



Faculty of Engineering

BLUR ASSESSMENT USING EDGE INFORMATION

ADELINE NG SIN LIN

Bachelor of Engineering with Honours
(Electronics & Computer Engineering)
2010

UNIVERSITI MALAYSIA SARAWAK

R13a

BORANG PENGESAHAN STATUS TESIS

Judul: BLUR ASSESSMENT USING EDGE INFORMATION

SESI PENGAJIAN: 2009/2010

Saya ADELINE NG SIN LIN
(HURUF BESAR)

mengaku membenarkan tesis * ini disimpan di Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sarawak.
2. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Membuat pendigitan untuk membangunkan Pangkalan Data Kandungan Tempatan.
4. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
5. ** Sila tandakan (✓) di kotak yang berkenaan

SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972).

TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan).

TIDAK TERHAD

Disahkan oleh

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat tetap: 242 LRG. 2 EASTERN PARK

93150 KUCHING, SARAWAK.

IR. DAVID BONG BOON LIANG

Nama Penyelia

Tarikh: 20 MAY 2010

Tarikh: _____

CATATAN

- * Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah, Sarjana dan Sarjana Muda.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

This Final Year Project attached here:

Title : Blur Assessment Using Edge Information

Student Name : Adeline Ng Sin Lin

Matric Number : 15896

has been read and approved by:

Ir. David Bong Boon Liang

(Supervisor)

Date

Blur Assessment Using Edge Information

ADELINE NG SIN LIN

This Thesis Is Submitted To
The Faculty of Engineering, Universiti Malaysia Sarawak
As A Partial Fulfilment of the Requirements for
The Degree of Bachelor of Engineering with Honours
(Electronic & Computer Engineering) 2010

Dedicated to my beloved family and friends

ACKNOWLEDGEMENT

Many individuals who contribute in assorted ways to the project and also in the making of the thesis deserved special mention here.

First and foremost, I am heartily thankful to my project supervisor, Ir. David Bong Boon Liang, whose abundant assistance, unflinching encouragement, guidance and support from the initial to the final level upon the completion of my final year project. I am much indebted to him for using his precious time to read this thesis and gave his critical comments about it. Without his persistent help this project and thesis would not have been possible.

Heartfelt thanks goes to my project coordinator, Mdm. Ade Syaheda Wani for her personal assistance in the thesis format and structure. I also appreciate the involvement of other lecturers who contribute their advice and incessantly sharing their crucial experience in producing a good thesis.

I would like to express my deepest gratitude to my beloved family members and friends who provide invaluable motivation and continuous support throughout the duration of the project.

Last but not least, I offer my regards and blessings to all of those who supported me in any respect till the completion of the project.

ABSTRAK

Kualiti imej digital sering dijejaskan oleh artifak kekaburan dalam keadaan seperti mampatan, ralat fokus, pergerakan relatif dan transmisi multimedia. Kehilangan komponen frekuensi tinggi menyebabkan kesan pengaburan dalam imej tersebut. Dalam kertas kerja ini, penilaian kekaburan yang berunsur rujukan penuh dan tidak penuh secara objektif dibentangkan untuk mengukur darjah *Gaussian blur* dalam imej berdasarkan maklumat yang diperolehi daripada pengesanan sisi imej. Darjah *Gaussian blur* suatu imej ialah jumlah purata lebar sisi daripada keseluruhan sisi yang dikesan. Prestasi penilaian kekaburan juga disahkan melalui keputusan subjektif. Keputusan menandakan hubungan rapat di antara penilaian kekaburan dengan persepsi manusia. Ukuran kekaburan sesuai digunakan dalam pelbagai aplikasi seperti anggaran kekaburan dalam fotografi digital, pemprosesan imej, percetakan atau sebagai perbandingan metrik antara dua imej. Kod bahasa pengaturcaraan untuk mengimplementasikan penilaian kekaburan ditulis dalam program MATLAB.

