Region of Interest based Coding Technique Applied to CT and MRI Images for Medical Image Compression

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Abstract

Medical image compression applications are quality-driven applications which demand high quality for certain regions that have diagnostic importance in an image. Medical imaging has a great impact on diagnosis of diseases and preparation to surgery. However, imaging devices continue to generate more data per patient. Current compression schemes bring great compression rates if loss of quality is affordable. Medicine cannot afford deficiency in diagnostically important regions. For most medical images, the diagnostically significant information is localized over relatively small regions. Thus there is need of compression scheme which can solve the above problem and preserve quality of the image in diagnostically critical regions. Owing to the great demand for high compression ratio while maintaining high image quality, Region of Interest (ROI) technique is suitable. Here an image is initially segmented into two regions, interested and non-interested region. Interested Region (IR) consists of the most important part that has diagnostic/medicinal importance while the Non-Interested Region (NIR) has data that is not considered vital for diagnosis purpose. In this paper, we have used DCT for non-ROI part and Wavelet coding for ROI area. Experimental evaluation is performed using CT images of colon and brain. Colon is the part of abdomen which is also called as large intestine. The ROI segmentation is evaluated in two stages. The first stage evaluated the performance of the ROI algorithm and the second stage analyzed the effect of ROI algorithm on compression. The quality metrics used during performance evaluation are compression efficiency in terms of bits per pixel, Peak Signal to Noise Ratio (PSNR) and visual comparison of the results.

Keywords: Image compression; Region of interest based coding; DCT; Wavelet coding; CT images.

1. Introduction

Research in diagnostic imaging and image processing is gaining prominence all over the world, particularly in developing countries. Engineers are developing technologies and tools, enabling the medical practitioners to provide efficient treatment [12]. Doctors prefer to focus on certain selected region(s) of interest from the elaborate medical information; also doctors are more comfortable with image-processing and analysis solutions that offer subjective analysis of medical images more than depending on the objective engineering results alone. Technology assisted, integrated diagnostic methods are of high relevance in this context.

Medical imaging is an evolving and growing area of research and development both in academia as well as in industry. It involves interdisciplinary research and development encompassing diverse domains. New techniques and directions are being proposed every day. The Computed Tomography machines of today’s modern era are creating huge number of high resolution, image of size 512 x 512 pixels, which requires about 1/4 MB of storage space, thus stressing the need for image compression algorithms [6].

Image compression is the process of eliminating redundant data in an image in a fashion that minimizes the storage space requirement while maintaining the quality of the image. The algorithms used for this purpose are categorized as lossy and lossless [1]. As healthcare professionals require accurate and clear picture, lossless techniques are not frequently used, owing to the great demand for high compression ratio while maintaining high image quality.

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2. Literature Survey

There have been numerous compression research studies examining the use of compression to medical images. Most have focused on lossless algorithms since the medical community has been reluctant to adopt lossy techniques. Popular traditional approaches used for encoding are Huffman encoding, Lempel-Ziv encoding, arithmetic encoding and run-length encoding [14]. Compression of medical images initially started with image preservation techniques like Scan pixel difference [13], followed by intra and inter-frame redundancy reduction [2]. Hu et al. [5] investigated linear predictive coding schemes. Several lossless compression techniques like Huffman coding, Lempel-Ziv coding, arithmetic coding have been proposed along with more recent coders like HINT (Hierarchical Interpolation), DP (Difference Pyramid), Bit-Plane encoding and block truncation coding. All these techniques have concentrated on producing low compression rates. Transformation based coding schemes like Principal Component Analysis, Discrete Cosine Transform, Discrete Wavelet Transform have also been proposed to get better compression rates [16]. Till 2000, JPEG and Wavelet were most popular among medical community. These two compression methods actually gained widespread acceptance as lossy methods. However, each can also be made lossless which is the preferred style in medical imaging. Several studies have been proposed to compress medical images using wavelets and comparison of these techniques has also been studied. Most of the studies have discussed the advantage of using wavelets for image compression. Most of the comparison studies have compared the performance of wavelets with JPEG coder [11].

3. Block Diagram of Proposed System:

Current compression schemes bring great compression rates if loss of quality is affordable. Medicine cannot afford deficiency in diagnostically important regions ('Region of Interest'). For most medical images, the diagnostically significant information is localized over relatively small regions of interest. In practice, the compression of medical images must be reliable because a minor loss may result in a serious consequence. Thus there is need of compression scheme which can solve the above problem and preserve quality of the image in diagnostically critical regions. Lossy encoding can be allowed for other regions. Owing to the great demand for high compression ratio while maintaining high image quality, Region of Interest (ROI) technique is suitable [7].

