
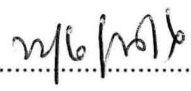


“I hereby declare that I have read through this report entitle “Aerial Monitoring on Mango Using Machine Vision Techniques” and found it has complied the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering”

Signature : 
Supervisor's Name : Nurkhalilah Mohd Ali
Signature : 

AERIAL MONITORING ON MANGO USING MACHINE VISION TECHNIQUES

OH KOK KEN

**A report submitted
in fulfilment of the requirement for the degree of Bachelor of Mechatronic
Engineering(Hons.)**

**Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

2015/2016

DECLARATION

"I declare that this report entitle "Aerial Monitoring on Mango using Machine Vision Techniques" is the result of my own research except as cited in the references. This report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature

:



Name

:

OH KOK KEN

Signature

:

23/6/2016

To my beloved father and mother

ACKNOWLEDGEMENT

First and foremost, I would thank Universiti Teknikal Malaysia Melaka (UTeM) for providing me an opportunity to conduct my final year project. I would like to express my deepest gratitude to my final year project's supervisor Madam Nursabillilah binti Mohd Ali from Faculty of Electrical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for her essential guidance and moral support towards completion of this report.

I would like to use this opportunity to thank Dr Muhammad Herman bin Jamaluddin for his precious advice and providing formal related lecture in this field.

I thanked my family as well as helpful peers for their consistent moral support and guidance in realizing the overall project. Last but not least, thank everyone who had lent their assistive support to the crucial parts in this project.

ABSTRACT

The entire project deals with development of shape identification algorithm and image training classification with Histogram of Oriented Gradient. The focus would be the process of detection and summing up the total number of mango on its tree with a drone and display it in MATLAB. The hypothesis made is the system could at least achieve the detection rate of 60%. The conventional method in harvesting mango has its limitation which leads to the degradation of mango's quality. Besides, the rate of production and the structure of the tree will be affected too. Previous researches have proven the significant role of machine vision to be embedded in agricultural technology. Nonetheless, the usage of a drone with an algorithm of image processing could be employed for a better and more precise mango's farming. The obvious benefit of utilizing drone is its capability to hover around the upper part of tree which is normally not reachable by human. The device could hover around mango trees and count the detected mango in a short operating time. It differentiates the mango from its background based on the images captured. The experiments were done in indoor as well as outdoor. Indoor experiment is less prone to noise meanwhile; outdoor experiment is sensible to noise. Eccentricity and form factor is the determining criteria for shape and size judgment. Machine vision's classification using training classifier would be another method under research. Analysis of obtainable result would be tabulated of based on confusion matrix. The detection rate in all experiments should exceed a detection rate of approximately eighty percent. In short, it provides a quick review for the mango grower, agricultural developer and investor.