ABSTRACT

Quality of digital images is often impaired by blur artifacts in situation such as compression, focus error, relative motion and multimedia transmission. The loss of high frequency content leads to blurring effect in the image. In this paper, objective full-reference and no-reference blur assessments are presented to measure the degree of Gaussian blur in the image by using edge information. The degree of Gaussian blur of an image is the average of total edge widths over all detected edges. The performance of the blur assessment is also validated with subjective results. The results show that the blur assessment correlates relatively well with human perception. The blur measurement is applicable to numerous applications such as blur estimation in digital photography, image processing, printing or as a simple metric in comparing two images. The source code of this low computational complexity blur assessment is written in MATLAB program.

TABLE OF CONTENTS

	Page	
Acknowledgement	i	
Abstrak	ii	
Abstract	iii	
Table of Contents	iv	
List of Tables	ix	
List of Figures	x	
List of Abbreviations	xv	
Chapter 1	INTRODUCTION	
1.1	Project Background	1
1.2	Problem Statement	2
1.3	Project Objectives	3
1.4	Project Scope	4
1.5	Thesis Outline	5
Chapter 2	LITERATURE REVIEW	
2.1	Introduction	6
2.2	Digital Images	7
2.2.1	Binary Image	8

2.2.2	Grayscale Image	9
2.2.3	RGB Image	9
2.3	Color Models	9
2.3.1	RGB Color Space	10
2.3.2	YCbCr Color Space	11
2.4	Image Quality Assessment	12
2.4.1	Objective Image Quality Assessment	13
2.4.2	Subjective Evaluation	15
2.4.3	Objective vs. Subjective Evaluation	16
2.5	Image Artifacts	17
2.5.1	Blurriness	17
2.5.2	Blockiness	18
2.5.3	Noisiness	18
2.6	Blur Assessment	19
2.7	Gaussian Filtering in Spatial Domain	21
2.8	Edge Detection	23
2.8.1	Sobel Edge Detection	24
2.9	MATLAB Software	26
2.9.1	Image Processing Toolbox	27

Chapter 3 METHODOLOGY

3.1	Introduction	28
3.2	Test Images	28
3.2.1	Creating Blur Images	29
3.2.2	Blur Images from LIVE Database	33

3.3	NR Implementation	33
3.4	FR Implementation	37
3.5	Blur Measurement	39
3.5.1	Edge Criteria	39
3.5.2	Find Local Minimum and Local Maximum	44
3.5.3	Blur Measurement Algorithm	46
3.6	Problems Anticipated	49
Chapter 4	RESULTS, ANALYSIS AND DISCUSSION	
4.1	Introduction	51
4.2	Results from Implementation	51
4.2.1	NR Blur Measurement on Luminance Component	55
4.2.2	Correlation with Subjective Evaluation	58
4.3	FR Implementation	60
4.4	Analysis of NR Blur Measurement	64
4.4.1	on Grayscale Component	64
4.4.2	using Grayscale Images	69
4.4.3	using Horizontal Edge Information	72
4.5	Analysis using LIVE Database Simulated Blur Images	77
4.5.1	NR Implementation	77
4.5.2	FR Implementation	83
4.6	Discussion	86

Chapter 5	CONCLUSION AND RECOMMENDATIONS	
5.1	Conclusion	89
5.2	Recommendations	91
	REFERENCES	92
	APPENDICES	
Appendix A	Name of Each Test Image and its Size	98
Appendix B	NR Blur Assessment MATLAB Source Code	99
Appendix C	FR Blur Assessment MATLAB Source Code	105
Appendix D	Insignificant Edge in Row 377 of Test Image 7 ($\sigma = 0.4$)	111
Appendix E	Insignificant Edge in Row 374 of Test Image 7 ($\sigma = 0.4$)	112
Appendix F	Insignificant Edge in Row 377 of Test Image 7 ($\sigma = 0.4$) Removed	113
Appendix G	Insignificant Edge in Row 374 of Test Image 7 ($\sigma = 0.4$) Removed	114
Appendix H	Test Images and its Graphical Results	115
Appendix I	Table of Results for NR Blur Measurement	144
Appendix J	Table of Results for FR Blur Measurement	145
Appendix K	Absolute Difference between NR and FR Blur Measurements	146

