Medical Image Compression by using Threshold Predicting Wavelet-Based Algorithm

Nik Shahidah Afifi Bt Md Taujuddin[1], Rosziati Ibrahim[1]

[1] Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia.

{shahidah, rosziati}@uthm.edu.my

Abstract. In recent decades with the rapid development in biomedical engineering, digital medical images have been becoming increasingly important in hospitals and clinical environment. Apparently, traversing medical images between hospitals need a complicated process. Many techniques have been developed to resolve these problems. Compressing an image will reduces the amount of redundant data with the good quality of the reproduced image sufficiently high, depending on the application. In the case of medical images, it is important to reproduce the image close to the original image so that even the smallest details readable. The aim of this paper is to reveal our new proposed compression algorithm. It started by segmenting the image area into Region of Interest (ROI) and Region of Background (ROB) and use the special features provide by wavelet algorithm to produce efficient coefficients. These coefficients is then will be thresholded by using our new proposed thresholding predicting algorithm. This method will provide a low computational cost algorithm besides decreasing the image size without tolerating with the precision of image quality.

1 Introduction

Advances over the past decade in many aspects of digital technology especially devices for image acquisition, data storage, and bitmapped printing and display have brought about many applications of digital imaging. However, problems involving storage space and network bandwidth requirements arise when large volumes of images are to be stored or transmitted, as is the case with medical images. From the diagnostic imaging point of view, the challenge is how to deliver clinically critical information in the shortest time possible. A solution to this problem is through image compression. The main objective of this compression is to reduce redundancy of the data image in order to be able to stored or transmit data in an efficient form[1][3][4][5][6].

Uncompressed multimedia (graphics, audio and video) data requires considerable storage capacity and transmission bandwidth. Despite rapid progress in mass-storage density, processor speeds, and digital communication system performance, demand for data storage capacity and data transmission bandwidth continues to outstrip the capabilities of available technologies. The recent growth of data intensive multimedia-based web applications have not only sustained the need for more efficient ways to encode signals and images but have made compression of such signals central to storage and communication technology.

2 Related Work on Image Compression

Even though nearly all image processing applications can accept some information loss, but in numerous critical areas such as medical, satellite, and legal imaging, lossless compression algorithms are preferred. Context Based, Adaptive, Lossless Image Codec (CALIC), JPEG-LS, and JPEG2000 are among outstanding lossless image compression algorithms that give high compression ratio in a practical time [6][7]. Compression ratio for typical image is best offered by CALIC, while JPEG-LS provide low complexitity alternative. As, JPEG provides a unified approach to lossy-to-lossless compression

Meanwhile, lossy method offer high compression ratio but with some tolerate corrupted data. It is always producing a sufficient enough data size for transmission and storage purpose. Some of the prominant lossy image-coding techniques are DCT, DFT, fractal-based coding, wavelet-based coding and vector quantization method.

CALIC[8] is a compression technique based on the setting of the pixels of some predetermined pattern of neighbor pixels. The method is capable of learning from the errors made in the previous predictions and in this way it can improve its prediction adaptively when the compression proceeds. Pixel values are calculated by a nonlinear predictor, which choose the prediction pixels and the particular prediction function amongst numerous potential prediction functions on the basis of the local context. The context is built up of the local gradient magnitudes in horizontal and vertical directions. The coefficients are chosen based on the training set drawn from the type of images to be compressed. The final set of prediction errors is coded by entropy coder. CALIC is proved provides best compression ratios in a reasonable time over typical images.

JPEG-LS[9] is the lossless/near lossless compression standard for continuous-tone image. It is based on context modeling and predictive coding combined with Huffman coding. The values of pixel are predicted adaptively based on an edge detector's output. The predicted value is chosen based on three neighboring pixel.

The Joint Photographic Expert Group (JPEG) standard is already used for almost 2 decades. This standard is used for the digital compression and coding of continuous tone. JPEG 2000 in other hand, provide international standard for image compression that give extra features where it can be operated in network and mobile environment.

In JPEG 2000, the image is transform into components and decomposed into tile. Each tile is then applied with wavelet transform to perform different resolution level. Subband of coefficient (decomposition level) illustrate the frequency characteristic of tile. Subband coeffiecient is then quantize and entropy coded so that the ROI can be coded at higher quality than ROB [10].

3 Related Work on Wavelet-Based Image Compression

Wavelet-based image compression techniques have raise interest amongst the medical community. Beside compression, wavelet also widely been used in noise reduction, detection of microcalcifications, image analysis and image enhancement. Wavelets has offer great compression ratio without harming the image quality and it became a solemn challenger to DCT [11].

Wavelet is well known because of its energy compactness in the frequency domain. Besides, the multiresolution analysis (MRA) offered by wavelet is providing much higher compression ratio at the same time preserving good image quality. In addition, wavelet-based compression scheme give the most excellent rate-distortion performance.

