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FACULTY OF ELECTRICAL ENGINEERING
(FKE)

BACHELOR ENGINEERING PROJECT REPORT 2

DEVELOPMENT OF INTERNAL PIPE SYSTEM INSPECTION MECHANISM

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DEVELOPMENT OF INTERNAL PIPE SYSTEM INSPECTION MECHANISM

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A report submitted

In fulfilment of the requirement for the degree of Bachelor of Mechatronics Engineering(Hons.)

Faculty of Electrical Engineering

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2016/2017

DECLARATION

"I declare that this report entitles "Development of Internal Pipe System Inspection Mechanism" is the result of my own research except as cited in the reference. This report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : ……………………………………….....

DEDICATION

Dedicated, in gratitude and appreciation for
support and encouragement to my beloved parents,
my sibling, and my friends
for their love and sacrifice

ACKNOWLEDGEMENT

The final year project is a platform for student in gaining new knowledge, industrial training and self-development. First and foremost, highest gratitude to Allah S.W.T for giving me the opportunity to undergo this study and to my parents that always being the consistent supporters for me while completing this course.

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I extend my sincere thanks to all of my fellow lecturers and student whom very supportive and aggressively assisted me directly or indirectly. throughout completing the final year project process.

I quote as this opportunity as a most valuable experience in my undergraduate study progress. I am passionate to use gained skills and knowledge throughout my study, and career progress in the future as well; doing improvement day by day in order to achieve the bachelor course objectives successfully.

ABSTRACT

This report presents a method for a defect detection in pipelines using image processing in vision approach. Standard inspection systems are based on closed-circuit television cameras (CCTV) which are mounted on remotely controlled robots and connected to remote video recording devices. However, the systems are lack of visibility in the interior of the pipes and the poor quality of the obtained images because of unfavorable lighting conditions.

The focus of this research is the development of image processing for detection and location of defects in internal surface of pipelines. The proposed overall system consists of mechanism and image processing parts. The mechanism part including an embedded system of pipe, motor, wheel and power supply. The mechanism is connected to the image processing parts using serial connector and controller. Meanwhile, image processing part functions as the camera obtains images of the internal pipelines and later being processed in Matlab software through several stages which are images input, grayscale conversion, threshold, unwanted object elimination and extraction of pipe image. Defects and anomalies can be detected using analysis of this extracted image.

ABSTRAK

Laporan ini membentangkan satu tatacara bagi mengesan kecacatan dalam saluran paip menggunakan pemprosesan imej dalam pendekatan penglihatan. Sistem penyeliaan biasa adalah berdasarkan kepada kamera televisyen litar tertutp (CCTV) yang digabungkan dengan robot berkawalan jauh dan tersambung ke video rakaman kawalan jauh. Bagaimanapun, sisten ini kekurangan dari segi penglihatan didalam paip dan imej dapatan berkualiti rendah kerana pengcahayaan yang kurang membantu.

Fokus projek ini adalah pembangunan pemprosesan image untuk pengesanan dan menempatan kecacatan di dalam permukaan dalaman paip. Sistem keseluruhan yang diunjurkan mengandungi bahagian mekanisma dan pemprosesan imej. Bahagian mekanisma meliputi paip, motor, roda dan bekalan kuasa. Mekanisma ini disambung kepada bahagian pemprosesan imej menggunakan penyambung bersiri dan pengawal. Manakala, bahagian pemprosesan imej mengandungi imje bahagian dalam paip yang kemudiannya diproses menggunakan Matlab melalui beberapa tingkat iaitu masukan imje, penukaran ke kelabu, dan lain lain. Kecacatan dan kerosakan boleh dikenalpasti dari hasil analisis imej tadi.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Treated tap water is a necessity in daily life in Malaysia. Treated tap water is used for daily activities such as cooking, washing and drinking. The tap water is being distributed from the water treatment plant by underground distribution pipe system to the costumers' household for daily usage started from main supply to branches of pipes in the house.

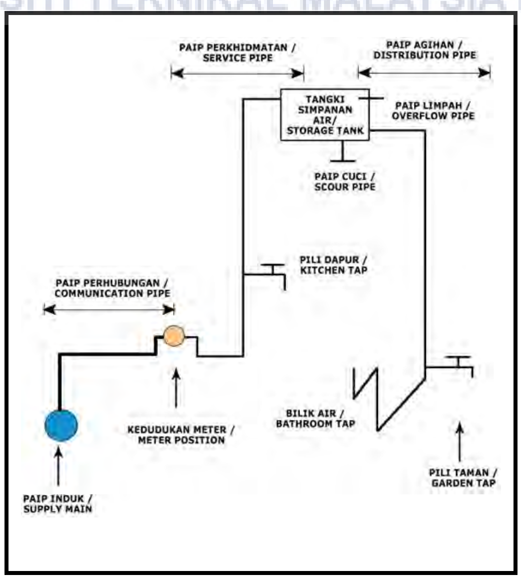


Figure 1.0: The indoor plumbing system in Malaysia [16]

In pipe system, there are a lot of criteria that need to be considered for a reliable and effective distribution system such as operability, economy, process package, safety and maintenance. In maintenance aspect, there are non-destructive inspection methods being used for defects detection and location for the internal pipe system such as ultrasonic, X-ray, dye penetrant, eddy current and visual. These inspection methods are useful in detecting, locating and classifying the defects of pipe system before any further actions to be taken.

Figure 1.1: Visual Inspection System

Lately, visual defect detection become popular as it is an important and complicated task in the computer vision field. It is widely used in engineering sector application like automatic object recognition, fault detection and location, object surveillance activity analysis, and human computer interaction. The advantages of the visual inspection system are the result can be done immediately and helps saving time, minimum training and part preparation needed that will help reduced cost and manpower, and the system is highly portable where it can be easily carried from place to place.

As a student, considering that importance of water in daily life, maintenance in the pipe system, advantages of visual inspection system and condition of pipes that were buried underground that difficult to be accessed, and hidden from visibility for observation, all these factors motivate the development the method of detecting defects in terms of surface and size, which helps to improvise and ease in internal pipe system inspection.

1.2 Problem statement

In Malaysia, most of the houses using PVC, uPVC and seamless steel pipe as the piping system material. As these pipes get older due to its life span, defects cause poor water flow and quality. In an indoor plumbing system, leakage due to defects such as cracks and holes is a common issue due to poor inspection system that leads to tap water wasting. manual inspection method by human have disadvantages such as low accuracy, high cost and time wasting. Less awareness from costumers, no time to take care of the pipe system, lack of knowledge in repairing and replacing the faulty equipment also contributes to ineffective pipe system inspection. Underground leakage also probably occurs and remains not realized until users received the high amount of water bill.

These situations will contribute to wastage of water and financial losses. As the internal piping system is important, it is a fatal burden for users if the system were abandoned and not being taken seriously. The difficulties of accessing the buried pipe underground and the condition of hidden pipe that not visible for observation does contributed to the main problem of internal pipe system inspection process. To overcome these difficulties, a research for the development of image processing in automated pipelines inspection mechanism based on the scanned images of internal pipelines has been developed.

The main efforts of the project are to develop internal pipe inspection based on vision approach, as methods for image pre- processing, segmentation of pipe objects (defects), defects allocation, feature extraction and classification of defects in terms of surface and size. This will help in making an effective and cost-saving preventive actions regarding the maintenance of pipe system in Malaysia.

1.3 Objective

The main objectives of conducting this project are:

1. To develop an internal pipe inspection mechanism based on vision approach.
2. To apply defect detection of internal pipe inspection based on vision approach.
3. To analyse defects in internal pipe system based on surface and size.

1.4 Scope of work

This project scope divided into three part which are literature review on the project of internal pipe inspection based on vision approach, hardware development and software development. The project's scopes are listed as follow: -

1. Comparison of existing journals related to visual inspection system for overview of the internal pipe system inspection.
2. A mechanism embedded with non-adjustable Logitech C170 webcam, which is controlled by the Arduino UNO microcontroller.
3. Speed of DC motor controlled by potentiometer and the direction of the DC motor manipulated using Double Pole Double Throw (DPDT) Toggle Switch.
4. MATLAB as the software, with the Image Region Analyzer Toolbox used to determine the size of the area and Image Processing Toolbox for the image processing and defect detection and location.
5. The system supposedly to detect holes only on UPVC Pipe BS4514 with dimension of 110mm x 2.2mm x 304.8mm.
6. Performance of real time test would vary depending on lighting and shadow limitation. distance from camera to the defects for image capture.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will elaborate the perspective of pipe inspection and methods of vision approach in the existing internal pipeline inspection and related industry. The full understanding of the theory and application from the overview by research done in this chapter is very important to successfully develop a method and doing analysis later on in the project.

2.1 Pipe Inspection System Development

Many of pipelines are damaged due to long time usage, extreme demand, embezzle, incomplete construction, poor management and deterioration. Limitations in accessing the pipe system are the reasons why maintenance of pipe system is almost abandoned; later causing a major failure, lead to troublesome and high cost repairs.

The seriousness of poor maintenance actions for pipe system is obvious. As reconstruction of the pipeline system is not cost effective, a consistent periodical pipe system inspection execution is needed. Thus, pipe system inspection methods are compulsory so that proper maintenance and conservation programs for pipe system can be done. These programs will indicate the preventive actions and precautions needed so the pipe system is repaired before its fully dysfunctional later on in the future.

Video images of internal pipelines are examined using image processing techniques and the damages are classified later on. Camera is for monitoring pipe defects in long range of pipeline images replacing the human limited observation ability such as exhaustion and inaccuracy. In addition, manual inspection for surface defects in the pipeline has a number of disadvantages, including mechanisms, huge amount of manpower, and inspection time consumption.

Pipe inspection is a must in the pipelines maintenance either external pipe, internal pipe and different size of pipe inspection. The use of current CCTV inspection techniques is not fully sufficient for further maintenance plans to inspect the pipe-downfall process, that begin with the small primary structural imperfections [13] Alternative pipe inspection methods such as infra-red thermography and ground penetrating radar, are under study as the pipe inspection methods but does not results the same output as the visual inspection technique (CCTV based).

Many pipe system inspection methods which are able to bear the weakness of the visual inspection system (CCTV based) methods have been created. [14] The KARO robot is a mechanism with a camera analyses light rings radiated onto internal surface of pipe for pipe deformations and obstacles detection. [15] Consequently, to these existing methods for pipe inspection systems, as in this project, student needed to design and develop internal pipe inspection mechanism involving mechanism construction and implementation of defect detection on the pipe surface using vision approach.

2.2 Existing Journals on Image Processing Methods in Internal Pipelines Inspection Mechanisms

These days, development of visual defects detection system shown that there are many other methods as implementation of novel algorithm method and intensity analysis, (single profile approach) one-lens system, largest variance comparison and prominent method, comparison between saved pictured and raw picture by calculating color percentage and simple image processing method (high in accuracy, speed, objectivity and consistency).