Appendix L	Blur Measurement using NR Method on Grayscale Component	147
Appendix M	Absolute Difference in Blur Measurement using Luminance and Grayscale Components	148
Appendix N	Blur Measurement on Grayscale Images	149
Appendix O	Absolute Difference in Blur Measurements between Grayscale Images and RGB Images Represented by Grayscale Component	150
Appendix P	Blur Measurement using Horizontal Edge Detection	151
Appendix Q	Gaussian Blur Standard Deviation Values to Distort Each Original Test Image from LIVE Database	152
Appendix R	Blur Measurement based on FR and NR Implementation using LIVE Database Gaussian Blur Images	156
Appendix S	DMOS Values	160
Appendix T	Table of Results of NBM based on NR Implementation (using LIVE Database Gaussian Blur Images)	164
Appendix U	Table of Results of NBM based on FR Implementation (using LIVE Database Gaussian Blur Images)	168

LIST OF TABLES

Table		Page
4.1	Number of Bins based on Gaussian Blur Standard Deviation (σ)	53
4.2	Blur Measurement Results for Test Image 1	56
4.3	Comparison of Blur Measurement for Test Image 1 based on NR and FR Implementations	61
4.4	Comparison of Blur Measurement for Test Image 1 based on NR Implementation measuring on Luminance Component and Grayscale Component	66
4.5	Comparison of Blur Measurements using Grayscale Image and RGB Image Represented by Grayscale Component of Test Image 1	70
4.6	Range of Blur Measurement using Vertical Edges and Horizontal Edges	75
4.7	Blur Measurements for Test Image 5	78
4.8	FR Blur Measurement for Test Image 5	83

LIST OF FIGURES

Figure		Page
2.1	A Grayscale Image as a Function	7
2.2	Digital Images: (a) Binary Image (b) Grayscale Image (c) RGB Image	8
2.3	Schematic of the RBG Color Cube	10
2.4	RGB to YCbCr Image Conversion: (a) RGB Image (b) YCbCr Image (c) Y Component Image (d) Cb Component Image (e) Cr Component Image	11
2.5	Distortion Types: (a) Blurriness (b) Blockiness (c) Noise	19
2.6	Gaussian Filtering: (a) Original Lena Image (b) Gaussian Filtering with $\sigma = 1.0$ (c) Gaussian Filtering with $\sigma = 5.0$	22
2.7	Edge Detection: (a) Model of an Ideal Digital Edge (b) Model of a Ramp Digital Edge	23
2.8	Sobel Operator: (a) Sobel Vertical Mask (b) Sobel Horizontal Mask	25
2.9	Sobel Edge Detection: (a) An Integrated Circuit (b) The Circuit after Sobel Filtering (c) The Circuit after Vertical Sobel Filtering (d) The Circuit after Horizontal Sobel Filtering	26

2.10	MATLAB version 7.6.0.324 (R2008A) Interface	27
3.1	Gaussian Blur on Test Image 1 with: (a) $\sigma = 0$ (b) $\sigma = 0.4$ (c) $\sigma = 0.8$ (d) $\sigma = 1.2$ (e) $\sigma = 1.6$ (f) $\sigma = 2.0$	30
3.2	Flow Chart of Creating Blur Images	32
3.3	Figure 3.3: Flow Chart of NR Blur Measurement on Luminance Component	35
3.4	Figure 3.4: Flow Chart of NR Blur Measurement on Gray-level Component	36
3.5	Figure 3.5: Flow Chart of FR Blur Measurement on Luminance Component	38
3.6	False Edge on Local Minimum and Local Maximum Positions in Row 400 of Test Image 7 Blurred with $\sigma = 0.4$	40
3.7	False Edge on Local Minimum and Local Maximum Positions in Row 400 of Test Image 7 Blurred with $\sigma = 0.4$ Removed	43
3.8	Flow Chart of Finding Local Minimum and Local Maximum	45
3.9	Measuring the Edge Width of an Edge in Row 400 of Test Image 1	47
3.10	Flow Chart on the Procedures to Obtain Blur Measurement	48
3.11	Two Regions Separated by a Vertical Edge	50

