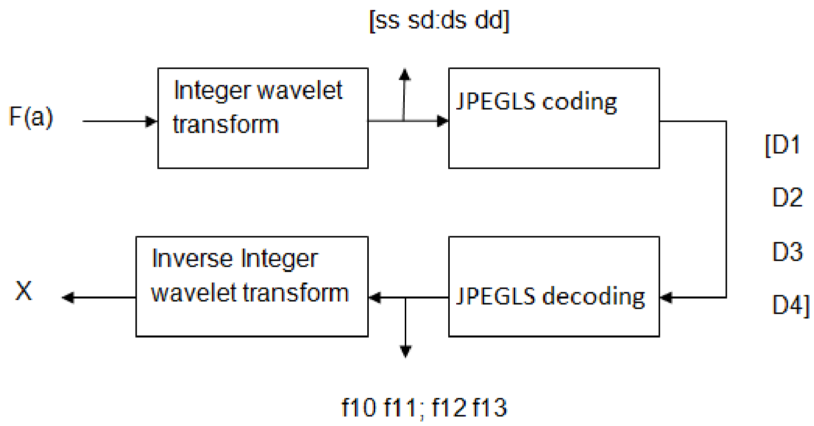

Figure1: Block Diagram for IWT Followed by Predictive Coding

The final four outputs are combined to from the transformed image. The image is transformed in different sub bands of which the first sub band is called LL (which represents the low resolution version of the image), the second sub band is called LH (which represents the horizontal fluctuations), the third band is called the HL (which represents the vertical fluctuations), and the fourth sub band is called the HH (which represents the diagonal fluctuations) (12).

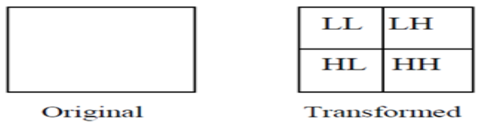

Figure2: Image after applying IWT

JPEGLS

Lossless JPEG refers to a 1993 addition to JPEG standard by the Joint Photographic Experts Group to enable lossless comparisons. However, it might be used as an umbrella term to refer to all lossless compression schemes developed by the Joint Photographic Expert group. They include JPEG 2000 and JPEG-LS. Lossless JPEG was developed as a late addition to JPEG in 1993, using a completely different technique from the lossy JPEG standard. It uses a predictive scheme based on the three nearest (causal) neighbors (upper, left, and upper-left), and entropy coding is used on the prediction error. It is not supported by the standard Independent JPEG Group libraries, although Ken Murchison of Oceana Matrix Ltd. wrote a patch that extends the IJG library to support Lossless JPEG. Lossless JPEG has some popularity in medical imaging, and is used in DNG and some digital cameras to compress raw images, but otherwise was never widely adopted (7, 13).

Lossless JPEG is actually a mode of operation of JPEG. This mode exists because the Discrete Cosine Transform (DCT) based form cannot guarantee that encoder input would exactly match decoder output since the Inverse DCT is not rigorously defined. Unlike the loss mode which is based on the DCT, the lossless coding process employs a simple predictive coding model called differential pulse code modulation (DPCM). This is a model in which predictions of the sample values are estimated from the neighbouring samples that are already coded in the image. Most predictors take the average of the samples immediately above and to the left of the target sample. DPCM encodes the differences between the predicted samples instead of encoding each sample independently (14-16).

The main steps of lossless operation mode are depicted in Fig.2. In the process, the predictor combines up to three neighbouring samples at A, B, and C shown in Fig.3 in order to produce a prediction of the sample value at the position labelled by X. The three neighbouring samples must be already predicted samples. Any one of the predictors shown in the table below can be used to estimate the sample located at X. Any one of the eight predictors listed in the table can be used. Note that selections 1, 2, and 3 are one-dimensional predictors and selections 4, 5, 6, and 7 are two-dimensional predictors. The first selection value in the table, zero, is only used for differential coding in the hierarchical mode of operation. Once all the samples are predicted, the differences between the samples can be obtained and entropy-coded in a lossless fashion using Huffman coding or arithmetic coding (3, 11 & 12).

Typically, compressions using lossless operation mode can achieve around 2:1 compression ratio for colour images. This mode is quite popular in the medical imaging field, and defined as an option in DNG standard, but otherwise it is not very widely used because of complexity of doing arithmetic's on 10, 12 or 14bpp values on typical embedded 32bit processor and a little resulting gain in space (16).

Selection-value	Prediction
0	No prediction
1	A
2	B
3	C
4	A + B – C
5	A + (B – C)>>1
6	B + (A – C)>>1
7	(A + B)>>1

Figure3: Prediction of the sample (A, B & C) value at the position labelled by X

JPEG-LS is a lossless/near-lossless compression standard for continuous-tone images. Its official designation is ISO-14495-1/ITU-T.87. It is a simple and efficient baseline algorithm which consists of two independent and distinct stages called modelling and encoding. JPEG-LS were developed with the aim of providing a low-complexity lossless and near-lossless image compression standard that could offer better compression efficiency than lossless JPEG (1, 4). It was developed because at the time, the Huffman coding-based JPEG lossless standard and other standards were limited in their compression performance. Total decorrelation cannot be achieved by first order entropy of the prediction residuals employed by these inferior standards. JPEG-LS, on the other hand, can obtain good decorrelation (3, 8). The core of JPEG-LS is based on the LOCO-I algorithm, that relies on prediction, residual modelling and context-based coding of the residuals. Most of the low complexity of this technique comes from the assumption that prediction residuals follow a two-sided geometric distribution (also called a discrete Laplace distribution) and from the use of Golomb-like codes, which are known to be approximately optimal for geometric distributions. Besides lossless compression, JPEG-LS also provide a lossy mode ("near-lossless") where the maximum absolute error can be controlled by the encoder. Compression for JPEG-LS is generally much faster than JPEG 2000 and much better than the original lossless JPEG standard (16-18).

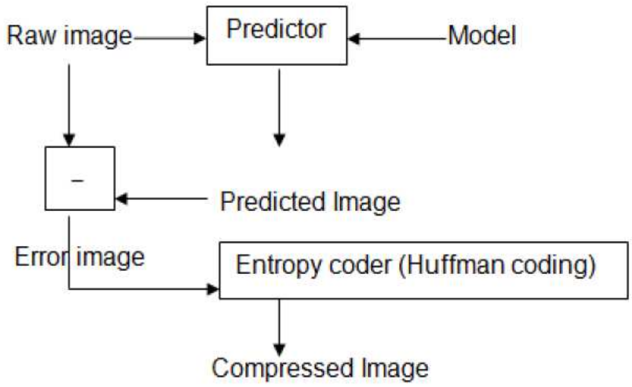

Figure4: Flow diagram of IWT process

CONCLUSION

In the lossless compression method, the image is transformed into four sub-bands using lifting technique, then predictive coding is applied to each sub-band using different predictor coefficients alpha and beta, giving an encoded image as output. Now the reverse process is applied to the encoded and the transformed image getting back the original image. The lifting scheme used is only a two-level lifting scheme. In order to improve the entropy of the transformed image, a multilevel lifting scheme is to be implemented. The performance of the predictive coding can be increased by using higher order predictors with two-dimensional predictions. Another possibility for improving the performance would be to use model-based and adaptive approaches. The performance for lossless compression techniques can also be improved by performing different combinations of various transforms and coding techniques involving IWT and predictive coding, for example, IWT followed by predictive or predictive followed by IWT, and by realizing the most optimal combination that gives the least entropy.

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