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COMPARISON OF DIFFERENT METHODS FOR LOSSLESS MEDICAL IMAGE COMPRESSION

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Abstract

Here, the concept of compression theory and lossless image compression methods are studied. In order to preserve the value of diagnostic medical images, it is necessary to provide lossless image compression. Apart from practical reasons, there are often legal restrictions on the lossless medical image compression. Lossless data compression has been suggested for many space science exploration mission applications either to increase the science return or to reduce the requirement for on-board memory, station contact time, and data archival volume. A Lossless compression technique guarantees full reconstruction of the original data without incurring any distortion in the process. As for the method of compression, predictive compression is much simpler than transformation-based compression, and in addition usually results in lower bit rate. During recent years, several algorithms for predictive lossless image compression have been presented. Predictive algorithms for image compression can be classified in two groups:

• The algorithms with a single pass, and
• The algorithms with two passes.

Keywords— *lossless image compression, medical images, high bit depth images, CALIC.*

I. Introduction

There are two major approaches in the image compression field, namely: lossless and lossy. In lossless compression, compressing and decompressing an image result in an exact replica of the original image. There are various applications where any loss in image information is unacceptable, e.g., medical imaging. In lossy compression, some image information is discarded in order to achieve better compression. This only allows a close replica of the original image to be reconstructed from the compressed data. Lossless compression is considered the base from which lossy compression algorithms are derived by means of a suitable quantization scheme. Hence, improvement in lossless compression schemes should also benefit lossy compression ones. The compression scheme presented in this paper is a lossless.

Medical image compression plays a key role as hospitals move towards filmless imaging and go completely digital. Image compression will allow Picture Archiving and Communication Systems (PACS) to reduce the file sizes on their storage requirements while maintaining relevant diagnostic information. Teleradiology sites benefit since reduced image file sizes yield reduced transmission times. Even as the capacity of storage media continues to increase, it is expected that the volume of uncompressed data produced by hospitals will exceed capacity and drive up costs. In this study we evaluate the performance of several lossless grayscale image compression algorithms.

Need for Compression

With the advance development in Internet and multimedia technologies, the amount of information that is handled by computers has grown exponentially over the past decades. This information requires large amount of storage space and transmission bandwidth that the current technology is unable to handle technically and economically. One of the possible solutions to this problem is to compress the information so that the storage space and transmission time can be reduced.

Image compression also plays an important role to any organization that requires the viewing and storing of images to be standardized, such as a chain of retail stores or a federal government agency. In the retail store example, the introduction and placement of new products or the removal of discontinued items can be much more easily completed when all employees receive, view and process images in the same way. Federal government agencies that standardize their image viewing, storage and transmitting processes can eliminate large amounts of time spent in explanation and problem solving. The time they save can then be applied to issues within the organization, such as the improvement of government and employee programs.

II. Medical Images & Compression

The compression of medical images has a great demand. The image for compression can be a single image or sequence of images. Medical images are widely used for surgical plan and diagnosis purposes. They include human body pictures and are being present in digital form. Imaging devices improve everyday and generate more data per patient. In the field of profiling patient's data, medical images need long-term storage. Therefore, images need compression. For such purpose compression ratio is important.(8)

As can be seen in Fig.1, lossless compression consists of two major parts: transformation and coding . Input image goes through transformation and encoding steps and form in a shorter manner as a compressed bit stream. Mostly, in lossy compression quantization adds to this flowchart.

Lossless JPEG, JPEG-LS and lossless version of JPEG2000 are lossless methods introduced by JPEG committee and are widely used in the world. The output of transformation step is the input of these encodings. Transformation decor relate input image and reduce entropy value. Entropy value is a measure for possibility of compression which is obtained by encoding.

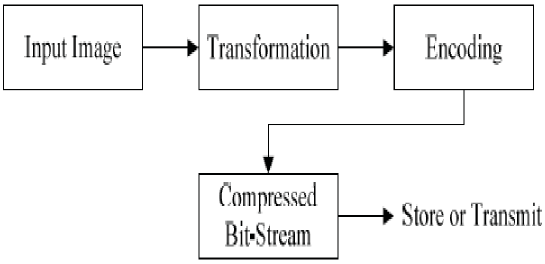

Figure1. Flowchart of Lossless Compression.

Differential Pulse Code Modulation (DPCM) and its adaptive predicting model are used in lossless JPEG and JPEG-LS respectively. Moreover, JPEG2000 takes advantage of reversible Discrete Wavelet Transform (DWT) for lossless compression. JPEG has about twenty years old and due to development and performance enhancement of digital medical imaging systems, it needs certain degree of improvements. In addition, JPEG2000 introduces some novelties and has a better compression ratio. However, it has higher computational resource requirement and is not cost effective in embedded environments. (4)CALIC is a relatively complex predictive image compression algorithm using arithmetic entropy coder, which because of the very good compression ratios is commonly used as a reference for other image compression algorithms.

