

IMPROVED THRESHOLDING AND QUANTIZATION TECHNIQUES FOR  
IMAGE COMPRESSION

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For my beloved husband, Ahmad Raqib Ab Ghani  
and kids, Siti Sofiyah and Uthman.

My lovely father Md Taujuddin Mohamad  
and my late mother Tuan Afifah Adib Tuan Dir.

Thank you for your constant prayer, enduring love and encouragement to fulfill my  
dreams.



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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. Next, the retained wavelet coefficients are subjected to the next proposed Minimizing Median Quantization Error Algorithm. The proposed algorithm utilizes the high occurrence of zero coefficient obtained by the previous thresholding process by re-allocating the zero and non-zero coefficients in different groups for quantization. Then, quantization error minimization mechanism is employed by calculating the median quantization error at each quantization interval class. 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 and ensures a better bit saving with smooth control at bit rate higher than 4 bpp. Thus, the proposed algorithm provides an alternative technique to compress the digital image.

## ABSTRAK

Sejak beberapa dekad yang lalu, imej digital telah menunjukkan perkembangan yang sangat memberangsangkan. Kemunculan pelbagai aplikasi imej digital telah membebaskan kapasiti storan dan keupayaan proses penghantaran. Walaupun teknologi terkini telah meningkatkan keupayaan storan dan penghantaran, namun, permintaan terhadapnya sentiasa melebihi keupayaan sebenar sistem. Disamping itu, proses memampatkan saiz imej telah mengurangkan kualiti imej. Jadi, untuk menyelesaikan masalah ini, penambahbaikan kepada teknik ambangan dan kuantuman adalah dicadangkan. Pertamanya, nilai ambangan pekali wavelet yang dihasilkan dari proses *Discrete Wavelet Transform* (DWT) dikira menggunakan algoritma '*Standard Deviation-Based Wavelet Coefficients Threshold Estimation*' yang dicadangkan. Algoritma ini akan menentukan nilai ambangan yang sesuai bagi setiap sub elemen. Ia mengeksploitasi kewujudan pekali bernilai hampir sifar dalam setiap sub elemen. Untuk imej yang berbeza, agihan pekali juga adalah berbeza. Jadi, dengan mengira standard deviasi setiap sub elemen, nilai pekali ambangan yang lebih baik akan diperolehi. Seterusnya, pekali wavelet yang berbaki akan dikuantumkan menggunakan algoritma '*Minimizing Median Quantization Error*' yang dicadangkan. Algoritma ini memaksimumkan penggunaan pekali sifar yang wujud dengan banyak hasil daripada proses ambangan. Semua pekali sifar akan dikumpulkan dalam kumpulan yang berasingan dengan pekali bukan sifar. Kemudian, teknik meminimumkan ralat median pengkuantuman diaplikasikan dengan meminimumkan beza ralat median pada setiap selang kelas pengkuantuman. Keputusan yang diperolehi kemudiannya akan dibandingkan dengan algoritma sedia ada. Didapati algorithm pemampatan yang dicadangkan menghasilkan pertambahan prestasi kadar pemampatan sebanyak dua kali ganda, menghasilkan imej berkualiti tinggi dengan PSNR melebihi 40dB dan penjimatan bit yang lebih baik dengan kawalan lancar pada kadar bit melebihi 4bpp. Justeru, algoritma yang dicadangkan menyediakan teknik alternatif dalam memampatkan imej digital.

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## LIST OF SYMBOLS AND ABBREVIATIONS

CR	-	Compression Ratio
BPP	-	Bit-Per-Pixel
MSE	-	Mean Square Error
PSNR	-	Peak-Signal-to-Noise Ratio
PSQNR	-	Peak-Signal-to-Quantization-Noise Ratio
CB-2SDQ	-	Cell-Based Two-Step Scalar Deadzone Quantization
RLE	-	Run Length Encoding
LZW	-	Lempel-Ziv-Welch
CALIC	-	Context Based, Adaptive, Lossless Image Codec
JPEG	-	Joint Photographic Expert Group
JPEG-LS	-	Joint Photographic Expert Group lossless/near lossless
JPEG2000	-	Joint Photographic Expert Group 2000
DCT	-	Discrete Cosine Transform
DFT	-	Discrete Fourier Transform
DWT	-	Discrete Wavelet Transform
ROI	-	Region of Interest
ROB	-	Region of Background
SM	-	Significance Map
KLT	-	Karhunen-Loeve Transform
DNA	-	Deoxyribonucleic Acid
LL	-	low resolution approximate image
HL	-	intensity variation along column, horizontal edge
LH	-	intensity variation along row, vertical edge
HH	-	intensity variation along diagonal
PAE	-	Peak Absolute Error
HVS	-	Human Visual System

