Mango (Harum Manis) Quality Grading System

Mohd Firdaus Bin Mohd Mokhtar

A project report submitted in partial fulfillment of the requirements for the award of the Degree of Master of Electrical Engineering

Faculty of Electric and Electronic Engineering
Tun Hussein Onn University of Malaysia

JANUARY 2014

ABSTRACT

Weight and size are the major parameters that the consumer identifies to be related to the grade of mango. According to Federal Agricultural Marketing Authority (FAMA) Malaysia, size of a mango is determined by weight. The mango named "Harum Manis" is a famous agricultural product of Perlis, Malaysia. To date, the farmers still rely manually on their visual inspection and experience to grade the mangoes into three sizes, i.e. A, B and C, where A is the largest mango, B is the medium and C is the smallest. This method is not consistent and erroneous amongst the farmers due to varying experience and human errors. Moreover, it becomes costly when more workers are needed. This paper investigates this issue and demonstrates a mechatronic system to grade the mangoes by weighing. The user could read the grade from a display. This method provides a consistent and easy-to-use solution to the farmer.

ABSTRAK

Berat dan saiz ialah paremeter utama yang dititikberat oleh pembeli dalam menentukan grad buah manga. Menurut Lembaga Pemasaran Pertanian Persekutuan (FAMA) Malaysia, saiz manga adalah ditentukan oleh berat mangga. Mangga yang dinamakan sebagai "Harum Manis" adalah produk pertanian yang terkenal di Perlis, Malaysia. Pada ketika ini, petani masih bergantung pada kaedah manual iaitu pemeriksaan visual dan pengalaman untuk penggredan mangga pada tiga saiz iaitu A, B dan C yang mana A ialah mangga yang paling besar, B untuk sederhana dan C untuk yang paling kecil. Kaedah ini tidak konsisten dan mewujudkan kesilapan di kalanagn petani kerana pengalaman dan kesilapan manusia. Selain itu, kos menjadi tinggi apabila lebih ramai pekerja diperlukan. Laporan ini mengkaji isu tersebut dan menunjukkan sistem mekatronik bagi penggredan mangga dengan menggunakan berat. Pengguna boleh membaca gred dari paparan. Kaedah ini disediakan untuk memudahkan petani mengred secara konsisten.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

DAQ	-	Data Acquisition
LabView	-	Laboratory Virtual Instrumentation Engineering Workbench
PC	-	Personal Computer
LCD	-	Liquid Crystal Display
GUI	-	Graphical User Interfaces
VDC	-	Voltage Direct Current
VAC	-	Voltage alternation Current
RGB	-	Red Green Blue
CCD	-	Charge- Coupled Device

CHAPTER 1

INTRODUCTION

This chapter discusses about the project background, the problem of the project, the objectives of the project and project scopes.

1.1 Project Background

Mango, Mangifera indica L., is a member of the family Anacardiaceae. Mango has become naturalized and adapted throughout the tropics and subtropics. There are over 500 classified of mango varieties, some of them have evolved and have been described throughout the world. The genus of Mangifera consists of 69 species and mostly restricted to tropical Asia [1].

The highest variety of mango occurs in Malaysia, particularly in peninsular area and about 28 species are found in this region (Ian, 2006). Malaysia lies wholly within the tropics, which encompasses heavy precipitation, high temperatures, and high humidity, which are the favoring factors for mango plants. There are several varieties of mango grown in Malaysia; the better known cultivars are Golek (MA 162), Masmuda (MA 204), Maha 65 (MA 165), Chok Anan (MA 224), Sala and Harum Manis. Generally, Harum Manis is very suitable for the export market as it has desirable color and sweetness and good eating quality with good aroma then other.

Overseas demand for Harum Manis has steadily increased especially from Japan market. However in Malaysia this mango only can grow in Perlis and fruiting season only last for two months. Under the Tenth Malaysia Plan, the Perlis State Government has approved a significant allocation to the Department of Agriculture of RM 1.8 million a year for RM 9 million. It is targeted 1,000 hectare of new planting Harum Manis will be developed by 2015, with an average of 200 hectare per year.[26]

Figure 1.1: Harum Manis Mango [25]

Figure 1.2: Texture of Harum Manis [25]

1.2 Problem Statement

Demand from consumer for quality produces, consistent behavior of machines in compare with humans, the insufficiency of labor and attempt to reduce labor costs are the main motivations of automated packing and sorting system in past decades [1]. In real environment for grading Harum Manis, plantation agencies or farmer just used his/her experience thru eye to select either to grading for size A, B or C by assuming the weight of Harum Manis . This manual sorting technique will generate some problem such as error in grading Harum Manis, delaying task for sorting because human can't work continuously and if there so many tons of Harum Manis in that season, farmer must pay more worker to do the job. This will increase a cost. A grading technique will be designed and developed to assist the farmers in order to overcome this weakness method. The system will make the grading process more effective, faster and most the important is farmer can afford this technique because it's a low cost system.

Figure 1.3: Harum Manis Manual Grading by Worker

1.3 Objectives

This project aims at improving the performance of grading Harum Manis mangoes. This aims is translated into set of objectives which can be summarized as follows:

1. To classify and grade Harum Manis.
2. To develop weight scale for Harum Manis.
3. To analysis weight of Harum Manis.

1.4 Scopes

Mango (Harum Manis) Quality Grading System is developed in order to overcome the grading process that is manually doing by farmer based on its size and weight. To make sure objectives of this project archive, scopes for this project was decided as list below:

1. Using Arduino Uno Board as grading system.
2. Using load cell as main sensor to determine weight.
3. LabView software for comparison between outputs from LCD.

1.5 Thesis Arrangement

As an overview, the structure of this report is organized as follows:

1. Chapter 1 - This chapter describes a general introduction of the project, problem statement, objectives and project scopes.
2. Chapter 2 - Provides details literature review that includes an introduction to some basic concepts and a survey of existing work in the areas of fruits grading systems and Harum Manis grading systems.
3. Chapter 3 - Illustrated the method of the project where the grading design is the main part of this project. This chapter explain the method that has been used for this project and the process of designing the software and circuits.

4. Chapter 4 - Displays some results from the system and these results are analysed and discussed.
5. Chapter 5 – Assessment of the objectives will be explained together with research efforts done and also future work for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will provide the review from previous research that is related to this final year project. There are previous researches on sorting and grading system using different materials and tools, design and other method to obtain weight and given grade of mango Harum Manis or other fruits.

