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CLASSIFICATION OF CANNED PINEAPPLE BASED ON FIRST ORDER COLOUR STATISTICS

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
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ABSTRACT

Automatic systems for various applications in agriculture have been applied using an image processing method. The implementation of this system produces a low cost system, efficient, fast and reliable product inspection. Grading the colour of canned pineapple is one of the specifications in Malaysian Standard of Canned pineapple before export. There are a few studies on fresh pineapple using computer vision, but not for canned pineapple. Today, canned pineapple colour fully depends on experienced workers to grade according to the standard of MPIB. This may lead to the misclassification standard due to human factors such as fatigue, emotional condition, personal preference and honesty. The objective of this research is to use image processing technique that can replace human in grading the standard colour of canned pineapple in optimizing the quality of canned pineapple being export. In our literature review, we found that grading and sorting colour has been popular with various methods applied. The image acquisition taken at MPIB laboratory are using controlled environment to prevent the outside illumination. Otsu's method has been chosen as image filtering technique during pre-processing image since it gives the best results in eliminating almost unwanted pixels in the canned pineapple image. In order to smooth the Region of Interest (ROI), morphological operations using dilation and erosion were used. The disk shape of a structuring element with radii of nine (9) and ten (10) were used in this operation. Multiplying the ROI with original image was the last step before features extraction. First order statistic such as minimum, maximum, mean and standard deviation were calculated for each RGB, HSV, and CIELAB. 100% classifications for Standard 15 were obtained using standard deviation and 93.3% for Standard 16 in HSV colour space. HSV colour space using hue were chosen as a method of classification in this research since it was simple for transformation of device-dependent RGB models and it was appropriate for human sight.

ABSTRAK

Sistem automatik untuk pelbagai aplikasi dalam bidang pertanian telah digunakan menggunakan kaedah pemprosesan imej. Pelaksanaan sistem ini menghasilkan kos sistem yang rendah, cekap, pemeriksaan produk yang cepat dan boleh dipercayai. Penggredan warna nanas dalam tin merupakan salah satu spesifikasi standard nanas tin malaysia sebelum dieksport. Terdapat beberapa kajian mengenai sistem penglihatan komputer menggunakan nanas segar, tetapi tidak nanas dalam tin. Hari ini, warna nanas dalam tin sepenuhnya bergantung kepada pengalaman pekerja untuk di gred mengikut standard Lembaga Perindustrian Nanas Malaysia (LPNM). Keadaan ini boleh menyebabkan kepada kesalahan klasifikasi yang diselaraskan disebabkan oleh faktor manusia seperti keletihan, keadaan emosi, keutamaan peribadi dan kejujuran. Objektif kajian ini adalah untuk menggunakan teknik pemprosesan imej yang boleh menggantikan manusia dalam penggredan warna nanas tin bagi mengoptimumkan kualiti eksport nanas tin. Dalam kajian literatur kami, kami mendapati bahawa penggredan dan pengasingan warna telah popular dengan kaedah yang berbeza digunakan. Gambar data diambil di makmal LPNM menggunakan persekitaran yang dikawal untuk menghalang pencahayaan dari luar. Kaedah Otsu telah dipilih sebagai teknik penapisan imej semasa pra-pemprosesan kerana ia memberikan hasil yang terbaik dan hampir dapat menyingkirkan piksel yang tidak diingini dalam imej nanas tin. Dalam usaha untuk mendapat kawasan yang diingini (ROI), operasi morfologi menggunakan pengembangan dan penguncupan telah digunakan. Bentuk penstrukturan cakera dengan radius sembilan (9) dan sepuluh (10) telah digunakan dalam operasi ini. Pendaraban ROI dengan imej asal adalah langkah terakhir sebelum ciri pengektrakan dilakukan. Statistik peringkat pertama seperti minimum, maksimum, purata dan sisihan piawai dikira bagi setiap RGB, HSV dan CIELAB. 100% pengkelasan untuk standart 15 diperolehi menggunakan sisihan piawai dan 93.3% untuk Standard 16 bagi warna HSV. HSV adalah dipilih sebagai kaedah pengkelasan dalam kajian ini kerana ia bergantung kepada penjelmaan mudah model RGB dan sesuai untuk penglihatan manusia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

A.P	Approval Permit
CC	Correlation Coefficient
CE	Control Environment
CPC	Canned Pineapple Colour
DSM	Department of Standards Malaysia
LOG	Laplacian of Gaussian
LPNM	Lembaga Perindustrian Nenas Malaysia
MPIB	Malaysia Pineapple Industrial Board
ROI	Region of Interest
SE	Structuring Element

CHAPTER 1

INTRODUCTION

This chapter discusses the background of this research, problem statement, objective, and the scope of this research. It starts with pineapple itself and the process of canned pineapple until the end process before export. During the process certain difficulties on the colour grading will be discussed in detail in this chapter. The outline of this research is explained for easier understanding of the flow of this thesis.

1.1 Research Background

The canned pineapple (Ananas Cosmosus) industry plays a role in contributing to the Malaysia's economy. This industry provides direct job opportunities in plantations and the processing industry, and indirectly in the transportation and manufacturing industries. The Malaysia Pineapple Industry Board (MPIB) is responsible for controlling the quality of industry manufactured products and provide the guarantee of safety either in processed form, semi-processed, or fresh form (Malaysia Pineapple Industry Board, 2010).

Canned pineapple process starts from harvesting the pineapples from the plantation and brings them to the factory. Pineapple cleaning is done to remove any dirt before inspection and grading the standard into 3 primary grades according to size. Next, the pineapple skin is peeled and the pith is removed before the fruit is cut into round slices or another shape. Cut pineapples will be filled with syrup solution then sealed, sterilized, cooled and dried until storage. These finished products are kept for two weeks to ensure product stability and freedom from contamination from microorganism during processing and operation (Malaysia Pineapple Industry Board, 2010c). The process ends with the canned pineapple going through a quality inspections performed by MPIB laboratory before export. The processing of canned pineapple until quality inspection is depicted in Figure 1.1.

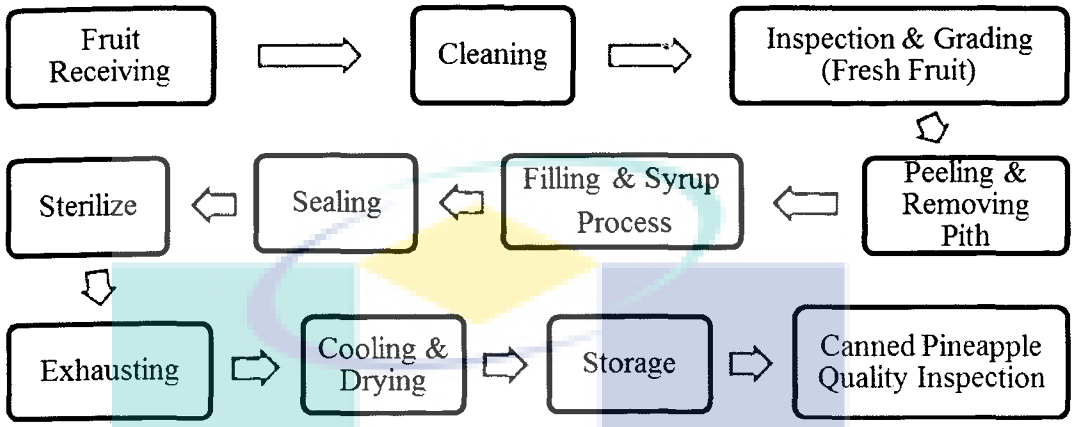


Figure 1.1 Pineapple Canning Process

There are a lot of quality inspections done in an MPIB lab, such as food chemical analysis service, proximate analysis service, microbiology analysis service, and grading analysis service (Malaysia Pineapple Industry Board, 2010c). There is a rule enacted to ensure the quality of canned pineapple as standardized by the Department of Standards Malaysia (DSM). The quality of canned pineapple is related to the depth of colour, uniformity of colour, uniformity of size and shape, absence of defect, texture, and flavour (Malaysian Standard, 2003).

One of the quality inspections in grading analysis service is the colour of canned pineapple before being exported. An export permit or Approval Permit (A.P) is a compulsory for a product to be marketed outside the country. The yellowish colour of canned pineapple is analysed in the laboratory to conform to the canned pineapple export permit. The manufacturer would not get permission to export their product if the colour does not match the MPIB standard. The yellowish of canned pineapple can be white to yellow (light yellow), middle yellow or yellow to orange. In an MPIB laboratory, they classify colour into a few standards as a quality control that must be performed by the manufacturer.

Nowadays, canned pineapple is fully dependent on experienced workers to grade colour quality according to the standard of MPIB. There is only one person that is really an expert in examining the canned pineapple standard colour. The expert relies on visual appearance to make a judgement. Unfortunately, according to Park et al., (1996), this approach is time consuming and labour intensive, the consistency and accuracy of human based pineapple maturity testing cannot be guaranteed, because it always involves subjective judgement.

However, agriculture industries nowadays applied an automated system that produces a low cost, efficient, fast and reliable product inspection system. Image processing has been applied in such automated systems for various applications in the fruit and vegetable industries. Since automated systems are faster, consistent, economic and more precise, they have been chosen to be used in grading of canned pineapple colour. This alternative provides non-destructive and cost effective techniques to achieve its requirements (Krishna Kumar Patel, et al., 2012).

This study is intended to overcome the problem faced by MPIB in quality inspection as specified by DSM. Using image processing, the quality process for colour inspection is convertible into a method which is easier than the traditional method. Based on this, an automatic canned pineapple grading that focuses on the quality of the colour was necessary as an alternative method. In addition, there is no research yet on canned pineapple colour, though there are a few on fresh pineapples. The algorithm of other application benchmark in this research is to be reviewed and explored more.

1.2 Problem Statement

There are a few problems leading to this study, which are:

(i) Manual quality colour inspections that judge based on visual appearance are still being practiced and done by experienced worker in the MPIB laboratory. The ability to perceive colour is one of the most important functions of human vision and contributes to human colour perception in daily life. Therefore, to recognize the yellowish canned pineapple maybe difficult for certain people, and this will affect the quality colour inspection.

(ii) The performance of human graders also influenced by human factors such as fatigue, emotional condition, personal preference and honesty, which risks leading to incorrect colour classification. So, this method is not suitable because it may lead to other problems which will affect the canned pineapple industry.

Therefore, this study is as an approach to replace the old fashion colour recognition in MPIB laboratory. In addition, the inspection and grading of fruits using an automated system was reported as having strong potential in providing the desired result. Furthermore, it also can help MPIB use a systematic procedure in their work.

1.3 Research Objectives

The objective of this research is to use image processing technique that can replace human in grading the standard colour of canned pineapple. The specific objectives are as follow:

(i) To propose colour features extraction using different Colour Space techniques: RGB, HSV, and CIELAB colour space.

(ii) To analyse using statistical technique in grading Canned Pineapple Colour (CPC).

1.4 Scope of Study

The scope of this research is as below.

(i) Canned pineapple cut is divided into several physical styles of cut, which are round cut slice, half slice, spiral cut slice, quarter slice, and cube. This research concentrates on round cut slicing canned pineapple.

(ii) The quality grades determined by MPIB are Fancy, Choice and Standard by taking into several quality factor. The quality factors include depth on colour, uniformity of colour, uniformity of size and shape texture and flavour. However, in this study we focus on colour.

(iii) There are a few standard colour of canned pineapple decided by MPIB and the well-known standards are 15, 16, 17, and 18. However, standards 15 and 16 were chosen to study in this research since they are the pass colour standards determined by MPIB for canned pineapple to be exported.

(iv) Grading canned pineapple colour was only done in non-real time mode.

(v) Data samples were taken in MPIB laboratory using controlled environment (CE). There was no outside lighting source during image acquisition.

1.5 Outline of the Thesis

Chapter 1: Introduction

This chapter introduces the background of the research and discusses the objective, scope of project, and the motivation that led to this research.

Chapter 2: Literature Review

This chapter discusses the previous works that have been done in image processing regarding grading method. It will also describe and explain how filtering was done to get a better ROI, morphological process, and pixel features.

Chapter 3: Methodology

In methodology, the method being used in this research for better grading process which is based on certain features will be detailed.

Chapter 4: Results and Analysis

In results and discussions, the results of the experiments are shown and explained and the features analysis in canned pineapple is discussed.

Chapter 5: Conclusion and Recommendation

The last chapter concludes the work and recommends future works which are based on the enhancements for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Canned fruits are familiar as an alternative for fresh fruits in desert or as other cooking ingredients. The nutrition in pineapple is well known and it is also used in the medical sector. In MPIB, the quality of canned pineapple is controlled from the plantation until the end process before export. There are certain standards and specifications enforced for this industrial product.

This chapter will discuss image processing and techniques to overcome the MPIB issue in grading the canned pineapple. It is based on various applications applied to fulfil recognition and grading issues using image processing. Such processing is not only used in medicine and finance but also in agriculture. There are a lot of techniques for different purposes in image processing to be discussed further in this chapter.

2.2 Canned Pineapple Industry

Canned pineapple is the second highest export after watermelon in the tropical fruit category (Malaysia Pineapple Industry Board, 2010a). This industry contributes to the country's economy and provides direct job opportunities in the plantation and processing industry and indirectly job opportunities in the transportation and manufacturing industry. Malaysia is capable of producing high quality product that is competitive in the mainstream market. It is one of the world major pineapple producers along with Thailand, the Philippines, Indonesia, Hawaii, Ivory Coast, Kenya, Brazil, Taiwan, Australia, India and South Africa. Canned pineapple fruit has high market demand in areas like Japan, the United States, the European Union, West Asia, and Singapore (Malaysia Pineapple Industrial Board, 2010a).

Malaysia is famous in generating quality canned pineapple with golden yellow colour. Malaysia's pineapples have different characteristics from competitors and have potential to improve in quality. Currently 95% of canned pineapple productions are for export market and 5% is for domestic market while fresh pineapple contributes 3% to export market and 70% to domestic market (Malaysia Pineapple Industrial Board, 2010b). There are a few processes that canned pineapple goes through before it is exported. Table 2.1 gives the details on how canned pineapple being processed (Malaysia Pineapple Industrial Board, 2010c). In grading analysis service, the focus is on canned pineapple quality inspection. One of the quality inspections is the colour of canned pineapple.

Table 2.1
Details on Canned Pineapple Processing (Malaysia Pineqpple Industry Board, 2010)

Process	Information
Pineapple fruit Receiving	Pineapple fruit received from plant and farm. Fruits are sorted and sent to unloading bay for grading.
Cleaning	Fruit will be placed into special wash tank filled with clean water. Pineapple fruit are then sent out using a conveyor which is equipped with spray system-with water for irrigation purposes.
Inspection & Grading	Pineapple fruit checked and graded to 3 primary grade according to size
Peeling & Removing Pith	Fruit that had been graded are peeled and pith removed using a *Kwong Nam* machine. Pineapple that has been peeled are then inspected to remove residual balance peel using knife. Then fruit will be channelled to "Slicing Machine" and "Resizing Machine" for various cutting shapes.
Pineapple Filling and Syrup Process	Fruit slice will be put inside the can and then will be brought to syrup machine. Syrup solutions with fix concentration is prepared separately and filled into the can using "syruping machine".

Table 2.1 continued.

Process	Information
Exhausting	After syrup process, pineapple pieces are admitted into the "exhausting box" to remove captured air in temperature of 70'c-80'c for 7-10 minutes depends on can size used. This is to create a vacuum state.
Sealing	After through "exhausting box" cans need to go through "seaming machine" and hermetically sealed.
Sterilize	Covered cans are then sterilized in "Sterilization Machine" in temperature of 105'c for 30 minutes.
Cooling & Drying	Cans that are sterilized will get through refrigeration machine in temperature 40- 44°c and then dried using a blower.
Storage	Products arranged on a pallet are kept for two weeks to ensure product stability and freedom from contamination.

All of the activities under MPIB are subject to the pineapple industry legislation. Pineapple Industrial Ordinate, 1957 guided the implementation of activities related with pineapple industrial development where some amendments on Act and regulations have been made. Pineapple Industrial Regulation (Fruit Control) 1957 is responsible in pineapple smallholder registration. This rule is related to the division of pineapple fruit to registered plants on a smallholder basis on fruit grade. Pineapple Industrial Regulation (Export Market) 1959 has a role to register exporter in Malaysia. It is also a fixed rule for purchasing canned pineapple by registered manufacturers, including price controls at the lowest level from market price (Malaysia Pineapple Industrial Board, 2010).

