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Biological Image Compression Using Wavelet Transforms

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***Abstract**: This paper is focused on selecting the most appropriate wavelet function for a given type of biological image. As a lot of hospitals handle their biological image data with computers. The amount of data produced by different techniques such as MRI, CT scan, ultrasound etc is vast and this might be a problem when sending the data over a network. To rise above from this problem, image compression technique has been introduced in the field of medical. The compression techniques can be categorized as, one is focusing on just a lossless compression method, other is, a lossy compression method, or focusing on both. Here, we shall propose an approach to improve the performance of medical image compression while satisfying both the medical team who need to use it, and the legal team who need to defend the hospital against any mal-practice resulting from misdiagnosis owing to faulty compression of medical images.*

Keywords: *Wavelet, Image Compression, MRI, JPEG.*

1. INTRODUCTION

Fast access to 2-D images is obtained by decoding only the corresponding information thus avoiding the reconstruction of the entire volume [2]. A novel medical data compression algorithm, termed layered set partitioning in hierarchical trees (LSPIHT) algorithm, is presented for telemedicine applications. In the LSPIHT, the encoded bit streams are divided into a number of layers for transmission and reconstruction. Starting from the base layer, by accumulating bit streams up to different enhancement layers, we can reconstruct medical data with various signal-to noise ratios (SNRs) and/or resolutions. Receivers with distinct specifications can then share the same source encoder to reduce the complexity of telecommunication networks for telemedicine applications. Numerical results show that, besides having low network complexity, the LSPIHT attains better rate-distortion performance as compared with other algorithms for encoding medical data.[3] Wavelets are mathematical tools for hierarchically decomposing functions. Wavelet Transform has been proved to be a very useful tool for image processing in recent years. It allows a function which may be described in terms of a coarse overall shape, plus details that range from broad to narrow. The most distinctive feature of Haar Transform lies in the fact that it lends itself easily to simple manual calculations. [4]So instead of representing a signal as the weighted sum of sinusoids as it is the case of the Fourier transform, we have the weighted summation of waves translated and dilated in time. The selection of mother wavelet determines the representation of the signal or the image. This transform is the basis of JPEG2000 standard [5]. Several compression methods for medical images have been proposed in the literature, some of which provide resolution and quality scalability up to lossless reconstruction.

2. TYPES OF IMAGE COMPRESSION

JPEG: JPEG stands for Joint Photographic Experts Group, the original name of the Committee that wrote the standard. JPEG is designed for compressing full color or Gray-scale images of natural, real-world scenes. It works well on photographs, naturalistic artwork, and similar material; not so well on lettering, simple cartoons, or line drawings. JPEG handles only still images, but there is a related standard called MPEG for motion pictures.

GIF: The Graphics Interchange Format (GIF) is an 8-bit-per-pixel bitmap image format that was introduced by CompuServe in 1987 and has since come into widespread usage on the World Wide Web due to its wide support and portability. The format uses a palette of up to 256 distinct colors from the 24-bit RGB color space. It also supports animations and allows a separate palette of 256 colors for each frame. The color limitation makes the GIF format unsuitable for reproducing color photographs and other images with continuous color, but it is well-suited for more simple images such as graphics or logos with solid areas of color.

Fractal Compression: is a lossy image compression method using fractals to achieve high levels of compression. The method is best suited for photographs of natural scenes (trees, mountains, ferns, clouds). The fractal compression technique relies on the fact that in certain images, parts of the image resemble other parts of the same image. Fractal compression differs from pixel-based compression schemes such as JPEG, GIF and MPEG since no pixels are saved. Once an image has been converted into fractal code its relationship to a specific resolution has been lost; it becomes resolution independent

[1]. The image can be recreated to fill any screen size without the introduction of image artifacts or loss of sharpness that occurs in pixel-based compression schemes.

