UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Automated Packaging Visual Inspector using Template Matching Algorithm in Image Processing

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours. The member of the supervisory is as follow:

.....

MR. SHAMSUL FAKHAR BIN ABD GANI

ABSTRAK

Isu yang melibatkan pembungkusan yang dihadapi oleh sektor pembuatan industri telah menjadi satu masalah yang besar. Isu ini telah mempengaruhi hasil statistik untuk industri pengeluar dan menjejaskan hasil pemasaran. Oleh itu, kemajuan teknologi dipilih untuk mengatasi masalah ini. Tujuan projek ini adalah untuk membangunkan algoritma yang cekap dan cepat untuk memantau kualiti pembungkusan. Oleh itu, projek ini meningkatkan pemeriksaan kualiti untuk pembungkusan dengan melaksanakan Sistem Automatik Visual Inspektor bagi pembungkusan dengan Menggunakan Teknik Template Pemadanan Algoritma dalam Image Processing. Sistem ini mengurangkan kebarangkalian kesalahan berlaku seperti pembungkusan campuran (pembungkusan salah) untuk produk yang akan dikeluarkan dalam masa yang tertentu dalam barisan pengeluaran.

ABSTRACT

The issue involving incorrect packaging faced by manufacturing industry has become a huge problem. This issue has influenced the statistical yield for industries manufacturers and affects the marketing outcome. Thus, the advancement of technologies is chosen to overcome this problem. The aim of this project is to develop an efficient and adaptable algorithm to monitor the quality of packaging whether correct packaging or incorrect packaging. Thus, this project enhances the quality inspection for packaging by implementing an Automated Packaging Visual Inspector using Template Matching Algorithm in Image Processing. This system minimizes the probability of faults to occur such as mixed packaging (wrong packaging) for a product that will be released in a certain time in a production line

DEDICATIONS

This thesis is dedicated to:

My Parents,

My beloved family,

My Supervisors,

My Lecturers,

And all my friends,

Thank you for their encouragement and support

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I would like to express my appreciation to my supervisor, Mr. Shamsul Fakhar Bin Abd Gani for giving me the valuable chance to have my final year project under his supervision. I appreciate all the assistance, inspiration and helpful discussion throughout the project. Despite being extremely busy with his work and responsibilities, he still managed to guide me, apart from advising me to find the finest solutions to almost every challenge.

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LIST OF ABBREVIATIONS

APVI	-	Automated Packaging Visual Inspector
TMA	-	Template Matching Algorithm
IP	-	Image Processing
LCD	-	Liquid Crystal Display
CV	-	Computer Vision
DIP	-	Digital Image Processing
SAD	-	Sum of Absolute Difference
NCC	-	Normalized Cross Correlation
MATLAB	-	Matrix Laboratory
LAPACK	-	Linear Algebra Package
BLAS	-	Basic Linear Algebra Subprogram
IPT	-	Image Processing Toolbox
IDE	-	Integrated Development Environment
BDP I	-	Bachelor Degree Project I
BDP II	-	Bachelor Degree Project II
SSP	-	Serial Port Protocol

CHAPTER 1

INTRODUCTION

1.0 Background

These days, computer vision and image processing have effectively comprehended the quality issue confronted by the modern segment. According to Weyrich et al. (2012), the human vision was stated as another necessity assistance from innovation for guaranteeing better yield. In this innovation period, a technologies framework was played a major part as it gives a colossal advantage to manufacturer contrasted with a manual inspection. This is on the grounds that the quality review is known as a strict association that will guarantee the nature of merchandise that will be discharged to market is a brilliant item that met the desire. In the case of Wang et al. (2012), among the measures expected to handle the issue of cheddar quality issue, a few examination has been led to recognize the primary driver of the issue. Through the observation, the fundamental issue was recognized. The issue is brought on by the packaging of the cheeses itself. Subsequently, the answer for control this issue was chosen. This issue is handled by building up a computerized review in light of machine vision. This arrangement gives the positive results toward the end of the testing. The quality of packaging was effectively controlled by machine vision. In addition, Priyadharsini & Devi (2014) found an assessment of veins in human eye permits prior identification of eye infections, for example, glaucoma and diabetic retinopathy. Computerized picture handling strategies assume an indispensable part in retinal vein location. Several image processing techniques and channels are practical to distinguish and separate the traits of retinal veins, for example, length ,width, pattern, and edges. Thus, different templates based coordinated channels, Threshold Methods, Segmentation strategies, and useful ways to deal with disengage the veins are clarified. Moreover, this project of APVI using TMA in IP is emphasized to distinguish between correct patterns or labels of packaging that

run in a production line from defective ones. This system is only interested in classifying the same label or pattern for each packaging that runs in certain specified time. The fact acknowledges that every manufacturer has their own marketing ideas for their packaging to attract their customer's attention. The new invention of any idea has to go through R&D process first before commercialization. Therefore, there will be many product releases with different types of packaging pattern or label. This will increase the probability of faults to occur such as mixed packaging (wrong packaging) for a product that will be released in a certain time. This system will be implemented at the end of the first level step for packaging. Thus, this project will prevent the wrong packaging label or pattern from passing through the line packaging and reaches the next level step for packaging process. The rejected packaging will be alerted by alarm and LCD will display the process status whether pass or rejected in order to monitor the output and minimize losses. This system will hopefully increase the output of production line without any losses (rejected product), enabling the production system to run smoothly and more efficiently.

1.1 Problem Statement

The idea for this project came out after observing an experience during working in a production line as a production coordinator at Mondelez International located in Johor Bahru. The conventional system that used for a quality checking gave the bad implications to production line and as well affected the manufacturers. Regarding Wang et al. (2012), CV and IP has created to observe the nature of cheese packaging. This execution has tackled the issue of packaging. This framework has transformed into an advantage to numerous viewpoint in the industrial sector. Problem statements stated:

1. The conventional system has a possibility of causing delays in reaching a target for finished goods in the production line when packaging are mixed up. This delay happens when finished goods contain mixed up packaging found by Quality checker. In order to complete the process of repacking,

other products need to be postponed until there are enough manpower's in a line.

2. Consume more time to undo the packaging (waste time). There are time-consuming for repacking process if the Quality checker found the rejected of finished goods. Manpower's need to undo the packaging from completed to started.
3. Huge losses will happen to the company (High labour payment). Manpower's need to work overtime and re-pack the packaging in order to reduce losses if there are rejected packaging. Due to this situation, there will be short of manpower to run another product in others lines and others shift manpower's also need to work overtime.

1.2 Objectives

The objectives of an APVI using TMA in IP are:

1. To study about IP that focuses on template matching techniques
2. To design an automatic system that can differentiate the correct and incorrect pattern/label for each packaging by using MATLAB and implement TMA.
3. To use Arduino to display a statistical yield data onto LCD screen and alert the detection of mismatch pattern by a buzzer.

1.3 Scope

The scope for an APVI using TMA in IP focused on faulty detections as stated in objectives which are:

1. To focus on exact pattern or label to be detected on packaging by using template matching technique.
2. To demonstrate the usage on small packaging sizes (estimation sizes±:8cm×11cm, thickness±2cm) only.
3. To display packaging status whether pass or rejected on LCD and alarmed the buzzer in ranging 100m when the pattern is rejected.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will review the idea used in this project based on the bases and material gathered from records, website or journal. Template matching algorithm is a selected technique to implement this project. MATLAB was chosen to be the platform for encoded a code. The benefit and drawback of other software will also be considered.

2.1 Study of Image Processing

According to Zhang (2013) in the mid-1920s, the newspaper industry was one of the principal utilization of Image processing. Harry G. Bartholomew and Maynard D. McFalane were the creators of Bartlane Cable Picture Transmission System. Pictures were implied for link exchange and reproduced at the less than desirable end on a broadcast printer. The submarine link was utilized to exchange pictures amongst London and New York and initially used to transmit a photo over the Atlantic in 1921. While in the mid to late 1920s, Bartlane framework was enhanced and created higher qualities pictures. The augmentation on a number of tones in replicated picture. In the 1960s, figuring innovation enhanced the work in computerized picture preparing and it started to be utilized as a part of medicinal applications in 1970s. In 1980s, the utilization of digital image processing has detonated and they are presently utilized for a wide range of task in a wide range of territories such as industrial review, medicinal and many more. Figure 2.1 demonstrates that the early computerized picture with the enhanced advanced at the late 1920s.

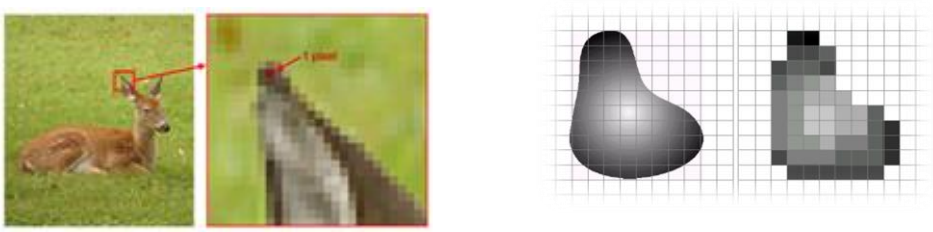
Figure 2. 1: Early digital image and improved digital image

(Zhang, 2013)

Figure 2. 2 : Early tone digital image

(Zhang, 2013)

Digital Image can be identified in two-dimensional pictures as a limited arrangement of computerized qualities $f(x, y)$. The strong point or gray level spoke to by the plentifulness of ƒ at any pair of commands (x, y), while x and y are spatial (plane) organizes. A limited number of components which has a specific area and quality are made out of a computerized picture and alluded to as pixels. Digitization demonstrates that an advanced picture is an estimate of a genuine scene. Figure 2.3(a) and 2.3(b) demonstrates a digitization of a picture. The crates speak to the pixels of the picture, which is 1 box is equivalent to 1 pixel.



