Computers in Biology and Medicine 37 (2007) 811–819

Computers in Biology and Medicine

www.intl.elsevierhealth.com/journals/cobm

Adaptive threshold-based block classification in medical image compression for teleradiology

Sukhwinder Singh, Vinod Kumar*, H.K. Verma

Instrumentation and Signal Processing Lab, Department of Electrical Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, Uttaranchal, India

Received 20 October 2005; received in revised form 23 July 2006; accepted 30 August 2006

Abstract

Telemedicine, among other things, involves storage and transmission of medical images, popularly known as teleradiology. Due to constraints on bandwidth and storage capacity, a medical image may be needed to be compressed before transmission/storage. Among various compression techniques, transform-based techniques that convert an image in spatial domain into the data in spectral domain are very effective. Discrete cosine transform (DCT) is possibly the most popular transform used in compression of images in standards like Joint Photographic Experts Group (JPEG). In DCT-based compression the image is split into smaller blocks for computational simplicity. The blocks are classified on the basis of information content to maximize compression ratio without sacrificing diagnostic information. The present paper presents a technique along with computational algorithm for classification of blocks on the basis of an adaptive threshold value of variance. The adaptive approach makes the classification technique applicable across the board to all medical images. Its efficacy is demonstrated by applying it to CT, X-ray and ultrasound images and by comparing the results against the JPEG in terms of various objective quality indices.

Keywords: Data compression; Telemedicine; Teleradiology; Discrete cosine transform (DCT); Medical image compression

1. Introduction

One of the greatest challenges facing humankind is to make high quality health care available to all. The World Health Organization (WHO) recommends that the WHO and its member states must integrate the appropriate use of health telematics in the overall policy and strategy for the attainment of health for all [1]. *Health Telematics* or *Telemedicine* is the delivery of health care and the exchange of health care information across distance. Teleradiology, one of the most used clinical aspects of telemedicine, has received a focused attention in the past few years. Basically, teleradiology attempts to transfer medical images of various modalities, like computerized tomography (CT) scans, magnetic resonance imaging (MRI), ultrasonography (US), and X-rays, etc. from one location to another. These transfers may be from one hospital to another, from an imaging center to a hospital, or from an imaging center or hospital to a physician's desk. Due to the bandwidth or storage limitations, the radiological images may be needed to be compressed before transmission to a distant location, or storage on picture archiving and communication system (PACS), or storage on the smart card of the patient.

Recently, there has been considerable interest in applying the lossy or irreversible compression for medical data, wherein the loss of fidelity must be contained to minimize diagnostic errors [2]. Lossy signal compression is achieved by processing the signal in the spatial/time domain or a transform domain [3–5]. In the transform domain, an invertible transform maps the signal to a set of coefficients. The transform typically is required to convert the statistically correlated input samples to a set of uncorrelated coefficients. For the purpose of compression, the dominant transform coefficients are retained and the remaining ones are discarded. The retained coefficients are then quantized and encoded for either storage or transmission. A transform is efficient if it can compact the energy in fewest of coefficients [6].

Discrete cosine transform (DCT) [7] is among the most popular transform techniques for image compression because of its high energy compaction capability. In fact several techniques to

* Corresponding author. Tel.: +91 1332 284352; fax: +91 1332 273560.
E-mail address: vinodfee@iitr.ernet.in (V. Kumar).

0010-4825/$ - see front matter
doi:10.1016/j.compbiomed.2006.08.021

that end have been proposed in the literature. The computation time of full frame DCT on a whole image is high, so the image is usually divided into non-overlapping blocks of appropriate size, e.g., 8×8 or 16×16 pixels. The DCT is then computed for each block and a quantizer is applied to the transform coefficients. Block-based DCT is a fundamental component of many image and video compression standards like JPEG (Joint Photographic Experts Group) [8].

