A Review on Medical Image Compression Techniques

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Abstract – Hospitals and clinical environments are moving towards computerization, digitization and centralization, resulting in prohibitive amounts of digital medical images. Advance in telecommunication and information technology and emergence of electronic management systems are other reasons that resonating image problems. Therefore, Compression techniques are essential in archival and communication of medical images. In this paper we present a brief review on medical image compression methods which are applicable in telemedicine, e-health, and teleconsulation systems.

Index Terms – lossless compression, lossy comression, medical image compression; telemedicine;e-health.

1. INTRODUCTION

Transmission of medical images through digital networks requires very high bandwidth. On the other hand, digital images needs huge amount of storage space to store and archive. With the development of internet and multimedia technologies, medical information needed to be transmitted faster. One of the possible solutions to this problem is to compress the data, so that the storage space and transmission time can be reduced. Image compression techniques are designed to reduce data redundancy by means of special image coding and as a result, can greatly reduce effective amount of image data and therefore, the volume storage or transmission time required per image. In other words, image compression is the process of encoding images such that less storage space is required to archive them and less transmission time is required to retrieve them over a network. Compression is possible because most images contain large sections (e.g. backgrounds) that are often smooth, containing nearly identical pixel values that contain duplicate information. This is referred to as 'statistical redundancy'. Ideally, an image compression technique strives to remove redundant information, and efficiently encode and preserve the remaining data.

Compression schemes are divided into two main categories: Lossless (or reversible) and Lossy (or irreversible). In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image. However lossless compression techniques can only achieve a modest amount of compression and suffer from low compression ratios. An image reconstructed following lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. However, lossy schemes are capable of achieving much higher compression. Under normal viewing conditions, no visible loss is perceived (visually lossless). Because of the importance of medical information in medical images lossless methods are preferable. However, due to rapid increase in medical data produced by hospitals and because of the high cost of providing a large transmission bandwidth and huge amount of storage space, compression of images is becoming increasingly important. Also, because the compression rates of lossless schemes are dramatically low, researchers use lossy compression methods to compress the medical data and images, but loss of some information is the major concern. Thus, researchers try to introduce different methods of lossy compression with high compression rates and preserving important diagnostic information. Due to the importance of image compression and image quality, different standards are introduced in this field. JPEG, JPEG 2000 and DICOM are examples of image compression standards. DICOM is a comprehensive set of standards for handling, storing and transmitting information in medical imaging. As an example of medical image sizes, different medical images and their size are shown in table 1.

Organization of this paper as follow: section 2 introduces lossless image compression methods, then, lossy image compression techniques are introduced. Then, some application of medical image compression techniques qre introduced. Finally, we present a brief conclusion about the different compression methods.

2. LOSSLESS COMPRESSION METHODS

The goal of lossless image compression is to represent an image with the smallest possible number of bits without loss of any information. Thus, the compressed file could be transmitted and stored easily with the minimum requirements.

These methods can reproduce the original image without any loss, so we called them irreversible. This is an important feature that makes these techniques appropriate for medical image compression systems. However, compression ratio of the lossless methods is low. The main part of Lossless compression algorithms is encoder which encodes the information in a way to reduce the number of bits as much as possible. Fig.1 presents a sample block diagram for lossless compression algorithms.

Modality	Image dimension	Gray Level (bits)	Avg. no of images per Exam	Avg. MBs per Exam
CT	512x512	12	30	16
MRI	256x256	12	50	6.5
DSA	1024x1024	8	20	20
Fluroscopy	1024x1024	8	15	15
Ultrasound	512x512	8, 12	30	10.5, 16
SPECK	128x128	8, 16	50	0.8 , 1.6
PET	128x128	16	62	2.0
CR	2048x2048	12	4	32
Digital Film	2048x2048	12	8	64

Table 1 medical image sizes [2]

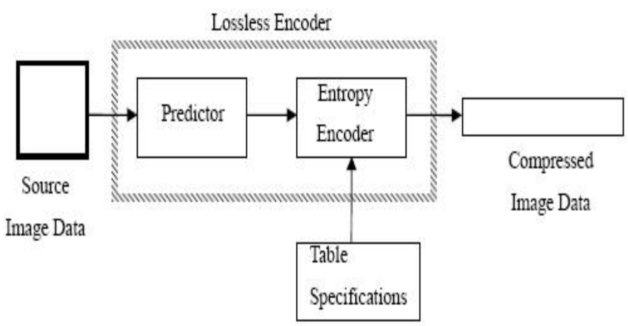

Fig. 1 Sample Block Diagram for Lossless Compression

Following techniques are included in lossless compression:

- Run length encoding
- Huffman encoding
- LZW coding
- Arithmetic coding, segmentation-based methods, different kinds of neural networks for image compression, and so on.

