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AUTOMATED FRUIT GRADING SYSTEM

KELVIN WONG LE THAI

Thesis submitted in fulfillment of the requirements
for the award of the Bachelor of
Mechatronics Engineering (Hons.)

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ABSTRAK

Dalam kebelakangan ini, automatik teknologi pemeriksaan visual telah menjadi lebih berpotensi dan penting kepada banyak bidang. Ia adalah kerana kualiti buah-buahan menjadi faktor penting bagi pengguna dan adalah penting untuk seragam pemasaran hasil yang berkualiti tinggi. Kilang buah-buahan penggredan telah ditubuhkan untuk mengurangkan kos pengeluaran dan meningkatkan kualiti buah-buahan. Di samping itu, sistem pemeriksaan visual automatik bertujuan untuk menggantikan teknik manual untuk penggredan buah-buahan sebagai pemeriksaan manual menghadapi masalah dalam mengekalkan konsisten dan keseragaman. Projek ini menerangkan reka bentuk sistem buah penggredan automatik. Satu prototaip sistem ini direka dan diuji. Dalam projek ini, pengesanan kecacatan permukaan buah-buahan yang dinyatakan secara terperinci. Sistem dibangunkan bermula proses dengan menangkap imej buah-buahan dengan menggunakan kamera di mana buah-buahan yang diletakkan di atas meja yang berputar. Kemudian, imej yang dihantar kepada tahap pemprosesan di mana penggredan dilakukan dengan menggunakan MATLAB. Buah-buahan yang digredkan berdasarkan kecacatan permukaan mereka.

ABSTRACT

In recent years, automatic visual inspection technology has become more potential and important to many areas. It is because the quality of fruits becoming an important factor for the consumer and is essential for marketing uniform high quality produce. The fruits grading factories have been set up to reduce production costs and improve fruit quality. Besides, an automatic visual inspection system aimed to replace the manual technique for grading of fruits as manual inspection faces problems in maintaining consistency and uniformity. This project describes the design of an automated fruit grading system. A prototype of the system is designed and tested. In this project, the detection of surface defect of fruits is described in details. The developed system starts the process by capturing the fruit's image using camera where the fruits are placed on a rotating desk. Then, the image is transmitted to the processing level where the grading is done using MATLAB. The fruits are graded based on their surface defects.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The quality of the fruits is important for the consumers and become the requirement from the suppliers to provide fruits with high standards of quality. So, in the past few years, fruit grading systems had established to fulfil the needs of the fruit processing industry. Besides that, the process of fruits involves several steps that can generally be classified into grading, sorting, packaging, transporting and storage. The grading is considered as the most important steps towards the high standard of quality.

Fruits are almost graded manually which is an expensive and time consuming process and labours shortage will affect to the operation during peak seasons. It has become increasingly difficult to hire or train the person who are willing to handle the monotonous task of inspection. In the meanwhile, a cost effective and accurate grading can be performed with automated grading system.

Generally, the fruits quality depends on outer parameters (size, colour intensity, shape, surface appearances) and inner parameters (sugar contents, acid contents) but colour and size is the most important factor for grading and sorting of fruits. Nowadays, the fruit grading system based on weight, colour and size are accessible in the fruit processing industries.

The fruit grading system techniques using computer machine vision and image processing play the important role of quality control in fruit processing industries. From the past few years, different techniques have been enhanced to sort and evaluate the quality of fruits. These methods can help to detect different physical properties of fruits and with certain quality factors.

For example, the vision- based systems include CCD or CMOS sensors that are used to estimate the size and shape of fruits. It helps to predict the size of the fruits from its RGB image frame with the help of CCD camera. Software plays an important role in this colour classification system. The software system is almost designed in MATLAB to detect the colour and size of the fruits. Colour is very important in the sorting of fruits but due to the similarity of colours between some fruits, the size also helps in solving the problems.

1.2 Problem Statement

Fruits are the important roots of energy and nutrients for human body. With an embossed consumption, the quality of fruits is becoming extremely important for the food processing industries. The inspection of defects of the fruits is an important procedure to grade the fruits. This procedure is labour intensive and subject to human error. Hence, an automated grading system is necessary for inspection of fruits. In order to produce the fruit grading system, many factors that should be considered. To prevent any mis-gradation, the types of fruit are chosen based on the colour of the outer surface, such as mango and apple, so that the camera can detect the colour of the surface clearly. Thus, only two types of fruits are included in this project which are namely mango and apple.

Another problem statement in this project is some researchers use more than one camera for grading of rotationally symmetric product which costs a lot so we are trying in this project to use one camera with rotating of the fruits.

1.3 Objectives

The objectives of the study are:

1. To grade the fruits (apple and mango) based on their outside surface area either to have defect or not.
2. To apply automatic visual inspection system for the detection of fruit defects (apple and mango).
3. To build a low cost visual inspection system for fruit decay finding.

1.4 Scope

In this project, we will only concern on two types of fruits which are an apple and mango. The inspection will be accomplished from only the lateral surface of fruits. Besides, we use only one camera for inspection, therefore a certain area of the fruits can't be detected well which are the upper and lower sides. The fruits are put manually onto the area of inspection. Furthermore, two to three classification of fruits will be considered in this project. The entire system is designed using MATLAB software.

1.5 Project Methodology

The project involves the following activities:

i. Literature review

15 journals regarding the topic was reviewed. From the journals reviewed, there are many methods to grade the fruits. Image processing is the most important method that is used to capture the image of the fruits by using camera. Then, the inspection of fruits are done by detecting the surface of fruits. Lastly, classification of fruits is achieved.

ii Problem Statement

Some problems related to the grading of fruits are listed out. To prevent any mis-gradation, the types of fruit are chosen based on the colour of the outer surface, such as mango and apple, so that the camera can detect the colour of the surface clearly. Thus, only two types of fruits are included in this project which are namely mango and apple. Another problem statement in this project is some researchers use more than one camera for grading of rotationally symmetric product which costs a lot so we are trying in this project to use one camera with rotating of the fruits.

iii Objective

The first objective of the project is to grade the fruits such as apple and mango based on their surface area either to have defects or not. Next objective is to apply automatic visual inspection system for the detection of fruit defects (apple and mango) and lastly is to build a low cost visual inspection system for fruit decay finding.

iv Scope

Project scope is a need to declare in the project so that we can focus and perform. The fruit grading system focus only on two types of fruits which are an apple and mango. The inspection will be accomplished from only the lateral surface of fruits. Besides, we use only one camera for inspection, therefore a certain area of the fruits cannot be detected well which are the upper and lower sides. The fruits are put manually onto the area of inspection. Furthermore, two to three classification of fruits will be considered in this project.

v Classification of fruits

Fruit varieties are further classified depending upon their appearance such as colour and size. Fruit classification and fruit disease identification can be seen as an instance of image categorization. Most of the researches in the field of fruit recognition or fruit disease detection have considered colour and texture properties for the categorization.

vi Automatic Inspection of fruits

Automatic visual inspection is the technology or method used to provide imaging-based automatic inspection and analysis for such application for example process control and robot guidance in industry. Computer Vision is one of the automatic visual inspection that have proven their dominance in the industry. In this project, CCD camera is used to capture the lateral surface of the fruits. The materials needed for performance are:

Table 1.1 Bill of materials

No.	Item	Price per unit (RM)	Quantity	Total price (RM)
1.	12V Brushless DC motor with DC motor driver	200.00	1	200.00
2.	CCD camera (JVC GC-XA1)	400.00	1	400.00
3.	Coupling (metal key hub 15mm)	40.00	1	40.00
4.	Light source	20.00	1	20.00

5.	Aluminium rotating plate, grade 6063 (diameter 300cm, thickness 20mm)	200.00	1	200.00
6.	PC		1	
			Total:	860.00

1.6 Flow Chart

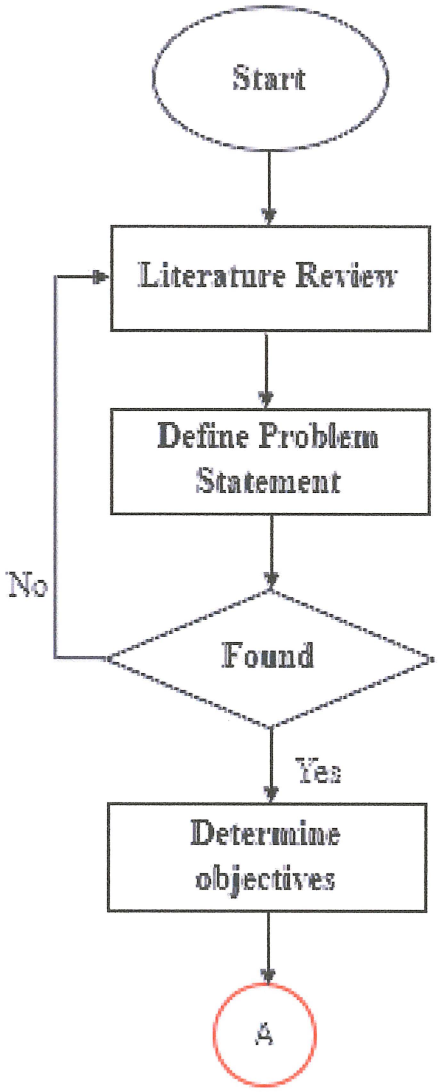

Figure 1.1 Flow chart of the project (part 1)

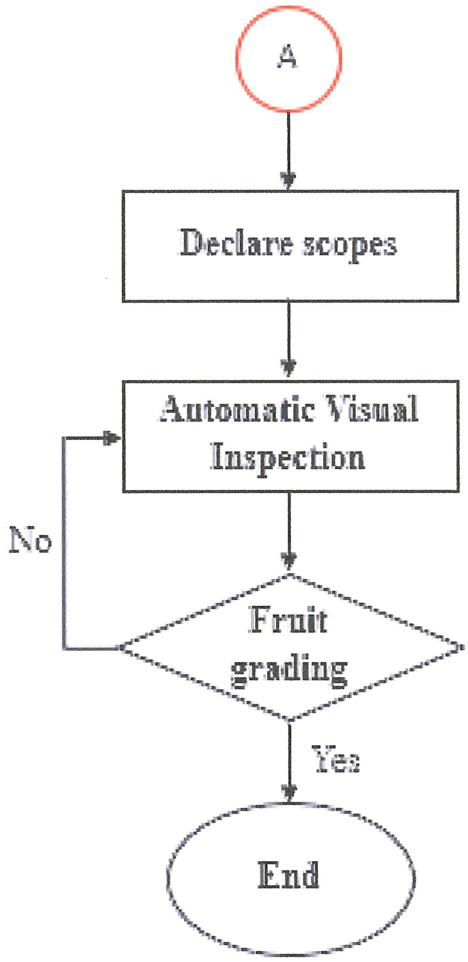

Figure 1.2 Flow chart of the project (part 2)

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the fruit grading and sorting system, images are really an important source for the collection of information. To collect the data, photography was the only method used in recent years. It is difficult to process or quantify the photographic data mathematically. Digital image analysis and image processing technology nowadays helps to improve images from microscopic to the telescopic visual range. Several applications of image processing technology have been developed for the agricultural operations.

2.2 Theoretical Background

It consists of the following subtopics:

2.2.1 Sorting

Traditionally, classification and grading are performed manually which are done often by the labours through their observations and experience which cause to slow and an error sometimes. As fruits play an important role in our daily life, the machine vision system are enhanced nowadays to increase the market value. This project presents the system for grading and sorting the fruits. The colour of fruits, size and grading system are based on image processing. The colour from the side view of the fruits and size are captured with a camera. Fruit quality such as size, colour can be measured by numbers of different methods. Fruit size is a physical property while colour is a visual property. The image processing is the common way for sorting system and will be used here as follows:

2.2.1.1 Image Processing Technique

Image Processing Algorithms are the basic for Computer Analysis and Machine Vision. The Image Processing Algorithms and Basic Machine Vision can be divided into few major groups for example: Grey-Level Segmentation or Thresholding Methods, Edge-Detection Techniques and Digital Morphology. Intelligent image processing technique such as Canny edge detector is presented in this section.

