BANANA RIPENESS DETECTION USING IMAGE PROCESSING AND FUZZY LOGIC

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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BANANA RIPENESS DETECTION USING IMAGE PROCESSING AND FUZZY LOGIC

IZZAT HAFIZ BIN HADFI

This report is submitted in partial fulfillment of the requirements for the

Bachelor of Computer Science (Artificial Intelligence)

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2016

DECLARATION

I hereby declare that this project report entitled

BANANA RIPENESS DETECTION USING IMAGE PROCESSING AND FUZZY LOGIC

is written by me and is my own effort and that no part has been plagiarized without citations.

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I hereby declare that I have read this project report and found this project report is sufficient in term of the scope and quality for the award of Bachelor of Computer Science (Artificial Intelligence) With Honours.

SUPERVISOR: ______________________ Date: 29/8/2017

DR. ZERATUL IZZAH MOHD YUSOH

DEDICATION

To my beloved parents, thanks for all the kinds of support during the development of this project.

To my supervisor, Dr. Zeratul Izzah Bt Mohd Yusoh. Thanks for all the knowledge and giving guidance during the project development period.

To my beloved friends, UTeM students from other course who are willing to share their knowledge during the project development.

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First I should give thanks to Him for all his sustenance, for giving good health and for being the reason that I am still breathing until now.

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I would also like to express my gratitudes to all my friends that gave contribution and support along the project development.

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ABSTRACT

Nowadays, the agricultural industries had been expanding widely, and brings competition among the agricultural industry which will need them to have critical product quality management in order to surpass the competition. These agriculture industries includes the banana plantation industry which is the second most widely cultivated fruit in Malaysia. The current method to detect the ripeness of banana is using chemicals in order to obtain the characteristic of the fruit. This method will harm the fruit and also affects its quality. There are also methods which is non-destructive to the products which uses man power to identify the banana. This method is time consuming. It is also a big disadvantage to use human eye to compare the indistinct color range of the banana. Furthermore, it is a disadvantage for the customer to pick a banana with less knowledge of the fruit and without knowing any recommendations on the current fruit ripeness. Thus the objective of this project is to determine the correct method in assisting users in selecting bananas. This project is proposing a combination of two Artificial Intelligence techniques, namely Image Processing technique and Fuzzy Logic rules in a knowledge-based system for the solution. Several samples of un-ripe, ripe and over-ripe banana are taken to identify their red, green and blue (RGB) value. The RGB values are extracted by using MATLAB software. The values are then analyzed to create the membership functions for the fuzzy logic. Then a set of knowledge-based rules are implemented for the system to give recommendations to the user on the banana. Another sample of banana is also will be taken for testing. The testing goes through RGB extraction and the fuzzy logic will be used to identify the ripeness of the banana. From the result of the ripeness, the system will give recommendations on the fruit including suggested meal preparation and the best before date to consume the banana. This proposed system contributes to both farmers and customers. As for the farmer, they can pick their best product to be sold to the market. While for the customers, they can choose efficiently their desired banana ripeness by using this system.

ABSTRAK

Pada masa kini, industri agrikultur telah berkembang dengan pesatnya dan telah membawa persaingan dikalangan industri-industri ini yang memerlukan mereka untuk mengutamakan pengurusan kualiti bagi mengatasi persaingan ini. Industri agrikultur ini termasuk industri perladangan pisang yang merupakan tanaman yang ke-dua terkerap di Malaysia. Teknik yang terkini bagi menilai tahap masak pisang ialah menggunakan bahan kimia untuk menghasilkan ciri-ciri buah tersebut. Teknik ini akan merosakkan buah tersebut dan menjejaskan kualitinya. Terdapat juga teknik lain yang menggunakan kuderat manusia. Teknik ini memakan masa yang lama. Ia juga satu kekurangan bagi menggunakan mata manusia bagi membezakan perbezaan warna yang kurang jelas sebuah pisang. Selain itu, ia merupakan satu kekurangan bagi pelanggan untuk memilih pisang dengan kurang pengetahuan tentang buah tersebut dan cadangan hidangannya. Sedemikian itu, objektif projek ini ialah untuk mengenalpasti teknik yang bersesuaian bagi membantu pengguna untuk memilih pisang. Projek ini menggabungkan dua teknik Kepintaran Buatan iaitu, Pemprosesan Imej dan Logik Kabur di dalam Sistem Berasaskan Pengetahuan bagi solusinya. Beberapa sampel pisand yang belum matang, sudah matang, dan terlebih matang dikumpul bagi mengenal pasti nilai RGBnya. Nilai RGB tersebut diekstrak menggunakan perisian MATLAB. Nilai tersebut di analisa bagi membangunkan *membership function* untuk proses Logik Kabur. Seterusnya beberapa set syarat Pengetahuan Berasas di implimen bagi sistem untuk beri cadangan kepada pengguna untuk pisang tersebut. Sampel pisang yang selebihnya akan digunakan untuk ujian. Ujian tersebut melalui pengakstrakan RGB dan Logik Kabur akan digunakan untuk mengenal pasti tahap masak pisang tersebut. Daripada keputusan tahap masak tersebut, sistem tersebut akan memberi cadangan terhadap pisang termasuk cadangan hidangan dan tarikh luput pisang tersebut. Sistem ini banyak memberi kelebihan kepada kedua tukang kebun dan juga pelanggan. Bagi tukang kebun, mereka boleh memilih produk terbaik mereka untuk pemasaran. Manakala untuk pelanggan, mereka boleh memilih dengan efisyen pisang yang dikehendaki dengan menggunakan sistem ini.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

As time passes, the human race are expanding and so do their needs which are foods. The agriculture industries play an important role in providing this needs. Therefore, with the human race expanding, the agriculture industries are also expanding. This causes a large competition among the agricultural industries. In order to surpass the competition, they need to have a critical product quality management.

The agriculture industries is not only about growing food crops and raising animals in farms, it also includes greenhouses and nurseries. The agriculture industries has many sectors, one of it is the banana plantation industry. The banana plantation industry is also a large industry in Malaysia where it is the second most widely cultivated fruit in Malaysia. (Anim, 2017). The banana plantation can yield many type of product. The fruit can be deep fried and also eaten raw, while the leaf can be used to wrap the infamous dish in Malaysia which is called the 'Nasi Lemak'.

As mentioned earlier, these industries need to have a product quality management in order to survive the competition. To ensure a quality product is to choose the best fruit to be sold at the market. A consistent and efficient method is also needed for the quality grading to ensure a consistent product quality. The current method uses man power which is in-consistent and also time consuming.

By developing the system which is Banana ripeness detection using image processing and Fuzzy Logic, it can help to overcome these problems faced by the banana plantation industry. By using a computerized method, the quality grading is not only consistent, but also a time saving method. This system uses image processing techniques in order to obtain the banana characteristics. With the help of Artificial Intelligence, Fuzzy Logic method, it can help the system to determine whether the banana is ripe or not.

With the help of this system, farmers can ensure the best quality of their product to be sold to the market. It is also saves the man power needed for the operation of the company. Besides farmers, customer also gain some advantages. Customers can also use the system to pick the desired banana to be bought.

Figure 1.1: Cavendish Banana

1.2 Problem Statements

Quality grading is crucial for the farmer to choose the best banana to be sold to the market. The current method to detect the ripeness of a banana is by using chemicals in order to gain the parameters needed to tell whether the banana is ripe or not. This method will both harm the fruit and also endangered the health of the consumer itself (Zulhusin *et al.*, 2008).

Furthermore, most of the banana plantation industry uses man power for the quality grading phase. With man power, it is not consistent and time consuming. This is because the person that can tell the ripeness of the banana needs to be an expert. The knowledge of the expert can also be passed but this can cause the inconsistency.

Man power can also cause to a limited color grading issue. This is because the human eye don't having lack of capability to compare the indistinct color range of the banana. As we know, the banana fruit does not only comes with the color yellow or green. Some of the fruit have a little amount of green color, some have a little yellow color and there are also both of the colors in one fruit.

Lastly, it is a big disadvantage for the customer whom have lack of knowledge of the banana to buy one. This is because the customer is not able to pick the right fruit based on their desires. There are some of the fruit condition which needs to be wait long enough until it can be eaten, and some fruit can be eaten raw by cooking it into any delicacies.

1.3 Objective

The project embarks on the following objectives:

- To investigate the suitable techniques in determining the ripeness of the banana and how to use it.
- To implement Artificial Intelligent techniques namely, Image Processing technique, Fuzzy Logic and Knowledge-based rules in the solution.
- To develop a knowledge-based system for recommendation to the user.

1.4 Scope

There are many types of species of bananas in the world, each shows different characteristics when it is ripe. The type of banana used in this project will be the Cavendish banana which is common in Malaysia. (Anem, 2012). The system is designed for both the farmer and also customers. This system is focusing on determining the ripeness of the banana and give recommendations on the fruit ripeness.

1.5 Project Significance

This project brings significance to the agricultural stream. It will help farmer to detect the ripeness of the banana. Upon completion of this project, the quality grading phase will no longer needs the help of man power which will save time and have consistency. This method will preserve the quality of the banana where it does not involve any chemical usage. Instead of farmer, customer can also easily identify the ripeness of the banana sold at the market. Thus the objective of this project

1.6 Expected Output

The system should be able to identify the correct ripeness of the banana. The system should be able to give recommendations for the user on the ripeness of the fruit. The method used should be a less time consuming and can determine the ripeness level of the banana correctly.

1.7 Conclusion

As a conclusion, the banana plantation industry needs to focus on their quality management in order to survive the competition among the other agriculture industry sectors. The current quality grading uses man power which is time consuming and inaccurate. There are also method using chemicals to show the ripeness of the banana. This method is accurate but it loses the quality of the banana and can endanger the health of the consumer. Thus the objective of this project is to determine the correct method in assisting users in selecting bananas. This project is proposing a combination of two Artificial Intelligence techniques, namely Image Processing technique and Fuzzy Logic rules in a knowledge-based system for the solution. The type of banana which will be used in this project is the Cavendish banana. While the user of the system are the farmer and also the customers. The expected outcome of this project is the system should be able to determine the ripeness of the banana correctly. By the end of this project, it will help the farmer in the quality grading phase and also eases the customer in choosing their desire banana.

As for the next chapter which is literature review and project methodology. It will be discussing more detail about the domain which is the banana, the technique used and the existing systems. It also explains how the system is developed.

CHAPTER II

LITERATURE REVIEW AND PROJECT METHODOLOGY

2.1 Introduction

In this chapter, it will be covering all of the background which is related to this project. This chapter will be explaining the domain of this research which is mainly explaining about bananas. Besides that, it will explain the techniques will be used in this project which are image processing and fuzzy logic. For this part, it will only explain the techniques in general. Moreover, it will be explaining the existing systems related to this project. It will only explain few existing systems such as recognizing banana ripeness using artificial neural network, determination of size and ripeness of banana using image processing and etc. Lastly, this chapter will be explaining the methods used in building thus system.

2.2 Facts and Findings

2.2.1 Domain

The domain of this project is the fruit of a banana. In Malaysia, banana is the second cultivated plant after durian. (Anim, 2017). As we can see in Malaysia there are many product that are made of banana. The fruit itself can be made into many delicacies such as the Malaysian traditional cuisine 'Lepat Pisang'. It can be dried, smoked, boil and even deep fried. Besides the fruit itself, the flower of the fruit, which is known as 'Jantung Pisang' in Malaysia can be made into meal. While the leaf of the tree is often use as an aroma to intensifies the flavor of the dish.

Bananas are one of the most widely consumed fruits in the world (Schuh, 2014). This is because banana contains the nutrition that is good for the human body. Banana contains vitamin B6, manganese, vitamin C, potassium, biotin and copper. All these nutrient contents give many health benefits. Due to its richness in potassium, it may reduce the future risk the formation of kidney stones. Bananas can also reduce the risk of cancer due to its good source of vitamin C (Ware, 2017).

Besides that, eating a large amount of banana does not assure that a person is in good health. The human body only needs the specific amount of minerals. In other means, we cannot consume foods that are lacking of minerals neither as consuming too much foods containing minerals. As stated before, bananas contains good source of mineral such as potassium. Consuming too much potassium can be harmful for those whose kidney are not fully functional and can be fatal.

Bananas have their ripening stages, mostly people only think that a green banana means that it is till unripe and yellow means that it is ripe and ready to be eaten. There are few aspects that needs to be considered before confirming a banana is ripe or not. The factors are such as size, color, and the brown spots formation on the fruit. Sometimes people consider the perfect yellow color of banana is a ripe banana and other people consider the brown spots on a banana are rotten spots. This is wrong, the rotten spots that formed on a banana indicates that sugar content has risen in the ripening process.

2.2.2 Existing Systems

In this section, it will be explaining a few systems that had been developed. These existing systems will be related to the proposed system in this project. The existing systems are such as 'Determination of Size and Ripeness of a Banana using Image Processing' (Mustafa *et al.*, 2008), 'Recognizing the Ripeness of Bananas Using Artificial Neural Network Based on Histogram Approach' (Saad *et al.*, 2009), 'Assessment of Banana Fruit Maturity by Image Processing Technique' (Prabha and Satheesh, 2013), 'Non-destructive Watermelon Ripeness Determination Using Image Processing and Artificial Neural Network' (Rizam *et al.*, 2009), 'Detection of Red Ripe Tomatoes on Stem Using Image Processing Techniques' (Monavar *et al.*, 2011).