ABSTRAK

Keseluruhan projek berkaitan dengan pembangunan algoritma berdasarkan pengenalan bentuk dan latihan klasifikasi imej dengan teori Histogram of Oriented Gradient. Tumpuan projek ialah pengesanan dan merumuskan jumlah mangga di atas pokok mangga. Hipotesis projek adalah sistem dapat mencapai kadar pengesanan 60% ke atas. Kaedah konvensional dalam penuaian mangga mempunyai kelemahan yang membawa kepada penurunan kualiti mangga itu. Selain itu, kadar pengeluaran dan struktur pokok itu akan terjejas juga. Kajian terdahulu telah membuktikan peranan penting penglihatan mesin yang boleh digunakan dalam teknologi pertanian. Namun begitu, penggunaan pesawat kawalan jauh dengan algoritma pemrosesan imej boleh digunakan untuk pertanian mangga yang lebih baik dan tepat itu. Manfaat yang jelas menggunakan pesawat kawalan jauh adalah keupayaan berlegar sekitar bahagian atas pokok yang biasanya tidak dapat dicapai oleh manusia. Peranti ini boleh berlegar sekitar pokok mangga dan mengira mangga dikesan. Kajian ini telah dilakukan dalam tempat yang mengalami kadar perubahan cahaya yang tinggi serta di tempat yang kadar perubahan cahaya yang rendah. Kesipian dan faktor kebentukan menjadi kriteria untuk menentukan bentuk dan saiz setiap mangga. Klasifikasi menggunakan latihan pengelasan mesin penglihatan akan menjadi satu lagi kaedah di bawah penyelidikan. Analisis keputusan diperolehi akan jadual daripada berdasarkan matriks kekeliruan yang berasaskan kaedah pembelajaran mesin. Dalam semua eksperimen, kasar ketentuan akan melebihi hampir lapan puluh peratus. Kesimpulannya, projek menyediakan satu kajian dan analisa cepat untuk penanam mangga, pemaju pertanian dan pelabur.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	i
	ABSTRACT	ii
	TABLE OF CONTENTS	iv
	LIST OF TABLES	vii
	LIST OF FIGURES	ix
	LIST OF ABBREVIATIONS	xiv
	LIST OF APPENDICES	xv
1	INTRODUCTION	1
	1.1 Motivation	1
	1.2 Problem Statement	4
	1.3 Objective	5
	1.4 Scopes	5
2	LITERATURE REVIEW	6
	2.1 Introduction	6
	2.2 Background	7
	2.2.1 Image Processing using Raspberry Pi	7
	2.2.2 Machine Vision in Agricultural Fruit Sorting	11
	2.2.3 Mango's Farming	24
	2.2.4 Object Classification and Pattern Recognition	32
	2.2.5 Training Classifier and Histogram of	37

	Oriented Gradient	
	2.3 Summary of the Chapter	41
3	METHODOLOGY	42
	3.1 Introduction	42
	3.2 Project Flowchart	42
	3.2.1 Project Methodology Flowchart	43
	3.2.2 Process Flow Diagram	44
	3.3 Gantt Chart	46
	3.4 Material Selection	46
	3.4.1 Type of Quadcopter	46
	3.4.2 Type of Controller Board	49
	3.4.3 Type of Sensor	50
	3.4.4 Type of Camera	52
	3.5 Hardware Design Sketches	54
	3.5.1 Raspberry Pi 2 Model B	54
	3.5.2 Raspberry Pi 2 with Prototype Case I	56
	3.5.3 Raspberry Pi 2 with Prototype Case II	58
	3.5.4 Quadcopter	60
	3.6 Software Design Key Stages	62
	3.6.1 Image Acquisition	62
	3.6.2 Image Type Conversion	63
	3.6.3 Image Enhancement	64
	3.6.4 Image Segmentation	65
	3.6.5 Morphological Processing	66
	3.6.6 Image Analysis	66
	3.7 Background Test	68
	3.7.1 Experiment 1	68
	3.7.2 Experiment 2	74
	3.8 Safety Factors and Precautions	83
4	RESULT AND DISCUSSION	84
	4.1 Introduction	84

4.2	Statistical Analysis	84
4.3	Eccentricity Analysis	92
4.4	Form Factor Analysis	94
4.5	Implementation of Confusion Matrix Algorithm	96
4.6	Training Image Classification	102
5	CONCLUSION AND RECOMMENDATIONS	113
5.1	Conclusion	113
5.2	Recommendations	115
6	REFERENCES	117
7	APPENDICES	121