4.1	(a) Grayscale Image of Test Image 1 (b) Gray-level Histogram of Original and Distorted Images of Test Image 1	52
4.2	(a) Pixel Value in Column 344~354 (Row 200) of Test Image 1 with $\sigma = 0$ (c) Pixel Values of Original and Distorted Images (d) Zoom-in Pixel Values	54
4.3	Luminance Component of Test Image 1 with (a) $\sigma = 0$ (b) $\sigma = 0.4$ (c) $\sigma = 0.8$ (d) $\sigma = 1.2$ (e) $\sigma = 1.6$ (f) $\sigma = 2.0$	55
4.4	Blur Measurement versus the Gaussian Blur (σ)	56
4.5	Objective Blur Measurement for Test Image 1	57
4.6	Blur Metric Comparison between 10 Test Images (Test Image 1 until Test Image 10)	58
4.7	Objective Blur Measurement for Test Image 1 by P. Marziliano et al.	59
4.8	FR Blur Measurement Results for Test Image 1	60
4.9	Comparison between NR and FR Blur Assessments	62
4.10	Absolute Difference between Blur Measurement from FR and NR Implementations for All 29 Test Images	63
4.11	Grayscale Component of Test Image 1 with (a) $\sigma = 0$ (b) $\sigma = 0.4$ (c) $\sigma = 0.8$ (d) $\sigma = 1.2$ (e) $\sigma = 1.6$ (f) $\sigma = 2.0$	65
4.12	Blur Measurement on Luminance Component and Grayscale Component for Test Image 1	67

4.13	Absolute Difference between Blur Measured on Luminance Component and Grayscale Component for All 29 Test Images	68
4.14	Comparison between Blur Measurement using Grayscale Image and RGB Image Represented by Grayscale Component of Test Image 1	71
4.15	Difference between Blur Measurement using Grayscale Image and RGB Image Represented by Grayscale Component for All 29 Test Images	72
4.16	Blur Assessment using Vertical Edge Information and Horizontal Edge Information for Test Image 1	73
4.17	Absolute Difference between Blur Measurement using Vertical Edges and Horizontal Edges for All 29 Test Images	74
4.18	The Range of Blur Measurements using Vertical Edges	76
4.19	The Range of Blur Measurements using Horizontal Edges	76
4.20	Blur Assessment using NR Method for Test Image 5	78
4.21	DMOS for All 29 Test Images Blurred with Different Standard Deviation Values	79
4.22	SDBM and DMOS versus Gaussian Blur Standard Deviation for Test Image 5	81
4.23	Scaling Results between Blur Measurements and DMOS values for Test Image 5	81

4.24	Correlation between Objective and Subjective Results for all 29 Test Images	82
4.25	Blur Assessment using FR Method for Test Image 5	84
4.26	SDBM and DMOS versus Gaussian Blur Standard Deviation for Test Image 5	84
4.27	Scaling Results between Blur Measurements and DMOS values	85
4.28	Correlation between Objective and Subjective Results for All 29 Test Images	86