- Run length encoding

This is a very simple compression method used for sequential data. It is very useful in case of repetitive data. This technique replaces sequences of identical symbols (pixels), called runs by shorter symbols [2]. The run length code for a gray scale image is presented by a sequence {Vi, Ri} where Vi is the intensity of pixel and Ri refers to the number of consecutive pixels with the intensity Vi as shown in Fig.2.

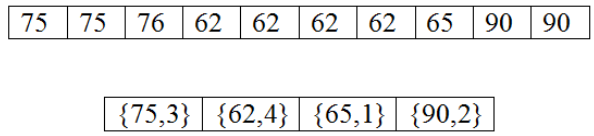

Fig. 2 Run-Length coding

- Huffman encoding

Huffman coding is an entropy encoding algorithm used for lossless data compression. As shown in Fig. 3, this is a general technique for coding symbols based on their statistical occurrence frequencies.

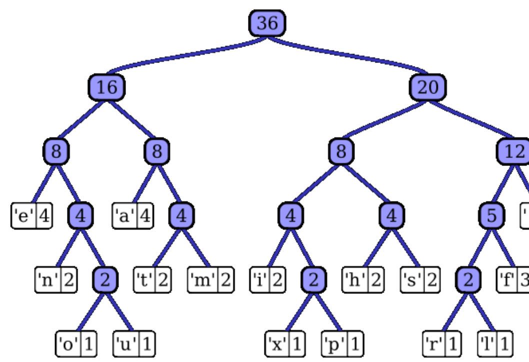

Fig. 3 Huffman Encoding

The pixels in the image are treated as symbols. The symbols that occur more frequently are assigned a smaller number of bits, while the symbols that occur less frequent are assigned a relatively larger number of bits. Huffman code is a prefix code. The binary code of any symbol is not the prefix of the code of any other symbol. Most image coding standards use lossy techniques in earlier stages of compression and use Huffman coding as the final step [3].

- LZW coding

LZW (Lempel-Ziv–Welch) is a dictionary based coding. Dictionary based coding can be static or dynamic. In static dictionary coding, dictionary is fixed during the encoding and decoding processes. In dynamic dictionary coding, the dictionary is updated on fly. LZW is widely used in computer industry and is implemented as compress command on UNIX [4].

The first step in LZW is initialization of the code table to include all the colors in the image file. For an 8-bit image, this would be up to 256 colors. If all colors were used, the codes would be the values from 0 through 255, each code requiring eight bits. The algorithm proceeds by processing the pixels in the image file from left to right and top to bottom of the image. The basic idea of the algorithm is that strings of colors are put into the code table as they are encountered. Grouping strings of colors together into a single code results in compression.(see Fig. 4).

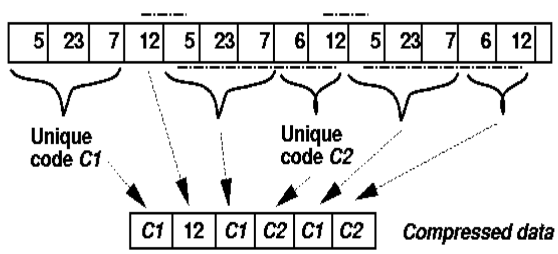

Fig. 4 LZW coding

3. LOSSY COMPRESSION

Conclusion In information theory lossy compression is a data encoding method that compresses data by discarding (losing) some of it. The aim of this procedure is to minimize the amount of data that needs to be held, handled and transmitted by a computer network. In the case of medical images lossless methods are preferable but because of storage and bandwidth limitations lossy techniques are used. Lossless compression techniques result in compression factors on order 2:1 to 3:1, which are insufficient to produce adequate reduction in transmission time or storage costs. To achieve these goals, compression factors on the order of 10:1 or higher are required, which implies that lossy compression must be used. That is, some information must be lost in the compression and decompression process. The major challenge is the adoption of lossy image compression in medical community. The characteristic of the human visual system are such that an image reconstructed after irreversible compression may appear indistinguishable from original. But it is important to preserve diagnostic details in the image to not affect the diagnosis quality [2].

In lossy image compression methods, image is decomposed using different kinds of transforms. Wavelet and Discrete Cosine Transform are used for transform images. The goal of transformation is to represent the original image in a more effective way. The second process is quantization which is the key issue for lossy methods and it is the difference between lossless and lossy methods. Quantization reduces the symbols used to represent the image. Two types of quantization are used in lossy compression methods: scalar quantization and vector quantization. In scalar quantization each symbol quantized separately but in vector quantization some number of successive symbols form a vector and that vector is quantized. Last part of lossy compression process is entropy encoding. Quantized symbols are encoded using different entropy coding algorithms, like Huffman encoding. The output of this process is a compressed image bitstream [5]. Fig.5 shows lossy image compression process.