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Object's compactness range corresponding to the shape.	8
2.2	Comparison between Previous Works	11
2.3	Classification based on Several Criteria	16
2.4	Comparison between methods used on Agricultural Fruit Sorting	22
2.5	Comparison over Method used in Mango's Farming	31
2.6	Comparison of Summarized Methods	36
3.1	Comparison between Model of Quadcopters.	47
3.2	Comparisons of Controller Board Used	49
3.3	Comparison between Types of Sensor Used	51
3.4	Comparisons of Type of Camera Used	52
3.5	Design Sketches of Raspberry Pi 2	54
3.6	Design Sketches of Raspberry Pi 2 with Prototype Case I	56
3.7	Design Sketches of Raspberry Pi in Prototype Case II	58
3.8	Design Sketches of Quadcopter with its Landing Skids	60
3.9	MATLAB Library for each Key Stages	67
3.10	Relationship between distance, a and distance, c to eccentricity	71
3.11	Type of Shape corresponded to Form Factor	72
3.12	Finalized Prototype	78
3.13	Actual Prototype	80
4.1	Sampled Mangoes under Inspection and Labelling	85
4.2	Actual Minor Axis Length, Measured Minor Axis Length, Actual Major Axis Length and Measured Major Axis Length.	87

4.3	Correlation between parameters x and y	88
4.4	Correlation between p and q	90
4.5	Types of Objects corresponded to its Eccentricity Values.	92
4.3	Type of Object corresponded with its Form Factor	94
4.7	Tabulated Data of Experiment	97
4.8	Table of Confusion Matrix	98
4.9	Detection Rate with its corresponding number of cascaded stages	102
4.10	Comparison of images with its corresponding number of training stages	103
4.11	Detection Rate with its corresponding False Positive Rate	105
4.12	Comparison of Total False Positive Number with varying False Positive Rate	107
4.13	Comparison of images with different RGB intensities	110
4.14	Comparison of bounding boxes merging method	111

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	The Production, Import and Export Statistics of Mango in Metric Tons [1].	2
1.2	Positioning Map for several tropical fruits in European market [2]	3
2.1	Raspberry Pi with Pi Camera Module [8].	7
2.2	Image processing steps involved to get a compact image of the object [8].	8
2.3	Histogram of HSI of objective image [9].	10
2.4	Histogram of HSI after Histogram Equalization [9].	10
2.5	Histogram of HSI after Histogram Equalization with Variable Enhancement Method [9].	10
2.6	Input Image of Orange [7].	12
2.7	Image processed by Gaussian Low Pass Filter [7].	12
2.8	Conversion from RGB into Binary Image [7]	12
2.9	Image after Restoration with Sobel Operator [7]	13
2.10	Edge Detection of Image [7]	13
2.11	Circular Fitting Method applied on image [7]	13
2.12	A plot of Manual Count against Machine Vision Algorithm [7]	14
2.13	Experimental Setup[11]	15
2.14	Experimental Setup [11]	15
2.15	Image Acquisition on Sampled Mango [12]	16

2.16	Mango on Chess Board [12]	17
2.17	Image Segmentation of Mango [12]	17
2.18	Improper Edge Detection [12]	17
2.19	Spline Curvature Splitting [12]	18
2.20	Major and Minor Axes [12]	18
2.21	Five Separated Regions for Analysing [12]	19
2.22	Tabulated Results sorted by Size and Region [12]	19
2.23	Overall Architecture of the System [13]	19
2.24	Mango's apex, stalk and equator [13]	20
2.25	Average values of RGB over few regions	20
2.26	A graph of sensitivity against Number of Features [13]	21
2.27	Conceptualized model of AAM [6]	24
2.28	AAM prototype [6]	24
2.29	Input Image [6]	25
2.30	Binary Image [6]	25
2.31	Peduncle Detection and Cutting [6]	26
2.32	Typical scene perceived by AAM robot [6]	26
2.33	Autonomous Orchard Fruit Harvester [13]	27
2.34	The control modes enabled by the autonomous orchard vehicle [13]	27
2.35	Laser-based row detection [13]	28
2.36	Harvesting Process [13]	28
2.37	Block Diagram of a Wireless Sensor Network [14]	28
2.38	Network Setup [14]	29
2.39	Hourly Chart Soil Moisture readings [14]	30
2.40	Daily Chart of Soil Moisture readings [14]	30
2.41	Confusion Matrix	32
2.42	Decision Trees	33
2.43	Probability Density Function of Bayesian Classifier	34
2.44	Clustering Analysis	35
2.45	Original grayscale image	37

