



AUTOMATED VISION-BASED BEVERAGE BOTTLE QUALITY AND LEVEL INSPECTION SYSTEM

NOR NABILAH SYAZANA BINTI ABDUL RAHMAN

MASTER OF SCIENCE IN ELECTRONIC ENGINEERING

2018



Faculty of Electronic and Computer Engineering

**AUTOMATED VISION-BASED BEVERAGE BOTTLE QUALITY
AND LEVEL INSPECTION SYSTEM**

Nor Nabilah Syazana binti Abdul Rahman

Master of Science in Electronic Engineering

2018

**AUTOMATED VISION-BASED BEVERAGE BOTTLE QUALITY AND LEVEL
INSPECTION SYSTEM**

NOR NABILAH SYAZANA BINTI ABDUL RAHMAN

**A thesis submitted
in fulfilment of the requirements for the degree of Master of Science
in Electronic Engineering**

Faculty of Electronic and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this thesis entitled “Automated Vision-Based Beverage Bottle Quality and Level Inspection System” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Nor Nabilah Syazana Binti Abdul Rahman

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of the Master of Science in Electronic Engineering.

Signature :

Supervisor Name : Dr. Norhashimah Binti Mohd Saad

Date :

DEDICATION

A million praise towards my family, my respectful supervisor, examiner and lecturers and to all my friends for their support and cooperation in helping me to complete this thesis.

Thanks to the Zamalah Scheme Universiti Teknikal Malaysia Melaka (UTeM) for the financial support for my study.

Your supports are highly appreciated and very meaningful to me.

ABSTRACT

Automated vision inspection emerged as an important part of the product quality monitoring process. It is a requirement of International Organization for Standardization (ISO) 9001 to appease the customer satisfaction in terms of frequent improvement of the quality of products. It is totally impractical to rely on human inspector to handle a large scale quality control production because human has major drawback in their performance such as inconsistency and time consuming. Therefore, an automatic inspection is a promising approach to maintain product quality as well as to resolve the existing problems relate to delay outputs and cost burden. This research presents a computerized analysis to detect defects occur in beverages production in order to minimize the defective products. Image processing techniques are proposed to detect defects of beverages bottle. The defects are categorized into three classes which are bottle shape defect, color concentration defect and liquid level defect. For shape defect detection, three techniques are proposed namely local standard deviation (LSD), morphological operation and adaptive thresholding. Statistical histogram, gray level co-occurrence matrix (GLCM) and quadratic distance are applied for color concentration defect detection. The liquid level is detected using Hough transform and coordinate of point techniques. The classification process is analyzed using rule-based and decision tree classifiers. In developing automated beverage bottle quality and level inspection system, the performance is verified in terms of accuracy. The simulation result demonstrate LSD, statistical histogram and Hough transform are selected as the best technique by achieving 98% of shape, 93% of color concentration and 91% of liquid level. For the system result, 93% average accuracy has achieved for three defect detections. The system is ready for internet of things (IoT) platform which is using raspberry pi that gives benefit to user for wirelessly access and monitor the results. For the results validation, field testing is conducted, and the proposed system shows the capability to classify the bottle defect accurately. Thus, it has proven the proposed system is appropriate to be implemented in real-time application for beverage bottle quality inspection.