Types of Imaging

Some of the imaging techniques are described below

X-rays

X-rays use beams of ionizing radiation to expose photographic film. Placing the human body between the beam and the film leaves an image of the body on the film. When radiation penetrates into the tissues easily black areas are seen, for example air in the lungs on a chest x-ray. Bones appear white because they are hardest to penetrate. X-rays are a good way of looking at bones and air inside the human body but they do not show up soft tissues well. X-rays have smaller wavelengths and therefore higher energy than ultraviolet waves.

Ultrasound scans

Ultrasound scans uses high frequency sound waves, which are emitted from a probe. Ultrasound is cyclic sound pressure with a frequency greater than the upper limit of human hearing. Although this limit varies from person to person, it is approximately 20 kilohertz (20,000 hertz) in healthy, young adults and thus, 20 kHz serves as a useful lower limit in describing ultrasound. The echoes that bounce back from structures in the body. The structures can be much more clearly seen when moving the probe over the body and watching the image on the screen.

Computerized Tomography (CT) scans

It uses multiple x-rays (ionizing radiation) to create a slice-by-slice image of the body. The slices (scans) are viewed as if you are looking up through the feet of the person to see the cross section. Therefore, a right-sided organ such as the liver appears on the left of the image. These can be used to take an accurate biopsy.

Magnetic Resonance Imaging (MRI) scans

MRI - images are similar to CT images except they show up the details of soft tissue better. MRI scans do not use X-rays but use a strong pulsed magnetic force to polarize cells - line up the (electrons) and measure the energy given off by the electrons when they bounce back into their normal orbits in-between pulses.

Mammography

Mammography is the process of using low-dose X-rays (usually around 0.7 mSv) to examine the human breast. It is used to look for different types of tumors and cysts. Mammography has been proven to reduce mortality from breast cancer. No other imaging technique has been shown to reduce risk, but breast self-examination (BSE) and physician examination are essential parts of regular breast care. At this time, mammography along with physical breast examination is still the modality of choice for screening for early breast cancer. It is the gold-standard which other imaging tests are compared with. CT has no role in screening for breast cancer at the present. Ultrasound, ductography, and magnetic resonance imaging are adjuncts to mammography. Ultrasound is typically used for further evaluation of masses found on mammography or palpable masses not seen on mammograms.

3. WAVELET TRANSFORMS

The development of wavelets can be linked to several separate trains of thought, starting with Haar's work in the early 20th century. Wavelet means a “small wave”. The smallness implies to a window function of finite length (compactly supported). Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. A wavelet is a waveform of effectively limited duration that has an average value of zero.

Wave in itself refers to the condition that this function is oscillatory. And Wavelet analysis has the ability to perform local analysis i.e. it can analyze a localized area of a larger signal. Wavelet analysis is capable of revealing aspects of data that other signal analysis techniques miss aspects like trends, breakdown points, discontinuities in higher derivatives, and self-similarity [6].

There are mainly two types of wavelet transforms-

1. Continuous Wavelet Transformation (CWT)
2. Discrete Wavelet Transformation (DWT)

Since our algorithm is to be based on discrete wavelet transform, so we will discuss only the concepts of DWT (leaving CWT as such) in the following paragraphs.

Two commonly used abbreviations are DWT and IDWT

DWT stands for Discrete Wavelet Transformation. It is the Transformation of sampled data, e.g. transformation of values in an array, into wavelet coefficients.

IDWT is Inverse Discrete Wavelet Transformation: The inverse procedure that converts wavelet coefficients into the original sampled data.

The usual steps involved in compressing and decompressing of image are

Step 1: Specifying the Rate (bits available) and Distortion (tolerable error) parameters for the target image.

Step 2: Dividing the image data into various classes, based on their importance.

Step 3: Dividing the available bit budget among these classes, such that the distortion is a minimum.

Step 4: Quantize each class separately using the bit allocation information derived in step 3.

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Step 5: Encode each class separately using an entropy coder and write to the file.
Step6: Reconstructing the image from the compressed data is usually a faster process than compression. The steps involved are
Step 7: Read in the quantized data from the file, using an entropy decoder. (Reverse of step 5).
Step 8: Dequantize the data. (Reverse of step 4).
Step 9: Rebuild the image. (Reverse of step 2).