2.2 Automation Of Sorting System

Automation of sorting by size is a challenging and complex research issue. There have been many attempts on automation of quality sorting such as using computer 2D/3D vision-based [2 ~ 4], microwave measurement technique [5] and weights control system [12, 14]. A computer vision-based system is the most reliable system for the analysis process. The vision system directly measures the fruits without physical contact with it. However, physical damage to mango may occur during the sorting and distribution process.

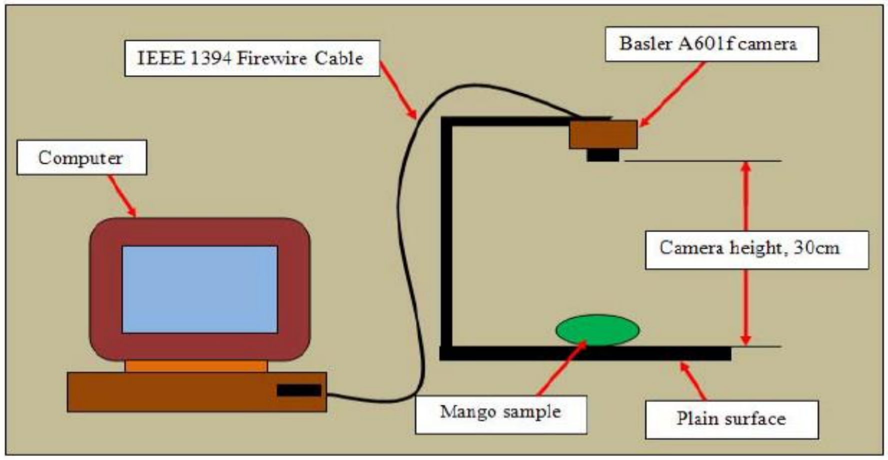
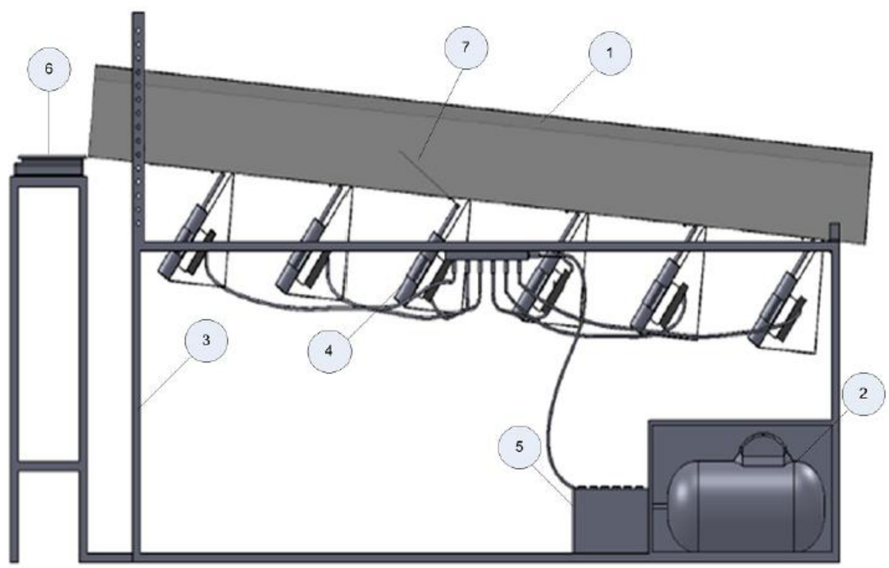


Figure 2.1: Elements of machine vision system by Bio-inspired Vision Fusion for Quality Assessment of Harum Manis Mangoes [2]

One of the methods to determine quality of Harum Manis is by using charge coupled device (CCD) camera and Infrared (IR) camera. Harum Manis Mango A Fourier-based shape separation method was developed from CCD camera images to grade mango by its shape and able to correctly classify 100%. Colour intensity from infrared image was used to distinguish and classify the level of maturity and ripeness of the fruits. The finding shows 92% correct classification of maturity levels by using infrared vision [2]. Unfortunately this method was not suitable for small and medium grower because the system is too expensive. Another reason is after Harum Manis has been taken from three, it will wash and pack inside a box for distribution. On the boxes surface the information about a date for Harum Manis maturity is estimate.

Other method, described image processing and computer vision techniques to analyse the 2D and 3D mango's physical properties. Some parameters are defined and calculated for physical properties. These include projected area (A), length (L), width (W), thickness (T), 3D volume (V), and 3D surface area (S). One hundred and eighty two "Nam Dokmai" cultivar mangoes in three sizes (SS, S and L) were evaluated. They proposed their techniques could be a good alternative and more feasible method for grading and sorting mango comparing to human's manual [3].

A weight-based sorting machine is designed for apple fruit. The designed machine employs load cell to sort the fruits in 6 categories. Using load cell in fabrication of a machine requires several considerations regarding its amplification. Peak Signal to Noise Ratio (PSNR) criterion is employed to overcome the challenges associated with load cell signal amplification. Modification of the primary machine based on PSNR results give rises to a machine with acceptable performance [12]. After that Hiwa Golpira and Hêmin Golpîra improve their machine by apply a load cell with rated capacity equal to 2 kg and 1mv/v sensitivity is employed in measuring system. The profiteered load cell output signal is amplified before being applied to the control unit in order to be easily detected by microcontroller. Then by using same technique PSNR criterion is used to analyse the machine performance which aids its improvement.[14].



The grading machine model; 1) duct; 2) pneumatic pump; 3) frame 4 Pneumatic cylinder; 5) electrical motor; 6) weight sensing unit; 7) chute

Figure 2.2: Apple Sorting Machine by Hiwa Golpira [14]

Advances in laboratory instrumentation have made it possible to introduce a variety of sensors for practical applications in specialty crops, but the transfer of the promising, and in many cases proven techniques to the industry is taking place at slow pace. Computer vision-based online fruit grading systems are already in use in Europe and the USA (Kondo, 2010); however, they are only used for basic colour and size measurements. Hence, there are great opportunities for turning these promising or proven techniques into computerized and automated equipment for commercial applications [6].

The best models for dropping and rising time of potato and tomato were found as a function of water and vegetables densities, shape factor and vegetables' volume. The differences between water and vegetables densities were found to be the most effective parameter on their dropping and rising time while shape factor and volume of vegetables hadn't important influence on traveling time. It can be concluded that in the sorting systems, difference in terminal velocities of vegetables can be used as a suitable factor for design the sorting system devices [7].