There are many Wavelets generic being introduced nowadays. Sophisticated wavelets produce smoother and more satisfactory compressed image. It makes no assumption concerning periodicity of the data. As a result, Wavelets are suitable for demonstrating sharp changes or even discontinuities. Some of the common Wavelet methods used in image processing are Haar, Embedded Zerotree Wavelet (EZW) and Set Partitioning in Hierarchical Trees (SPIHT). While the extended versions that already being well accepted in committee are Wavelet Difference Reduction (WDR) and Adaptively Scanned Wavelet Difference Reduction (ASWDR). Wavelets has offer great compression ratio without harming the image quality and it became a solemn challenger to DCT[11].

The Table 1 shows the summary of Haar, EZW, SPIHT, WDR and ASWDR.

Table 1: Summary of various wavelet-based compression algorithm

Algorithm	Technique	Advantage	Limitation
HAAR [12]	'Square-shaped' function	Good analysis on signal with sudden transition or discontinuity. Averaging the pixel together to get new lower resolution image.	Unpleased compression rate
EZW [13]	Zero-tree concept for significant-map information	More finer reconstructed magnitude value	
SPIHT [14]	Parent-offspring dependencies is spatial orientation tree	Compactness	High-memory requirement, frequently repeat seeking process and also complex management of list
WDR [15]	3 basic steps: Discrete Wavelet Transform, Differential Coding and Binary coding	Encoding can be stopped at any point, allowing a target rate to be met accurately	Limited scanning order
ASWDR [16]	Enhanced version of WDR algorithm with the new scanning orders	Improve the subjective perceptual qualities of compressed images and improve the results of objective distortion measures	Unsatisfied on preserving edge details

4 Experimental Results on Wavelet-Based Compression Methods

To analyze the performance of SPIHT, EZW, WDR and ASWDR, three sample standard images used; Lena.bmp, Cameraman.tif and Barbara.bmp. The image dimension of Lena.bmp is 256 x 256, while Cameraman.tif and Barbara.bmp is 512 x 512. These standard images are used with the assumption that the image compression performance of the selected wavelet-based algorithm (SPIHT, EZW, WDR and ASWDR) will be imitate if the medical images are used.

The quantitative and perceptual quality measures of the compression performance are done on the sample image. Qualitative measure is done via compression performance, that is evaluated using compression ratio (CR) and Bit-Per-Pixel (BPP). The compression ratio means the ratio of the original image size over the compressed image size, while the BPP is the number of bits required to store one pixel of the image [14].

For perceptual quality, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are used [15]. MSE represent the mean squared error between compresses and the original image, while PSNR stand for a measure of the peak error and is expressed in decibels [16].

Table 2: Quantitative and Perceptual Quality Measures of Compression performance on Lena.bmp

Methods	Compression ratio	PSNR	MSE	BPP
SPIHT	2.3239	32.1101	40.0013	0.1859
STW	3.3707	32.9988	32.5986	0.2697
EZW	3.4946	32.8449	33.7743	0.2796
WDR	3.7579	32.8449	33.7743	0.3006
ASWDR	3.6617	32.8449	33.7743	0.2929

Table 2 shows the objective compressions performance of Lena image respectively. It is difficult to observe the differences between these images. This illustrates that all compression methods produce equally good compressions at moderately high bit rates. WDR shows the greatest performance in compression ratio, PSNR, MSE and BPP compared to another 4 algorithm. In almost every case the PSNR and MSE value for EZW, WDR and ASDWR is the same. These numerical results are consistent with the increased preservation of details within EZW, WDR and ASDWR.

Table 3: Quantitative and Perceptual Quality Measures of Compression performance on Cameraman.tif

Methods	Compression ratio	PSNR	MSE	BPP
SPIHT	2.5791	32.5701	35.9809	0.2063
STW	3.6903	33.6661	27.9557	0.2952
EZW	7.4116	37.5756	11.3637	0.5929
WDR	7.8918	37.5756	11.3637	0.6313
ASWDR	7.7354	37.5756	11.3637	0.6188

WDR and ASWDR compressed images appear sharper than SPHIT and EZW compressed images. The ASWDR and WDR compressions have higher edge correlation than SPIHT compression. The WDR compression ratio is slightly higher than ASWDR edge correlation as can be seen on Table 3.

Table 4: Quantitative and Perceptual Quality Measures of Compression performance on Barbara.bmp

Methods	Compression ratio	PSNR	MSE	BPP
SPIHT	5.4680	28.8597	84.5496	0.4374
STW	7.9754	29.8815	66.8242	0.6380
EZW	15.5819	33.9452	26.2158	1.2466
WDR	18.5459	33.9452	26.2158	1.4837
ASWDR	18.0099	33.9452	26.2158	1.4408

By referring to Table 4, it can be noticed that the compression ratio and BPP of WDR for Barbara image is clearly superior to both ASWDR and SPHIT. While PSNR and MSE value for EZW, WDR and ASWDR retain the same.

5 Methodology

Although there are numerous number of research are done on medical image compression in the wavelet domain, there still have rooms for improvement. Especially in predicting the accurate threshold value for wavelet coefficient because by using the typical hard threshold in quantizing the coefficients it will lead to blocky artifact on medical image [17]. Medical community also raise a high intention to produce a low computational cost algorithm with high speed compression and decompression to assist the existence network bandwidth capability while reducing the image size to upkeep the limited storage size.