ABSTRAK

Pemeriksaan penglihatan automatik telah muncul sebagai bahagian penting dalam proses pemantauan kualiti produk. Ia adalah keperluan Pertubuhan Pemiawaian Antarabangsa 9001 bagi memenuhi kepuasan pelanggan dari segi kekerapan peningkatan kualiti produk. Adalah tidak praktikal untuk bergantung kepada pemeriksa manusia bagi mengendalikan pengeluaran kawalan dalam kualiti yang berskala besar kerana manusia mempunyai kelemahan utama dalam prestasi mereka seperti tidak konsisten dan mengambil masa yang sangat lama. Oleh itu, pemeriksaan automatik adalah pendekatan yang menjanjikan dapat mengekalkan kualiti produk serta menyelesaikan masalah yang ada berkaitan dengan kelewatan pengeluaran dan beban harga. Penyelidikan ini membentangkan analisis berkomputer untuk mengesan kecacatan berlaku dalam pengeluaran minuman untuk meminimumkan produk yang cacat. Teknik pemprosesan imej dicadangkan untuk mengesan kecacatan botol minuman. Kecacatan ini dikategorikan kepada tiga kelas iaitu kecacatan bentuk botol, kecacatan kepekatan warna dan kecacatan paras cecair. Untuk mengesan kecacatan pada bentuk, tiga teknik dicadangkan iaitu sisihan piawai tempatan, operasi morfologi dan ambang adaptif. Statistik histogram, matrik gray level co-occurrence (GLCM) dan jarak kuadratik digunakan untuk mengesan kecacatan kepekatan warna. Paras cecair dikesan menggunakan jelmaan Hough dan titik koordinat. Proses klasifikasi dianalisis dengan menggunakan asas aturan dan akar pokok keputusan. Dalam membangunkan sistem pemeriksaan kualiti botol minuman dan aras berasaskan penglihatan automatik, teknik terbaik telah dipilih dari segi ketepatan. Hasil ketepatan simulasi menunjukkan sisihan piawai tempatan, statistik histogram dan jelmaan Hough dipilih sebagai teknik terbaik dengan mencapai 98% bentuk, 93% kepekatan warna dan 91% paras cecair. Bagi keputusan sistem, ketepatan purata 93% telah dicapai bagi ketiga-tiga pengesanan kecacatan. Sistem ini telah bersedia untuk penggunaan platform internet of things dengan menggunakan raspberry pi yang akan memberikan manfaat kepada pengguna untuk mengakses dan mengawasi keputusan tanpa wayar. Untuk pengesanan keputusan, ujian lapangan dijalankan, dan sistem yang dicadangkan menunjukkan keupayaan untuk mengklasifikasikan kecacatan botol dengan tepat. Oleh itu, ia telah membuktikan sistem yang dicadangkan sesuai untuk dilaksanakan dalam permohonan masa nyata bagi pemeriksaan kualiti produk. Penyelidikan ini akan menyokong IKS dalam membangunkan teknologi automatik canggih yang sejajar dengan revolusi perindustrian keempat.

ACKNOWLEDGEMENTS

First of all, Alhamdulillah thanks to Allah Almighty because of His blessing I would able to finish out my research. In preparing this thesis, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my supervisor, Dr. Norhashimah binti Mohd. Saad for her supports, trust, guidance critics, encouragement and advices throughout this research.

Then, a million thanks towards my co-supervisor Associate Professor Dr. Ir. Abdul Rahim bin Abdullah for his guidance, advices and motivation. Without their continued support and interest, this research would not have been same as presented here. I am also indebted to Universiti Teknikal Malaysia Melaka Zamalah Scheme and Ministry of Higher Education (MOHE) for scholarship and research grant GLuar/STEVIA/2016/FKE-CeRIA/100009. I also want to thank my parents for their endless support, spirit, motivation and advices for continuing my studies. Behind that entire process they also have contributed, financially.

Next, my fellow postgraduate students from Advanced Digital Signal Processing (ADSP) laboratory should also be recognized for their support and cooperation in completing this thesis. Finally, my sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members. Thank you very much.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	x
LIST OF APPENDICES	xvi
LIST OF ABBREVIATIONS	xvii
LIST OF SYMBOLS	xix
LIST OF PUBLICATIONS	xxi
CHAPTER	
1. INTRODUCTION	1
1.1 Introduction	1
1.2 Problem Statement	3
1.3 Research Objectives	4
1.4 Scope of Works	4
1.5 Proposed System Design	5
1.6 Research Contributions	7
1.7 Thesis Organization	8
2. LITERATURE REVIEW	10
2.1 Introduction	10
2.2 Vision Based Defect Detection	10
2.2.1 Manual Inspection	11
2.2.2 Automated Inspection	12
2.3 Techniques for Automated Quality Inspection System	13
2.3.1 Shape Inspection	13
2.3.2 Color Inspection	18
2.3.3 Liquid Level Inspection	22
2.4 Defect Detection Techniques	26
2.4.1 Shape Defect Detection Techniques	26
2.4.1.1 Adaptive Thresholding	27
2.4.1.2 Morphological Operation	28
2.4.1.3 Local Standard Deviation	29
2.4.2 Color Concentration Defect Detection Techniques	30
2.4.2.1 K-Means Clustering	30
2.4.2.2 Otsu's Thresholding	31
2.4.3 Liquid Level Defect Detection Techniques	32
2.4.3.1 Sobel Edge Detection	33
2.4.3.2 Canny Edge Detection	34
2.4.3.3 Hough Transform	35
2.5 Classification Techniques	36

