Medical Image Compression using Standard Deviation-Based Wavelet Coefficients Thresholding Method

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Abstract

In recent decades, digital images have become increasingly important. With many modern applications use image graphics extensively, it tends to burden both the storage and transmission process. Despite the technological advances in storage and transmission, the demands placed on storage and bandwidth capacities still exceeded its availability. Moreover, the compression process involves eliminating some data that degrades the image quality. Therefore, to overcome this problem, an improved thresholding and quantization techniques for image compression is proposed. Firstly, the generated wavelet coefficients obtained from the Discrete Wavelet Transform (DWT) process are thresholded by the proposed Standard Deviation-Based Wavelet Coefficients Threshold Estimation Algorithm. The proposed algorithm estimates the best threshold value at each detail subbands. This algorithm exploits the huge number of near-zero coefficients exist in detail subbands. For different images, the distribution of wavelet coefficients at each subband are substantially different. So, by calculating the standard deviation value of each subband, a better threshold value can be obtained. The results are then compared to the existing algorithms and it is found that the proposed compression algorithm shows double increase in compression ratio performance, produces higher image quality with PSNR value above 40dB.

Keywords: Image compression, thresholding, wavelets

1. Introduction

Recently, there is a growing interest among researchers focusing on compression of various types of images and data. Advances over the past decade in many aspects of digital technology especially devices for image acquisition, data storage, bitmapped printing and display have brought out many applications for digital imaging. With increasing demand on digital images, the uncompressed images requires considerable transmission bandwidth and storage capacity. For example, reputable social media such as Flickr and Facebook allows their users to manage their daily digital photographs online in a very convenient way which led to enormous amounts of digital images uploaded. Now, it already reach 3000 photo upload per minute for Flickr and 58000 photo upload per minute for Facebook [1]. Hence, compression is one of the promising technique that can reduce the storage and network traffic requirements, therefore improving system efficiency [2].

2. Literature Review

In the contemporary multimedia world, digital imaging plays an important role in social network, education, business, remote sensing, military as well as in the clinical environment. This is mainly motivated by the special features of digital imaging such that it can be easily archived, stored and shared with another. Besides that, it can be used in more than one location at the same time. In addition, digital data also do not suffer from aging [3].

With advances in digital imaging application it offer broader range of images types and sizes. The recent image type named High Dynamic Range (HDR) image is an image with extended bit. It able to capture the full visible color of real world with details in highlights and shadows. Although it consume a large storage capacity, HDR gaining its popularity in photography and 3D games [4], [5].

Image compression is a process of reducing the amount of data in an image by removing the redundant data without affecting the quality of the image by keeping the resolution and visual quality of the reconstructed image as close to the original image as possible. There are a huge number of approaches proposed in literature, mainly focusing on developing an algorithm able to compact as much as possible the original image in few coefficients. From the reading, it is identified that wavelet is the most prominent tool used in compression as proved by the amount of algorithms suggested [6]–[9].

Discrete Wavelet Transform (DWT) is an algorithm that sampling the small wave discretely. It can effectively separate the frequency of input into high frequency and low frequency subbands leading to a better resolution capability [10]. Besides, DWT has analysis filter where here, some points will be eliminated. This operation is called downsampling. The process is done to maximize the amount of necessary detail and ignore ‘not-
so-wanted’ details. Here, some coefficient values for pixels in an image are thrown out or set to zero. This is called the thresholding process and it give a smoothing effect to the image [11]. Paul in his work proposing a method that approximating the threshold value using Shannon Entropy [12]. Shannon Entropy is used to measure the randomness of image probabilistic partition, then by using this value, a set of threshold value is generated. This method provide less error or information loss because of multiple threshold value are used, but, it suffer with high computational time.

In a study conducted by Devi and Mini, they use the prediction concept in attaining the threshold value. The threshold value is predicted based on previous neighbouring sample [13]. They calculate the weighted sum of previous sample and predict the threshold value for the next sample using Auto Regression (AR) model. Because of the aim of this algorithm is to reduce the redundant info, it just suitable with image with high correlation such as medical images.

