Chapter XXXVI
Medical Image Compression Using Integer Wavelet Transforms

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ABSTRACT

In this chapter, we have focused on compression of medical images using integer wavelet transforms. Lifting transforms such as S, TS, S+P(B), S+P(C), 5/3, 2+@, 2, 9/7-M and 9/7-F transforms are used to evaluate the performances of lossless and lossy compression. Four medical images, namely, MRI, CT, ultrasound, and angiograms are used as test data sets. It is found from the experiments that, among the different transforms, the 9/7-M wavelet transform is identified as the optimal method for lossless and lossy compression of medical images.

INTRODUCTION

Compression of medical images is an area of discussion among the medical community due to the fact that compressing an image could lead to vital diagnostic information being lost. On the other hand, images obtained from imaging modalities such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), and other modalities require large amounts of space for storage and also pose a problem during transmission. Hence, there is a need to achieve high compression and at the same time preserve the image quality. In telemedicine applications, the compression of medical images plays a paramount role in reducing the image file size, thereby reducing the bandwidth for transmission over a network.

There has been a tremendous increase in the use of wavelets as image-compression tools due to their ability to achieve high compression while sustaining image quality (Antonini, Barlaud, Mathieu, & Daubechies, 1992; Averbuch, Lazar, & Israeli, 1996). One of the advantages of wavelet-based compression is that it supports progressive lossy to lossless reconstruction (Adams & Kossentini, 2000; Said & Pearlman, 1996a, 1996b; Sheng, Bilgin, Sementilli, & Marcellin, 1998). The Joint Photographic Experts Group (JPEG2000) compression standard is based on wavelets. Wavelet-based entropy coders have been developed to enhance compression that exploits the spatial similarities among the wavelet coefficients. These coders, called zero-tree coders, include embedded zero-tree wavelet (EZW; Shapiro, 1993), set partitioning in hierarchical trees (SPIHT; Said & Pearlman, 1996a, 1996b), an advancement of EZW, and embedded block coding with optimized truncation (EBCOT; Taubman, 2000). With the development of integer wavelets, lossless compression could be realized (Calderbank, Daubechies, Sweldens, & Yeo, 1997, 1998). Integer wavelets generate integer coefficients, whereas the conventional wavelets generate floating-point coefficients. Lossless compression could not be achieved with the conventional wavelets due to having to round off these floating-point values. Integer wavelets are possible with the construction of wavelets based on the lifting scheme (Sweldens, 1998). The lifting scheme provides fast, efficient, and in-place calculation of the wavelet transform.

The main objective of this work is to evaluate different integer wavelets on the basis of their lossy and lossless compression performance for various medical images. The core idea behind compression is that in an image, there exists some correlation among the neighborhood pixels. The task is to decorrelate the image data so as to eliminate the redundancy and reduce the entropy of the image. The general architecture for a lifting-based wavelet compression scheme is depicted in Figure 1. The image is first transformed from a spatial domain to a wavelet domain using two-dimensional lifting wavelet transform (2D-LWT). The resulting wavelet coefficients are entropy coded to obtain a compressed image. In this chapter, SPIHT is used for entropy coding as it is fast and easy to implement and provides superior compression among the wavelet-based coders. To reconstruct the image, the process is reversed. The compressed image is first entropy decoded and then two-dimensional inverse lifting wavelet transform (2D-ILWT) is applied to obtain the original image.

The chapter is arranged as follows. In the next section, a brief description of the lifting wavelet transform will be presented, followed by the description of the SPIHT coder. A number of integer wavelets for various medical images are then analyzed based on their lossless and progressive lossy compression performance.

LIFTING WAVELET TRANSFORM

The lifting approach of constructing wavelets was proposed by Sweldens (1998). It allows fast, efficient, and in-place calculation of the wavelet transform. Besides this, it is feasible to construct integer wavelets based on this scheme.

Consider an image I of size N x N with N being an integer power n of 2. and each row and column consisting of 2^n pixels. The two-dimensional wavelet transform is performed by first applying one-dimensional wavelet transform along the columns and then applying one-dimensional wavelet transform along the rows or vice-versa. Therefore, we can treat the image as N x N one-dimensional vectors with each vector consisting of 2^n pixels. Hereafter, we refer to the one-dimensional vector as a signal x_n. Applying wavelet transform to x_n divides it into coarse s_{n-1} values and detail d_{n-1} values,

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