(a) (b)

Figure 2. 3 : Digitization of an image (a) RGB image (b) Grayscale image

(Zhang, 2013)

The common image formats include:

1. One tester per point (Black /White or Greyscale)
2. Three testers per point (RGB)
3. Four testers per point (RGB and Alpha/Opacity)

2.1.1 Fundamental Step in Digital Image Processing

Souza (2014) states there are some essential steps in IP. Figure 2.4 shows an essential steps in Arithmetical IP

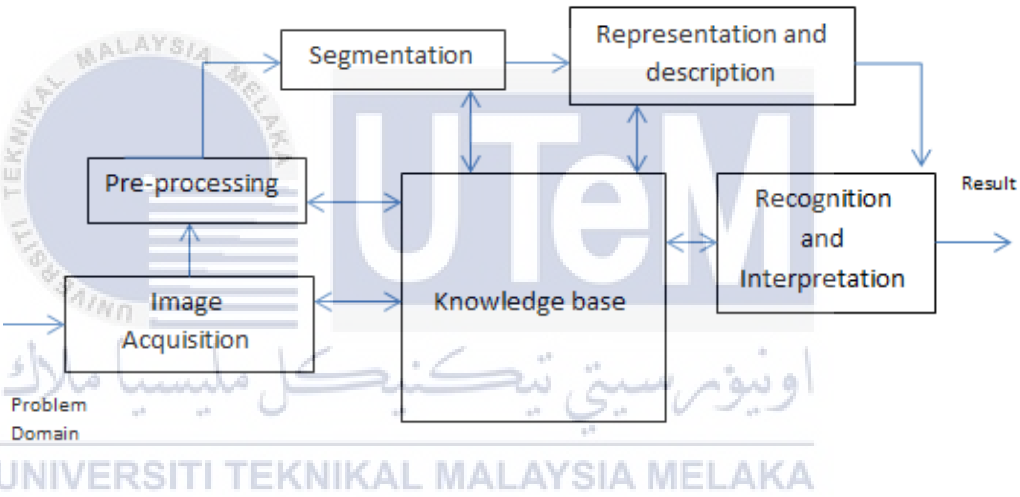


Figure 2. 4 : Essential steps in arithmetical image processing

(Souza, 2014)

These fundamental step are described as an image acquisition for acquiring an image from input(sensor). Firstly, image pre-processing will improve an image in a way (contrast enhancement, noise reducing, region isolating) that will increase the chance of other process to be success. Thus, image separation was used as an input image that will be divided into its suitable parts or objects and raw pixel data as a output. Image representation will works for the input sense to be converted into a suitable form for computer be able to process. The image description will extract a related features. Furthermore, image recognition will assigned an image with a label by its

descriptors based on information provided and lastly, image clarification is most important. An importance is relegated to an ensemble of a recognized objects.

2.1.2 Application of DIP

In the case of Gonzalez & Woods (2013), DIP has deployed in almost all field.

2.1.2.1 Application in Industrial Inspection

As was mentioned by Zhang (2013), digital image processing is beneficial applications in almost field. Other than medical application, there also application in Industrial inspection and much more. Obviously, digital image processing has extensively used in the industrialized field. Human operators are costly, moderate and untrustworthy. IP is effective on industrial inspection for defective detection, measuring, tracking, monitoring and much more. As for industrial inspection, DIP is used in order to make a machine do the task instead of manpower.

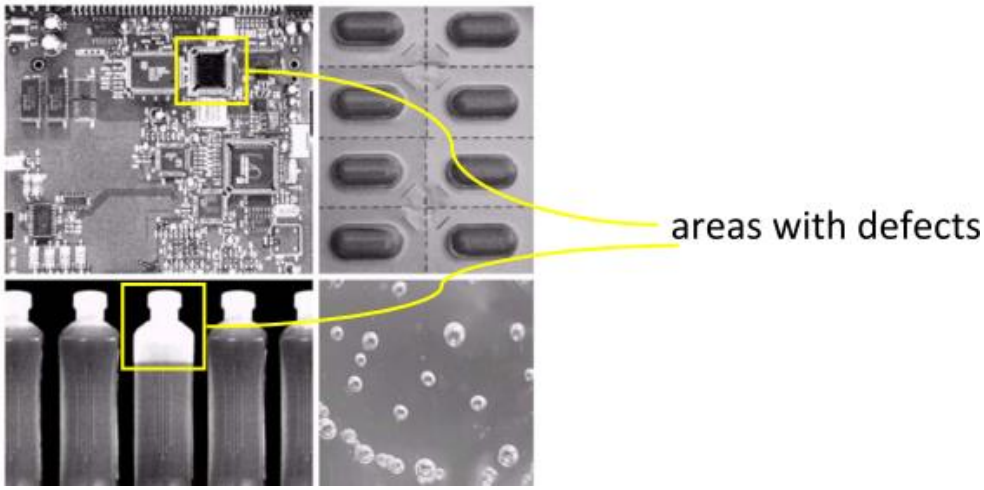


Figure 2. 5 : Examples of industrial inspection for defective products (Zhang,2013)

2.2 Study of Pattern Recognition

Tayebi et al. (2014) are concerned, pattern recognition is a categorization of input data into perceptible classes by taking out an important feature and unrelated details from a background. Based on the case study, this technique (pattern recognition) is useful for segmentation of vessel structures automatically. This technique was approached with 6 different approaches. Hence, it has brought about a positive result toward the end of the task.

According to Yu et al. (2012), impersonating human's visual abilities is dependably a test in machine vision. The hindrance emerges from the wide crevice of parallelizing handling speed between human's brain and the computer. Beyond the doubtful expense of building a computer for copying a mind, naturally, planning machine vision with compact calculations is a productive decision to adjust innate disadvantages of computers design. Tragically, even the essential picture handling like color segmentation and edge recognition normally credited to human's vision, separating an element by connecting up whole intrigue pixels into a conceivable example (shape) is an extreme occupation to computers.

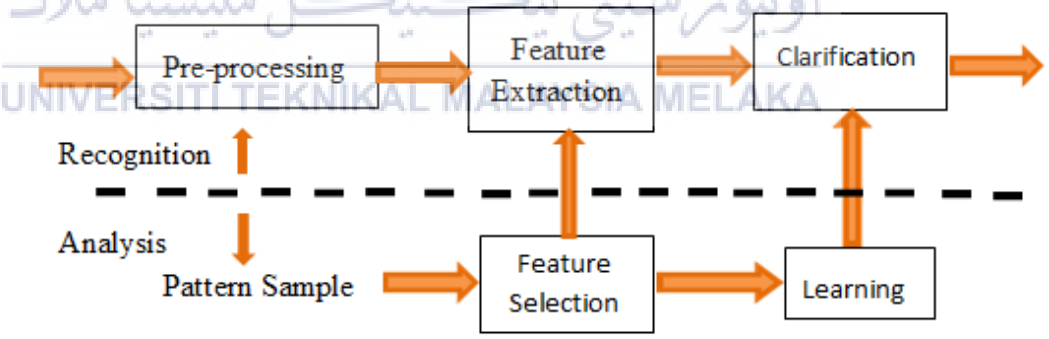


Figure 2. 6 : Pattern recognition model (Deep et al., 2014)

2.3 Study of Template Matching Technique

Johansson et al. (2015) claims that template matching is highly accurate technique used with the arrangement of down-sampling of board pictures to low pixel density. In arithmetical image processing, template matching is a illustrative

strategy for differentiating and recognizing an objects. The technique attempts to find a sub-picture (a reference) in a bigger pursuit picture by looking at the pixel values. Either a likeness or a disparity measure is figured for each point in the inquiry picture. Template matching does not rely on upon the item having an especially unmistakable component to have the capacity to distinguish it. This technique gave the huge beneficial in many aspects. The traceability system is successfully carried on using this technique.

According to Kumar et al. (2014), Template matching has turned out to be a capable innovation in the arena of Image processing for the diverse requests identified with remote detecting, medicinal, and other connected regions. A template based methodology gives a few application systems to identified arithmetical image processing handling ideas for a location of different components in the picture bits themself giving the necessary data from the particular picture segments. A combination of user uses the picture enlistments to gather records from the physical measures of the picture. A template matching in fundamental is similar the particular items of the basis picture utilizing a layout picture as appeared in figure 2.7. Common methodologies for complaint acknowledgment can be characterized into two general classifications; area based and feature based methodology. Area based approach sometimes called correlation sorts manage the pictures without endeavoring to distinguish striking objects window of favored size or the quest window is utilized for estimation of items while feature based techniques are central with respect to coordinating elements of the pictures utilizing contrast, color, hue, saturation and so on. Image registration has likewise been a vital point while the comparison of pictures or transient information study demonstrated the importance of image registration from various sensors and diverse perspectives with focuses in satellite pictures, matching stereo pictures and the fundamental innovation utilized as a part of the registration procedure couple of areas incorporated into the paper indicates feature based, search space, similarity metric, and so on regions secured in it are the medical control and computer vision. Comparative works are reflected additionally mirrored the change measures like Euclidian, similarity affine and so forth., with registration methods as pixel based, feature based, contour based, multi-modular and so forth. Template matching is the procedure of indenting any object in the primary picture better called as source picture with a template, small

portion or any distinctive picture. It can be accomplished through an assortment of strategies like SAD ,NCC and so on.

Figure 2. 7 :Process of template matching (Kumar et al., 2014)

Mahalakshmi et al. (2012) classify there are some strategies to confirm an accuracy of template matching technique. Template matching approach based on area-based approach also recognized as correlation. This technique is most appropriate for the formats which have no solid elements with the picture since they work specifically on the greater part of qualities. Matches are assessed based on intensity values of both picture and template. The strategies under this class including squared differences in fixed intensities, correction-based methods, optimization methods and mutual information. The technique for the area based template matching approaches for the similarity measures is normalized cross-correlation. The similarity is confirmed by the maximum match. This technique is effective for rotation and scaling. The limitations of correlation methods are the levelness of the peaks and high computational complexity, the peaks can be corrected by vector correlation. However, Cross-correlation based techniques are utilized for the simple implementation of hardware and processing image for continuous applications.

2.4 Study of Automatic Inspection in Industrial

Weyrich et al. (2012) found that automatic inspection is a viable framework contrasted with manual inspection in the industrial sector. Additionally, the implementation of an automatic inspection with a processing

conveyed items are cases for methodical work. The advancement of this framework can control the losses since this framework can be built as desired. Hence, objects that out of the determinations can be checked and repaired. This automatic inspection made the tremendous advantages to the manufacturer.