The Industrial Pineapple Rule (Factory Control) 1959 was enacted to ensure quality of pineapple products which will be exported by providing quality control guideline starting from raw material level, processing, storage, packaging and final issue. The legislation also includes the Industrial Rule Pineapple (to export) 1959, Pineapple Industrial Regulation (Replanting Financial Assistance) 1971, Amendment 1985, and Pineapple Industrial Regulation (Replanting Financial Assistance) 1971

Amendment 1985, which focus on cess collection of canned pineapple exports from registered pineapple factories and allow MPIB to provide financial assistance to farmers. This rule is also responsible to give aid grants for pineapple cultivation to entrepreneurs who want to cultivate a pineapple plantation. Financial assistance is RM 3,500 per hectare of new crops and RM 1,750 per hectare of replanting. This function is conducted by the Ministry of Agriculture (Malaysia Pineapple Industrial Board, 2010).

2.3 Canned Pineapple Standard

The Malaysian Standard MS 302:2003, Specification for Canned Pineapple (First Revision) by DSM prescribes the requirements and test methods for canned pineapple. There are many cut styles for canned pineapple including slice, half slice, cube, dice, tidbit, and chunk. The definition of round slice in this research is shall consists of uniformly cut circular slice or ring cut across the axis of the peeled, cored pineapple cylinder. All of these styles except crushed pineapple have a quality grade and the quality factors of each quality grades are as specified in Table 2.2.

Table 2.2
Quality Grades (All Styles of Packing except Crushed Pineapple) (Malaysian Standard MS 302:2003)

Quality Factor	**Grade**		
	Fancy	**Choice**	**Standard**
Depth of colour	Fancy	Choice	Standard
Uniformity of colour	Minimum 80 %	Minimum 70 %	Less than 70 %
Uniformity of size and shape	Uniform	Reasonably uniform	Fairly uniform
Absence of defect	Free	Practically free	Relatively free
Texture	Good	Reasonable good	Fairly good
Flavour	Good	Reasonable good	Fairly good

Canned pineapple cuts may contain white radiating streaks. By referring to the colour chart shown in Appendix B, depth of colour is determined by matching the average colour shade of the sample. The uniformity of colour determined visually from the percentage of the separate portions contained in the sample. However, the remaining percentage shall be at least within one grade lower than the specified grade (Malaysian Standard MS 302:2003). Table 2.3 details the quality factors for uniformity of size and shape regarding slice cut.

Table 2.3.
Uniformity of Size and Shape - Round and Spiral Cut Slices (Malaysian Standard MS 302:2003)

Parameter	**Degree of Uniformity**	**Quality designation**
Variation in: Diameter of the slice Thickness of the slice Radial axis of the same slice	 ≤ 2 mm ≤ 2 mm ≤ 3 mm	Uniform
Variation in: Diameter of the slice Thickness of the slice Radial axis of the same slice	 2mm to 3mm 2mm to 3mm 3mm to 6mm	Reasonable Uniform
Variation in: Diameter of the slice Thickness of the slice Radial axis of the same slice	 ≥3mm ≥3mm ≥6mm	Fairly Uniform

The quality grade decided by MPIB worker are dependent on the sampling of canned pineapple that refers to the specifications for canned pineapple, Malaysian Standard MS 302:2003. The sampling should follow these standards:

(i) Sample size shall consist of six cans of the same denomination and drawn from a single batch of manufacture.

(ii) The number of sampling to be taken shall be previously negotiated and agreed upon with each individual cannery, based on production and the results of grading and analysis.

(iii) The samples are delivered promptly to an analyst of the certifying agent for subsequent grading and analysis.

(iv) The receipts of all samples taken shall bear particulars of name of cannery, code mark, canner's quality grade, can size and quantity.

(v) Sample cans shall be drawn at random from the same running line or otherwise extracted from different levels of the same stacked pallet.

(vi) Examination and grading of sample cans shall be carried out at least 14 days after date of manufacture

Therefore, this study will improve the quality judgment from manual to automatic system using image processing by measuring one quality grade. The colour of canned pineapple were analysed using new standards namely Standard 15, Standard 16, standard 17 and standard 18 as explained by MPIB's expert. Normally, standards to be exported are Standard 15 and Standard 16. Standard 17 and standard 18 are classified as a ripe pineapple and not suitable to be exported. The yellowish colour of Standard 15 and Standard 16 will be a set of data that classify automatically to give license to manufacturer and to overcome the problem as stated in the problem statement. The other quality grade is still based on the above explanation.

2.4 Image Processing

Image processing is important in various field of computer vision such as face detection, finger print detection, medical image analysis, agriculture, food grading and geographic. It is a tool in science or engineering to provide more effective work in human daily life. Image processing is used for various applications in agriculture. Sorting and grading commonly use image processing in this field. Image processing is a procedure of converting an image into digital form to take out information by applying some operation on it, in order to get an improved image (Basavaprasad B & Ravi M, 2014).

Some of the example of image processing in agriculture is study on grade judgment fruit vegetables using machine vision (Mosateru Nogato et al., 1998), apple fruit analysis for fruit colour, shape and texture (Stajnko et al., 2009), grading tomato maturity estimator (Syahrir et al., 2009) and automated strawberry grading system (Liming & Yanchao, 2010). It is also applied in other agriculture industry such as pears (Yoshitaka Motonaga et al., 2010), star fruits (Mokji M.M. & Abu Bakar S.A.R, 2007), papaya (Amarasinghe D.I & Sonnadara D. U. J., 2009), tomatoes (Xinzhong Wang et al., 2011), palm oil (Ahmed Jaffar, et al., 2009) and apples (Paolo Gay et al., 2002). Most of this research was focused on grading or classify the colour of fruits by using image processing. They applied various colour techniques such as normalized RGB, a linear one-dimensional colour feature (Hue) and an average value of RGB and HSI and also used colour scale chart.

Normally the grading works are done by human decision, but this old method can be replaced by using image processing. Figure 2.1 is the work flow of image processing technique in general which is human observer replaced by the image processing. Based on s previous study that used image processing in agriculture, there are a few steps involved in general. Almost all of the research as stated before were taking image acquisition, image pre-processing, and features extraction as the main issues. Gunasekaran and Ding, (1993) divided the image processing into three levels known as low, intermediate, and high. Figure 2.2 shows the detailed levels of image processing.

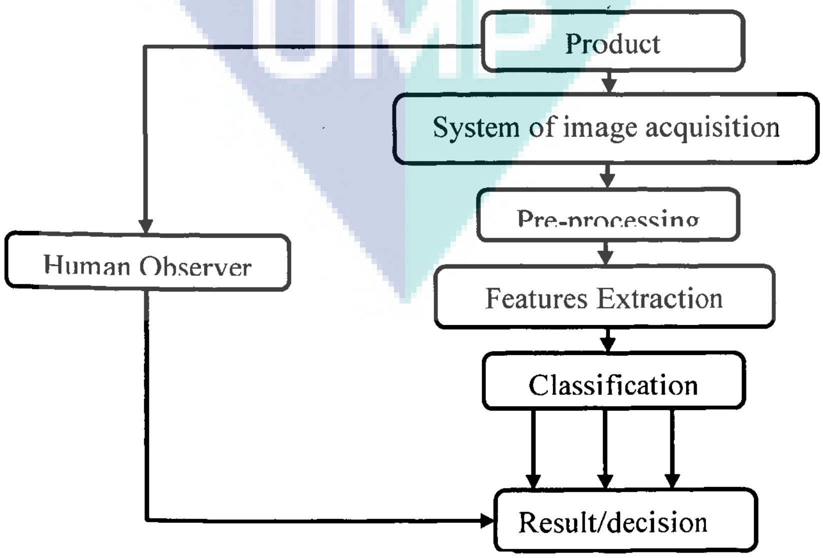


Figure 2.1 Work Flow of Image Processing Technique & Human Observer

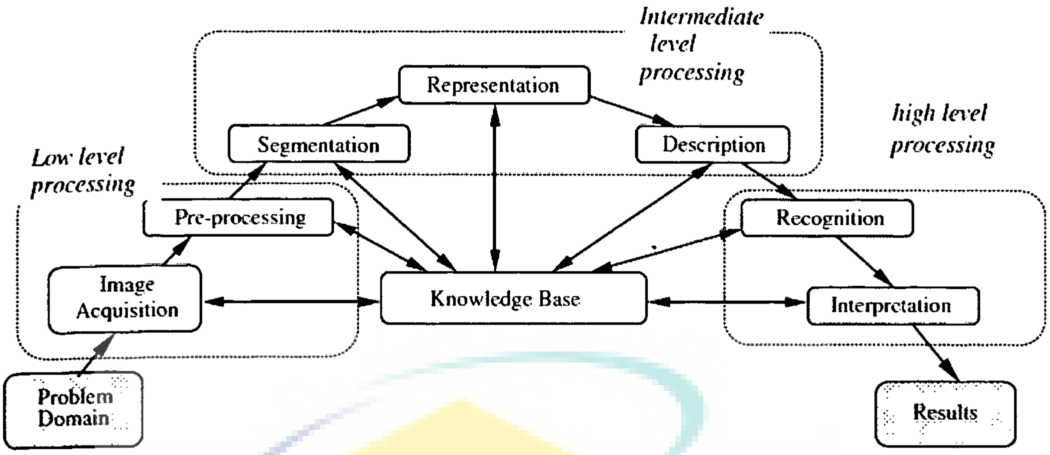


Figure 2.2. Steps and levels in image processing

Source Sun, 2000

2.5 Research Opportunity on CPC

There are limited research developing an automatic system for pineapple fruits. One of the research involving image processing and pineapple is regarding harvesting robots. They harvest the pineapple with real time and accurate image matching by taking the yellow as a ripe fruit using RGB (Bin Li et al., 2010). Until this date, there are just a few studies on fresh pineapple for automatic grading technique. They grade the maturity of pineapple based on the skin colour changes from green to yellow and extracted the features to determine whether the pineapple group into which seven (7) level (Kaewapichai et al., 2006; Rohana Abdul Karim et al., 2009; Shuhairie Mohamed, 2013). The seven (7) maturity index was as Figure 2.3 that provide by (Federal Agriculture Marketing Agency, 2004). Somehow other researcher were used different maturity index to analyse the physicochemical properties of pineapple fruits index (Brat et al., 2004; Rosnah Shamsudin et al., 2009; Rosnah Shamsudin et al., 2007).

Ada tujuh (7) indeks kematangan untuk nanas:

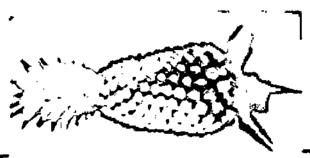
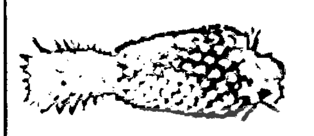
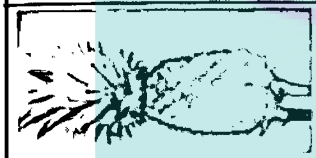
	Indeks 1 – Muda atau tidak matang. Keseluruhan permukaan kulit atau mata berbentuk agak bujur meruncing ke atas, berwarna hijau tua dengan braktea berwarna kemerah-merahan. Isi sangat pejal. Tidak sesuai untuk dipetik.
	Indeks 2 – Peringkat permulaan matang. Keseluruhan mata agak lebih bulat berwarna hijau tua dengan sedikit kekuning-kuningan antara mata di bahagian pangkal. Braktea berwarna keputih-putihan dan kering. Isi pejal. Buah sudah boleh dipetik. Sesuai untuk dieksport.
	Indeks 3 – Matang. Keseluruhan mata berwarna hijau dengan 1-2 mata di bahagian pangkal berwarna kuning. Sesuai untuk dieksport.
	Indeks 4 – Buah mula masak. Purata 25% daripada barisan mata bermula dari bahagian pangkal buah bertukar menjadi oren kekuning-kuningan. Isi pejal.
	Indeks 5 – Hampir 50% mata menjadi oren kekuning-kuningan bermula dari bahagian pangkal buah. Isi kurang pejal dan berjus.
	Indeks 6 – Lebih 75% matanya berwarna oren kekuning-kuningan. Isi agak lembik dan agak banyak jus. Kurang sesuai untuk dieksport.
	Indeks 7 – Masak ranum. Keseluruhan mata berwarna oren kuning. Isi lembik dan terlalu banyak jus. Tidak sesuai untuk pasaran.

Figure 2.3 Seven (7) Maturity Index

Source FAMA, 2004

These researcher using a different cultivar types of fresh pineapple such as Pattavia (Kaewapichai et al., 2006), Josapine (Rohana et al., 2009), and hybrid N36 (Shuhairie Mohamad, et al., 2012). They are also applying different method and technique in image processing to fulfil the maturity classification of fresh pineapple. W Kaewapichai et al., (2007) fitted a pineapple model for automatic maturity system to be used for any kind of pineapple in order to extract the classification features. Rohana et al., (2009) calculated the pixel with linear thresholding and Shuhairire et al., (2013) used statistical techniques and syntactical classifier.

Unfortunately, there is no research done for canned pineapples that really focus on real end of product processes especially on grading the Canned Pineapple Colour (CPC). W Kaewapichai et al., (2007) was checking the colour for canned pineapple, but still refers to the skin of fresh pineapple. Image processing provides various techniques in finding the fruit classification that also can be implementing on CPC. Based on previous study, it is also not impossible to implement the image processing on (CPC) grading according to its standard, as prescribed by DSM in order to increase the performance of quality inspection by MPIB.

2.6 Acquisition Method

In image processing, researchers are concerned about image acquisition, which is the first important step in pre-processing or segmentation process. Various image acquisition have been used as reported by (Shveta Mahajan et al., 2015). The image acquisition of fruits greatly influences the evaluation accuracy, convenience and the utility of the fruit colour chart (Yoshitaka Motonaga et al., 2010). Many researchers were considering illumination, position of the camera and environment during image capturing. Bai et al., (2013) also claimed that their proposed segmentation method is robust to outdoor illumination variations and lighting conditions.

The distance approach during image capture has been used in oil palm classification (Norasyikin et al., 2012). Image of watermelon captured by considering the position, angle and height of camera and the timing captured (Nasaruddin et al., 2011). The images of tomato were captured by placing a PC camera at approximately 100mm on the top of the tomato, by using same background and same visible light condition (Syahrir et al., 2009). Gejima & Nagata, (2003) also created natural light white fluorescent lamp (round) and high-frequency switching equipment to capture tomato images. They used a CCD camera (SOW, DXC-ISIA, CCD-IRIS/RGB colour video camera, 380 thousand pixels) to capture diffusion light. The CCD camera was attached to the computer and tomatoes were placed under it. Figure 2.4 is the illustration of experiment setup for tomatoes.

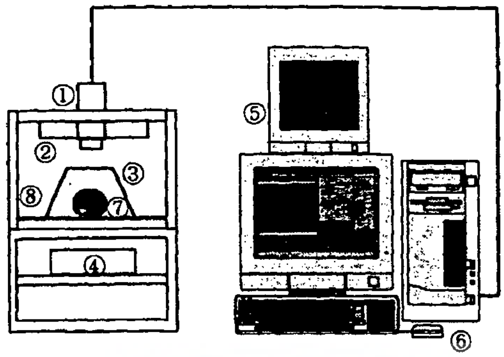


Figure 2.4. Image Acquisition for Tomatoes

Source Gejima & Nagata, 2003

It is also reported that a dark box was used to create an imaging chamber in order to avoid backscattering effects from other light sources in grading date (A. Manickavasagana, et.al,2014). Figure 2.5 is a setting of image acquisition for Legume by Shveta Mhajan et al., (2014) and Figure 2.6 is a setting of image acquisition for fresh pineapple by Shuhairie (2014).