LMQ	-	Lloyd Max Quantizer
EZW	-	Embedded Zerotree Wavelet
SAQ	-	Successive Approximate Quantization
SPIHT	-	Set Partitioning in Hierarchical Trees
SQP	-	SQuare Partitioning
WDR	-	Wavelet Difference Reduction
ASWDR	-	Adaptive Scanned Wavelet Different Reduction
USC-SIPI	-	University of Southern California, Signal and Image Processing Institute
Sym5	-	Symlet 5
MSSIM	-	Mean Structural SIMilarity
HDR	-	High Dynamic Range
RGB	-	Red Green Blue
3D	-	3 Dimentional
RD	-	Rate Distortion



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### Journals:

- (i) Taujuddin, N. S. A. M. and Ibrahim, R. (2013). A Comparative Analysis on the Wavelet-Based Image Compression Techniques. *Journal Of Computer Science And Engineering*, Volume 21, Issue 1, ISSN 2043-9091.
- (ii) Taujuddin, N. S. A. M., Ibrahim, R. and Sari, S. (2015). Threshold Estimation by Adapting Standard Deviation at Wavelet Details Subbands for Image Compression. *ARPJ Journal of Engineering and Applied Science*. Vol.10, No.19, ISSN 1819-6608. 2015 (Indexed by SCOPUS).
- (iii) Taujuddin, N. S. A. M., Ibrahim, R. and Sari, S. (2015). Wavelet Coefficient Reduction Method Based on Standard Deviation Concept for High Quality Compressed Image. *Journal Of Theoretical And Applied Information Technology*. Volume 79, September 2015, E-ISSN 1817-3195 / ISSN 1992-8645, pg 380-388 (Indexed by SCOPUS).

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- (i) Taujuddin, N. S. A. M. and Ibrahim, R. (2014). Medical Image Compression by Using Threshold Predicting Wavelet-Based Algorithm. Lect. Notes Electrical Eng, Advance Computer and Communication Technology, Vol 315, ISBN978-3-319-07673-7 (Print ISBN) 978-3-319-07674-4 (Online ISBN), Springer International Publishing, pg 755-765 (Indexed by SCOPUS).
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- (iii) Taujuddin, N. S. A. M., Ibrahim, R. and Sari, S. (2015). Progressive Pixel-to-Pixel Evaluation to Obtain the Hard and Smooth Region for Image Compression. IEEE Computer Society (6th International Conference on Intelligent Systems, Modelling and Simulation), pg 102-106, ISBN: 2166-0670/15 (Indexed by SCOPUS).
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- (vii) Taujuddin, N. S. A. M., Ibrahim, R. and Sari, S. (2016). Minimizing Median Difference Quantization Error for Image Compression. IEEE Communications Society (International Conference on ICT Convergence 2016), ISBN 978-1-5090-1325-8/16, pg 1160-1164.
- (viii) Taujuddin, N. S. A. M., Ibrahim, R. and Sari, S. (2016). Reconstruction of 'Phi' in Thresholding Process for a Better Compressed Image Quality. 3<sup>rd</sup> International Conference on Information Science and Security, ISBN 978-1-5090-5493-0, pg 106-110.



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## LIST OF AWARDS

(i) **Best Paper Award; Information Technology Track (1<sup>st</sup> prize)**

**[MUCET 2014]:**

Taujuddin, N. S. A. M., Ibrahim, R. and Sari, S. “A Comparative Analysis of PSNR value for Images using Wavelet Based Thresholding Methods”.



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## CHAPTER 1

### INTRODUCTION

#### 1.1 Research Background

In recent decades, with rapid development in the multimedia world, digital images have become important. With many modern applications employing image graphics extensively, it tends to burden the storage as well as transmission process. For example, an image with height and width of 512 pixel and each pixel carries 24 bit data will comprise up to 6291456 bits ( $512 \times 512 \times 24$ ). Therefore, there is a need to reduce the image size and compression is one of the promising technique (Ahmadi *et al.*, 2015).

Compression is a process of reducing the amount of redundant data while maintaining the good quality of the reproduced image (Rekha & Samundiswary, 2016; Enesi & Zanaj, 2011). Compression is essential particularly to reduce storage space, transmission time, bandwidth utilization and to enable rapid browsing and retrieval of images from the database (Hashemi-berenjabad *et al.*, 2011).