2.2.2.1 Determination of Size and Ripeness of a Banana using Image Processing

The main purpose of this system is to help the farmer to choose their products to be sold on the market and also to help the customers to choose the right banana for them to buy. In order to determine the best quality of a banana is to identify its size and its ripeness. Thus they apply image processing technique in order to full fill these requirements.

To measure the size of the banana, the image is first will be converted into black and white and the function regionprops is used to measure the properties of a selected region of an image in pixel count. Next they used the function imfill to fill the holes that are formed on the banana due to the black spots on the banana. The pixel count of the image depends on the distance of the camera with the object. The further the camera from the object the smaller the pixel count. To overcome this problem, they put a coin as reference object.

To determine the ripeness of the banana, they use ripeness percentage as the result. The total number of pixels is determined by converting the image to black and white. Based on the image the white color is assumed as the total pixel of the image. They used the function graythresh to compute the global threshold. The ripeness is determined with the formula.

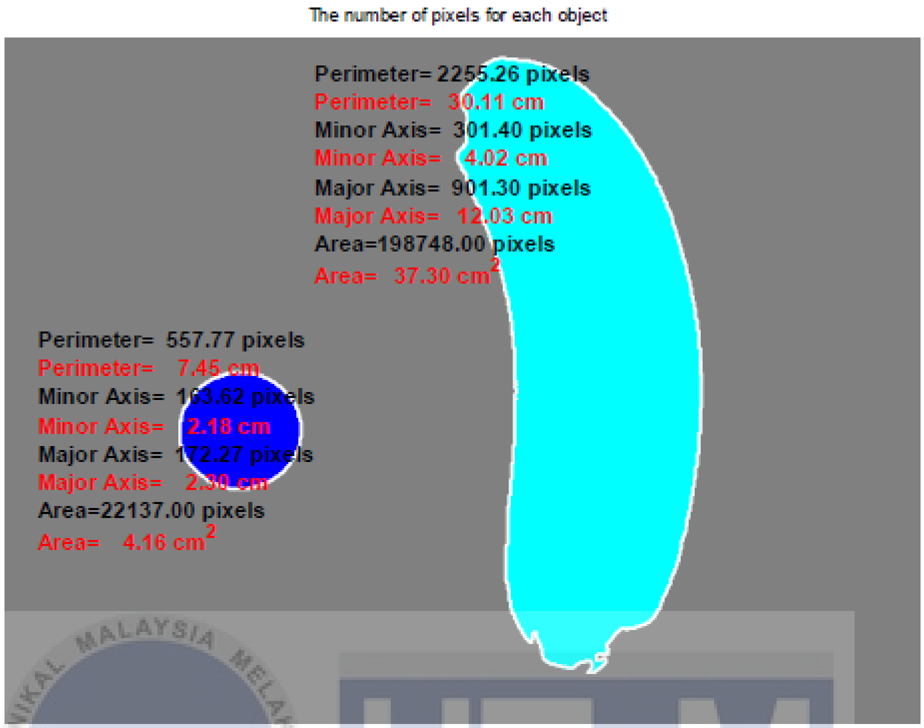

Figure 2.1: Number of Pixels and Actual Dimension (Mustafa *et al.*, 2008)

2.2.2.2 Recognizing the Ripeness of Bananas Using Artificial Neural Network Based on Histogram Approach

In this project, they used artificial neural network to recognize the ripeness of a banana. They used supervised learning rules for the learning rules. Supervised learning is where the data is trained from a set of examples. The examples will be the input, then the output will be compared with target which is the correct output. The learning rules is then used to adjust the weights and biases of the network in order to move output as close as to the target.

The project starts by gathering 3 sets of the unripe, ripe, and overripe of the banana image. Each set of the category contains 20 images. The image is then being resized and apply the process of extraction of RGB component. Each of the components contains pixel values ranging from 0 to 255, then it is divided into 3 groups of intensity. The values of the pixels are then exported into Microsoft Excels and graph is plotted based on the pixel values.

After the network has been trained, the optimization process is applied in order to choose the Smallest Mean Error value. In the process, it uses try and error in order to find the most suitable number of hidden nodes. It is found that 7 hidden layers will be used to get the most optimized results.

The results of the system is as the expected results. The system can successfully recognize between unripe banana, ripe banana and overripe banana. There are some results that are unable to be classified. The author claims that it is due to luminance effect of the sample because the captured images were not taken under control condition.

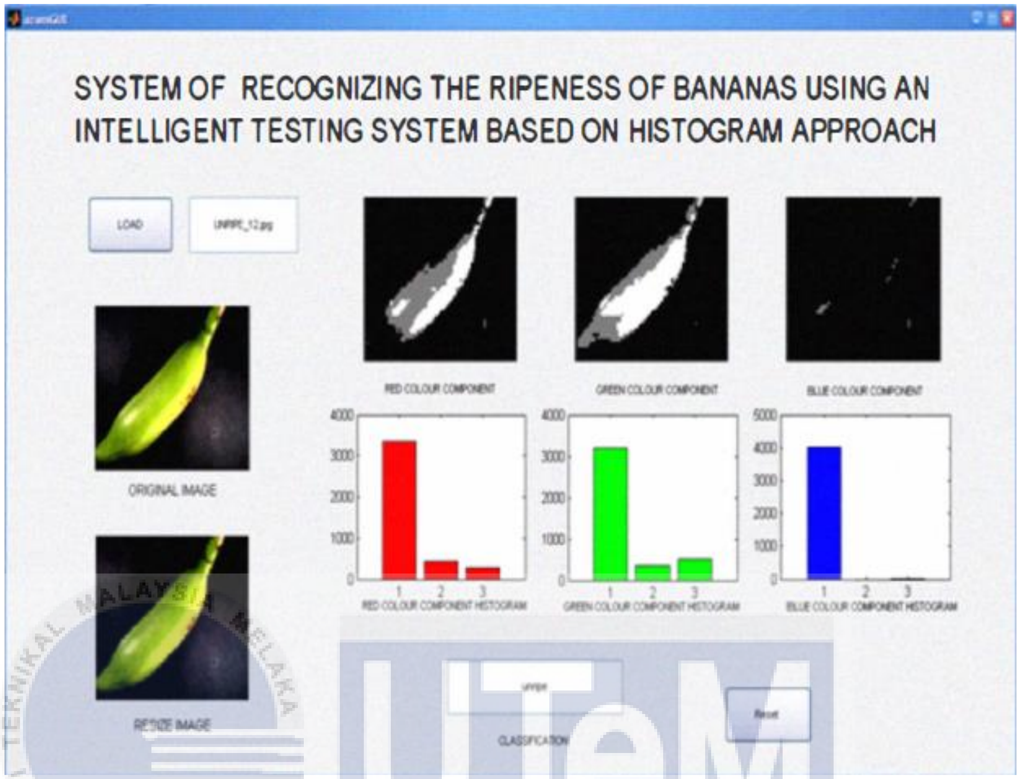

Figure 2.2: User Interface Layout of the System (Saad *et al.*, 2009)

2.2.2.3 Assessment of Banana Fruit Maturity by Image Processing Technique

The first phase of this project is the data sampling. The samples were collected from farmer's field at Sirumugai village, Theni District, Tamil Nadu, India and Erasakkanayakanur village, Theni District, Tamil Nadu, India. 120 banana fruits were collected and selected by its maturity stages from three categories which are under-mature, mature and over-mature. The fruits are selected by the skilled persons which engaged specifically for maturity prediction and harvesting.

The sample image of the bananas were taken and the background is removed using toolbox in Matlab. As the background is removed, the RGB color intensity was calculated using statistical moments obtained from histogram. The graph is then calculated its mean, variance, smoothness texture, skewness, and kurtosis.

Next the size of the banana is measured. The fruit was measured by its area and perimeter by measuring the number of pixels in the fruit region and measuring the number of pixels in the boundary region of the fruit respectively. The pixels measurement is then converted into cm in order to ease the farmer. The way to convert this measurement is by putting a cross section of a banana fruit next to a banana fruit on a graph sheet.

Analysis of variance (ANOVA) with Duncan's multiple range test (DMRT) was used to compare the significance of datasets of color mean intensity value, area, perimeter, major axis length and minor axis length between each banana group. The datasets were processed using two classifiers algorithm which are box and whisker plot technique.

The result of the project was going according to plan. They implement graphical user interface in Matlab to make it simpler and user friendly

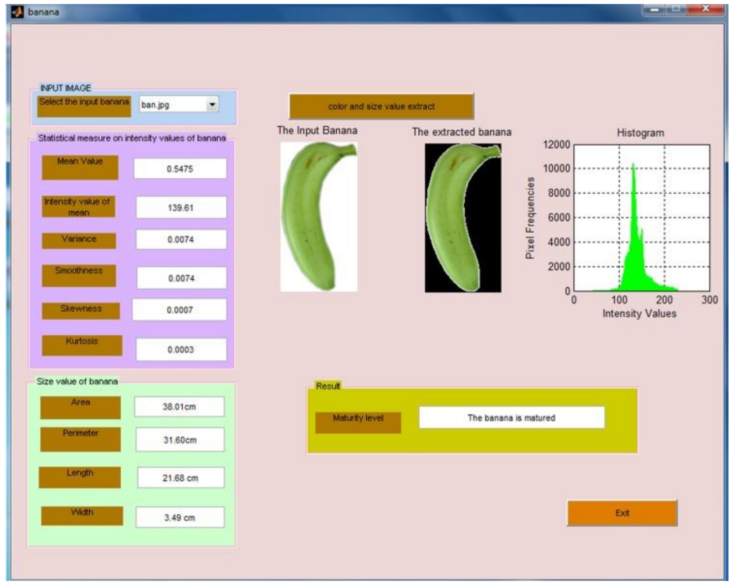

Figure 2.3: User Interface of the System (Prabha and Satheesh, 2013)

2.2.2.4 Non-destructive Watermelon Ripeness Determination Using Image Processing and Artificial Neural Network

The overall process of this project is to determine a ripe watermelon by extracting its color feature and process the data using supervised learning in Neural Network. Firstly the data of the watermelon need to be collected. They obtain the data from Melon Master Sdn. Bhd.; Selayang. The samples are divided into three categories which are ripe, under ripe, and over ripe. 90 watermelons were collected. Since the set is too small for Artificial Neural Network training, the data set was added noise and creates a total of 360 data sets all together.

The image is then acquired in the Image Capturing Studio Room where the environment were controlled. The captured image is then analyzed using MATLAB software. The image were converted into YCbCr color space. The data collected is then stored in one data base which is used to train the Artificial Neural Network. The sum of Y component in YCbCr were neglected because it is the brightness of the image where it does not affect the results.

For this project, they used supervised learning where the target values for the output are presented to the network in order for the network to update its weights. The input of the Artificial Neural Network model will be the mean value of the Cb and Cr color components. The Levenberg-Marquardt algorithm is applied due to its fast processing speed. Graphs were plotted to see the performance accuracy. From the results they found out that the best hidden unit with higher accuracy is at 32 hidden units.   .

2.2.2.5 Detection of Red Ripe Tomatoes on Stem Using Image Processing Techniques

This project was held in the greenhouse at Hashtgerd Greenhouse Center in Alborz province (Iran). 28 tomato trees were selected where at least 5 tomatoes with more than 50 percent redness. For the image acquisition process, a personal computer based on the microprocessor was used. At one expansion slot of the computer, an image digitizer was placed. The images were taken from a distance of 135cm and three images were obtained from the same tomato tree.

The image then processed by converting from RGB to HIS and YCbCr color spaces. The image is then filtered with the threshold values to give the image of the regions of interest. Before proceeding to all this process, the image is first converted to grey scale for removing unvalued data.

To measure the performance of the project, the red area of tomato image was computed using an own script in MATLAB. The performance of the algorithm was calculated using formula.

The different of this project with the other existing project is that the image sample is taken straight from the tree were the environment of the image is not controlled and the image is full of noise.

2.2.2.6 Comparison of Existing System

All the existing systems have similarity and differences. The table below will show the comparison between all these five existing systems.

Table 2.1: Comparison between Existing Systems

	Determination of Size and Ripeness of a Banana using Image Processing	**Recognizing the Ripeness of Bananas Using Artificial Neural Network Based on Histogram Approach**	**Assessment of Banana Fruit Maturity by Image Processing Technique**	**Non-destructive Watermelon Ripeness Determination Using Image Processing and Artificial Neural Network**	**Detection of Red Ripe Tomatoes on Stem Using Image Processing Techniques**
Type of fruit used	Banana	Banana	Banana	Watermelon	Tomato
AI technique used	Image processing	Image processing and Artificial	Image processing	Image processing and	Image processing

		Neural Network		Artificial Neural Network	
GUI application	No	Yes	Yes	No	No

2.2.3 Techniques

2.2.3.1 Image Processing

Image processing is a process of processing images using mathematical operations using any form of signal processing for which the input is a digital image or a video (Image processing, 2017). Image processing usually focuses on two tasks which are improvement of an informative image for human interpretation and processing of an image data for storage, transmission and representation. The input

With the help of image processing, many of the tasks that are impossible to be done by the human naked eyes are now possible. For example, law enforces uses image processing techniques to enhance an unclear image of suspect’s car plate number. Image processing is also applied in finger print recognition which is impossible for human eyes to recognize.

The input of an image into the image processing platform needs to be a digital image. A digital image is a representation of a two-dimensional image as a finite set of a digital values, called picture elements or pixels. Each pixel of an image has its own values. The values are often grey levels which ranges from 0 to 255 which indicates from black to white. All the values will be stored in matrices composed of M rows and N columns.