4. RESULT, CONCLUSIONS AND FUTURE WORK

Analysis of X-Ray Images

For X-Rays Images I have analyzed the compression ratio with different wavelet functions for PSNR = 5.9866. By this analysis we have observed that for MRI Images 'haar' wavelet can perform relatively better than other Wavelet functions. By using 'haar' Wavelet we can achieve compression ratio upto 3.1591.

Table 7.1: Compression ratio of x-ray images for different wavelet functions

Type of Wavelet function	Compression Ratio
Haar Wavelet	3.1591
Coiflets Wavelet (coif5)	2.7399
Daubechies Wavelet (dB4)	3.0691
Biorthogonal Wavelet - bior6.8	2.6914

Graph

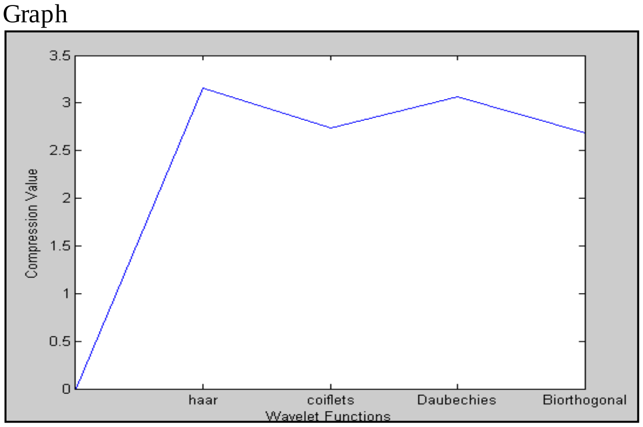

Figure 7.1: Graph between various wavelet functions and their compression ratios for x-ray images.

Analysis of MRI Images

For MRI Images I have analyzed the compression ratio with different wavelet functions for PSNR = 5.9866. By this analysis we have observed that for MRI Images 'haar' wavelet can perform relatively better than other Wavelet functions. By using 'haar' Wavelet we can achieve compression ratio upto 3.5227.

Table 7.2: Compression ratio of MRI images for different wavelet functions

Type of Wavelet function	Compression Ratio
Haar Wavelet	3.5227
Coiflets Wavelet (coif5)	1.9607
Daubechies Wavelet (dB4)	2.1582
Biorthogonal Wavelet - bior6.8	1.9608

Graph

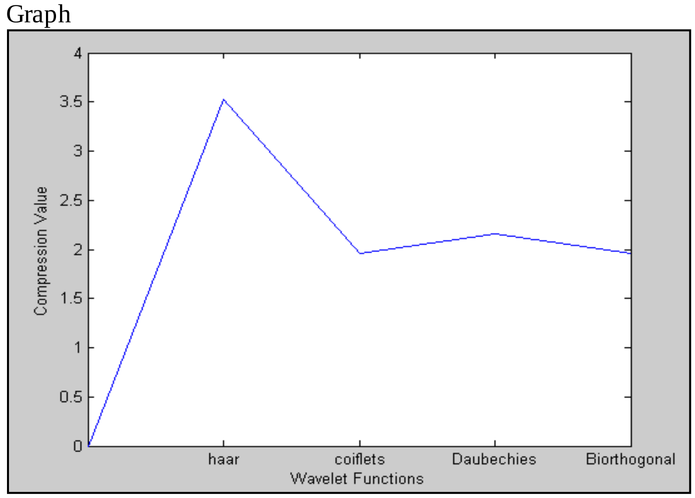

Figure 7.2: Graph between various wavelet functions and their compression ratios for MRI images

Analysis of Ultrasound Images

For Ultrasound Images I have analyzed the compression ratio with different wavelet functions for PSNR = 5.9866. By this analysis we have observed that for MRI Images 'Daubechies' wavelet can perform relatively better than other Wavelet functions. By using 'haar' Wavelet we can achieve compression ratio up to 3.4008.