Later, Kim in his research extend this work by implementing it on RGBW (Red, Green, Blue, White) image [14]. In addition to the above method, Savic proposed a pixel value prediction threshold in the pre-processing stage [15]. In this research, the correlation between adjacent pixels is defined using histogram analysis. The information obtained in histogram of variances is then being used to decide the threshold value. This algorithm is suitable to be implemented in low bit rate system. However, prediction of this algorithm will be less accurate for less correlated image.

3. Methodology

In this research, grey scale (8 bit) images are used for analysis purposes. Although the current digital images uses colour (24 bit or more) images, but for research and analysis purposes, grey scale image is frequently being used in developing algorithm to simplifies the algorithm and reduces computational requirements [9], [16].

This research uses medical images with different Region of Interest (ROI) and Region of Background (ROB) obtained from DICOM (Digital Imaging and Communication in Medicine) Library [17]. This database provides real medical images for education and research purpose [18]–[21].

Figure 1 shows the framework of the proposed method. At the first phase, the original image was transformed into wavelet coefficients using Discrete Wavelet Transform (DWT). Discrete Wavelet Transform is used as transformation tool. It will divide the image into four different subbands. The approximate coefficients are placed in approximate subband (low resolution approximate image) while the detail coefficients are placed in horizontal subband (intensity variation along column, horizontal edge), vertical subband (intensity variation along row, vertical edge) and diagonal subband (intensity variation along diagonal). Then, the wavelet coefficients will do through thresholding process where here the dispersion trend of the wavelet coefficients is measured and then the threshold value at detail subbands is estimated. The purpose of this process is to obtain a higher compression ratio without harming the image quality.
The wavelet coefficients for approximate subband are represented by:

\[
\omega_0(j_0, k_1, k_2) = \frac{1}{\sqrt{N_1 N_2}} \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N_2-1} s(n_1, n_2) \varnothing_{j_0, k_1, k_2}(n_1, n_2)
\]

Where:
- \( j_0 \) is the wavelet scale;
- \( N_1 \) and \( N_2 \) are the length and width of an image;
- \( s(n_1, n_2) \) is the image function;
- \( k_1 \) and \( k_2 \) are the index written from \( n_1 \) and \( n_2 \) respectively;
- \( \varnothing \) is the scaling function filter.

While the detail subbands are expressed as:

\[
\omega_i(j_i, k_1, k_2) = \frac{1}{\sqrt{N_1 N_2}} \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N_2-1} s(n_1, n_2) \varphi_{j_i, k_1, k_2}(n_1, n_2)
\]

Where:
- \( i \) is the details subband either Diagonal (D), Vertical (V) or Horizontal (H);
- \( \varphi \) is the wavelet filter.

In the wavelet transform, the noise energy is distribute in all wavelet coefficients, while the original signal energy is found in some of the coefficients. Therefore, the signal energy is found much larger than noise energy. So, small coefficients can be considered as caused by noise while large coefficients are triggered by significant signal features.

Based on this idea, thresholding process where the removing of the small absolute coefficients value while retaining the large absolute coefficient value can be done. It will produce finer reconstruct signal. Since this method is taking the condition that the amplitude of wavelet transform coefficients signals are much larger than noises, so the unconsidered noise will be removed while holding the significant.

Here, the thresholding value is calculated using the Standard Deviation concept. The standard deviation can be defined as:

\[
\sigma = \left( \frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2 \right)^{1/2}
\]

Where,
\[
\bar{x} = \frac{1}{n} \sum_{i=n}^{n} x_i
\]

By applying equation (2) into equation (3) and (4), the new detail subband threshold value can be calculated. After the new estimated threshold value is obtained, the thresholding process will take place. At this point, each coefficient value that is lower than \( \lambda_n \) will be discarded while the rest are remain.

### 4. Result and Analysis

This experiment was carried out on Matlab platform by using medical images obtained at DICOM Library (see Figure 2).

![Medical Images Obtained from DICOM Library](image)

Figure 2: Medical Images Obtained from DICOM (Digital Imaging and Communication in Medicine) Library [17]

To test the performance of the proposed method, it was compared with the prominent wavelet-based compression algorithm: Embedded Zerotree Wavelet (EZW), Set Partitioning in Hierarchical Trees (SPHIT), Wavelet Different Reduction (WDR) and Adaptive Scanned Wavelet Different Reduction (ASWDR). The performance analysis is done on Peak Signal to Noise Ratio (PSNR) and Compression Ratio (CR).