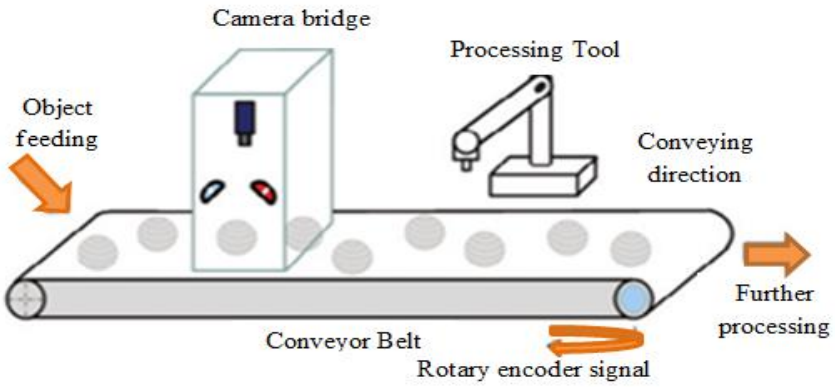


Figure 2. 8 :Concept of the inspection and processing system (Weyrich et al.,2012)

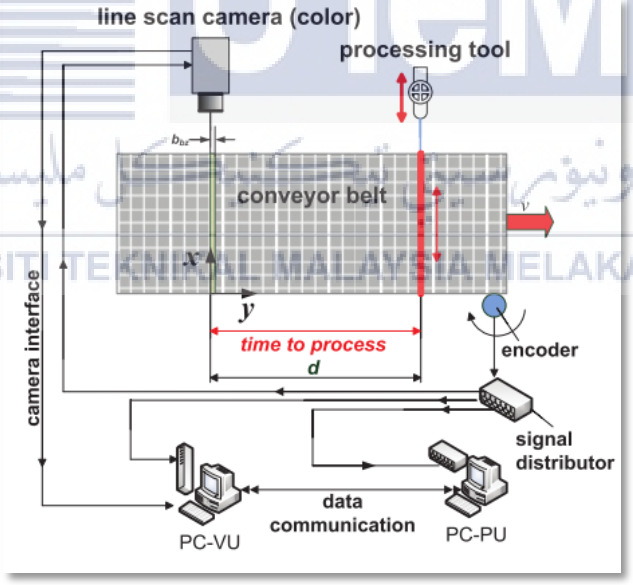


Figure 2. 9 : Configuration of inspection and processing system (Weyrich et al. 2012)

According to Wang et al. (2012), numerous issues have raised on cheeses (Food industry). The quality of cheeses is looked from a few perspectives. Notwithstanding, the principle variable of the low quality is because of packaging.

Consequently, with the assistance of computer vision, an automated inspection concentrating on quality of cheeses packaging has determined the issue.

2.5 Hardware and Software

This part will define the hardware and software that will be used in this project. The main software used is MATLAB, while hardware part such as robot arm, conveyor and LCD display will be controlled by Arduino.

2.5.1 Software

This project will concentrate on the software. Hence, it is imperative to survey the product accessible in the market as the initial step to pick the best software for this project can be executed effectively.

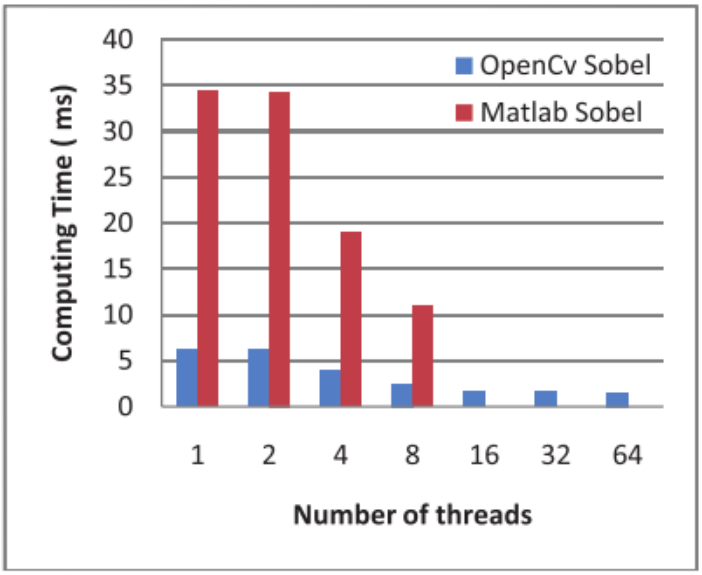
Table 2. 1:Comparison of software

(Tasner et al., 2012)

Criteria	Software		
	MATLAB	OpenCV	LABVIEW
Program Coding/Construction	Simple Code	Complex Code	Simple Construction
Time Execution	Faster	Slow	Slow
Efficiency	Less Efficient	More Efficient	Less Efficient
Computation	Better	Good	Less Better Than MATLAB
Resources	More	Less	Less
Licensing	Expensive	Free	Expensive

Table 2. 2 : Comparison of time utilization of Sobel algorithm

(Matuska et al., 2012)



For graphical perspective, comparison of time utilization of Sobel algorithm for a picture with resolution 1024x768 in OpenCV and MATLAB appears in Table 2. OpenCv with 8 workers was quicker than MATLAB with 8 laborers 4.5 times and with 16 threads against 8 workers 7 times. More threads at that point 16 in OpenCv didn't enhance processing time of Sobel calculation. (Matuska et al. 2012)

2.5.1.1 MATLAB Simulink with Image Processing Toolbox

Name et al. (2014) states that MATLAB (Matrix Laboratory) was composed initially to give simple access to matrix programming created by the LIN-PACK (Linear System Package) and EISPACK (Eigen System Package) projects. Today, MATLAB engines incorporate the LAPACK (Linear Algebra Package) and BLAS (Basic Linear Algebra Subprograms) libraries, constituting the best in class in programming for the matrix. MATLAB is highly recommended for this project because it coordinates calculation, perception, and programming in a simple-to-use environment where issues and solutions are communicated in a recognizable numerical documentation. Thus, MATLAB has provided an Image Processing

Toolbox. The Image Processing Toolbox is an accumulation of MATLAB functions (called M-functions or M-files) that amplify the capability of the MATLAB environment for the arrangement of DIP issues.

2.5.1.2 Arduino IDE

Arduino Integrated Development Environment (IDE) is a platform (software) used to creates the coding to control the equipment. Arduino IDE utilized C++ to performed the task. Sketches (alluded to program code) are composed in the text editor and save with ".ino". These representations will be modified to control conveyor, LCD display, buzzer and Bluetooth.

2.5.2 Hardware

The hardware of this project will represent the characteristic of the project where main of the component use for this project will be the feature of the device.

2.5.2.1 Arduino

Jagdish Arora (2014) states Arduino microcontroller is the most chosen controller nowadays. Mechanical frameworks (Robotic system) are turning out to be perpetually mind boggling ordinary and the requirement for frameworks that can make undertakings less demanding which make utilization of labor, time and assets if done physically. In this project, an automated inspection is equipped with conveyor (start and stop), LCD display and buzzer are accomplished by programming in Arduino. Thus, in this project, Arduino Uno was selected as a controller among the

other types. This type provided 14 digital input/output pins, 6 analogue inputs and available for USB connection. This type has fulfilled this project criterion. It also can be owned at a reasonable price.

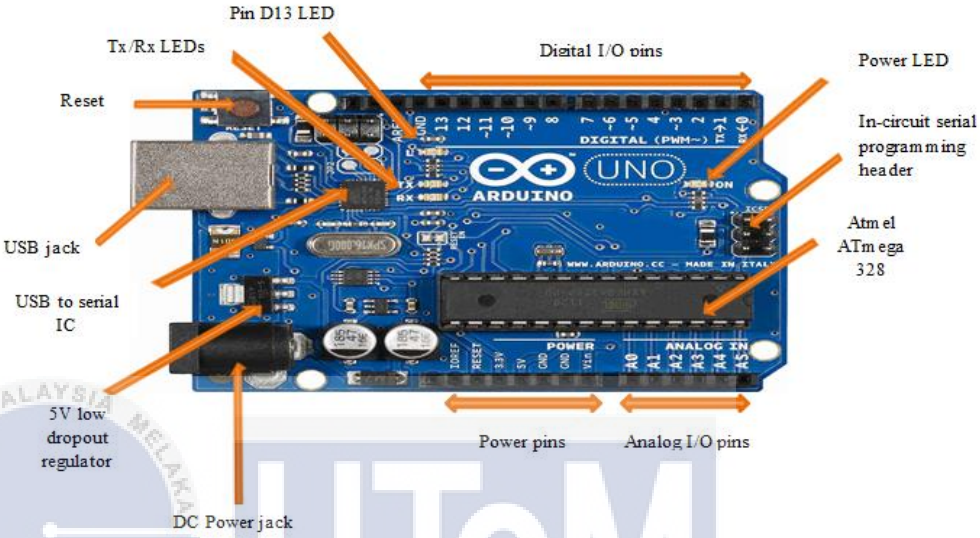
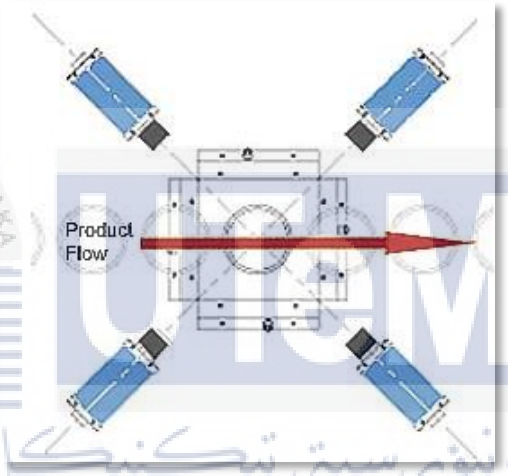


Figure 2. 10 : Example of Arduino UNO microcontroller

2.5.2.2 Camera selection

(Move and Size n.d.) states there are two purposes in picking a camera. It is either for network system or industrial. System cameras IP(Internet Protocol), typically utilized as a part of observation applications consolidated with industrial cameras. This type is packaged with a great variety of functions. The industrial camera is more productive in keeping the picture, Industrial cameras are based on the manner either in area scan camera or line scan camera. Also, color camera is most appropriate rather of a monochrome camera for inadequate this project specifications.

(a)



(b)

Figure 2. 11 : Types of industrial cameras

(a) Line scan camera (b) Area scan camera

2.5.2.3 Interfaces

According to (Move and Size n.d.), the interface serves as the contact between the camera and computer, sending picture information from the camera sensor to the parts that process the pictures, for an instance, the equipment and programming. Thus, there are several criteria in selecting best interfaces for connection

between hardware and software. As for this project, USB3.0 are capable to transferred input from Arduino to PC.

Table 2. 3 : Comparison of interfaces

Source: (Move and Size n.d.)

Criteria	Camera Link	GigaBit Ethernet (GigE)	USB 3.0
			
Cable length	10m	100m	8m
Bandwidth max in MB/s	850	100	350
Cost	Expensive	Cheaper	Cheaper
Compatibility	All performance classes	Plug and play	Plug and play

2.5.2.4 LCD Display

There are many types of LCD capable with Arduino available in market depending on needs and expectations. This project preferred a 16×2 LCD instead of 20×4 LCD.