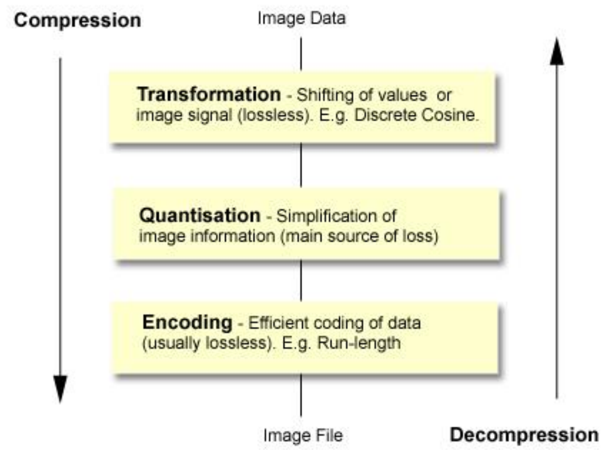

Fig. 5 Lossy Compression Block Diagram

Different image compression methods are presented in literature. Transform based image compression algorithms are very popular in medical community. Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are used broadly in this field. DCT based JPEG standard, divides the input image into blocks, DCT is performed on each block then the resulting coefficients are quantized and coded. The main problem of this compression method is blocking artifact [6]. After the introduction of wavelet transform, it has gained broad popularity according to its unique de-correlation property. The most important advantage of DWT based image compression techniques is lack of blocking artifact [7]. After the introduction of DWT, many compression algorithms were proposed to code wavelet coefficient. Among these algorithms, Embedded Zero tree Wavelet (EZW) [8], Set Partitioning In Hierarchical Trees (SPIHT) [9], Embedded Block Coding with Optimized Truncation (EBCOT) [10] are the most popular methods.

After the introduction of contourlet transform, researcher used this new processing tool for different image processing tasks such as image compression. The Contourlet transform is a directional transform, capable of capturing contours and fine details in images. The Contourlet expansion is composed of basis function oriented at various directions in multiple scales, with flexible aspect ratios. Using this rich set of basic functions, the Contourlet transform effectively capture the smooth contours that are dominant feature in images [3].

Fractal compression algorithm is another compression technique. The essential idea here is to decompose the image into segments by using standard image processing techniques such as color separation, edge detection, and spectrum and texture analysis. Then each segment is looked up in a library of fractals. The library actually contains codes called iterated function system codes, which are compact sets of numbers. Using a systematic procedure, a set of codes for a given image are determined, such that when the IFS codes are applied to a suitable set of image blocks yield an image that is a very close approximation of the original. This scheme is highly effective for compressing images that have good regularity and self-similarity [11].

Other kinds of lossy compression algorithms are presented in literature. Region of interest (ROI) based methods or context-based methods are examples of these techniques. The context based compression is one of the best choice to achieve the optimum compression ratios without any loss of useful information which is done by selecting different important regions of an image along with the background and then compression method is applied on these regions separately. Low compression or lossless is applied on diagnostically important region while high compression is applied on the background and unimportant parts.

4. APPLICATION OF MEDICAL IMAGE COMPRESSION

Advances in healthcare management systems, archiving and communication systems (PACS) and information technology require quick transmission of medical images and data. Beside hardware developments, improving compression techniques is an essential part of these systems. Image compression will allow PACS to reduce the file size on their storage requirements while maintaining relevant diagnostic information. Medical images could be saved in the electronic records of the patients efficiently and could be recovered if necessary.

Medical image compression plays a critical role in telemedicine and teleconsulation. Its importance is obvious especially where we have narrow bandwidth or large image datasets. Due to image modality different compression are used.

5. CONCLUSION

The development of digital medical imaging creates obvious problem of the transmission of the images within healthcare centers, and from one establishment to another, as well as the problem of storage and archival. Compression techniques can therefore be extremely useful when we consider the large quantities of data.

Lossless compression techniques used for reducing data sizes, but they suffer from low compression ratios. As a solution to this problem researcher used lossy compression methods to compress medical data. But, physicians were hostile towards the compression of data. The risk of losing a piece of diagnostic information does not sit well with medical ethics. Failing to identify a life-threatening illness in its early stages due to lost information is unthinkable, given the importance of early diagnosis in such cases. The evaluation of digital imaging, retrieval systems and Picture Archiving and Communication Systems (PACS), alongside compression systems, has resulted in changing attitudes and compression is now accepted and even desired by medical experts. Since then, different medical images are introduced and researchers try to improve compression techniques in the case of compression ratio and quality of reconstructed images.

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