(a) Canny Edge Detection

Edge detection is the process of finding the outside limit of an object, area or surface. (J.Ramprabhu & S.Nandhini, 2014) has found that edge extraction of Canny edge detection can be considered as the key factor for size detecting. Canny method use a multi-stage algorithm to detect a wide range of edges in images which has been widely used in several kinds of computer vision systems.

(b) Image Processing Using MATLAB

Image processing are suitable to be done by MATLAB. MATLAB provides the Image Processing Toolbox™ which provide a powerful and flexible environment for analysis and image processing. Matrix-oriented language from MATLAB is suitable for image manipulation which are visual renderings of matrices and the result is easy to be analysed in term of expressing image processing operation. There are five types of images in MATLAB for example: Grayscale, Truecolour RGB, Indexed, Binary.

2.2.2 Automatic Visual Inspection

Automatic visual inspection is the technology or method used to provide imaging-based automatic inspection and analysis for such application for example process control and robot guidance in industry. Besides, (Ali, Mailah, Kazi, Tang, 2012) states that visual test is one of the popular method that gives possibility to detect the defects. The test can be done by using magnifying glass or cameras for inspection or by naked eyes.

2.2.2.1 Line Scans Camera System

Line scans camera system has a single row of pixel sensors and are continuously fed to the computer that joins them together to make an image. Line scans camera system is an image capturing device which is formed by a single line of photosensitive elements that has a CCD sensor. (Ali, Mailah, Kazi, Tang, 2012). Line scan camera produces high resolution images that able to scan the cylindrical object with multi-diameters components. The line scan camera produces a better resolution than the matrix camera.(Ali, Mailah, Kazi, Tang, 2012).

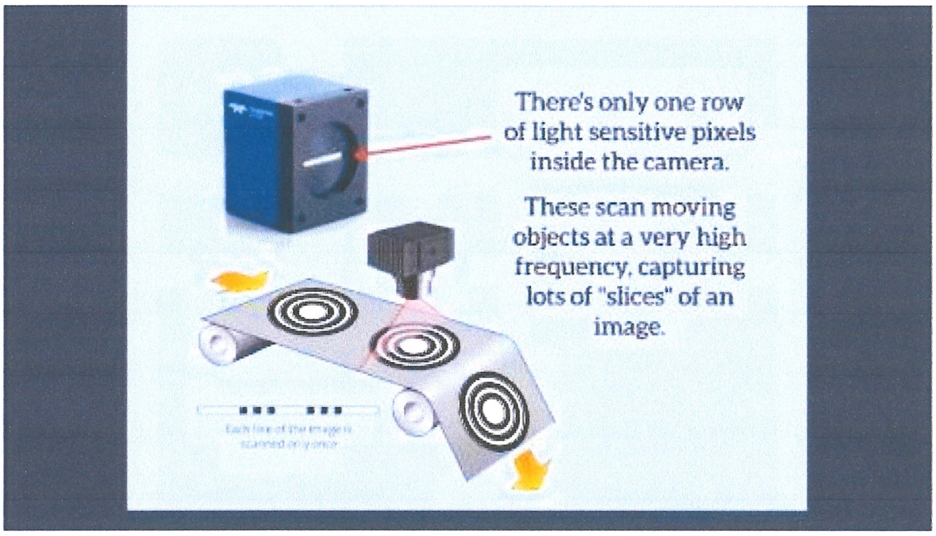

Figure 2.1 Line scan camera system.

Source: (http://www.stemmer-imaging.co.uk/en/technical-tips/line-scan-cameras/)

2.2.2.2 Matrix Camera System

Matrix camera that use to capture the images by using rectangular mosaic of pixels is actually an array image sensor. Matrix camera system works well in capturing the objects smaller than the field-of-view of a camera (Ali, Mailah, Kazi, Tang, 2012). The camera is suitable for text identification and image processing in one-frame unit. Besides, two systems are implemented to inspect the cylindrical objects using matrix camera: a) camera with conical mirrors. b) camera with multiple flat mirrors.

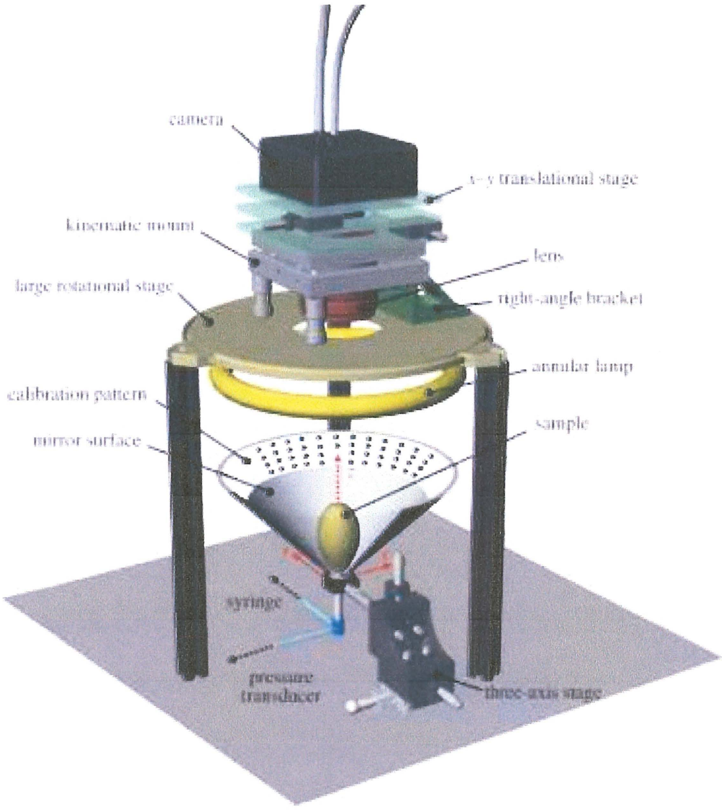

Figure 2.2 Matrix camera with conical mirror system.

Source: (N. Brierley, T. Tippetts, P. Cawley, May 14, 2014)

Figure 2.3 Close view of conical mirror.

Source: (Mohammed A.H. Ali, M. Mailah, H. H. Tang, & S. Kazi, 2012)

Figure 2.4 Matrix camera with multiple flat mirrors system.

Source: (Mohammed A.H. Ali, M. Mailah, H. H. Tang, & S. Kazi, 2012)

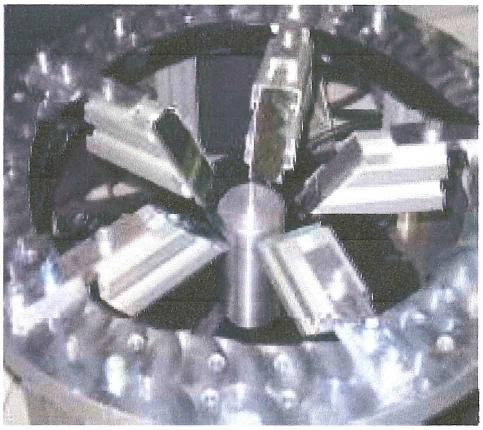

Figure 2.5 Close view of multi flat mirrors.

Source: (Mohammed A.H. Ali, M. Mailah, H. H. Tang, & S. Kazi, 2012)

2.2.2.3 Matrix Camera with conical mirror system vs Matrix Camera with multiple flat mirrors system

Table 2.1 Characteristics of different types of Matrix camera

Types of matrix camera	Characteristics
Matrix camera (conical mirror)	• The mapping of pinhole camera from points in 3D to 2D in an image. • Images produced has good resolution and accuracy.
Matrix camera (multiple flat mirrors)	• Inspect the objects having different diameters. • Images produced has good resolution but bad accuracy.

Source: (Mohammed A.H. Ali, M. Mailah, H. H. Tang, & S. Kazi, 2012)

2.3 Types of Algorithms

There are many types of algorithms that are used for detecting and sorting of different kind of fruits from the acquired image. To classify and sort different kind of fruits, we need an appropriate algorithms. From the literature, different types of algorithms are used for automatic fruit grading system for example Fuzzy Logic Technique, Artificial Neural Network Technique (ANN), K-Nearest Neighbours Classifier (KNN).

2.3.1 Fuzzy Logic Technique

Fuzzy logic (FL) used to solve the automatic visual inspection problem. Applications area of fuzzy logic is very wide for example control of the processes, management and decision making, pattern identification and classification (Ms. Seema Banot, Dr. P. M. Mahajan, 2016). Fuzzy logic is used to be in charge of uncertainty, ambiguity and vagueness. This automated system uses a computer and a CCD camera to analyse and recognise images.

2.3.2 Artificial Neural Network

Neural Networks method has become popular to characterise biological processes.

Neural Network has the best decision-making capability which can be used in image analysis of biological products where the size and shape classification is not achieved by another algorithm (Kavdir I, Guyer DE, 2008). The advantage of Artificial Neural Network is well suited to analyse complex problems while disadvantages are the problems of the scales, greater amount of samples and longer processing time (Rashmi Pandey, Sapan Naik, Roma Marfatia, 2013).

2.3.3 K-Nearest Neighbours Classifier

K-Nearest Neighbours Classifier (KNN) is used to identify the input data by comparing it with the trained data. It uses the Euclidean distance measurements to measure the distance between points in the input data and trained data. (Pragati Ninaws et al, 2014) proposed new fruits identification techniques with combining some features analysis method. Features like shape, size and colour, texture based method are to increase the accuracy of recognition of fruits. (Woo Chaw Seng, Seyed Hadi Mirisaee, 2009) presented about the classification of fruits based on average colour values of the fruits, shape of the fruit, area and perimeter of the fruit by using the KNN algorithm as a classifier.

2.4 Literature Review

J. Ramprabhu and S. Nandhini (2014) had enhanced the technique for sorting and grading the fruit quality by using Pixel wise classification method called Gaussian Mixture Model (GMM) to improve the accuracy, reliability, consistency and quantitative information apart from handling large volumes of fruits. By referring to the results, the edge extraction is one of the important key factor for size detecting. By using the most powerful edge-detection method (Canny method) that uses a multi-stage algorithms, we are able to detect a wide range of edges in images.

Mohammed A. H. Ali et. al, (2012) had the visual inspection to test the lateral surface of cylindrical products by using cameras and image processing. According to the results, the lines scan camera system which is formed by a single line of photosensitive element hold a CCD sensor while matrix camera system capture the images by involving a rectangular mosaic of pixels. The image resolution in line scan camera is better compare to matrix camera system.

Ms. Rupali et. al, (2013) had used image processing that provide the solution for automated fruit size detecting and grading system to solve the non-destructive quality evaluation of fruits. There are two ways in the results that is circular shaped fruits according colour and grading are done according to size; another way is designed over MATLAB software to inspect the colour and size of the fruits and categorised to four groups: for example red colour with small in size, red colour with big in size, green colour with small in size and green colour with big in size.

Different types of algorithms and classifier are available to extract feature of fruit characters to solve the problems for fruit detecting and grading system by Ms. Seema Banot and Dr. P. M. Mahajan (2016). Based on the results, there are four ways : a) fuzzy logic that utilise digital fuzzy image processing, content predicted analysis, and statistical analysis; b) artificial neural network that used develop algorithms and detect to get the better result for colour and morphology; c) K-nearest neighbours classifier (KNN) that identify the input data by comparing it with the trained data and last d) colour mapping that used to evaluate the quality and maturity stage.

