



UNIVERSITI PUTRA MALAYSIA

**REGULATING THE DEGREE OF CONTRAST ENHANCEMENT IN
GLOBAL HISTOGRAM EQUALIZATION-BASED METHOD FOR
GRAYSACLE PHOTO PROCESSING**

CHEN SOONG DER

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**DOCTOR OF PHILOSOPHY
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2007



**REGULATING THE DEGREE OF CONTRAST ENHANCEMENT IN GLOBAL
HISTOGRAM EQUALIZATION-BASED METHOD FOR GRAYSCALE PHOTO
PROCESSING**

By

CHEN SOONG DER

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirements for the degree of Doctor of Philosophy**

November 2007



DEDICATION

This thesis is dedicated to my parents whose selfless sacrifices and dedications have made it possible for me to reach this stage of my studies.



Abstract of thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

REGULATING THE DEGREE OF CONTRAST ENHANCEMENT IN GLOBAL HISTOGRAM EQUALIZATION-BASED METHOD FOR GRAYSCALE PHOTO PROCESSING

By

CHEN SOONG DER

November, 2007

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Global Histogram equalization (GHE) is a popular image contrast enhancement method. However, it is rarely used on photo processing because it tends to create noise-artifacts, especially in simple-structure-image. A few GHE-based methods have been proposed to address this issue but whether they are noise-artifacts-proof remains questionable. This is because the methods are fully automatic and the evaluation conducted was not comprehensive.

A novel automatic GHE-based method called Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE) has been proposed in this thesis. It has been evaluated thoroughly together with the existing automatic methods. The results have proven that none of the automatic GHE-based methods is noise-artifacts-proof. The



conclusion has motivated author to look into scalable GHE-based methods that allows user to regulate the degree of contrast enhancement.

A novel scalable GHE-based method called Recursive Mean-Separate Histogram Equalization (RMSHE) has been proposed in this thesis. It has been evaluated thoroughly together with other two existing scalable methods - Clip Limited Adaptive HE (CLAHE) and Stark's Adaptive HE (StarkAHE). The results of separate evaluations consistently showed that none of the three methods could effectively enhance the contrast of simple-structure-image without creating any noise-artifacts.

Another novel scalable GHE-based method called Scalable Global Histogram Equalization with Selective Enhancement (SGHESE) has been developed then to overcome the limitation of the existing methods. Evaluation results showed that SGHESE could enhance the image's contrast effectively without creating any noise-artifacts. The results of subjective evaluation involving human observer also showed that the preference level of SGHESE was significantly higher compared to those of other methods.

Finally, the thesis recommends extending the study of SGHESE to color image processing because majority of the images nowadays are color images.



Abstrak tesis yang dikemukakan kepada Senat Univeriti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PENYESUAIAN TAHAP PENINGKATAN KEJELASAN IMEJ DALAM
TEKNIK YANG BERASASKAN PENYAMAAN HISTOGRAM GLOBAL BAGI
PEMROSESAN FOTO HITAM-PUTIH**

Oleh

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Penyamaan Histogram Global (GHE) adalah satu kaedah yang popular bagi meningkatkan kejelasan imej. Namun, ia jarang digunakan dalam pemprosesan foto kerana ia sering mendatangkan kesan hingar, terutama sekali dalam memproses foto-berstruktur-mudah. Beberapa kaedah yang berasaskan GHE telah dicadangkan sebelum ini, namun ia masih menjadi satu persoalan samada masalah kesan hingar telah diselesaikan. Ini kerana kaedah tersebut adalah automatik dan kajiannya tidak dijalankan secara menyeluruh.

Satu kaedah baru yang digelar Penyamaan Dwi-Histogram dengan Putra Ralat Kecerahan Minima (MMBEBHE) telah dibentangkan dalam tesis ini. Kaedah ini telah dikaji secara teliti bersama dengan kaedah automatik yang lain. Kajian telah membuktikan bahawa



tiada satu pun daripada kaedah automatik tersebut dapat menyelesaikan masalah kesan hingar secara menyeluruh. Keputusan yang sedemikian telah memberi motivasi supaya mengkaji kaedah berskala yang boleh dilaraskan tahap peningkatan-kejelasan-imej.

Satu kaedah berskala baru yang digelar Penyamaan Histogram secara Pembahagian-Purata Berulang (RMSHE) telah dibentangkan dalam tesis ini. Ia telah dikaji secara teliti bersama dua kaedah berskala yang lain – Penyamaan Histogram Tempatan Berhad (CLAHE) dan Penyamaan Histogram Tempatan (StarkAHE). Keputusan daripada kajian berasingan secara konsistennya menunjukkan bahawa, tiada satu pun daripada kaedah berskala tersebut dapat meningkatkan kejelasan imej dengan berkesan tanpa mendatangkan kesan hingar.

Lanjutan daripada kajian di atas, satu lagi kaedah berskala baru yang digelar Penyamaan Histogram Berskala Terpilih (SGHESE) telah dicadangkan bagi mengatasi kelemahan kaedah berskala yang sedia ada. Kajian menunjukkan SGHESE berupaya meningkatkan kejelasan imej dengan berkesan tanpa mendatangkan kesan hingar. Kajian subjektif yang melibatkan pemerhatian manusia juga menunjukkan tahap kegemaran pemerhati terhadap SGHESE adalah jauh lebih tinggi berbanding kaedah-kaedah yang lain.