These methods are reliable but still to figure out the best method, comparison need to be made considering the limitation and advantages of these system. Below is the comparison of ten (10) selected journals related to image processing in student's final year project prospects.

As results of the comparison of journals below, student successfully being able to identify, understand, analyze and choose the proper method to proceed and come out with some improvement in the project. In the methodology section later, further explanation on the project will be carried out.

Table 2.0: Comparison of Journals

Authors	Proposed Methods	Processes
M. S. Safizadeh & T. Azizzadeh, 2012 [1]	CCD camera/laser diode Novel method for image extract and analysis	Image extraction Intensity adjustment Median filter Canny edge detector Intensity diagram
Olga Duran, Kaspar Althoefer & Lakmal D. Seneviratne, 2002 [2]	Intelligent classification stage Novel algorithm for intensity distribution along projected ring	Image segmentation Signal Conditioning Ellipse extraction – conic fitting Feature Extraction
Wondae kim, Hwan Kook Hwang & Myung Jin Chae, 2007 [3]	One lens system Digital camera and mirror system Image mosaic Laser distance meter	Distance calibration Registration Distortion calibration Side view unwrapping Stitching
Nur Afiqah Binti Haji Yahya, Negin Ashrafi, & Ali Hussein Humod, 2014 [4]	Largest varience comparison Feature prominent method Pre-treatment image with high quality	-not mentioned-

Table

2.0: Comparison of Journals – Continue-

Authors	Proposed Methods	Processes
S.A.I. Stent, C. Girerd , P.J.G. Long & R. Cipolla [5]	Rotating camera array Lightweight capture unit Pre-treatment image with high quality	System reconstructing Image mosaicking for condition inspection Cataloguing segments using barcode detection
Mayuri Dharma Shinde, 2014 [6]	Preprocessing Defect and pipe extraction Defect detection and identification	Image pre processing Extraction of pipe Defect detection and identification
Sang Wook Lee, [7]	Defect recognition method	Image acquisition Image processing Data analysis • Eigenvalues generation • Image comparison

Table 2.0: Comparison of Journals – Continue-

Authors	Proposed Methods	Processes
Mira Park, Jesse S. Jin, Sherlock L. Au, Suhuai Luo & Yue Cui, 2009 [9]	Algorithm using image processing Morphology operation	Counting objects in input image Color based segmentation of region of interests Identification of individual objects Defect identification Mask image creation Segmentation Defect detection and location
Mayuri Dharma Shinde & Kishor Wane, 2016 [8]	RGB to grayscale image conversion Extract pipe Detects and identify the defects	Input image acquisition Grayscale image conversion Threshold effects Unwanted noise elimination Extraction of pipe Defects detection and identification
N. M. Z. Hashim, N. H. Mohamad, Z. Zakaria, H. Bakri & F. Sakaguchi, 2012 [10]	Comparison between reference image and input image captured Calculating color percentage	Image detection Image comparison Color maps Display color Acquiring image form webcam in Matlab Calculation of image color GUI creation

2.3 Existing Journals on Image Processing Methods in Internal Pipelines Inspection Mechanisms Description.

From the previous study, there are several methods on internal pipe system inspection on visual approach. Some of the method used are Novel methods for image extract and analysis [1] and [9] and for intensity distribution along projected light ring [2], comparison between reference image and input image captured [10] and largest variance comparison method [4], image preprocessing method, extraction and defect detection and identification [6] and [8], data analysis using eigenvalues generation and image comparison [7], image mosaic from one lens system [3] and image mosaic from rotating camera array [5].

Comparison methods are used to determine the defects in products; based on the reference image color properties from color matching process with input image and with a value of percentage, the image will be classified in its grade [10]. Also, the defect detection using CCD camera and light ring does detect the defects in the internal pipe; by analyzing the light intensity through stages such as intensity extraction logarithm and intensity diagram [1] and ellipse extraction – conic fitting, gradient method for feature extraction [2]. In [3] and [5], image mosaic method take place, as the manipulation of one lens system and rotating camera array for the image analysis. These methods have its own advantage and disadvantage; however, the most important factor is the result successfully achieved the objectives of the project.

For defect detection and identification, the [6] and [8] successfully shown the steps on how the results being carried out from several steps of image processing processes such as input image acquisition grayscale image conversion, threshold effects, unwanted noise elimination, extraction of pipe and at last, the defects detection and identification.

As conclusion, a proper method of defects detection in internal pipe system mechanism based on visual approach will be developed based on [8] as the stages are much easier to be understood and in terms of surface, the defect can be detected and located. In addition to that, the idea for defects classification (hole or crack) has been proposed in this journal, as will be carried out in this project

2.4 Description on Defect Properties.

2.4.1 Surface of uPVC Pipe

A white uPVC pipe has a mirror-smooth internal surface, where the surface contributes to minimum flow head loss in the internal sides of the pipe. Any defects or damage in the internal pipe will cause the flow head loss and yet influence the pressure of the water flow. Less pressure in the water flow, the water will run slow. Below are the factors that will affect flow head loss in internal pipe, regarding the surface of the internal pipe: -

i. Internal diameter of the pipe

The diameter size of internal pipe influenced the flow head loss in the pipe. As size of pipe's diameter is large, flow area will increase and the velocity of the water will reduce. This will lower the loss because of the friction reduction on the pipe surface. Likewise, with smaller internal pipe diameter, decrement of flow area will happen and cause the water velocity become faster. As result, the friction to the surface will be higher and head flow loss will increase. Below is the relation or formula for the diameter and flow rate calculation: -

$$v = q/A = 4q/D^2 . \pi,$$

Where is D – internal pipe diameter
q – volumetric flow rate
v- velocity
A – pipe cross section area

ii. Roughness of the pipe surface

The boundary layer of liquid's thickness is influenced by internal pipe surface's roughness. The resulting reduction in flow area increases the velocity of the liquid and increases the head loss due to friction. The analysis of internal pipe inspection system will help the user to manage the increment of internal surface diameter because of buildup deposits from dirt or oil, or the uneven surface of the uPVC internal pipe due to crack, holes and corrosion on the surface of it.

2.4.2 Defects' Size Estimation

Estimation of defects size is important in order to classify the defects and to calculate time to dysfunctional. This can be done after a successful rectitude evaluation, or using conservative assumption. However, in this project the defect will only being analyze and evaluated by its area and eccentricity of its image processed by the Matlab software later. The area property in Matlab, result a scalar that specifies the pixel number of the region have. The calculation of area of a binary image is as follow: -

Table 2.1: Image Labeled Component

0	0	0	0	0	0	0	0
0	0	1	0	0	1	1	0
0	1	1	0	1	1	0	0
0	0	1	1	1	1	0	0
0	1	1	1	1	0	0	0
0	0	0	0	0	2	2	0
0	0	0	0	2	2	2	0
0	0	0	0	0	0	0	0

From the table above, for component of image 1 the area is the actual pixels that the region has which is 15. Meanwhile for the image 2, the area is 5.

Meanwhile, the eccentricity is the ratio of the distance between the foci of the ellipse (a) and its major axis length (c). The value of eccentricity is between 0 and 1 where the value of getting exactly 0 and 1 is special case. An ellipse whose eccentricity is 0 is actually a circle, while an ellipse whose eccentricity is 1 is a line segment. Below is the figure of an ellipse labeled for each elements for determining the eccentricity of an ellipse.

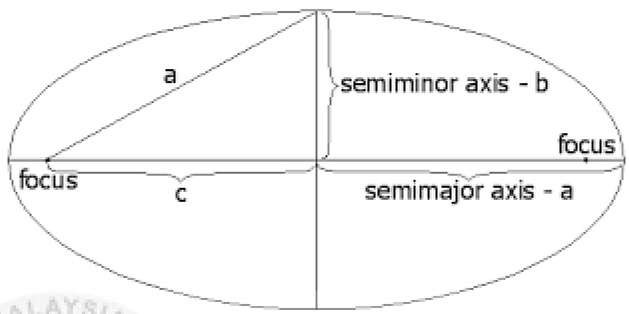


Figure 2.0: Ellipse label

Later the area and eccentricity of the defects been calculated, and the defects being classified based on the eccentricity value, either hole or crack.

2.5 Hardware Review

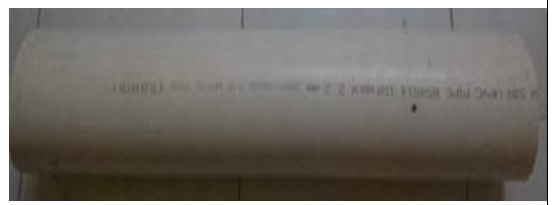
It is important to make a proper selection of hardware for the project, as it will result better outcome and analysis. In this project, Logitech C170 Webcam with 5MP photo quality and 1024x768 pixel video capture embedded with mechanism driven by 3V DC motors and controlled by Arduino Uno microcontroller, using Arduino IDE as the coding compiler that alter to be uploaded to Arduino for execution process. “Unplasticized PVC” (uPVC) is used as the material for project’s defects detection in internal pipe system, in terms of surface and size.

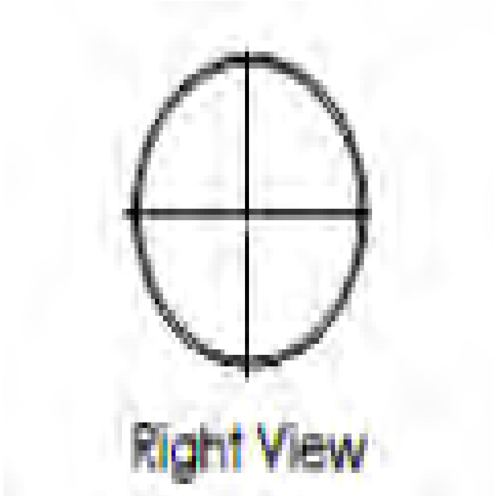
2.5.1 uPVC Pipe Material

uPVC pipe is one of the most common element used in creating the pipe system. “Unplasticized Polyvinyl Chloride” (uPVC) is based on polyvinyl chloride (PVC) that undergone through a formulation to become uPVC so that the flexibility, recyclability and weather resistant characteristics can be achieved. Also, they are resistant to chemical or electrochemical corrosive like metallic corrosion and due to its non-conductor characteristic, uPVC is not affected by the galvanic and electro chemical effects.