2.46	Image filtered by Dx kernel [18]	37
2.47	Image filtered with Dy kernel [18]	38
2.48	Cell Groups [18]	39
2.49	Gradient Indication [18]	39
2.50	Face detection [21]	40
3.1	Project Flow Chart	43
3.2	Process Flow Diagram of FYP 1	44
3.3	Process Flow Diagram of FYP 2	45
3.4	Model 1	47
3.5	Model 2	47
3.6	Model 3	47
3.7	Finalised Quadcopter	48
3.8	Arduino Uno Rev.3	49
3.9	Raspberry Pi 2	49
3.10	Finalised Controller Board: Raspberry Pi 2	50
3.11	Logitech Webcam C310	52
3.12	Pi Camera	52
3.13	Finalised Camera Used	53
3.14	Solid Works's Copyright Logo	54
3.15	Top View of Raspberry Pi	54
3.16	Front View of Raspberry Pi	55
3.17	Side View of Raspberry Pi 2	55
3.18	Isometric View of Raspberry Pi 2	55
3.19	Top View of Raspberry Pi 2 with Wooden Case	56
3.20	Front View of Raspberry Pi 2 with Wooden Case	56
3.21	Side View of Raspberry Pi 2 with Wooden Case	57
3.22	Isometric View of Raspberry Pi 2 with Case No.1	57
3.23	Top View of Raspberry Pi 2 with Plastic Case	58
3.24	Front View of Raspberry Pi 2 with Plastic Case	58
3.25	Side View of Raspberry Pi 2 with Plastic Case	59
3.26	Isometric View of Raspberry Pi 2 with Plastic Case	59

3.27	Top View of Quadcopter	60
3.28	Front View of Quadcopter	60
3.29	Side View of Quadcopter	61
3.30	Isometric View of Quadcopter	61
3.31	MATLAB's Copyrighted Logo	62
3.32	Process in Image Acquisition	62
3.33	Image Acquisition	63
3.34	Image Conversion from RGB to Gray Scale	63
3.35	Filtering an Image	64
3.36	Binarize an Image	65
3.37	Dilate an Image	66
3.38	Labelling an object	66
3.39	Indoor Experimental Setup (Top View)	68
3.40	Indoor Experimental Setup	68
3.41	Tested Samples of Mango with Vernier Calipers used.	69
3.42	Process Flow Diagram of Experiment	70
3.43	Graph of Eccentricity against Distance, e	71
3.44	Illustration of an elliptical shape with varying amount of eccentricity	72
3.45	Sketched Circle	72
3.46	Sketched Square	73
3.47	Sketched Rectangle	73
3.48	Putty Configuration	74
3.49	VNC Server	75
3.50	Image Training Labeller	76
3.51	Cascading training labeller in MATLAB IDE	76
3.52	MATLAB IDE	77
3.53	Top View of Prototype	78
3.54	Front View of Prototype	78
3.55	Side View of Prototype	79
3.56	Isometric View of Prototype	79

3.57	Top View of Actual Prototype	80
3.58	Front View of Actual Prototype	80
3.59	Side View of Actual Prototype	80
3.60	Isometric View of Actual Prototype	81
3.61	The quadcopter hovers under a low light intensity	81
3.62	The quadcopter hovers under average light intensity condition	82
3.63	The quadcopter hovers under average light intensity condition	82
4.1	Graph of Eccentricity against Number of Sampled Objects	93
4.2	Bar Graph of Average Eccentricity of Tested Samples	93
4.3	Graph of Form Factor against Number of Sampled Objects	95
4.4	Average Form Factor against Type of Sampled Objects	95
4.5	Confusion Matrix	99
4.6	Graph of Confusion Matrix	101
4.7	Detection Rate Versus Number of Cascaded Stages	102
4.8	Variation of False Positive Detection with Number of Cascaded stages	104
4.9	Detection Rate against False Positive Rate	106
4.10	Variation of False Positive Rate with Number of False Positive Detection	108
4.11	Sign of Occluded Mangoes	111
4.12	Sign of Overlapped Mangoes	111
4.13	Merging bounding boxes into one single unit	112