Recently, there is a growing interest among researchers focusing on compression of various types of images and data. There are many examples of existing research on standard grey scale images (Bekhtin, 2011; Horng, 2012; Savic *et al.*, 2015; Hussain *et al.*, 2015), medical images (Ayu *et al.*, 2016; Tiwari *et al.*, 2015; Thepade 2013) and ECG signals (Abo-Zahhad *et al.*, 2013; Kumar *et al.*, 2013). Amongst various compression algorithms, transform-based compression is one of the more promising algorithms (Jiang *et al.*, 2012).

## 1.2 Research Motivation

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. E-commerce, health care, social media, education, business and remote sensing are some examples of applications that deal with massive amounts of digital images (Thepade, 2013; Rufai *et al.*, 2014). With increasing demand on digital images, the uncompressed images requires considerable transmission bandwidth and storage capacity. Despite the technological advances in transmission and storage, the demands placed on the bandwidth of communication and storage capacities by far outstrips its' availability (Enesi & Zanaj, 2011; Janaki, 2012; Devi & Mini, 2012).

For example, medical images normally need up to 16 kBits/sec for image transmission but conventional computer just can allow for 8 kBits/sec. Linear mapping for transmission is unacceptable for medical images since important image detail may be corrupted or lost (Papitha *et al.*, 2013).

In addition, 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 (Xu *et al.*, 2016).

Until now, image compression turn out to be an extremely a must for almost all application and play important role to reduce the image size, storage capacity and bandwidth requirement (Ruiz *et al.*, 2013; Loganathan & Kumaraswamy, 2013; Kho *et al.*, 2015; Wang, 2011; Guo *et al.*, 2016). Above and beyond, compression can also increase the speed and efficiency of transmission system (Quan, 2013).

To support the compression process, Discrete Wavelet Transform (DWT) is usually used as transformation tool as it provides a flexible signal filters that theoretically can suppress the signal at desired point (Velho *et al.*, 2009). Besides, the resulting suppress signal contain enough data to reconstruct the original signal by reversing the transform (Andries *et al.*, 2014). Here, a compact data format is produced and this is the strength of DWT that would be an advantage in image compression.

### 1.3 Problem Statement

Despite the fact that great efforts are made to seek image compression at modest complexity and efficient performance, it still facing many challenges in achieving various degrees of scalability at different target bit rate based on user's individual requirements (Paul & Bandyopadhyay, 2014; Andries *et al.*, 2014; Cheng & Lerner, 2015; Hussain *et al.*, 2015).

Besides, data reduction and elimination in compression process will harm the image quality as it will give bad effect to perception of the Human Visual System (HVS). HVS is a normal human sense that sensitive to image structure or color changes. Modification on images, as done during compression process will cause blurring and image quality degradations resulting degradation of visual appearance according human eye (Baranitharan, 2013; Wan & Panetta, 2016; Song *et al.*, 2016).

Many algorithms have been developed for image compression (Biswas & Om, 2012; Abirami *et al.*, 2013; Quan, 2013; Bernatin & Sundari, 2014; Wu, 2014; Cheng & Lerner, 2015; Kho *et al.*, 2015; Guo *et al.*, 2016). In most of these methods, the researchers are exploiting the correlation across scales provided by wavelet transform. Wavelet is very practical and popular among the researcher since it can separate the image into several subbands based on energy correlation thus it is scalable and provide ample room for improvement. However, it is expensive with respect to time and resources (Kho *et al.*, 2015).

In some other works, the focus is on reducing the inter-image redundancy based on correlation among neighboring coefficients (Quan, 2013; Bernatin & Sundari, 2014; Wu, 2014; Guo *et al.*, 2016). Although this method can precisely predict the coefficient to be reduce, this method suffer with edge spreads over the neighboring coefficients which degrade the coding efficiency (Pan *et al.*, 2010).

There are several attempts done to reduce wavelet coefficients to a smaller amount by performing thresholding process (Biswas & Om, 2012; Tan & Tan, 2012; Mathar, 2013; Kho *et al.*, 2015). But, the most challenging part in wavelet coefficient reduction is the selection of its threshold(s) (Tay *et al.*, 2011). Weak decision in indicating threshold leads to a large amount of selected coefficients that turn out to insignificant decrease on compression ratio with longer computational time (Auli-Llinas, 2013; Hosseini & Naghsh-Nilchi, 2012).

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