Table 2. 4 : Comparison of 16x2 LCD

Criteria	16×2 LCD Module	Standard LCD 16×2	Basic 16×2 Character LCD
			
Cost	Cheap	Cheaper than 16×2 LCD Module	Expensive
Colour	White backlight	Blue Background	Green Background
Text Display	Blue	White	Black
Compatibility	HDD44780 standard	HDD44780 standard	All Arduino Microcontrollers
Features	-	-Support English and Japanese Text -Can display up to 8 custom character	-consists of 11 general I/O pins to interface -can display up to 32 characters

2.5.2.5 Conveyor

The conveyor system is used for conveying loads with quick and efficient. Conveyors system are widely used in almost every industrial sector. The conveyor design is chosen based on desired applications process. Thus, there are various types and available designs of the conveyor in the market. For instance, belt conveyor is most popular due to the capability conveying loads to different elevations.

2.5.2.6 Bluetooth Module

According to (D, 2015) in his home automation system presented paper, Bluetooth operates over the unlicensed, globally available frequency of 2.4GHz. It can link digital devices within the range of about 100m. This system used HC-05 Bluetooth module to control the home appliances without going to the switch board, when the user present within the home. Hence, HC-05 Bluetooth module is preferred to control software and hardware in this project.

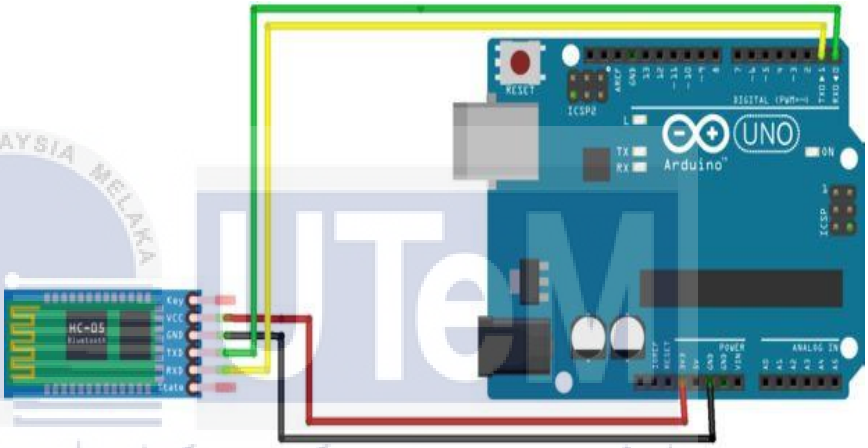


Figure 2. 12 : Interfacing of Bluetooth module on Arduino UNO board

2.5.2.7 Infrared Distance Sensor

(Engineering and Bahru 2013) states IR sensors are proficient in measuring information up to 0.05 cm of determination in movement. Based on Application of Infrared Sensor for Shape Detection paper, Infrared (IR) sensor has been broadly utilized as a part of engineering and medicinal fields for numerous applications. IR sensors play an essential part in getting precise information with a specific end goal to diminish the noise level and faults as much as could be expected in each and every test. There are two sorts of IR sensor which are modular and discrete

sensor both can be utilized to quantify distance at close and further distance. In the meantime, the determination of this sensor can be up to 0.1 mm. In conclusion, Infrared Distance Sensor E18-D80NK was chose. The innovation behind this successful distance sensor is Modulation of Infrared Light. The receiver is delicate merely to infrared light and simply when it receives the exact signal. Thus, it is not too sensitive to ambient light associated to plain Infrared detectors.

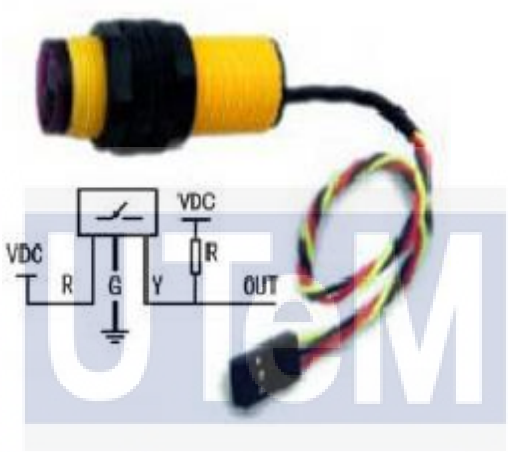


Figure 2. 13 : Infrared distance sensor E18-D80NK

CHAPTER 3

METHODOLOGY

3.0 Introduction

This chapter will review on how the research is carrying out. The idea and objective for this project is found based on self-observation and use internet and book as further studies.

3.1 Project Development

Project development will be done by taking after the flow of task anticipating Bachelor's Degree Project (BDP I). Methodology, tool requirements and work plan have been characterized. Activities in schedule will be carrying on guaranteeing that deliverables for every development stage are conveyed on time. Appendices A shows the process flow of BDP I and BDP II. BDP I shows the early planning to implement this project while the BDP II shows the action taken to generate the project to ensure the project will be performed well as required.

3.1.1 Overview Of The System

The operation of the whole system will be explicated in this part. The schematic image as shown in Figure 3.1 will describe the flow of this system. A schematic image will provide a better understand of how the system work and function. Based on figure 3.1, the process start when Arduino run the conveyor until the sensor detect the packaging on the

conveyor. Then, camera will capture the image and sent the input (Packaging Pattern) sense to the MATLAB. MATLAB will process the image (Packaging pattern) detected to determine either the packaging pass or fails. The Arduino will control the conveyor, LCD display and trigger the buzzer. LCD will display the result of pass or reject packaging while the buzzer will alarm if rejected packaging detected.

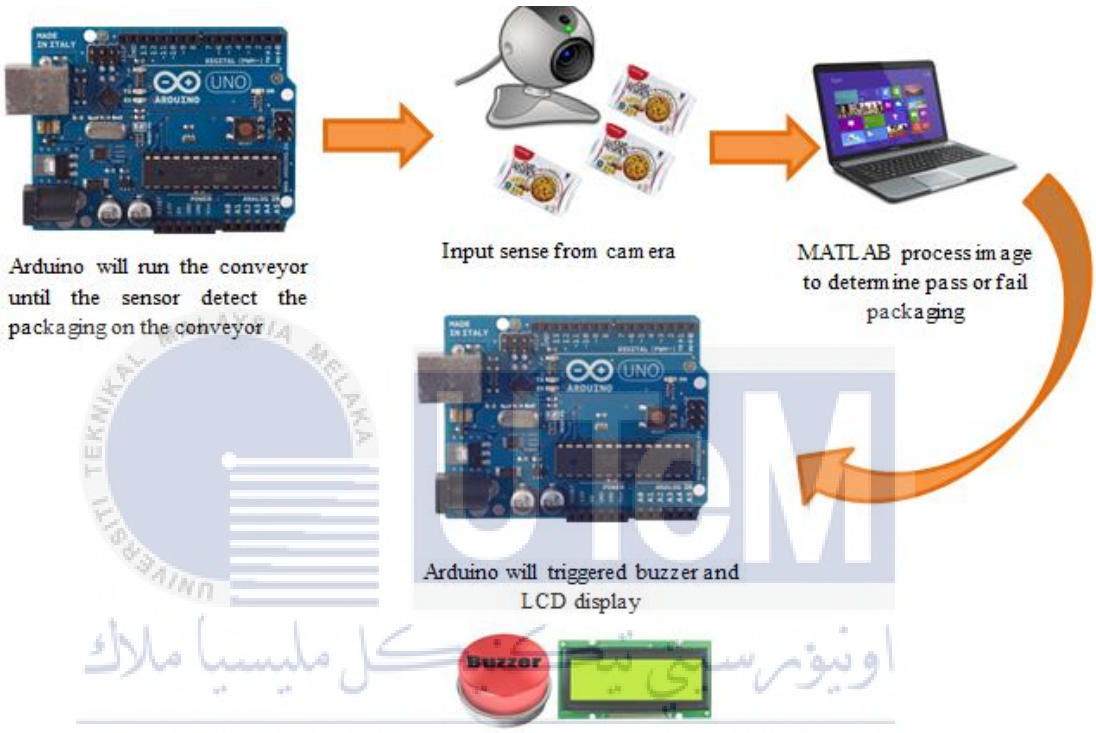


Figure 3. 1 : Schematic of APVI using TMA in IP

3.1.2 Flowchart

This part will describe the flowchart and block diagram that will be used as guideline in this project. Flowchart represents the overall procedure that needed to be take place in order to develop the project accordingly. Flowcharts are utilized to build the comprehension the advancement of the research and how the data analysis is obtained.

3.1.2.1 Flowchart of Overall Progress

Appendices B shows the flow chart use on the proposal paper will be reuse to ensure that the process of developing the project follow exactly as the properly planned.

3.2 Software Development

In this section, some software was utilized as a part of a request to run the analysis and the correspondence with the equipment part. The primary software of this research is MATLAB where it will be utilized to run the analysis of matching the captured image with template image (reference image).

3.2.1 MATLAB

The system will be comparing the input (image) from the camera with the template and give a yield of closeness by using correlation coefficient method.

Basically, there are four step to implemented this correlation coefficient function. Firstly, the image captured and template image will be initialized before proceed to correlation calculation. In this correlation calculation, sequence is generated by convolution sum. Furthermore, there 4 procedures in the convolution. There are folding, delay, multiplication and summation. Thus, next step will be finding the most likely region before proceed to hypothesis test to display the result as shown in figure 3.2 below.