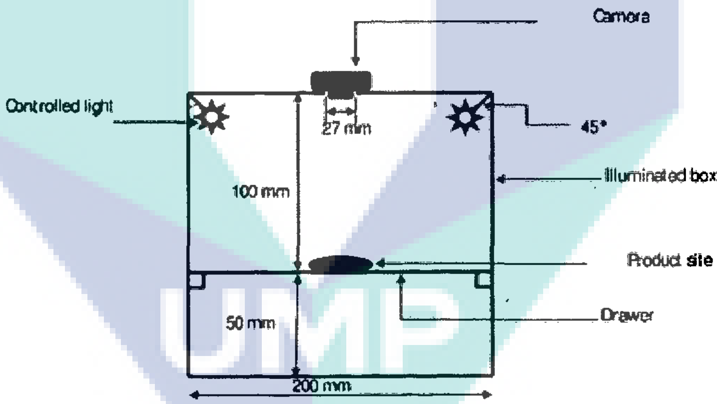


Figure 2.5 Image Acquisition for Legume

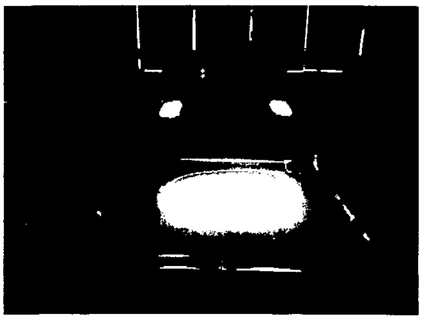


Figure 2.6 Image Acquisition for Fresh Pineapple

The illumination environment is very important as it determines the quality of images acquired, especially for glossy products (Njoroge et al., 2002). Canned pineapple is also a glossy product because of the liquid or syrup in the can. Whenever sliced canned pineapple is removed from the can, it become glossy when it was exposed to the light. Since the outcome image during image acquisition is in RGB format, it is done under control lighting environment as RGB colour space is strongly influenced by light (Nasaruddin et al., 2011). The environment control can avoid lighting factor that may cause colour and illumination inconsistencies by using a low-cost digital camera (Jamil, et al., 2009). Image acquisition plays an important role when getting feature information in image.

2.7 Segmentation & Thresholding

An image contains a background and foreground that can be separated using image processing techniques. There are various segmentation and thresholding techniques that have been used in image processing area. Lo & Tsai (1995) proposed Grey-Scale Hough Transform for detecting bands in grey-scale images that can detect the band shape. Some researchers have applied the edge detection algorithm to detect discontinuities in brightness and finding the boundaries of objects within images. Last but not least, they proposed a non-linear weighted statistical algorithm for multi-scale edge detection of grey image based on wavelet analysis to detect the image of bubble gas–liquid (Guo et al., 2010).

Otsu's method is one of the methods that is commonly used in image thresholding. Otsu's calculate automatically threshold value to minimize interclass variance between two colours which is black and white pixel (Farrahi Moghaddam & Cheriet, 2012). It is also a one-dimensional (1D) algorithm. Otsu's method is said as having poor adaptability to noise image segmentation and time consuming. This problem was overcome with a novel two dimensional (2D) Otsu thresholding algorithm based on local grid box filter, which significantly reduces the time of segmentation process and simultaneously allows higher segmentation accuracy (Guo W et al., 2014).

There is a lot of research that has discussed Otsu's method and at the same time applying this method. Otsu's thresholding method applied in apple sorting and grading and automatically adjusts the classification of hyperplanes and also avoids the problems caused by lighting factor and the colour of the fruit (Mizushima & Lu, 2013). The pupil location based on the Otsu's method was also applied to get a binary image by ensuring the automatic threshold value (Lin & Yu, 2011). The skin colour detection algorithm based on self-adaptive skin colour model set a global threshold automatically using Otsu's method to find the threshold by optimizing the size of DPT separated on the histogram analysis (Yang et al., 2010).

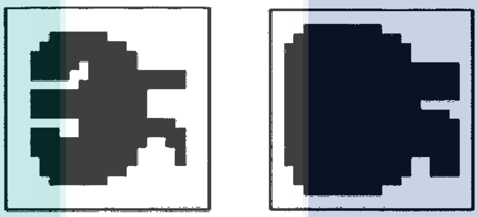
2.8 Morphology Operation

Morphology is an approach using mathematical equations that are applied to image processing. These operations provide a quantitative description of structuring element that come together with the morphological operator. The morphological technique in image processing is a collection of non-linear operations related to the shape in an image. It is a process to eliminate unwanted pixel in the image and to focus on region of interest (ROI). Basic morphological operators are erosion and dilation. Abdul Kadir (2007) also discussed the morphological techniques and operations based on erosion and dilation. Image segmentation, feature extraction, edge detection, and image enhancement in image processing are commonly used morphology operations to get the desired outcome from a binary image (Zhang, 2009).

2.8.1 Dilation Operation

Dilation is the basic effect of the operator on a binary image to gradually enlarge the boundaries of regions of foreground pixels. Dilation adds pixels to the boundaries of objects in an image depending on the chosen structuring element. Thus, areas of foreground pixels grow in size while holes within those regions become small. Figure 2.7(a) is the original image and 2.7 (b) is the image after the dilation process. Mathematically, with A as an image and B as a structuring element (square as in Figure 2.7) sets in Z, $\bar{B}$ is the reflection of B and shifting this reflection by z. The dilation of A (image) by B is defined in equation 2.1.

$$A \oplus B = \{Z|(\overline{B})_Z \cap A \neq \emptyset\} \tag{2.1}$$



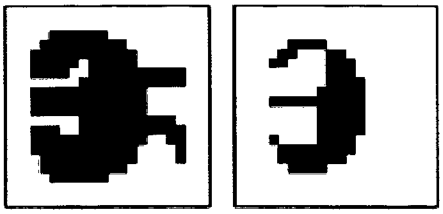
(a) (b)

Figure 2.7. (a) Original Image (b) Image after Dilation

2.8.2 Erosion Operation

Erosion erodes away the boundaries of regions of foreground pixels. Erosion removes pixels on object boundaries. Thus, areas of foreground pixels shrink in size, and holes within those areas become larger. Figure 2.8(a) is the original image and 2.8(b) is the image after erosion process. With A as an image and B as a structuring element (square as in Figure 2.8) sets in Z, which is the set of all points z such that B, translated by z, and it was combined in A. The erosion of A by B is defined as equation 2.2.

$$A \ominus B = \{Z|(B)_Z \subseteq A\} \tag{2.2}$$



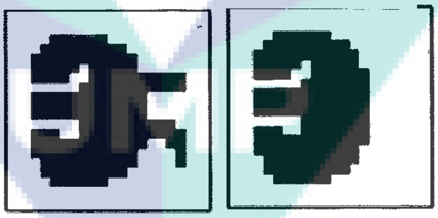
(a) (b)

Figure 2.8. (a) Original Image (b) Image after Erosion

2.8.3 Opening Operation

Opening operation is a combination between dilation operations followed by erosion. Opening performs a morphological operation by remove small objects from the foreground image to get the desired ROI. Figure 2.9(a) is the original image and 2.9(b) is the image after opening process. The structuring element of a square (as in Figure 2.9) is still applied in this operation with the mathematical equation as defined in equation 2.3. The symbols $\oplus$ and $\ominus$ represent dilation and erosion, with A as an image and B as a structuring element.

$$A \circ B = (A \ominus B) \oplus B\} \qquad (2.3)$$



(a) (b)

Figure 2.9. (a) Original Image (b) Image after Opening

2.8.4 Closing Operation

Closing operation is a combination of erosion operations followed by dilation. Opening performs morphological operation by closing the small hole in the foreground image to get the desired ROI. Figure 2.10(a) is the original image and 2.10(b) is the image after the closing process. The structuring element is still applied in this operation with the mathematical equation as defined as equation 2.4. The symbols ⊕ and ⊖ represent dilation and erosion, with A as an image and B as a structuring element (square, as in Figure 2.10).

$$A \bullet B = (A \oplus B) \ominus B \qquad (2.4)$$

(a) (b)

Figure 2.10. (a) Original Image (b) Image after Closing

2.8.5 Structuring Element

Structuring Element (SE) in morphology is a shape that act as a filtering to the image in use by specifying the size. The number of pixels added or removed from the objects in an image depends on the size and shape of the SE used to process the image. Disk, diamond, square, line, rectangular and arbitrary are examples of shapes applied in morphology operations. SE uses a disk shape while specifying the radius according to the size of image being filtered. The size of diamond refers to the distance of SE to the origin of diamond. A square SE size depend on width while rectangular refer to the size of width and height. Various SE and size also have been used in the edge detection for gastric tumour pathologic cell images Li, T. G, et al., 2009). Figure 2.11 is example of SE using different sizes for disk, diamond, and square.

010 111 010	111 111 111	010 111 010
Diamond size 3.	Square size 3.	Disc size 3.
0001000 0011100 0111110 1111111 0111110 0011100 0001000	1111111 1111111 1111111 1111111 1111111 1111111 1111111	0001000 0111110 0111110 1111111 0111110 0111110 0001000
Diamond size 7.	Square size 7.	Disc size 7.

Figure 2.11. Example of structuring element using different sizes

The selected SE shape and size lead the result of ROI or image enhancement. Some application using the SE with fixed size. However, Pan, S., & Kudo, M. (2011) used disk shape with different size to meet the condition of pores wood in their research. Zhang (2009) also used different structuring element algorithm in his analysis about earth post-earthquake UAV aerial images that proposed extended closing operator in mathematical morphology.

2.9 Colour Space

In machine vision, many automation tasks use different colour space schemes. Agricultures sector also applying colour processing in their desired output using three dimensional colour space (Lee, et al., (2011). Colour is a basic characteristic in an image and is the most widely used because it is easy to extract with a different colour space (Junhua & Jing, 2012).

Human defines a colour according to the brain reaction and perceive by it attribute of brightness, hue and colourfulness. However, the computer defines it as quantitative value of red, green and blue to match the colour. There are many colour space that have been used nowadays such as RGB, CMYK, CIEXYZ, CIELAB, YCbCr and HSV. These colour spaces were reported being used in many grading and classification analysis using image processing. Colour space analysis is one of the methods to grade the suitable canned pineapple. Therefore, image processing that uses colour to classify and grade according to the standards will be used in this research.

2.9.1 RGB Colour Space

The RGB colour model is a colour model in which red, green, and blue are combined together in various ways to reproduce a broad array of colours. An RGB image resides in a single m-by-n-by-3 array, where m and n are the numbers of rows and columns of pixels in the image, and the third dimension consists of three planes, containing red, green, and blue intensity values. For each pixel in the image, the red, green, and blue elements combine to create the pixel's actual colour. Figure 2.12 is the cube of RGB colour space.

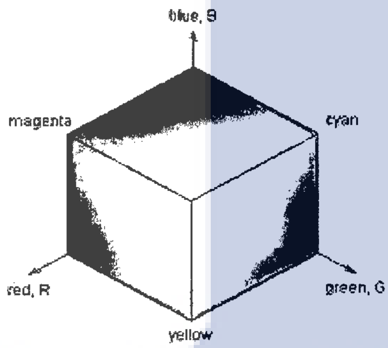
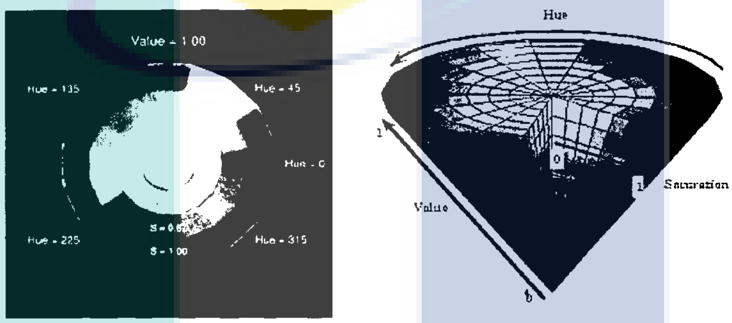


Figure 2.12. RGB cube (www.peterstone.name)

RGB colour imaging technique is used to classify dates into classes (Manickavasagan A et al., 2014) and the ripeness of watermelon in terms of the mean value of each RGB colour component (Nasaruddin et al., 2011). The correlation coefficient in G plane also applied in classifying the tomato maturity (Gejima & Nagata, 2003). Lee et al., (2011) also presented a new colour mapping based on the RGB colour space. Last but not least, a normalized RGB technique has been used to classify the maturity of fresh pineapple (Shuhairie et al., 2011) and also to differentiate oil palm bunches based on RGB intensity.

2.9.2 HSV Colour Space

HSV is also known as H: Hue, referring to shade; S: Saturation or referring to intensity of specific hue; and V: Value ranging from black to the maximum colour intensity. According to human intuitive colour concepts, it is easy to describe the colour in terms of shade, tint, and tone, or hue, saturation, and brightness. Therefore, HSV colour is more appropriate for human sight. The hue H of HSV colour space is the most important resolution of visual features (Junhua & Jing, 2012). Figure 2.13(a) and 2.13(b) show description images of HSV colour space.



(a) Top view (b) 3D view

Figure 2.13. HSV Colour Space (www.rohan.sdsu.edu)

Conversion between RGB to HSV is defined as equations 2.5 to 2.7. The MAX and MIN are the value of maximum and minimum RGB.

$$H = \begin{cases} \dfrac{\left(\dfrac{G'-B'}{MAX-MIN}\right)}{6} & ,\text{if } R'=MAX \\[2ex] \dfrac{\left(2+\dfrac{B'-R'}{MAX-MIN}\right)}{6} & ,\text{if } G'=MAX \\[2ex] \dfrac{\left(4+\dfrac{R'-G'}{MAX-MIN}\right)}{6} & ,\text{if } B'=MAX \end{cases} \tag{2.5}$$

$$S = \frac{MAX-MIN}{MAX} \tag{2.6}$$

$$V = MAX \tag{2.7}$$

There are a few researchers that have applied this colour space in segmentation of colour images using HSV colour space (Huang & Liu, 2007), starfruit classification based on linear hue (Mokji M.M., and Abu Bakar S.À.R, 2007), and a hand detection method using a background subtraction technique to extract the region of a person in HSV colour model (Rahmat et al., 2013). The second-order difference signals and predicting error photorealistic computer graphics images are also extracted in the HSV colour space.

2.9.3 CIELAB Colour Space

CIELAB is the third colour space used in this research after RGB because it is much more intuitive than RGB and has similarity to the human perception of colour. It can thus be used to make accurate colour balance corrections by modifying output curves in the *a (green to red) and *b (blue to yellow) components, or to adjust the lightness contrast using the L component. Figures 2.14(a) and 2.14(b) show the description image of CIELAB colour space.

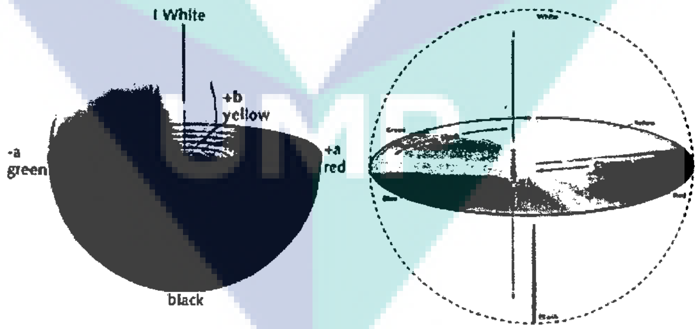


Figure 2.14. CIELAB Colour Space (www.micro-epsilon.de)

The conversion equations between RGB to CIELAB are given in equations 2.8 to equation 2.13. RGB must be converted to XYZ colour space, then converted again to get the values of L, a and b.

$$L = 116\left(\frac{Y}{Y_n}\right)^{1/3} - 16, \quad \text{for } \left(\frac{Y}{Y_n}\right) > 0.008856 \tag{2.8}$$

$$L = 903.3\left(\frac{Y}{Y_n}\right), \text{ otherwise} \tag{2.9}$$

$$a = 500(f(\left(\frac{X}{X_n}\right) - F\left(\frac{Y}{Y_n}\right)) \tag{2.10}$$

$$b = 200(f(=500(f(\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)) \tag{2.11}$$

$$\text{where } f(t) = t^{\frac{1}{3}}, \text{ for } t > 0.008856 \tag{2.12}$$

$$f(t) = 7.787t + \frac{16}{166}, \text{ otherwise} \tag{2.13}$$

CIELAB colour space has been claimed to give the best result in segmenting the cranberry and it also analyses pixel statistics using L, *a and *b component (Cherawala, Lepage, & Doyon, 2006). Image enhancement technique for iris recognition has been proposed based on the CIELAB histogram (Matheww K. Monaco, 2007). Bai et al., (2013) proposed a crop segmentation method by determining crop colour region using CIELAB colour space. Liming et al., (2009) proposed frequency of *a value to distinguish differences in mature strawberries.

2.10 Colour Extraction Analysis

Discussing the image processing technique will lead to the conclusion that one of related point is colour extraction analysis. The study on agriculture, biomedical or computer vision using different method is to extract the information in an image. Some of the study proposed 2-D wavelet transform decomposition for skin defect detection of pomegranates (Pawar & Deshpande, 2012), least Mean Square Error for grading tropical fruit using magnetic resonance imaging (Wasiu A. Balogun et al., 2013) autocorrelation of ECG segments (Agrafioti & Hatzinakos, 2008), image histogram, and many other features.