Rashmi Pandey et. al, (2013) had developed several algorithms to grade and sort of different types of fruits by image processing and machine learning technique. From the results, Guo Feng and Cao Qixin had claimed OHTA colour space and blob extraction was applied to detect fruit contour then HSI colour space is to calculate the colour ratio. Besides, different types of colour spaces for example RGB, XYZ, HSI, La*b*, Lu*v* were tested for sorting of citrus fruits by J. Blasco et. al.

According to Chandran Kumar et. al (2015), a system for sorting and colour grading (GLCM parameter) is used for the classifications of citrus fruit. Based on the results, contrast shows the amount of local variation present in the image. Thus, when i and j are with the same value, then (i-j)=0, then contrast is zero. Moreover, GLCM consider the relationship between two pixels at one time, called neighbour pixel and reference.

M. Khojastehnazhand et. al (2010) had done an experiment on lemon sorting system based on colour and size by using the system that able to inspect two stages : external and internal fruit inspection. Based on the results, all the information will be saved in the database, then, the information during the sorting and the information in the database will be compared to collect more accurate result.

Embedded colour-based system on a field programmable gate array (FPGA) device is used to solve the problem for the citrus grading system. (Marco Aurelio Nuno-Maganda et. al). From the results, FPGAs are suitable because they supply a high figuration power to achieve the high performance by reducing the cycles of the design.

A CCD camera is mounted on the conveyor belt to collect images of the fruits by Chandra Sekhar Nandi et. al (2014). With the fuzzy rule based algorithms, fruits are sorted into four grades. Mis-gradation may also occur when different maturity level having almost the same colour pattern.

An experiment on distributed network architecture to interface the camera unit to a computer system through GigE LAN environment for automated inspection and grading of fruits is done by Yogitha. S and Sakthivel. P. According to the results, computer mission vision system involves image acquisition, image processing and decision making. Besides, the grading and sorting system is based on external parameters for example colour, size and shape.

V. Pavithra et. al (2015) had designed an automatic and non-destructive grading and sorting system of cherry tomatoes based on maturity and quality. The algorithms involves two phases : a) in terms of maturity and b) in terms of quality. First phase grading was based on colour and second phase are based on colour, texture and shape. Quality based classification has been performed using KNN based SVM classification.

Image inspection for the approximation of the external quality of the pear by the software of Lab Windows/CVI is done by Yanru Zhao et. al, (2009). The system can be used to detect the external conditions such as size, shape colour and surface decay. The system can also be used for several kinds of fruit for example apples, peaches and for vegetable like cucumbers.

Devrim Unay, Bernard Gosselin had designed an artificial neural network-based segmentation and apple grading system by machine vision. Based on the results, information consists of one-view images of apples are captured using a monochrome digital camera. Linear Discriminant Classifier (LDC), separates the feature space into two half-spaces by minimizing a criterion function and Nearest Neighbour Classifier (k-NN), similarity measurement to find the nearest samples is the Euclidean distance.

Jyoti Jhawar (2015) had done the investigation on the orange sorting system by involving pattern identification on colour image. According to the results, because of blending background removal and feature extraction algorithms together, only one scan of the whole image is needed. Besides, images are with least resolution (640x480), thus, the time required is very short.

Image processing for the ripeness, size and decays were done. (Asghar Mousavi balestani et. al, (2012)). Based on the experiment results, cherries are categorized based on the total soluble solids that is the index for ripeness. By using binary images of the cherries, the algorithms based on size was expanded. Lastly, the reflected light in the images were removed to decrease the error rate in computing the average colour components of the fruits.

Table 2.2 A brief of literature review

	Author	Problem	Solution
1.	J.Ramprabhu and S.Nandhini (2014)	Enhanced Technique for sorting and grading the fruit quality.	Pixel wise classification method called Gaussian Mixture Model(GMM) to provide accurate, reliable, consistent and quantitative information apart from handling large volumes.
2.	Mohammed A.H. Ali, M. Mailah, H. H. Tang,	The testing of the lateral surface of cylindrical products.	Visual identification of cylindrical product lateral surface of object by using cameras and image processing.

	S. Kazi (2012)		
3.	Ms.Rupali S.Jadhav and PROF. S.S.Patil (Nov-Dec 2013)	Non-destructive quality evaluation of fruits.	Image processing provide solution for automated fruit size detecting and grading system.
4.	Ms. Seema Banot and Dr.P.M.Mahajan (Jan 2016)	Fruit grading system using image processing.	Different types of algorithms are available to extract feature of fruit characters by capturing the fruit image.
5.	Rashmi Pandey, Sapan Naik, Roma Marfatia (2013)	Image processing and machine learning for automated fruit grading system.	Quality grading and sorting of different types of fruit using algorithms.
6.	Chandran Kumar, Siddharth, R.Narmadha Alla, Harika Mounica Gurram (2015)	Classifications of citrus fruit using image processing.	System for the sorting on citrus fruit and for colour grading of the defected fruit-GLCM parameter.
7.	M. Khojastehnazhand, M.Omid*, A. Tabatabaeefar (2010)	Lemon sorting system based on colour and size.	System that able to inspect two stages: external fruit inspection and internal fruit inspection.

8.	Marco Aurelio Nuno-Maganda, Yahir Hernandez-Mier, Cesar Torres-Huitzil, Josue Jimenez-Arteaga	Citrus Classification System.	Embedded colour-based citrus selection system on a field programmable gate array (FPGA) device.
9.	Chandra Sekhar Nandi, Bipan Tudu, Chiranjib Koley (2014)	Automatic fruit grading system based on visual inspection	A camera is placed on a conveyor belt to collect the image of the fruit.
10.	Yogitha.S, Sakthivel.P	Computer machine vision system for automated inspection and grading of fruits.	Distributed network architecture to interface the camera unit to a computer system through GigE LAN environment.
11.	V.Pavithra, R.Pounroja, Dr.B.SathyaBama(2015)	Automatic sorting using machine vision	Automatic and non-destructive grading of cherry tomatoes based on maturity and quality.
12.	Yanru Zhao, Dongsheng Wang, Dongping Qian (2009)	Fruit quality detection.	Image Analysis for the approcimation of External Quality of fruits by the software of Lab Windows/CVI.
13.	Devrim Unay, Bernard Gosselin	Computer vision based system.	Apple grading by machine vision.
14.	Jyoti Jhawar (2015)	Sorting and grading system of fruits	Applying pattern identification on colour image of the fruits.

15.	Asghar Mausari balestani, Parviz Ahmadimaghaddam, Assad Modares motlaq, Hamed Dolaty (2012)	Sort and grade of cherry	Size and decay detection using image processing.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In order to design a system to grade the fruit, image acquisition and features classification is the important steps. The design is first concerned with establishing a basic structure of a system. Before that, the camera is used to capture the image of the fruits to do the classification of fruits. Fruit varieties are further classified depending upon their appearance such as colour and size. Fruit classification and fruit disease identification can be seen as an instance of image categorization. To measure and calculate the features from the image samples and to distinguish between one type of image from another, feature extraction are used. The feature extraction process is done using the MATLAB image processing toolbox.

3.2 Materials and methods

The apparatus used for fruit classification in this project is made by simple image processing equipment. In this project, the computer vision system will be set up to detect the lateral surface of the fruits shown in Figure 3.1. The system was tested by using a samples of apples and mangoes. Firstly, the fruit is brought manually to the rotating desk which the rotating desk will be connected to the shaft of the 12V DC motor. The DC motor is then set by Arduino to rotate 180° for twice. The image of the fruit is captured by two times. For the first time, the half side of the fruit being captured and for the second time another half side of fruit was captured. Then, the camera will capture the image and show the analysed image at the Graphical User Interface (GUI). Besides, we can observe the surface defects and decay of fruits through GUI.

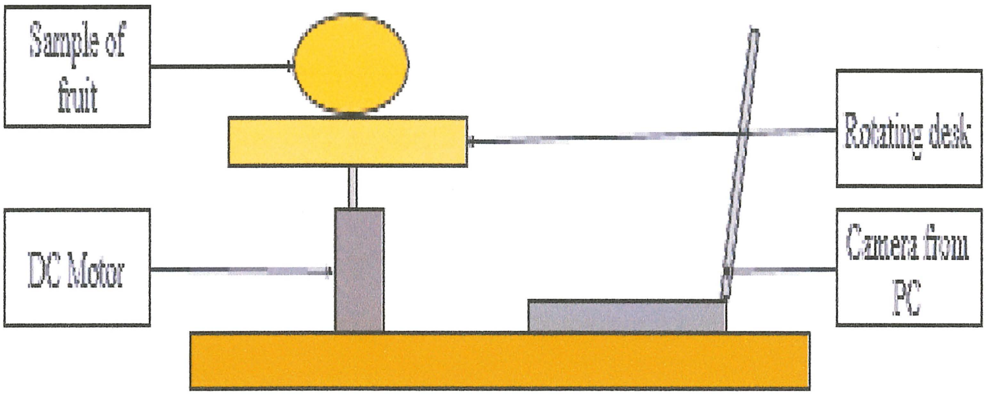

Figure 3.1 The automatic fruit grading system

The mechanical calculation for the consideration of DC motor is shown below. From the calculation, the DC motor is able to rotate the rotating desk together with fruit on top of it.

- Maximum weight of fruit sample

  = *1.0kg*

- Weight of rotating desk

  = *0.3kg*

- Weight of fruit sample + weight of rotating desk

  = *1.0kg + 0.3kg*

- Radius of DC-Motor

  = *1.8cm*

- Torque needed to turn the rotating desk and sample of fruit

  = *1.8cm x 1.3kg*

  = *2.34kgcm*

- Convert the *kg cm* to *N.m*

  $= 2.34kgcm \; x \; \frac{9.81}{100}$

  = *0.23N.m*

- Torque of DC motor

$= 0.784 N.m$

3.2.1 Electrical part

Arduino Mega 2560

Arduino is an open source electronics platform that designed to make electronics to be more accessible to anyone who is interested in creating interactive objects. Arduino Mega 2560 which is a microcontroller board which contain 54 digital input/ output pins, 16 analogue inputs, 4 hardware serial ports, 16 Mega Hertz crystal oscillator, an In-Circuit Serial Programming (ICSP) header is used in the project. Arduino Mega 2560 is used to control the rotation of angle for the DC motor that connected to the rotating desk. Arduino mega 2560 is set to rotate the motor for 180° two times for one fruit. Figure 3.2 shows the Arduino Mega 2560.