2.5.1	Support Vector Machine	36
2.5.2	Decision Tree Classifier	37
2.5.3	Rule-Based Classifier	38
2.6	Summary	38
3.	RESEARCH METHODOLOGY	41
3.1	Introduction	41
3.2	Image Acquisition	43
3.3	Pre-Processing	45
3.4	Shape Defect Detection Analysis	46
3.4.1	Adaptive Thresholding	47
3.4.2	Morphological Operation	48
3.4.3	Local Standard Deviation	52
3.4.4	Parameters for Shape Feature Extraction	53
3.5	Color Concentration Defect Detection Analysis	55
3.5.1	Statistical Histogram	55
3.5.2	Gray Level Co-Occurrence Matrix	58
3.5.3	Parameters for Color Concentration Feature Extraction	61
3.5.3.1	Quadratic Distance Measurement	61
3.6	Liquid Level Defect Detection Analysis	63
3.6.1	Hough Transform	63
3.6.2	Coordinate of point	65
3.6.3	Parameters for Liquid Level Feature Extraction	67
3.6.3.1	Maximum and Minimum Line	67
3.6.3.2	Two Point Position	68
3.7	Classification	69
3.7.1	Rule-Based Classifier	69
3.7.2	Decision Tree Classifier	72
3.8	Performance Measurements of Analysis Technique	72
3.9	System Development	74
3.9.1	Hardware Development	75
3.9.2	Software Development	76
3.10	Experimental Setup	77
3.11	Summary	79
4.	RESULT AND DISCUSSION	81
4.1	Introduction	81
4.2	Sample Image	81
4.3	Shape Defect Detection	83
4.3.1	Adaptive Thresholding	83
4.3.2	Morphological Operation	85
4.3.3	Local Standard Deviation	87
4.4	Color Concentration Defect Detection	89
4.4.1	Statistical Histogram	89
4.4.1.1	Quadratic Distance Measurement for Statistical Histogram	99
4.4.2	Gray Level Co-Occurrence Matrix	101
4.4.2.1	Quadratic Distance Measurement for GLCM	113
4.5	Liquid Level Defect Detection	115
4.5.1	Hough Transform	115

4.5.2	Coordinate of Point	117
4.6	Classification	120
4.6.1	Rule-based Classifier	120
4.6.1.1	Shape Defect Detection	121
4.6.1.2	Color Concentration Defect Detection	123
4.6.1.3	Liquid Level Defect Detection	126
4.6.2	Decision Tree Classifier	129
4.6.2.1	Shape Defect Detection	129
4.6.2.2	Color Concentration Defect Detection	131
4.6.2.3	Liquid Level Defect Detection	133
4.7	Performance Analysis Technique	134
4.7.1	Performance Analysis for Shape Defect Detection	137
4.7.2	Performance Analysis for Color Concentration Defect Detection	140
4.7.3	Performance Analysis for Liquid Level Defect Detection	144
4.8	System Software	149
4.8.1	Shape Defect Detection	151
4.8.2	Color Concentration Defect Detection	151
4.8.3	Liquid Level Defect Detection	153
4.8.4	Data Logger	153
4.8.5	System Performance Verification	155
4.9	Field Testing	155
4.10	Summary	157
5.	CONCLUSION AND RECOMMENDATIONS	159
5.1	Conclusion	159
5.2	Recommendations	161
	REFERENCES	162
	APPENDICES	187

