A STUDY OF IMAGE COMPRESSION TECHNIQUES AND ITS APPLICATION IN TELEMEDICINE AND TELECONSULTATION

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ABSTRACT: *Image Compression is the technique of reducing the image size without degrading the quality of the image. Medical image compression plays a critical role in telmetics especially in Telemedicine. There is an immense need for efficient compression tech niques for use in compressing medical images to decrease the storage space and efficiency of transfer the images over network for access. In this paper we study about the image compression, need of compression, its principles, types of compression the various Image Compression Techniques and its Application in Telemedicine and Teleconsultion.*

KEY WORDS: Compression Techniques, Lossy and Lossless compression, Medical Image Compression, Telemedicine, Teleconsultation.

1. INTRODUCTION :

WITH the advent of computer, the digital technology has been playing an increasingly important roles in daily human life. Unlike the traditional analog pictures, digital pictures are arranged into individual picture element (pixel).

The digitization of the medical image information is of immense interest to the medical community which can lead to the implementation of e-health, telemedicine, teleconsultatin and telematics. To reduce transmission time and storage costs, efficient image compression schemes without degradation of image quality is required. There exist many medical image compression techniques for both lossy and lossless compression.

One of the most important problems in multimedia applications is the storage and transmission of image, video and audio data. This made the field of developing image compression methods necessary and vital. Different image compression techniques were proposed to achieve high compression ratio and high image qualities in low computation time.

In this paper, a study of different compression techniques, the recent trends and their applications in the emerging fields of medical science such as telemedicine and teleconsultation has been carried out.

2 IMAGE COMPRESSION

Image compression address the problem of reducing the amount of data required to represent a digital image with no significant loss of information.

2.1 Classifcation of compression.

A number of methods have been presented over the years to perform image compression. They all have one comman goal to alter the representation of information contained in an image so that it can be represented sufficiently well with less information. Regardless of the details of each image compression method, the methods can be classified into two general categories: lossy or lossless.

Original data can be recovered exactly from the compressed data in lossless compression. This is an important requirement for medical imaging domains because not only high quality is demanded, but unaltered archiving is also a legal requirement. Although, lossy techniques can achieve more compression for storing or transmitting the approximation of the original image but there is always distortion or noise in the reconstructed image. Therefore, such lossy schemes have not been conclusively adopted for medical imaging community due to perceived or actual distortions of clinically important details.

Compression methods actually can be classified as Lossy and Lossless. From which Lossless method includes RLE (Run Length Encoding), Huffman coding, Arithmatic coding, LZW, whereas Lossy method includes Vector Quantization, Predictive coding, DCT based Transform, Wavelet Transform, and Fractal image compression.

2.2 Types of Redundancy

A common characteristic of most images is that the neightbouring pixels are correlated and, therefore contain redundant information. The foremost task is then to find less correlated representation of the image. The two fundamental components of compression are redundancy and irrelevancy reduction.

1) **Redundancy reduction:** aims to duplication

removal from the signal source (image/video).

2) **Irrelevancy reduction**: omits parts of the signal that will not be noticed by the signal receiver; namely the Human Visual System (HVS).

Redundancy is the difference between the data and the information.

Redundancy = data – information

Three basic types of redundancy can be identified in an image are Coding redundancy, interpixel redundancy and psychovisual redundancy.

- **Coding redundancy:** Inefficient allocation of bits for symbols. It occurs when the data used to represent the image are not utilized in an optimal manner. For example it we have an 8 bits/pixel image that allow 256 gray-level values, but the actual image contains only 16 gray-level values, this is a sub optimal coding because only 4 bits/pixel are actually needed.
- **Interpixel redundancy**: Predictibility in data, i.e. if a pixel value can be reasonably predicted from its neighbouring (preceding/following) pixels, image is said to contain interpixel redundancy. It occurs because of adjacent pixels tend to be highly correlatd. This is a result of the fact that in most images the brightness do not change rapidly, it changes gradually, so that adjacent pixel values tend to relatively close to each other in value.
- **Psychovisual redundancy:** More data than we can see/hear i.e. data is ignored by the normal visual system.

2.3 Performance Parameters

A very logical way of measuring how well a compression algorithm compresses a given set of data is the ration of the number of bits required to represent the data before compression to the number of bits required to represent the dta after compression. i.e. compression ration. Suppose an image made up of a square array of 256*256 pixels and each pixel require 8 bits to represent its color, then its storage requires 65,536 bytes. If this image is compressed and the compressed version requires 16,384 bytes, then we can say that the compression ratio attained is 4:1 [Abh02].

$$\text{Compression Ratio} = \frac{\text{Uncompressed Size}}{\text{Compressed Size}}$$

Two of the error metrics used to compare the various image compression techniques are the Mean Square Error (MSE) and the Peak Signal to Noise Ration (PSNR). The MSE is the cumulative squared error between the compressed and the original image, where as PSNR is a measure of the peak erro. The mathematical formulae of the two are

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}\left[I(x,y) - I'(x,y)\right]^2$$

PSNR = 20 * log10 (255 / sqrt (MSE))

Where I(x,y) is the original image, I'(x,y) is the approximated version (which is actually the decompressed image) and M,N are the dimensions of the images. A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction. So, if you find a compression scheme having a lower MSE (and a high PSNR), you can recognize that it it's a better one.