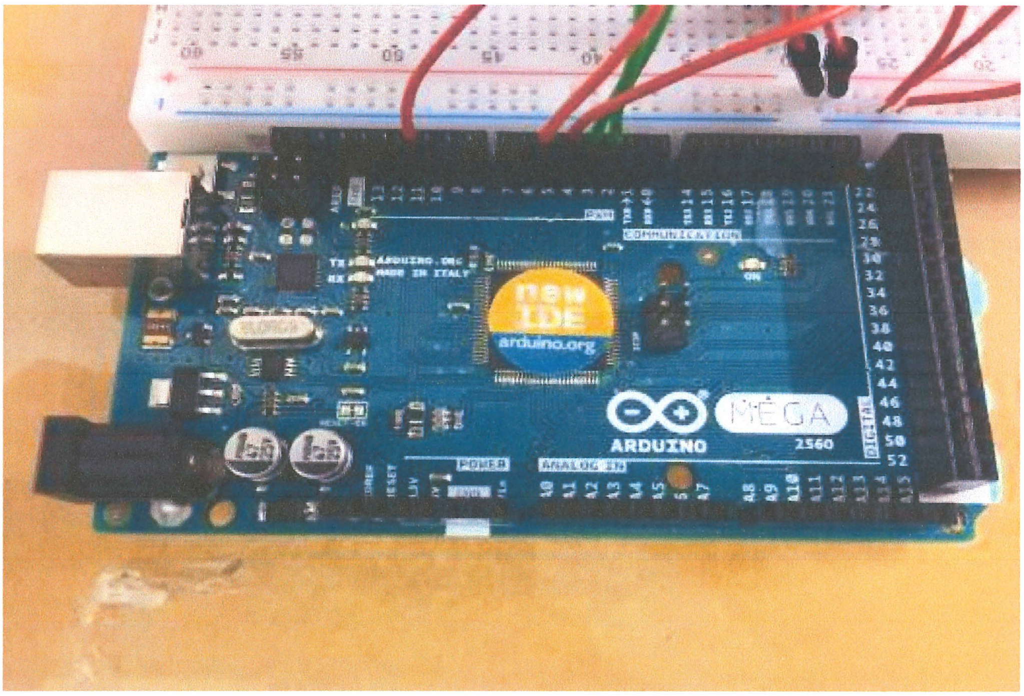

Figure 3.2 Arduino Mega 2560

12V DC Geared Motor

12V DC Geared Motor with encoder is selected in this project. The model is SPG30-200k, the motor specification are presented as rated voltage (12V DC), current at free run (without load), revolution per minute which is 17 RPM, and rated torque with

784mNm is selected in this project. The function of the DC motor in this project is to rotate the rotating desk which is set to rotate 180 degree.

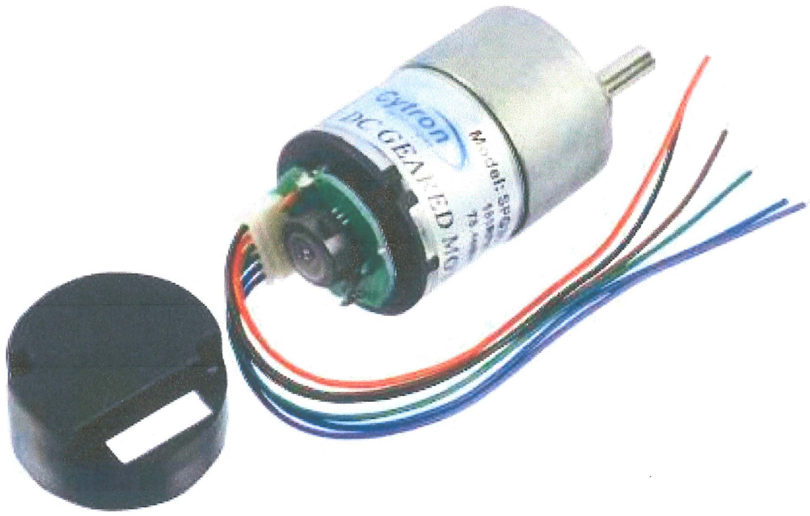

Figure 3.3 12V DC Geared Motor with encoder SPG30-200K

Source: (https://www.google.com/search?q=12v+dc+motor+spg30-200k)

DC Motor driver

Motor driver is needed for the DC motor to function completely. L293D motor driver which is a motor driver IC is used that allows DC motor to rotate either clockwise direction or anticlockwise direction. L293D contains 16-pin IC which can control a set of two DC motors simultaneously in any direction. It means that with the L293D motor driver, two DC motors can be controlled in one time. Since only one motor is used in the project, so only pin 1 to 8 from L293D motor driver is used. Figure below shows the motor driver L293D.

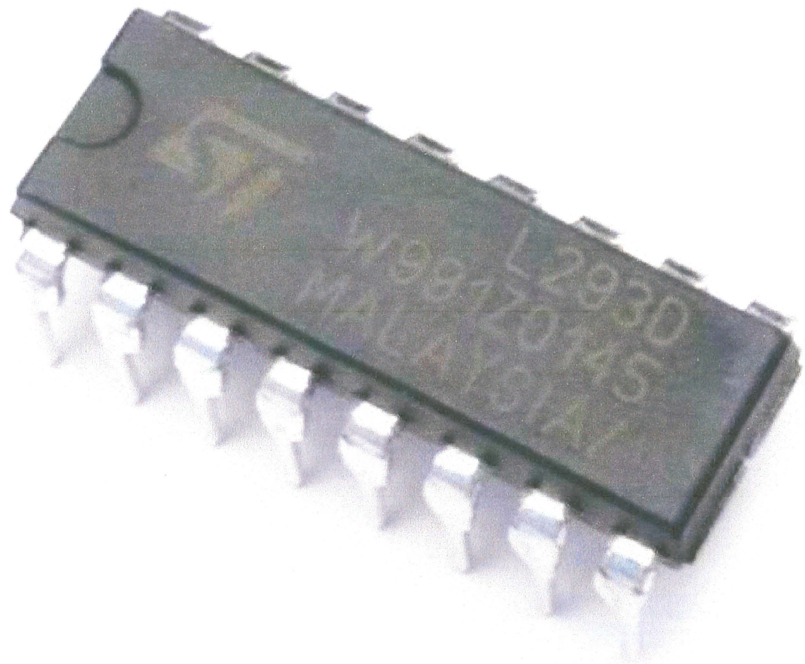

Figure 3.4 Motor driver L293D

Source: (https://www.google.com/search?q=l293d+motor+driver)

Power Supply

12V Power supply is needed to supply the voltage to the Arduino Mega 2560. 12V adaptor is used to supply the voltage for Arduino Mega to control the rotation of the DC motor. If Arduino Mega is just connected with USB cable which is 5V, the encoder of the DC motor could not function because the power supply is insufficient. In addition, the DC motor can only rotate with a low speed. So, 12V power adaptor is used instead of USB cable.

Figure 3.5 12V Power Adaptor

3.2.2 Hardware

The automatic fruit grading system is shown in figure 3.1. In this project, camera of the computer is positioned to detect the lateral surface of the fruit. The sample of fruits are brought to the rotating desk for inspection and grading. The DC motor is used to rotate the desk which allow the camera to capture the lateral surface of the fruit for both apple and mango. PC is used for image capturing, acquisition and software processing. The automatic fruit grading system drawn by Catia software is shown in figure 3.6.

In this project, the classification of fruits is accomplished based on the types of defects. First, two types of fruits are being chosen for this project which are namely apple and mango. Then, mangoes are divided into two groups which are anthracnose and normal mango. Apples are divided into two groups also which are bull-eye rot and normal apple. The camera will capture the image of the surface of fruits and will analyse the types of fruit defect. Lastly, the GUI will show the red circle and black spots if there is defect.

Figures 3.8 and 3.9 show the types of defects of apples.

For Apple:

Figure 3.8 Apple with Bull-eye rot

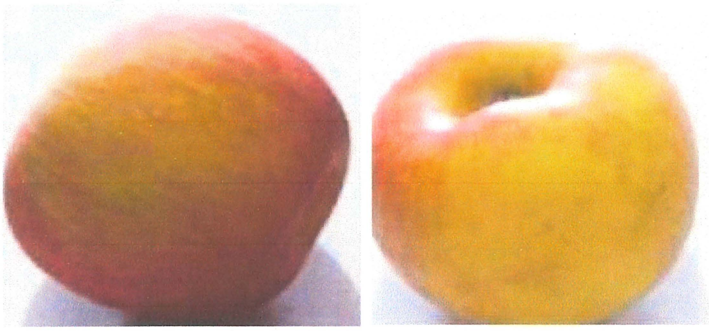

Figure 3.9 Normal Apple

Figures 3.10 and 3.11 show the types of defects of mangoes.

For Mango:

Figure 3.10 Mango with Anthracnose

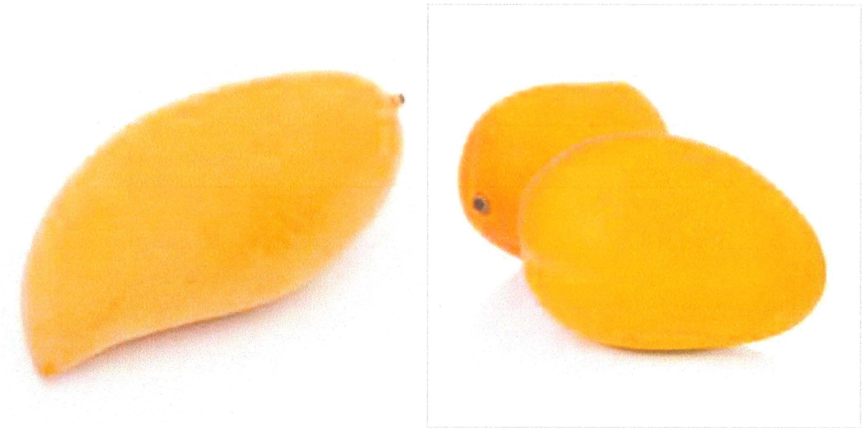

Figure 3.11 Normal Mango

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will discuss about the automatic fruit grading system. Automatic grading system begins with the fruit sample being captured using camera with white background and ended with image analysis that can be applied to make grading in MATLAB. Image processing in MATLAB is used to extract the parameter of apple and mango in order to prepare the input for classification. The features such as surface defects or decay of fruits are used in this project.

4.2 Electrical Circuit

As mentioned in chapter 3, Arduino Mega 2560 is used to set the angle of rotation of DC motor. DC motor is set to rotate 180° two times for one fruit to detect the whole lateral surface area of fruit. L293D motor driver which is a motor driver IC is used that allows DC motor to rotate either clockwise direction or anticlockwise direction and 12V power adaptor that provide sufficient voltage is used to supply the voltage to the Arduino Mega. Figure 4.1 shows the simulation of the circuit by software.