2.10.1 Image Histogram

Histogram is defined as a graph that shows the pixel of number in an image with different intensity of pixel value. The intensity range were found using the image histogram as used in liver tumour diagnosis (Kumar et al., 2012). The correlation coefficient also showed by the histogram of RGB values in grading the tomatoes maturity (Gejima & Nagata, 2003). (Chen W.T et al., 2008) proposed fast image segmentation based on HSV histogram that automatically generates the cluster value. Creating an image histogram can help to enhance the quality work in the image analysis. A viewer also will be able to judge the entire tonal distribution at a glance for specific image using a histogram. Figure 2.15 is an example of a histogram of an RGB image.

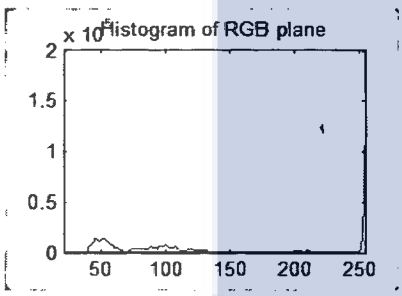


Figure 2.15. Histogram of Original Image

2.10.2 Pixel quantization

Quantization involved in image processing is a loss compression technique achieved by compressing a range of values to a single quantum value. When the number of discrete symbols in a given stream is reduced, the stream becomes more compressible. Figure 2.16 is an example of image of the quantization. The number of pixel values were reduced compared to image (a). Quantization is important to overcome the problem with too many colour in image. It helps to reduce problems with display or device restriction, storage space, processing time and the complexity during analysis (Celebi, 2012).

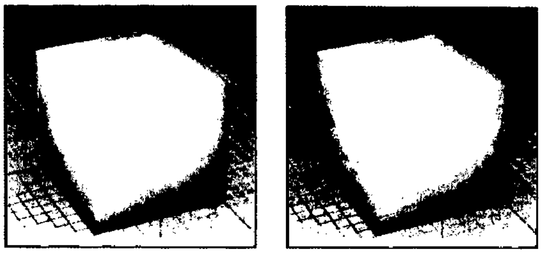


Figure 2.16. Image Before and After Quantization

Bing et al., (2004) proposed a colour quantization to choose the right colour palette and to reconstruct the original image by replacing its colour with the most similar colour palette. Colour quantization has been proposed by many researchers but with the new adaptive method. Celebi (2011) implemented k-means clustering with an appropriate initialization strategy and claimed serve as a very effective colour quantized. Ozdemir & Akarun (2002) suggested a fuzzy algorithm for colour quantization of images and claimed the perception of the human visual system and illustrate that substantial quality improvements are achieved. The variations of network parameters and training sample size can be adapting using sample-size adaptive SOM (SA-SOM) algorithm for colour quantization as also claimed by Wang et al. (2007).

2.10.3 Pixel Colour Statistic

Pixel colour information can be retrieved from the calculated pixel statistic. Statistic of pixel calculated also known as colour features analysis. Minimum, maximum, mean, and standard deviation of pixel value are commonly used in image processing.

Statistical analyses used in content-based image retrieval to evaluate melon fresh colour (Yoshioka & Fukino, 2009), grading of apple fruits by multispectral machine vision (Devrim et al., 2010), sorting cranberries (Chherawala et al., 2006) and other image processing applications. Colour image retrieval technique in retrieving similar images from the digital image databases used statistical properties based on colour features. Table 2.4 is a summary of research that used this first order statistic to achieve their objectives.

Table 2.4
Summary of A Few Research Use First Order Statistic

Author	Type of grading	Type of Statistic
Pawar & Deshpande, (2012)	Skin defect detection of Pomegranates	Mean, variance, mean intensity
Chherawala et al., (2006)	Fresh cranberries grading	Mean, statistical validity by an analysis of variance-one-way.
Lu & Chang (2007)	Image retrieval	Mean, standard deviation
Li et al., (2010)	Identifying Photorealistic Computer Graphics	Second order statistic, variance, kurtosis, correlation
Gejima & Nagata (2003)	Level of Maturity for Tomato Quality	Average value of a* (CIELAB)
Mizushima & Lu, (2013)	Apple Sorting & Grading	Means of RGB values

The correlation coefficient (CC) is a statistical criterion that presents the degree of similarity of any two given image. S.Grgi & Mrak (2004) proposed picture quality measure use CC in their research to measure the quality after compression. Research that analysed the relationship between colour features of strawberry and vitamin C was conducted using this statistic (Liming et al., 2009). Applied geography area also use CC to explore the spatial pattern changes of bird species richness at multiple scales (Ma et al., 2012). However, this measure is not sufficient to perform identification and is thus employed as a pre-classification scheme, which significantly reduces the applicability of this research (Agrafioti & Hatzinakos, 2008).

2.11 Summary

Based on the literature review, grading and sorting application using image processing are not new in computer vision system. Many researchers have discussed this matter starting from image acquisition, pre-processing, and colour features information using mathematical statistic. In image acquisition, object preparations and certain setting were involved to get the excellent quality of image. This may lead to the result of edge detection or thresholding process in the pre-processing stage.

Last but not least, the result of ROI from pre-processing stage was employed in getting all the pixel information. From the result of features extraction, the classification and decision were made. Various techniques have been used in many research to make a classification especially in grading and sorting matter. The outcomes of their research were widely embedded in the build system for agriculture sector. However, as mentioned above, there was limited research in pineapple especially for canned pineapple. Under these terms automatic canned pineapple grading and sorting according to the requirement stated by MPIB is not possible to implement.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Canned pineapples in this study have gone through few steps to achieve the grading colour according to MPIB. Each slice of canned pineapple pixel colour was analysed from the first step starting from how image was captured until the decision making. The stages are shown in Figure 3.1, from image acquisition, pre-processing, features extraction, classification and grading decisions. The two standards of canned pineapple will be explained in detail.

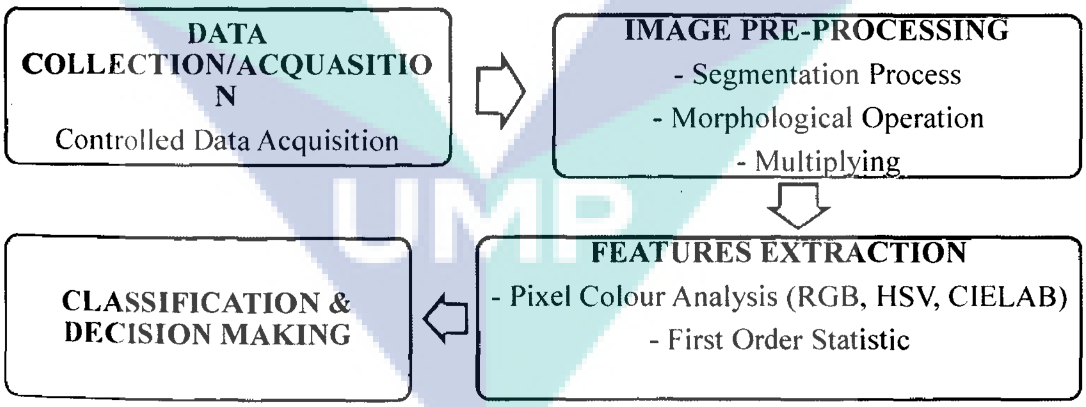


Figure 3.1. Research Methodology Block Diagram

In the first part, this research focused on data acquisition step. This involves controlled data acquisition with a certain setup to eliminate other light sources during image capture. The data taken were divided into two sections which are the training set and the testing set. Secondly, image preprocessing was implemented using a few techniques for segmentation to find the suitable region boundaries. Based on the chosen segmentation, the image data will go through the morphological process, with image multiplying between the original image and the ROI image.

Next, all the image information was extracted using quantization, pixel colour analysis and colour scale. Finally, decision making was finalized in grading and sorting the standard CPC. The entire decision making in training process also have been applied for the testing data. The research steps from data collection until decision making were done in non-real time mode throughout the experiment.

3.2 Image Acquisition

Canned pineapple images were captured at the Malaysia Pineapple Industry Board (MPIB) laboratory at Johor Bharu, Johor. The sample of canned pineapple were sent by the manufacturer for the quality inspection purposes in order to get the permit (AP) as explained in Chapter 2. All images were taken under supervision of expert worker in MPIB to make sure the canned pineapple data in the correct standard. The pineapple images are based on Joint Photographic Experts Group (JPEG) image format. There were 100 datasets for each standard of canned pineapple for training purpose and 20 datasets that taken randomly for testing purpose. The standard type of canned pineapple in this research was Standard 15 and Standard 16, as explained in Chapter 2. So, there was 200 data points used for training purposes and 40 data points used for testing purposes.

Image acquisition is the first stage of any vision system. The data acquisitions in this study were taken illumination sensitivity as important thing to be considered. This method ensures the best results on the ROI or known as image of canned pineapple when doing the pre-processing process until the masking image were obtained.

3.2.1 Control data acquisition

In image acquisition, the image was taken under control environment (CE) using two cool white light bulbs with luminous flux 600Lm. Logitech webcam with version 2.31 software were used during data snapshot and the image resolution was set to 640x480 pixels. The distance from camera to canned pineapple was 35cm. The image resolution was converted to decrease the processing time during the simulation. The webcam was place on top of a box where no other light source may come in except for the light sources as mentioned previously. The image acquisition in the control environment is as shown in Figure 3.2.

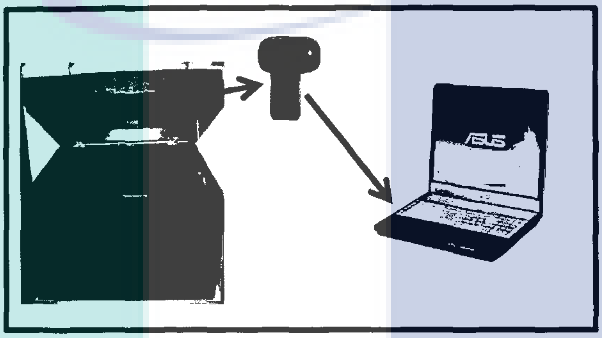
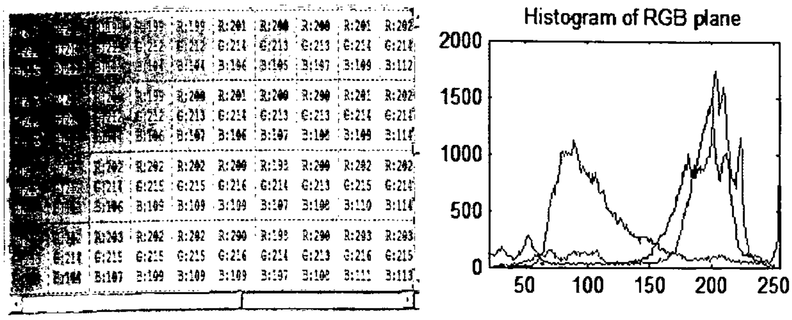


Figure 3.2. Image Acquisition in CE

The canned pineapple was place on a blue background to make sure a clear image is obtained since in RGB colour space blue component in yellow colour was less compared to other components. Figure 3.3(a) shows pixel values of blue component were less than other component in RGB when the image focus on certain part or cube of canned pineapple. Figure 3.3(b) also showing that the canned pineapple colour denominated by others colour compared to blue component using image histogram. Both figures strengthen why blue background was using in this image acquisition.



(a) (b)

Figure 3.3. (a) Pixel Value of Canned pineapple cube b) Histogram of ROI

Figure 3.4 show the examples of canned pineapple image Standard 16 and Figure 3.5 images for Standard 15. The difference between the two pineapple images is in the yellow colour in Standard 15 and Standard 16. The white strike on canned pineapple is also different between both standards and it influences the colour analysis in this research. Standard 15 should be lighter than Standard 16 according to MPIB. However, sometimes the yellowish colour cannot be determined by our eyes at first sight.

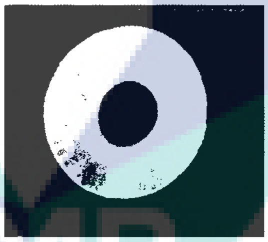


Figure 3.4. Canned Pineapple Image Standard 16

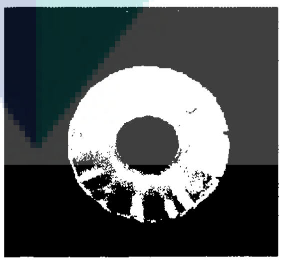


Figure 3.5. Canned Pineapple Image Standard 15

3.3 Pre-Processing

Image pre-processing is the method to get the image of canned pineapple and eliminate others unwanted pixel value from the image. In this stage, the image of canned pineapple was focused and the other pixels were ignored. Figure 3.6 shows the block diagram of pre-processing process in this research. The image datasets will go through binarization process and morphological process to get the mask image. In other words, the foreground of image was converted to white pixel colour and background colour was black. Then, class converting processes were done since the format of image was not the same after the preprocessing technique. The background pixel will be converted to black since black is equal to [0, 0, 0] and will become [0, 0, 0] after multiplying it with the original image. The binarization and morphological processes are discussed in section 3.3.1 and 3.3.2.

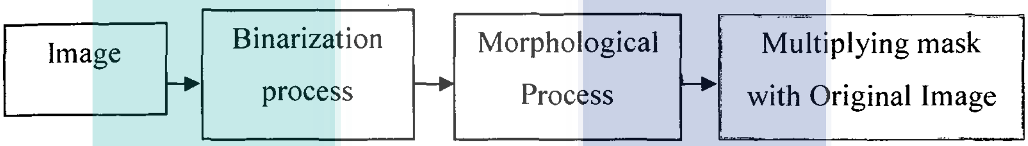


Figure 3.6. Block diagram of pre-processing process

3.3.1 Binarization process

There are a few techniques used in image processing area, such as grayscale edge using Sobel, Prewitt, Roberts, LOG, and Canny. As this research intended to find the ROI, these techniques have been applied to get the desired outcome in this process. Furthermore, the grayscale edge discussed in Chapter 2 stated that edge points have only one response to a single edge. A few experiments on these techniques using Sobel, Prewitt, Roberts, LOG and Canny have been applied with various successful results based on the desired outcome and the input (R. Maini & H. Aggraval, 2009). However, the acquired data was unable to get the smooth ROI using this technique.

As an alternative to eliminate unwanted pixel as desired outcome, Otsu's method was chosen instead of other filtering process before applying morphological process. In global thresholding, Otsu's method is one of the chosen threshold method for real world image with regards to uniformity and shapes measure (S. Arora et al., 2008). Furthermore, this experiment using bi-level thresholding in which only two different regions are been segmented. So, there is no issue on time consuming as reported by Dongju Liu and Jian Yu (2009), since it was not using multilevel thresholding.

In this study, Otsu's method gives the best result for eliminating unwanted pixels in the canned pineapple image. The grey threshold in Otsu's method, chooses the threshold to minimize the intraclass variance of the black and white pixels. The binarizing equation for this thresholding process is as equation 3.1. Figures 3.7 and 3.8 show the different binary image using Otsu's method and without Otsu's method. Even there were some small hole within the white pixels, Otsu's show that the image of canned pineapple definitely according to its shape. there were extra pixels on the image without Otsu's method which cannot be eliminated using morphological techniques. These techniques will be discussed in next point.

$$B(x,y) = \begin{Bmatrix} 1 & White \\ 0 & Black \end{Bmatrix} \tag{3.1}$$

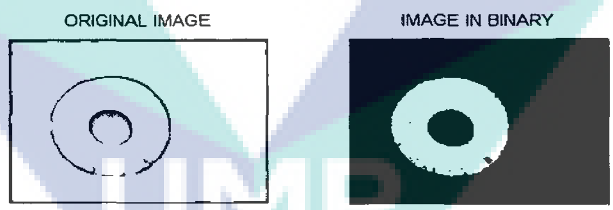


Figure 3.7. Binary Image with Otsu's Method

Figure 3.8. Binary Image without Otsu's Method

3.3.2 Morphological Operation

During the iteration of the process in this research, some of pixel images evaluated are to be removed. Morphological operation is one technique that can manipulate by removing and adding the pixel value in image. This operation was employed in getting the ROI image for the canned pineapple sample. Morphological operations were only work on grayscale image or binary image.