In this study, we put special emphasis on the medical images of human Colon and Brain. Colon is the part of human abdomen which may also be called as large intestine. The medical images are divided into two parts. The diagnostically important part is called as Region of interest (ROI) and the other part which is not critical is called as non ROI. In this coding scheme, two different compression schemes are used one for ROI and other for non-ROI. The general theme is to preserve quality in diagnostically critical regions, while allowing lossy encoding for the other regions [9]. The main reason for preserving regions other than ROI is to locate the position of the critical regions in the original image more easily, and to evaluate possible interactions with surrounding organs. Therefore, lossy compression scheme is suitable in non-ROI regions to give a global picture to the user while a lossless compression scheme is necessary for ROI regions[15]. The block diagram of proposed system is shown in figure1.

Fig.1 Block Diagram of proposed system

Original medical image obtained by CT scanner or MRI technique is having some part which is of diagnostic importance. The image is segmented into two parts: Region of interest (ROI) Part and Non region of interest (Non ROI).Seeded region growing technique is used to perform this segmentation. Lossy coding technique like DCT (Discrete Cosine Transform) is applied to non ROI part. The ROI Part which is of clinical interest is coded by DWT technique. Wavelet technique is used for proper reconstruction of ROI Part.

4. Seeded Region Growing Process

The goal of region growing process is to map the input image data into sets of connected pixels, called regions, according to a prescribed criterion which generally examines the properties of local groups of pixels. The growing starts from a pixel in the proximity of the seed point initially selected by the user. The pixel can be chosen based on either its distance from the seed point or the statistical properties of the neighborhood [3]. Then each of the 4 or 8 neighbours of that pixel are visited to determine if they belong to the same region. This growing expands further by visiting the neighbors of each of these 4 or 8 neighbor pixels. This recursive process continues until either some termination criterion is met or all pixels in the image are examined [4]. The result is a set of connected pixels determined to be located within the region of interest.

The goal of region growing segmentation algorithm is to group regions having common properties between a pixel and its neighbor[17]. The properties can be intensity values
of the original image or unique texture patterns of each region or spectral profiles that provide multidimensional image data. The algorithm provides multiple merits during segmentation. The borders of regions found by region growing are perfectly thin and well connected [10]. The method used for determining the ROI can be either manual or automatic, both with the same aim of achieving optimal compression balance between lossy and lossless regions.

Algorithm for Region growing process consists of the following steps.
1. Divide the image into 16×16 blocks. Calculate initial seed points as follows.
2. For each block, calculate threshold T as average of maximum and minimum intensity.
3. Repeat Steps (4) to (6) till T converges.
4. Group pixels of each block into two groups, G1 and G2, where G1 has pixels whose intensity value is greater than T and G2 has pixels whose intensity value is less than T.
5. Calculate Mean (μ1 and μ2) and Standard Deviation (σ1 and σ2) of G1 and G2 respectively. 6. Re-estimate T, such that T = 0.5 * [(μ1 and μ2) + (σ1 and σ2)] and go to step 4.
7. Calculate total variance (TV) and mean variance (MV)
8. Calculate Seed Threshold, TS = TV + MV
9. Determine pixels with Ts < T and select them as initial candidate seed points.
10. After selecting seed point, calculate intensity difference between seed point and its neighborhood pixels.
11. Check the neighboring pixels and add them to the region if they are similar to the seed point.
12. Repeat steps 10 and 11 until no more pixels can be added.

5. Experimental Results

Experimental evaluation is performed using Colon CT images and brainMIRI images. The ROI segmentation is evaluated in two stages. The first stage evaluated the performance of the ROI algorithms and the second stage analyzed the effect of ROI algorithms on compression. The quality metrics used during performance evaluation are compression efficiency in terms of bits per pixel, Peak Signal to Noise Ratio (PSNR) and visual comparison of the results. All the programs are conducted using a computer with Pentium-V processor with 2 GB RAM and the implementation tool is done MATLAB 2009a.

Fig.2 shows original image which is one of the slice of Colon image obtained by CT scanner.

Fig.3 represents process of ROI coding. In this process by using mouse click, doctor can select diagnostic important area. The mask gets applied over whole image and new image is formed by burning the mask which separates the image into two parts ROI and Non ROI.

Fig.4 shows Non ROI Image, in which ROI part is removed and Non ROI part is left as per original image. Non ROI part is to be coded by using DCT technique. The result of DCT Quantization performed on non ROI part is shown in fig.5.
Non ROI part which is compressed by using DCT technique is shown in fig.6. The ROI Part which is of clinical interest is extracted from original image, which is shown in fig.7.

The ROI part which is of clinical interest is coded using Wavelets (sub band coding technique) as shown in fig.8. Filtered image which represents low pass low coefficients, after first level decomposition is final compressed image obtained using wavelets. This image is shown in Fig.9.

The ROI coding technique is also applied to brain MRI image, the result of which is shown below in Fig.10.