In addition, uPVC is neutral as it is tasteless and odorless, and inert so that it is safe for a material for pipe system. In this project, the white uPVC pipe is used for the hardware as it has the mirror-smooth internal surface, any defects occurred in on the surface can be easily found out by the camera for image acquisition section. Due to small diameter of the size uPVC pipe, the size of the defect can be determined and estimated by using the Matlab software later in image processing section. Below is the diagram of the UPVC Pipe BS4514 (110mm x 2.2mm x 304.8mm) surface for defects detection used in this project: -

Table 2.2: White color uPVC pipe

View	Pipe Surface Sketch	Actual Pipe Surface
Top	 Figure 2.1 (a) Top view of pipe sketch	 Figure 2.1 (b) Top view of actual pipe
Front	 Figure 2.2(a) Front View of pipe sketch	 Figure 2.12(b) Front view of actual pipe

Side	 Figure 2.3 (a) Right view of pipe sketch	 Figure 2.3 (b) Right view of actual pipe
Isometric	 Figure 2.4 (a) Isometric view of pipe sketch	 Figure 2.4 (b) Isometric view of actual pipe

2.5.2 Logitech Webcam C170

The camera selection is also important so that the quality of the image capture is at its best and clear enough for the next image processing stages. In this project, due to cost aspect, the Logitech Webcam C170 is selected as its features is suitable for the minimum requirement for the project. Logitech Webcam C170 is a web camera with connectivity of USB 2.0. Made with the Logitech's Fluid Crystal Technology; equipped with VGA sensor supports video calling at 640 x 480 resolution. This webcam capture video at 1024 x 768 resolution and embedded with built-in microphone with noise reduction. In addition, this webcam is able to capture image up to 5Mp with Logitech software assistance. Below is the image of Logitech Webcam C170: -

Figure 2.5: Logitech C170 Webcam

2.5.3 3V DC Motor

In this project, DC motor is used to move the mechanism from one point to another. In brief, DC motor is a component that converts the electrical energy to mechanical energy by using the principal of electromagnetic field cutting by the armature whenever the current flows in according to the Fleming's left hand rule. Later in circuit design, the speed and direction of the DC motor rotation will be manipulated using PWM concept by Arduino Uno. Below is the 3V DC motor and its specification: -

Figure 2.6: 3 V DC Motor

Table 2.3: 3V DC Motor Specification.

Product Name:	3V DC Motor
Rated voltage:	2.4V - 3.0V DC
Speed at free run:	225
Current at free run:	1.6 – 2.0A
Rated torque:	1.0 – 1.3 nM.m
RPM:	14300-17400 r/min

2.5.4 5V AC-DC Power Supply Adapter

Arduino Uno and most of the electronic components used in this project are requiring the DC power supply, so that it can operate at its optimum state. A 5V AC-DC power supply adapter supply 5V of direct current supply (DC supply) for the circuit and ensure protection from excessive power supply, heat and electrical noise reduction. Below is the 5V AC-DC power supply adapter being used in the project and its specification: -

Figure 2.7: 5V 1A AC to DC Power Supply Adapter (MOSO)

Table 2.4: 5V 1A AC to DC Power Supply Adapter (MOSO)

Product Name	5V 1A AC to DC Power Supply Adapter (MOSO)
Input Voltage:	AC Supply 100V-240V 50/60Hz
Output Voltage:	DC Supply 5V
Output Current:	1A

2.5.5 Arduino Uno

There are many controllers board out in the market, such as Arduino by Atmel Corporation and Raspberry Pi with Arm Processor. Arduino Uno is chosen in this project, as Arduino IDE as its operating system. With the affordable price, Arduino Uno comes with the PWM function, that able for DC motor speed and direction control and simple circuit built, such as lighting the LED and servo motor angle manipulation. Below is the Arduino Uno used and its specification: -

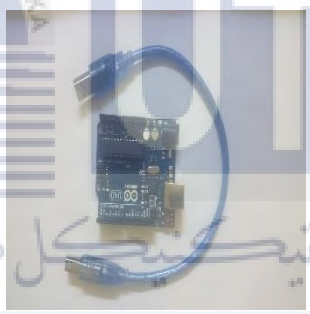


Figure 2.8: Arduino Uno

Table 2.5: Arduino Uno

Product Name:	Arduino Uno
Microcontroller:	ATmega328
Operating Voltage:	5V
Input Voltage (recommended):	7-12V
Input Voltage (limits):	6-20V
Digital I/O Pins:	14 (of which 6 provide PWM output)
Analog Input Pins:	6
DC Current per I/O Pin:	40 Ma
DC Current for 3.3V Pin:	50 Ma
Flash Memory:	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM:	2 KB (ATmega328)
EEPROM:	1 KB (ATmega328)

Clock Speed:	16 MHz

2.5.6 Toshiba C800

Toshiba C800 is used as the platform for the software to run, as the computer itself is a n electronic device that consist of input output hardware such as monitor, keyboard and webcam; processor as the brain of the computer, memory for data storage and the motherboard for data processing. Capability of the computer to process data in a fast manner, will save time and space for the operation of the project to be successful. Below is the Toshiba C800 and its specification:

Figure 2.9: Toshiba C800

Table 2.6: Toshiba C800 Specifications

Product Name:	Toshiba C800
Windows Edition:	Windows 10 (64-bit), ver. 1607
Processor:	Intel (R) Pentium (R) CPU 2020M @ 2.40 GHz
Internal Storage:	500MB
RAM:	6.00 GB
Display Adapter:	Intel (R) HD Graphics
Audio:	Intel (R) Display Audio

Also, there are several electronic components being used in the circuit building as follow: -

1. 20k Potentiometer (B-20k 3PIN VR)
2. Male to Male Jumper Wire (40Px200MM (Double Head) 40Way)
3. 2.2k Ohm Resistor
4. 2N 2222 Transistor
5. DO-41 1A 400V Diode (IN 4004)
6. Single Core Cable
7. Breadbox
8. PCB

The hardware selection of the project made based on the cost, features and the most suitable approach for the project to be done. In the methodology section, the assembly of the mechanism and the image processing development will be explained further.

2.6 Software Review

Software is a data of computer instruction, or an interface between hardware and the computer. In this project, several software was used such as Multisim, Arduino IDE, Solidworks and Matlab. All the software is necessary for compiling the coding for Arduino to run, doing electronics design and simulation process, mechanism design and image processing development. Despite of many similar types of software within the features, these above are the software that widely used in the industry and technical field with their unique and helpful features that help this project to be done successfully.

2.6.1 Multisim

In this project, Multisim is used as the software for circuit creation, simulation and testing of the mechanism's circuit. Multisim is easy to be use, convenient interface and user-friendly simulator. In general, Multisim is a SPICE simulation environment and the Multisim design approach ease user to save the working process and optimize printed circuit board (PCB) designs to the highest potential. However, there is no Arduino component in Multisim library, and users are highly recommended to use Fritzing or Eagle software for Arduino circuit design. Below is the interface of the Multisim: -

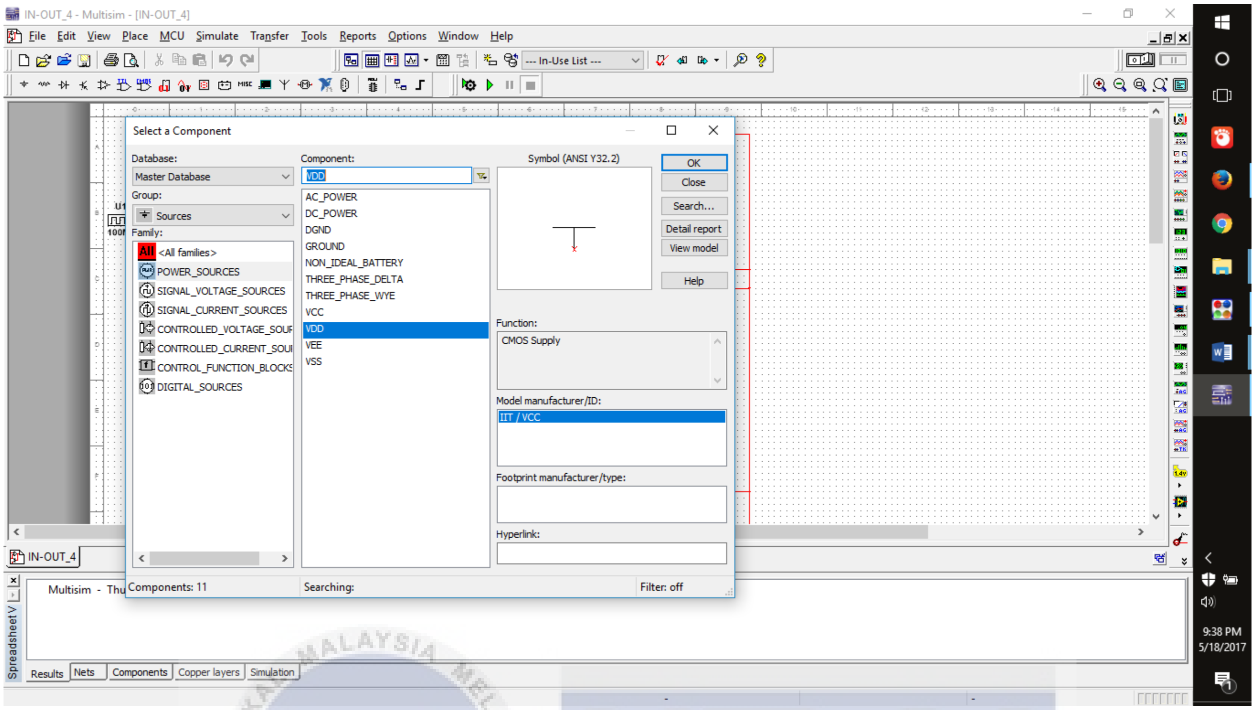


Figure 2.10: Multisim User Interface

2.6.2 Arduino IDE

Meanwhile, Arduino IDE (Integrated Development Environment) software is used to write, compile for error checking and code upload process and serial monitor observation in the circuit. Arduino IDE can be downloaded from the Arduino developer website for free and kept updated time by time. Below is the interface of Arduino IDE: -