One of image processing platform is Matlab. In Matlab, there are many tools that are already in the software such as, image enhancement, image segmentation, line detection and etc. These tools uses mathematical operations to modify the pixel values of the image to give the desired information from the image for the user. With all the tools provided in the Matlab toolbox. The RGB values of the bananas can be obtained easily. Furthermore, this technique is a non-destructive to the fruits.

MATLAB
The Language of Technical Computing

Figure 2.4: Matlab logo

2.2.3.2 Fuzzy Logic

Precision is what most people trying to achieve and solve their daily life problems. But we humans cannot run from our imprecise reasoning. For example parking a car, humans cannot park a car into a parking lot on the same position every day. There might be even a little imprecision if the driver is fully experience.

The meaning of fuzzy is not sharp, unclear, imprecise or approximate. Therefore fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1 (Fuzzy logic, 2017). Fuzzy logic needs a membership function in order to operate. Membership function is a graph that is plotted line that defines how each point in the input space is mapped to a membership value or degree of membership which are between 0 and 1. There are many methods in assigning the membership functions such as intuition, inference and rank ordering. Besides these methods, some other artificial intelligent techniques can be applied such as neural network, genetic algorithms and etc.

The first process of fuzzy logic is fuzzification. This is where the membership functions are obtain more than one. While the last process is called defuzzification. This process involves converting the fuzzy sets into crisp sets. There are many methods used for deffuzification such as max-membership principle, centroid method, weighted average and etc. Each of this method has its own advantage and disadvantage based on each situation.

2.3 Project Methodology

For this project, it applies the waterfall model for the project methodology. Waterfall model is a linear-sequential life cycle model where each phase must be completed before proceeding to the next phase. Besides that, the system development life cycle of waterfall model is easy to use and understand.

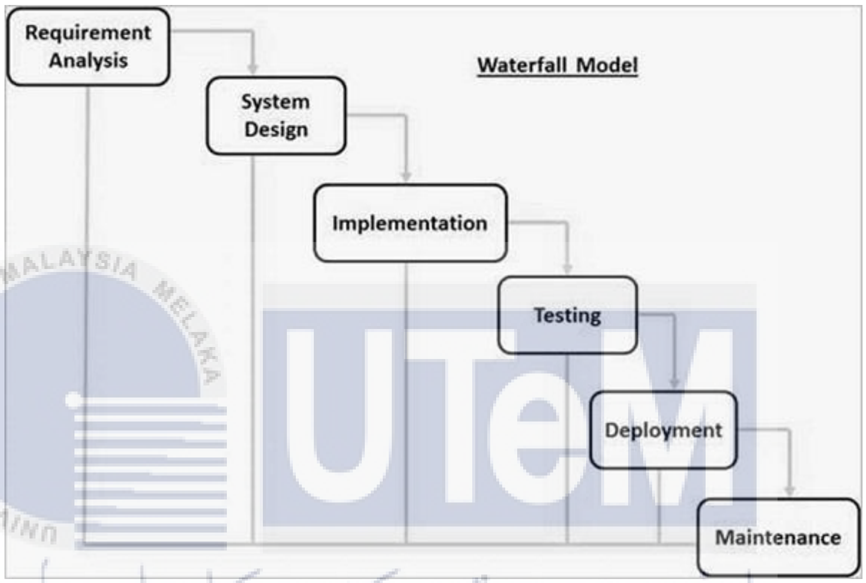

Figure 2.5: Software Development Life Cycle of Waterfall Model

2.3.1 Phase 1: Requirement Gathering and Analysis

In this phase, all the possible requirements in developing the system are documented. The possible requirements are the research papers of the previous existing systems which related to the project and also the facts about bananas.

2.3.2 Phase 2: System Design

To proceed to the second phase, all the requirements that were gathered from the first phase is studied in this phase. By studying the existing systems, .we can see the advantage and disadvantages of the previous system. The suitable AI technique will be decided in this phase. This will help the system designing phase.

2.3.3 Phase 3: Implementation

As the system is successfully designed, we can now proceed to the implementation phase. This phase involves the coding part. The coding is only developed by its small functions. These functions will be tested for any faults.

2.3.4 Phase 4: Integration and Testing

All the small functions will be integrated into one whole system. The system will also be tested for any faults.

2.3.5 Phase 5: Deployment of the System

Once the system is functional, the product is ready to be deployed. In this case, it will be presenting to the supervisor whether the system is suitable or not.

2.3.6 Phase 6: Maintenance

There will be some faults or unmet specification of the system with the supervisor. To fix the issues the phases will be repeated based on the fault that needed to be fixed.

2.4 Project Requirements

2.4.1 Software Requirements

Table 2.2: Software Requirements

Matlab R2015a	Coding tools for AI techniques
Microsoft Excel 2013	Data sorting
Microsoft Word 2013	Documentation
Microsoft Power Point 2013	Presentation
Adobe Illustrator	Poster design

2.4.2 Hardware Requirements

Table 2.3: Hardware Requirements

Asus A550C, Intel core i3, 4GB RAM	Personal computer
Apple iPhone 5, 8-megapixel iSight camera	Image acquisition

2.4.3 Other Requirement

Table 2.4: Other Requirement

Cavendish banana	Data training and testing

2.5 Project Schedule and Milestone

Table 2.5: FYP1 Project Schedule and Milestone

Week	Activity	Note / Action
1 **13-17 Feb** Meeting 1	Proposal PSM: Discussion & Submission using PSM Online System	Deliverable – Proposal Action – Student
	Proposal assessment & verification	Action – Supervisor, Evaluator
2 **20-24 Feb**	Proposal Correction/Improvement	Action – Student
	List of supervisor/title	Action – PSM/PD Committee
3 **27 - 3March** Meeting 2	Proposal Presentation Chapter 1 (System Development Begins)	Deliverable – Proposal Presentation (PP) Action – Student
4 **6-10 March**	Chapter 1 Chapter 2	Deliverable – Chapter 1 Action – Student, Supervisor
5 13-17 **March**	Chapter 2	Action – Student
6 **20-24 March** Meeting 3	Chapter 2 Chapter 3	Deliverable – Chapter 2 Progress Presentation 1 / Pembentangan Kemajuan 1 (PK 1) Action – Student, Supervisor
	Student Status	Warning Letter 1 Action – Supervisor, PSM/PD Committee
7 **27-3**1 **March**	Chapter 3 Chapter 4	Action – Student
8 **3-7 Apr**	MID SEMESTER BREAK	
9 **10-1**4 **Apr**	Chapter 4 Project Demo	Deliverable: Chapter 3 Action – Student, Supervisor
10 **17-21 Apr** Meeting 4	Chapter 4 Project Demo	Deliverable – Progress Presentation 2 / Pembentangan Kemajuan 2 (PK 2) Action – Student, Supervisor

	Student Status	Warning Letter 2 Action – Supervisor, PSM/PD Committee
11 **24-28 Apr** Demonstration	Project Demo	Action – Student
	Determination of student status (Continue/Withdraw)	Submit student status to Committee Action – Supervisor, PSM/PD Committee
12 1-5 **May**	Project Demo PSM1 Report	Action – Student, Supervisor
13 **8-1**2 **May** Meeting 5	Project Demo PSM1 Report	Action – Student, Supervisor
	Presentation schedule	Action – PSM/PD Committee
14 1**5-19 May**	Project Demo PSM1 Report	Deliverable – Complete PSM1 Draft Report Action – Student, Supervisor
15 **22-2**6 **May** Final Presentation	FINAL PRESENTATION & PROJECT DEMO	Action – Student, Supervisor, Evaluator
16 19-23 Dec	REVISION WEEK Correction on the draft report based on the comments by the Supervisor and Evaluator during the final presentation session Submit PSM1 Logbooks to PSM Online System	Deliverable – Complete PSM1 Logbooks Action – Student, Supervisor
	Submission of overall marks to PSM/PD committee	Deliverable: Overall PSM1 score sheet Action – Supervisor, Evaluator, PSM/PD Committee
17 & 18 26 Dec - 8 Jan 2017	FINAL EXAMINATION WEEKS	

Table 2.6: FYP2 Project Schedule and Milestone

Week	Activity	Note/Action
1 3- 7 Jul	Chapter 4: Design Chapter 5: Implementation	Deliverable – **Chapter 4** Action – Student
2 10 – 14 Jul	Chapter 5: Implementation Progress Evaluation	Deliverable – **Progress Presentation 1 (Pembentangan Kemajuan 1,(PK1)** Action – Student, Supervisor
3 17 – 21 Jul	Chapter 5: Implementation Chapter 6: Testing	Deliverable – **Chapter 5** Action – Student, Supervisor
4 23 – 28 Jul	Chapter 6: Testing	Deliverable – **Progress Presentation 2 (Pembentangan Kemajuan ,(PK) 2)** Action – Student, Supervisor
	Student Status	Action –PSM/PD Committee, Supervisor Warning Letter 1
5 31 Jul – 4 Aug	Chapter 6: Testing Chapter 7: Conclusion Progress Evaluation	Deliverable – **Chapter 6** Action – Student, Supervisor
6 7 – 11 Aug	Chapter 7: Conclusion Complete Final Report (draft) Determination of student status	Deliverable – **Chapter 7** Action – Student, Supervisor
7 14 – 18 Aug	Presentation Schedule PSM 2 presentation and evaluation	Deliverable – **Complete Report(draft)** Action – Student, Supervisor, Committee

8 21 – 25 Aug	- Correction report based on supervisor's and evaluator's comments during the final presentation session. -Submit overall marks to committee	Action – Evaluator, Supervisor, Committee
9 28 Aug – 1 Sept	-Submit PSM complete report for supervisor's signature and binding	Deliverable – **PSM report, log book, project materials** Action – Student, Supervisor

Table 2.7: FYP1 Project Gantt chart

Date / Activity	13-17 2	20-24 2	27-3 3	6-10 3	13-17 3	20-24 3	27-31 3	3-7 4	10-14 4	17-21 4	24-28 4	1-5 5	8-12 5	15-19 5	22-26 5	29-2 6
Proposal discussion & submission through PSM online system																
Proposal correction																
Proposal presentation																
System development (Chapter 1)																
Chapter 2																
Chapter 3																
Chapter 4																
Project demo																
PSM 1 Report																
PSM 1 Report correction																
PSM 1 Logbooks submission through PSM online system																

Table 2.8: FYP2 Project Gantt chart

Date / Activity	3-7 Jul	10-14 Jul	17-21 Jul	23-28 Jul	31 Jul- 4 Aug	7-11 Aug	14-18 Aug	21-25 Aug	28 Au- 1 Sept
Chapter 4: Design									
Chapter 5: Implementation									
Progress Evaluation									
Chapter 6: Testing									
Chapter 7: Conclusion									
Complete final report									
PSM 2 presentation									
Report correction									
Submission of PSM 2 complete report									

2.6 Conclusion

This chapter have discussed on the literature review and methodology of this project. It helps to review the facts and also existing systems to aid in the development process of this project. It also guides the development process of this project. For the next chapter, it will be discussing more about analysis.

CHAPTER III

ANALYSIS

3.1 Introduction

In this chapter, it will be explaining about the analysis that will be made in order to develop the system. It will explain in detail on how the existing systems work or functioning. From the existing systems, we are able to analyze the flaw or the weakness of the system. This chapter will also explain the requirements to develop the system such as the data requirement, functional requirement and non-functional requirement.

3.2 Problem Analysis

The existing system that is related to this project is the 'Recognizing the Ripeness of Banana Using Artificial Neural Network Based on Histogram Approach'. Firstly, the project starts by gathering 3 sets of the unripe, ripe and overripe banana. The image of the bananas are taken and go through image processing in order to obtain RGB value of the banana. The neural network will be trained by using all these RGB values. Finally the system applies graphical user interface (GUI) in order to ease the use for the user.

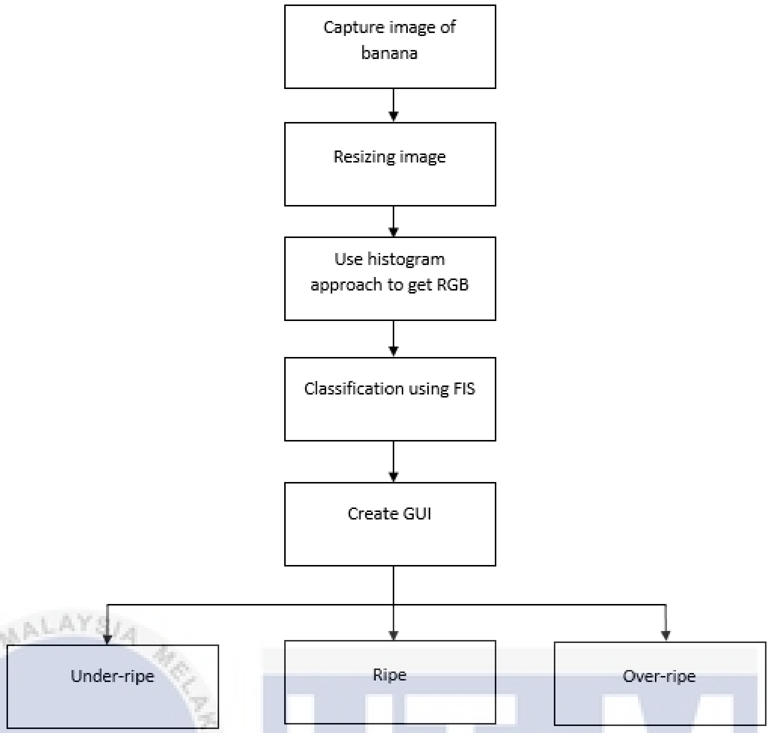

Figure 3.1: Flowchart of the Project Development

There are few problems in this existing system. Firstly is that the system can only predict the category of the fruit which are unripe, ripe and overripe. The system cannot tell the percentage of the ripeness. This is because it only uses artificial neural network to predict the ripeness. This is because, bananas have phases for its ripeness. The banana can be still unripe but will be ripe in a few days more. Without using fuzzy logic, these values cannot be obtained. The system is also lack of recommendation for the users. The recommendations are such as how much longer will the fruit be ripe or what is the best way to eat the fruit during its current ripeness state. Lastly, the user interface of the system is not user friendly because the window contains too much information. Furthermore the developer creates the GUI by using Matlab GUI which is the graphical user interface development environment (GUIDE). GUIDE is just a simple interface development environment where it has less functions options, color options and etc.