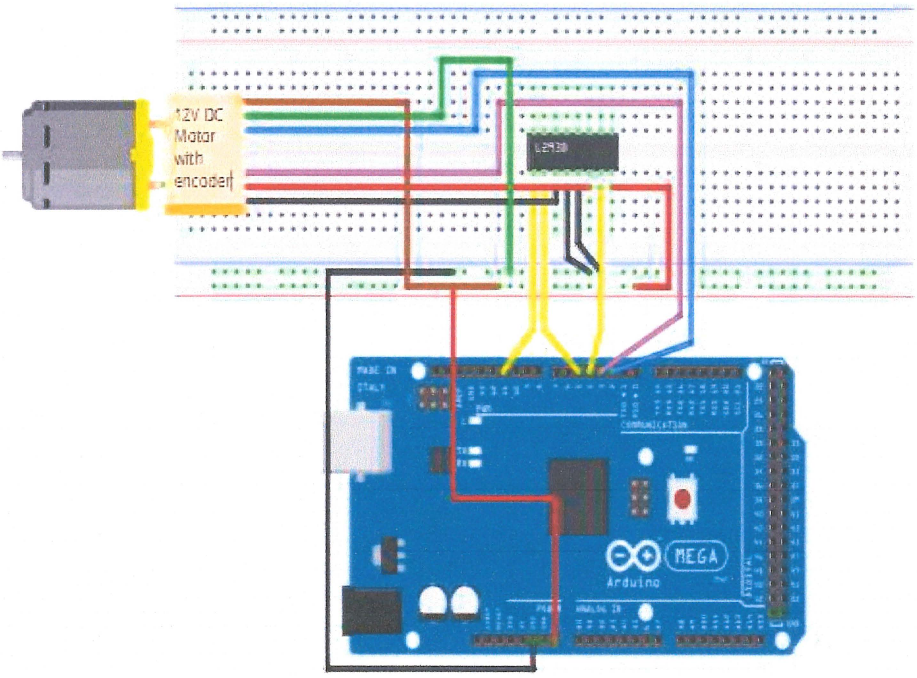

Figure 4.1 Schematic diagram of the circuit

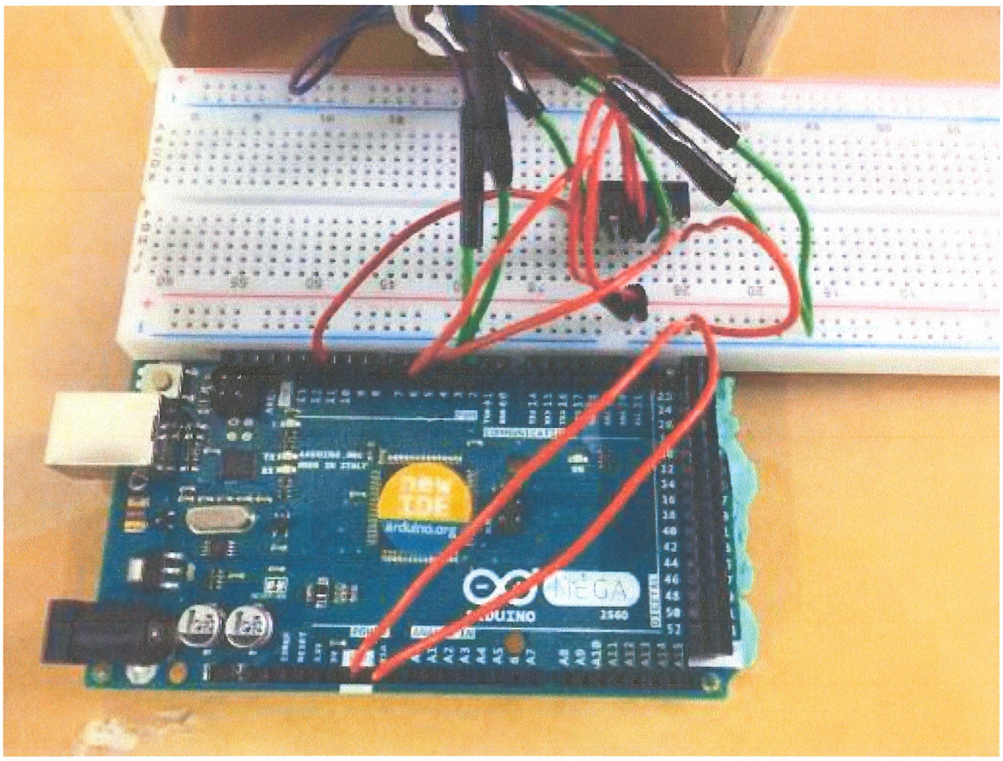

Figure 4.2 Actual circuit diagram

4.3 Image Capture

An image of the fruits is captured by using a camera and is loaded into the MATLAB by using the function 'videoinput'. This function reads the image from the camera. As if it is an coloured input, it need to be converted into grayscale by the function 'rgb2gray(image)' and the syntax is *I=rgb2gray(image)* which converts truecolour image RGB into grayscale intensity image. Then, the image is converted into binary in which the image consists only two colours that are black and white. Canny edge detection method is used in this project to detect the edge of the image of the fruits and the corresponding syntax is *BW = edge(I,'canny')* to extract the boundary. Since the image is captured with white background, the background have pixel value of 255 indicating white colour. Figure 4.3 shows the white background that is used to capture the image of fruits.

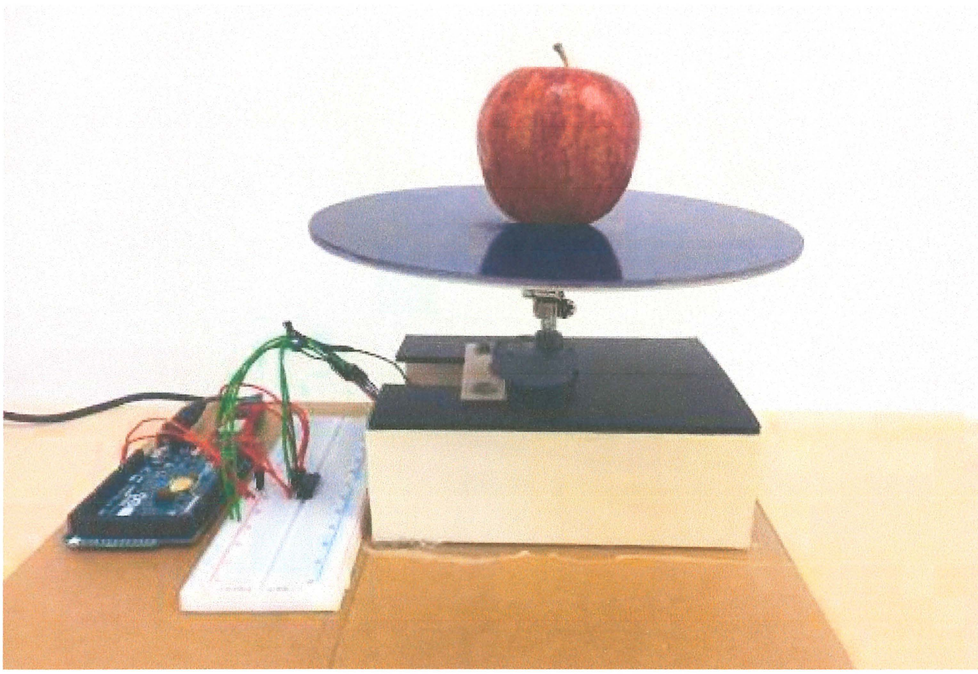

Figure 4.3 Automatic inspection prototype with white background

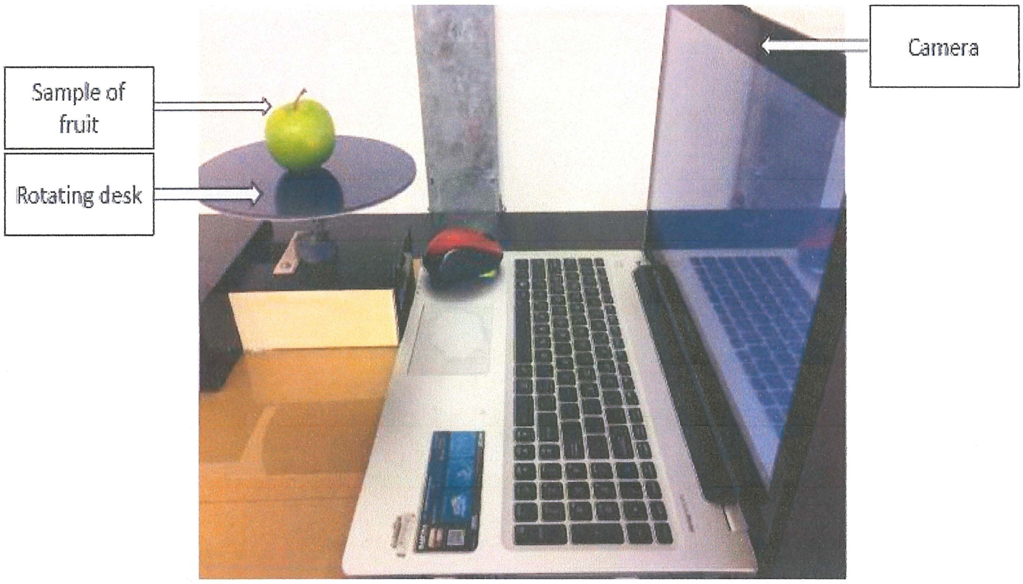

Figure 4.4 Prototype of the system

4.3.1 Detection of defects

To detect the surface defect of the fruit, the Graphical User interface (GUI) is created. The GUI is created to show the original image of the fruit that captured by the camera and the image analysed through image processing. Besides, the GUI that created also shows the position of defects in pixels and number of defect. The GUI was built with a "Start" button. Whenever the fruit is ready on the rotating desk, then the start button at the GUI is press to begin the surface detection process.

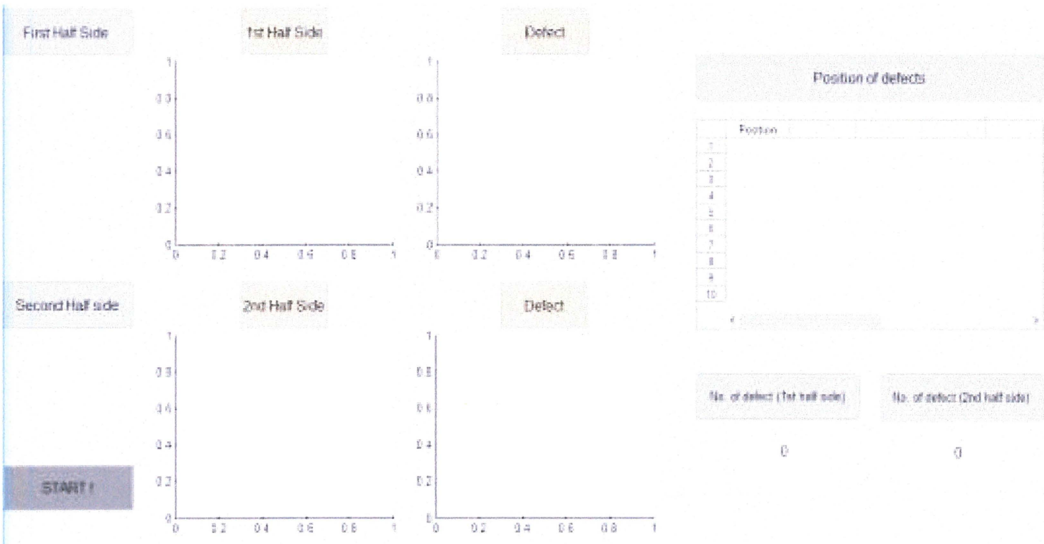

Figure 4.5 Graphical User Interface (GUI) of the system

4.4 Texture

Texture is important for image analysis because the recognition of colour by computer vision system is different if the surfaces of the fruits have different textures. For example, the texture for the area with defects on the surface of fruits will be darker. Thus, the dark patches or holes present in the image are filled using the function 'imfill()', and its syntax is *BW1 = imfill(BW1, 'holes')* that fills holes in binary image BW.

4.5 Results and Analysis

The results and analysis is the final step which shows the outcome of the project is being displayed. The prototype of the implemented system is shown in Figure 4.3. To capture the images of fruits, DC motor is set by Arduino to rotate twice to capture the whole lateral surface of fruits. For first 180°, the camera will capture the first half side of fruit; for the second 180°, the camera will capture the second half side of fruit. The GUI is created for the user to observe the analysed image of the fruits.

To grade the fruits, some apples and mangoes are brought to the rotating desk. By observing the image analysed by MATLAB and shown in GUI, the dark patches or spots will be occurred at the area of fruit's defects, which almost has a circular shape. In this project, the command *'[centers, radii] = imfindcircles(image,[10 40])'* is used on the image to find the defects which are almost in circular shape with the search radius of [10 40] pixels. From the GUI, if there is any dark patches or spots at the analysed image, then, there is defect or decay on the surface of fruits. In addition, if there is defect on the surface of fruit, the GUI will show the position of the defect and number of defect. Moreover, a red circle will appear if there is a defect. The GUI for apple with defect is shown in figure 4.6.

