

# DCT and DWT in Medical Image Compression

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**Abstract** – Medical images are very important in the field of medicine. Every year, terabytes of medical image data are generated through advance imaging modalities such as magnetic resonance imaging (MRI), ultrasonography (US), computed tomography (CT), digital subtraction angiography (DSA), digital fluorography (DF), positron emission tomography (PET), X-rays and many more recent techniques of medical imaging. But storing and transferring these huge voluminous data could be a tedious job. The digitization of the medical image information is of immense interest to the medical community which can lead to the implementation of e-health, teleradiology, teleconsultation, telemedicine and telematics. The digitization and the development of picture archiving and communication systems (PACS) depend critically on efficient compression algorithms. Furthermore medical images are needed to be stored for future reference of the patients and their hospital findings. Thereby, to reduce transmission time and storage costs, efficient image compression schemes without degradation of image quality are needed. There has been various trends emerging in the field of medical image compression. Many new techniques have been discovered to help in efficient compression of these bulky images. Generally, compression algorithms can be categorized into 2 main categories: one is the lossless category and the other is the lossy category. This paper simply investigates some of the medical image compression techniques that are existing as of today.

**Index Terms**— *Telemedicine, Teleconsultation, PACS, lossy and lossless compression, CR, MRI, CT, US, PET, DF and DSA.*

## I. INTRODUCTION

Medical image analysis and data compression are rapidly evolving field with growing applications in the healthcare services e.g. teleradiology, teleconsultation, e-health, telemedicine and statistical medical data analysis [1, 2]. Not only it has brought a drastic change in the health care systems but also it has made the concept of tele-consultation and telemedicine a reality. For the telemedicine, medical image compression (MIC) and analysis may even be more useful and can play an important role for the diagnosis of more sophisticated and complicated images through consultation of experts [3]. As in telemedicine, videos and the medical images

are transmitted through advanced telecommunication links, so the help of medical image compression to compress the data without any loss of useful information is immense importance for the faster transfer of the information [4]. The image transmission time depends on the bandwidth and the data transfer rate, so for the optimum use of the channel bandwidth and the faster data transfer, it is necessary to transmit the medical image data in compressed form.

There are many medical image compression techniques are available and evolving in day to day basis. The study of all such compression techniques are important, different techniques uses different medical images like Magnetic resonance images (MRI) and X-ray angiograms (XA) etc. DICOM (digital imaging and communications in medicine) is used for storing, transmitting and viewing of the medical images. Now-a-days wavelet based compression techniques have become more popular because they provide exceptional image quality at high compression rate.

Technically, all image data compression schemes can be broadly categorized into two types. One is *reversible compression*, also referred to as “*lossless*.” A reversible scheme achieves modest compression ratios of the order of two, but will allow exact recovery of the original image from the compressed version. An *irreversible scheme*, or a “*lossy*” scheme, will not allow exact recovery after compression, but can achieve much higher compression ratios, e.g., ranging from ten to fifty or more. Generally, more compression is obtained at the expense of more image degradation, i.e., the image quality declines as the compression ratio increases. Image degradation may or may not be visually apparent. The term “*visually lossless*” has been used to characterize lossy schemes that result in no visible loss under normal radiologic viewing conditions.

Currently, lossy algorithms are not being used by the radiologists in clinical practice. The reason is that lossy compression has raised new legal questions and regulatory policies for the manufacturers, the users, and the United States Food and Drug Administration (FDA)

[5], [6]. The physicians and radiologists are concerned with the legal consequences of an incorrect diagnosis based on a lossy compressed image. There is, however, insufficient clinical testing to develop reasonable policies and acceptable standards for the use of lossy processing on medical images.

## II. FUNDAMENTALS OF DIGITAL RADIOLOGIC IMAGES

This section briefly describes the fundamental concepts of radiologic imaging as related to digitization and compression.

**A. Digital Radiologic Images** A digital radiologic image is a digital image acquired by a certain radiologic procedure. It is a two-dimensional  $M \times N$  array of non-negative integers  $f(x,y)$ , where  $1 \leq x \leq M$  and  $1 \leq y \leq N$  are the coordinates of anatomical structures in the image. The image segment represented by the coordinates  $(x,y)$  is called a picture element, or a pixel, and  $f(x, y)$  is its functional value or gray level. The radiologic procedure can be X-rays, ultrasound, computerized tomography, nuclear magnetic resonance, or another digital modality. Depending on the digitization procedure or the radiologic procedure, the gray level can range from 0 to 255, 0 to 511, 0 to 1023, 0 to 2047 and 0 to 4095. These gray levels represent some physical or chemical properties of the object structure. As an example, in an image obtained by digitizing an X-ray film, the gray level value of a pixel denotes the optical density of the square area of that film. For X-ray computerized tomography (XCT), the gray level value represents the relative linear attenuation coefficient of the tissue. For magnetic resonance imaging (MRI), it corresponds to the magnetic resonance signal response of the tissue. In contrast with most other types of biomedical images, a radiologic image is monochrome, i.e., there is no need to do color compression.