Theoretical models predict that fruit will reach terminal velocity within a few centimetres of starting from rest and that fruit mass has only a small effect on drop time. Fruit density is a strong indicator of internal sugar status in kiwifruit, and this measurement minus the density of the supporting fluid has a major effect on drop velocity and thus on the transit time to reach the bottom of a fluid tank. Practical studies show that the models give a good account of fruit movement, although fruit mass seems to have an even lower effect than predicted. Fruit hairs, fruit shape, and initial fruit orientation also effect velocity but should not be of a magnitude to cause concern [8].

Density is the most effective parameter of these apricot varieties as concerns the dropping time, and that apricot fruits of approximately constant volume can be sorted based on their densities. This is due to the fact that fruits with approximately constant volume and different densities show different dropping times and can be separated accordingly [9]. The best model for terminal velocity of tomato as a function of water and tomato densities, shape factor and volume was modelled with determination coefficient of 0.84. Based on statistical analysis, fruit density created a considerable influence on terminal velocity while the parameter of fruit volume shape factor had small effect on terminal velocity. It can be concluded that in sorting systems, difference in terminal velocities of tomatoes could be addressed as a crucial factor for designing sorting systems [10].

The recent developments in computer vision system in the field of agricultural and food products. The adoption of this emerging technology in sorting and grading of fruits and vegetables will be of immense benefit to this country. Some of the other associated benefits include more efficient operation, production of more consistent product quality, greater product stability and safety. Computer vision systems have been used increasingly in industry for inspection and evaluation purposes as they can provide rapid, economic, hygienic, consistent and objective assessment. However, difficulties still exist, evident from the relatively slow commercial uptake of computer vision technology in all sectors. Even though adequately efficient and accurate algorithms have been produced, processing speeds still fail to meet modern manufacturing requirements [11].

During transport and handling, apple fruits are subjected to various loading conditions that may lead to damage and bruising. Methods for assessing and predicting apple bruising caused by repetitive impact loads during the course of transport and handling, impact pressure and fruit bruising using a pressure-sensitive film technique were measured by a simple drop test. As the impact test, apples were dropped from different heights for a certain number of times. Both bruising areas and volume increased relative to the dropping height and the number of drops. For the different number of drops, significant difference in bruising area or volume was found as a result of dropping height. Thus, impact force and pressure between the apple and the impact surface were analyses in order to assess and predict apple bruising [13].

2.3 Grading System

In agricultural industry the efficiency and the proper grading process is very important to increase the productivity. Currently, the agriculture industry has a better improvement, particularly in terms of grading of fruits, but the process is needed to be upgraded. This is because the grading of the fruit is vital to improve the quality of fruits. Indirectly, high quality fruits can be exported to other countries and generates a good income. Mango is the third most important fruit product next to pineapple and banana in term of value and volume of production. There are demands for this fresh fruit from both local and foreign market. However, mangoes grading by humans in agricultural setting are inefficient, labour intensive and prone to errors. Automated grading system not only speeds up the time of the process but also minimize error.

Analysing image using computer vision has many potential functions for automated agriculture tasks. One of the researchers has made the methods to grading of Harum Manis is by using digital fuzzy image. Tajul Rosli B. Razak, Mahmod B. Othman, Mohd Nazari bin Abu Bakar, Khairul Adilah bt Ahmad has introduced the digital fuzzy image to grading the Harum Manis [16]. The main objectives of this study are to perform mango grading process by applied the fuzzy image clustering for local mango in Perlis and follow three objective. First objective to propose and develop fuzzy image clustering algorithm, second objective to identify and evaluate the best algorithm for clustering on local mango in Perlis and third objective compare the experimental results with human expert grading decision and to further optimize the system. This study proposes a mango grading method for mangoes quality classification by using fuzzy image analysis. Refer Table 2.1, show step and method to grading Harum Manis. The algorithm of the proposed method consisted of five steps :

Table 2.1: Step and method to grading process [16]

STEP	METHOD
Step 1	Determine the size of mango by calculating the area of image object
Step 2	Detect the colour of mango by determine the mean of three colour array for red, green and blue.
Step 3	Apply edge detection algorithm to determine skin of image mango
Step 4	Fuzzy Inference Rule is applied for three values of size, colour and skin to compute the grade of mango.
Step 5	Rank the mango quality based on mango grade

The framework of this study is shown in Figure 2.3 and the result from the process grading is shown in Figure 2.4 result of digital image processing and Figure 2.5 is a result from fuzzy logic.

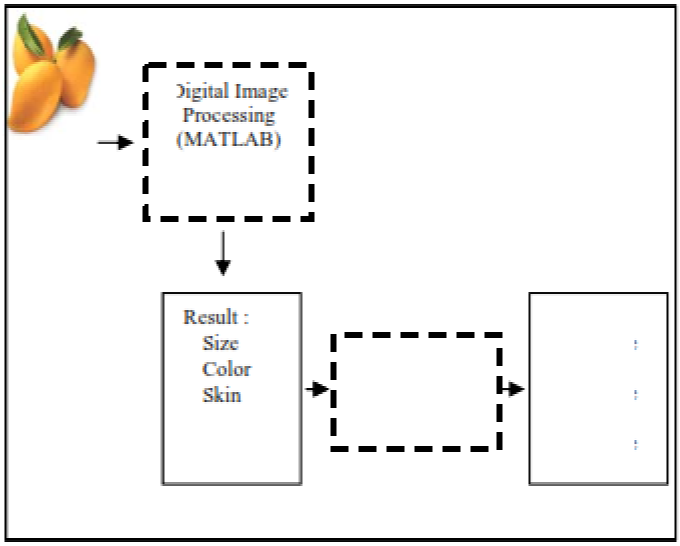


Figure 2.3: Framework of digital fuzzy image to grading the Harum Manis [16]

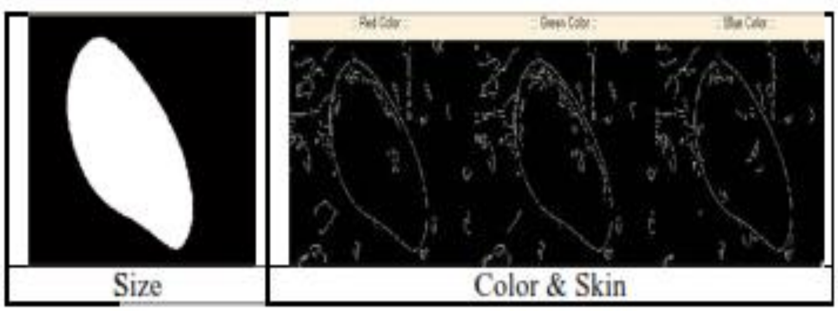


Figure 2.4: The result of digital image processing [16]

Sample of Mango	Size	Color	Skin	Fuzzy Result	Grading
	8.4391	10.5541	90.1548	5.0	GRADE B
	11.75	10.94	97.17	5.3	GRADE B
	7.20	10.938	83.40	5.4	GRADE B

Figure 2.5: Result of fuzzy classification [16]

The other researcher has made automated oil palm fruit grading system using artificial intelligence. Automated grading system for oil palm fruit is developed using the RGB colour model and artificial fuzzy logic. The purpose of this grading system is to distinguish between the three different classes of oil palm fruit which are under ripe, ripe and overripe [17]. The ripeness or colour ripening index was based on different colour intensity. The grading system uses a computer and a CCD camera to analyse and interpret images correspondent to human eye and mind. The computer program is developed for the image processing part like the segmentation of colours, the calculation of the mean colour intensity based on RGB colour model and the decision making process using fuzzy logic to train the data and make the classification for the oil palm fruit. The grading system depends on the colour extracted from the image. Therefore, colour features extraction plays an important role in developing this grading system. Figure 2.6 show about automated grading system process [17].