3.3 Requirement Analysis

3.3.1 Data Requirements

The system does not use database because it only focuses on the prediction. In order to train the data to predict the ripeness of a banana, a few samples of banana will be collected and processed by using image processing. Three bunches of banana from the same species which is the Cavendish banana is first collected. Each three bunches has different ripeness category which are under-ripe, ripe, and over-ripe. From these samples, only 14 bananas from each bunch were used for the data training. While the extra fruits from each bunch is used for the testing.

Table 3.1: RGB Values of the Bananas

CATEGORY	**COLORS**					
	Red		Green		Blue	
	Min	Max	Min	Max	Min	Max
Under-ripe	63.0068	96.2164	62.2021	96.8271	44.2462	82.165
Ripe	61.9038	92.4391	60.253	92.0277	51.5791	84.19
Over-ripe	57.8701	88.8048	55.0951	85.9635	32.9443	80.8753
Minimum	57.8701	88.8048	55.0951	85.9635	32.9443	80.8753
Maximum	63.0068	96.2164	62.2021	96.8271	51.5791	84.19
Average	76.4815		75.1551		61.8598	

Table 3.2: Membership Function for the FIS

CATEGORY	RED	GREEN	BLUE
Low	0-60	0-60	0-45
Medium	50-95	50-95	35-82
High	90-100	90-100	75-100

3.3.2 Functional Requirements

There are few functions used in developing this system. All this functions are provided in the Matlab R2015a. There three sections in this system with different coding. The sections are image processing, Fuzzy Inference System and GUIDE in Matlab.

In the image processing, there are few functions used. Firstly, the desired image is read and the image is converted from RGB to grayscale. This method is used in order to make the image into binary form which are 0 and 255. In the grayscale conversion, we use three different process which involves only including the desired channel of the image. For example is channel 1 is for red channel, channel 2 is for green channel and channel 3 is for blue channel. By using this method, we can obtain the RGB value of the image by counting the thresholded pixels of each channel.

For the Fuzzy Inference System is provided in Matlab toolbox. The toolbox enable the user to choose what type of Fuzzy Inference System. For this system it uses Mamdani. The membership values are assigned from the sample images of the bananas. The input for the membership function are Red, Green and Blue while the output is Category. For each input have 3 linguistic values which are low, medium and high. For the output are under-ripe, ripe and over ripe. For the deffuzification is using centroid method.

The GUI of this system uses the GUIDE toolbox provided in Matlab. The GUIDE toolbox is a simple user interface developing tool. For this system, it uses button function for the user to select the desired banana image from a directory. Besides that is axis box. The axis box is a space provided to display image or graphical image in a box. The axis box is used in this system to view the image of the banana according to their RGB channel and its image histogram. A static text box is used to display a string data type in the space provided. In this system, the static box will be displaying the total number of pixels according to their channel. The total number of pixel is a large number and makes it inconvenience for the user, thus the value is divided by 2 000 000 and multiplied by 100.

Figure 3.2: Matlab R2015a logo

3.3.3 Non-functional Requirements

The non-functional requirement is important to ensure the system runs smoothly. The requirements are as below.

Table 3.3: Non-functional Requirements

Requirement	**Description**
Simple GUI	The interface of the system should not be too full of text or information. It needs to be as simple as possible and user friendly.
Reliability	The system should be well functioning and able to determine the ripeness of the banana correctly.

3.3.4 Other Requirements

- **Software Requirements**

Table 3.4: Software Requirements

Item	**Description**
Microsoft Windows 10	An operating system for the system
Matlab R2015a	For the system development
Microsoft Words 2013	Project documentation
Microsoft Excel 2013	Data sorting

- **Hardware Requirements**

Table 3.5: Hardware Requirements

Item	Description
Asus A550C, Intel core i3, 4GB RAM	Personal computer
Apple iPhone 5, 8-megapixel iSight camera	Image acquisition

3.4 Conclusion

In this chapter, all the requirements for the system were gathered in order assure the functionality of the system. This chapter had also provide few flow charts as early visual of the system planning. For the next chapter will be design. It will be explaining in detail about the designing phase of the system.

CHAPTER IV

DESIGN

4.1 Introduction

In this chapter, it will be explaining in detail about the design of the system. All the high-level design such as the system architecture, user interface, input and output design and etc. will be explained in detail. This chapter is mostly related to the previous chapter which is the analysis. Therefore, the design of the system is depending on the previous chapter because the system must be designed according to the requirement needed that had been reached in thee analysis stage.

4.2 High-level Design

4.2.1 System Architecture

System architecture is the structure of the program component and data that are required to build the computer-based system. This system will be consisting of four different sections which are image processing, Fuzzy Inference System, Knowledge Based System and the user interface.

The first phase is the image processing phase. This phase is implemented together with the user interface code. Matlab provides many functions for the image processing toolbox. In the system, it uses some of the functions in order to obtain the RGB value of the image. The next phase is the Fuzzy Inference System (FIS). The FIS will be implemented separately from the main system because the Matlab FIS toolbox is separated from the Matlab user interface toolbox. The FIS will be the main structure for the system to predict the ripeness of the banana. For the last phase is the user interface phase. This phase will be using Matlab graphical user interface development environment (GUIDE). The GUIDE toolbox provides few simple function to develop an interface. The interface will be used for the user to choose their banana image and obtain the RGB values from the user interface.

The process of system will be starting from the user interface. The user will need to choose the banana image to be predicted. The image will be processed and will be displaying the three different channel image which are red channel, green channel and blue channel. Each channel image will be displaying its image histogram below each image. The value of the RGB will be displayed on top of the image. Next, user needs to open the Matlab FIS toolbox for the system to predict the ripeness of the banana. The user needs to input each of the RGB values into the FIS. The FIS will display the level of ripeness of the banana. Lastly is the Knowledge Based phase. In this phase user will be asked to few questions. From the questions, the knowledge based rules will be evaluated and the output will be giving recommendations to the user for the banana.

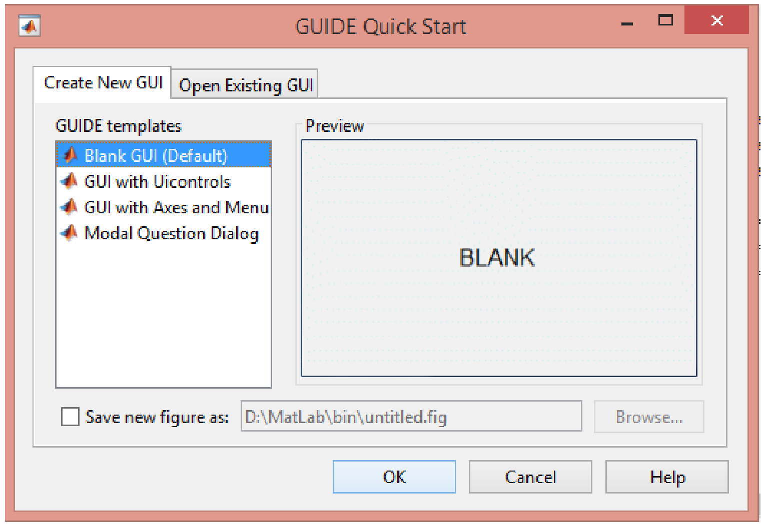

Figure 4.1: Matlab GUIDE toolbox

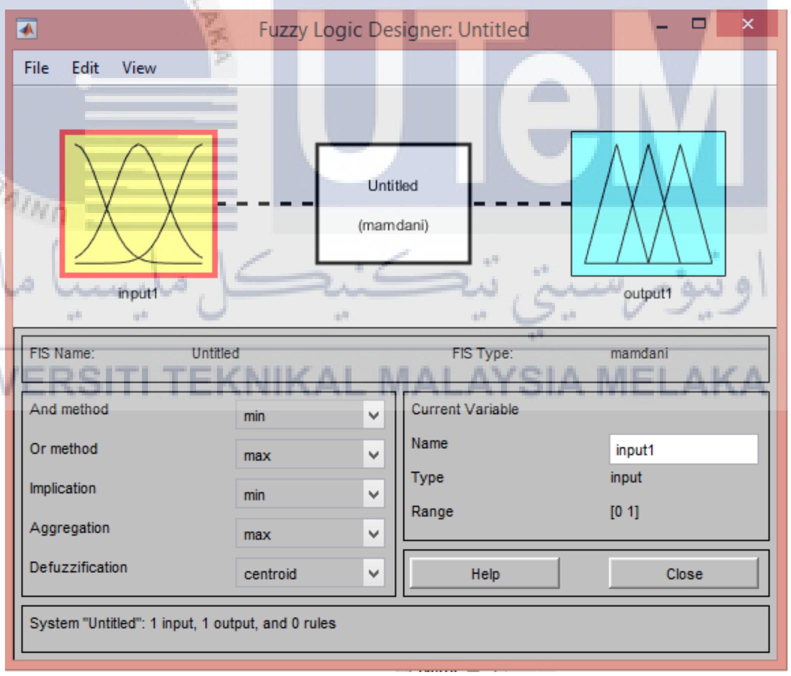

Figure 4.2: Matlab FIS toolbox

4.2.2 User Interface

The user interface for the system is divided into three sections. The first section is the user interface for the image processing. This user interface is for the user to choose the desired image and to obtain the RGB value of the image. The second section is the user interface for the FIS. This user interface is basically the Matlab FIS toolbox of rule viewer. It displays all the rules of the FIS including its membership functions for both input and output. The user will need to enter the RGB value of the image in the input section and the system will display the predicted ripeness of the fruit. Lastly is the interface for the Knowledge Base System. This interface will be required for the user to answer few questions.

Figure 4.3: Main User Interface

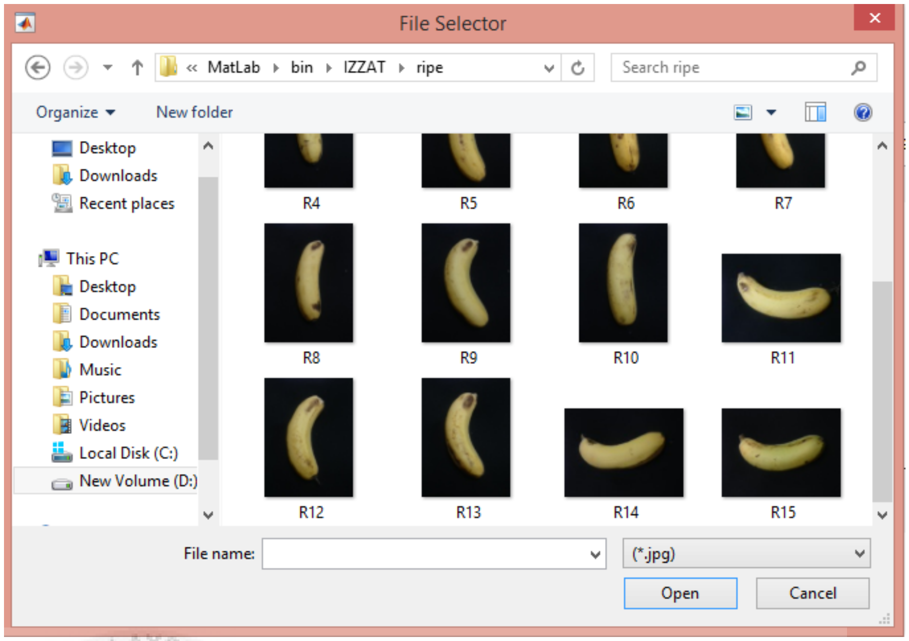

Figure 4.4: File Selector Window

Figure 4.5: Matlab FIS Rule Viewer

4.2.2.1 Navigation Design

The navigation design of the system is the flow of the system. The design needs to be simple and user friendly to make the system easier for the user to use.

4.2.2.2 Input Design

As we know that the system is divided into three parts which are the image processing and the FIS. Each have different input design. For the image processing phase, the input is only the image selected by the user. The image can be in any type of file such as Joint Photographic Experts Group (JPEG), Portable Network Graphics (PNG) and etc. While for the FIS phase, it accepts three different inputs. These three inputs are the total number of pixels that are processed from the image processing phase. The three inputs are total number of red pixels, total number of green pixels, and total number of blue pixels which all these three inputs only accept integer or double data type. For the Knowledge Based System, it acquires many user input such as, ripeness percentage, servings for the banana, texture of the banana,, age of the banana, desired ripeness of the banana and banana storage. All these inputs were inserted using radio button from the Qt editor.

4.2.2.3 Technical Design

The AI techniques that were used in this system is image processing technique, fuzzy logic and knowledge based system. The image processing technique is used to analyze the image of a banana in order to obtain its RGB value. While for the fuzzy logic is for the system to determine the ripeness level of the banana fruit. Lastly the knowledge based is to give recommendations for the user.