| MODALITY | IMAGE DIMENSION | GRAY LEVEL(bits) | AVERAGE NUMBER OF IMAGES PER EXAM | AVERAGE Mbytes PER EXAM |
|----------|-----------------|------------------|-----------------------------------|-------------------------|
| CT       | 512x512         | 12               | 30                                | 16                      |
| MRI      | 256x256         | 12               | 50                                | 6.5                     |
| DSA      | 1024x1024       | 8                | 20                                | 20                      |

|                      |           |         |    |            |
|----------------------|-----------|---------|----|------------|
| DIGITAL FLUOROGRAPHY | 1024x1024 | 8       | 15 | 15         |
| ULTRASOUND           | 512x512   | 6       | 36 | 9.5        |
| SPECT                | 128x128   | 8 or 16 | 50 | 0.8 or 1.6 |
| PET                  | 128x128   | 16      | 62 | 2          |
| CR                   | 2048x2048 | 12      | 4  | 32         |
| DIGITIZED FILM       | 2048x2048 | 12      | 4  | 32         |

Table 1 lists the average number of megabytes per patient examination generated by radiologic imaging technologies [3], [7].

**B. Performance parameters** Considering the evaluation of performance of any medical image compression can be made by the parameters such as PSNR (peak signal-to-noise ratio), BR (Bit Rate).

$$PSNR (dB) = 20 \times \log_{10} (\text{Maximum pixel value}) / \sqrt{MSE} \quad (1)$$

Where, MSE represents the mean squared error of the image defined as,

$$MSE = 1/N \times \sum_i \sum_j (f(i,j) - F(i,j))^2 \quad (2)$$

Where,  $N$  is the total number of pixels,  $F(i, j)$  denotes the pixel value in the reconstructed image and  $f(i, j)$  is the pixel value in the original image.

$$BR (bpp) = \frac{\text{Size of the compressed image in bits}}{\text{Total no of pixel}} \quad (3)$$

If the bit rate increases, it results in improvement in quality of the reconstructed image.

## III. IMAGE COMPRESSION FRAMEWORK

This section describes the general framework for radiologic image compression. Similar to other digital compression fields, the framework includes three major stages: **image transformation**, **quantization** (irreversible compression only), and **entropy encoding** [4], [7]. The relative importance of each stage varies from one technique to another, and not all stages are necessary included in a particular scheme. All reversible compression techniques do not involve the stage of quantization.

The image transformation, sometimes also referred as **decorrelation**, is used to reduce the dynamic range of the signal, to eliminate redundant information, and to provide a suitable representation for efficient entropy coding. A transformation should satisfy three conditions.

First, all transform coefficients become statistically independent. Decorrelation with concomitant entropy reduction is important so that the transformed outputs are suitable for entropy encoding. Second, the energy of the transformed image is compacted into a minimum number of coefficients. Efficient energy compaction requires good localization of the sampling functions in both the spatial and the frequency domains. Third, the transform coefficients are concentrated in minimum frequency or transform scale regions.

Quantization is fundamentally lossy, i.e., pertaining to irreversible compression only. It achieves compression by representing transform coefficients with no greater precision than is necessary to achieve desired image quality.

#### IV. TRANSFORMS USED FOR IMAGE COMPRESSION:

**Discrete Cosine Transforms:** The DCT was first introduced by Ahmed in 70's [4] and has since been used for lossy image compression more than any other techniques. It is also included in the recent Joint Photographic Experts Group (JPEG) and Moving Picture Experts Group (MPEG) compression standards for general purpose still-image and video image applications. DCT-based image compression relies on two techniques to reduce the data required to represent the image. The first is *quantization* of the image's DCT coefficients; the second is *entropy coding* of the quantized coefficients. Quantization is the process of reducing the number of possible values of a quantity, thereby reducing the number of bits needed to represent it. Entropy coding is a technique for representing the quantized data as compactly as possible. In the JPEG image compression standard, each DCT coefficient is quantized using a weight that depends on the frequencies for that coefficient. The coefficients in each 8 x 8 block are divided by a corresponding entry of an 8 x 8 quantization matrix, and the result is rounded to the nearest integer. The 2-D DCT for an  $N \times N$  block is given by:

$$F(u, v) = (4/N^2)c(u)c(v) \times \left[ \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} x(m, n) \cos((\pi(2m+1)u)/2N) \times \cos((\pi(2n+1)v)/2N) \right]$$

$$x(m, n) = \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} c(u)c(v) F(u, v) \cos((\pi(2m+1)u)/2N) \times \cos((\pi(2n+1)v)/2N)$$

Where,

$$c(w) = 2^{-1/2} \text{ for } w = 0; \quad c(w) = 1 \text{ for } w=1,2,\dots,N-1$$

In many applications of the DCT for image compression, the original image is divided into adjacent blocks, e.g., 8 x 8 submatrices as in the JPEG compression standard. The DCT is then computed for each block and a quantizer is applied to the transform coefficients.