Predictive encoding is a major class of encoding schemes that is utilized in lossless compression.(2) Compressions is accomplished by making use of the previously encoded pixels that are available to both the encoder and the decoder in order to predict the value for the next pixel to be encoded. Instead of the actual pixel value, the prediction error is then encoded.(5) Context-based predictions is a kind of adaptive predictive encoding in which pixels are classified into different classes (a.k.a. contexts) based on pixel neighbourhood characteristics. A suitable predictor for each context is adaptively selected and utilized for each context. As the most important predictors for lossless image compression the median predictor used in standard JPEG-LS and the gradient predictor, used in CALIC algorithm, are emphasized. Novel solution for the simple linear prediction is based on the detection of edges, called the GED and its comparison with the described predictors is made. GED algorithm is a mixture of distinguish features of most representative linear predictors, namely MED and GAP.

III. Algorithm

In this section we characterize briefly the CALIC algorithm(1). CALIC, which stands for Context-Based, Adaptive, Lossless Image Coding which is a very powerful continuous-tone images compression codec. CALIC is a one-pass coding scheme that encodes and decodes in raster scan order. It uses the previous scan lines of coded pixels to do the prediction and form the context. In order to achieve high performance in binary images (Images that only have two distinct gray scale values) or binary portion in encoding images, CALIC operates in two modes: binary and continuous tone modes. The system selects one of the two modes on the fly during the coding process, depending on the context of the current pixel.

First step in CALIC scheme is prediction; this compression algorithm has GAP Gradient- Adjusted Prediction that utilizes priorities knowledge of image smoothness. The GAP is simple, adaptive, nonlinear predictor, which can adapt itself to the intensity gradients near the predicted pixel; it weights the neighbouring pixels of current sample according to the estimated gradients of the image.(7) The GAP predictor, which is employed in CALIC, adapts itself to the gradients of horizontal and vertical edges. The GAP step only removes part of the redundancy in the image. Even GAP is a well constructed predictor, it still cannot capture the feature for different contexts. In order to refine our GAP prediction result, CALIC tries to model the context of the prediction error so that the higher order structures such as texture patterns and local activity in the image can be exploit.

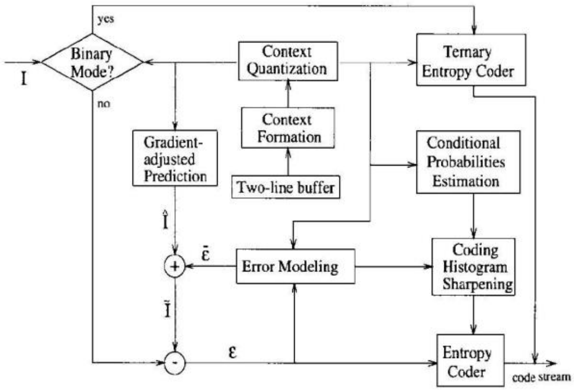

Fig 2. CALIC Frame Structure

Let us denote value of current pixel as *I*[*i*, *j*]. For prediction and modelling causal template illustrated in figure 3 is used.

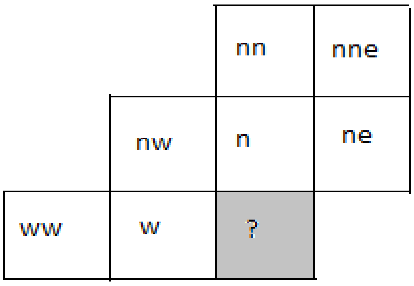

Fig3. Causal template for adjacent pixels in prediction and modelling

Let us denote adjacent samples as follows:

$$I_n = I[i,j-1], I_w = I[i-1,j], I_{ne} = I[i+1,j-1]$$
$$I_{nw} = I[i-1,j-1], I_{nn} = I[i,j-2], I_{ww} = I[i-2,j] \quad \text{(A)}$$
$$I_{nne} = I[i+1,j-2]$$

Formulas (A) mean north, west, northeast, northwest, north-north, west-west and north-northeast respectively.