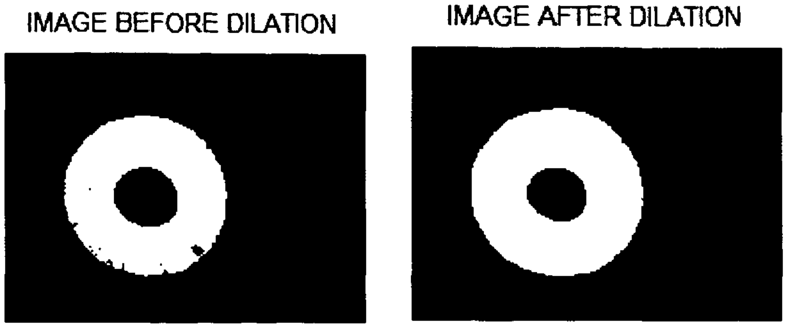
According to Figure 3.7 after Otsu's method, the pineapple image can be seen in binary image which contains white [1] and black [0]. However, this image contains numerous imperfection because there is a black pixel within the shape of pineapple itself or In other words, the pineapple image was not complete because contains a small hole. So, the binary pineapple images need to fill the hole using morphological process.

3.3.3 Morphological Structuring element (SE)

In order to execute morphological process, a suitable SE needs to be considered. Since the SE depends on the specified shape, disk was chosen as it was fit to the shape of slice canned pineapple. Although there are a few operators in morphology processes, this research consists of dilation and erosion. The parameter for radius in disk SE was ten (10) for erosion and nine (9) for dilation. All of the datasets were used this parameter without any changes during the preprocessing step.

3.3.4 Dilation

Dilation is one of the morphological proses that adds pixel in the image according to the types and size of SE. Dilation is the basic effect of the operator on a binary image to gradually enlarge the boundaries of regions of foreground pixels, so in this stage dilation was the first step to be used. Thus areas of black hole in pineapple image or the pixels will grow in size while holes within those regions become all in white colour. At the same time, the white area will become larger with replacement of black pixels with white pixels. Figure 3.9(a) shows the image of canned pineapple before dilation process and Figure 3.9(b) shows the image of canned pineapple after dilation process.



(a) (b)

Figure 3.9. (a) Before dilation process (b) After dilation process.

3.3.5 Erosion

Since using dilation operations cannot give the best image of canned pineapple, erosion was used to erode away the unwanted white pixel and return the image at the end of this process into blue colour. Thus, areas of canned pineapple pixels become smaller in size, and holes within those areas become larger. Figure 3.10 shows the CE image before morphology.

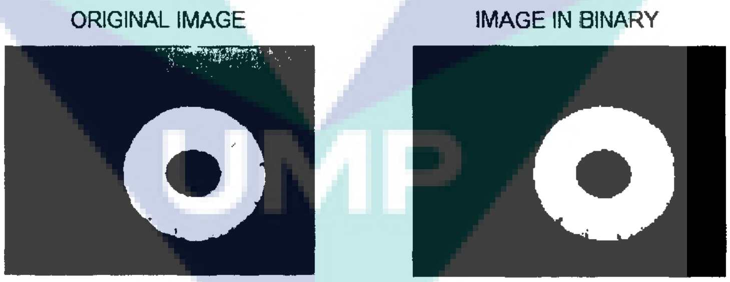


Figure 3.10. Image before morphology

The unsmooth edge in Figure 3.10 is according to the white strike is assign as a background image during filtering process. So, the black pixels were change into white using dilation process. However, the dilation process did not give 100% desired ROI because the white pixel region becomes larger than the canned pineapple. So the erosion process eliminates or changes the pixel into black around the edge of white region. Figure 3.11 is the final output after both dilation and erosion process, known as ROI.

Figure 3.11. Image after morphology

3.3.6 Multiplying mask image

The image of binary or ROI after filtering using morphology was call as mask image. Every image will have their own mask and will be multiplied with their original image. A mask image after the preprocessing contains the values one (white pixel) and zero (black pixel) and the ROI (canned pineapple) refers to the white pixels. When multiplying both original images with its own masking image, the white pixel in masking image will give out the pixel value of canned pineapple itself while the black pixel remains. So, finally we get the pineapple image with the yellowish pixel and black foreground pixel.

Equation 3.2 is multiplying technique between these two images. A is the masking image and B is the original images producing output (C) in which each pixel value is multiplied.

$$C(i,j) = A(i,j)*B(i,j) \qquad (3.2)$$

The output C was on the new RGB image to be analysed after multiplying process. Figure 3.12 is the example of final pineapple image that concentrated on the yellowish canned pineapple with a little and no other unwanted pixel. The success of this final image will be discussed in Chapter 4.

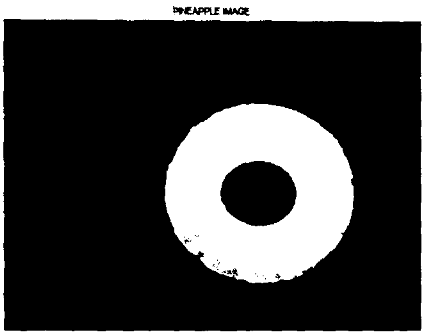


Figure 3.12. The Final Pineapple Image

3.4 Features Extraction

Features extraction is a step to collect various properties or information in images. The data from features extraction must be correspondence to each dataset, which in this research are Standard 15 and Standard 16. The objective of these steps is to determine the features that can described the standard of canned pineapple. Furthermore, the extracted value can be used in separating the standard by its own group. As this research is to grading the canned pineapple, features extraction may help in differentiate both standards.

The important thing at this point is extracting efficient features from the final image, as discussed in the section 3.3. The extracted data from final image were analysed to obtain the maximum desire outcome. This section will discuss details on the first order pixel colour statistic.

3.4.1 Pixel Colour Analysis

In image processing, the colour space can be converted into another suitable colour space for certain purpose during extracting the pixel information. The final images of each datasets in this research are in RGB colour space. Instead of using RGB colour space we also chose HSV and CIELAB colour space in extracting the pixel information. RGB is Red, Green and Blue plane, while HSV is Hue, Saturation and Value converted in equations 2.7 to equation 2.9 in Chapter 2. While, CIELAB is a conversion from RGB into xyz, then from xyz into LAB as equation 2.10 until equation 2.15 in Chapter 2.

Based on the final image after pre-processing process, a pixel statistics were analysed using min, max, and standard deviation. These statistical equations were applied to RGB, CIELAB and HSV colour space. The minimum pixel value represents the lowest value and the maximum value represents the highest value in each plane extracted from the image according to each component in Colour Space. This statistical mathematical Equation represents as equation 3.3, 3.4, 3.5, and 3.6. Equation 3.3 and 3.4 shows that *n* refers to the total number of pixels inside the masking image and the *Ci* refers to the intensity value for the pixel.

$$minimum\ (min) = min(C_i)\ for\ i = 1, \dots, N \tag{3.3}$$

$$maximum\ (max) = max(C_i)\ for\ i = 1, \dots, N \tag{3.4}$$

$$mean(\mu) = \frac{1}{n}\sum_{i=1}^{n} C_i \tag{3.5}$$

$$standard\ deviation\ (\sigma) = \left(\frac{1}{n-1}\sum_{i=1}^{n}(C_i - \mu)^2\right)^{1/2} \tag{3.6}$$

This statistical value was used to determine whether the pixel colour value can differentiate the standard of canned pineapple. Mean and standard deviations were calculated for each red, green and blue plane in RGB, hue, saturation and value in HSV, and L, a*, b* in CIELAB.

3.5 Features Selection on Training Dataset

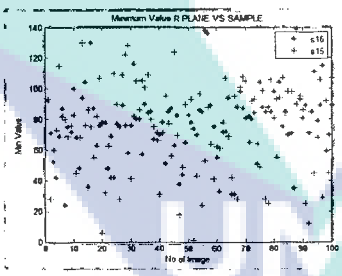
Based on the features extraction using first order statistic, there were a few finding for both Standard 15 and 16. The threshold values from minimum, maximum, mean, and standard deviation were set according to the plotted graph showing the gap value for each standard of canned pineapple.

3.5.1 First Order Statistic in RGB

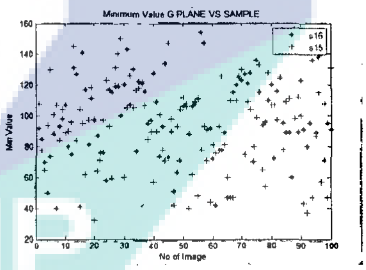
Minimum and maximum pixel values in RGB colour space was obtained for each red, green and blue plane. The minimum value and maximum value is to find out the differentiation of yellowish pixel colour combination in both standards. Minimum values indicate the lowest pixel value in each plane. While, maximum values indicate the highest pixel value. By finding both statistics, RGB plane portray the yellowish colour of both standards.

3.5.1.1 Minimum

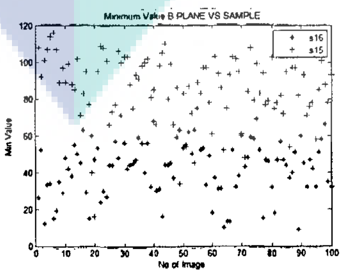
100 image data sets were tested and the results are as in figure 3.13(a) for minimum pixel red plane, Figure 3.13(b) for minimum pixel in green plane, and Figure 3.13(c) for minimum pixel in blue plane. This scatter plots showing the distribution of minimum value for each sample in Standard 15 and 16. The different gaps between each standard can be seen obviously by looking at the minimum pixel for blue in Figure 3.13(c).



(a) Minimum in R Plane



(b) Minimum in G Plane

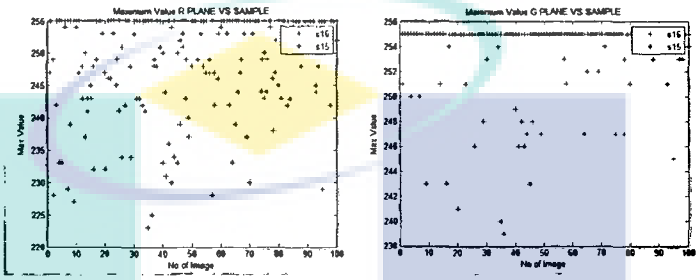


(c) Minimum in B Plane

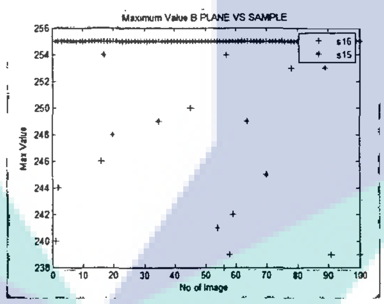
Figure 3.13. Minimum Values in RGB

3.5.1.2 Maximum

Figure 3.14(a), (b) and (c) show the maximum value of each standard in RGB. G plane and R plane in pineapple image were giving almost same pixel value for both standards. The yellowish colour is a combination of R plane, G plane and B plane with the value of B plane determine dark or light yellow in canned pineapple.



(a) Maximum in R Plane (b) Maximum in G Plane



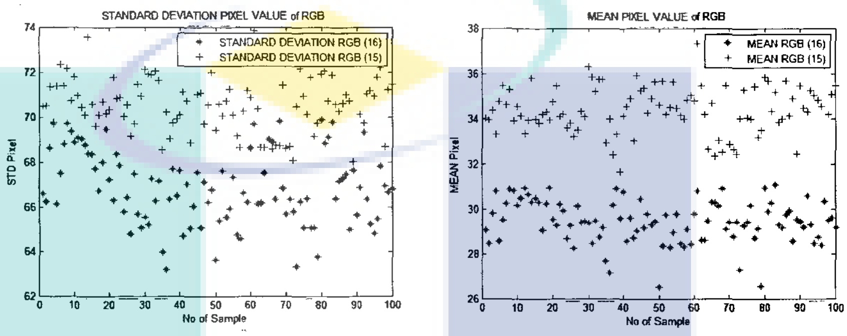
(c) Maximum in B Plane

Figure 3.14. Maximum Values in RGB

Although the ROI through our eyes is more like yellow, there are a few pixels in this ROI which are whitish yellow. In this case, the maximum pixel values are high, giving us the average value of pixel colour was 246 for R plane, 253 for G plane and 255 for B plane. These RGB combinations make a pixel become whitish. The RGB pixel value combinations are as explained in the Chapter 2.

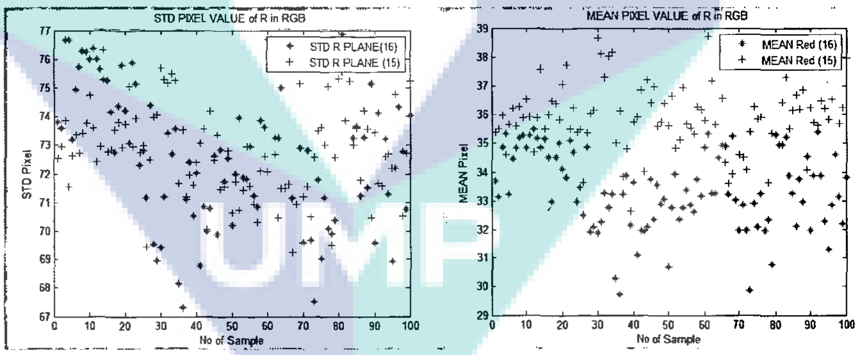
3.5.1.3 Mean & Standard Deviation

Mean and standard deviation of RGB were calculating by finding it from R, G, and B plane then divided it into three. In other words, the mean and standard deviation of all elements in an image will calculate. The graphs on the comparison between both standards on each plane are also plotted as Figures 3.15, 3.16, 3.17, and 3.18. These graphs represent the mean and standard deviation versus number of images.



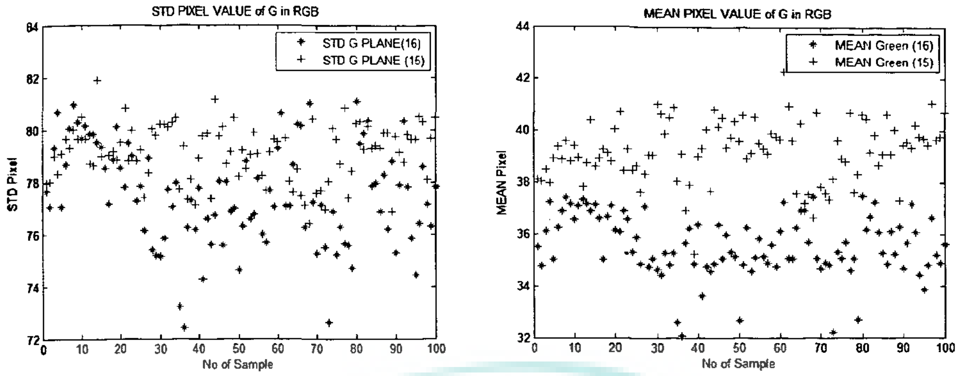
(a) (b)

Figure 3.15. Standard deviation of RGB Colour Space (b) Mean of RGB Colour Space



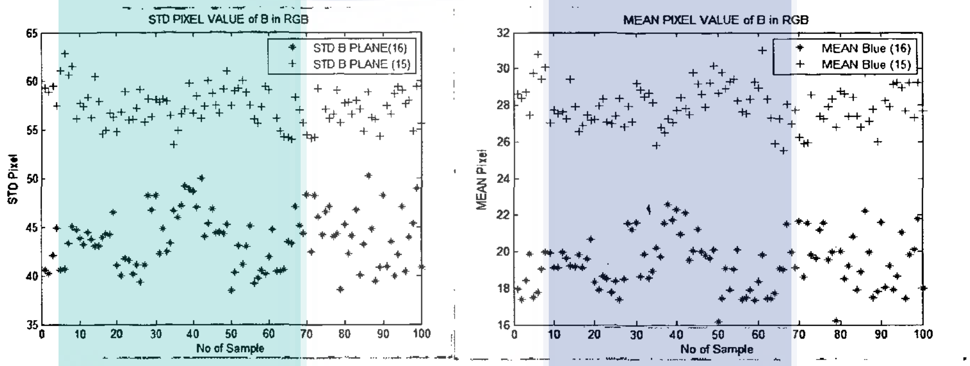
(a) (b)

Figure 3.16. (a) Standard deviation of Red Plane (b) Mean of Red Plane



(a) (b)

Figure 3.17. (a) Standard deviation of Green Plane (b) Mean of Green Plane



(a) (b)

Figure 3.18. (a) Standard deviation of Blue Colour Space (b) Mean of Blue Colour Space

The graph distribution for Standard 15 and 16 in RGB using mean and standard deviation classify standard of canned pineapple better than minimum and maximum pixel statistic. There was either a little or no data overlap for each plane, especially in blue plane. This graph appears to show that the blue plane plays an important role in giving the yellowish colour tone. The threshold values for each minimum, maximum, mean and standard deviation have been summarized in Table 3.1.