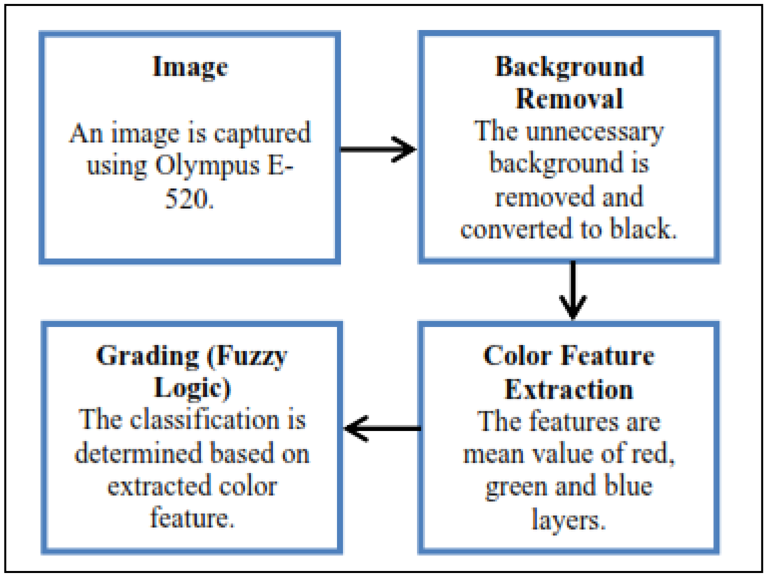


Figure 2.6: Automated grading system process [17]

Next researcher Üsmail Kavdir and Daniel E. Guyer developed Apple Grading Using Fuzzy Logic. The following objectives were included in this study first to design a FL technique to classify apples according to their external features developing effective fuzzy membership functions and fuzzy rules for input and output variables based on quality standards and expert expectations, second to compare the classification results from the FL approach and from sensory evaluation by a human expert and last objective is to establish a multi-sensor measuring system for quality features in the long term. Finding from this study are FL was successfully applied to serve as a decision support technique in grading apples [18]. Grading results obtained from FL showed a good general agreement with the results from the human expert, providing good flexibility in reflecting the expert expectations and grading standards into the results. It was also seen that color, defects and size are 3 important criteria in apple classification.

Muhaemin, M, Herwanto, T, Prijatna, D, Saukat, M and Sugandhi, WK [19] introduced An Automatic Tomato Grading Machine Based on Visual Evaluation. based on visual evaluation. This method requires highly skilful labour. Nevertheless, it may results inconsistently. Therefore it is necessary to devise a new method which can grade tomato fast and accurately. The objective of this research is to design an automatic tomato grading machine based on visual evaluation. Most tomato grading schemes are conducted based on the weight and maturity of tomato. In this research, both variables were predicted from captured tomato image and then processed with image processing algorithms. Developed image processing program successfully classified tomato with an accuracy of 95.5%. Based on this, a prototype machine with mechanical feeder was designed and fabricated. Test results showed that it has a capacity of 1200 tomato/hour. However, rough handling during processing lead to mechanical bruise on 4% of processed tomatoes.

Abdolabbas Jafari, Mohammad Reza Zarezadeh and Atefeh Fazayeli [20] introduced Orange Grading Based on Visual Texture Features. The objectives of this project were to extract some texture features from the images captured in visible spectra from citruses with different skin thicknesses, determine the skin thickness factors of the samples from the cross sectional images and investigate the correlation between the textural features of the images and skin thicknesses of the fruits. It is commonly known that citruses with coarser surface have a thicker skin while smooth and thin skin is more preferred.

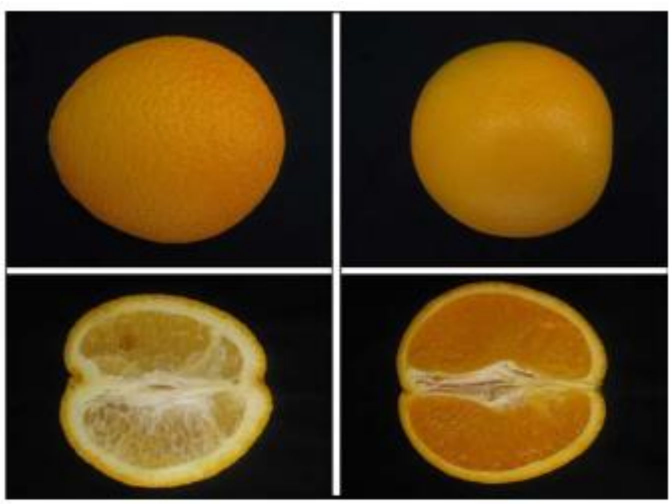


Figure 2.7: Oranges with coarse and smooth surfaces and their corresponding skin thicknesses [20]

To provide a wide range of data for such verification, oranges with various skin roughness's been collected. Images were taken by means of a normal RGB camera with a resolution of 2592×1944 pixels. To investigate the correlation between the coarseness and thickness of the skins two separate measurements were made as following.

Based on the literature review, the researchers try to apply different methods to grade the fruits. The most popular technology for fruit grading system normally based on the colour of the skin of the fruits. It used camera with the implementation of fuzzy logic algorithm for grading classification. Harum Manis is a special fruits, the skin colour of Harum Manis mango is always green even when fully ripe [27, 28]. Thus, the skin colour technique that used camera is not suitable for grading Harum Manis. Therefor another method that use load cell will develop to grading Harum Manis. Furthermore grading by using load cell is a most low cost technique.