So, to archive this aim, we propose a new algorithm that can encode these coefficients effectively. Below are the proposed algorithm steps:

1. The original image is segmented to Region of Interest (ROI) and Region of Background (ROB).
2. DWT is used to produce sequence of wavelet coefficient and separate it to low frequency and high frequency subband.
3. Analyze the correlation between adjacent wavelet coefficients to get the best suit coefficient relationship.
4. Resulting wavelet coefficient are thresholded by using proposed efficient prediction scheme to get the best truncated threshold. Then the prediction equation is applied for thresholding process to get the significant predicted wavelet coefficient.

In the previous works, the wavelet coefficient is predicted based on fix location and variables. But, medical images have its own statistical distribution and have different properties on different subbands. So, to get more precise prediction, the amount of predictor variable must be adjust based on the image's properties.

6 Conclusion

Based on the preliminary analysis on existence wavelet-based algorithm, there is a need to develop an effective algorithm that can provide the improvement preservation details at low bit rates. Protecting details at low bit rates is crucial for sensitive data such as remote medical diagnosis via rapid transmission of compressed image and rapid retrieval of image in databases.

Therefore, modification on prediction procedure as proposed in our algorithm should be performed to eliminate the blocking and edge effect while increasing the effectiveness and reliability of the compressed image.

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References

[1] M. G. Strintzis, "A review of compression methods for medical images in PACS.," *Int. J. Med. Inform.*, vol. 52, no. 1–3, pp. 159–65, 1998.

[2] S. Wong, L. Zaremba, D. Gooden, and H. K. Huang, "Radiologic image compression-a review," *Proc. IEEE*, vol. 83, no. 2, pp. 194–219, 1995.

[3] S. Burak, G. Carlo, T. Bernd, and G. Chris, "Medical Image Compression Based on Region of Interest, With Application to Colon CT Images," in *23rd Annual EMBS International Conference*, 2001, pp. 2453–2456.

[4] E. Kofidis, N. Kolokotronis, A. Vassilarakou, S. Theodoridis, and D. Cavouras, "Wavelet-based medical image compression," *Futur. Gener. Comput. Syst.*, vol. 15, no. 2, pp. 223–243, 1999.

[5] R. Janaki, "Enhanced ROI (Region of Interest Algorithms) for Medical Image Compression," *Int. J. Comput. Appl.*, vol. 38, no. 2, pp. 38–44, 2012.

[6] M. U. Celik, G. Sharma, and A. M. Tekalp, "Gray-level-embedded lossless image compression," *Signal Process. Image Commun.*, vol. 18, no. 6, pp. 443–454, Jul. 2003.

[7] J. Kivijärvi, T. Ojala, T. Kaukoranta, a Kuba, L. Nyúl, and O. Nevalainen, "A comparison of lossless compression methods for medical images.," *Comput. Med. Imaging Graph.*, vol. 22, no. 4, pp. 323–39, 1998.

[8] X. Wu, S. Member, and N. Memon, "Context-Based , Adaptive , Lossless Image Coding," *IEEE Trans. Commun.*, vol. 45, no. 4, pp. 437–444, 1997.

[9] M. J. Weinberger, G. Seroussi, and G. Sapiro, "The LOCO-I lossless image compression algorithm: principles and standardization into JPEG-LS.," *IEEE Trans. Image Process.*, vol. 9, no. 8, pp. 1309–24, Jan. 2000.

[10] A. Skodras, C. Christopoulos, and T. Ebrahimi, "The JPEG 2000 Still Image," *IEEE Signal Process. Mag.*, no. September, pp. 36–58, 2001.

[11] A. Bruckmann and A. Uhl, "Selective medical image compression techniques for telemedical and archiving applications.," *Comput. Biol. Med.*, vol. 30, no. 3, pp. 153–69, May 2000.

[12] D. I. Belc, "A Hybrid Wavelet Filter for Medical Image Compression," Florida State University, Florida, 2006.

[13] J. M. Shapiro, "A fast technique for identifying zerotrees in the EZW algorithm," *1996 IEEE Int. Conf. Acoust. Speech, Signal Process. Conf. Proc.*, vol. 3, pp. 1455–1458.

[14] A. Said, W. A. Pearlman, and S. Member, "A New , Fast , and Efficient Image Codec Based on Set Partitioning in Hierarchical Trees," vol. 6, no. 3, 1996.

[15] J. Tian and R. Wells, "A Lossy Image Codec Based on Index Coding," *IEEE Signal Process. Mag.*, p. 456, 1996.

[16] J. S. Walker, "Lossy image codec based on adaptively scanned wavelet difference reduction," *Opt. Eng.*, vol. 39, no. 7, p. 1891, Jul. 2000.

[17] V. N. Prudhvi and T. Venkateswarlu, "Denoising of medical images using dual tree complex wavelet transform," *Procedia Technol.*, vol. 4, pp. 238–244, 2012.