<table>
<thead>
<tr>
<th>Image</th>
<th>EZW</th>
<th>SPHIT</th>
<th>WDR</th>
<th>ASWDR</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT_Brain</td>
<td>36.52</td>
<td>36.52</td>
<td>36.52</td>
<td>36.52</td>
<td>48.11</td>
</tr>
<tr>
<td>CT_Chest</td>
<td>43.20</td>
<td>39.47</td>
<td>43.20</td>
<td>43.20</td>
<td>54.82</td>
</tr>
<tr>
<td>Xray_Kidney</td>
<td>39.24</td>
<td>34.47</td>
<td>39.24</td>
<td>39.24</td>
<td>47.03</td>
</tr>
<tr>
<td>Xray_Teeth</td>
<td>38.89</td>
<td>37.90</td>
<td>38.89</td>
<td>38.89</td>
<td>44.03</td>
</tr>
<tr>
<td>MR_Knee</td>
<td>35.77</td>
<td>35.08</td>
<td>35.77</td>
<td>35.77</td>
<td>46.04</td>
</tr>
<tr>
<td>MR_Brain</td>
<td>38.58</td>
<td>37.11</td>
<td>38.58</td>
<td>38.58</td>
<td>46.60</td>
</tr>
</tbody>
</table>

Higher PSNR value indicate the improvement of image quality. Besides, images with a PSNR value of more than 40dB is considered as very good [22] because the normal human eye observation...
cannot virtually differentiate between the original and reconstructed image [23]. This PSNR value also indicates no blurring or image quality degradations appear on reconstructed image.

Table 4.2: Compression Ratio Comparison between Wavelet-Based Compression Algorithms with Proposed Method

<table>
<thead>
<tr>
<th>Image</th>
<th>EZW</th>
<th>SPIHT</th>
<th>WDR</th>
<th>ASWDR</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT_Brain</td>
<td>8.63</td>
<td>5.54</td>
<td><strong>7.14</strong></td>
<td>9.10</td>
<td>6.47</td>
</tr>
<tr>
<td>CT_Chest</td>
<td>5.43</td>
<td>2.03</td>
<td>5.90</td>
<td>5.70</td>
<td><strong>7.02</strong></td>
</tr>
<tr>
<td>Xray_Kidney</td>
<td>4.17</td>
<td>1.51</td>
<td>4.34</td>
<td>4.23</td>
<td><strong>10.03</strong></td>
</tr>
<tr>
<td>Xray_Teeth</td>
<td>1.15</td>
<td>0.74</td>
<td>1.11</td>
<td>1.08</td>
<td><strong>8.05</strong></td>
</tr>
<tr>
<td>MR_Knee</td>
<td>7.23</td>
<td>4.80</td>
<td>7.66</td>
<td>7.53</td>
<td><strong>9.04</strong></td>
</tr>
<tr>
<td>MR_Brain</td>
<td>7.14</td>
<td>4.36</td>
<td>7.24</td>
<td>7.04</td>
<td><strong>9.60</strong></td>
</tr>
</tbody>
</table>

As for EZW, SPIHT, WDR and ASWDR algorithms, the threshold value was initially set based on significance of wavelet coefficients [24]. Thus it does not exploiting the different characteristic at each subband. It also do not allow lossless reconstruction even on the retaining coefficients. Besides, the EZW, SPIHT, WDR and ASWDR algorithms use uniform quantization that partially fails to recognize the near zero coefficients that largely found in each subband.

On the other hand, the proposed Standard Deviation-Based Wavelet Coefficients Thresholding method exploiting the different characteristic of subband by estimating the near zero coefficient for a satisfactory threshold value. By using this property, an efficient threshold estimation was obtained thus resulting in a better PSNR and compression ratio value as stated in this section.

5. Conclusion

In this work, the Medical Image Compression using Standard Deviation-Based Wavelet Coefficients Thresholding Method is proposed. The proposed method can estimate the suitable threshold value by measuring the dispersion trend or characteristic of wavelet coefficients in each detail subband using standard deviation concept. Throughout the experiments done, it was found that the proposed Standard Deviation-Based Thresholding Algorithm benefited in reducing the image size as can be seen in higher compression ratio without harming the image quality as can be seen in higher PSNR value. As for the future work, the proposed method will be implemented in colour image by executing the proposed method in parallel.

References