The first phase which is the image processing phase. In this phase, the code is implemented together with the user interface codes. The first step of the image processing phase is that reading the selected image. The selected image will then be converted into three different binary form which consist of three different channels. The channels are red, green and blue which will be the RGB value of the image. Before counting the total number of pixels, the threshold value of each channel must be set. The threshold value need to be set according to the image histogram. We need to find position of between two peaks of the image histogram. Then the number of pixels in each image is counted. In this process, the pixels are counted by each row with the selected threshold.

The next phase is to implement fuzzy inference system (FIS) to the system. For this project, the FIS is implemented separately from the main system because it uses different toolbox in Matlab. The Matlab FIS toolbox provides all the functions in developing an FIS. Firstly the FIS need to have its membership function. This member ship function is developed from the sample data that were provided. The sample data were obtain by analyzing the RGB value of each three different ripeness category of the banana. The data were then sorted. The membership function is developed based on the data that were collected from the banana sample. In this system, the input for the membership function are Red, Green and Blue. Each membership function consists of three different linguistic value which are low, medium and high. Next for the output is Ripeness, it also consist of three linguistic value which are under-ripe, ripe and over-ripe. Then the toolbox will do the deffuzification by using centroid method.

The last phase is applying Knowledge Based System. The knowledge based system is also applied separately from the Matlab application. Because it has better interface design. All the input from the user will be stored into the database. While all the knowledge based rules will be implemented in the system.

Figure 4.6: Sample Images of Different Ripeness of Banana, from Left: Under-ripe, Ripe, Over-ripe

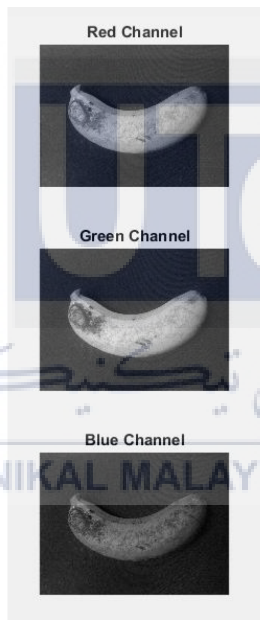

Figure 4.7: Binary Image of Each Red, Green and Blue Channels

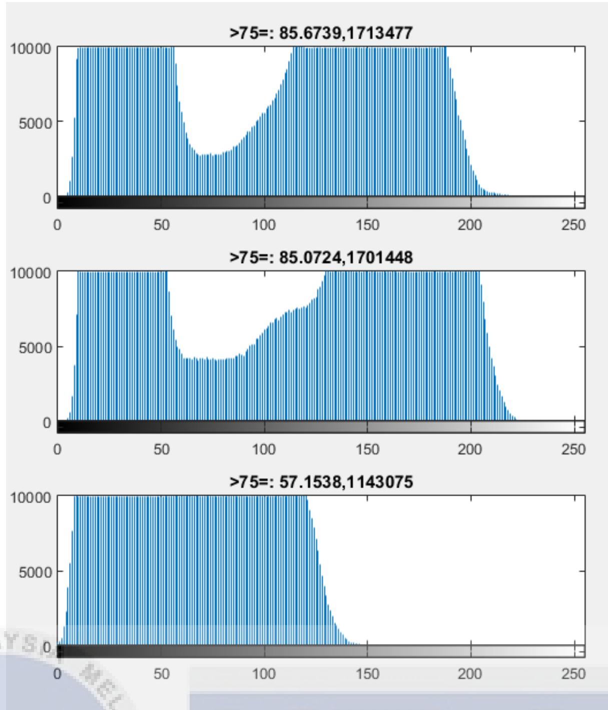

Figure 4.8: Image Histogram of Red, Green and Blue Channel

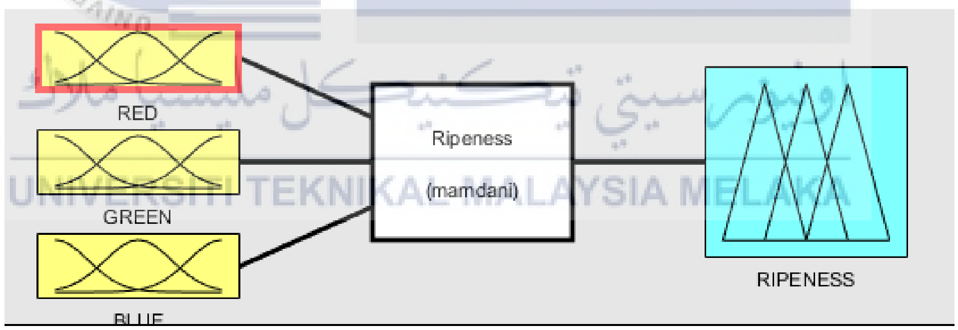

Figure 4.9: FIS Membership Function

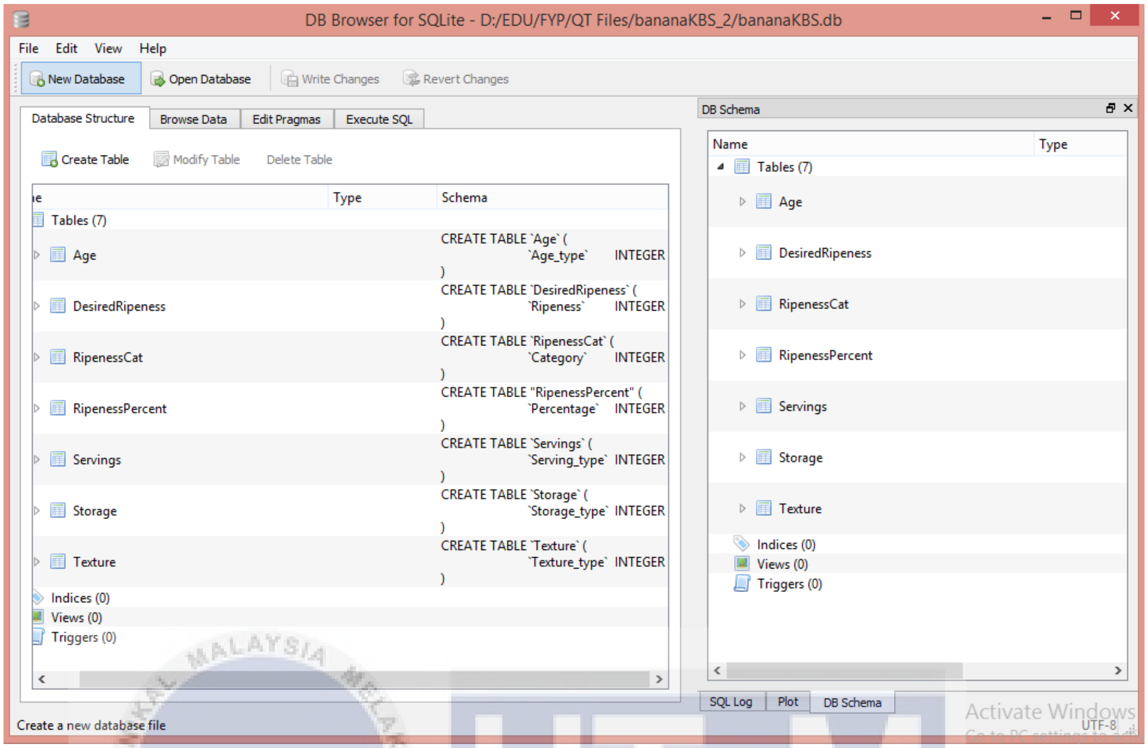

Figure 4.10: User Input Database

4.2.2.4 Output Design

There are few outputs that will be display by the system. For the image processing phase, the output will be divided into three different output which are the Red, Green and Blue channels. Each channel will be displaying its binary image based on the selected color channel, image histogram and total number of pixels. The total number of pixels are divided by 2 000 000 and multiplied by 100 in order to make it easier for the user to read. While for the fuzzy logic phase, there will be only one output which is the ripeness of the fruit. For the knowledge based phase, there will be three output which are the ripeness of the banana, servings recommendation of the banana and shelf life of the banana.

4.2.3 Database Design

4.2.3.1 Non-database Design

The system does not have a database because it only focuses in predicting the ripeness of the banana fruit. Thus in this section will be explaining about the business rules of the system. The business rules are as follows.

i. All type of user can use the system.
ii. User can only choose an image type file in choosing the image section.
iii. User can only enter integer data type in the FIS input.

4.3 Detailed Design

4.3.1 Software Design

In this section, it will be explaining in detail all the functions and algorithm used in the system. Which this system is divided into three phases which are image processing phase, fuzzy logic phase and knowledge based phase. For the fuzzy logic phase, it uses from Matlab FIS toolbox. Thus it does not need any algorithm to develop where it only needs to setup the membership functions and insert the fuzzy rules.

4.3.1.1 Image Processing Phase

Table 4.1: Image processing functions

Function	Operations
imread	Reads the selected image by the user
(:,:,1)	Converting the RGB image into binary red channel image.
(:,:,2)	Converting the RGB image into binary green channel image.
(:,:,3)	Converting the RGB image into binary blue channel image.
sum((:))	Counts the number of pixels row by row.
imshow	Displays the image.
imhist	Displays the histogram of an image.

Algorithm:

1.0 Start.

2.0 Read image**.**

3.1 Convert into binary red channel.

3.2 Convert into binary green channel.

3.3 Convert into binary blue channel.

4.0 Counts total number of pixels.

5.0 Display image.

6.0 Display image histogram.

4.3.1.2 Knowledge based phase

For this phase, it will be explaining in detail about the knowledge based system.

4.3.1.2.1 Block diagram

Block diagram is a useful way of describing the relationship between the factors and the goal. The block diagram only shows the main relation of the knowledge based rules. The KBS phase of this system consists of three different section of KBS which are ripeness, servings and shelf life. The ripeness section is to predict the ripeness of the banana from the percentage value that were obtained from the FIS. For the servings section is to give recommendation to the user on how to serve the banana based on the ripeness of the banana and from the desire of the user. Last one is the shelf life, this section will give recommendation to the user on the shelf life of the banana.

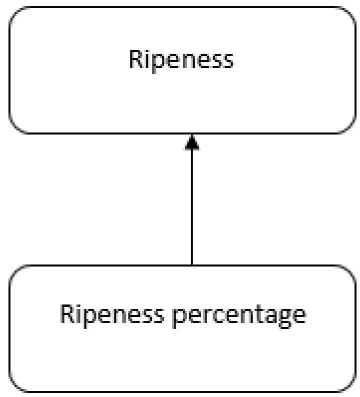

Figure 4.11: Block diagram of ripeness

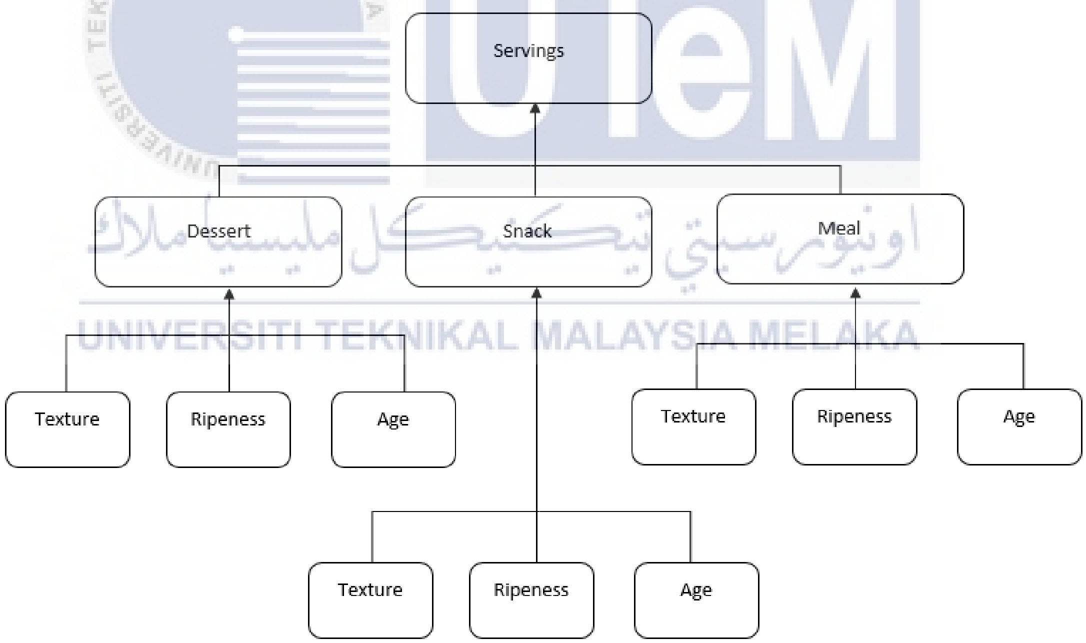

Figure 4.12: Block Diagram of Servings

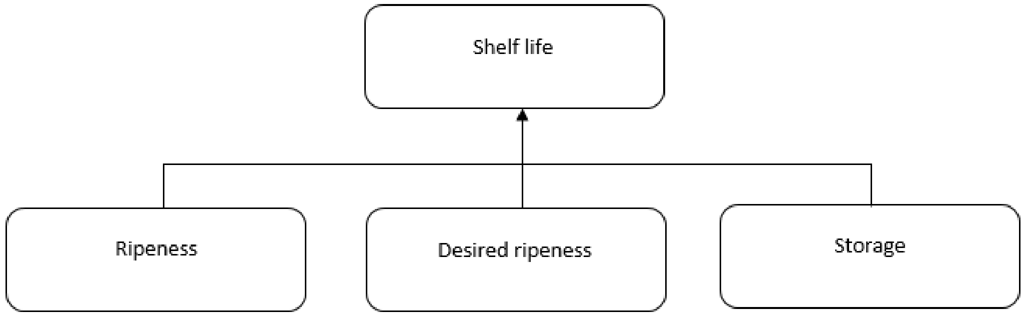

Figure 4.13: Block Diagram of Shelf life

4.3.1.2.2 Mockler Chart

Mockler chart is a chart that displays in detail the relation of the knowledge based rules.