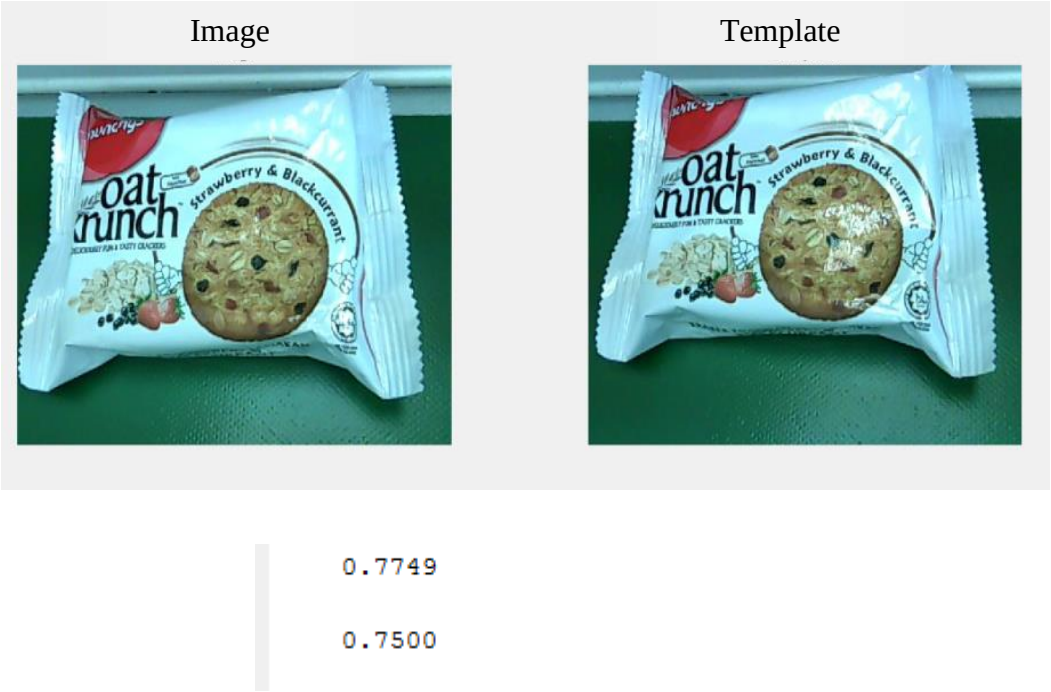


Figure 3. 2: MATLAB process resulting in matched pattern

Figure 3.2 shows the result when image captured compared to the template image resulting in matching pattern when the maximum value obtained is 0.7749 which is above the threshold value set, 0.7500.

3.2.2 Arduino IDE

Arduino Integrated Development Environment (IDE) utilized C++ to control the conveyor , LCD display and buzzer that will be implemented by Uno Arduino to control the speed of the motor (conveyor), if there is object detected, the program passes 0, then the motor will stop and if there is no object detected on conveyor, then it will keep running at full speed.

3.3 Hardware Development

The Automated Packaging Visual Inspector will integrated with the Arduino UNO. The Arduino UNO will control the conveyor. A camera will be the input to capture a running packaging (pattern) on conveyor. The output will be performed by LCD display and buzzer.

3.3.1 Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328P chosen to control conveyor, buzzer and LCD display. It has 14 digital input/output pins (of which 6 can be utilized as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything expected to bolster the microcontroller; just interface it to a PC with a USB link or power it with an AC-to-DC connector or battery to begin.

Figure 3. 3 : Arduino UNO

Table 3. 1 : Technical Specifications of Arduino UNO

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O pins	6
Analog input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) Of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P
Clock Speed	16Mhz
Length	68..6 mm
Width	53.4mm
Weight	25g

3.3.1.1 Conveyor (Motor)

The conveyor will be performed according to the software programming and hardware implementation. Thus, below has states the connections for switch motor (hardware) by Arduino Uno:

Table 3. 2 : Pin initializations for connecting Arduino

Arduino 5V pin	Relay module VCC pin
Arduino GND pin	Relay module GND pin
Arduino pin 9	Relay module IN1

After done connecting the motor, the relay switch module need to be power by itself. By utilizing the Arduino, the wires can be connected and send signs to activate the relay switches.

3.3.1.2 LCD Display

The LCD can interface with an Arduino to provide the user interface. The 16x2 LCD utilized as a part of this project has a total of 16 pins. As appeared in the table below, eight of the pins are data lines (pins 7-14), two are for power and ground (pins 1 and 16), three are utilized to control the operation of LCD (pins 4-6), and one is utilized to adjust the LCD screen brightness (pin 3). The remaining two pins (15 and 16) power the backlight. The details of interest of the LCD terminals and the corresponding pin connection on the Arduino used are as per the following:

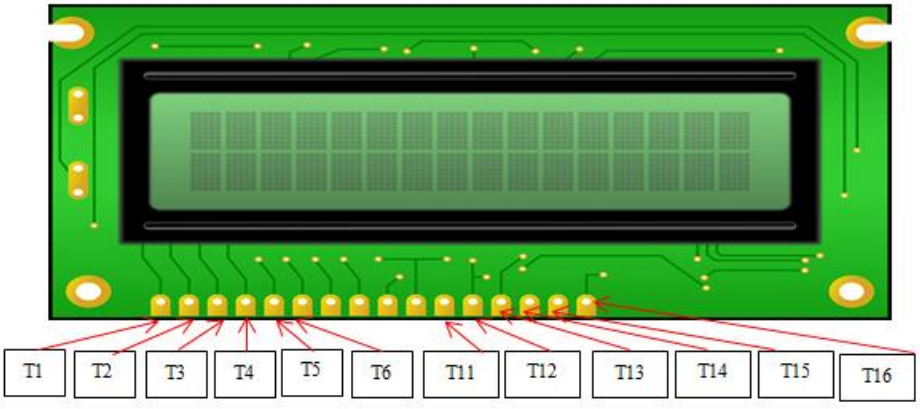


Figure 3. 4 : The LCD pins

Table 3. 3 : Pin initializations for LCD terminals

Terminal 1	GND
Terminal 2	+5V
Terminal 3	Mid Terminal of Potentiometer (adjustable contrast)
Terminal 4	A0
Terminal 5	GND
Terminal 6	A1
Terminal 7	-
Terminal 8	-
Terminal 9	-
Terminal 10	-
Terminal 11	A2
Terminal 12	A3
Terminal 13	A4
Terminal 14	A5
Terminal 15	+5V
Terminal 16	GND

3.3.1.3 HC-05 Bluetooth Module

HC-05 Bluetooth module is a simple to utilize Bluetooth SPP module, intended for straightforward remote serial connection setup. Serial port Bluetooth module is completely qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. CSR

Bluecore04-External single chip Bluetooth system with CMOS innovation and with AFH(Adaptive Frequency Hopping Feature).

3.3.1.4 Infrared Distance Sensor E18-D80NK

The sensor provided long recognition distance, and has less obstruction by obvious light since it utilizes balanced Infrared light. This sensor has a screwdriver acclimation to set the spotted distance, then gives a digital yield when it senses something within that range. This sensor does not give back a distance value. This sensor used to detect the occurrence of object on conveyor then, control the motor (run/stop). The connections as in below table.

Table 3. 4 : Connections of E18-D80NK

Red	Green	Yellow
+5V	Ground	D4

3.4 Hardware Implementation

Figure 3.5 and figure 3.6 below shows the basic hardware. The data from MATLAB will be transfer and receive by HC-05 Bluetooth module. Computer will be connected with the HC-05 Bluetooth module after success in pairing. In Matlab coding, when pattern detected was matched, it will send result to Arduino for control a conveyor, LCD display and buzzer. A voltage regulator of output 3.3V was used to supply voltage to HC-05 Bluetooth module. The conveyor will be controlled by relay when sensor detects an object on conveyor. Hence, Arduino and Matlab will start their process.

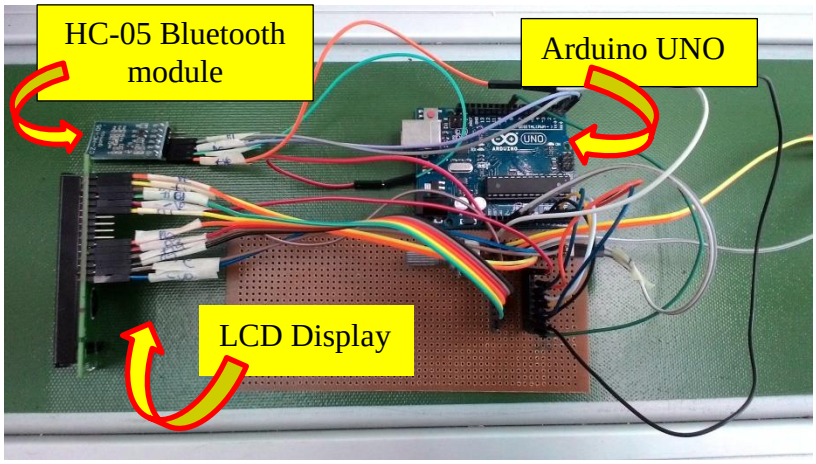


Figure 3. 5 : Arduino UNO connected with Bluetooth and LCD display

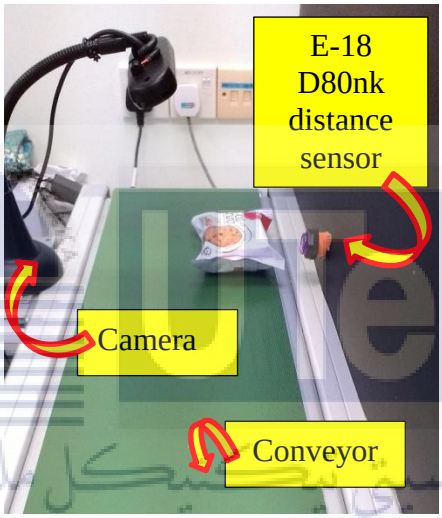


Figure 3. 6 : Camera and sensor placed to detect and capture sample

CHAPTER 4

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter will present the analysis result of APVI using TM in IP. The analysis was run to determine the efficiency of template matching technique on packaging pattern. Two analysis was performed, correlation coefficient technique and Speed-Up Robust Features(SURF) detectors technique. Both techniques were chosen for analyzed the template matching algorithm. Thus, two different types of packaging pattern were used as shown in below figure below.

Figure 4. 1 : Packaging sample (a) Chunky hazelnut flavor (b) Strawberry and blackcurrant flavor

One of this pattern will be the template while the other one pattern will be the images captured by the webcam that will be analyzed. The acceptance maximum value will be resulting in matching image. However, the rejected value will turn on the buzzer as an alert there are images were rejected.

4.1 Discussion

In overview, to accomplish this project, there a few obstacles were faced and need to be overcome. The main problem is the brightness. This project has been tested in a provided room since the conveyor cannot be taken out from the room. The provided room are not equipped with curtains that cause light to penetrate the room. The unpredictable weather did not help to run the project smoothly plus the room lights alone cannot solve the problem. Originally, this system was created to be run automatically. Unfortunately, the time execution for Template matching process takes a much time than expected. The signal first must be sent to MATLAB from Arduino by Bluetooth function once the sensor detect the packaging on a conveyor. However, this signal takes a long time to be received by MATLAB until the MATLAB has reached out the time and unable to process the image. Other than that, the analysis of template matching is performed to show the efficiency of techniques for process the image. However, this technique will be failed in position change, brightness change, size and orientation even though the pattern are same between image captured and template image.