3 IMAGE COMPRESSION ALGORITHMS

3.1 RLE Run Length Encoding

Run-length encoding (RLE) is a very simple form of data compression in which runs of data are stored as a single data value and count, rather than as the original run. This is most useful on data that contains many such runs: for example, relatively simple graphic images such as icons, line drawings, and animations.

A little example, we have the file: "aaaaaabcddccc" The encoder should output that: a,a,4,b,c,d,d,0,c,c,1 And the decoder will be able to decompress it.

This algorithm is easy to implement and does not require much CPU time. RLE compression is only efficient with files that contain lots of repetitive data. These can be text files if they contain lots of spaces for indenting but images that contain large white or black areas are far more suitable. Computer generated colour images) can also give fair compression ratios

3.2 LZW Compression

LZW compression is the compression of files into smaller files using a table-based look up algorithm. The GIF and TIFF are the two commonly used file formats which are used to compress using the LZW compression.

The working of the LZW compression is as follows; an algorithm takes each input series of bits and created an entry into a table for that particular bit series. So when the next input is read any pattern that has the same result as the above is put back in the table and hence space is saved. The LZW algorithm does not include the look-up table of codes in the final compressed file. The decoding program is set in such a way that the decoding program by itself with the help of an algorithm can produce the output. So now you realize why the LZW compression is one of the most popular compressing techniques.

The compression algorithm used in the LZW compression is so powerful that you can compress to nearly half its original size. This is very effective when you want to reduce large files and want to transfer into a different medium and when the compressed file is later decompressed for use, the quality of the output is quite good. The LZW compression technique is used in many compression utilities too.

3.3 Huffman coding

The basic idea in Huffman coding is to assign short codewords to those input blocks with high probabilities and long codewords to those with low probabilities. This concept is similar to that of the Morse code. A Huffman code is designed by merging together the two least probable characters and repeating this process until there is only one character remaining. A code tree is thus generated and the Huffman code is obtained from the labeling of the code tree.

A Huffman code can be represented as a binary tree whose leaves are the symbols that are to be encoded. At each non-leaf node of the binary tree there is a set containing all the symbols in the leaves that lie below the node. In addition, each symbol at a leaf is assigned a weight (its relative frequency), and each non-leaf node contains a weight that is the sum of all the weights of the leaves lying below it.

Huffman coding finds the optimal way to take advantage of varying character frequencies in a particular file. On average, usng a Huffman coding on standard files can shrink them anywhere from 10% to 30% depending on the character distribution

Huffman coding suffers from the fact that decompressin require to have knowledge of the probabilities of the symbols in the compressed file this can need more bit to encode the file. It is well suited for gray scale (black and white) bit map images.

The Huffman and Lempelel-Ziv encoding methods were compared as applied to MRI images in Cohen (1991). It showed that Lempel-Ziv encoding methods achieve higher compression than compression ratios resulting from using Huffman coding.

3.4 DCT Based Tramsform

- The discrete cosine transform (DCT) is a technique for converting a signal into elementary frequency components. DCT works by separting images into parts of different frequencies.During quantization,less important frequencies are discarded, hence it is termed lossy. Only most important frequencies are used to retrive the image, and retrived image can contain some distortion.
- In DCT we take each 8x8 pixel blocks and represent it as amounts (coefficients) of the basis functions (the frequency set).
- represent the 8x8 pixels as amounts of lowest frequency (the average or DC value) through to the highest frequency
- 64 pixels values are TRANSFORMED into 64 coefficients which represent the amount of each frequency.
- The DCT itself does not achieve compression but it prepares the image for compression
- Once in the frequency domain the image's high-frequency coefficients can be coarsely quantized so that many of them(> 50%) can be truncated to zero
- The coefficients can then be arranged so that the zeroes are clustered(zig-zag collection) and Run-Length Encoded.
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- The remaining data is then compressed with Huffman coding*.

3.4 Fractal Image Compression

3.4 Wavelet Transform

Wavelet compression is a form of data compression well suited for image compression.

First a wavelet transform is applied. This produces as many coefficients as there are pixels in the image (i.e., there is no compression yet since it is only a transform). These coefficients can then be compressed more easily because the information is statistically concentrated in just a few coefficients. This principle is called transform coding. After that, the coefficients are quantized and the quantized values are entropy encoded and /or run length encoded.