Apple:

With defect

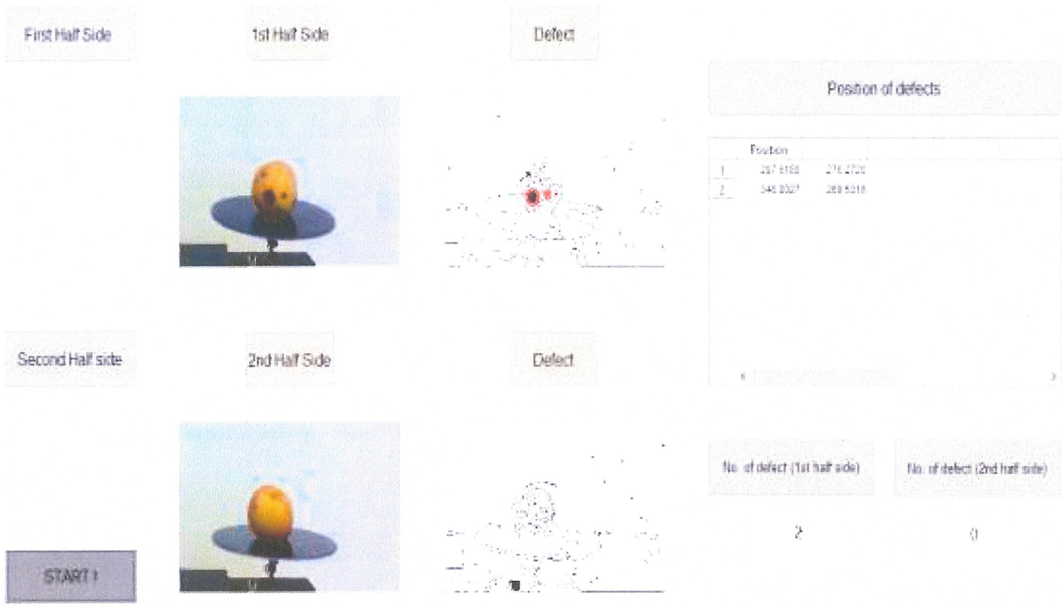

Figure 4.6 GUI for apple with defect

From the analysed image in figure 4.6, there are black patches on the surface of fruit for the first half side but there is no black patch on the surface of fruit for the second half side. Additionally, defects are marked by red circles on the first half side of fruits means that there are defects.

Without defect

Figure 4.7 GUI for apple without defect

From the analysed image in figure 4.7, there is no black patches for the both first half side of apple and the second half side of apple. So, there is no defect for both first half side and second half side of apple. So, the number of defect for the first half side and the second half side show the value zero.

Mango:

With defect

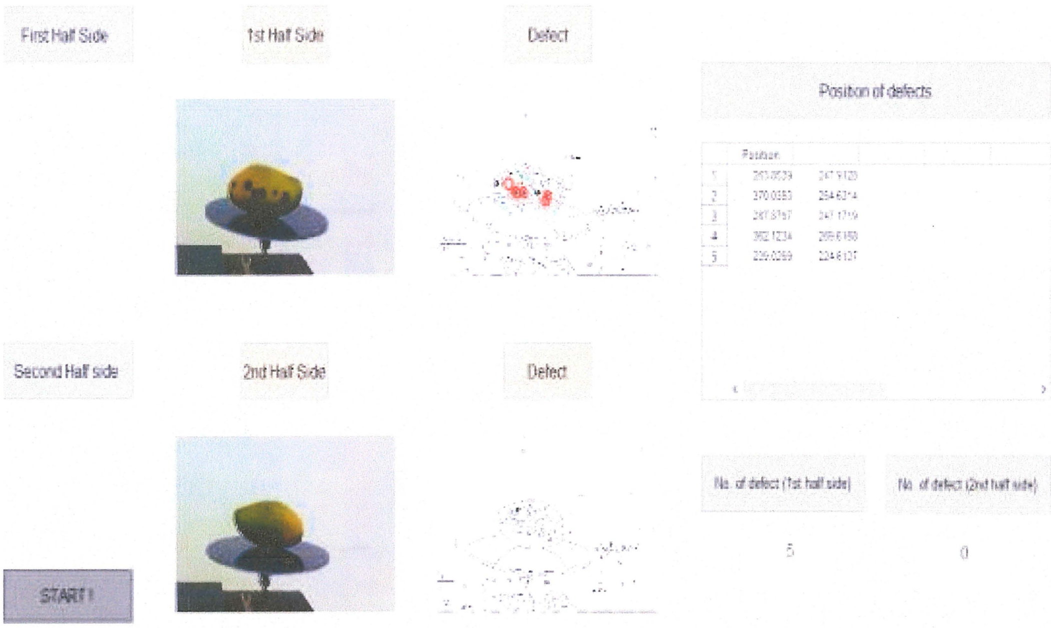

Figure 4.8 GUI for mango1 with defect

From the analysed image in figure 4.8, there are black patches for the first half side of mango but there is no black patch at the second half side of mango. So, there are defects on the first half side but no defect on the second half side of mango. Besides, the GUI shows that there are five red circles on the first half side of mango means that there are five defects while there is no red circle at the second half side means that there is no defect.

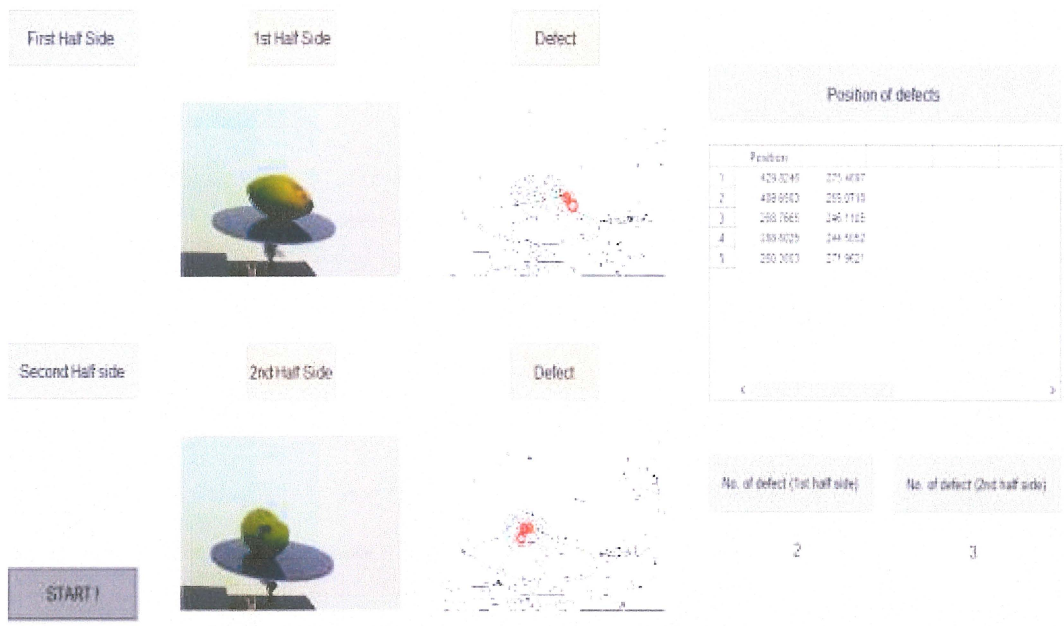

Figure 4.9 GUI for mango2 with defect

From the analysed image in figure 4.9, there are black patches for the first half side of mango and black patch at the second half side of mango. So, there are defects on the first half side and the second half side of mango. Besides, the GUI shows that there are two red circles on the first half side of mango means that there are two defects while there are three red circles at the second half side means that there are three defects.

Without defect

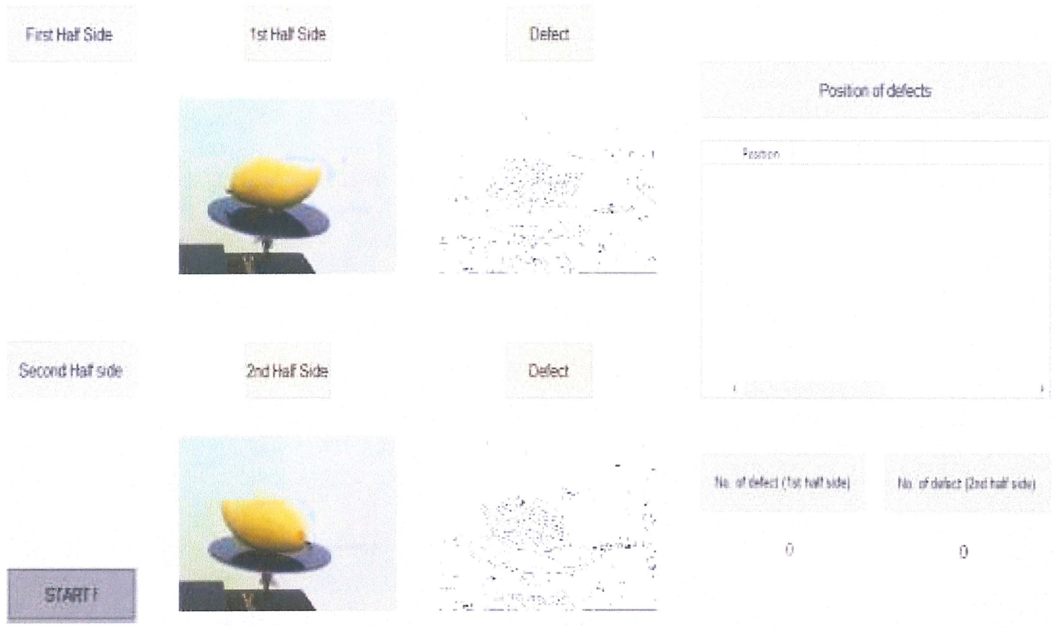

Figure 4.10 GUI for mango1 without defect

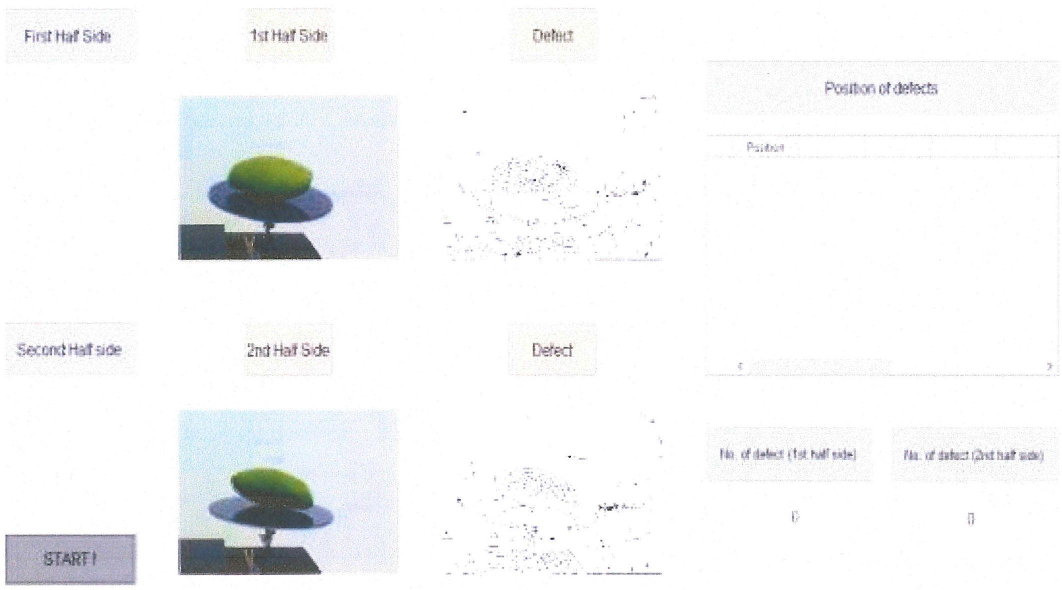

Figure 4.11 GUI for mango2 without defect

From the analysed image in figure 4.10 and 4.11, there is no black patch for the both first half side and second half side of mango. So, there is no defect for both first half side and second half side of mango. So, the number of defect for the first half side and second half side show the value zero.