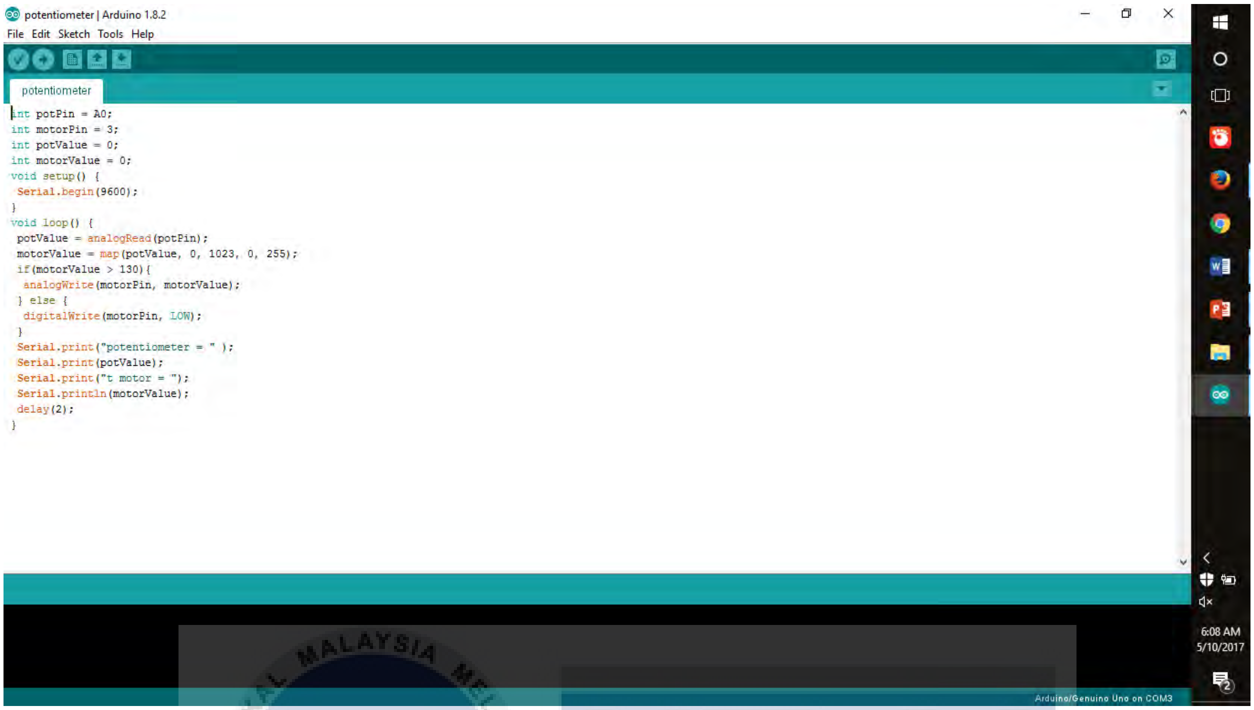


Figure 2.11: Arduino IDE User Interface

2.6.3 Solidworks

In this project, a mechanism has been designed for internal pipe inspection using Solidworks software. Solidworks software is a platform of MCAD and CAE for users to do modelling. It is a solid modeler, and utilizes a parametric feature-based approach to create models and assemblies. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. It can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Below is the user interface of Solidworks: -

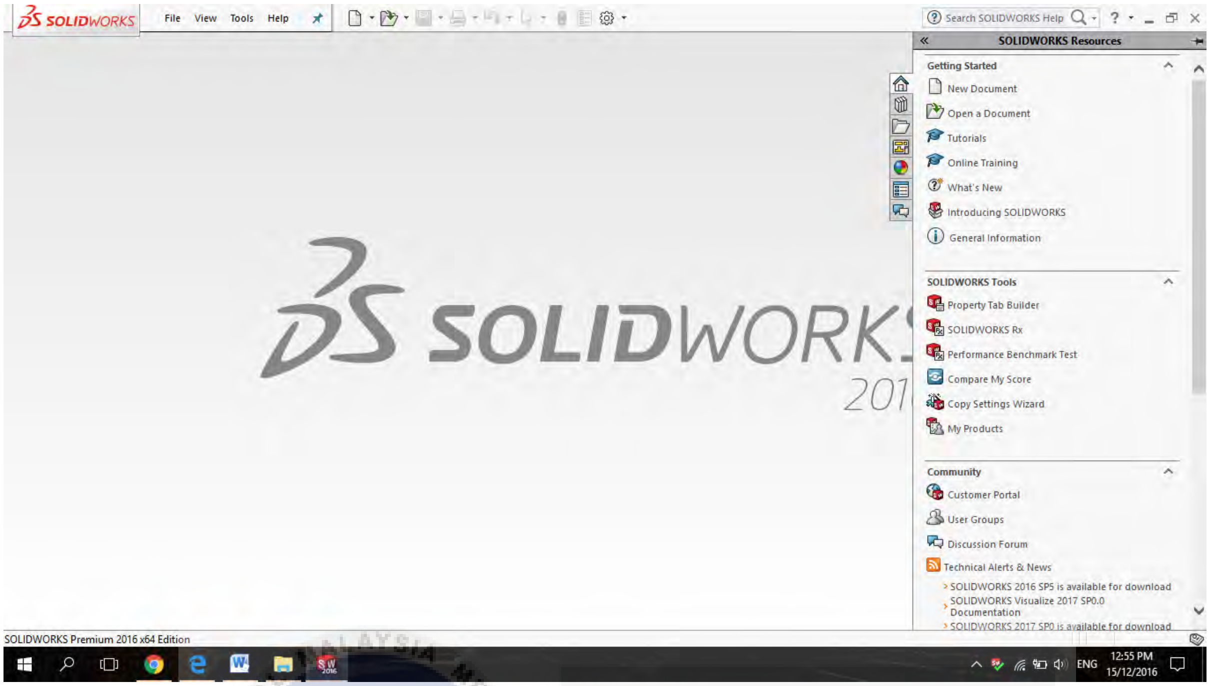


Figure 2.12: Solidworks User Interface

2.6.4 Matlab

MATLAB is used for the image processing in this project, as Image Region Analyzer Toolbox and Image Processing Toolbox are the components needed for the purpose. However, to connect the C170 Logitech webcam and being recognized by the Matlab interface, additional driver and interface are need which are “dcamhardware” and “osgenericvideointerface”. In general, Matlab using a high-generation programming language and numerical analysis environment. MATLAB is capable to do math, statistic and optimization; control system design and analysis; signal processing and communication; image processing and computer vision; and test and measurement. As the common, widely used software in industry, with wonderful applications and features, Matlab allows developers to interface with programs of different languages, which makes it easy for the maximum usage of image processing development in this project. Below is the interface of Matlab: -

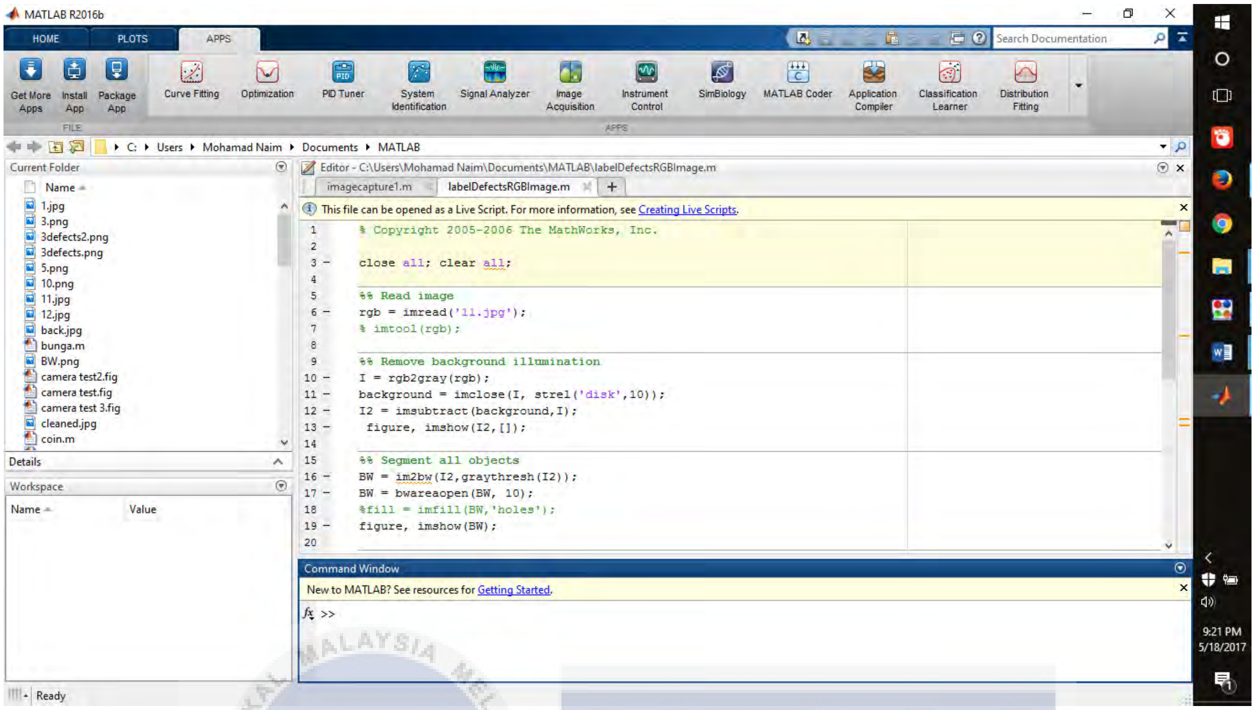


Figure 2.13: Matlab User Interface

2.7 Image Processing on Internal Pipelines Inspection

In brief, digital image processing focuses on two major tasks which are improvement of pictorial information for human interpretation, processing of image data for storage, transmission and representation for autonomous machine perception. These leads to some arguments about where image processing ends and fields such as image analysis and computer vision start. There are key stages (summaries) of the digital image processing as follow: -

2.7.0 Image Acquisition

Defined as production of photographic images, usually involving image sensors and light-sensitive cameras, include range sensors, tomography devices, radar and ultra-sonic cameras. The resulting image data is an ordinary 2D image, a 3D volume, or an image sequence depending on the equipment type used.

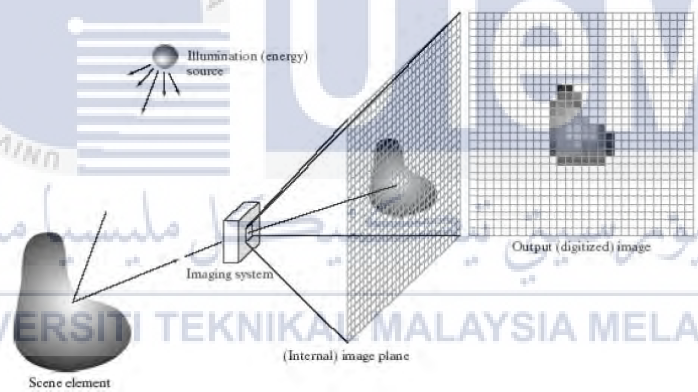


Figure 2.14: Image acquisition diagram. [11]

2.7.1 Image Enhancement

Process of making images more useful. Image enhancement usually done for the purposes of highlighting interesting detail in images, removing noise from images and making images more visually appealing. There are two broad categories of image enhancement techniques which are spatial domain techniques that implement the direct manipulation of image pixels and frequency domain techniques which manipulate on Fourier transform or wavelet transform of an image.