2.4 Summary

Overall this chapter refers to previous studies that have been conducted researchers found that many studies have shown positive results or outcomes of the techniques for sorting and grading of Harum Manis. Therefore, the information discusses in the literature review chapter directly reinforces the finding of the project undertaken.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Figure 3.1 shows flowchart of methodology implemented during this project. Quality grading system has a varies in different ways of design and development. It depends on the aim, objectives and applications. Nowadays, there are plenty of researches, tests and trials being conducted to discover the most effective, simplest and cost effective ways of grading system. In common, grading system consists of different design options, various types of sensors and so on. Each design components has its own specific functions, advantages and disadvantages compared to others design. Therefore, the purpose of this chapter is to deliver the first hand conceptual ideas of the vital criteria such as the most suitable, light-weighted, user-friendly and commercial available for this project.

In this chapter, a brief introduction of the selected component that has use will be described. For the hardware section, the selected component and tools used in this design will be listed clearly regarding their specification and characteristics. Next, the procedures of setting up the software are included in the software section.

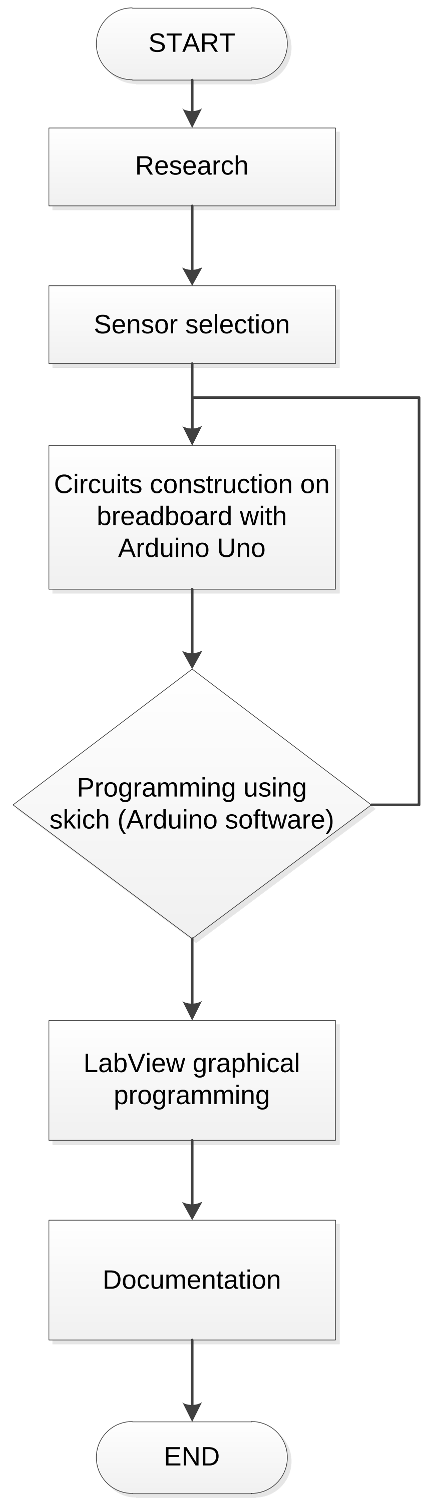


Figure 3.1: Flowchart of overall project

3.2 System Operational

The methodology for the implementation of this proposed grading mango Harum Manis based on their weights refer to Figure 3.2. A model is designed adaptation from Hiwa Golpira, Hêmin Golpîra ,'Improvement of an Apple Sorting Machine Using PSNR Criterion '.

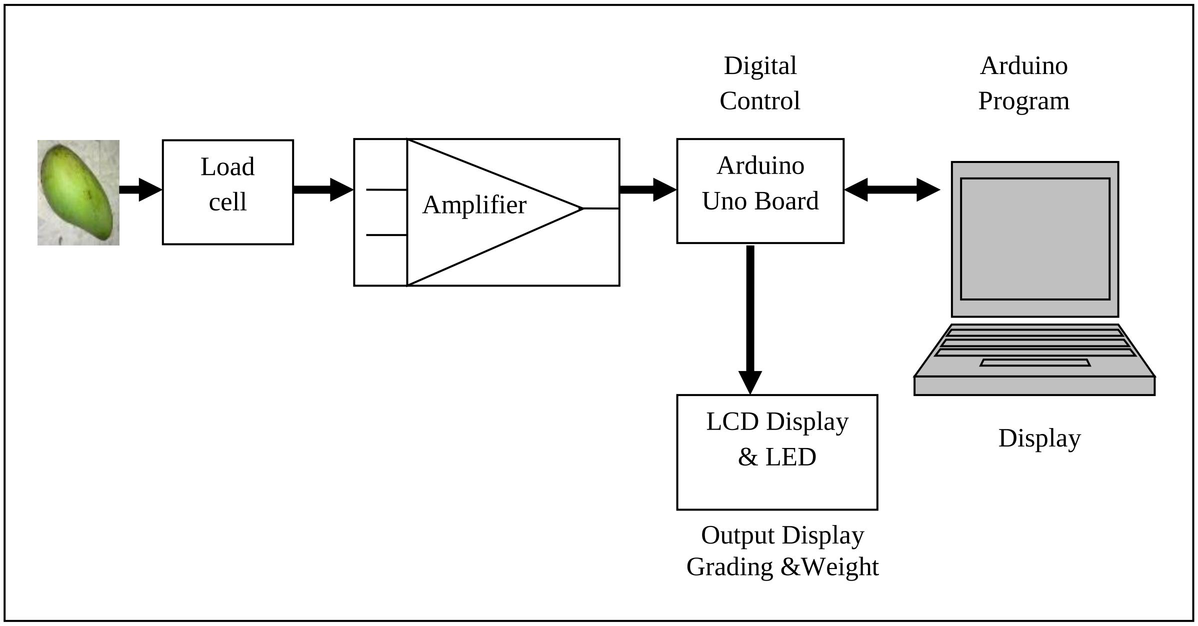


Figure 3.2: Block diagram of the grading system

According to the suggested model the experimental system is fabricated as shown Figure 3.2 above. A load cell sensing weight of mango. The function of amplifier is to increase voltage from load cell and then transfer the value to Arduino Uno Board. Arduino Uno Board process the voltage and transfer to PC using Arduino software for display analogue value and weight in gram. At the same time LCD will display the suggestion weight and LED for grading will on. In this project use three LED to sign grade of Harum Manis. Blue LED for display grade A, green LED for display grade B and red LED for display grade C. Blue LED will on if the weight of mangoes more than 600 grams for grade A, while the green LED will on if the weight of mangoes between 300 grams to 600 grams and red LED will on if the weight less 300 grams for grade C. The flow chart of this process is shown in Figure 3.3.