4.2 Analysis Result

The brightness of the image and template can vary due to lighting and exposure condition. Thus, for this technique, the room brightness itself play an important role. The pixels of image unable to be detected in spite of the fact that the image captured and template image are in same pattern.

4.2.1 Correlation Coefficient Techniques

Correlation coefficient was chose as it is a quantity that measures particular category of correlation and dependence, meaning statistical connections between two or more random variables or experimental data

values. In other mean, correlation coefficient is a quantity of the strong point and path of the linear relationship between two variables that is defined as the (tester) covariance of the variables divided by the product of their (tester) standard deviations. The result will show the best point match between image captured and template image itself. Thus, segmentation implicates splitting an image into sections (or their contours) conforming to objects. The simplest things that pixels in a region can share is intensity. Thus, threshold was tested with two value, 50% and 75% to find the best score. If the score of template match is higher than this threshold, the result will revealing of a good match and Arduino will be received a signal to run the conveyor. Thus, LCD will display Pattern Match and Pass. The yield will be the correlation with the best potential score. Sometimes, the best potential score could be very low. For an instance, below 50%. This means that even with this finest score, it is very improbable to found the pattern match. Thus, it's a good idea to implement a threshold. When trying to find the finest score, if that score is advanced than some threshold (say 75%), then this may show that the pattern is truly same. The result show in table 4.1 until table 4.6 below.

Many sample has been taken to show the effectiveness of this techniques. Table 4.1 below indicates the value when both of the image captured and template image have a similar pattern and same brightness of image. The maximum value will obviously equal to 1. The maximum value of 1 also indicates 100% match. The exact match was is sought. The template is totally same size and position with the image captured. This term make the result equal to 100% match.

Table 4. 1 : The same brightness of images captured and template image for similar pattern

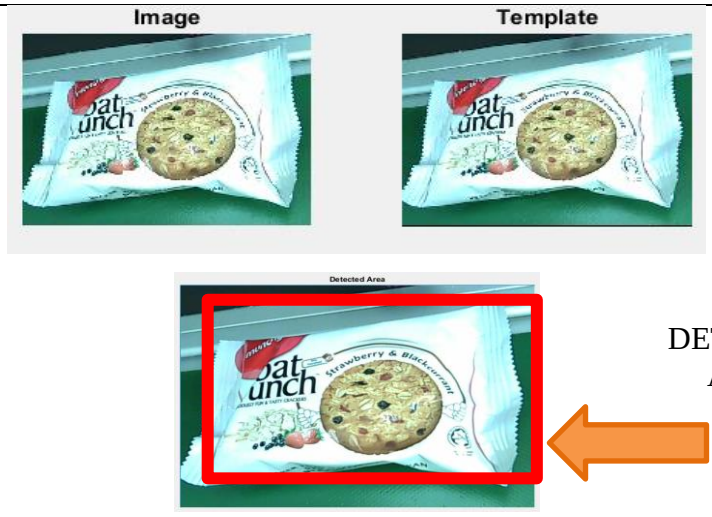
		
Max Value = 1.0000	Threshold = 0.7500	Time Process = 82.8660s

Table 4. 2 : The same brightness of images captured (image flip and mirror) and template image for similar pattern

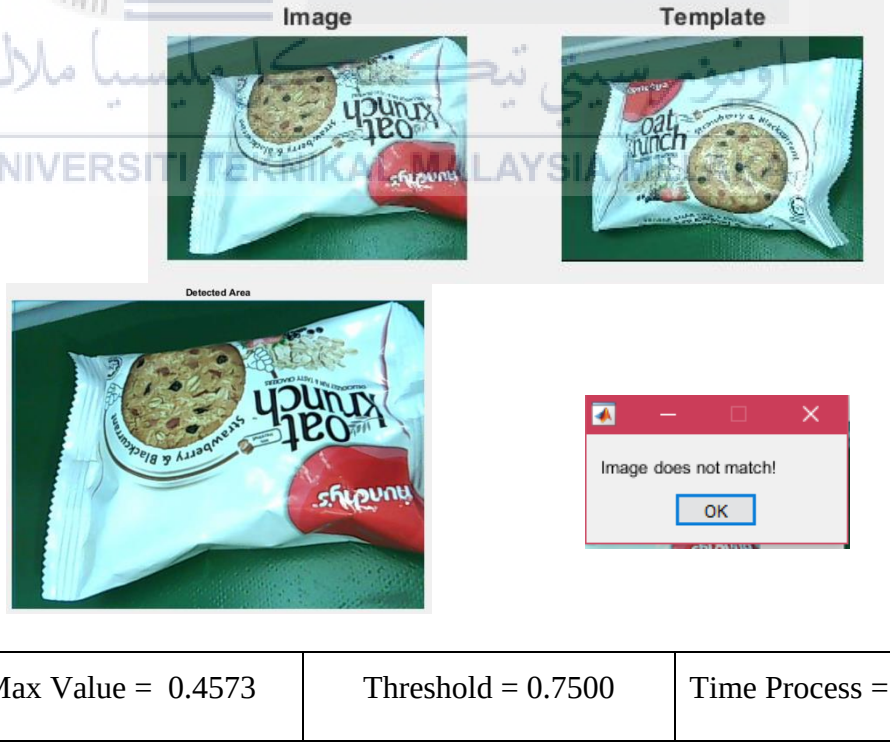
		
Max Value = 0.4573	Threshold = 0.7500	Time Process = 71.9210s

Table 4.2 above indicates the value when both of the image captured and template image have a similar pattern. However, the image

captured has been rotated and flip. The maximum value template drop to 0.4573 compared to result in Table 4.1 . The time process to identify the matching point less than previous which is 71.9210s. The maximum value obviously drop because the total template did not effective in rotation or translation invariance.

Table 4. 3 : The different brightness of images captured and image for similar pattern

<table>
<tr><td colspan="3"> 
</td></tr>
<tr><td>Max Value = 0.9444</td><td>Threshold = 0.7500</td><td>Time Process =83.3770s</td></tr>
</table>

Table 4.3 above shows the value when both of the image captured and template image again have a similar pattern but the images captured in different brightness. The maximum value increase to 0.944 . The time process to identify the matching point is 83.3770s. Even though the images different brightness, the process still recognized the pattern but the maximum value will not become 100% matching.

Table 4. 4 : The same brightness of images captured and template image for different pattern

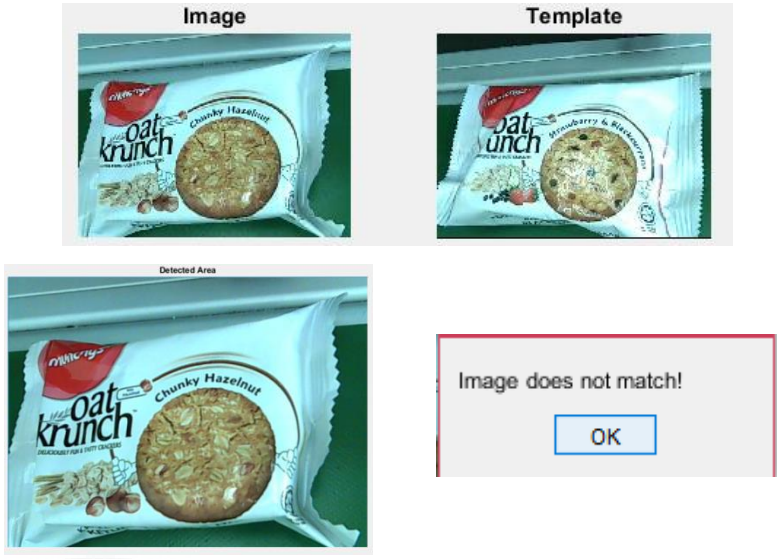
		
Max Value = 0.4720	Threshold = 0.7500	Time Process=82.4420s

Table 4.4 above shows the value when the image captured is different pattern with the template image and have a same brightness. The maximum value drop to 0.4720 . This is because the image captured is totally not same with the template image.

Table 4. 5 : The brightness of images captured and template image for different pattern

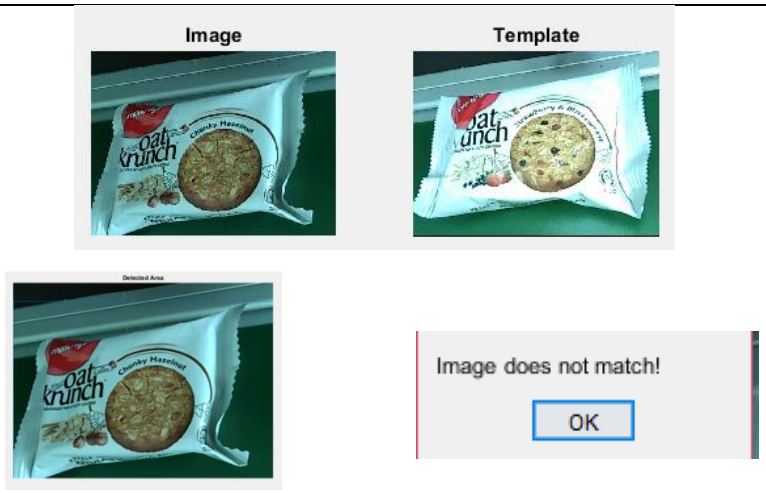
		
Max Value = 0.5503	Threshold = 0.7500	Time Process = 75.1470

Table 4.5 above shows the value when the image captured is different pattern with the template image and have a different brightness. The maximum value is to 0.5503 . The time process is much faster than others previous. The time process is equal to 75.1470. Noted that the efficiency of time process not depends of the result. The time process is related to MATLAB process, the time execution for each analysis

4.2.2 Speed-Up Robust Features(SURF) Detectors Technique

SURF is a rotation invariant descriptor propelled by SIFT. In other meaning, SURF is done by extracting a key points using in two images and then match the retrieved key points.

Table 4.7 below indicate the recorded value for match and mismatch pattern. The result of similar position, size and orientation are 1 while the different pattern image captured resulting in rejected pattern. The time execution for this process much faster than correlation technique because this technique approximates or even overtakes earlier proposed plans as for repeatability, particularity, and strength, yet can be figured and compared much quicker. The time execution for MATLAB will be more faster when the MATLAB execute for several times compared to first execution. SURF is great at taking care of pictures with obscuring and rotation, however not great at taking care of perspective change and light change.