Dalam mengakhiri tesis ini, pengarang telah mengesyorkan supaya melanjutkan kajian terhadap SGHESE dalam pemprosesan imej berwarna kerana kebanyakan imej sekarang adalah imej berwarna.

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I certify that an Examination Committee has met on 28th Nov 2007 to conduct the final examination of Mr. Chen Soong Der on his PhD thesis entitled " REGULATING THE DEGREE OF CONTRAST ENHANCEMENT IN GLOBAL HISTOGRAM EQUALIZATION-BASED METHOD FOR GRAYSCALE PHOTO PROCESSING" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

CHEN SOONG DER

Date: 1 Dec 2007



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GLOSSARY OF TERMS

AHE	Adaptive Histogram Equalization
AMBE	Absolute Mean Brightness Error
BBHE	Brightness Preserving Bi-Histogram Equalization
BMA	Block Matching Algorithm
CDF	Cumulative Density Function
CLAHE	Clip Limited Adaptive Histogram Equalization
CRT	Cathode Ray Tube
CT	Computed Tomography
DSIHE	Dualistic Sub-Image Histogram Equalization
DSPI	Digital Speckle Pattern Interferometry
FPGA	Field Programmable Gate Array
GHE	Global Histogram Equalization
GOES	Geostationary Operational Environmental Satellite
GUI	Graphical User Interface
HE	Histogram Equalization
LPF	Low Pass Filter
LRM	Local Range Modification
MaxBE	Maximum Brightness Error
MIDAG	Medical Image Display and Analysis Group
MLE	Multi Level Histogram Equalization
MMBEBHE	Minimum Mean Brightness Error Bi-Histogram Equalization
MRI	Magnetic Resonance Image



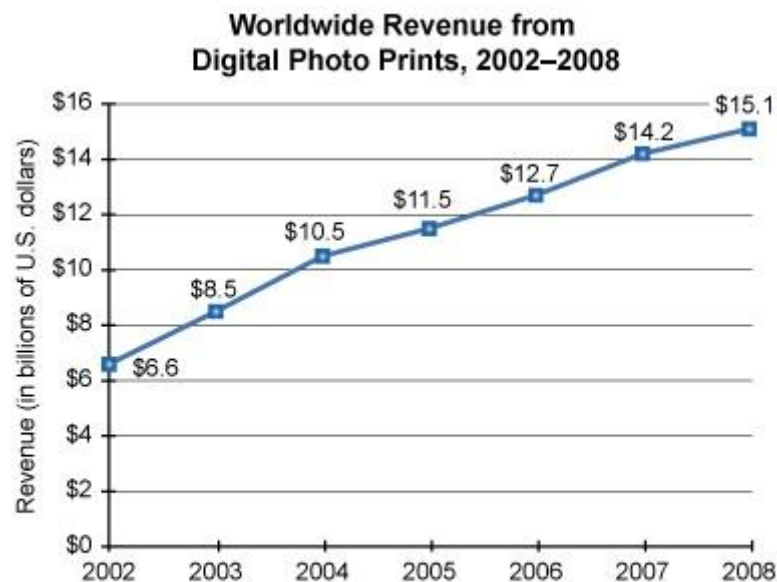
MSE	Mean Square Error
PC	Personal Computer
PCA	Principal Component Analysis
PDF	Probability Density Function
POSHE	Partially Overlapped Sub-Block HE
PSNR	Peak Signal to Noise Ratio
RMSHE	Recursive Mean-Separate Histogram Equalization
SEM	Scanning Electron Microscope
SGHESE	Scalable Global Histogram Equalization with Selective Enhancement
SIMD	Single Instruction Multiple Data
SSIM	Structural- Similarity-Based Image Assessment
TIPS	TM Image Processing Software



CHAPTER 1

INTRODUCTION

Figure 1.1 shows graph of the forecasted worldwide revenue from digital photo prints, 2002-2008 (Lyra Research Inc, 2004). The graph indicates that digital photo processing is getting more important as the demand for it is expanding rapidly. There are a few types of image processing methods used to process digital photo. One of them is image enhancement. Image enhancement aims to improve the detect-ability of important image details or objects by man or machine (Shapiro and Stockman, 2001). Contrast enhancement, image sharpening and image smoothing are among the most common type of enhancement (Gonzalez and Woods, 2002).



Source: Lyra Research, Inc.,
Digital Photography Advisory Service, First-Half 2004 Forecast

Figure 1.1: Worldwide revenue from digital photo prints, 2002-2008

1.1 Background

The purpose of image contrast enhancement is to increase the visibility of an image.

Figure 1.2a and 1.2b show an image before and after contrast enhancement. Notice



Figure 1.2a: Original image, *girl*



Figure 1.2b: after contrast enhancement

that the image shows better visibility after contrast enhancement. Many methods have been proposed and they can be generally classified into two main categories: intensity-based methods and feature-based methods (Zhu et al., 1999).

In feature-based methods, the ways to extract the feature components to be enhanced must be based on the knowledge about these features. So feature-based methods are often used in special applications such detecting tumor in medical imaging. On the other hand, the intensity-based methods are more general. They are widely used in the preprocessing of various types of image. One of the very popular intensity-based methods is histogram equalization (HE) (Zhu et al., 1999). Intensity-based methods can be further classified into two main categories: global and adaptive methods. In global methods, a single transformation of the image gray levels is applied to the