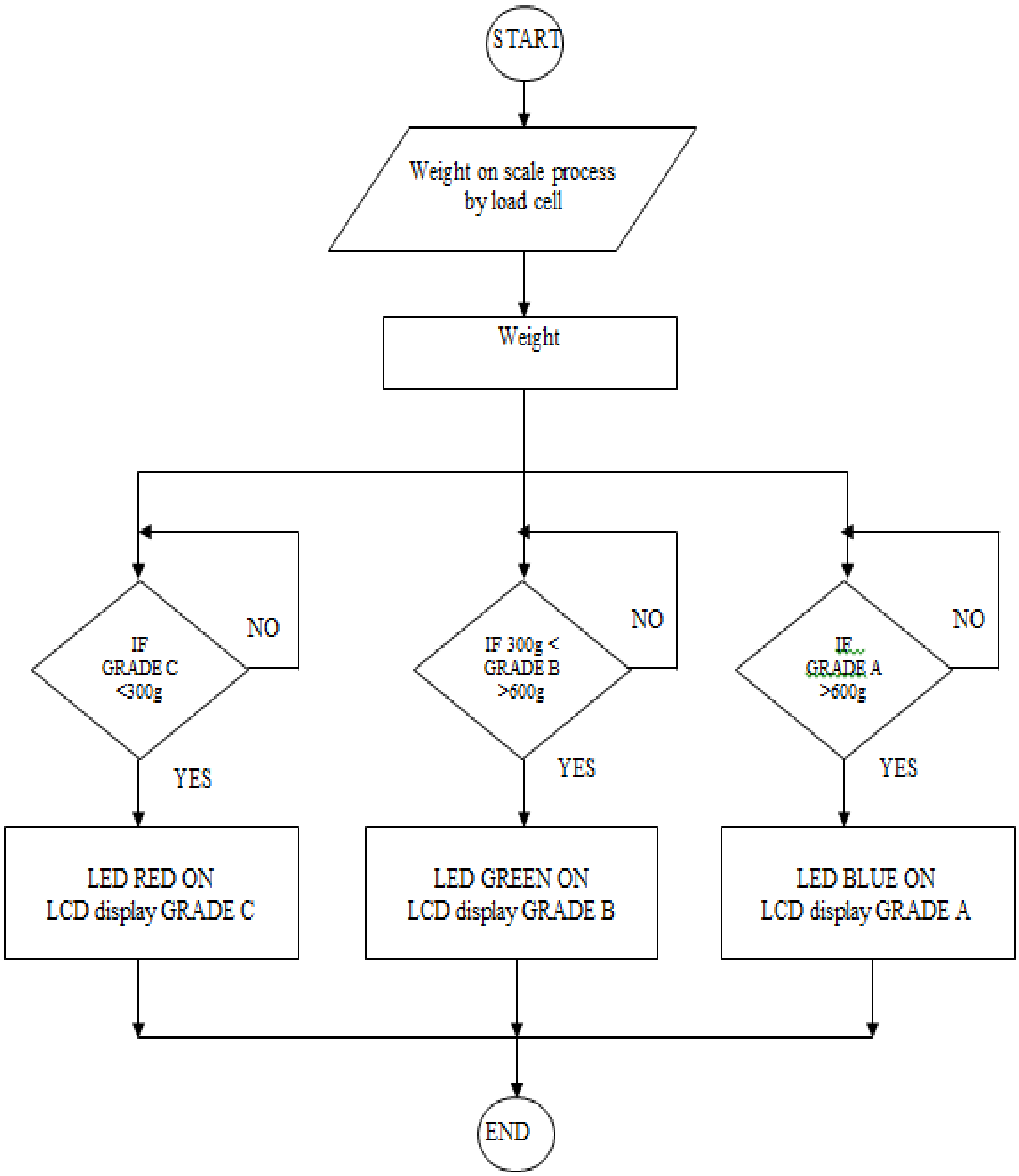


Figure 3.3 : Flowchart of the Grading System

3.3 Load Cell

The load cell in Figure 3.4 is an aluminium beam with two strain gages mounted on opposing sides. Common load cell are made of a resistive metallic foil that is mounted to a non-conductive backing material. Applying a force to the load cell, normal to the gages, creates a twisting moment in the cell, resulting in tensile and compressive forces in the gage and a respective increase or decrease in resistance.

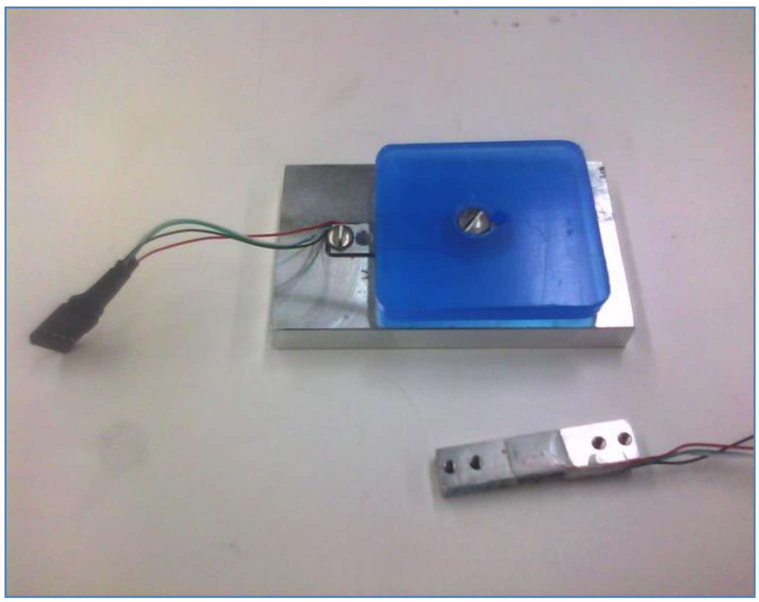


Figure 3.4 : Strain Gauge (Load Cell)

The load cell is acting as a catilever beam. When a force is applied to the right end of the beam, the lower train gage is strained in compression and the upper gage is in tension. The compressive and tensile strains cause the resistance of the strain gages to change (lower for compressive and higher for tensile) [21]. Load cell only make a very small change in voltage, so researcher have use an instrumentation amplifier to increase the voltage to use with other equipment. So researcher use INA125 Instrumentation Amplifier to settle this problem.

3.4. INA125 Instrumentation Amplifier

This component used because output from load cell is very small. It gained signal from load cell to suitable value where the Arduino Uno board can used for signal processing.