Table 4. 6 : Recorded value for match and mismatch pattern

Result[o]	Matching Value	Time Execution(s)
Pattern match	1	1.5270
Pattern match	1	1.0180
Pattern not match	0.1200	1.0170
Pattern not match	0.0400	1.0500

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This project has completely achieved the target when the result turned out to be a new system called an APVI using TMA in IP. The successfulness of the objectives will be concluded in this section and a few suggestions for improving future work also were included.

5.1 Conclusion

In conclusion, the objectives to be achieved in this project were succeeded where an APVI using TMA in IP was able to run as required. Template Matching technique was used to implemented the Automatic Visual Inspector by differentiate the correct and incorrect label of packaging pattern. The humans error perhaps will be reduced by this system.

Apart from that, the process of MATLAB and Arduino were connected with Bluetooth where the output of MATLAB will be performed by Arduino . The result received by Arduino will give a digital signal in order to control the relay of conveyor motor. The run and stop of the conveyor will shows either the packaging pass or rejected. If the packaging pass, the conveyor will run till the sensor sense a new packaging and stop again. However, once the packaging rejected, the conveyor will not run again, plus the yield will be alerted by a buzzer. The acceptance value of pass(match) and rejected(not match) was set and easy to understand.

5.2 Recommendations

There are other factors might affect this project and the overall system itself. The future improvement can be implemented to make the system more systematic and effective. Below are some improvements idea for future :

(a) Instead of using correlation coefficient technique, Grayscale-based matching technique is recommended in order to enhance the efficiency of detections the image orientations.

(b) Compute multi-angle of template image (multiple of possible orientation)

(c) Create a database to monitor the yield by working hour.

(d) Use motor to throw out the defective packaging without stopping the conveyor again.

(e) Change the serial communication from Bluetooth to WIFI in order to increase the range of functional.

(f) Use good quality of webcam to capture the images detected.

(g) Create an own photo booth to ensure there will be no problems occur with the lighting.

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APPENDIX A

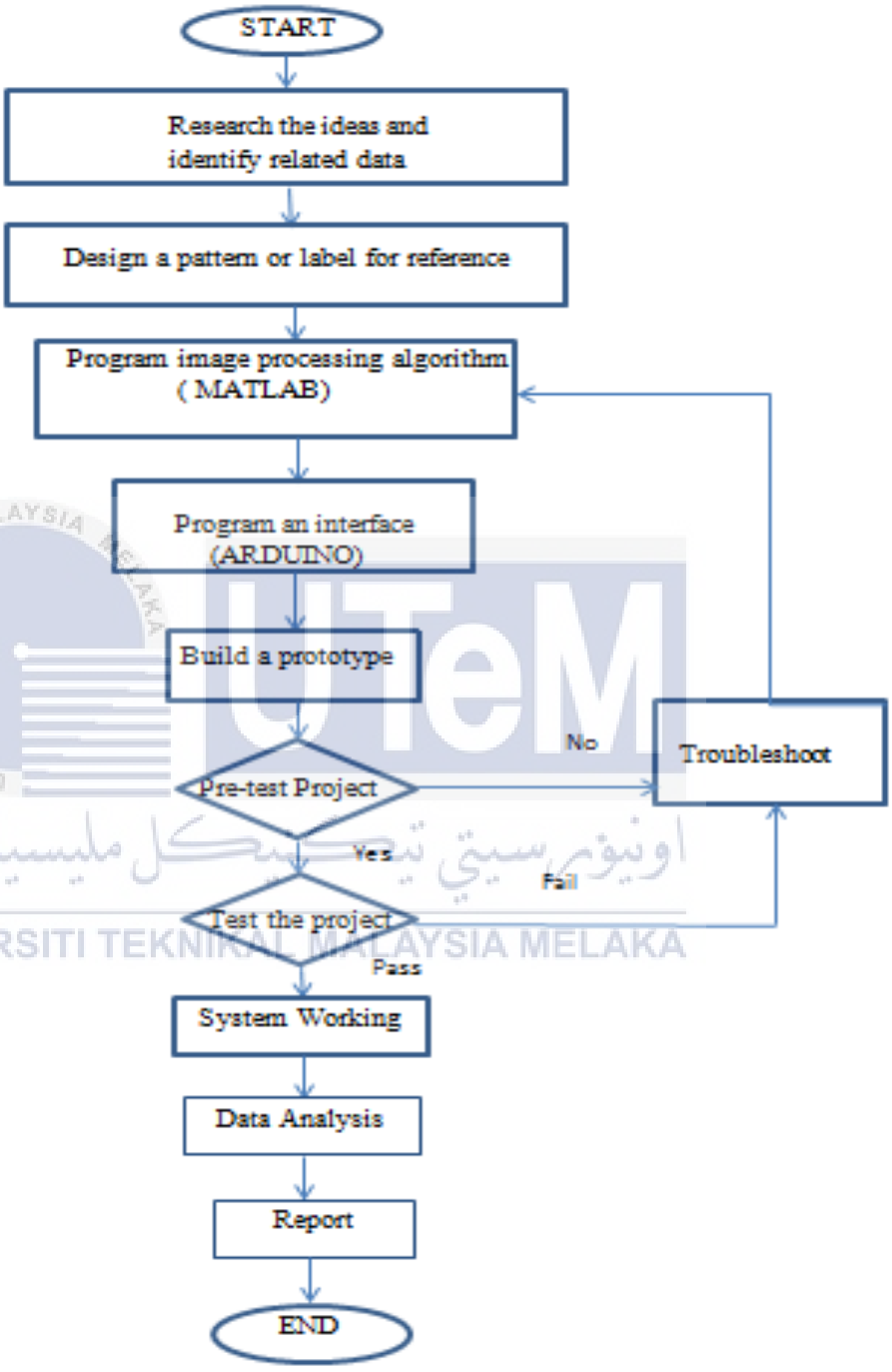
GANTT CHART

Project Activity	Feb		Mac				April				May				June			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Research the idea for project Implementation	BP Briefing							Mid Term Break								Study Week	Final Semester Examination	
Identify the problem statement																		
Submission of project proposal																		
Research of Literature Review for related case.																		
Identify approach methodology that will be implemented																		
Identify require software and hardware involved																		
PSM 1Final Report Preparation																		
Program simple coding Involved																		
Presentation Preparation & Presentation																		
Submission of PSM1 final report																		

Project Activity	Sep			Oct					Nov				Dec		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Choose A label or pattern to be used								mid term break							
Program coding involved															
Program an interface used															
PSM 2 Finl Report Preparations															
Build/Prepare a prototype															
Pre-test a completed project															
Collect the result obtained and make a comparison															
Troubleshooting															
Final Test completed project															
Submission of PSM 2 Final Report															
PSM 2 Presentation															

APPENDIX B

FLOWCHART



APPENDIX C

MATLAB ALGORITHM(CORRELATION COEFFICIENT)

```
clear all
webcamlist
% Use cam as the name of the object. Use 'Logitech' to connect to the Logitech camera.
cam = webcam('Logitech Webcam C210');
preview(cam)
clear('cam');

vid = videoinput('winvideo',1,'RGB24_640x480');

for i=1:1
   x=i;
   frame=getsnapshot(vid);
   imshow(frame*x);
   fname=strcat('Image', num2str(i),'.jpg');
   imwrite(frame,fname);
   pause(5);
end
```

```
 % ------------------------------------------------------------
% Template Matching using Correlation Coefficients
% 21/10/2016
% ------------------------------------------------------------

clear all
close all

z =clock;
%% Prepare the image for analysis
F = imread('Image1.jpg'); % read image
T = imread('TemplateS.jpg'); % read in template image
%% display frame and template
figure, subplot(121),imshow(F),title('Image');
subplot(122),imshow(T),title('Template');
%% correlation matching
[corrScore, boundingBox] = corrMatching(F,T);
```



```
%% show results
figure,imagesc(abs(corrScore)),axis image, axis off, colorbar,
title('Corr Measurement Space')

bY = [boundingBox(1),boundingBox(1)+boundingBox(3),boundingBox(1)+boundingBox(3),boundingBox(1),boundingBox
bX = [boundingBox(2),boundingBox(2),boundingBox(2)+boundingBox(4),boundingBox(2)+boundingBox(4),boundingBox
figure,imshow(F),line(bX,bY),title('Detected Area');

disp('Time Process=');
disp(etime(clock, z));
```

APPENDIX D

MATLAB ALGORITHM(SURF-SPEEDED UP ROBUST FEATURE)

```
%Clearing the workspace and all variables
clc;
clear;

z =clock;

 vid = videoinput('winvideo',1,'RGB24_640x480');

for i=1:1
    x=i;
    frame=getsnapshot(vid);
    imshow(frame*x);
    fname=strcat('Image', num2str(i),'.jpg');
    imwrite(frame,fname);
    pause(5);
end


%ITEM 1
```

```
%ITEM 1
item1 = imread('Image1.jpg');%Retrieve order 1 and digitize it.
item1Grey  = rgb2gray(item1);%convert to grayscale, 2 dimensional matrix
item1KP = detectSURFFeatures(item1Grey,'MetricThreshold',600);%get SURF dectectors or interest points
strong1 = item1KP.selectStrongest(50);
[item1Features, item1Points] = extractFeatures(item1Grey, strong1,'SURFSize',128); % using SURFSize of 128

%INPUT : Aquire Image
input= imread('Image2.jpg');%Retrieve input and digitize it.
inputGrey  = rgb2gray(input);%convert to grayscale, 2 dimensional matrix
inputKP = detectSURFFeatures(inputGrey,'MetricThreshold',600);%get SURF dectectors or interest
strongInput = inputKP.selectStrongest(50);
[inputFeatures, inputPoints] = extractFeatures(inputGrey, strongInput,'SURFSize',128); % using SURFSize of

pairs = matchFeatures(item1Features, inputFeatures, 'MaxRatio',1); %matching SURF Features
totalFeatures = length(item1Features); %baseline number of features
numPairs = length(pairs); %the number of pairs
```

```
totalFeatures = length(item1Features); %baseline number of features
numPairs = length(pairs); %the number of pairs
percentage  = numPairs/50;

if percentage >= 0.99
    disp('Pattern Match');
    disp(percentage);
else
    disp('Pattern Rejected');
    disp(percentage);
end

figure, subplot(121),imshow(item1),title('Image');
subplot(122),imshow(input),title('Template');

disp('Time Process=');
disp(etime(clock, z));
```