Fig.10 (a) represents original image which is one of the slice of brain MRI scanning. (b) Shows Non ROI part. (d) represents ROI part (c) shows ROI part coded with Wavelets.
6. Statistical performance Parameters

Image compression technique introduces some amount of distortion in the reconstructed image; therefore, evaluation of the image quality is an important issue [8]. The quality of reconstructed images can be evaluated in terms of objective measure and subjective measure. In objective evaluation, statistical properties are considered whereas, in subjective evaluation, viewers see and investigate image directly to determine the image quality. The objective evaluation measure includes peak signal to noise ratio (PSNR), compression ratio (CR) etc.

6.1 Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) has been the most popular tool for the objective quality measurement of the compressed image and video. It is simple to compute. The PSNR in decibel is evaluated as follows

$$PSNR = 10 \log_{10} \frac{I^2}{MSE}$$  

where, $I$ is allowable image pixel intensity level. For 8 bit per pixel image, $I = 2^8 - 1 = 255$ and MSE is the mean square error.

6.2 Mean Square Error (MSE)

MSE is another important evaluation parameter for measuring the quality of compressed image generally used along with the PSNR analysis [20]. It compares the original data and reconstructed data and results the level of distortion. The MSE between the original data and the reconstructed data is:

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (A_{ij} - B_{ij})^2$$  

Where, $A =$ Original image of size $M \times N$  
$B =$ Reconstructed image of size $M \times N$

6.3. Compression Ratio (CR)

It is the ratio of number of bits required for original image to number of bits required for compressed image. It is expressed as:

$$CR = \frac{Number \ of \ bits \ required \ for \ original \ image}{Number \ of \ bits \ required \ for \ compressed \ image}$$  

Table-I gives comparison among three techniques which are used for compression of medical test images.

The graphical representation of various performance parameters for different test images is shown in fig.11. (a) Shows compression ratio achieved with three different techniques. b) Shows PSNR obtained with three different techniques. c) Shows MSE obtained with three different

Fig.10. ROI technique is applied to brain MRI image
Table-1 Comparison of compression techniques

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Parameters</th>
<th>DCT</th>
<th>DWT</th>
<th>ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compression ratio (CR)</td>
<td>1.4776</td>
<td>3.0335</td>
<td>4.1134</td>
</tr>
<tr>
<td>2</td>
<td>Mean Square Error(MSE)</td>
<td>4.19E03</td>
<td>2.64E03</td>
<td>0.263</td>
</tr>
<tr>
<td>3</td>
<td>Peak signal to noise ratio(PSNR)</td>
<td>11.9059</td>
<td>13.9010</td>
<td>54.3964</td>
</tr>
<tr>
<td>4</td>
<td>Bits per Pixel(BPP)</td>
<td>1.9449</td>
<td>2.6372</td>
<td>5.4142</td>
</tr>
</tbody>
</table>

d) Shows bits per pixel obtained with three different techniques.

From the Table-I and graphical representation it is seen that ROI based coding technique has compression ratio of acceptable level. It works best for different test images. Hence it can be concluded that alone DCT or DWT cannot achieve best performance, but the ROI technique which is combination of both DCT and DWT technique gives optimum performance which is required for medical image compression.

Table-II represents Sizes of ROI and Non ROI Parts in original and reconstructed images. It is seen that Compression of both parts i.e. Non ROI and ROI part takes place. For Non ROI Part we are using DCT coding technique. The reason for using DCT coding is that DCT is lossy coding technique. Non ROI part is not of that much importance. We can consider it as background; hence DCT coding is applied for it. ROI part which is of clinical interest is coded with Discrete Wavelet technique. Here we are using sub band coding up to the first level of decomposition using Wavelet Transform. The DWT coded image contains all the four types of coefficients. i.e., LL, LH, HL, HH. The dominant part is LL region, hence final ROI compressed image is one fourth of DWT compressed image.

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Name of sample Image</th>
<th>Original Image</th>
<th>Reconstructed Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Colon CT Image 505x427 pixels 117 K bytes</td>
<td>110 K bytes</td>
<td>7 K bytes</td>
</tr>
<tr>
<td>2</td>
<td>Brain MRI Image 564x 428 pixels 85 K bytes</td>
<td>76.2 K bytes</td>
<td>8.85 K bytes</td>
</tr>
</tbody>
</table>

(d) Bits per pixel

Fig.11 Graphical representation of various Performance parameters
It is almost certain that Seeded Region Growing method works efficient and has a better compression ratio compared to previous methods. Finally, for various kinds of test images, results exhibit that ROI based coding technique shows improvement over DCT and DWT techniques.

7. Conclusion

Seeded region growing is rapid, robust segmentation procedure requiring neither tuning parameters nor training sets. It is applicable to wide range of image types. Region growing methods can provide the images which have clear edges with good segmentation results. ROI technique, by itself, is not self contained process, as it also requires the input of few control points in the image known as seeds. These can be manually entered or can be output of other image processing algorithm. Further, we compare this method with previous JPEG standards such as lossless JPEG and JPEG2000. As it has been proved and illustrated by simulations, the new compression method cause good compression ratio and improves older methods. On the other hand, it is a low complex method in spite of its compression ability.

References


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