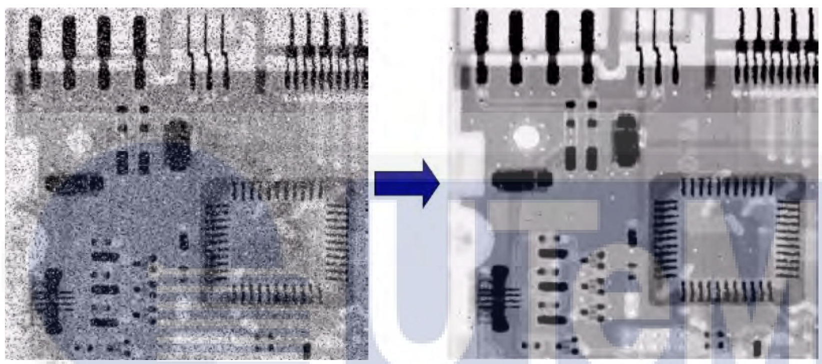


Figure 2.15: Image Enhancement Result [11]

2.7.2 Image Restoration

In contrast to image enhancement, in image restoration the degradation is modelled. This enables the effects of the degradation to be (largely) removed. Image degradations elements are 1) original, 2) optical blur, 3) focus blur, 4) motion blur, 5) spatial quantization (discrete pixels), and 6) additive intensity noise. Several methods used in the image restoration such as 1) The inverse filter (deconvolution/noise amplification), 2) The Wiener filter (motion/focus deblurring) and 3) Maximum a posteriori (MAP) formulation (super resolution output/ blind deblurring). The application of image restoration can be seen in rotating DV camera and reading car's number plate in law enforcement.

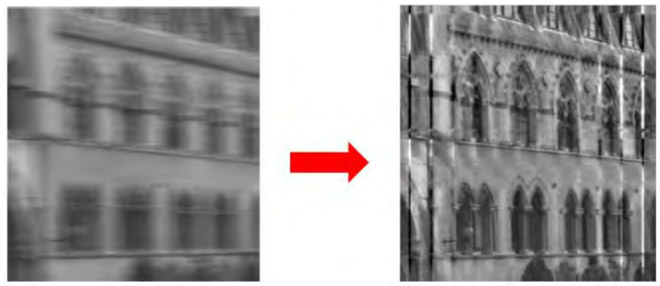


Figure 2.16: Motion deblurring using Weiner filter method example [11]

2.7.3 Morphological Processing

Constructed with operations on sets of pixels where binary morphology uses only set membership and is indifferent to the value, such as gray level or color, of a pixel (structuring element). This process involving the pixel location and set operation (union, intersection, difference and reflection), dilation and erosion, boundary extraction (opening and closing) and region filling.

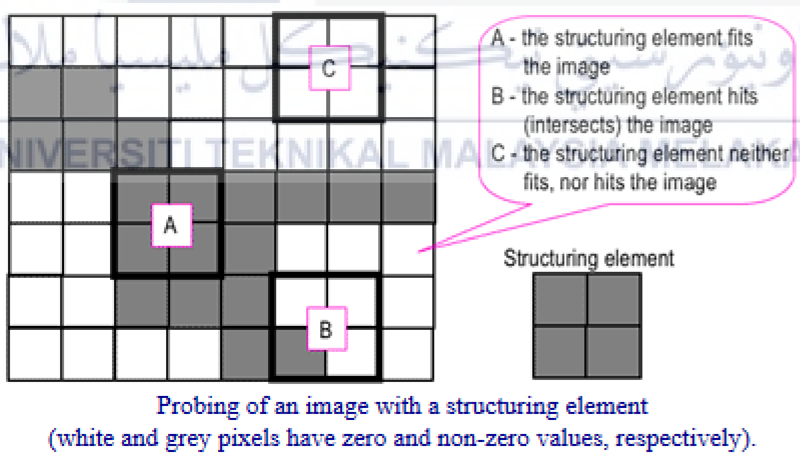


Figure 2.17: Diagram on pixel location and set operation. [11]

2.7.4 Segmentation

Segmentation is to subdivide an image into its constituent regions or objects and should stop when the objects of interest in an application have been isolated. This process extract attributes (objects) of interest from an image including points, lines and regions. Common properties considered in segmentation are discontinuities and similarities where several approaches considered in this process such as 1) Point and line detection (Edge linking), 2) Thresholding methods (Histogram, adaptive) and 3) Region growing and splitting.

Figure 2.18: Edge based segmentation sample [11]

2.7.5 Object Recognition

Processing images to derive information about various structures within the image (area of object, perimeter, number of objects). Usually, given an image containing one or more objects of interest (and background) and a set of labels corresponding to a set of models *known* to the system, the system should assign correct labels to regions, or a set of regions, in the image. Below is the diagram of stages (feature detector, hypothesis formation, model base and hypothesis verification) and components (image, features, candidate objects, object class) of image recognition process.

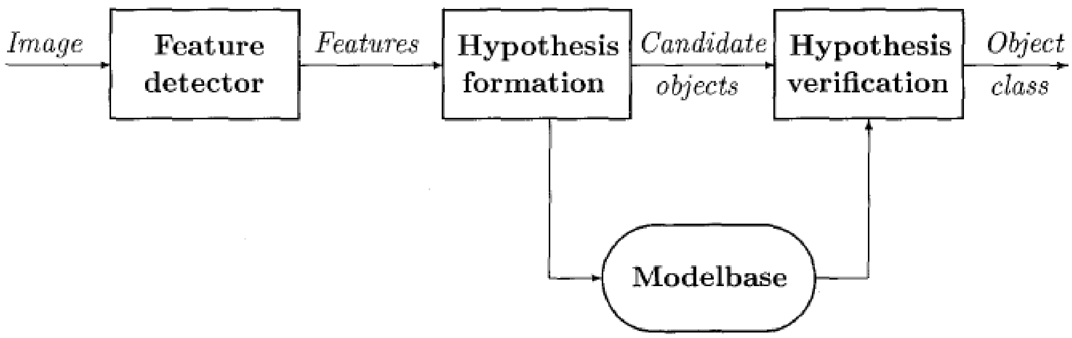
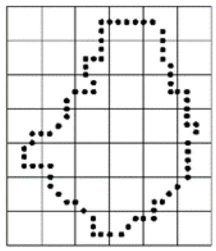
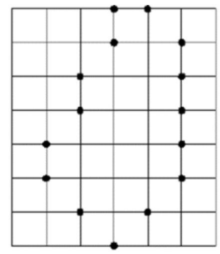
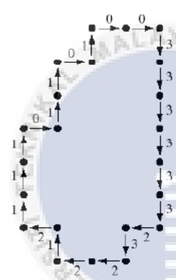
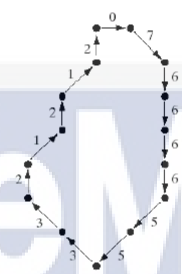


Figure 2.19 Stages and components of image recognition system [12]

2.7.6 Representation and Description

Representation used to make the data useful to a computer and the further process (description). This process representing region in 2 ways; first, in terms of its external characteristics or boundary that focus on shape characteristics. Secondly, in terms of its internal characteristics or region that focus on regional properties, e.g., color, texture. However, sometimes both ways may need to be used depending on the situation. Description describes the region based on the chosen representation. For instance, the description of a boundary (as chosen representation) are length of the boundary, orientation of the straight line joining its extreme points, and the number of concavities in the boundary. Methods used in this process are 1) Merging/Splitting techniques 2) Descriptors (Boundary, Fourier, Regional, Simple and Topological)

Table 2.7: Chain Codes application in digital image presentation [12]

 a) Digital boundary with resampling grid superimposed	 b) Result of resampling
 c) 4 - direction chain code	 d) 8 - direction chain code

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

This section provides technical solution that fulfill the functional factors required for the system's mechanism. This includes the study of development on internal pipe inspection mechanisms and defect detection based on vision approach. The development of this project consists of three main parts. The first part is basically on literature review followed by the software and hardware development.

3.1 PROJECT PLANNING

As referred to Figure 3, the project development is started on literature review where a small research on the theory and applications on anything that related to the internal pipe inspection mechanisms. It is an important part in order to collect the information from published materials and resources. Secondly, the mechanism development focuses on the mechanism that carries the camera for the image capture process. The next part focuses on the software development where the image processing processes takes place in MATLAB programming followed by hardware development of the project. The analysis of defect detection and allocation, area and eccentricity value used as the outputs for the project. Below is the project planning flowchart, from the initial stage to the final stage of the project: -

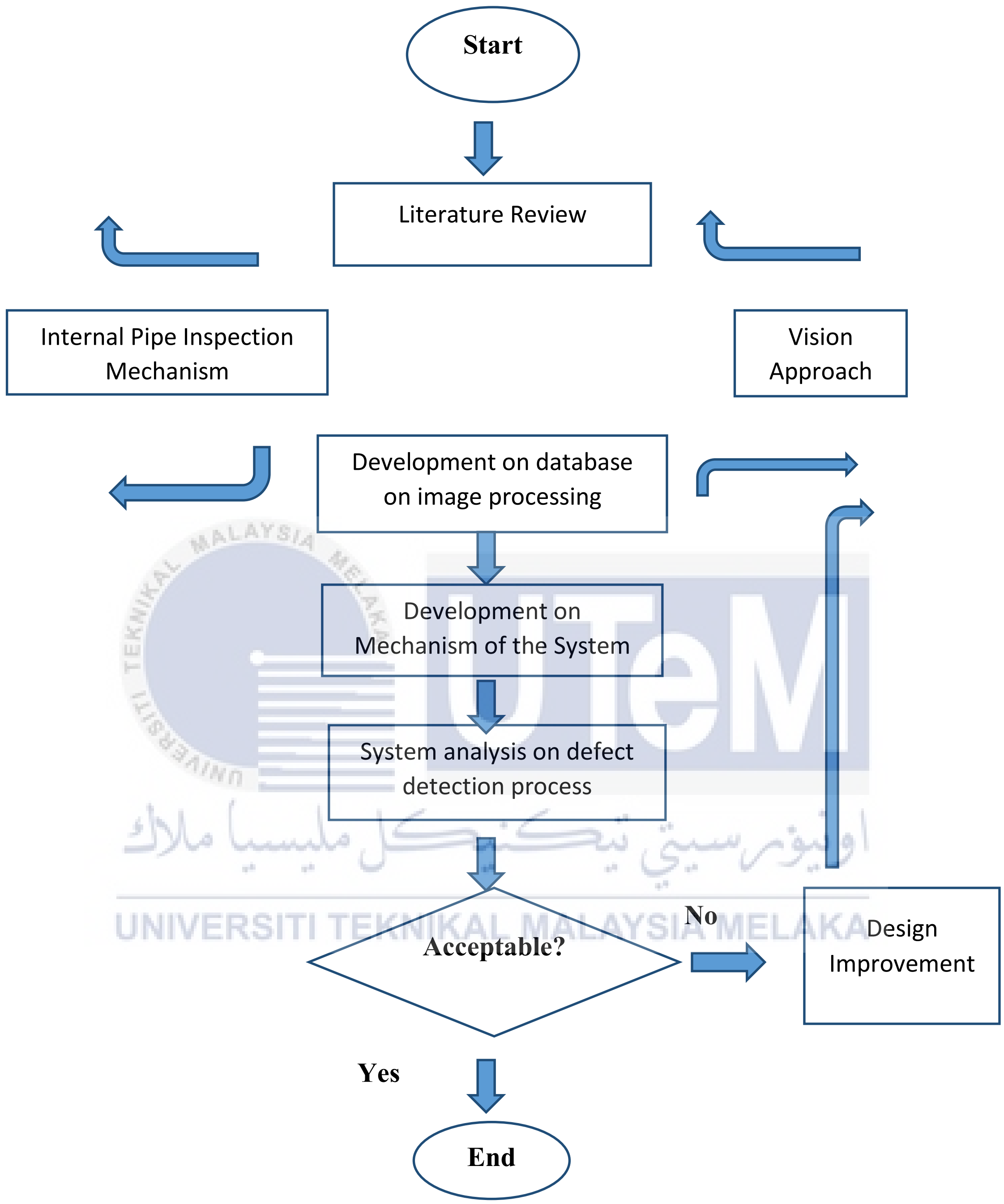


Figure 3.0: Project Planning Flowchart

3.2 PROJECT OVERVIEW

Figure 3.2 shows an overview of the system. The input image which is captured using integrated webcam by the mechanism controlled by Arduino UNO microcontroller that consist of mechanism frame prototype building, electronics circuit design and simulation; and later on the frame, electronics circuit and camera installation and assembly process is transferred to MATLAB programming for the image processing processes. The data from image processing will be analyzed and defect detection will be produced as the output of the system.