The best known example for block DCT image compression is the JPEG Standard [8] for compression of continuous-tone still images. This standard specifies lossy and lossless codec processes. The lossy coding is based on an 8 x 8 block DCT. To simplify the entropy coding, after quantization, the 64 DCT coefficients are scanned in a zigzag order (see Fig. 1), beginning with the DC coefficient of zero frequency. This zigzag ordering helps to facilitate better entropy coding by placing low-frequency coefficients, which are more likely to be nonzero, before high-frequency coefficients. While the JPEG standard offers quantization tables modeled according to human contrast sensitivity, there is complete freedom in choosing the quantization. The quantization table may be altered within an image.

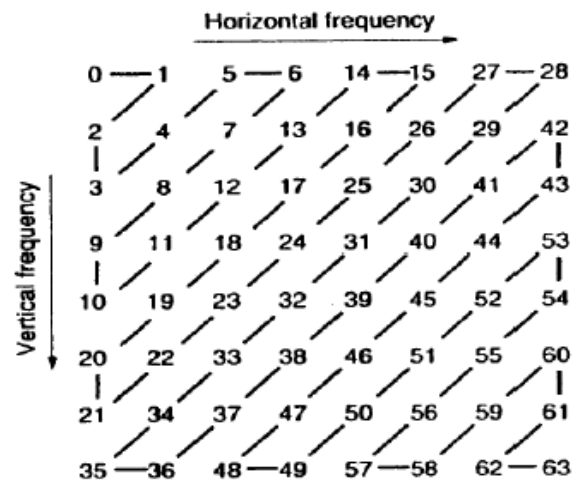


Figure 1-Zigzag ordering of the DCT coefficients for entropy encoding

The large and quickly growing volume of radiologic image data has prompted significant interest in the feasibility of applying the lossy DCT to medical images. Procedure for DCT Based compression:

- Convert the continuous/analog image to digital image that is in the pixel values.
- For reducing redundancy divide the image into small blocks of either 4\*4, 8\*8, 16\*16 matrix.
- Apply the suitable transformation to each block of whole image, we have applied DCT.

- For the further Compression either apply Quantization process of some pixel values of the image. and the quantized image matrix is given by  $= C = \text{round}(\text{actual image matrix}/\text{quant})$
- For the reconstruction of the image we should apply inverse transformation to each block of the whole image.
- Finally results can be compared by calculating the difference between the respective pixel values of original image and recovered image.
- Also compression can be calculated to know the % of compression which is simply the ratio of the size of the image file before and after compression.

Radiologic image compression with the DCT works well if the important clinical information of an image can be represented within a relatively narrow frequency range. Many details of medical images, however, are quite singular and nonstationary and demand a wide spectral range, i.e., many transform coefficients, for their representation. If one is not careful in quantizing the coefficients, the decoded image will have fringes parallel to edges. Thus, ideally, transforms for radiologic image compression should have the *space-frequency localization* attribute [ 10].

Furthermore, the shortcomings of the block structure of the transform manifest themselves by block boundaries that appear in the decoded image; particularly, when edge enhancement must be employed after the codec operation. **Discrete wavelet transforms:** A wavelet is waveform of limited duration that has an average value of zero. Wavelets are localized waves and they extend not from  $-\infty$  to  $+\infty$  but only for finite time duration. The basis of Discrete Cosine Transform (DCT) is cosine functions while the basis of Discrete Wavelet Transform (DWT) is wavelet function that satisfies requirement of multi resolution analysis. DWT represents image on different resolution level i.e., it possesses the property of Multi-resolution.

A *subband coder* performs a set Of filtering Operations on an image to divide it into spectral components or bands. Successive higher spectral bands that contain the necessary edge information can be added to the low-frequency components to reproduce the sharpness of original image. The signal is decomposed into a low-pass and a high-pass band of equal bandwidth. Assuming the ideal filtering, the decomposed signals would have half the bandwidth of the original and can be subsampled by a factor of 2. The process of bandsplitting and decimation by two can be applied to both the high- and the low-pass bands of a preceding decomposition and a subband *filterbank tree* is obtained.