LIST OF ABBREVIATIONS

FYP	-	Final Year Project
MATLAB	-	Matrix Laboratory
RGB	-	Red, Green and Blue
HSI	-	Hue, Saturation and Intensity
HSV	-	Hue, Saturation and Value
CCD	-	Coupled Charge Camera
CMOS	-	Complementary Metal Oxide Semiconductor

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	MATLAB Code	121
B1	Gantt Chart for FYP 1	127
B2	Gantt Chart for FYP 2	128

CHAPTER 1

INTRODUCTION

1.1 Motivation

In pre-historic time, most human race survives and builds up their early civilization via agricultural-based living. Food like tropical fruit remained to be a vital source of fiber and minerals to all livings. Meanwhile, in economic wise, agricultural sector has shifted from a field merely outsourcing product to fit industrialization purpose to an utmost importance field [1]. It provides increment in exports revenue, employment rate and level of food security of developing countries. In [1], mango as local tropical fruit has become the main focus in horticulture industry particularly in developing countries for exporting purpose.

50% of all tropical fruit produced worldwide is mango. Mango's production has skyrocketed over a decade to fulfill the world wide's demand, especially United States of America and Europe. In addition, most mango producing countries has potentials to increase the production rate.

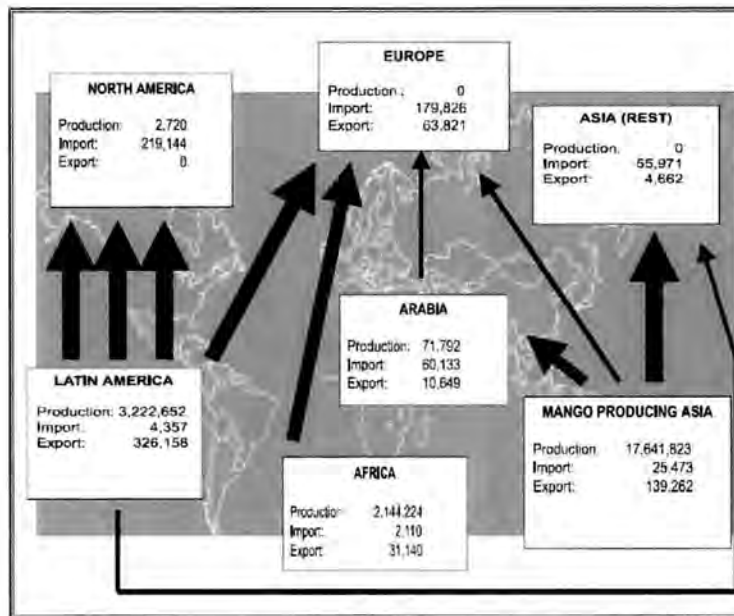


Figure 1.1: The Production, Import and Export Statistics of Mango in Metric Tons [1].

According to [2], one of the major fruit produced in Malaysia is mango. It marks the export quantity of 126,000 metric tonnes in the year of 2002. [3] also iterates that tropical fruit are highly demanded and its valuable for market competition with other fruits. Pineapple, papaya and mango would be the most common tropical fruits. Mango has been categorized as a year-round demanded tropical fruit in European market. Its exoticness promotes penetrability into European market. They forecast the possible increment import volume for several major tropical fruits with largest percentage increment for mango which is 9.7%.