Figure 3.1: Project System Overview

3.3 MECHANISM DEVELOPMENT

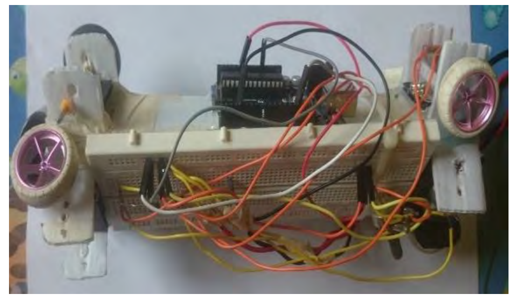
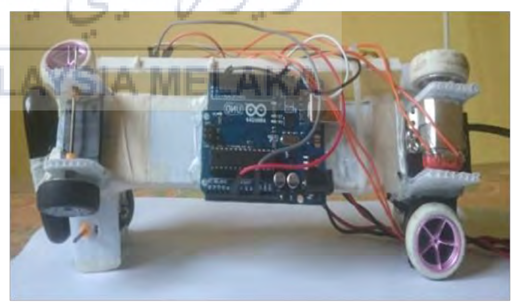
3.3.1 MECHANISM DESIGN

Before starting the design process, many factors need to be considered such as material, components and software/hardware selection. By using a 110mm x 2.2mm UPVC pipe as the reference, a purposed design of mechanism frame using Solidworks software has been produced and using mild steel as the material. However, for the prototype for the next demonstration, a slight change for the mechanism frame has been done for simpler and easier operation in assembly purpose.

3.3.2 Prototype Frame of Mechanism

Using the corrugated board plastic, the prototype of the mechanism is made. By having 12 pieces of 25mmx35mm, glued to the end sides of 3 set of 40mmx210mm joined to a shape of cylindrical pyramid, a sample frame of the mechanism was obtained as figure below: -

Table 3.0: Comparison between prototype sketch and actual prototype

View	Prototype Sketch	Mechanism Prototype
Top	 Figure 3.2 (a) Top view of Mechanism Sketch	 Figure 3.2 (b) Top View of Mechanism Prototype
Front	 Figure 3.3 (a) Front View of Mechanism Sketch	 Figure 3.3 (b) Front View of Mechanism Prototype

Side	 Figure 3.4 (a) Right View of Mechanism Sketch	 Figure 3.4 (b) Right View of Mechanism Prototype
Isometric	 Figure 3.5 (a) Isometric View of Mechanism Sketch	 Figure 3.5 (b) Isometric view of Mechanism Prototype

3.4 MATERIAL AND DEFECTS SETUP

In this project, 3 holes of 3.2mm diameter are drilled on the different spot of UPVC Pipe BS4514 (110mm x 2.2mm x 304.8mm) surface for defects detection.

Figure 3.6: Hole on the pipe surface

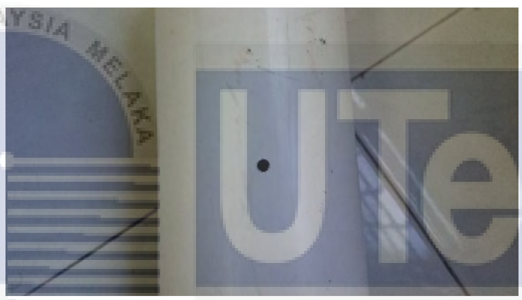


Figure 3.7: Hole on the pipe surface

Figure 3.8: Internal Pipe Holes View

3.5 MECHANISM DEVELOPMENT METHOD SECTION

3.5.1 Circuit Design and Implementation

All the electronic components have been used for the circuit design using the Multisim and the being simulate for the operation. At first, the design process of the circuit is implementing the idea of speed control using a potentiometer as the potentiometer will manipulated the voltage out for the motor to use as the input voltage. An input power of 5V is supplied to the 10k ohm potentiometer, and then connected to 2N222 transistor and 1N4004 diode. To understand the function of potentiometer, a voltmeter with ohmmeter setup is connected to the potentiometer before the ground. Then the value of resistance at 10 % of potentiometer and 50% and 70% is taken, indicating as the value of percentage of potentiometer is increased, the resistance value is also increasing; causing the output voltage to also increase. This corresponding to the speed of the DC motor later in the assembly process as the greater voltage in, the faster DC motor will rotate. The initial circuit is as below: -