The INA125 is a low power, high accuracy instrumentation amplifier with a precision voltage reference. It provides complete bridge excitation and precision differential-input amplification on a single integrated circuit. A single external resistor sets any gain from 4 to 10,000. The INA125 is laser-trimmed for low offset voltage (250µV), low offset drift (2µV/°C), and high common-mode rejection (100dB at G = 100). It operates on single (+2.7V to +36V) or dual (±1.35V to ±18V) supplies. The voltage reference is externally adjustable with pin-selectable voltages of 2.5V, 5V, or 10V, allowing use with a variety of transducers. The reference voltage is accurate to ±0.5% (max) with ±35ppm/°C drift (max). Sleep mode allows shutdown and duty cycle operation to save power. The INA125 is available in 16-pin plastic DIP and SO-16 surface-mount packages and is specified for the -40°C to +85°C industrial temperature range [22]. Refer to figure 3.5 is an example of INA125 that has been used.

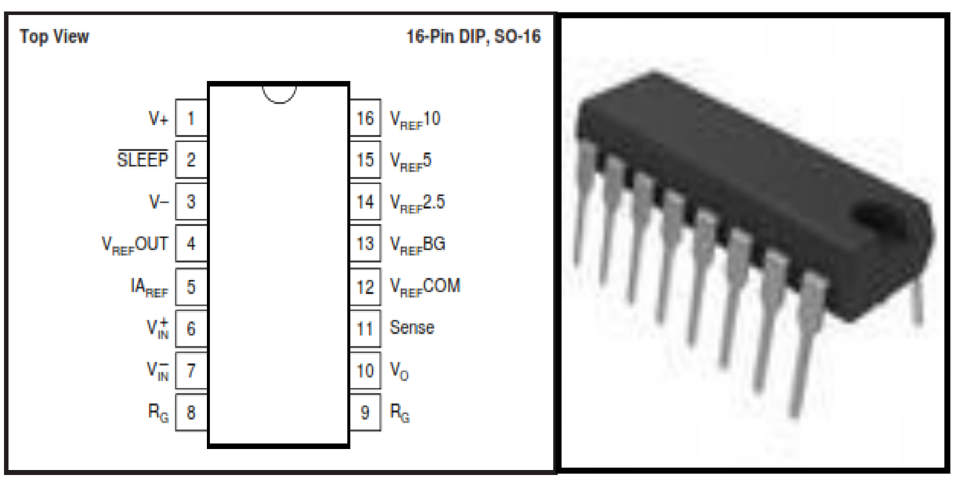


Figure 3.5 : Instrumental Amplifier INA125 And It's Pin Configuration

3.4.1 Types of operational amplifiers

Six configuration of operational amplifier are reported. There are:

1. Inverting amplifier.
2. Non-inverting amplifier.
3. Differential amplifier.
4. Summing amplifier.
5. Voltage follower amplifier.
6. Instrument amplifier

1. Inverting amplifier

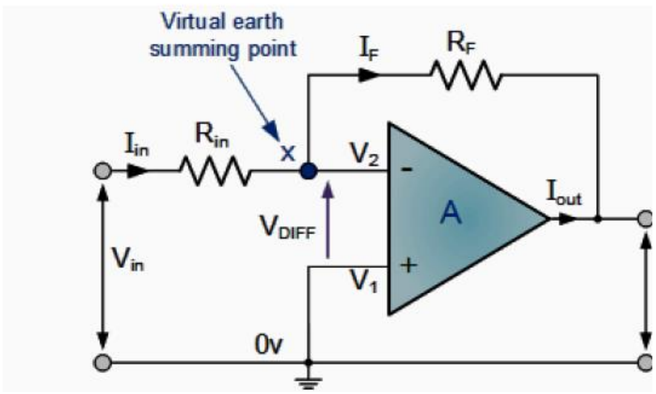


Figure 3.6: Inverting amplifier circuit [24]

In this Inverting Amplifier circuit Figure 3.6 the operational amplifier is connected with feedback to produce a closed loop operation. For ideal op-amps there are two very important rules in inverting amplifiers, these are: "no current flows into the input terminal" and that "V1 equals V2", (in real op-amps both these rules are broken). This is because the junction of the input and feedback signal (X) is at the same potential as the positive (+) input which is at zero volts or ground then, the junction is a "Virtual Earth". Because of this virtual earth node the input resistance of the amplifier is equal to the value of the input resistor, Rin and the closed loop gain of the inverting amplifier can be set by the ratio of the two external resistors. Current, (i) flows through the resistor network as shown in Figure 3.7. Equations shown below (3.1 - 3.7) are the equation involved in inverting amplifier operation.

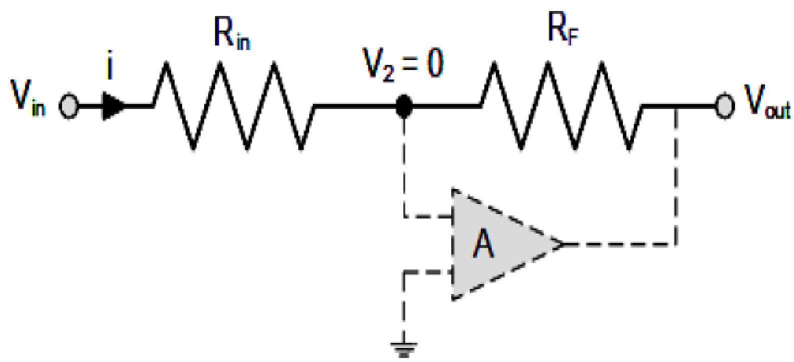


Figure 3.7: Inverting amplifier operation [24]

$$i = \frac{V_{in} - V_{out}}{R_{in} + R_{out}} \tag{3.1}$$

$$i = \frac{V_{in} - V_2}{R_{in}} = \frac{V_2 - V_{out}}{R_f} \tag{3.2}$$

$$i = \frac{V_{in}}{R_{in}} - \frac{V_2}{R_{in}} = \frac{V_2}{R_f} - \frac{V_{out}}{R_f} \tag{3.3}$$

$$\frac{V_{in}}{R_{in}} = V_2 \left[\frac{1}{R_{in}} + \frac{1}{R_f}\right] - \frac{V_{out}}{R_f} \tag{3.4}$$

$$i = \frac{V_{in} - 0}{R_{in}} = \frac{0 - V_{out}}{R_f} \tag{3.5}$$

$$\frac{R_f}{R_{in}} = \frac{0 - V_{out}}{V_{in} - 0} \tag{3.6}$$

The Closed Loop Gain (Av) is given as,

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}} \tag{3.7}$$

REFERENCES

[1.] Ian, S.E. 2006. Species profiles for pacific island agro forestry. Mangifera indica (mango). (ver. 3.1). Retrieved on August 30, 2007 from: www.traditionaltree.org

[2.] Fathinul Syahir.A.S, A.Y.M. Shakaff, A. Zakaria1, M.Z.Abdullah, A.H.Adom "Bio-inspired Vision Fusion for Quality Assessment of Harumanis Mangoes" 2012 Third International Conference on Intelligent Systems Modelling and Simulation.