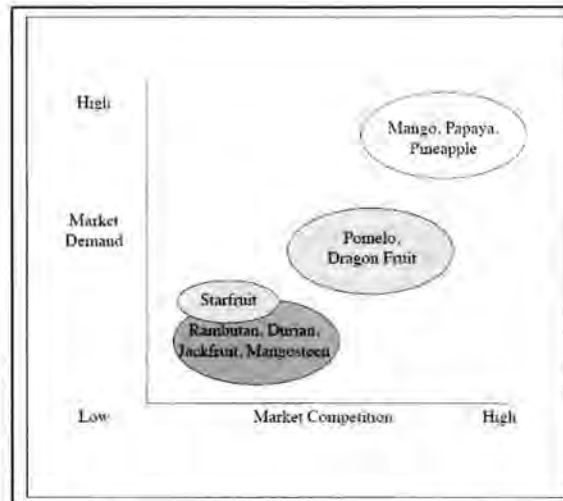


Figure 1.2: Positioning Map for several tropical fruits in European market [2].

In order to promote Malaysia's local mangoes as tastier and tender, investment is needed for various profitable segments or platforms. Japanese expresses their affection towards mangoes because of its texture around mid-year 2007 [5]. In certain point of view, mango was accessed as it contains the most acceptable sweet taste with its texture too. Besides, respondents were showing positive attitude towards mango as they were most likely to purchase.

In Malaysia alone, approximately 26% of the Gross Domestic Product is contributed by agricultural sector. Within the cultivated area, 6.4% is allocated for fruits particularly mango. According to Department of Agriculture, in year 2013, 5,270.4 hectares of land is mango farm with a harvested area of 3259.8 hectares. The total value of production costs around RM 61,958,000. The statistical figure denotes the significance of maintaining and further improving the amount of harvested product which in turn could contribute to Malaysia's economy [5].

1.2 Problem Statement

Sustainable agricultural concept requires an adequate and optimum level of modern technology to yield a good quality crop. There were numerous obstacles encounter by mango's grower to nurture a standardized product. One of the issues troubling agriculture's entrepreneur is heavy loss due to damaged and spoilt mangoes [6]. The common reasons were inadequate knowledge in technical and management wise. For instance, manual plucking and vibrator's assistance method to harvest goods is a leading factor. Both ways of harvesting without proper judgment made on the crops would surely dampen the production rate and generated revenue. Shortage in skilled labour will result in unripe fruit to be pluck off or over-ripened mango becomes useless. In addition, challenging or unpredictable environmental changes would also affect the yields. Mango tree is not sustainable to windy condition. For example, mango will be blown and sway in the wind. Most mangoes will turn bad after falling into bare ground without any protective wrapper.

Machine vision technique based on shape analysis will be applied to tackle the issues arises [7]. Nevertheless, a compatible colour detection algorithm will be complement for the former method to further improve the system's efficiency. Both of the methods used will quantify the related parameters in the project. A better perspective of monitoring system using aerial vehicle is expected to further enhance the result. Relevant experiments will be conducted throughout the project to offer a judgment that applied machine vision technique is capable to replace human workforce. The allocated device will scan the ripeness of the mango and provide logical justification.

1.3 Objective

The main objectives of conducting the project are:-

1. To develop an algorithm for mango identification by extracting specific image of ripe mango on the tree.
2. To develop an intelligent shape detection system based on the extracted mango features.
3. To validate the performance of the system using a remote-controlled aerial vehicle.

1.4 Scope

The scopes of the research are listed as follow:-

1. The project covers the development of algorithm and verification of image processed via an aerial vehicle.
2. A non-movable camera is attached on the lower part of the aerial vehicle.
3. Surrounding lighting, shadow's visibility and occlusion will be taken as algorithm's parameters while conducting field test.
4. The developed algorithm is supposed to navigate on a single mango tree only.
5. The height of flight test shall not be more than 10 meters. Camera attached is position properly so that it can capture appropriate images.
6. The formatted system is applied to mango's detection on its tree only.
7. Performance of real time test would vary depending on lighting and shadow formation constraint.