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Summary of shape detection system	17
2.2	Summary of color detection system	21
2.3	Summary of liquid level detection system	25
3.1	Confusion matrix representation	73
3.2	Components of automated vision-based beverage bottle quality and level inspection system	77
4.1	Total sample image	83
4.2	Parameters of bottle shape detection using adaptive thresholding	85
4.3	Parameters of bottle shape detection using morphological operation	87
4.4	Parameters of bottle shape detection using local standard deviation	89
4.5	Red component histogram bin value for normal concentration	93
4.6	Green component histogram bin value for normal concentration	93
4.7	Blue component histogram bin value for normal concentration	93
4.8	RGB component histogram bin value for normal concentration	93
4.9	Red component histogram bin value for low concentration	96
4.10	Green component histogram bin value for low concentration	96
4.11	Blue component histogram bin value for low concentration	96
4.12	RGB component histogram bin value for low concentration	96
4.13	Red component histogram bin value for high concentration	99

4.14	Green component histogram bin value for high concentration	99
4.15	Blue component histogram bin value for high concentration	99
4.16	RGB component histogram bin value for high concentration	99
4.17	Quadratic distance value of normal green color concentration	100
4.18	Optimal normal color distance of statistical histogram using quadratic distance	101
4.19	Red component histogram bin value for normal concentration	105
4.20	Green component histogram bin value for normal concentration	105
4.21	Blue component histogram bin value for normal concentration	105
4.22	RGB component histogram bin value for normal concentration	105
4.23	Red component histogram bin value for low concentration	109
4.24	Green component histogram bin value for low concentration	109
4.25	Blue component histogram bin value for low concentration	109
4.26	RGB component histogram bin value for low concentration	109
4.27	Red component histogram bin value for high concentration	113
4.28	Green component histogram bin value for high concentration	113
4.29	Blue component histogram bin value for high concentration	113
4.30	RGB component histogram bin value for high concentration	113
4.31	Quadratic distance value of normal red color concentration	114
4.32	Optimal normal color distance of GLCM using quadratic distance	114
4.33	Parameters of liquid level using Hough transform	117
4.34	Parameters of liquid level using coordinate of point	120
4.35	Maximum and minimum extent value for the proposed technique	121
4.36	Classification result of adaptive thresholding technique	122

4.37	Classification result of morphological operation technique	122
4.38	Classification result of LSD technique	123
4.39	Maximum and minimum color distance value for the proposed technique	123
4.40	Classification result of statistical histogram with quadratic distance classifier	125
4.41	Classification result of GLCM with quadratic distance classifier	126
4.42	Maximum and minimum level distance value for the proposed technique	127
4.43	Classification result of Hough transform	128
4.44	Classification result of coordinate of point	128
4.45	Confusion matrix for proposed techniques	135

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Algorithm framework block diagram	6
2.1	Example of an automated quality inspection system (Marhoon et al., 2013)	13
2.2	Bottle image: (a) Broad bottle, (b) slim bottle (Ramli et al., 2012)	14
2.3	Blood image: (a) Blood sample, (b) blood detection (Yamin et al., 2017)	20
2.4	Bottle image: (a) Normal level, (b) underfilled level (Sharma et al., 2015)	24
3.1	Flowchart of beverage bottle inspection system	42
3.2	Offline experimental setup	43
3.3	Shape defect detection analysis flowchart	46
3.4	Segmented image: (a) $T = 0.4$, (b) $T = 0.5$, (c) $T = 0.6$	48
3.5	Example of Matlab code using adaptive thresholding	48
3.6	Structuring element representation: (a) 0s and 1s, (b) 1s only (Srisha and Khan, 2013)	49
3.7	Dilation process (Saad et al., 2017)	50
3.8	Erosion process (Saad et al., 2017)	50
3.9	Segmented image: (a) $T = 0.5$, (b) $T = 0.6$, (c) $T = 0.7$	51
3.10	Example of Matlab code using morphological operation	52
3.11	Segmented image: (a) $std = 4$, (b) $std = 5$, (c) $std = 6$	53
3.12	Example of Matlab code using LSD	53