The gradient of the intensity function is estimated by following quantities:

$$d_h = |I_w - I_{ww}| + |I_n - I_{nw}| + |I_n - I_{ne}|$$
$$d_v = |I_w - I_{nw}| + |I_n - I_{nn}| + |I_{ne} - I_{nne}| \quad \text{(B)}$$

Clearly, d_h and d_v are estimates within a scaling factor of the gradients of the intensity function near current pixel *I*[*i*, *j*] in the horizontal and vertical directions. Values of d_h and d_v for detecting magnitude and orientation of edges in the input image are used. In formulas (B) the absolute values are used, the reason for using absolute differences is to prevent cancellation of values of opposite signs. Value of $d_h$means value of horizontal gradient, d_v means value of vertical gradient. GAP predictor uses values of gradients by following principle. If value of vertical gradient d_v bigger than value of horizontal gradient d_h on some threshold value (typical threshold value is 80), then in current part of image exists clearly marked horizontal edge, therefore predictor value $\hat{I}$ [*i*, *j*] for current pixel equals value of left pixel $I_w = I[i-1,j]$. Similarly, if value of horizontal gradient bigger than value of vertical gradient on 80, then prediction value $\hat{I}$ [i, j] equals value of upper pixel I_n = I[i, j -1] .

Otherwise, the prediction value is obtained by following linear predictor:

$$\hat{I} = \frac{I_w + I_n}{2} + \frac{I_{ne} - I_{nw}}{4} \quad \text{(C)}$$

In CALIC contexts for error modelling are formed by embedding 144 texture contexts into four energy contexts to form a total of 576 compound contexts. Prediction is the crucial part of the compression, because it removes most of the spatial redundancy, and the choice of the optimal predictor is essential for the efficiency of compression methods. The prediction may be linear or nonlinear.

IV. Compression Efficiency

Compression efficiency is measured for lossless and lossy compression. For lossless coding it is simply measured by the achieved compression ratio for each one of the test images.

The most obvious measure of the compression efficiency is the bit rate, which gives the average number of bits per stored pixel of the image:

$$\text{Compression Ratio (CR)} = \frac{\text{size of uncompressed file}}{\text{size of compressed file}}$$

Lossless image compression must preserve every pixel intensity value regardless whether it is a noise or not. Efficiency of compression codec is usually described by compression ratio. Compression ratio is ratio between memory space needed to store raw image and memory space needed to store compressed data, i.e. code stream. Equivalent measure is bit rate, which shows how many bits per pixel are required for an image in average.

V. Results

Here results of CALIC, JPEG-LS and JPEG2k are measured and compared. Measure performance predictor can be expressed over the degree of compression i.e. compression ratio. Results are calculated on number of medical images. Table given below shows that compression ratio of CALIC is better compared to JPEG2k.

Image name	Actual size	Compression ratio with JPEG2k	Compression ratio with CALIC
Brain			
1	33878	0.401569	0.39308
2	415030	0.44537	0.32973
3	325558	0.32511	0.32446
4	179254	0.435218	0.41906
5	162998	0.408453	0.38904
6	150326	0.449045	0.3348
7	123958	0.504545	0.40517
8	31798	0.302313	0.28485
9	43190	0.403834	0.3798
10	49078	0.493326	0.45283
Hand			
1	415030	0.107106	0.096414
2	367606	0.509054	0.42676
3	389590	0.404227	0.36101
4	263158	0.253929	0.20354
5	210742	0.399269	0.31218
6	303478	0.104858	0.10059
7	194678	0.240522	0.12258
8	367606	0.203465	0.19401
9	346262	0.306456	0.24967
Leg			
1	52662	0.402590	0.30423
2	49078	0.301844	0.25724
3	46550	0.296584	0.2274
4	38390	0.392891	0.31103
5	36854	0.206315	0.19844
6	33878	0.211737	0.12933
7	11414	0.507820	0.45165
8	64182	0.403712	0.30153
9	59158	0.262399	0.26012
Other			
1	19894	0.300575	0.25324
2	29302	0.409707	0.31601
3	27286	0.607968	0.57371
4	25270	0.492996	0.4926
5	29302	0.624267	0.50014
6	22582	0.406640	0.35189
7	21910	0.499817	0.41952
8	23926	0.302713	0.26127
9	23926	0.409620	0.37451
Chest			
1	18358	0.507925	0.48905
2	415030	0.408178	0.39551
3	338998	0.407964	0.34669
4	212758	0.454693	0.40008
5	153142	0.407368	0.36385
6	76470	0.482367	0.41773
7	39094	0.406479	0.39736
8	28310	0.596718	0.51807

VI. Conclusion

We have studied the various lossless compression methods JPEG2K, CALIC. The main focus in this work is lossless compression algorithms based on context modeling and arithmetic coding. In order to demonstrate the compression performance of CALIC we compare it with lossless image compression techniques like JPEG2K. So, from results we get that CALIC is very efficient lossless compression algorithm which gives high compression ratio compared to JPEG2k. For lossless image compression, by statistically modelling the context correlation, a good coding scheme can be achieved.

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