4 IMAGE COMPRESSION STANDARDS

4.1 The JPEG Standard

JPEG is an image compression standard that was developed by the "Joing Photographic Experts Group". JPEG was formally accepted as an internation standard in 1992.

JPEG is a lossy compression method. It employs a transform coding method using the DCT (Discrete Cosine Transform)

The effectiveness of the DCT transform coding method on JPEG relies on the observation that, useful image contents change relatively slowly across the image, i.e. it is unusual fo intensity values to vary widely several times in a small area, for example, within an 8*8 image block. Much of the information in an image is repeated, hence "spatial redundancy".

The following is the overview of JPEG process.

1. The image is broken into 8*8 block of pixels
2. Working from left to right, top to bottom, the DCT isapplied to each block.
3. Each block is compressed through quantization.
4. The array of blocks that constitutes the image is stored in reduced amount of space.
5. When required image is reconstructe through decompression.

4.1 The JPEG-2000 Standard

JPEG-2000 provides additional functionalities lacking in the current JPEG standard. The JPEG-2000 standard address the following problems, lossless and Lossy compression

1. There is currently no standard that can provide superior lossless compression and lossy compression in a single bitstream.
2. JPEG 2000 structure is a new wavelet based compression methodology that provides for a number

of benefits over the Discrete Cosine Transformation compression method, which was used in the JPEG format.

3. When high quality is a concern, JPEG 2000 proves to be a much better compression tool. JPEG 2000 offers both lossy and lossless compression in the same file stream, while JPEG usually only utilizes lossy compression

An example of some PSNR efficiencies for JPEG 2000 and JPEG is shown in Table 1. Two different color images were compressed using several different bit rates (measured in bits per pixel, or bpp) using both JPEG 2000 and JPEG. A higher bit rate will result in a higher quality picture. The analysis was performed by Maryline Charrier, Diego Santa Cruz, and Mathias Larsson as part of an overview of JPEG 2000. The results indicate that JPEG 2000 consistently offers higher compression efficiency. One should note that since the PSNR is measured on a log scale, the data in Table 1 indicates that in actuality the test showed that JPEG 2000 compresses almost twice more than JPEG.

TABLE 1
COMPARISON OF PSNR COMPRESSION EFFICIENCIES (IN DB)
FOR TWO IMAGES AT VARIOUS BIT RATES

Bpp	0.125	0.50	2.00
Image 1 JPEG	24.42	31.17	35.15
Image 1 JPEG 2000	28.12	32.95	37.35
Image 2 JPEG	22.60	28.92	35.99
Image 2 JPEG 2000	24.85	31.13	38.80

JPEG 2000 is also able to offer compression ratios of about 2.5:1 for lossless compression, whereas JPEG was not able to satisfactorily perform lossless compression at all. Lossless compression ratios are simply measured by how much less memory the compressed image uses.

5 IMAGE COMPRESSION AND TELEMEDICINE

Telemedicine is the integration of telecommunication technology with the advancements of information technology. It is aimed at enhancing healthcare delivery to a wider population. It supports the transfer of medical reports of patients across the telemedicine networks, in order to provide consultation by doctors located in geographically different locations.

Compressed medical images take a fraction of time to transmit compared to a regular medical image. The key challenge is to identify compression techniques which is near lossless, but does not loss any of its important characteristics.

Generally medical images require large space and due to their large size it requires high bendwidth for transmission. This becomes a major issue for rural medical centers which may not have sufficient telecommunication infrastructure. Lossless compression becomes a viable solution with advantage of bandwidth saving. However we have to improve the compression ratio such that it does not loss its visual characteristics and at the same time can be effectively used for automated image retirval applications.

TABLE 2
IMAGE SIZE AND BANDWIDTH ANALYSIS

Data	Size	Transmission Bandwidth
Grayscale image	512*512	2.1 Mb/image
Color image	512*512	6.29 Mb/image
Medical image	2048*1680	41.3 Mb/image

6 CONCLUSION

The goal of both lossless and lossy compression techniques is to reduce the size of the compressed image, to reduce storage requirements and to increase image transmission speed.

The size of the compressed image is influenced by the compression ratio, with lossless compression methods yielding ratios of 2:1 to 3:1 (Huang, 2004), and lossy or irreversible compression having ratios ranging from 10:1 to 50:1 or more (Huang, 2004). It is well know that as the compression ratio increases, less storage space is required and faster transmission speeds are possible, but at the expense of image quality degradation (Chen et. al., 2003).

It is also well established that the quality of digital images plays an important role in helping the radiologist to provide an accurate diagnosis

Image compression in digital radiology would have to be optimized based on the types of images being generated, interpreted for primary diagnosis, stored, and transmitted to remote sites for clinical review by physicians other than radiologists

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