3.13	Bounding box dimension	54
3.14	Color concentration defect detection analysis flowchart	55
3.15	Framework analysis for color concentration process	56
3.16	Segmented image using Otsu's thresholding	56
3.17	RGB image	57
3.18	Statistical histogram for RGB image: (a) Reference image, (b) RGB distribution graph	58
3.19	Example of Matlab code using statistical histogram	58
3.20	GLCM for RGB image: (a) Reference image, (b) contour plot at = 256	60
3.21	Example of Matlab code using GLCM	60
3.22	Color concentration histogram: (a) Red component, (b) green component, (c) blue component, (d) RGB combination	62
3.23	Liquid level defect detection analysis flowchart	63
3.24	Created lines using Hough transform	64
3.25	Example of Matlab code using Hough transform	65
3.26	Bottle image: (a) Binary image, (b) features image	65
3.27	Binary image of two points	66
3.28	Example of Matlab code using coordinate of point	66
3.29	Maximum and minimum level of liquid	67
3.30	Label for liquid level	68
3.31	Two marked points of the image	69
3.32	Rule-based classifier pseudo code (Mohd Saad et al., 2017)	70
3.33	Flowchart of rule-based classification process	71
3.34	Decision tree process	72
3.35	Block diagram for automated vision-based beverage quality inspection system	75

3.36	General flow of system	75
3.37	Experimental setup for real-time beverage bottle quality and level inspection system	78
4.1	Five types of reference image: (a) Strawberry, (b) fruitade, (c) orange, (d) grapes, (e) citrus	82
4.2	Shape detection process: (a) Input stage, (b) pre-processing stage, (c) adaptive thresholding stage, (d) feature extraction stage	84
4.3	Shape detection process: (a) Input stage, (b) pre-processing stage, (c) morphological operation stage, (d) feature extraction stage	86
4.4	Shape detection process: (a) Input stage, (b) pre-processing stage, (c) LSD stage, (d) feature extraction stage	88
4.5	Color concentration detection process: (a) Normal concentration of green color, (b) RGB to HSV conversion, (c) segmentation using Otsu's, (d) binary to RGB conversion	90
4.6	RGB distribution graph of normal green color concentration	91
4.7	Normal concentration of green color histogram: (a) Red component, (b) green component, (c) blue component, (d) RGB combination	92
4.8	Color concentration detection process: (a) Low concentration of green color, (b) RGB to HSV conversion, (c) segmentation using Otsu's, (d) binary to RGB conversion	94
4.9	RGB distribution graph of low green color concentration	94
4.10	Low concentration of green color histogram: (a) Red component, (b) green component, (c) blue component, (d) RGB combination	95
4.11	Color concentration detection process: (a) High concentration of green color, (b) RGB to HSV conversion, (c) segmentation using Otsu's, (d) binary to RGB conversion	97
4.12	RGB distribution graph of high green color concentration	97
4.13	High concentration of green color histogram: (a) Red component, (b) green component, (c) blue component, (d) RGB combination	98
4.14	Color concentration detection process: (a) Normal concentration of red color, (b) RGB to HSV conversion, (c) segmentation using Otsu's, (d) binary to RGB conversion, (e) RGB to gray scale	102

conversion using GLCM

4.15	GLCM contour and cross section graph of normal red color concentration: (a) Red component contour, (b) red component cross section, (c) green component contour, (d) green component cross section, (e) blue component contour, (f) blue component cross section	103
4.16	Normal concentration of red color histogram: (a) Red component, (b) green component, (c) blue component, (d) RGB combination	104
4.17	Color concentration detection process: (a) Low concentration of red color, (b) RGB to HSV conversion, (c) segmentation using Otsu's, (d) Binary to RGB conversion, (e) RGB to gray scale conversion using GLCM	106
4.18	GLCM contour and cross section graph of low red color concentration: (a) Red component contour, (b) red component cross section, (c) green component contour, (d) green component cross section, (e) blue component contour, (f) blue component cross section	107
4.19	Low concentration of red color histogram: (a) Red component, (b) green component, (c) blue component, (d) RGB combination	108
4.20	Color concentration detection process: (a) High concentration of red color, (b) RGB to HSV conversion, (c) segmentation using GLCM, (d) binary to RGB conversion, (e) RGB to gray scale conversion using GLCM	110
4.21	GLCM contour and cross section graph of high red color concentration: (a) Red component contour, (b) red component cross section, (c) green component contour, (d) green component cross section, (e) blue component contour, (f) blue component cross section	111
4.22	High concentration of red color histogram: (a) Red component, (b) green component, (c) blue component, (d) RGB combination	112
4.23	Normal liquid level image: (a) Sample image, (b) segmented image, (c) Hough transform image, (d) line detection image	115
4.24	Underfilled liquid level image: (a) Sample image, (b) segmented image, (c) Hough transform image, (d) line detection image	116
4.25	Overfilled liquid level image: (a) Sample image, (b) segmented image, (c) Hough transform image, (d) line detection image	116