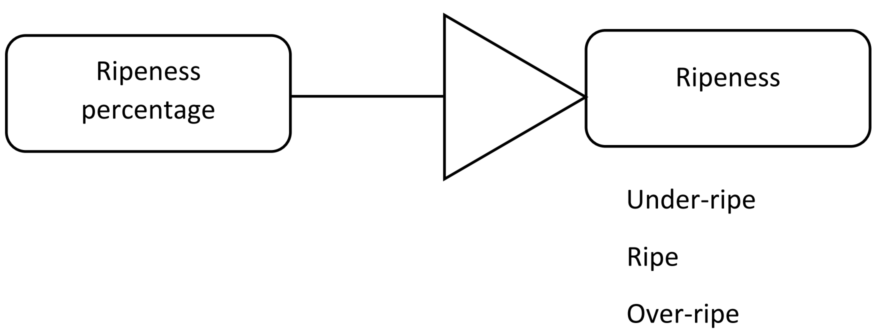

Figure 4.14: Ripeness Mockler Chart

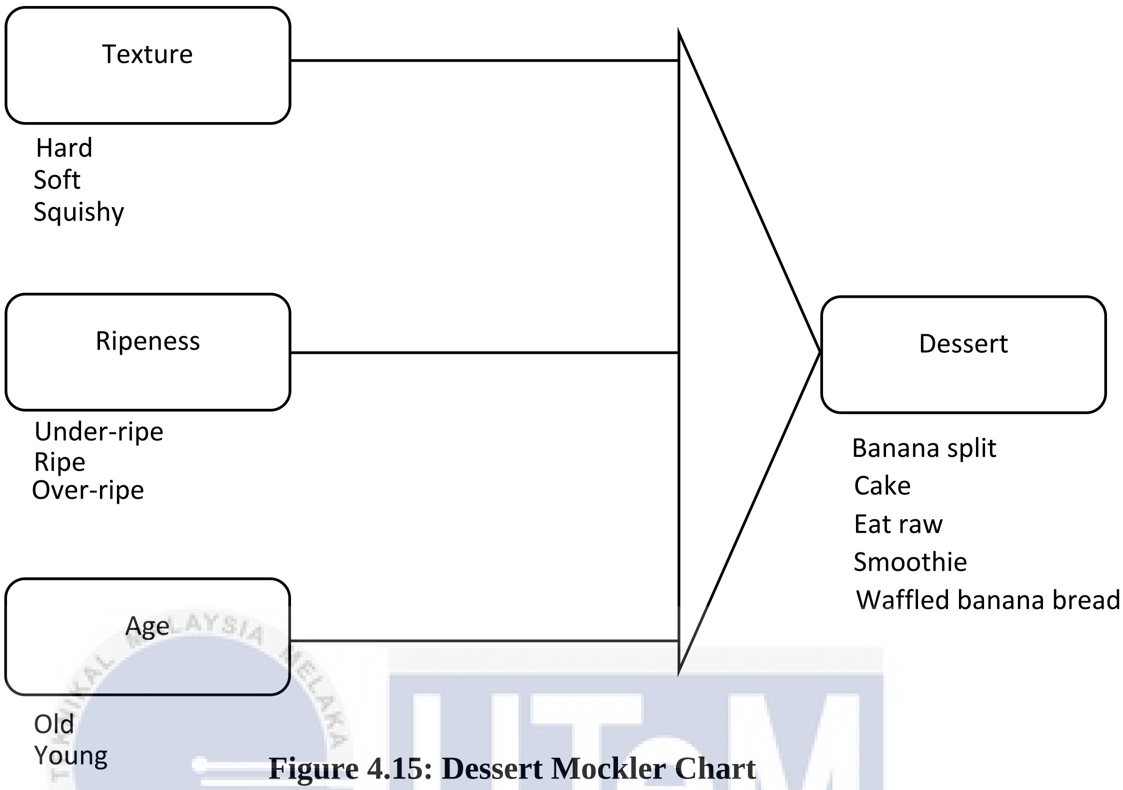

Figure 4.15: Dessert Mockler Chart

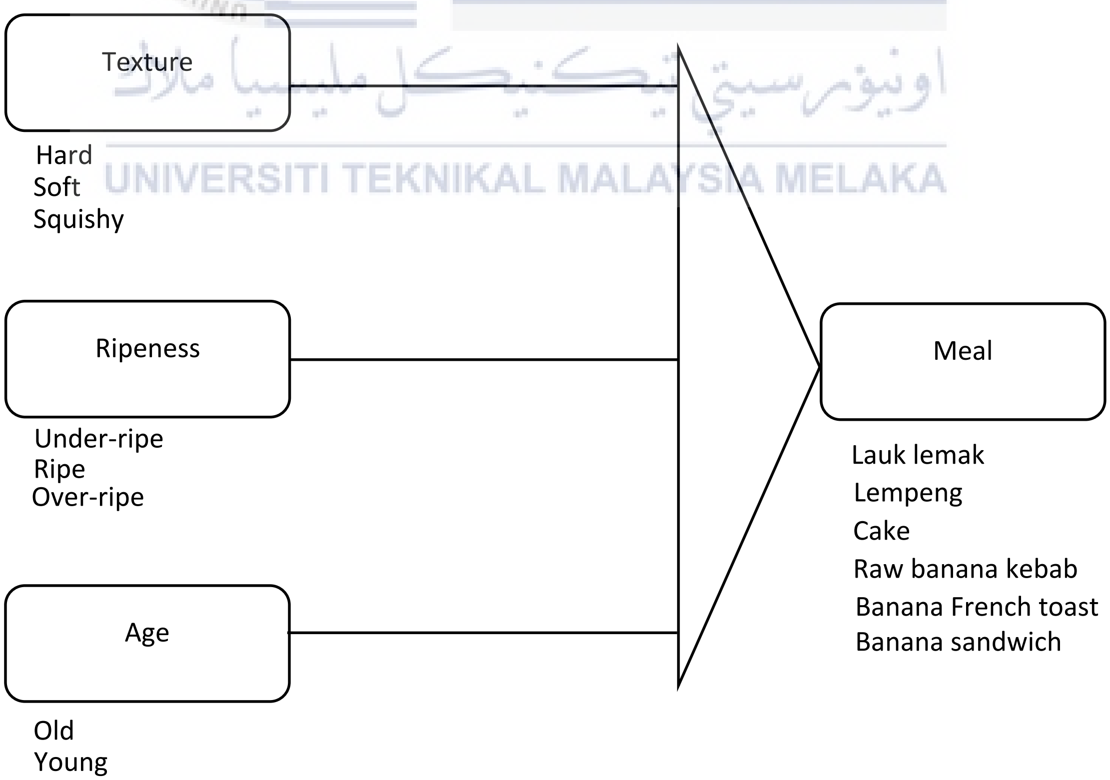

Figure 4.16: Meal Mockler Chart

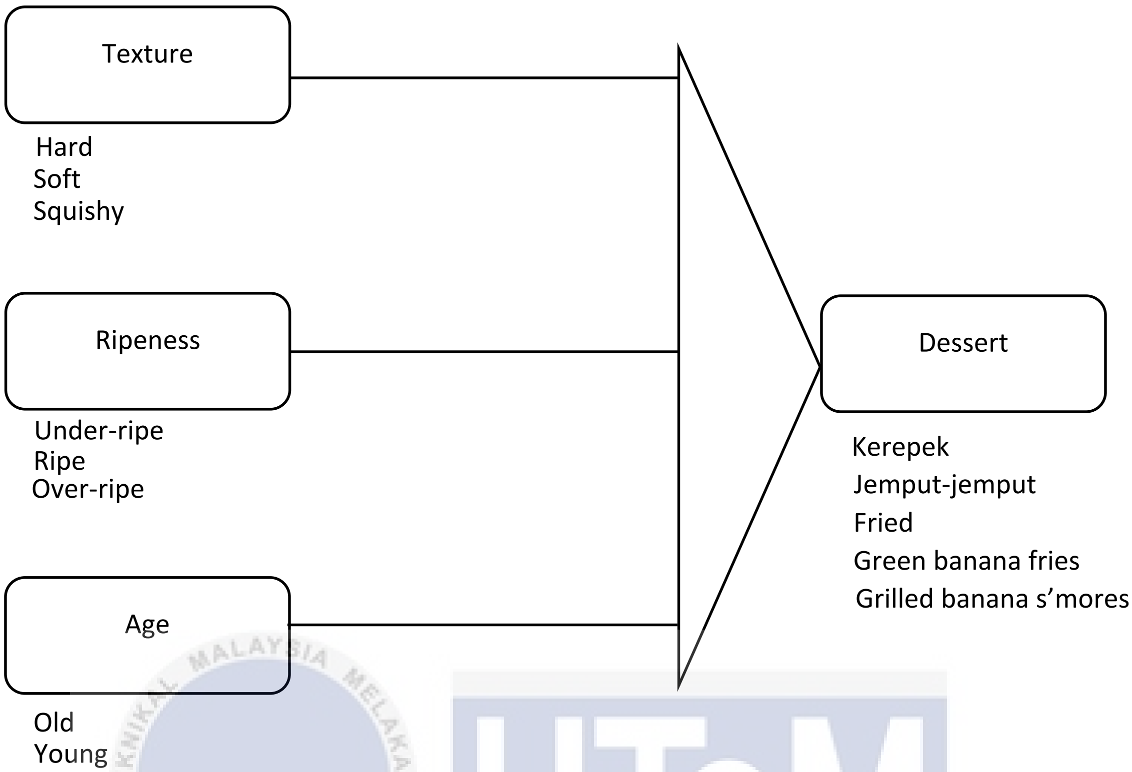

Figure 4.17: Dessert Mockler Chart

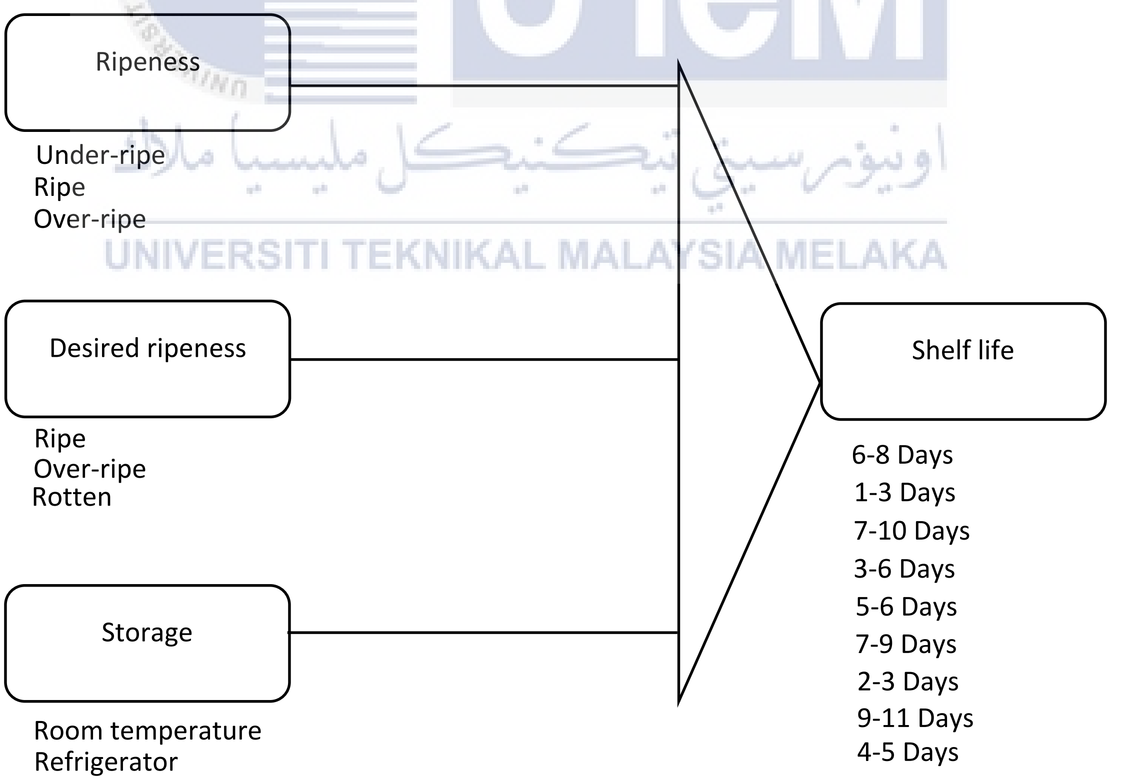

Figure 4.18: Shelf Life Mockler Chart

4.3.1.2.3 Decision table

Decision table is important because it shows the interrelationships of values to the outcome of any intermediate phase or final recommendation of the system

Table 4.2: Dessert Decision Table

Rule	Texture	Ripeness	Age	Dessert
R1	Hard	Under-ripe	Old	Smoothie
R2	Soft	Ripe	Old	Banana Split / Eat raw / Cake
R3	Squishy	Ripe	Old	Eat raw / Cake
R4	Soft	Over-ripe	Old	Waffled Banana Bread
R5	Squishy	Over-ripe	Old	Waffled Banana Bread
R6	Hard	Under-ripe	Young	Smoothie
R7	Soft	Ripe	Young	Banana Split / Eat raw / Cake
R8	Squishy	Ripe	Young	Eat Raw / Cake
R9	Soft	Over-ripe	Young	Waffled Banana Bread
R10	Squishhy	Over-ripe	Young	Waffled Banana Bread