LIST OF ABBREVIATIONS

BM	–	Blur metric
Bmp	–	Bitmap
DCT	–	Discrete Cosine Transform
DMOS	–	Differential Mean Opinion Score
FR	–	Full-reference
HVS	–	Human Visual System
JPEG	–	Joint Photographic Experts Group
MOS	–	Mean Opinion Score
MSE	–	Mean Square Error
NBM	–	Normalized blur measurement
NR	–	No-reference
PSNR	–	Peak Signal-to-Noise Ratio
RGB	–	Red Green Blue
RF	–	Reduced-reference
SDBM	–	Square root of difference in blur measurement
VQEG	–	Video Quality Experts Group
YCbCr	–	Luminance and Chrominance information
YIQ	–	Luminance In-phase Quadrature
YUV	–	Luminance and Chrominance information
α	–	Gain between two gradients
σ	–	Gaussian blur standard deviation

BM_{FR}	–	Blur measurement from FR implementation
BM_G	–	Blur measurement on gray-level component
BM_{GI}	–	Blur measurement using grayscale image
BM_H	–	Blur measurement using horizontal edge detection
BM_{NR}	–	Blur measurement from NR implementation
BM_{RI}	–	Blur measurement on RGB image represented by grayscale component
BM_V	–	Blur measurement using vertical edge detection
BM_Y	–	Blur measurement on luminance component

CHAPTER 1

INTRODUCTION

1.1 Project Background

Along with the rapid advances in digital and multimedia imaging industry, digital images have been playing an increasingly important role in the communication of visual information. Digital images can be classified as binary images, color images, grayscale images and so forth. Unfortunately, these images can be degraded during acquisition, compression, transmission or even processing. Thus, a measure to the image quality is necessary to assess the degree of degradation. There are indeed many great efforts made towards the development of image quality assessment to produce suitable methods of assessing the quality of the image to measure visual artifacts like brightness, blurriness and jerkiness.

Methods of measuring the artifacts are categorized into objective and subjective evaluation. Objective method is based on mathematical measure while subjective method relies on the perception of a selected group of human observers such as professionals or lay viewers. Human visual perception on the quality of the image is very important as human observers are the final arbiters who determine the acceptability of the image contents.

Researchers have developed various perceptual image quality metrics where these metrics are used to measure the global distortion but a perceptual objective image quality analysis to measure a specific artifact is rarely found. There are a few objective measurements proposed for blockiness but less attention is devoted for other artifacts like blur and noise. Therefore, the aim of this project is to propose an objective blur assessment using edge information which correlates well with human visual perception.

1.2 Problem Statement

Most digital imaging capture devices and electronically displaying visual information devices aim to produce the best image quality. When an artifact like blur is introduced in an image due to acquisition or compression, the blur image has to be enhanced in order to look visually appealing. However, there is a possibility that this corrected image might not satisfy human perception. Various people evaluate the quality differently due to the sensitivity of human eye. Therefore, a blur metric which correlates with human visual is necessary to measure the blur image to determine the level of degradation so that it can be corrected to a certain extent to produce a better quality image and maintain the pleasure of human observers in viewing the image. For instance, in digital photography application, the metric is used to notify user the level of blurring in the image that has been captured.

The blur assessment proposed in this thesis is an objective method. Objective image assessment is least preferable as the most reliable means to assess the image quality is through subjective evaluation where the quality of the image is evaluated

by human. However, it is not an easy task to conduct a subjective evaluation image assessment because it is expensive and time-consuming [1]. Due to the limitations in subjective evaluation, researchers believed that it is useful to design objective method as long as it produces results that correlate closely with human visual system (HVS) [2]. There are 3 approaches to objective image quality assessment that can be considered such as no-reference (NR) measurement, reduced-reference (RR) measurement and full-reference (FR) measurement.

1.3 Project Objectives

The objectives of the project are:

- a) To implement objective NR and FR blur assessments using edge information with MATLAB as the assessment tool.
- b) To compare and analyze the blur metric that is measured on luminance component for color images and grayscale intensity component for gray-level images.
- c) To compare and investigate the difference between blur assessment using grayscale images and RGB images measuring on grayscale component.
- d) To test the difference of blur assessment using vertical edge detection and horizontal edge detection.
- e) To validate the performance of the objective blur assessment with subjective testing results.