APPENDIX E

SOURCE CODE ARDUINO

_1stAttempt

```
#define Sensor1 4
#define Motor1 9
#define buzzer 12


#include <SoftwareSerial.h>
#include <LiquidCrystal.h>

LiquidCrystal lcd(A0,A1,A2,A3,A4,A5);
SoftwareSerial mySerial(0, 1); // RX, TX

int Signal;
int maxVal;

void setup()
{
 Serial.begin (9600);
 pinMode(Sensor1, INPUT);
 pinMode(Motor1,OUTPUT);
 pinMode(buzzer,OUTPUT);

 mySerial.begin(9600);
 lcd.begin(16,2);
}

void loop()
{
 Signal = digitalRead(Sensor1);

   if (Signal==1)
   {
```

```
 digitalWrite(Motor1,HIGH);
 Serial.print (Signal);
 Serial.println("NO OBJECT");
 delay(300);
 lcd.setCursor(0,0);
 lcd.print("    NO OBJECT    ");
 lcd.setCursor(0,1);
 lcd.print("     WAITING     ");
 }
else
 {

 digitalWrite(Motor1,LOW);
 Serial.print (Signal);
 Serial.println("OBJECT DETECTED");
 delay(300);
 lcd.setCursor(0,0);
 lcd.print(" OBJECT DETECTED");
 lcd.setCursor(0,1);
 lcd.print("  PROCESS IMAGE ");

if (mySerial.available())
{
 Serial.println("myserial=");
 Serial.println(mySerial.read());
 Serial.write(mySerial.read());

 if(mySerial.read()<48)
   {
     digitalWrite(Motor1,HIGH);
```

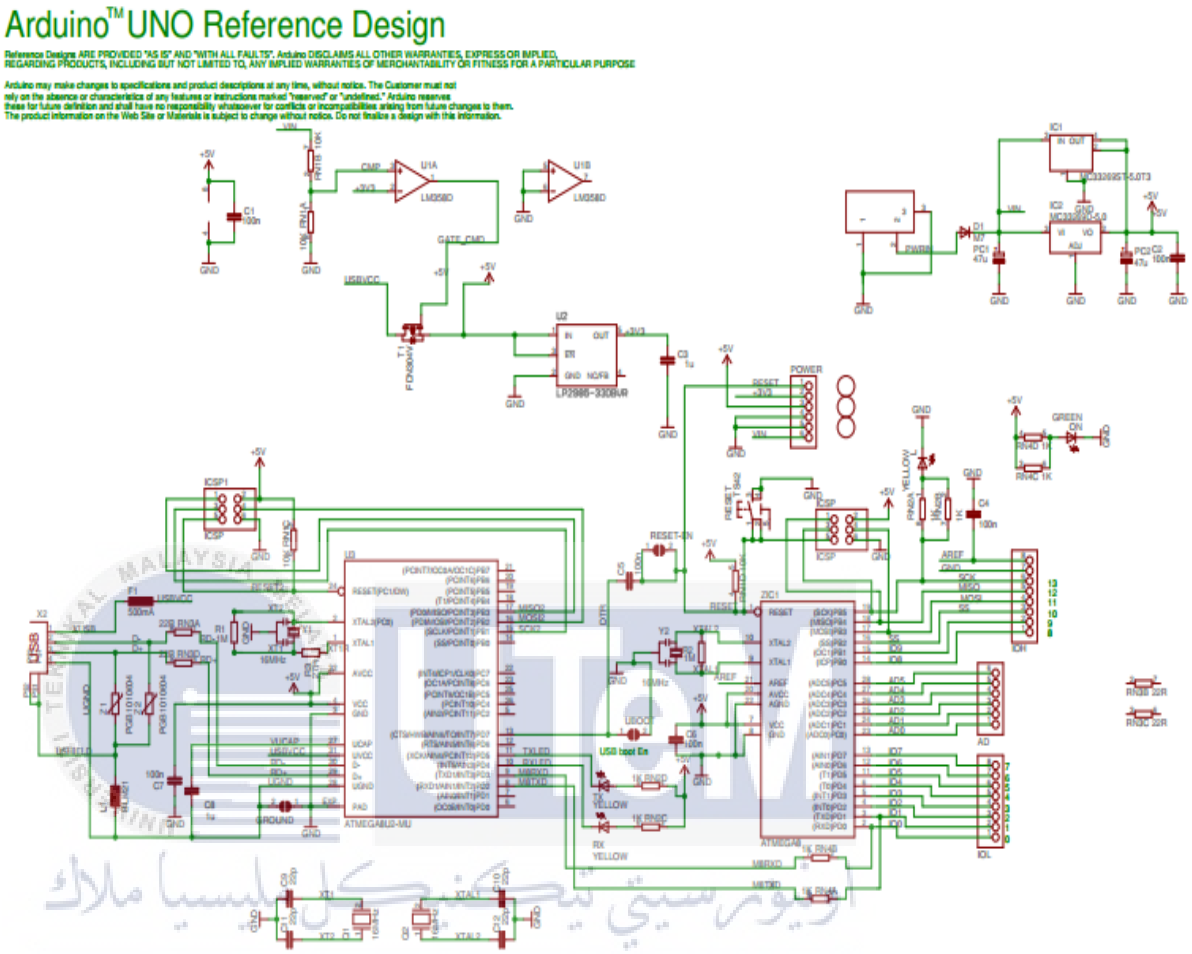
```
        digitalWrite(Motor1,HIGH);
        lcd.clear();
        lcd.setCursor(0,0);
        lcd.print("  PATTERN MATCH ");
        lcd.setCursor(0,1);
        Serial.println("      PASS      ");
        lcd.print("      PASS      ");
        delay(10000);

        lcd.clear();
      }


    else if(mySerial.read()>50)
    {
      digitalWrite(Motor1,LOW);
        digitalWrite(buzzer,HIGH);
        delay (300);
        lcd.clear();
        lcd.setCursor(0,0);
        lcd.print("   NOT MATCH   ");
        lcd.setCursor(0,1);
        Serial.println("     REJECT     ");
        lcd.print("     REJECT     ");
        digitalWrite(buzzer,LOW);
        delay (10000);
        lcd.clear();
    }
}
}
}
```

APPENDIX F

ARDUINO DATA SHEET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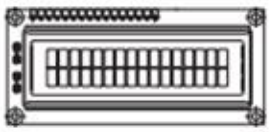
ATMEGA8U2-MU
ATMEGA328
POWER
ICSP
ICSP1
USB
AD
IOH
IOL
GREEN ON
YELLOW
RX YELLOW
USB tool En
RESET-EN
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPENDIX G

LCD DATA SHEET

16 x 2 Character LCD



FEATURES

- 5 x 8 dots with cursor
- Built-in controller (KS 0066 or Equivalent)
- + 5V power supply (Also available for + 3V)
- 1/16 duty cycle
- B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A,K (LED)
- N.V. optional for + 3V power supply

MECHANICAL DATA

ITEM	STANDARD VALUE	UNIT
Module Dimension	80.0 x 36.0	mm
Viewing Area	66.0 x 16.0	mm
Dot Size	0.56 x 0.66	mm
Character Size	2.96 x 5.56	mm

ABSOLUTE MAXIMUM RATING

ITEM	SYMBOL	STANDARD VALUE			UNIT
		MIN.	TYP.	MAX.	
Power Supply	VDD-VSS	- 0.3	–	7.0	V
Input Voltage	VI	- 0.3	–	VDD	V

NOTE: VSS = 0 Volt, VDD = 5.0 Volt

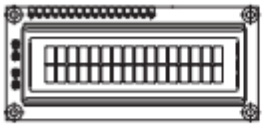
ELECTRICAL SPECIFICATIONS

ITEM	SYMBOL	CONDITION		STANDARD VALUE			UNIT
				MIN.	TYP.	MAX.	
Input Voltage	VDD	VDD = + 5V		4.7	5.0	5.3	V
		VDD = + 3V		2.7	3.0	5.3	V
Supply Current	IDD	VDD = 5V		–	1.2	3.0	mA
Recommended LC Driving Voltage for Normal Temp. Version Module	VDD - V0	- 20 °C		–	–	–	V
		0°C		4.2	4.8	5.1	
		25°C		3.8	4.2	4.6	
		50°C		3.6	4.0	4.4	
		70°C		–	–	–	
LED Forward Voltage	VF	25°C		–	4.2	4.6	V
LED Forward Current	IF	25°C	Array	–	130	260	mA
			Edge	–	20	40	
EL Power Supply Current	IEL	Vel = 110VAC/400Hz		–	–	5.0	mA

DISPLAY CHARACTER ADDRESS CODE:

Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01														0F
DD RAM Address	40	41														4F

16 x 2 Character LCD



FEATURES

- 5 x 8 dots with cursor
- Built-in controller (KS 0066 or Equivalent)
- + 5V power supply (Also available for + 3V)
- 1/16 duty cycle
- B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A,K (LED)
- N.V. optional for + 3V power supply

MECHANICAL DATA		
ITEM	STANDARD VALUE	UNIT
Module Dimension	80.0 x 36.0	mm
Viewing Area	66.0 x 16.0	mm
Dot Size	0.56 x 0.66	mm
Character Size	2.96 x 5.56	mm

ABSOLUTE MAXIMUM RATING					
ITEM	SYMBOL	STANDARD VALUE			UNIT
		MIN.	TYP.	MAX.	
Power Supply	VDD-VSS	- 0.3	–	7.0	V
Input Voltage	VI	- 0.3	–	VDD	V

NOTE: VSS = 0 Volt, VDD = 5.0 Volt

ELECTRICAL SPECIFICATIONS							
ITEM	SYMBOL	CONDITION		STANDARD VALUE			UNIT
				MIN.	TYP.	MAX.	
Input Voltage	VDD	VDD = + 5V		4.7	5.0	5.3	V
		VDD = + 3V		2.7	3.0	5.3	V
Supply Current	IDD	VDD = 5V		–	1.2	3.0	mA
Recommended LC Driving Voltage for Normal Temp. Version Module	VDD - V0	- 20 °C		–	–	–	V
		0°C		4.2	4.8	5.1	
		25°C		3.8	4.2	4.6	
		50°C		3.6	4.0	4.4	
		70°C		–	–	–	
LED Forward Voltage	VF	25°C		–	4.2	4.6	V
LED Forward Current	IF	25°C	Array	–	130	260	mA
			Edge	–	20	40	
EL Power Supply Current	IEL	Vel = 110VAC=400Hz		–	–	5.0	mA

DISPLAY CHARACTER ADDRESS CODE:																
Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01														0F
DD RAM Address	40	41														4F