Table 3.1
The threshold value for canned pineapple standard in RGB

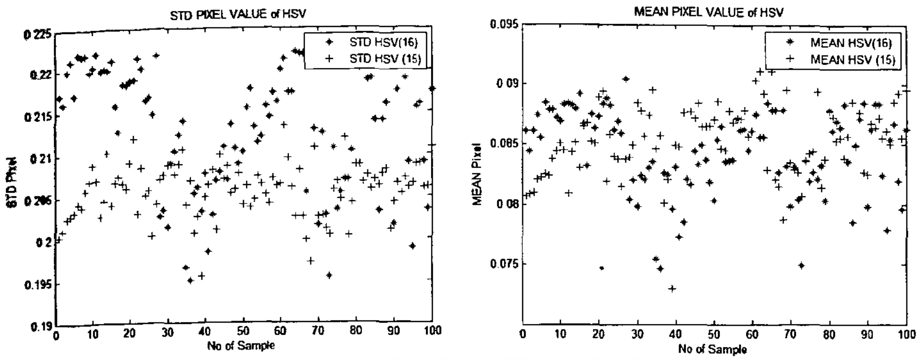
RGB PLANE	Threshold			
	Minimum	Maximum	Mean	Standard Deviation
RGB	-	-	31.92	68.70
RED	76.14	248.62	34.69	72.88
GREEN	96.34	253.79	37.37	78.31
BLUE	64.31	254.16	23.70	50.57

Threshold values were found by calculating the middle line of mean for each statistic and each standard. Each standard of canned pineapple was determined by the threshold value. Based on Table 3.1, the threshold for mean pixel in Blue plane has been set into 23.70. Every sample in blue plane will decided as Standard 15 if it is above than 23.70. Meanwhile, if the value below than 23.70 it goes to Standard 16. This condition was applicable for each plane and statistic according to the threshold value. Equation 3.7 represents the classification of both standards using the threshold as in Table 3.1. S15 was referred to as Standard 15, S16 Standard 16 and T_{RGB}.

$$S15<T_{RGB}<S16 \qquad 3.7$$

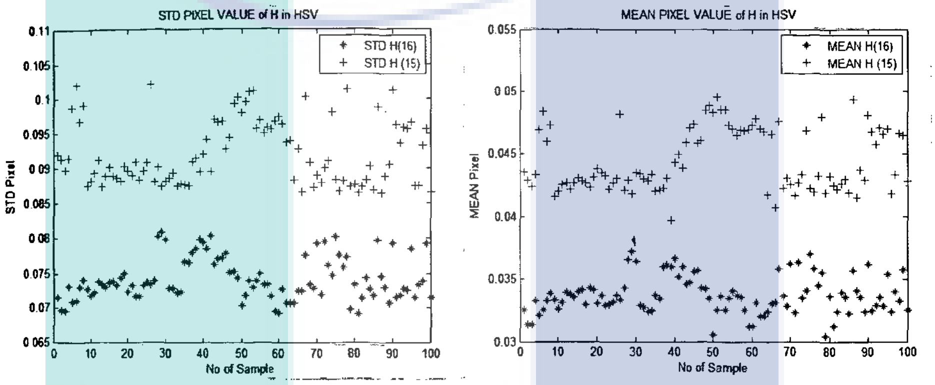
3.5.2 First Order Statistic in HSV

HSV colour space also has been calculated using mean and standard deviation for each component. The mean and standard deviation pixel of HSV, and its components such as Hue, Saturation, and Value were plotted vs 100 sample of each standard as in Figures 3.19, 3.20, 3.21, and 3.22.



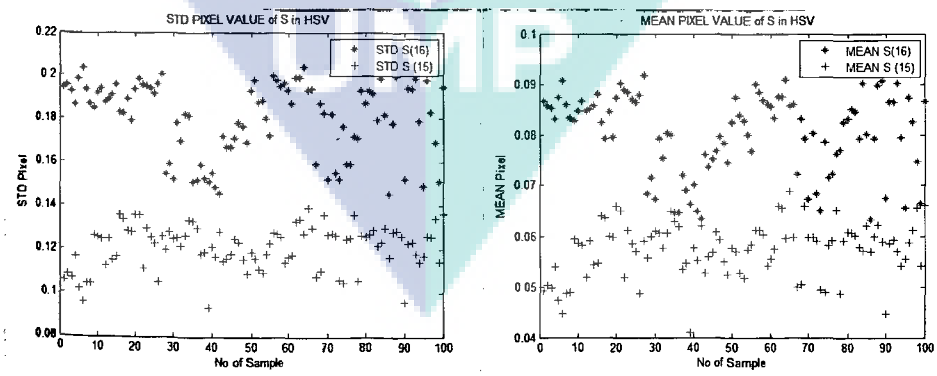
(a) (b)

Figure 3.19. (a) Standard deviation of HSV (b) Mean of HSV



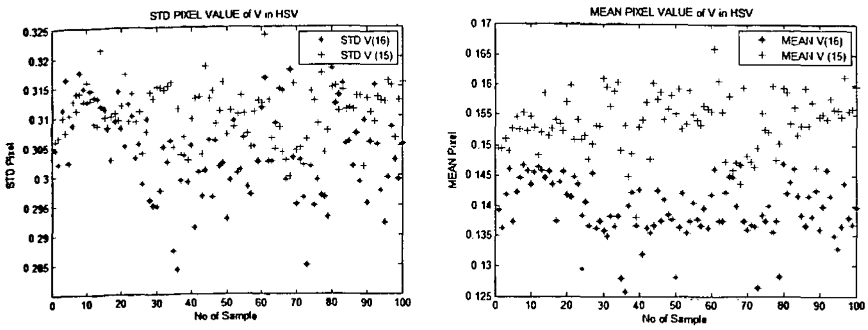
(a) (b)

Figure 3.20. (a) Standard deviation of H (b) Mean of H



(a) (b)

Figure 3.21. (a) Standard deviation of S (b) Mean of S



(a) (b)

Figure 3.22. (a) Standard deviation of V (b) Mean of V

Table 3.2 represents the threshold value for each component in HSV. In Hue component, if the mean or standard deviation of each image was below than the threshold value, so it was referred to as Standard 16. While, if the mean or standard deviation above the threshold value, it was referred to as Standard 15. This classification can be referred using equation 3.8 until 3.11 which is TH refer to Threshold of hue, TS Threshold of saturation, TV Threshold of value, S15 for Standard 15 and S16 for Standard 16.

$$S15<T_{HSV}<S16 \quad (3.8)$$

$$S16<T_{H}<S15 \quad (3.9)$$

$$S15<T_{S}<S16 \quad (3.10)$$

$$S16<T_{V}<S15 \quad (3.11)$$

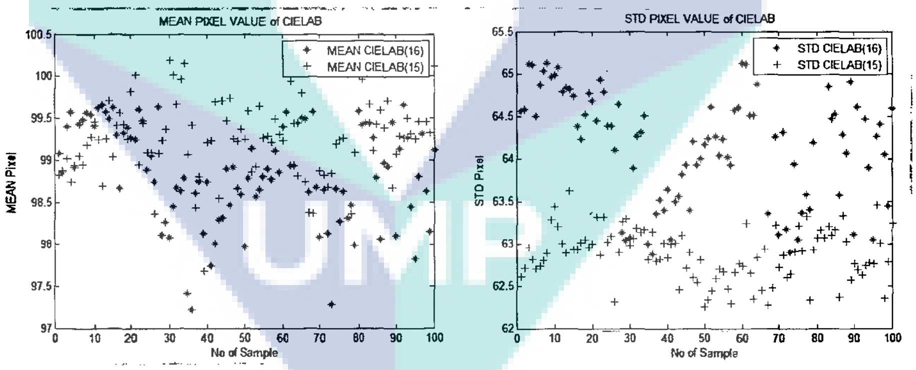
Table 3.2

The threshold value for canned pineapple standard in HSV

	Threshold	
HSV PLANE	Mean	Standard Deviation
HSV	0.085	0.209
HUE	0.039	0.083
SATURATION	0.069	0.151
VALUE	0.147	0.307

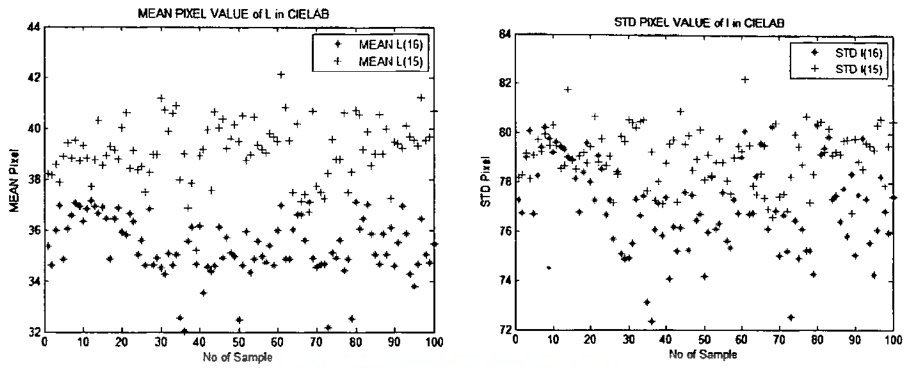
3.5.3 First Order Statistic in CIELAB

Each sample in Standard 15 and Standard 16 also has been calculated using mean and standard deviation after all the pre-processing step. CIELAB pixel values consist of lumination (L), *a and *b component were plotted versus the number of sample separately as in Figure 3.23 until Figure3.26.



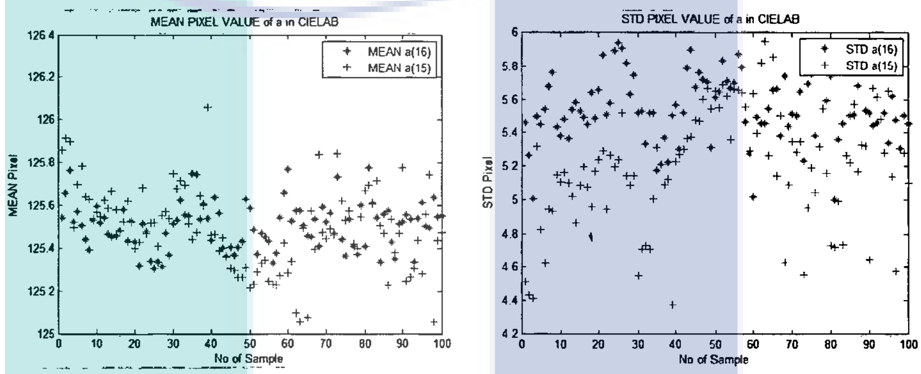
(a) (b)

Figure 3.23. (a) Mean of LAB (b) Standard Deviation of LAB



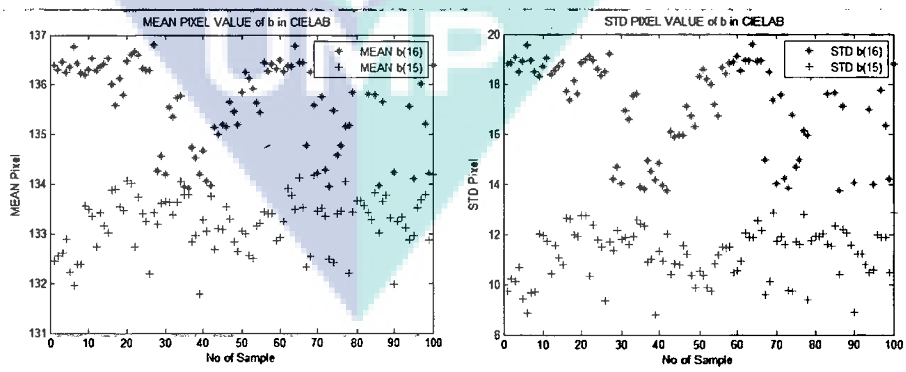
(a) (b)

Figure 3.24. (a) Mean of L (b) Standard Deviation of L



(a) (b)

Figure 3.25. (a) Mean of a (b) Standard Deviation of a



(a) (b)

Figure 3.26. (a) Mean of b (b) Standard Deviation of b

The threshold value also set in this colour space by calculating middle line of average 100 sample mean and standard deviation in each standard. Equation 3.12 until equation 3.15 represent S15 as Standard 15, S16 as Standard 16, TLAB as threshold for LAB, TL as threshold lamination, Ta as threshold *a component and Tb as threshold *b component. All standards were classified with this equation and the threshold value as in Table 3.3.

$$S15<T_{lab}<S16 \quad (3.12)$$

$$S16<T_{L}<S15 \quad (3.13)$$

$$S15<T_{a}<S16 \quad (3.14)$$

$$S15<T_{b}<S16 \quad (3.15)$$

Table 3.3
The threshold value for canned pineapple standard in CIELAB

	Threshold	
CIELAB PLANE	Mean	Standard Deviation
LAB	99.073	63.548
L	37.264	78.061
*a	125.497	5.376
*b	134.457	14.259

From all the features selection on training dataset, the highest accuracy of first order statistic in differentiating Standard 15 and Standard 16 will be used as the guidance in tested dataset. The results of the tested datasets will discuss further in Chapter 4.

3.6 Classification and Decision

Classification and decision is the final stage in grading canned pineapple according to its standard. The classification between Standard 15 and Standard 16 referred to as the value of pixel colour analysis using first order statistic. Before deciding, the standard of CPC data acquisition is also taken as an important step. The illumination controlling in capturing the image of canned pineapple are considered before the classification made.

Pixel colour analysis using mathematical statistic such as min, max, mean, and standard deviation are the key point in identifying and differentiating the standard of CPC also have been applied. The average pixel values are calculated from the 640x480 image resolution will be used to recognize the standard colour of canned pineapple. Statistical value might be different for both standards because the yellowish colour of canned pineapple was said to be different by MPIB. Since the yellowish colour is dependent on the pixel value, minimum and maximum pixel also can classify the canned pineapple colour based on the unique combination of pixel value in each colour space.

Last but not least, the comparison between each colour space was made to decide the best colour in classifying Standard 15 and Standard 16. Statistical operation for RGB, HSV, and CIELAB are used as an addition method in deciding the grading technique. This study is not going further with other algorithm regarding classification since the results on the analysis are acceptable to classify both standards of canned pineapple. Based on that, the decision of canned pineapple standards for export will be applied.

Canned pineapple features seem simple but yet powerful tool to come out with the solution to distinguish the differences between each Standard 15 and Standard 16. Lastly, the classification of CPC standard in this study involved the chosen colour space to obtain accurate results during the grading process.

3.7 Summary

All of the flow in this research has been discussed in detail according to the block diagram in Figure 3.1. The images of canned pineapple were taken from MPIB laboratory and the images were acquired using controlled and uncontrolled environment. Mask image obtained after a few pre-processing process until the desired outcome achieved. By using the mask image, the pixels were quantized to compress the counted pixel and produce the yellowish colour scale.

Lastly, RGB, CIELAB and HSV statistical value such as minimum, maximum, mean, and standard deviation from the mask could also be used to classify and grade the images of canned pineapple. The accuracy of all the methods will be discussed further in Chapter 4.

CHAPTER 4

RESULT & ANALYSIS

4.1 Introduction

This chapter will discuss the results of the methodology applied in this study. The effectiveness of environmental control for data acquisition for further steps in this study was discussed. The analysis of pre-processing process in order to get desired ROI also talk over to explain the important of successful ROI influence the result on features extraction. The accuracy of statistical result from features extraction and result on the colour space analysis are explained detailed in this chapter.

4.2 The Effectiveness of Environmental Control

Canned pineapple colour was based on yellowish pixels during image acquisition. Image acquisition method in this research has been explained in chapter 3. This acquisition will influence the result performance in each experiment if not done properly. The techniques during image acquisition step were giving most accurate result not even on ROI but also while getting the pixel information because of the consistency during image acquisition.

The method used in image acquisition that controlled the lighting source, camera position and others was known as Controlled Environment (CE) image in this study. CE was found to be successful in getting the ROI and the yellowish canned pineapple colour is not change even the images was capture in the other place since it is fully covered and no other light source except for the bulb inside the box as Figure 3.2. 100 images taken using this technique in each standard successfully eliminated the other unwanted pixels using all the methods as explain before. Thus, the environment, lighting level, surface, camera position, and camera features can give different pixel information even the object is same.