Table 4.3: Snack Decision Table

Rule	Texture	Ripeness	Age	Snack
R11	Hard	Under-ripe	Old	Kerepek / Green Banana Fries
R12	Soft	Ripe	Old	Fried
R13	Squishy	Ripe	Old	Cekodok
R14	Soft	Over-ripe	Old	Grilled Banana S'mores
R15	Squishy	Over-ripe	Old	Cekodok
R16	Hard	Under-ripe	Young	Kerepek / Green Banana Fries
R17	Soft	Ripe	Young	Fried
R18	Squishy	Ripe	Young	Cekodok
R19	Soft	Over-ripe	Young	Grilled Banana S'mores
R20	Squishhy	Over-ripe	Young	Cekodok

Table 4.4: Meal Decision Table

Rule	Texture	Ripeness	Age	Snack
R21	Hard	Under-ripe	Old	Raw Banana Kebab
R22	Soft	Ripe	Old	Lempeng
R23	Squishy	Ripe	Old	Lempeng
R24	Soft	Over-ripe	Old	Cake / Banana French Toast / Sandwich
R25	Squishy	Over-ripe	Old	Cake
R26	Hard	Under-ripe	Young	Lauk Lemak / Raw Banana Kebab
R27	Soft	Ripe	Young	Lempeng
R28	Squishy	Ripe	Young	Lempeng
R29	Soft	Over-ripe	Young	Cake / Sandwich / French Toast
R30	Squishhy	Over-ripe	Young	Cake

Table 4.5: Shelf Life Decision Table

Rule	Ripeness	Desired Ripenesss	Storage	Days
R31	Under-ripe	Ripe	Room Temperature	4-5 Days
R32	Under-ripe	Over-ripe	Room Temperature	6-8 Days
R33	Ripe	Over-ripe	Room Temperature	1-3 Days
R34	Under-ripe	Rotten	Room Temperature	7-10 Days
R35	Ripe	Rotten	Room Temperature	3-6 Days
R36	Over-ripe	Rotten	Room Temperature	1-3 Days
R37	Under-ripe	Ripe	Refrigerator	5-6 Days
R38	Under-ripe	Over-ripe	Refrigerator	7-9 Days
R39	Ripe	Over-ripe	Refrigerator	2-3 Days
R40	Under-ripe	Rotten	Refrigerator	9-11 Days
R41	Ripe	Rotten	Refrigerator	4-5 Days
R42	Over-ripe	Rotten	Refrigerator	2-3 Days

4.3.1.2.4 List of all rules

Table 4.6: List of Rules

Rule	Description
1	IF texture = hard AND ripeness = under-ripe AND age = old THEN dessert = smoothie
2	IF texture = soft AND ripeness = ripe AND age = old THEN dessert = banana split / eat raw / cake
3	IF texture = squishy AND ripeness = ripe AND age = old THEN dessert = eat raw / cake
4	IF texture = soft AND ripeness = over-ripe AND age = old THEN dessert = smoothie
5	IF texture = squishy AND ripeness = over-ripe AND age = old THEN dessert = waffle bread
6	IF texture = hard AND ripeness = under-ripe AND age = young THEN dessert = smoothie

7	IF texture = soft AND ripeness = ripe AND age = young THEN dessert = banana split / eat raw / cake
8	IF texture = squishy AND ripeness = ripe AND age = young THEN dessert = eat raw / cake
9	IF texture = soft AND ripeness = over-ripe AND age = young THEN dessert = waffle bread
10	IF texture = squishy AND ripeness = over-ripe AND age = young THEN dessert = waffle bread
11	IF texture = hard AND ripeness = under-ripe AND age = old THEN dessert = kerepek / green banana fries
12	IF texture = soft AND ripeness = ripe AND age = old THEN dessert = deep fried
13	IF texture = squishy AND ripeness = ripe AND age = old

	THEN dessert = cekodok
14	IF texture = soft AND ripeness = over-ripe AND age = old THEN dessert = grilled banana s'mores
15	IF texture = squishy AND ripeness = over-ripe AND age = old THEN dessert = cekodok
16	IF texture = hard AND ripeness = under-ripe AND age = young THEN dessert = kerepek / green banana fries
17	IF texture = soft AND ripeness = ripe AND age = young THEN dessert = deep fried
18	IF texture = squishy AND ripeness = ripe AND age = young THEN dessert = cekodok
19	IF texture = soft AND ripeness = over-ripe AND age = young THEN dessert = grilled banana s'mores
20	IF texture = squishy AND ripeness = over-ripe AND age = young THEN dessert = cekodok

21	IF texture = hard AND ripeness = under-ripe AND age = old THEN dessert = raw banana kebab
22	IF texture = soft AND ripeness = ripe AND age = old THEN dessert = lempeng
23	IF texture = squishy AND ripeness = ripe AND age = old THEN dessert = lempeng
24	IF texture = soft AND ripeness = over-ripe AND age = old THEN dessert = cake / banana French toast / banana sandwiches
25	IF texture = squishy AND ripeness = over-ripe AND age = old THEN dessert = cake / banana French toast / banana sandwiches
26	IF texture = hard AND ripeness = under-ripe AND age = young THEN dessert = cake / banana French toast / banana sandwiches

27	IF texture = soft AND ripeness = ripe AND age = lempeng THEN dessert = lempeng
28	IF texture = squishy AND ripeness = ripe AND age = young THEN dessert = lempeng
29	IF texture = soft AND ripeness = over-ripe AND age = young THEN dessert = cake / banana sandwich / banana French toast
30	IF texture = squishy AND ripeness = over-ripe AND age = young THEN dessert = cake
31	IF ripeness = under-ripe AND desired ripeness = ripe AND storage = room temperature THEN days = 4-5
32	IF ripeness = under-ripe AND desired ripeness = over-ripe AND storage = room temperature THEN days = 6-8
33	IF ripeness = ripe AND desired ripeness = over-ripe AND storage = room temperature THEN days = 1-3

34	IF ripeness = under-ripe AND desired ripeness = rotten AND storage = room temperature THEN days = 7-10
35	IF ripeness = ripe AND desired ripeness = rotten AND storage = room temperature THEN days = 3-6
36	IF ripeness = under-ripe AND desired ripeness = ripe AND storage = room temperature THEN days = 1-3
37	IF ripeness = under-ripe AND desired ripeness = ripe AND storage = refrigerator THEN days = 5-6
38	IF ripeness = under-ripe AND desired ripeness = over-ripe AND storage = refrigerator THEN days = 7-9
39	IF ripeness = ripe AND desired ripeness = over-ripe AND storage = refrigerator THEN days = 2-3
40	IF ripeness = under-ripe AND desired ripeness = rotten AND storage = refrigerator THEN days = 9-11

41	IF ripeness = ripe AND desired ripeness = rotten AND storage = refrigerator THEN days = 4-5
42	IF ripeness = over-ripe AND desired ripeness = rotten AND storage = refrigerator THEN days = 2-3

4.4 Conclusion

The designing phase is an important phase for every project development. It needs to avoid any major problem while doing the implementation including user interface, navigation, input output design and the system architecture. For the next chapter will be explaining about implementation.

CHAPTER V

IMPLEMENTATION

5.1 Introduction

The development of the system is depending on the requirements and architectural design. In this chapter, it will be explaining the implementation of this project. It will explain on the software setup, hardware and others during the development of this system.

5.2 Software Development Environment Setup

Overall of this system uses two different programming platforms which are Matlab R2015a and Qt 5.6.2 (msvc2013). Besides programming platform, this system also uses SqliteBrowser 3.7.0 for the database.

In this project, Matlab R2015a is used for the image processing and fuzzy logic phase of the system. Matlab provides many toolbox for image processing. These toolbox simplifies the complicated process of the image processing phase. Matlab also provides toolbox for fuzzy logic which is called the FIS toolbox. This toolbox is complete with all the steps for all the fuzzification and defuzzyfication. Besides mathematical toolbox, Matlab also provide GUI editor which is called GUIDE.

Next software is the Qt 5.6.2 (msvc2013). In this part of the project, the Qt software is used to develop the knowledge based system phase of the system. It needs to be done separately from the Matlab because the Qt creator does not provide the toolbox from Matlab. The Qt software has an editor named Qt creator where all the source codes will be implemented there. It provides variants programming language such as C++, C and Java. Qt also offers a GUI editor name Qt editor. In the Qt editor provides many types of GUI widgets. It can be used to develop a very user friendly interface.

Lastly is the database software which is the SqliteBrowser 3.7.0. The SqliteBrowser is used to save the facts that is inserted by the user. The SqliteBrowser is only used for the knowledge based phase.

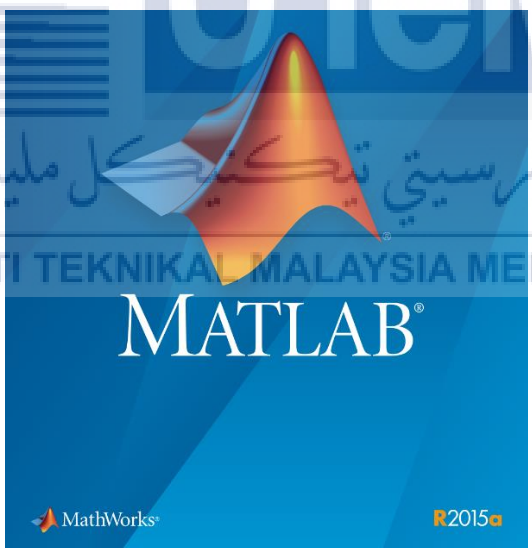

Figure 5.1: Matlab R2015a Logo

Figure 5.2: Qt Logo

Figure 5.3: Sqlite Browser Logo

5.3 Software Configuration Management

This section will be divided into two parts for the system configuration environment setup and version control procedure.

5.3.1 Configuration Environment Setup

For the Matlab software, it needs to be the Matlab R2015a. It needs to be this version as it has the current and latest toolbox.

The Qt software which is Qt 5.6.2 (msvc2013). This software is downloaded from the Qt webpage. The Qt software used for this project requires windows x64-bit. The requirement of this software is that the machine used for the software needs to have Microsoft Visual Studio 2013 as the compiler.

5.3.2 Version Control Procedure

During the implementation of the system, the codes and the designs will be keep on changing due time. These changes needs to be recorded for future reference. It is to make sure that the system has its own history record. Below shows the version of the system.

Table 5.1: Version Control Procedure

Version	Description
V 1.0	This version is the testing version for image processing

V 1.1	This version is the testing version for the fuzzy logic toolbox
V 1.2	This version only consists of interfaces without any function
V 1.3	This version is the user interface with including functions.
V 2.0	This version consist only the interface for the knowledge based phase.
V 2.1	This version consist of all the knowledge based rules
V 2.2	This is the complete version of the system

5.4 Implementation Status

Implementation status is the milestone for the whole project. It is used to see the status and also the progress of the project in a specific time.

Table 5.2: Implement Status of Each Module

Module	Description	Duration to Complete
Image processing module	Developing the suitable algorithm of image processing to obtain the RGB values of the banana	2 weeks
Fuzzy inference system module	Developing the membership functions for the fuzzy inference system	1 week

Matlab user interface design	Developing the suitable user interface for the system	10 days
Implementing user interface with image processing and fuzzy logic	Implement the image processing and fuzzy inference system into the interface	12 days
Knowledge based rules development	Developing the knowledge based rules using the Qt creator.	2 weeks
Qt editor user interface development	Designing the user interface for the knowledge based rules using Qt editor	10 days
Implementing user interface with knowledge based rules	Implementing the knowledge based rules into the interface	1 week

5.5 Banana Ripeness Knowledge Based System

This system is the last phase of the whole system which is the knowledge based phase. This system is developed separately from the main system. In the banana ripeness knowledge based system, it can give recommendations on the banana based on the information that the user inserted. All the information will matched from the 42 rules of the knowledge based system. The system comprises of three sections, these sections are the ripeness, servings and the shelf life sections. All these sections will be explained further below.

Figure 5.4: Main Window of the System.

5.5.1 Ripeness Section

This section will need the user to insert the final result from the FIS which is the ripeness percentage of the banana.