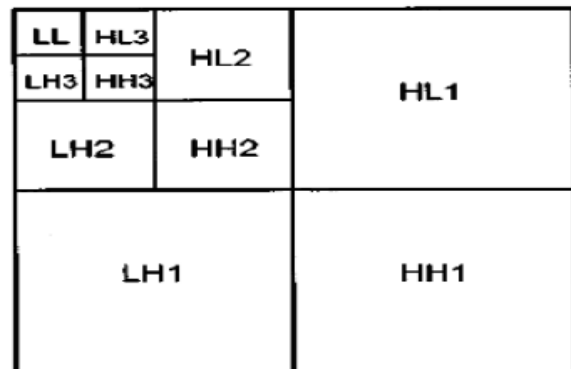


Figure 2 Wavelet Subband Decomposition of image

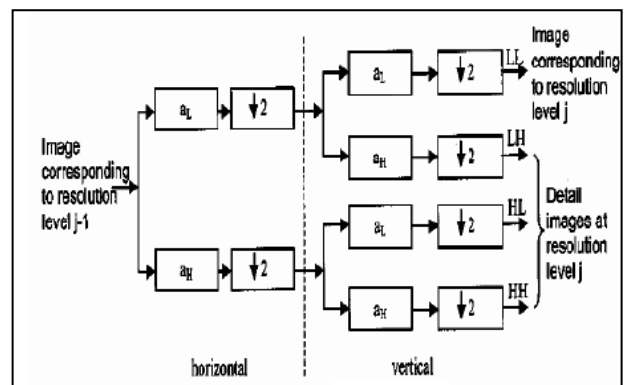


Figure 3 Decomposition of image to jth level.

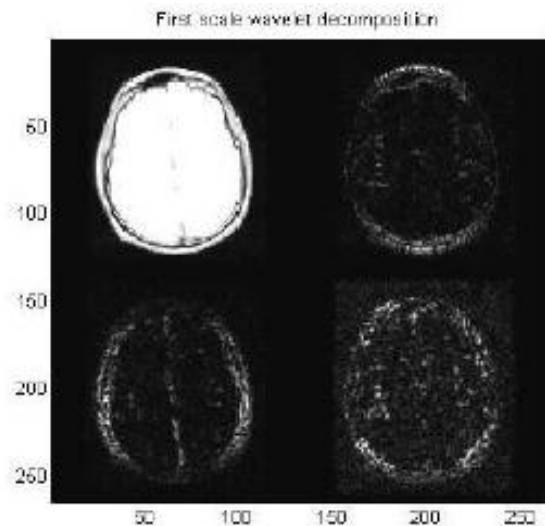


Figure 4 Wavelet Decomposition of MRI brain image upto first level

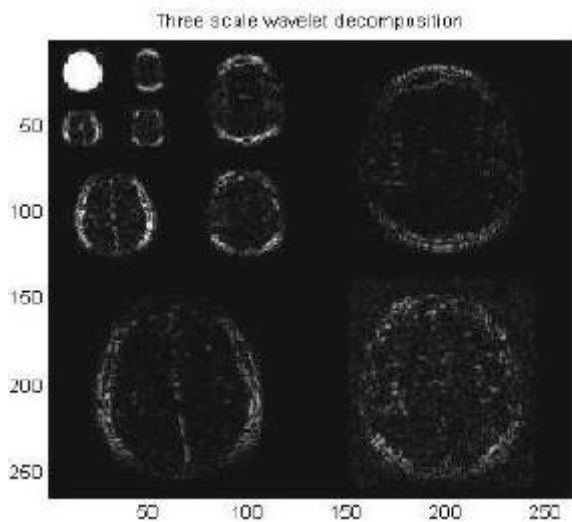


Figure 5 Wavelet Decomposition upto third level

Procedure For Image Compression Using Discrete Wavelet Transform:

- Read the image and convert the continuous image in to discrete pixel values.
- Transformation: Apply 2 Dimensional DWT using haar and Daubechies wavelet over the image.
- Threshold Detail Coefficients: For each level, a threshold is selected and hard thresholding is applied to the detail coefficients. Compression is based on the concept that the regular signal component can be accurately approximated using the following elements: a small number of approximation coefficients and some of the detail coefficients. This step basically provides compression to the image.
- After that Compressed image is transmitted through Channel.
- Inverse Transformation/ Reconstruction: Reconstruct an estimate of the original image by applying the corresponding inverse transform.
- Display the resulting images and analyze the quality of the image.
- Calculate MSE, SNR and Energy retained for corresponding reconstructed image.
- Display and compare the various results like MSE, SNR and Compression ratio at different Threshold values.
- The same process is repeated for various images and their performances are compared.

## V. CONCLUSION

Medical image compression is the current research area of interest. Various algorithms have been proposed to compress the images produced from the various modalities in the field of medicine. Transforms like DCT and DWT further aid in compressing the images in an efficient manner. the programs can be efficiently developed in MATLAB.

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