4.26	Normal liquid level image: (a) Sample image, (b) segmented image, (c) two-points image, (d) level detection image	118
4.27	Underfilled liquid level image: (a) Sample image, (b) segmented image, (c) two-points image, (d) level detection image	118
4.28	Overfilled liquid level image: (a) Sample image, (b) segmented image, (c) two-points image, (d) level detection image	119
4.29	Scatter plot diagram of shape defect detection classification using adaptive thresholding	129
4.30	Scatter plot diagram of shape defect detection classification using morphological operation	130
4.31	Scatter plot diagram of shape defect detection classification using LSD technique	131
4.32	Scatter plot diagram of color concentration defect detection classification using statistical histogram and quadratic distance technique	132
4.33	Scatter plot diagram of color concentration defect detection classification using GLCM and quadratic distance technique	132
4.34	Scatter plot diagram of liquid level defect detection classification using Hough transform	133
4.35	Scatter plot diagram of liquid level defect detection classification using coordinate of point	134
4.36	Performance analysis for shape defect detection based on rule-based classifier	137
4.37	Performance analysis for shape defect detection based on decision tree classifier	138
4.38	Average simulation time for classification of shape defect detection using rule-based classifier	139
4.39	Average simulation time for classification of shape defect detection using decision tree classifier	140
4.40	Performance analysis for color concentration defect detection based on rule-based classifier	141
4.41	Performance analysis for color concentration defect detection based on decision tree classifier	142

4.42	Average simulation time for classification of color concentration defect detection using rule-based classifier	143
4.43	Average simulation time for classification of color concentration defect detection using decision tree classifier	144
4.44	Performance analysis for liquid level defect detection based on rule-based classifier	145
4.45	Performance analysis for liquid level defect detection based on decision tree classifier	146
4.46	Average simulation time for classification of liquid level defect detection using rule-based classifier	147
4.47	Average simulation time for classification of liquid level defect detection using decision tree classifier	148
4.48	System development: (a) System GUI, (b) connection of raspberry pi between webcam and conveyor	150
4.49	Shape representation analysis: (a) Sample image, (b) shape parameters	151
4.50	Color concentration representation analysis: (a) Sample image, (b) red component histogram, (c) green component histogram, (d) blue component histogram, (e) RGB component histogram	152
4.51	Liquid level representation analysis: (a) Sample image, (b) level parameters	153
4.52	File location of recorded data	154
4.53	Recorded parameters and classification results of sample image	154
4.54	Performance comparison between simulation and system	155
4.55	Experimental classification result	156

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Components of hardware development	187
B	Parameters of shape, color concentration and liquid level	192

LIST OF ABBREVIATIONS

2D	-	2-Dimensional
ACE	-	Adaptive Contrast Enhancement
ACM	-	Active Counter Model
ADSP Lab	-	Advanced Digital Signal Processing Laboratory
DWI	-	Diffusion-Weighted Imaging
FCM	-	Fuzzy C-means
FN	-	False Negative
FP	-	False Positive
FPGA	-	Field Programmable Gate Array
GLCM	-	Gray Level Co-Occurrence Matrix
GUI	-	Graphical User Interface
HD	-	High Definition
HSV	-	Hue Saturation Value
IoT	-	Internet of Thing
IP	-	Internet Protocol
ISEF	-	Infinite Symmetrical Edge Filter
ISO	-	International Organization for Standardization
LED	-	Light Emitting Diode
LSD	-	Local Standard Deviation
MLP	-	Multilayer Perceptron
NN	-	Neural Network
PC	-	Personal Computer
RBPNN	-	Radial Basis Probabilistic Neural Network
RGB	-	Red Green Blue
ROI	-	Region of Interest
SHFCM	-	Statistical Histogram based Fuzzy C-means

SME	-	Small and Medium Enterprise
SVM	-	Support Vector Machine
T	-	Threshold
TN	-	True Negative
TP	-	True Positive
UTeM	-	Universiti Teknikal Malaysia Melaka
VS	-	Visual Studio