4.6 Conclusion

The camera is used to capture the image of the fruit. Then the image of the fruit will be analysed using image processing. The fruit on the rotating desk must be able to rotate 360 degree to detect the defect on the lateral surface. So, the Graphical User Interface (GUI) is build to show the original image and the analysed image of the fruits. Whenever there is a surface defect on the fruit, the GUI will show the position of surface defect and number of defect. Another function is a red circle will occur whenever there is defect. Figures above show a few sample of apple and mango.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this project, an automatic fruit grading system was designed. This system consists of mechanical part such as rotating desk that act as a place for inspection; electrical parts such as DC motor, Arduino, computer and software such as image processing in MATLAB. This automatic grading system has been designed to meet the demands in grading fruits' operation compared to manual grading. The grading of the fruits is based on the external quality factor which is surface defect and decay. The images of the fruits were captured and the features have been extracted. This system has saved time, effort and better accuracy than manual grading. This system starts with a DC motor that is programmed by Arduino to rotate 180° twice for each lateral surface of the fruit. The DC motor shaft is connected to the rotating desk. Firstly, the fruit is brought manually to the rotating desk for inspection. Then, the DC motor is switched on to rotate while the camera will capture the lateral surface of fruit. Finally, the software MATLAB will be used for the image processing to show the analysed image at the graphical user interface (GUI). If there is a defect on the surface of fruit, then the red circle will appear around the defect at the analysed image however if there is no defect, then the red circle will not appear at the image. Generally image capture is a challenge, so, the images are captured by using white background to improve the accuracy and avoid the texture problem.

5.2 Recommendations for the Future Work

The other parameters such as size, shape can also be included in this project for future research. These parameters will play valuable role for quality analysis process.

Besides, further research work can be used for sorting of fruits for agricultural products. In addition, since there will be some kind of fruits with same colour i.e. tomato and apple, so, there will be a misclassification. Hence one feature can be added also namely texture while classifying such kinds of fruits. Besides, an impact sensors might improve the automatic visual inspection system like infrared sensor or capacitive sensor.

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APPENDIX A
GANTT CHART FYP 1

	Task	Semester 1 (Week)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	FYP briefing and choose the project title	■	■												
2	Project briefing by supervisor			■											
3	Literature Review			■	■	■									
4	Define Problem Statement					■	■								
5	Define Objective							■							
6	Declare the Project Scope								■	■					
7	Classification of fruits									■	■	■			
8	Write Project Proposal											■	■		
9	Submission Project Proposal and slide												■	■	
10	Proposal Presentation													■	

APPENDIX B
GANTT CHART FYP 2

	Task	Semester 2 (Week)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	FYP1 Report	■	■												
2	Submission of FYP1 report		■	■											
3	Classification of fruits			■	■	■									
4	Design the rotating desk				■	■									
5	CCD camera interact with PC					■	■								
6	Test and troubleshooting							■	■	■					
7	Result, discussion and analysis								■	■	■				
8	Design Poster									■	■	■			
9	Poster presentation											■	■		
10	Finalize the thesis												■	■	
11	Submission of thesis												■	■	

APPENDIX C
ARDUINO CODE

```
int pulses1;
int encoderA1 = 2;
int encoderB1 = 3;
const int pwm1 = 11;   //l293d [1]
const int M11 = 5;   //l293d [2]
const int M12 = 4;   //l293d [7]
int angle1 = 0;
int angle1out = 0;
//const int pin5V = 22;
//#define total 2400
//#include "math.h"
//using namespace std;
//time difference
unsigned long time;
 float dt=0;
 float prev=0;
//PID_A
float e_A=0;
float I_A=0;
float D_A=0;
float prev_eA=0;
int oA=0;
//user input angle
```

```
//String detha;
String detha_null;
int angtopul1=0;
void setup() {
  Serial.begin(9600);
  //pinMode(pin5V,OUTPUT);
  //digitalWrite(pin5V, HIGH);
  pinMode(pwm1, OUTPUT);
  pinMode(M11, OUTPUT);
  pinMode(M12, OUTPUT);
  analogWrite(pwm1, 0);
  digitalWrite(M11, HIGH);
  digitalWrite(M12, HIGH);
  pinMode(encoderA1, INPUT);
  digitalWrite(encoderA1,HIGH);
  pinMode(encoderB1, INPUT);
  digitalWrite(encoderB1,HIGH);
  attachInterrupt(0, A1_CHANGE, CHANGE);
  attachInterrupt(1, B1_CHANGE, CHANGE);
}//setup
void loop(){
   //while(Serial.available() == 0);//{
   angle1 = angle1+180;
   Serial.println(angle1);
   angtopul1=angle1*6.66666667;
```

```
    //angtopul1=600;
    //Serial.println(angtopul1);
  //}
    for(int m = 0;m<200;m++){
    timer();
    PID_A(angtopul1);
    }
    delay(5000);
}
void start(){
   //if (Serial.available() > 0){
  // detha_null  = Serial.readStringUntil('\0');
  Serial.println("starting");
  delay(8000);
   angle1 = angle1+90;
   Serial.println(angle1);
   angtopul1=angle1*6.66666667;
   //angtopul1=600;
   Serial.println(angtopul1);
   while(Serial.available() == 0){
   PID_A(angtopul1);
   timer();
   Serial.println("if loop");
 }
// }
```

```
  //delay(5000);
}
void timer()
{
  time = millis();
  dt=(time-prev)*0.001;
  prev=time;
  delay(10);
}
void PID_A(int setpoint)
{
  e_A=setpoint-pulses1;
  I_A=I_A+e_A*dt;
  D_A=(e_A-prev_eA)/dt;
  oA=e_A*0.7+0.04*D_A;
  prev_eA=e_A;
  delay(dt);
  if (oA<-255 ){
    oA=-255 ;
   }
   else if(oA>255){
     oA=255;
    }
    else{
      oA=oA;
```

```
}
 if (oA<0){
 oA=-1*oA;
 oA=oA*0.67058+75;
 analogWrite(pwm1,oA);
 digitalWrite(M11,LOW);
 digitalWrite(M12,HIGH);
 if (oA<83)
 {
  oA=0;
 digitalWrite(M11,LOW);
 digitalWrite(M12,LOW);
 }
 else{
  oA=oA;
 }
    }
else{
 oA=oA*0.67058+75;
 analogWrite(pwm1,oA);
 digitalWrite(M11,HIGH);
 digitalWrite(M12,LOW);
 if (oA<83)
 {
  oA=0;
```

```
      digitalWrite(M11,LOW);
      digitalWrite(M12,LOW);
      }
      else{
       oA=oA;
      }
     }
}
void A1_CHANGE(){
 if( digitalRead(encoderB1) == 0 ) {
  if ( digitalRead(encoderA1) == 0 ) { // A fell, B is low
   pulses1--;
  } else {// A rose, B is low
   pulses1++;
  }
 }else {
  if ( digitalRead(encoderA1) == 0 ) { // B fell, A is high
   pulses1++;
  } else {// B rose, A is high
   pulses1--;
  }
 }
}
void B1_CHANGE(){
 if ( digitalRead(encoderA1) == 0 ) {
```

```
    if ( digitalRead(encoderB1) == 0 ) { // B fell, A is low
      pulses1++;
    } else {// B rose, A is low
      pulses1--;
    }
  } else {
    if ( digitalRead(encoderB1) == 0 ) {// B fell, A is high
      pulses1--;
    } else {// B rose, A is high
      pulses1++;
    }
  }
}
```

APPENDIX D
MATLAB CODE

```
clc
clear all
for (n=1:1:2)
vid = videoinput('winvideo',1);
preview (vid);
 start(vid);
for(i=1:1:6)
data=getdata(vid,1);
end
if (n==1)
io=size(data)
kio=data;
y1=abs(io(1)/2)-100;
x1=abs(io(2)/2)-100;
GH=imcrop(data,[x1 y1 io(2)+500 io(1)+500]);
IS=rgb2gray(GH);
PSF = fspecial( 'gaussian',3,3);
I = imfilter(IS,PSF,'symmetric' ,'conv');
BWA = edge(I,'sobel');
BWP = edge(I,'prewitt');
BWC = edge(I,'canny');
P = imfill(BWC, 'holes');
P = ~P
[centers, radii] = imfindcircles(P,[10 40],'ObjectPolarity','dark','Sensitivity',0.9)
delete(vid)
else
io1=size(data)
kio1=data;
```

```
y11=abs(io1(1)/2)-100;
x11=abs(io1(2)/2)-100;
GH1=imcrop(data,[x11 y11 io1(2)+500 io1(1)+500]);
IS1=rgb2gray(GH1);
PSF1 = fspecial( 'gaussian',3,3);
I1= imfilter(IS1,PSF1,'symmetric' ,'conv');
BWA1 = edge(I1,'sobel');
BWP1 = edge(I1,'prewitt');
BWC1 = edge(I1,'canny');
P1= imfill(BWC1, 'holes');
P1 = ~P1;
[centers1, radii1] = imfindcircles(P1,[10 40],'ObjectPolarity','dark','Sensitivity',0.9)
delete(vid)
end
end

subplot(2,3,1), imshow(GH)
subplot(2,3,2), imshow(GH1)
subplot(2,3,3), imshow(P)
subplot(2,3,4), imshow(P1)
```

APPENDIX E
CONFERENCE PAPER

AUTOMATED FRUIT GRADING SYSTEM

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Abstract- **In recent years, automatic visual inspection technology has become more potential and important to many areas. It is because the quality of fruits becoming an important factor for the consumer and is essential for marketing uniform high quality produce. The fruits grading factories have been set up to reduce production costs and improve fruit quality. Besides, an automatic visual inspection system aimed to replace the manual technique for grading of fruits as manual inspection faces problems in maintaining consistency and uniformity. This project describes the design of an automated fruit grading system. A prototype of the system is designed and tested. In this project, the detection of surface defect of fruits is described in details. The developed system starts the process by capturing the fruit's image using camera of computer where the fruits are placed on a rotating desk. Then, the image is transmitted to the processing level where the grading is done using MATLAB. The fruits are classified based on their surface defects.**

I. INTRODUCTION

The quality of the fruits is important for the consumers and become the requirement from the suppliers to provide fruits with high standards of quality. So, in the past few years, fruit grading systems had established to fulfil the needs of the fruit processing industry. Besides that, the process of fruits involves several steps that can generally be classified into grading, sorting, packaging, transporting and storage. The grading are considered as the most important steps towards the high standard of quality.

Fruits are almost graded manually which is an expensive and time consuming process and labours shortage will affect to the operation during peak seasons. It has become increasingly difficult to hire or train the person who are willing to handle the monotonous task of inspection. In the meanwhile, a cost effective and accurate grading can be performed with automated grading system.

Generally, the fruits quality depends on outer parameters (size, colour intensity, shape, surface appearances) and inner parameters (sugar contents, acid contents) but colour and size is the most important factor for grading and sorting of fruits. Nowadays, the fruit grading system based on weight, colour and size are accessible in the fruit processing industries.

The fruit grading system techniques using computer machine vision and image processing play the important role of quality control in fruit processing industries. From the past few years, different techniques have been enhanced to grade and evaluate the quality of fruits. These methods can help to detect different physical properties of fruits and with certain quality factors. For example, the vision-based systems include CCD or CMOS sensors that are used to estimate the size and shape of fruits. It helps to predict the size of the fruits from its RGB image frame with the help of CCD camera. Software plays an important role in this colour classification system. The software system is almost designed in MATLAB to detect the colour and size of the fruits. Colour is very important in the sorting of fruits but due to the similarity of colours between some fruits, the size also helps in solving the problems.

II. METHODOLOGY

The grading system relies on the features extracted from the image. Therefore, feature extraction plays an important role in developing the system.