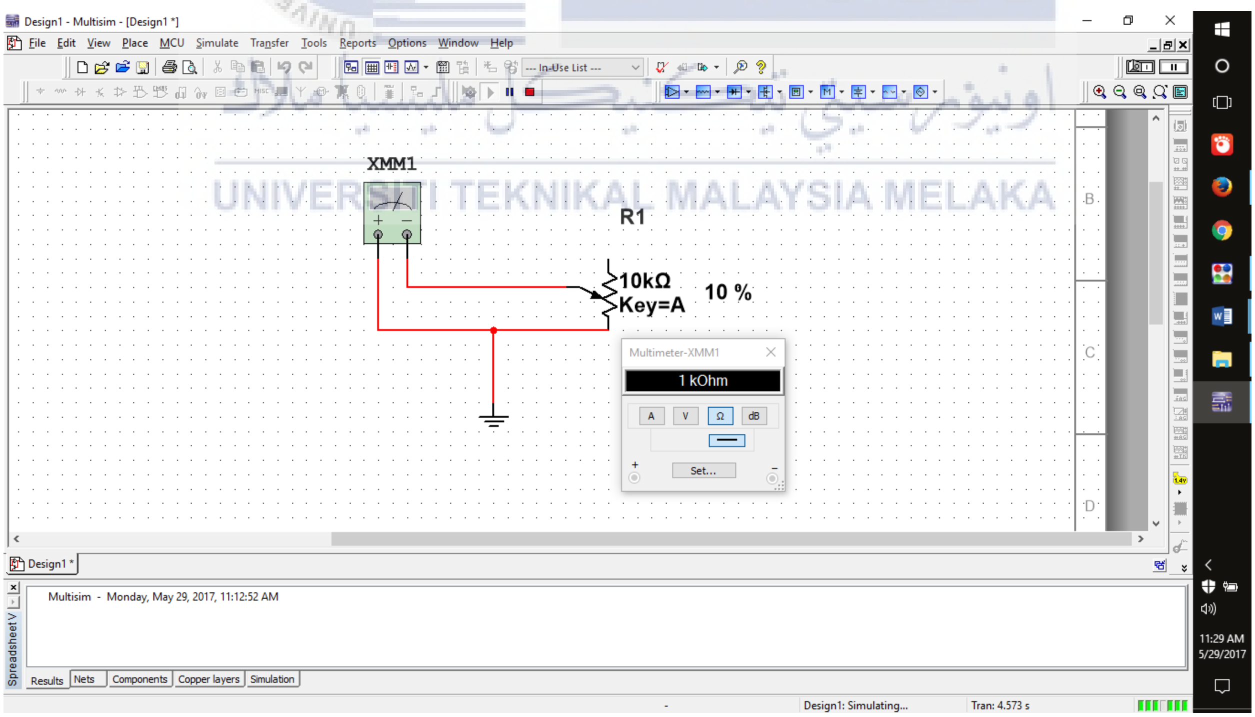


Figure 3.9: Ohmmeter output at 10% potentiometer in Multisim

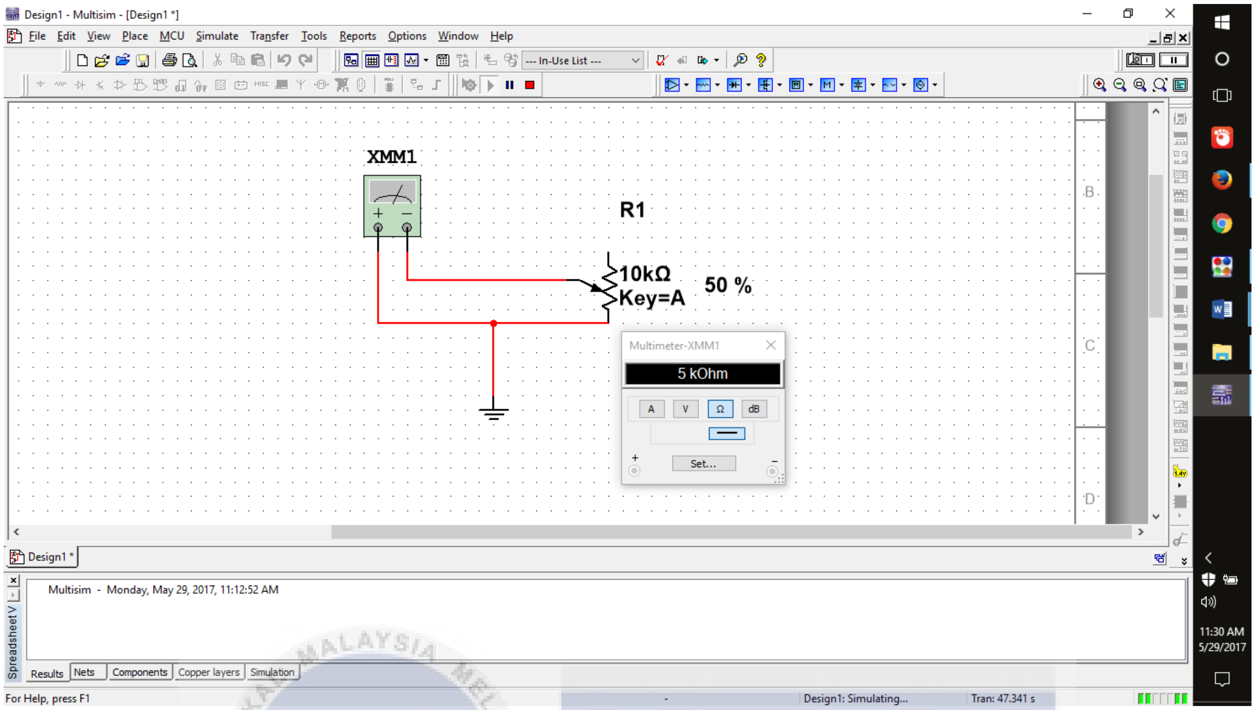


Figure 3.14: Ohmmeter output at 50% potentiometer in Multisim

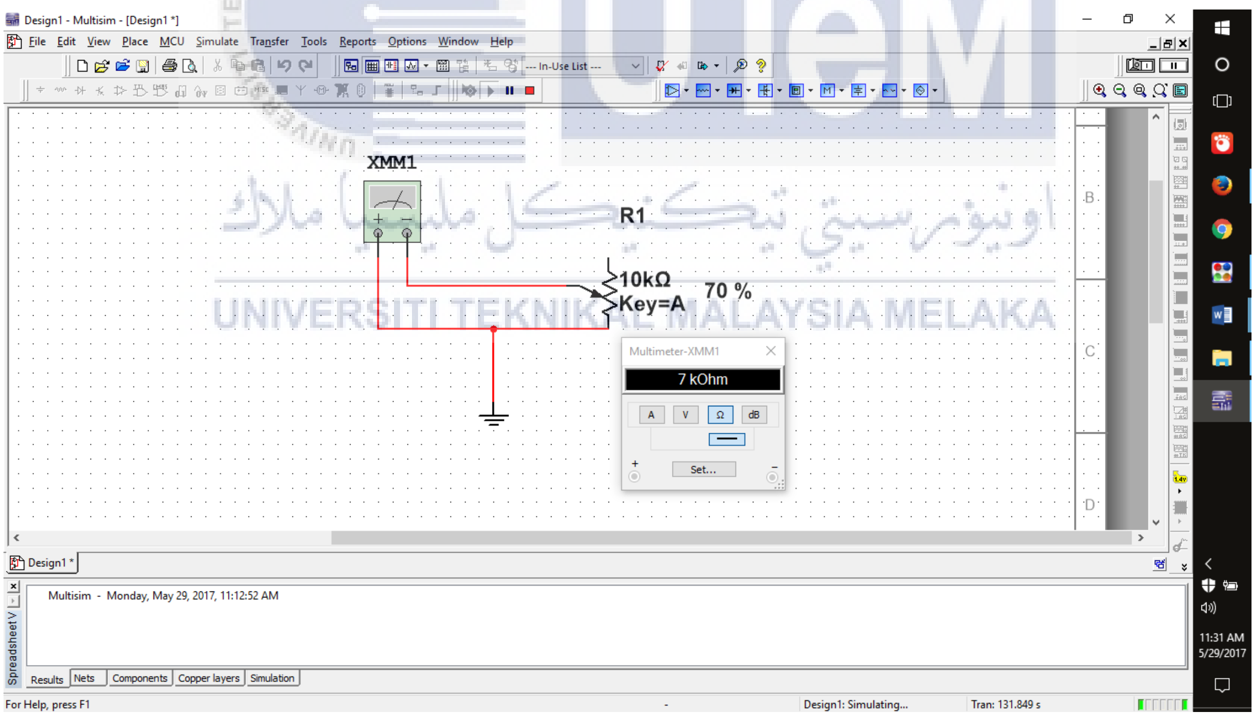


Figure 3.14: Ohmmeter output at 70% potentiometer in Multisim

Later on, the circuit being edited, and translated into real component using Arduino Uno as the controller, and implementing PWM principle and DC Motor control using potentiometer. Arduino is capable to manipulate the analog circuit with the digital output where the digital output of high (5V) or Low (0V) will generate a square wave signal.

This can control the speed of the DC motor as the potentiometer will be turn into the desired speed which student needed. By connecting the central pin of 20k potentiometer to pin A0, the controller will process the signal and produce digital input through the pin PWM 3 accordingly to the input value of the potentiometer as Figure 3.12 and Figure 3.13 below: -

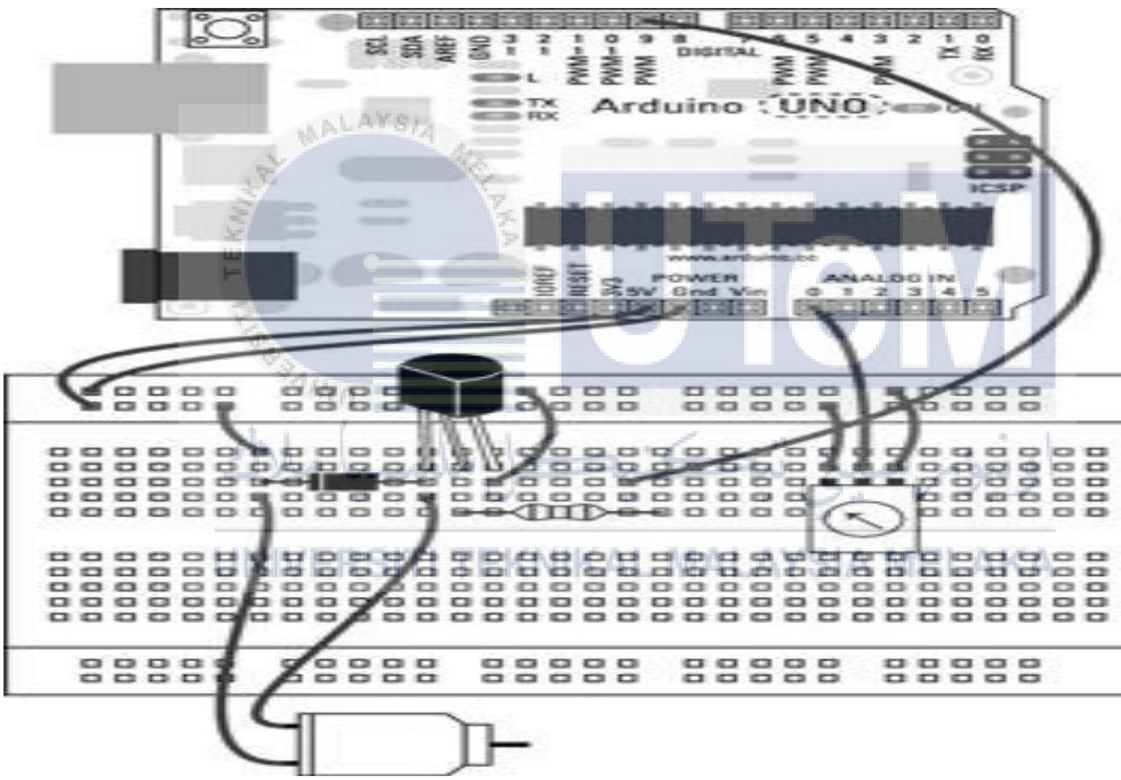


Figure 3.12: Schematic diagram for DC Motor Speed Control using potentiometer [17]

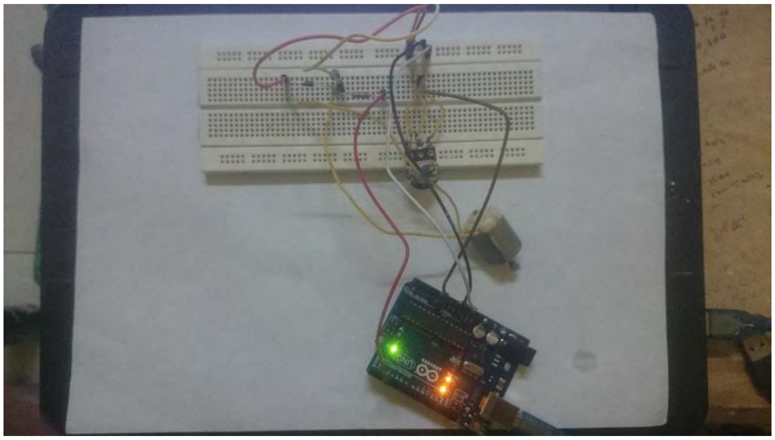


Figure 3.13: Working Circuit built for DC Motor Speed Control Using Potentiometer

The speed control was done by giving the relative duty cycle, higher duty cycle for faster speed or lower duty cycle for less speed. The example of duty cycle by percentage is as Figure 3.14 below: -

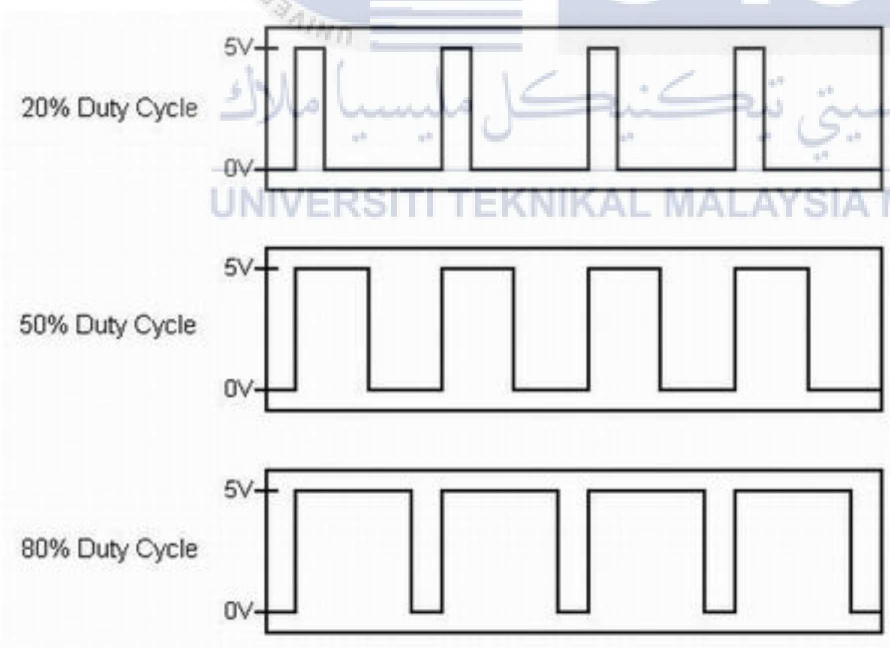


Figure 3.14: Duty Cycle in PWM by percentage [17]

However, it is more convenient to estimate the reading needed for the potentiometer for initial start of the motor for DC motor to run is smoother and easier to be configured. By observing the serial monitor, the initial needed value can be recognized so that the speed motor can be determined. This will be explained in the result and discussion section.