Recently DCT has been used in medical image compression. Tai et al. [9] gave a segmentation technique for medical image compression based on the local energy magnitude for segmentation of blocks of the image into different energy levels. A 3D cuboid, which is formed by grouping together the blocks with same energy level, is compressed using 3D DCT. Wu et al. considered DCT as a band pass filter which decomposes a block into equal size bands [10]. The task of compression of medical images is utilizing the spectral similarity among bands. Wu gave an adaptive sampling algorithm for medical image compression using DCT. A classification of blocks was used to enhance the compression [11]. Although DCT has been used very effectively in these works without any intangible loss of information, there exists a lot of scope for further improvement especially on the classification of blocks. The present paper proposes the use of an adaptive threshold for classification of blocks. Sampling of DCT coefficients is used to compute a set of "significant" coefficients as the compressed data. The decoder retrieves the significant coefficients directly from the compressed data and calculates the other coefficients using linear interpolation.

An improved block classification technique based on adaptive threshold is put forward in Section 2, which also presents classification and sampling algorithms. Various parameters used for evaluation of reconstructed image quality and results are given in Sections 3 and 4, respectively. Finally, the conclusions are presented in Section 5. Section 6 contains a summary of the paper.

2. Image compression using proposed classification of blocks

2.1. Encoder configuration

The encoder configuration presented in Fig. 1 has been selected for the present work. In DCT-based compression schemes, the original image is often divided into smaller blocks to get the advantages of reduced computational complexity and

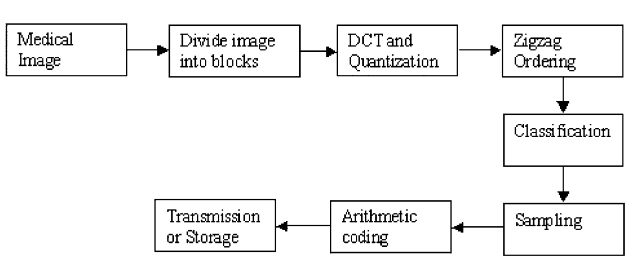

Fig. 1. Encoder configuration.

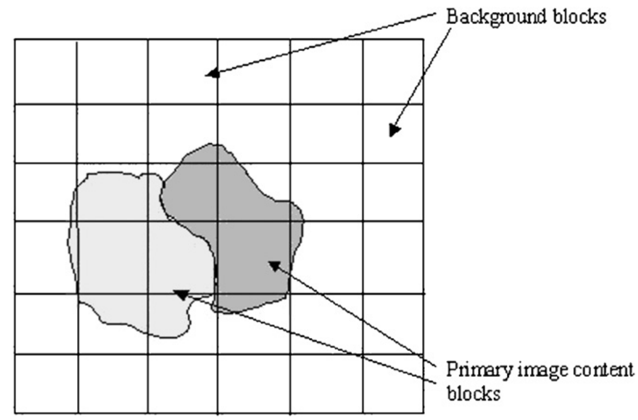

Fig. 2. Indicative medical image.

memory requirement. However, the achievable compression ratio (CR) reduces with smaller block size. Thus, a trade-off is to be maintained between computational complexity and CR in deciding the block size. In this work a block size of 16×16 pixels has been chosen [12]. Then the two-dimensional (2D) DCT is computed for each block and quantization is performed on the transform coefficients so obtained.

In the present study, sampling of 1D signals on the basis of the distortion area is carried out to compress medical images. However, the spectrum of medical images being 2D, a tool to transform 2D signals into 1D signals is required. The majority of the DCT coding schemes use *zigzag* scan for this purpose and the same is used here. The zigzag ordering helps to facilitate better entropy coding by first placing low-frequency coefficients, which are most likely to be nonzero, followed by high-frequency coefficients [8].

2.2. Proposed block classification technique

Medical images acquired in most radiological applications are visually examined by a radiologist. Therefore, any image compression method must ensure that there is no significant loss of diagnostic information for visual examination as well as subsequent medical image analysis. Medical images show characteristic information about the physiological properties of the structures and tissues. However, the quality and visibility of information depends on imaging modality and the response functions of the imaging scanner.

In medical images, most of the primary objects are typically located in the central region and the background is dark gray as shown in Fig. 2. Also the importance of every block inside the medical image is not the same. Thus the blocks can be classified into two categories, namely, *pure* and *complex*, based on variance in the block. The block with higher complexity has more information about the image, so more coefficients must be chosen to preserve the diagnostic information of the image.

As pure regions occupy most of the image and having minimum information content, better CRs can be obtained by