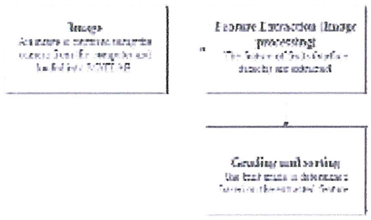

Fig.1. Flowchart of grading process

In order to design a system to grade the fruit, image acquisition and features classification is the important steps. The design is first concerned with establishing a basic structure of a system. Before that, the CCD camera/ camera from computer is used to capture the image of the fruits to do the classification of fruits. Fruit varieties are further classified depending upon their appearance such as colour and size. Fruit classification and fruit disease identification can be seen as an instance of image categorization. To measure and calculate the features from the image samples to distinguish between one type of image from another, feature extraction is used. The feature extraction process is done using the MATLAB image processing toolbox.

A. Materials and methods

The apparatus used for fruit classification in this project is made by simple image processing equipment. In this project, the computer vision system will be set up to detect the lateral surface of the fruits shown in Figure 2. The system was tested by using a samples of apples and mangoes. Firstly, the fruit is brought manually to the rotating desk which the rotating desk will be connected to the shaft of the 12V DC motor. The DC motor is then set by Arduino to rotate 180° for two times for each of the fruits to detect the defects of the lateral surface of fruits. Then, the camera will capture the image and show the analysed image at the Graphical User Interface (GUI). Besides, we can observe the surface defects and decay of fruits through GUI.

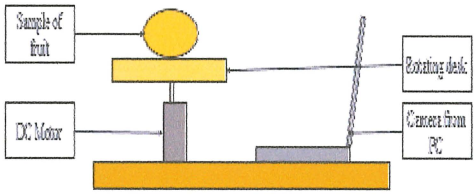

Fig.2. Automatic fruit grading system

Below shows the mechanical calculation for the consideration of DC motor. From the calculation, the DC motor is able to rotate the rotating desk with fruit on it.

- Maximum weight of fruit sample

  $= 1.0kg$

- Weight of rotating desk

  $= 0.3kg$

- Torque of DC motor

  $= 0.784N.m$

- Weight of fruit sample + weight of rotating desk

  $= 1.0kg + 0.3kg$

- Radius of DC-Motor

  $= 1.8cm$

Torque needed to turn the rotating desk and sample of fruit

$= 1.8cm \times 1.3kg$

$= 2.34kgcm$

Convert the kg cm to N.m

$= 2.34kgcm \times \frac{9.81}{100}$

$= 0.23N.m$

B. Hardware

The automatic fruit grading system is shown in figure 3. In this project, camera from laptop is positioned to detect the lateral surface of the fruit. The sample of fruits are brought to the rotating desk for grading. The DC motor is used to rotate the desk which allow the camera to capture the lateral surface of the fruits.

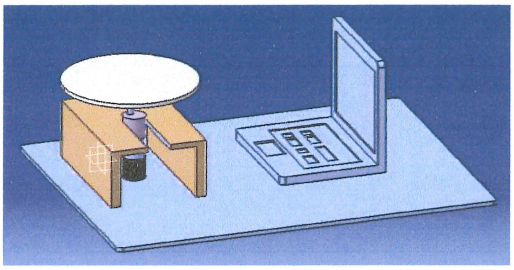

Fig.3. Hardware draw by Catia software

C. Graphical User Interface (GUI)

Graphical user interface (GUI) is a type of user interface that allows users to interact with electronic devices. GUI is used in this project to show the user the defects of lateral surface of fruits. The image of the fruits that captured by the camera will show at the box in GUI. Then, the centers and radii of defects of apple and mango are analysed.

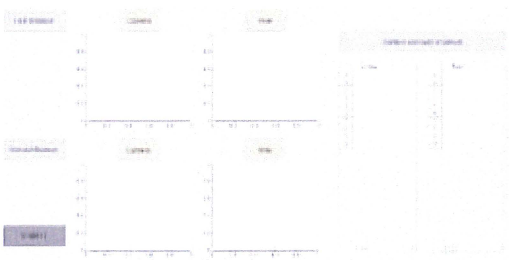

Fig.4. Graphical User Interface (GUI)

D. Classification of fruits

In this project, the classification of fruits is important. The classification of fruits are based on the types of defects. First, two types of fruits are being chosen for this project that are apple and mango. Then, mangoes are divided into two groups that are anthracnose and normal mango. Apples are divided into two groups also that are bull-eye rot and normal apple. The camera will capture the image of the surface of fruits and will analyse the types of defects of the fruits.

III. RESULTS AND DISCUSSIONS

As stated earlier, two types of fruits; apples and mangoes are used for classification. The grading system has so far been developed for apples and mangoes however, the basic concept and method is the same. The performance of the grading system depends on many factors that farmers use for measuring the fruit quality. These factors can be classified into two groups that are external quality factors and internal quality factors. The external quality factors can be defined as visual appearance of the fruit. Commonly used factors are size, shape, colour, surface defects and decay. The internal quality factors are smell, taste, sweetness and sourness but in this project we will only concern on the external quality factors that is surface defects and decay.

Automatic grading system is the implementation that begins with the fruit sample being captured using camera with white background that image analysis can be applied to make grading in MATLAB. Image processing in MATLAB is used to extract the parameter of apple and mango in order to prepare the input for classification. The features such as surface defects or decay of fruits is used in this project.

Firstly, an image of the fruits is captured by using a camera and is loaded into the MATLAB by using the function 'videoinput'. This function reads the image from the camera. As if it is an coloured input, it need to be converted into grayscale by the function 'rgb2gray(image)' and the syntax is *I=rgb2gray(image)* which converts truecolour image RGB into grayscale intensity image. Then, the image is converted into binary which the image consists only two colours that are black and white. Canny edge detection method is used in this project to detect the edge of the image of the fruits and the corresponding syntax is *BW = edge(I,'canny')* to extract the boundary. Since the image is captured with white background, the background will be having pixel value of 255 indicating white colour. Figure 5 show the white background is used to capture the image of fruits.

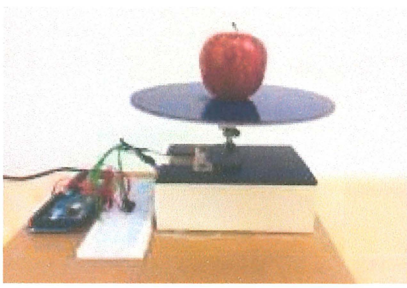

Fig.5. Image captured with white background

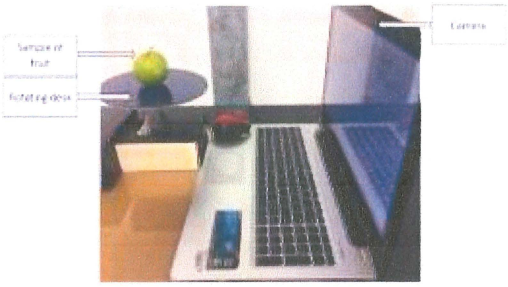

Fig.6 Prototype of the system

Besides, texture is important for image analysis because the recognition of colour by computer vision system is different if the surfaces of the fruits have different textures. For example, the texture for the area with defects on the surface of fruits will be darker. Thus, the dark patches or holes present in the image are filled using the function 'imfill()', and its syntax is *BW1 = imfill(BW1,'holes')* that fills holes in binary image BW.

To grade the fruits, some apples and mangoes are brought to the rotating desk. By observing the image analysed by MATLAB and shown in GUI, the dark patches or spots will be occurred at the area of fruit's defects, which almost has a circular shape. In this project, the command *'[centers, radii] = imfindcircles(image,[10 40])'* is used on the image to find the defects which are almost in circular shape with the search radius of [10 40] pixels. From the GUI, if there is any dark patches or spots at the analysed image, then, there is defect or decay on the surface of fruits. In addition, if there is defect on the surface of fruit, the GUI will show the position of the defect and number of defect. Moreover, a red circle will appear if there is a defect.

Below show the GUI for apple and mango with defects and without defect.

Apple:

With defect

Fig.7. GUI for apple with defect

From the analysed image in figure 7, there are black patches on the surface of fruit for the first half side but there is no black patch on the surface of fruit for the second half side. Therefore, there are defects on the first half side of fruit but no defect on the second half side of fruit. Additionally, there are two red circles on the first half side of fruits means that there are two defects.

Without defect

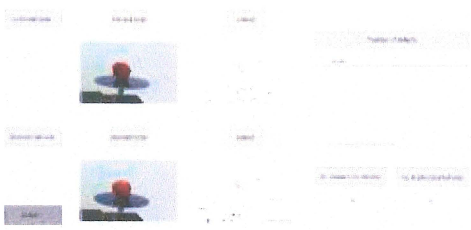

Fig.8. GUI for apple without defect

From the analysed image in figure 8, there is no black patches for the both first half side of apple and the second half side of apple. So, there is no defect for both first half side and second half side of apple.

Mango:

With defect

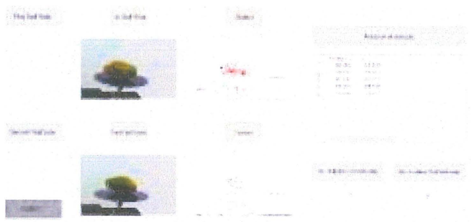

Fig.9. GUI for mango with defect

From the analysed image in figure 9, there are black patches for the first half side of mango but there is no black patch at the second half side of mango. So, there are defects on the first half side but no defect on the second half side of mango. Besides, the GUI shows that there are five red circles on the first half side of mango means that there are five defects while there is no red circle at the second half side means that there is no defect.

Without defect

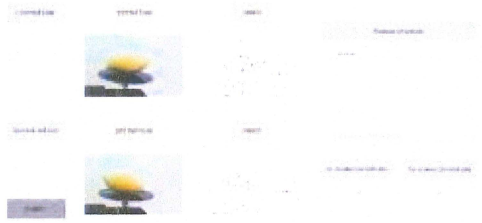

Fig.10. GUI for mango1 without defect

Fig.11. GUI for mango2 without defect

From the analysed image in figure 10 and 11, there is no black patch for the both first half side and second half side of mango. So, there is no defect for both first half side and second half side of mango.

IV. CONCLUSION

In this project, an automatic fruit grading system was designed. This system consists of mechanical part such as rotating desk that act as a place for inspection; electrical parts such as DC motor, Arduino, computer and software such as image processing in MATLAB. This automatic grading system has been designed to meet the demands in grading fruits' operation compared to manual grading. The grading of the fruits is based on the external quality factor that is surface defect and decay. The images of the fruits were captured and features been extracted. This system has saved time, effort and better accuracy than manual sorting. This system start with a DC motor that is programmed by Arduino to rotate 180° twice for each of the fruit. The DC motor shaft is connected to the rotating desk. Firstly, the fruit is brought manually to the rotating desk for inspection. Then, the DC motor is switched on to rotate while the camera will capture the lateral surface of fruit. Finally, the software MATLAB will do the image processing to show the analysed image at the graphical user interface (GUI). If there is a defect on the surface of fruit, then the red circle will appear around the defect at the analysed image whereas if there is no defect, then the red circle will not appear at the image. Generally image capture is a challenge, so, the images are captured by using white background to improve the accuracy and avoid the texture problem.

V. FUTURE WORK

The other parameters such as size, shape can also be included in this project for future research. These parameters will play valuable role for quality analysis process. Besides, further this research work can be used for grading and sorting of fruits for agricultural products with the help of digital images which involve inspection, image analysis and visual examination. In addition, since there will have some kind of fruits with same colour for example tomato and apple, so, there will be having some misclassification. Hence one feature can be added also namely texture while classifying such kinds of fruits. Besides, an impact sensor might improve the automatic visual inspection system.

VI. ACKNOWLEDGEMENT

The authors would like to express gratitude and acknowledge the Facility of Manufacturing Engineering, Universiti Malaysia Pahang (UMP) for continuous support.

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Bagging on F ruit Q uality in N avel. *Electronic Publishing*, *7*(5), 5–7.

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