4.3 Pre-Processing Results

4.3.1 Binarization Process

To implement the features extraction technique, a few segmentation techniques have been tested. Deciding the best segmentation is very important in order to obtain the maximum performance during classification and to prevent misclassification error. It significantly reduces the amount of data and filters out unwanted pixels. Otsu's method has been applied to convert the RGB image for CE image data. Eventually the images of slice pineapple are clearly seen with a little noise. Figure 4.1 shows a CE image using Otsu's method.

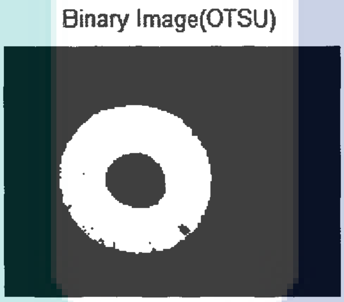


Figure 4.1. Otsu's Method

4.3.2 Morphology, Indexing, and Multiplying

Morphological operation using dilation and erosion by applying disk as structuring element was giving the desired ROI to be multiplied with original image. All of the images in this study are going through in this process to make sure there is no pixel colour in each image were not analysed during feature extraction. It was because the sizes and positions of each canned pineapple during image acquisition were not exactly same. Figure 4.2 shows the ROI of controlled image after the morphology process.

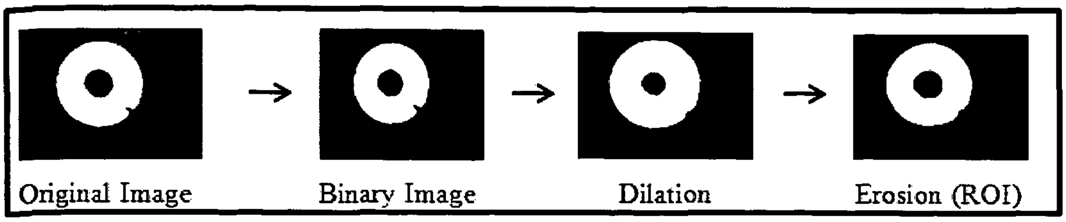


Figure 4.2. ROI of CE image after Morphological Process

The structuring element (SE) used in this study is a disk with the size nine (9) for dilation process and ten (10) for erosion process. Table 4.1 is the result of SE using disk shape with different size and same sample of canned pineapple. The comparisons between each disk sizes showing that the final images of canned pineapple are not the same, with a little hole in the image of canned pineapple. During the morphological operation, SE using disk size have batter output than other SE shapes.

Table 4.1
Comparison of SE Size using Disk

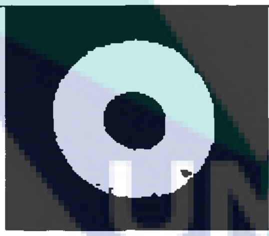
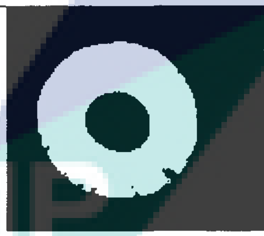
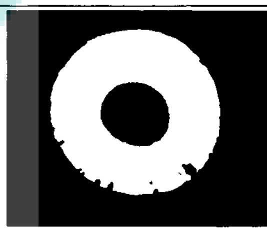
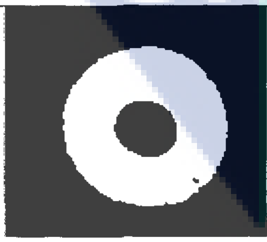
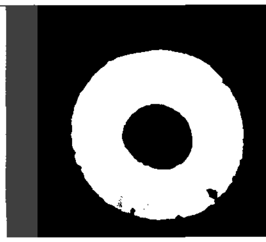
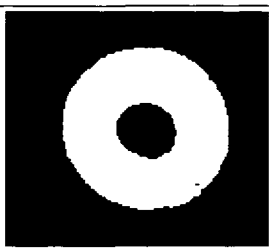
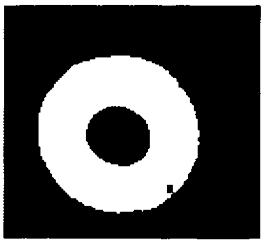
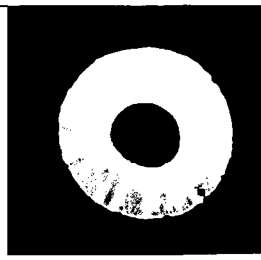
Size Disk		**Dilation**	**Erosion**	**Final Image**
Dilate	**Erode**			
1	2			
3	4			
5	5			

Table 4.1 continued.

Size Disk		Dilation	Erosion	Final Image
Dilate	Erode			
9	10			

Indexing is one of the processes before multiplying the masking image with original image. This was because the image format after binarization and morphological process is different than the original image. After multiplying, the blue background was removes and remains the black background and the image of canned pineapple. A sample of four images of canned pineapple after all pre-processing is shown in Figure 4.3.

Figure 4.3. Canned Pineapple Image

4.4 Result From Features Extraction

The most frequent pixel colour in the yellowish canned pineapple of each pineapple image is not consistent. Meaning that, even in normal eyesight, the yellowish colour looks the same but the actual pixel colours were different for each image. The pixel value and the total pixels are different for each image. Tables 4.2 and 4.3 shows a sample of 10 images in

Standard 16 for Standard 15 with the higher counted frequent pixel value according to each colour scale.

Table 4.2
Sum of Frequent Pixel Value in Image Standard 16

No of image	Total colour in image	Total most frequent pixel	Pixel value R G B
Image 1	17360	40	[182 196 75]
Image 2	14417	58	[217 224 128]
Image 3	15630	58	[213 219 93]
Image 4	17275	45	[198 213 84]
Image 5	17474	45	[190 204 69]
Image 6	16692	61	[191 205 156]
Image 7	17120	59	[198 213 84]
Image 8	15452	56	[190 204 90]
Image 9	15231	72	[199 212 96]
Image 10	17256	56	[192 206 71]

Table 4.3
Sum of Frequent Pixel Value in Image Standard 15

No of image	Total colour in image	Total most frequent pixel	Pixel value R G B
Image 1	11324	220	[175 191 120]
Image 2	10597	274	[193 204 136]
Image 3	9836	226	[193 204 136]
Image 4	9835	138	[173 193 122]
Image 5	11857	137	[178 193 128]
Image 6	12506	161	[181 199 137]
Image 7	10313	197	[175 191 128]
Image 8	10572	173	[192 206 145]
Image 9	10217	162	[195 206 130]
Image 10	9705	159	[178 194 228]

The use of most frequent pixel colour was not applicable. It was because the values of RGB component were inconsistent for both Standard 15 and 16. The range pixel colour for blue component in Standard 15 might be in the Standard 16. It also goes to the other component in RGB. So, the first order pixel colour statistics solves this problem.

4.5 Results from Pixel Colour Analysis

Yellowish canned pineapple statistical values are calculated using different colour space. However, the analyses for minimum and maximum values come only from the RGB colour space and the values were divided into each plane. In the meantime, the statistical value for mean and standard deviation were calculated using three colour space RGB, HSV and CIELAB. The implementation of these colour space is to decide the suitable colour space to be used during ROI feature analysis.

4.5.1 The Accuracy of Features Selection

The accuracy of features selection was defining whether canned pineapple of each standard met the condition that has been set using a threshold value. This accuracy was a tool in deciding the best features to be used in testing data set. First order statistics such as minimum, maximum, mean and standard deviation were calculated using the three colour spaces RGB, HSV, and CIELAB.

These features work on mathematical statistic with different colour space by using the characteristic of each component. The image data for CE are still the same without new data or changing technique in image acquisition and image pre-processing. By using the same masking and multiplying image to get the ROI, some conversion between RGB to HSV and RGB to CIELAB has been applied. The conversion technique between these colour space has been discussed in detail in Chapter 3.

4.5.2.1 RGB Colour Space

Table 4.4 showing classification results of Standard 15 and 16 using minimum pixel value. According to this table, blue component in RGB give 92% of classification. Meanwhile, the other two components, which are red and green, were 50% and 51.5%. The accuracy value in Table 4.4 concludes that the success percentage in classification for these two standards is low. B plane provided 53.5% of classification which are almost 50% different from minimum statistic. These show that the blue component was important in classifying the scale of yellow colour and it was proven that the yellowish colour between these two standards was varied. Minimum and maximum value for RGB was not calculated since it contributed all three components in this colour space.

While in RGB colour space, 99.5% classification in mean and 86% in standard deviation were obtained. B plane shows 100% classification between these two standards for both standard deviation and mean calculation. This shows that B plane provide a higher result for this step compare to the other plane in RGB. The yellowish colour is a combination of red green and blue in RGB colour space and influence the result of mean and standard deviation compare to the stand alone plane.

Table 4.4
The Accuracy of Classification between RGB Plane

RGB PLANE	Accuracy (%) using Minimum Threshold	Accuracy (%) using Maximum Threshold	Accuracy (%) using Mean Threshold	Accuracy (%) using Standard Deviation Threshold
RED	50.00	32.00	80.50	48.50
GREEN	51.50	43.5	95.50	72.00
BLUE	92.00	53.50	100.00	100.00
RGB	-	-	99.50	86.00

4.5.2.2 HSV colour space

Table 4.5 is the accuracy result for mean and standard deviation in HSV colour space. Since hue is the component that represents colour information, the results are showing the different yellowish colour of this canned pineapple standard. 100% successful differentiations are obtained for both mean and standard deviation in the hue component.

From the table, classification using intensity of yellowish colour or known as Saturation is 97.5% for standard deviation and 92.5% for mean. While, mean and standard deviation in HSV colour space cannot be distinguished between the two standards of canned pineapple using brightness or value. Since the brightness of yellowish colour cannot be compared, the value component was ignored in terms of HSV. Detailed explanation of comparison of colour space is given in section 4.6.

Table 4.5
The Accuracy of Classification between HSV Components

PLANE	Mean Accuracy (%)	Standard Deviation Accuracy (%)
Hue	100.00	100.00
Saturation	92.50	97.50
Value	95.50	72.00
HSV	52.00	80.50

4.4.2.3 CIELAB colour space

Referring to Table 4.6, *b channel in CIELAB give 100% of classification using Standard Deviation and 93% classification were successful using Mean. As explained earlier, the *b channel is an axis from blue to yellow and this channel show the yellowish differentiation between both standards. All of the channels are separated in order to evaluate the colour conditions in this colour space.

Table 4.6

The Accuracy of Classification between CIELAB Component

PLANE	Standard Deviation Accuracy (%)	Mean Accuracy (%)
L	74.50	97.00
a*	88.00	64.00
b*	100.00	93.00
Lab	89.00	65.50

4.6 Colour Space Comparison

Every pixel value in an image is significant in research using image processing, especially colour techniques. In RGB colour space, a yellowish colour was dependent on each component contribution, but blue component in RGB contributed the percentage in yellowish colour. Hue represents the yellow colour without intensity and brightness and also an attribute of a visual sensation according to which area appears to be similar to one of the perceived colour, in this case yellowish canned pineapple. In CIELAB colour space b+* is for yellow colour.

Comparisons of these three colour space that contribute to the yellowish colour of canned pineapple are important during the statistical analysis in section 4.4. The results are not same or consistent for all colour space. Therefore, we are looking for the suitable colour space to be chosen in this research. The average value of B component in RGB, Hue in HSV and b* component in CIELAB are describing the yellowish colour in the Standard 15 and 16. Table 4.7 are the summarized result for yellowish contribution component using mean and standard deviation in CE image.

Table 4.7
Summarized Result for Mean and Standard Deviation

	Accuracy (%)	
Colour Component	Standard Deviation	Mean
Blue(RGB)	100	100
Hue(HSV)	100	100
b(CIELAB)	100	93

B component in CIELAB gave 100% classification using standard deviation but only 93% using mean. So, we are setting aside this colour space and looking to HSV and RGB. Although both blue components in RGB and hue give 100% classification, HSV colour space was chosen as a method of classification in this research. It was because; HSV is simple transformations of device-dependent RGB models. The physical colours depend on the colours of red, green, and blue primaries of the device or of the particular RGB space, and on the gamma correction used to represent the amounts of those primaries.

4.7 Result of Tested Dataset

20 samples were allocated for each standard of canned pineapple for testing set. Datasets were captured using CE image acquisition. As a consequence, we have a total of 40 canned pineapple samples for the testing set. Table 4.8 and 4.9 were the comparison result on features analysis for training and testing dataset using mean and standard deviation.

Table 4.8
Accuracy of Mean Pixel between Training and Testing Dataset

	Accuracy (%)	
PLANE	Training Sample	Testing Sample
Hue (HSV)	100.00	90
Blue(RGB)	100.00	82.5

Table 4.9
Accuracy of Standard Deviation Pixel between Training and Testing Dataset

	Accuracy (%)	
PLANE	Training Sample	Testing Sample
Hue (HSV)	100.00	96.6
Blue(RGB)	100.00	90

The threshold value for hue in this system was set to 0.083 for standard deviation and 0.039 for mean. Blue plane in RGB image were setting to the 50.57 for standard deviation and 23.7 for mean. Standard 15 will be set if the value of standard deviation and mean is under system threshold and Standard 16 if it is above the system threshold. These threshold values were set during the experimental of training dataset using mean and standard deviation. The mean of each plotting graph for both standards was dividing by two to find the threshold value.

4.8 Decision

Based on the experimental result that we have obtained in this study, the standard of canned pineapple will be decided based on the colour space and statistical value from the CE image dataset that we have used. Image acquisition is setup as explained in Chapter 3. This step is to ensure that the threshold value remain same without any changes. If the position of the camera, surface, or bulb is different, the result might be different since the yellowish colour between Standard 15 and Standard 16 are most similar to each other.

The combination of preprocessing technique in this study also proposed to be used. Segmentation process, morphological operation using dilation and erosion, and also features extraction on the image using colour space and statistic value. HSV colour space is taking place during features extraction. Thus, the canned pineapple image will be converted into HSV colour space. The Hue value may be evaluated in each image and will follow the threshold value of mean and standard deviation during grading session.

The threshold value using hue for canned pineapple for standard deviation is above 0.083 for Standard 15 and below 0.083 for Standard 16. Canned pineapple colour also decided as Standard 16 or Standard 15 based on the mean value. If the mean is above 0.039, the canned pineapple colour is decided as Standard 15. If the mean is below 0.039 the canned pineapple was determined to be Standard 16. All of the canned pineapple colour quality inspections are required to be conducted according to state standards. This is to ensure the grading standards of canned pineapple colour are as they should be.

4.9 Thesis Contribution

In recent years, there is a research that focused on fresh pineapple. Kaewapichai et al., (2006), Rohana Abdul Karim et al., (2009), Shuhairie et al., (2011) and Nazriyah Che Zan et al., (2013) were comparing the maturity of fresh pineapple using image processing. However, based on our research knowledge there is no research that focus on the quality colour of canned pineapple. So, we are proud to have developed a successful method to overcome the problem regarding grading canned pineapple colour for MPIB.

The original work began with finding a data collection method suitable to the needs of developing an algorithm. Image processing was applied and compared using several techniques in pre-processing and features extraction until the desired ROI of canned pineapple is achieved. Useful information was extracted by using statistical based features namely arithmetic mean and standard deviation to represent the pixel colour distribution of canned pineapple.

Lastly, from the proposed technique in this study, the quality of canned pineapple colour grading was developed using image processing for an automatic implementation. This study is highly accurate and highly applicable.

4.10 Summary

The experimental results in this chapter classify the right standard of canned pineapple as declare by MPIB. Basically, the processing time for this system depends on the image size being processed. As an example, processing time using 640x480 pixel resolutions is shorter compared to the 10 Megapixel images. The features analysis results were dependent on the controlled environment during image acquisition until the pre-processing image, which is include the Otsu method and morphological operation. ROIs of the image were analysed using different colour spaces to make sure the best classification result were obtained.

The statistical analyses that refer to RGB colour space included minimum, maximum, mean and standard deviation. All the calculated statistics indicate that the highest percentage difference between Standard 15 and Standard 16 are referred to as blue plane. Mean and standard deviation are also analysed for HSV and CIELAB colour space. Based on the classification results mean and standard deviation values in HSV colour space give a very excellent differentiation with, none of the images tested falling to the other standard of canned pineapple.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

Grading the standard of canned pineapple according to its colour standard using image processing before export is the main aim of this research. MPIB plays important roles in this research when providing the information regarding the standard of canned pineapple exported overseas or for the local market. There are 4 standard types that provided by MPIB, but this research is grading only two standards which are Standard 15 and Standard 16.