[3.] Thanarat Chalidabhongse, Panitnat Yimyam and Panmanas Sirisomboon, "2D/3D Vision-Based Mango's Feature Extraction and Sorting" 1-4244-0342-1/06 2006 IEEE

[4.] Siti Khairunniza-Bejo, Syahidah Kamarudin "Chokanan Mango Sweetness Determination using HSB Color Space" 2011 Third International Conference on Computational Intelligence, Modelling & Simulation.

[5.] Khairudi Mohd Juni, Mohd Fareq Abd Malek and Manjur Ahmed, "Harum Manis Mango Dielectric Properties Based on Maturity" 2011 IEEE International RF and Microwave Conference (RFM 2011), 12th - 14th December 2011, Seremban, Malaysia.

[6.] M. Ruiz-Altisenta, L. Ruiz-Garciaa, G.P. Moredaa, Renfu Lub, N. Hernandez-Sancheza, “Sensors for product characterization and quality of specialty crops—A review”, Computers and Electronics in Agriculture 74 (2010) 176–194.

[7.] Amin Taheri-Garavand, Shahin Rafiee, Alireza Keyhani, Esmaeel Mirzaee , “A Traveling Time Model As Function Of Water Density And Vegetable Size, Shape And Density“ 2010 Vol. 73, 143-149.

[8.] Jordan, R.B. and Clark, C.J. (2004). “Sorting of kiwifruit for quality using drop velocity in water”. ASAE, 47 (6), 1991–1998.

[9.] E. Mirzaee 1, S. Rafiee 1, A. Keyhani 1, Z. Emam-Djomeh2, K. Kheiralipour1, "Hydro-sorting of apricots based on some physical characteristics "RES. AGR. ENG., 55, 2009 (4): 159–164

[10.] Taheri Garavand, S. Rafiee, A. Keyhani and E. Mirzaee ,"Mathematical Modeling of Tomato Terminal Velocity in Water" Advance Journal of Food Science and Technology 2(2): 100-103, Maxwell Scientific Organization, 2010.

[11.] Mahendran R, Jayashree GC, Alagusundaram K (2012) Application of Computer Vision Technique on Sorting and Grading of Fruits and Vegetables. J Food Process Technol S1-001. doi:10.4172/2157-7110.S1-001

[12.] H. Golpira. “Development of apple sorting machine“, The 11th International Congress on Mechanization and Energy in Agriculture, Turkey, Istanbul. pp. 38. 2011

[13.] Fei Lu 1, Yutaka Ishikawa 2*, Hiroaki Kitazawa 2 and Takaaki Satake 3,"Assessment and prediction of repetitive impact damage to apple fruit using pressure- sensitive film technique" Journal of Food, Agriculture & Environment Vol.10 (2): 156-160. 2012.

[14.] Hiwa Golpira, Hêmin Golpîra ,'Improvement of an Apple Sorting Machine Using PSNR Criterion ' Proceedings of the 2012 International Conference on Advanced Mechatronic Systems, Tokyo, Japan.

[15] C.C. Teoh and A.R. Mohd Syaifudin, Image processing and analysis techniques for estimating weight of Chokanan mangoes. J. Trop. Agric. and Fd. Sc. 35(1)(2007): 183–190

[16.] Tajul Rosli B. Razak, Mahmod B. Othman, Mohd Nazari bin Abu Bakar, Khairul Adilah bt Ahmad, Ab Razak Mansor, Mango Grading By Using Fuzzy Image Analysis, Faculty of Computer and Mathematical Sciences, Universiti Teknologi Mara (Perlis). International Conference on Agricultural, Environment and Biological Sciences (ICAEBS'2012) May 26-27, 2012 Phuket

[17.] Z. May and M. H. Amaran, Automated Oil Palm Fruit Grading System Using Artificial Intelligence, Electrical and Electronic Engineering Department Universiti Teknologi PETRONAS. June 2011

[18.] Yousef Al Ohali, "Computer vision based date fruit grading system: design and implemation", Journal of King Saud University ‐ Computer and Information Sciences (2011) 23, 29–36

[19.] Muhaemin, M, Herwanto, T, Prijatna, D, Saukat, M and Sugandhi, WK. Development of An Automatic Tomato Grading Machine Based on

Visual Evaluation. Faculty of Agro-industrial Technology, Padjadjaran University, Bandung. November 2006.

[20.] Abdolabbas Jafari, Mohammad Reza Zarezadeh and Atefeh Fazayeli. Orange Grading Based on Visual Texture Features. Agricultural Machinery Dept., Shiraz University, Shiraz, Iran. July 2010

[21.] Sachin Syal, Tanvi Mehta and Priya Darshni, "Design & Development of Intelligent System for Grading of Jatropha Fruit by Its Feature Value Extraction Using Fuzzy Logics" 7 July 2013

[22.] Instrumentation Amplifier With Precision Voltage Reference. http://datasheet.octopart.com/INA125-Texas-Instruments-datasheet-148984.pdf, access on 12 September 2013.

[24.] Arduino Uno. http://arduino.cc/en/Main/arduinoBoardUno, access on 12 September 2013.

[25.] Mohd Alif Zikri Bin Ghazali (2012). Load Cell.Amplifier. Universiti Teknologi Malaysia, Johor.

[26.] Harum Manis. Retrieved from http://www.mbg.com.my/MBG/products/fresh-fruits/1102-harum-manis-mango.html acesss on 12 September 2013.

[27.] Harum Manis. Retrieved from http://harummanis.webs.com/infoharummanis.htm acesss on 12 September 2013.

[28.] Zakaria.A, Md Shafaff, A.Y, Masnan, M.J, Ahmad Saad, F.S, Adom, A.H, Ahmad, M.N & Jaafar, M.N.(2012). Improved maturity andripeness classifications of Magnifera Indica cv. Harumanis mangoes through sensor fusionof and electronic nose and acoustic sensor.

[29.] Z.Zakaria, M.S.B. Mansor, R.A. Rahim, I.Balkis, M.H.F.Rahman, H.A. Rhim & S.Yaacob. (2013). Magnetic induction tomography: A review on the potential application in agricultural industry of Malaysia. Journal of Agricultural Science;Vol.5, No.9.