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Table 7.3: Compression ratio of ultrasound images for different wavelet functions.

Type of Wavelet function	Compression Ratio
Haar Wavelet	3.0063
Coiflets Wavelet (coif5)	2.8208
Daubechies Wavelet (dB4)	3.4008
Biorthogonal Wavelet - bior6.8	2.7560

Graph

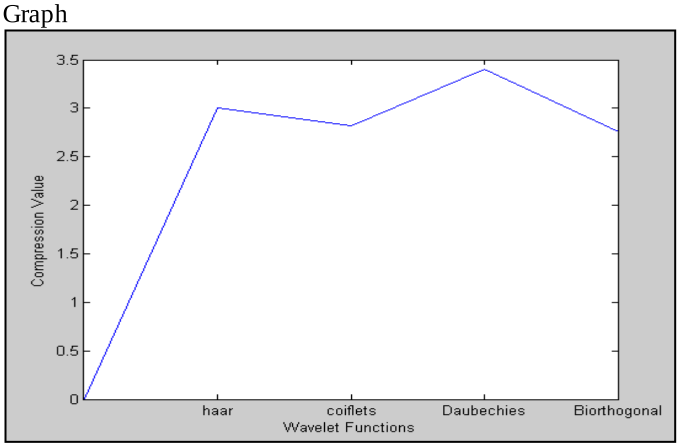

Figure 7.3: Graph between various wavelet functions and their compression ratios for ultrasound images

Analysis of Mammography Images

For Mammography Images I have analyzed the compression ratio with different wavelet functions for PSNR = 5.9866. By this analysis we have observed that for MRI Images 'Coiflets' wavelet can perform relatively better than other Wavelet functions. By using 'haar' Wavelet we can achieve compression ratio up to 3.3726.

Type of Wavelet function	Compression Ratio
Haar Wavelet	3.0804
Coiflets Wavelet (coif5)	3.3726
Daubechies Wavelet (dB4)	2.4749
Biorthogonal Wavelet - bior6.8	2.0253

Graph

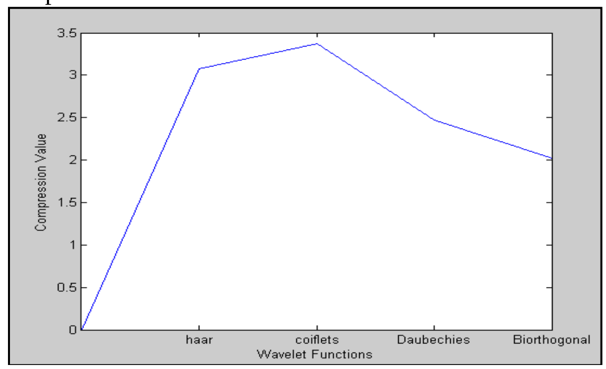

Figure 7.4: Graph between various wavelet functions and their compression ratios for Mammography images

In our study we have applied different Wavelet functions on different type of biomedical images for a fix PSNR value and calculated the compression ratio.

After analysis we have found that, for X-Ray Images 'Haar' can provide the best result as its compression ratio is 3.1591.For MRI Images 'Haar' gives better result in comparison to other Wavelet functions it provide compression ratio approximately 3.5227.For Ultrasound Images 'Daubechies' provides the better result and its compression ratio is 3.4008. For Mammography Images 'Coiflets' perform the most compression as it can provide compression ratio up to 3.3726. This result is outcomes of the analysis given below. In this analysis we fix the threshold and PSNR of the image compression and use different type of wavelets to compress each image at the given Threshold and PSNR value.

We analyzed that the compression ratio obtained after each compression and decides which wavelet function can provide maximum compression ratio for a particular biomedical image.

In this, we have considered the methods only for best compression but, the choice of optimal wavelet depends on the method, which is used for picture quality evaluation.After this we will have an optimal system having best compression ratio with best image quality.

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