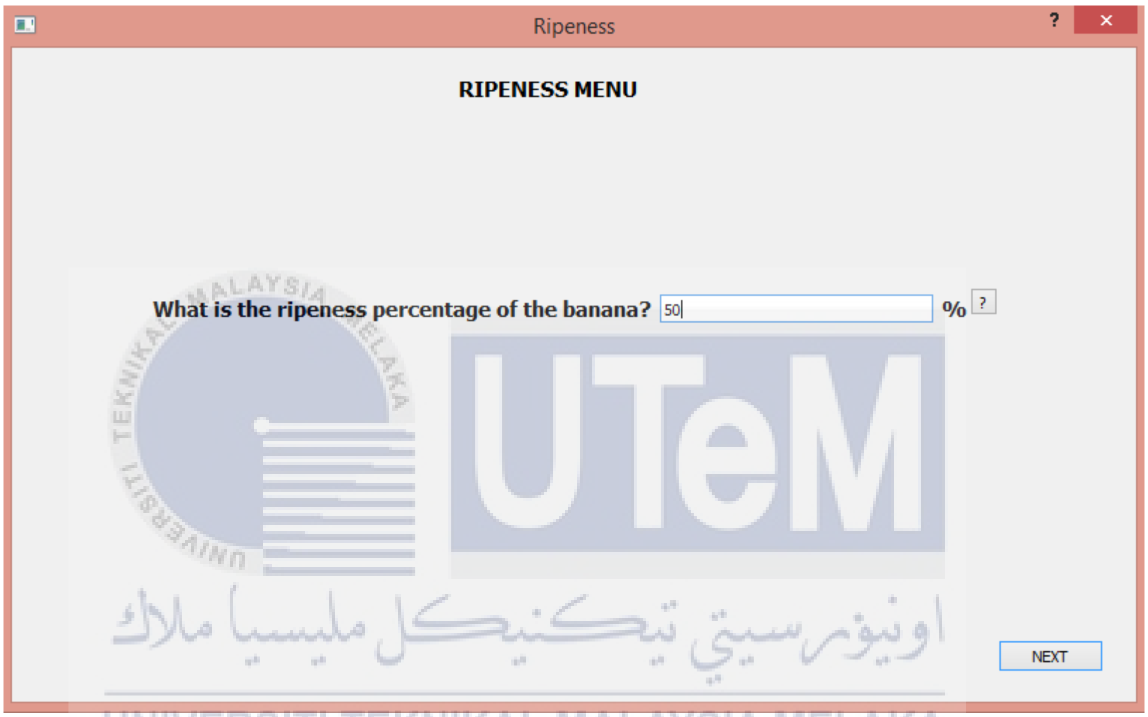

Figure 5.5: Ripeness Menu of the System

5.5.2 Servings Section

This section is to give recommendations to the user on the servings for the banana. The user will have to insert the characteristics of the banana and the user's desired servings.

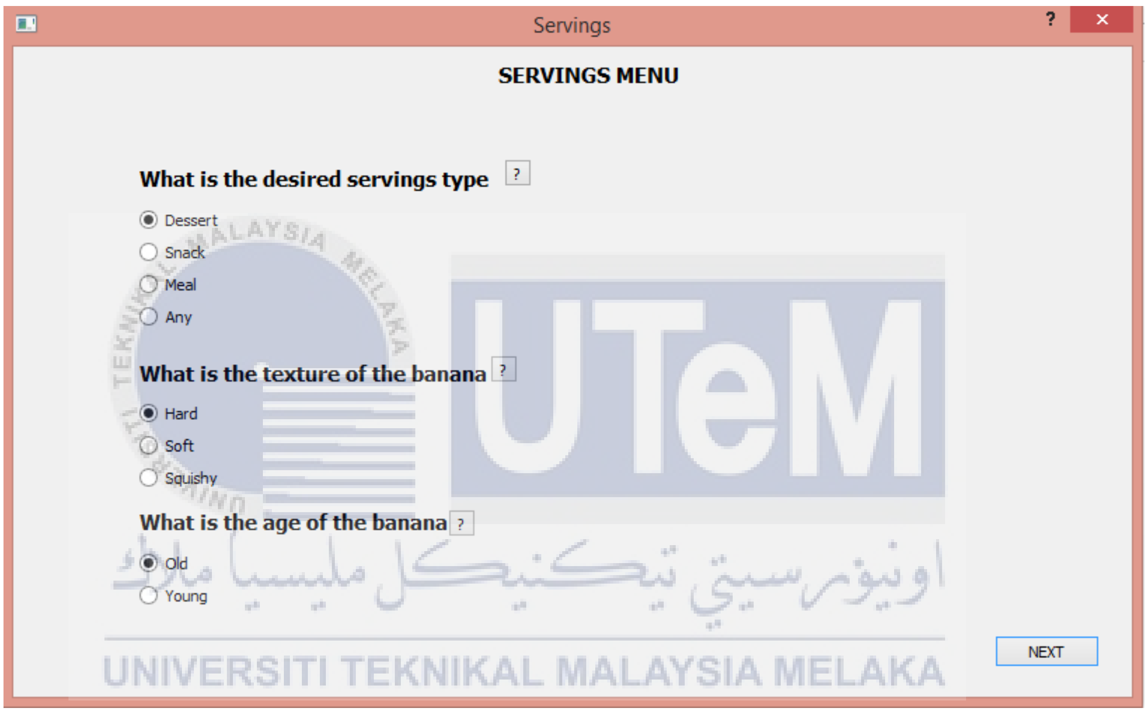

Figure 5.6: Servings Menu of the System

5.5.3 Shelf Life Section

This section is to predict the shelf life of the banana until the selected ripeness. User will need to enter the desired ripeness of the banana and the storage of the banana.

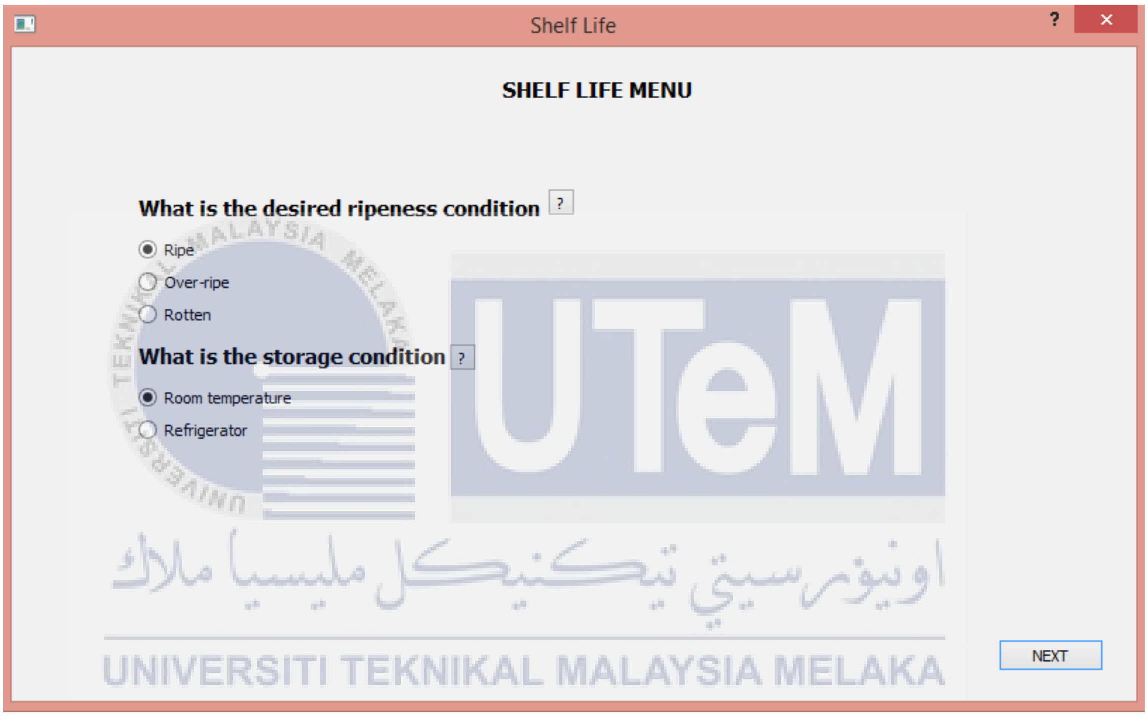

Figure 5.7 Shelf Life Menu of the System

5.6 Conclusion

In conclusion, this chapter explains the required setup environment for the deployment of the system. The software required and environment setup has been shown in this chapter along with the installation steps.

The development of this system involves using two different programming software which are Matlab R2015a and also Qt 5.6.2 (msvc2013). Where the Matlab software is used for the image processing and fuzzy logic phase, while the Qt software is for the knowledge based rules.

In the next chapter will be the system testing phase which text plan, test strategy, test design and test result will be discussed.

CHAPTER VI

TESTING

6.1 Introduction

This chapter will be explaining about the testing of the system. This is to evaluate the completion of the system. Software testing is a crucial part that must be carried out in order to evaluate the capability of the system and to determine the requirement that needs to fulfil. The test plan and results will be discussed in this chapter.

6.2 Test Plan

Test plan is the design of the testing phase itself. It also acquires observation and evaluation of the testing outcome. The test plan involves test organization, test environment and test schedule.

6.2.1 Test Organization

The developer itself can be the tester and observer of for the system testing. Few other user will also be the tester to assure different point of view of the system. Besides students, the project supervisor will be part of the testing phase.

6.2.2 Test Environment

Test environment explains about the environment during the testing. These environment is including the location of testing to be carried out and all the hardware and software configuration during the testing. For this project, the location of testing can be carried out anywhere because it does not affect any of the system output. The hardware and software configurations are as below.

Hardware

- Asus A550C, Intel core i3, 4GB RAM

Software

- Microsoft Windows 10
- Matlab R2015a
- Qt 5.6.2 (msvc2013)
- SqliteBrowser 3.7.0

6.2.3 Test Schedule

Table 6.1: Test Schedule

No	Activity	Days
1	Prepare test plan	2
2	Prepare test specification	2
3	Prepare for hardware and software environment	2
4	Execute test procedure	4
5	Perform unit testing	4

6.3 Test Strategy

Test strategy is prepared for the testing feature of the system whether it meets the requirements or not. The strategy for the testing is known as black box testing where the user does not need any acknowledgement about the system and its coding.

6.3.1 Classes of Test

a) **Error Handling Test**

This test is involving the GUI of the system. It needs to test to insert any possible wrong value or wrong input into the system. All the incorrect input will be displayed an error massage.

b) **User Acceptance Test**

This test is to find out whether the user finds the system is convenient and user friendly or not.

c) **System Test**

This test is to test all the functionality of the system. To check whether all the interface are arranged correctly and all the buttons function properly.

d) **Database Test**

This test involves the database for the knowledge based phase. The test includes testing the data is saved into the correct table, the query executing properly.

6.4 Test Implementation

Test implementation will include the test description and test data. More of the test implementation will be explained below.

6.4.1 Test Description

Table 6.2: Testing Description

Test No	Module	Description
T01	Image selection	Test whether the image selection is working properly
T02	RGB extraction	Test the RGB extraction of the image
T03	Fuzzy inference system	Test the fuzzy inference system
T04	User interface testing	Test the user interface including button and any text edit field
T05	Knowledge based rules testing	Test all the possible rules of the knowledge based system
T06	Database testing	Test the input of the system, to check whether the database is working properly or not.
T07	Knowledge based interface testing	Test the knowledge based interface with error handling

6.5 Test Result and Analysis

After completing the testing, the result will be documented. The test case results documents the outputs from sets of input tested. If the predicted output were achieved, the system is functioning according to its specification.

Table 6.3: Test Case Result

Test No	Tester Identification (OK / Failed)	Result (OK / Failed)
T01	OK	OK
T02	OK	OK
T03	Failed	Failed, the system failed to predict the correct ripeness percentage of the banana.
T04	OK	OK
T05	OK	OK
T06	OK	OK
T07	OK	OK

6.6 Conclusion

In this chapter, the entire test plan, test strategies and the test results had been discussed. From the test results, almost all the test module achieved its expected output. The only module that is faulty is the fuzzy inference system module. The FIS failed to predict the correct ripeness percentage of the banana. This is due to inconsistent of the image acquisition process. From the inconsistency, it will affect the RGB value of the image and thus effecting the FIS. The next chapter will be the conclusion of the project where it will be discussing the strength and weakness of the project

CHAPTER VII

CONCLUSION

7.1 Observation on Weakness and Strengths

From the observation and analysis of the system, it has its own strengths and also weakness. From these strength and weakness, the system can be improved for future projects.

7.1.1 Strengths

One of the strength of this system is that it can read image and extract the RGB value of the image correctly. This is because it applies few image processing techniques in order to obtain the right region of interests. For the knowledge based interface is also user friendly because it has simple and easy to use widgets.

7.1.2 Weakness

The main weakness of the system is that the fuzzy inference system is not working as it is expected to be. Besides that, the image acquisition needs to be in a controlled environment room with no excessive light exposure. Thus it is hard to be put into market. Lastly is that the system uses two different interface from two different platform. This is inconvenient for the user where it need to open two different applications. Lastly is that this system is not tested by experts, thus the accuracy of the system is not valued.

7.2 Propositions for Improvements

For further improvements, the fuzzy logic phase needs to be improved. Where the fuzzy inference system needs to have the correct membership functions. In order to improve this, the image of the banana for training needs to be controlled. The distance of the object from the camera needs to consistent, the lighting of the environment needs to be controlled and the background of the image needs to be a non-light-reflecting object.

Besides that, the system can be improved by its image acquisition process. The system can be upgraded where it can overcome any type lighting surrounding. Thus the user can take the picture despite the surrounding condition of the object. This process will need a more advanced image processing technique.

Lastly, the system can be improved by combining all the AI techniques which are image processing, fuzzy logic and knowledge based system into one. The system developed is using two different platform to run the process. It also uses two different interface which is inconvenient for the user. Thus in future the system will be develop using only one platform.

7.3 Project Contribution

- Contributions to university. This system is the results of the project of a degree student in UTeM, thus it can be as reference for the other student who will be doing a significant project domain.

- Contributions to banana plantation industries. This system can help ease the process of choosing the best product of their plantation. Besides it will give consistency to the product sold of the industry. It also saves man power of the industry.

- Contributions to shopper. Shopper can now pick his/her best suitable banana. Shopper can also choose the suitable banana by his/her desired servings, ripeness and also the banana’s shelf life.

7.4 Conclusion

The project documentation for the project had come to the end for this part. The introduction, literature review, project methodology, analysis and design had been successfully presented in the documentations and completed in the provided time period.

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