There were 200 images taken at MPIB laboratory in CE during image acquisitions. Controlled images with 640x480 resolutions are captured in a box to avoid external illumination except from the lighting place. This technique was acceptable in this study because the desired ROI was successful performed and the colour of canned pineapple did not change for the whole image. Image acquisition used along with pre-processing, features extraction, classification with a few methods may achieve the desired ROI by choosing the controlled image as data in this research.

Feature analyses were used to determine the yellowish colour of canned pineapple. Colour scales were developed for each standard of canned pineapple. The yellowish colour scale can be used as a reference during manual grading tasks done in the MPIB Lab. However, it cannot give an accurate result because the canned pineapple colours in Standard 15 and 16 are too close. This colour scale includes the entire pixel colour in canned pineapple which is not perceived by human eye recognition.

Pixels statistical of canned pineapple were calculated using min, max, mean, and standard deviation. From the calculated statistics, mean and standard deviation were chosen as in getting pixel information to grade the standard colour of canned pineapple. HSV and CIELAB colour space was analysed to choose the best result for classification between standard using all component instead of RGB colour space after all the pre-processing processes. The colour fractions in each colour space according to its component were help a lot in this study. The contribution of Hue in HSV colour space and *b in CIELAB colour space was identified to be used in grading the canned pineapple standard.

Based on the all experiments done in this research, we conclude that the aim of this research is achieved. By using image processing, the suitable control environment data successfully goes through all the preprocessing process, colour conversion, and the first order statistical technique. HSV colour space gives an incredible value with 100% classification in training stage and 93.3% in tested stage between both standard using mathematical statistic mean and standard deviation on CPC pixel value. Therefore, we propose that this canned pineapple grading colour which is based on the HSV colour space use the value of the statistical calculation.

5.2 Recommendation

In this research, several recommendations are suggested for future investigation to facilitate the work in grading the yellowish colour. This is important to get the highest accurate quality colour inspection and to increase the quality of work in MPIB. Since the proposed system is done in non-real time mode, we recommend that it is upgraded to use a real time mode.

This research was focused on slices of canned pineapple having the same shape and size. It is suggested that future research the researchers are suggested use others shapes such as cube, half slice and broken slice. In this study, the canned pineapple is in one piece. Therefore, we also suggest a heap of canned pineapple placed into a plate. Then, the sizes of canned pineapple would be different and the other features analysis can also be considered. In the literature review, there are a lot of different analyses that can be used for grading using image processing.

Because human eyes are not able to differentiate correctly the yellowish colour between these two standards, it is recommended that a two colour scale is developed to be used automatically with computer vision rather than print into a paper. The printed colour could also be different because it depends on the quality of the printer. Lighting sources during grading also influence the grading results because the natural colour of canned pineapple is not the same throughout the whole surface.

Due to a limited amount of canned pineapple provided by factory to the MPIB laboratory, this research only considered two standards during grading. In the future, it would be better if the grading canned pineapple standard colour has another standard to be analysed. If so, the other colour or standard would be determined automatically without any mistakes made by expert workers.

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APPENDIX A

LIST OF PUBLICATIONS

Sharmiza, Sunardi, Kamarul Hawari Ghazali & Najmi Hafizi Zabawi (2012). Grading Canned Pineapple Using Colour Technique, *Proceedings of Malaysian Postgraduate Conference onElectrical, Electronic and Control Technology (MCEECT 2012).*

Sharmiza, Sunardi, Kamarul Hawari Ghazali (2013). Canned Pineapple Grading Using Colour Analysis. *International Conference on Latest Trends in Electronics and Electrical Engineering (ICLTEEE)*.pp. 118–122.

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Sharmiza Kamaruddin, Sunardi, Kamarul Hawari Ghazali, Rina Raha Hamid, Bakiss Hiyana (2013). Yellowish Canned Pineapple For Quality Inspection, *CiE-TVET 2013*.pp. 40

APPENDIX B

COLOUR CHART FOR CANNED PINEAPPLE GRADES

(Fancy, Choice and Standard)

1 DARKER YELLOW ⟶ 2 ⟶ 3 LIGHTER YELLOW

Fancy 1	Fancy 2	Fancy 3
Choice 1	Choice 2	Choice 3
Standard 1	Standard 2	Standard 3

APPENDIX C

SAMPLE OF 10 IMAGES IN STANDARD

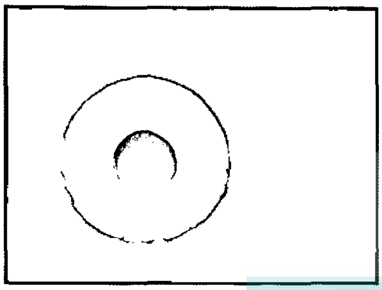

Image 1

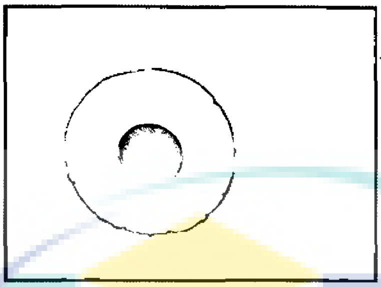

Image 2

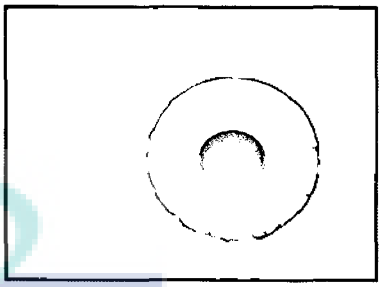

Image 3

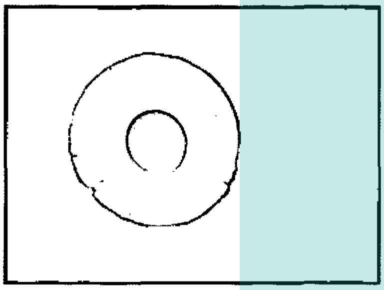

Image 4

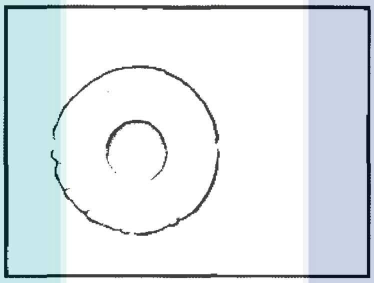

Image 5

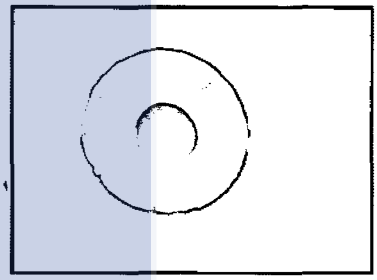

Image 6

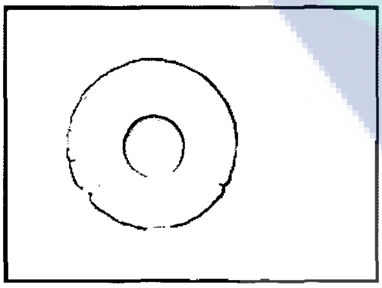

Image 7

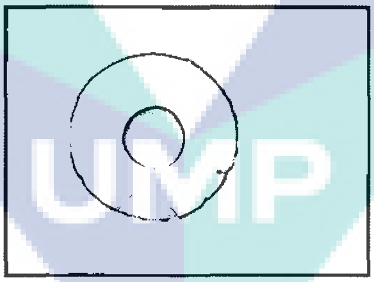

Image 8

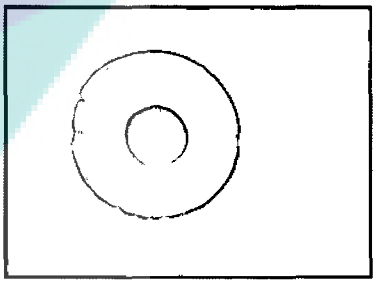

Image 9

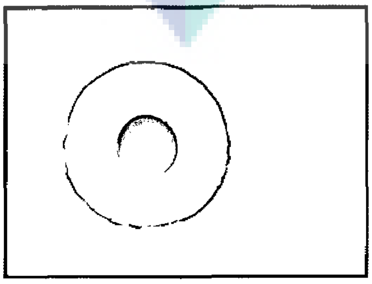

Image 10

APPENDIX D

SAMPLE OF 10 IMAGES IN STANDARD 15

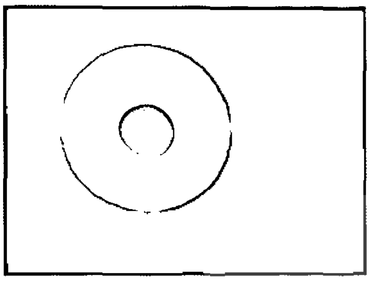

Image 1

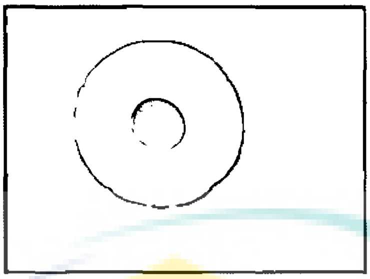

Image 2

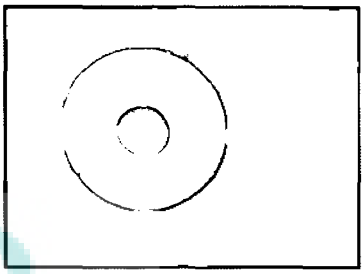

Image 3

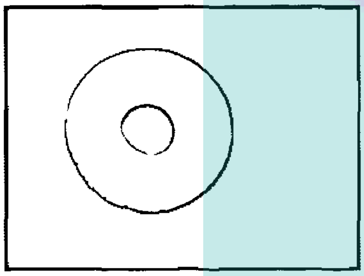

Image 4

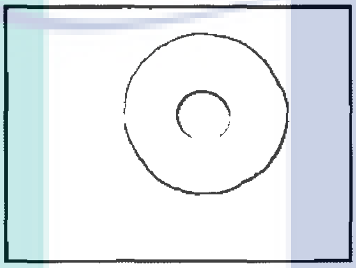

Image 5

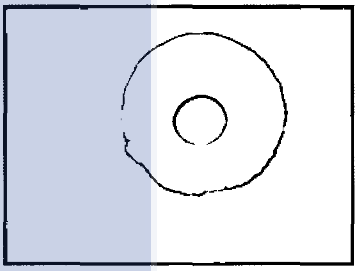

Image 6

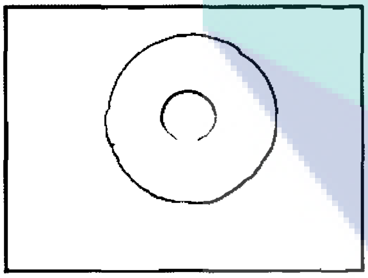

Image 7

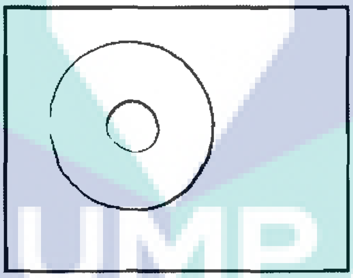

Image 8

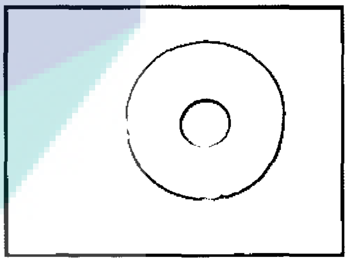

Image 9

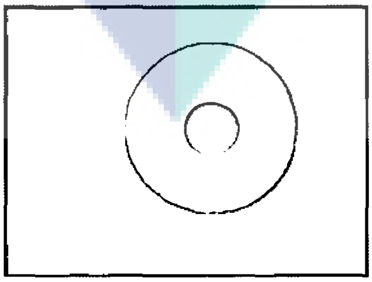

Image 10

APPENDIX E

MATLAB ALGORITHMS (CE IMAGE)

```
% ----------------------------------------------------------------
% Start by clearing workspace and command window
% ----------------------------------------------------------------

clc
close all
clear all

% ----------------------------------------------------------------
% Opening files to save data value
% ----------------------------------------------------------------

data=fopen('mean16(rgb).txt','w+');
data1=fopen('mean16(green).txt','w+');
data2=fopen('mean16(blue).txt','w+');
data3=fopen('mean15(red).txt','w+');

% ----------------------------------------------------------------
% Browsing and read images file
% ----------------------------------------------------------------

image=100;
text='D:\matlab\METHOD1-mean\316\B16';

for num=1:image
   filename=strcat(text,int2str(num));
   filename=strcat(filename,'.jpg');
   I=imread(filename);

% ----------------------------------------------------------------
% SHOW ORIGINAL IMAGE
% ----------------------------------------------------------------

figure(),subplot(1,2,1),imshow(I),title('ORIGINAL IMAGE');

% ----------------------------------------------------------------
% CONVERT TO BINARY IMAGE
% ----------------------------------------------------------------

level=graythresh(I);
I_BW=im2bw(I,level);
figure(1),subplot(1,2,2),imshow(BW),title('IMAGE IN BINARY');
```

```
% ------------------------------------------------------------------
% MORPHOLOGY PROCESS
% ------------------------------------------------------------------

se = strel('disk',9);
I_DIL=imdilate(I_BW,se);
figure(1),subplot(2,2,3),imshow(I_DIL),title('After Dilation');

se = strel('disk',10);
I_MOR=imerode(I_DIL,se);

figure(1),subplot(2,2,4),imshow(I_MOR),title('IMAGE AFTER DILATION & EROSION
PROCESS (MASK)');

% ------------------------------------------------------------------
% INDEXING
% ------------------------------------------------------------------

indexslice=gray2ind(I_MOR,256);
rgbslice=ind2rgb(indexslice,gray());
RGB=uint8(rgbslice);

% ------------------------------------------------------------------
% MULTIPLY ORIGINAL IMAGE WITH MASK
% ------------------------------------------------------------------

I_PINEA=immultiply(I,RGB);
figure(),subplot(1,2,2),imshow(I_PINEA),title('PINEAPPLE IMAGE');

% ------------------------------------------------------------------
% FEATURES EXTRACTION (MIN, MAX, MEAN, STD, MSE, PSNR) IN RGB
COMPONENT
% ------------------------------------------------------------------

MEAN_PINEA1=mean2(I_PINEA);
fprintf(data,'%f',MEAN_PINEA1);
fprintf(data,'\n');

MEAN_PINEA2=mean2(I_PINEA(:,:,2));
fprintf(data1,'%f',MEAN_PINEA2);
fprintf(data1,'\n');
%
MEAN_PINEA3=mean2(I_PINEA(:,:,3));
fprintf(data2,'%f',MEAN_PINEA3);
fprintf(data2,'\n');



MEAN_PINEA4=mean2(I_PINEA(:,:,1));
fprintf(data3,'%f',MEAN_PINEA4);
```

```
fprintf(data3,'\n');

% ------------------------------------------------------------------
% FIND MIN & ELIMINATE BLACK BACKGROUND : BLACK=0,0,0
% ------------------------------------------------------------------

slice_reshape=reshape(I_PINEA,[],3);
[unique_RGB,m,n]=unique(slice_reshape,'rows');
minRGB2=sort(unique_RGB(:,:,1));

minRGB22=minRGB2(2,:);
[R]=minRGB22(:,1);
[G]=minRGB22(:,2);
[B]=minRGB22(:,3);

end
```

APPENDIX F

COLOUR CONVERSION CODE

```
% -------------------------------------------------------------------
% COLOUR CONVERSION RGB2HSV, RGB2LAB
% -------------------------------------------------------------------

I_HSV = rgb2hsv(I_PINEA);
figure(),imshow(I_HSV),title(' PINEAPPLE IMAGE IN HSV COLOR SPACE');

cform = makecform('srgb2lab');
I_LAB = applycform(I_PINEA, cform);
figure(),imshow(I_LAB),title(' PINEAPPLE IMAGE IN HSV COLOR SPACE');

% -------------------------------------------------------------------
% QUANTIZATION
% -------------------------------------------------------------------

[X,map] = rgb2ind(I_PINEA,5);
figure(),imagesc(X),title('PINEAPPLE QUANTIZATION IMAGE');
```