Next, the Arduino board is glued at side of the frame, together with the circuit firmly inserted on the breadbox. The camera faced to front at the frame, with the LED light in front of the camera for lighting purpose. Next, the motor and wheel being placed into the rear part of the frame. Each back of the rear is attached with a 3V DC motor, on the other hand in the front will only inserted with the tire only.

3.5.2 Experiment Procedure.

The experimental procedure and the figure are as follow: -

1. The laptop is turned on, Matlab and Arduino Software is opened.
2. The supply cable plugged in to the JACK socket of Arduino board, and camera USB cable plugged into the laptop USB port.
3. The mechanism is inserted into the pipe then ran using ON/OFF/ON double pole toggle switch. The Matlab coding is generated for the image acquisition process.
4. After getting the position of the defects in the video frame, the image is captured and later saved in the Matlab.
5. The mechanism is turned off and separated from the pipe.
6. The image is process using the Matlab coding, the result of image processing being taken and recorded.
7. Defects, size and calculation being calculated and recorded.
8. Laptop is turned off and all the hardware kept in its respective place.

Figure 3.15: Experiment Setup

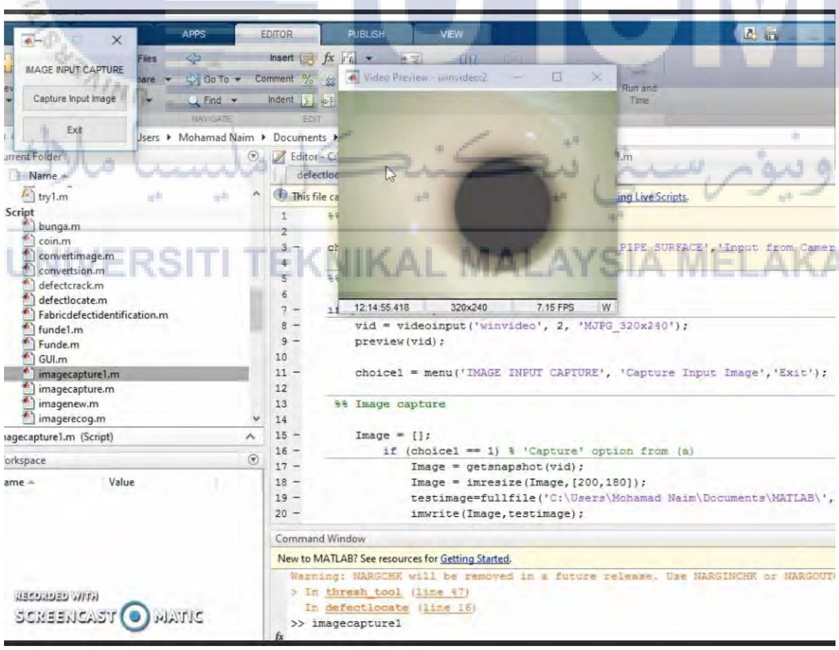


Figure 3.16: Image Acquisition Process

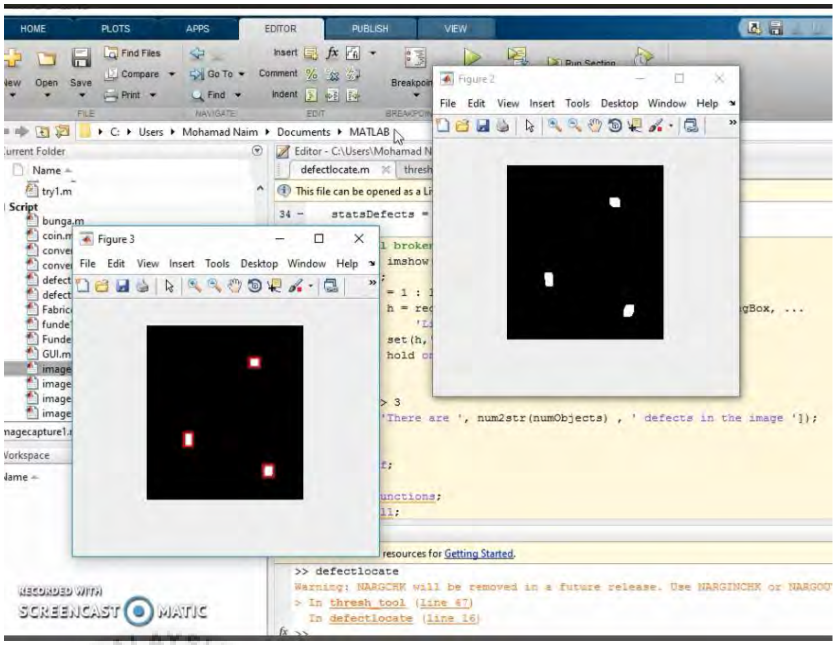


Figure 3.17: Defect detection and location (Surface)

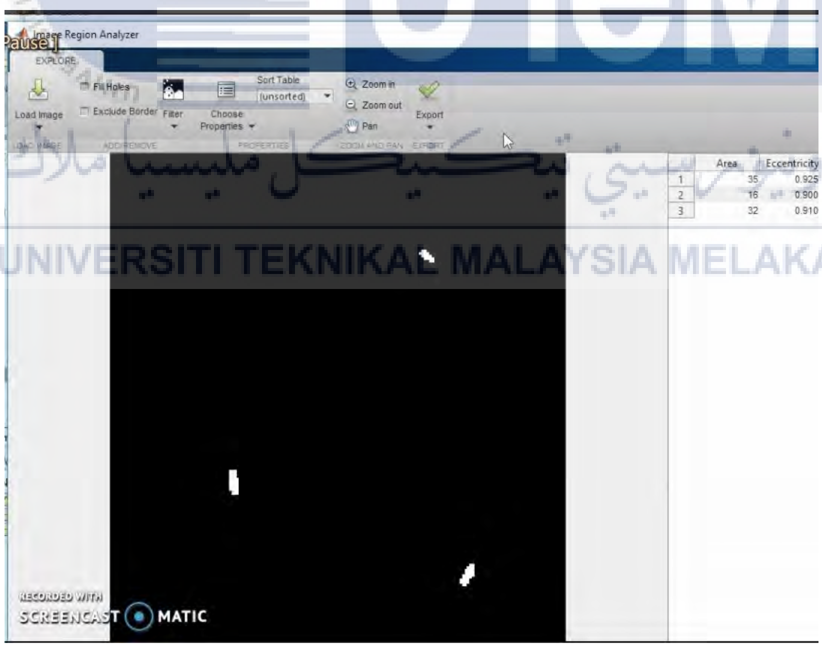


Figure 3.18: Defect size calculation (Area & Eccentricity)

3.6 IMAGE PROCESSING METHOD SECTION

3.6.1 Image Acquisition

In this section, the input internal pipe surface image is captured via integrated webcam. Once the input image is captured, image will be saved in the laptop before being uploaded into Matlab for the next process. Below are the images of Matlab GUI for image acquisition process: -

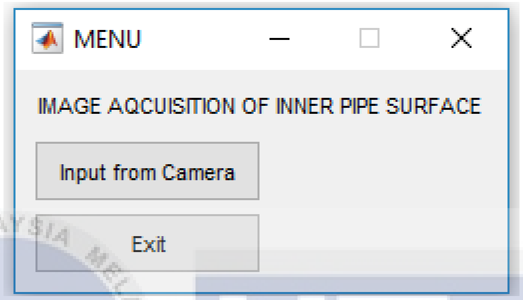


Figure 3.19 Menu GUI Option 1

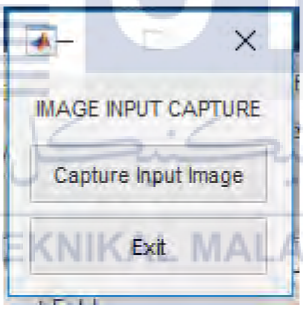


Figure 3.20 Menu GUI Option 2

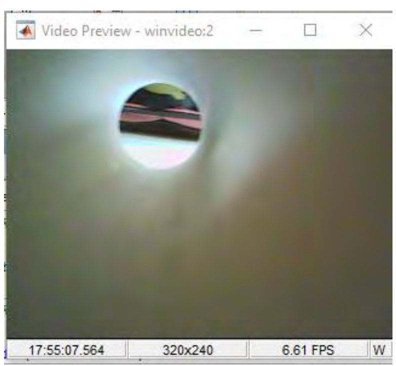


Figure 3.24 Video Preview 320x240 6.61 fps

3.6.2 Image Resizing

Image resize commonly used to change the size of an image or scale an image. The content of the image is then enlarged or shrunk accordingly the desired size. But while the actual image pixels and colors are modified, the content represented by the image is essentially left unchanged. Interpolation techniques are frequently used for directly resizing the image in the spatial domain as nearest neighbor is the simplest and fastest implementation of image scaling technique. However, images are usually represented in the transform domain as compressed data for efficient storage purpose. Below are the images of resizing (enlarged and reduced): -

Figure 3.22 Image Reduction (200x200 to 180x200)

Figure 3.23 Image Enlargement (180x200 to 200x200)

3.6.3 Image Pre-processing

1. Image Conversion

In this project, student convert truecolor image (RGB) input internal pipe surface image to grayscale (rgb2gray) that eliminating the hue and saturation information while retaining the luminance and convert grayscale image to binary image (imbinarize) by creates a binary image from image by replacing values above a globally determined threshold with 1s and below to 0s using Otsu's method (Matlab default setting).

Otsu' method which chooses the threshold value to minimize the intraclass variance of the thresholded black and white pixels. Below are the example of calculation using Otsu' method to find binary image from a segment image.

<u>Segment image</u>

50	80	50	90
95	108	160	130
75	130	108	130
50	130	75	50

<u>Binary converted</u>

0	0	0	0
0	1	1	1
0	1	1	1
0	1	0	0

a) Threshold value

$(160 + 50)/2 = 105$

$\mu 1 = (50+80+50+90+95+75+50+75+50)/9$
$\mu 1 = \underline{68.3333}$

$\mu 2 = (108+160+130+130+108+130+130)/7$
$\mu 1 = \underline{128}$

$\gamma = (\mu 1 + \mu 2)/2$
$\gamma = (68.33 + 128)/2$
$\gamma = \underline{98.1667}$

By replacing the values above the threshold with 1s and below with 0s, a binary image conversion has been made.

2. Image Threshold (Matlab Thresh Tool)

For this section, student using the built in tool in Matlab, THRESH_TOOL that display graphical user interface (GUI) for thresholding purpose. The intensity input image is displayed in the top left corner, colorbar and the input image histogram are displayed on the bottom. A binary image is displayed in the top right based on the selected level. The level of threshold can be adjusted manually, as the output image updates automatically. If user did not specify the level value, threshold process will by default using Otsu's method. Below is the figure of thresh tool used in this project: -

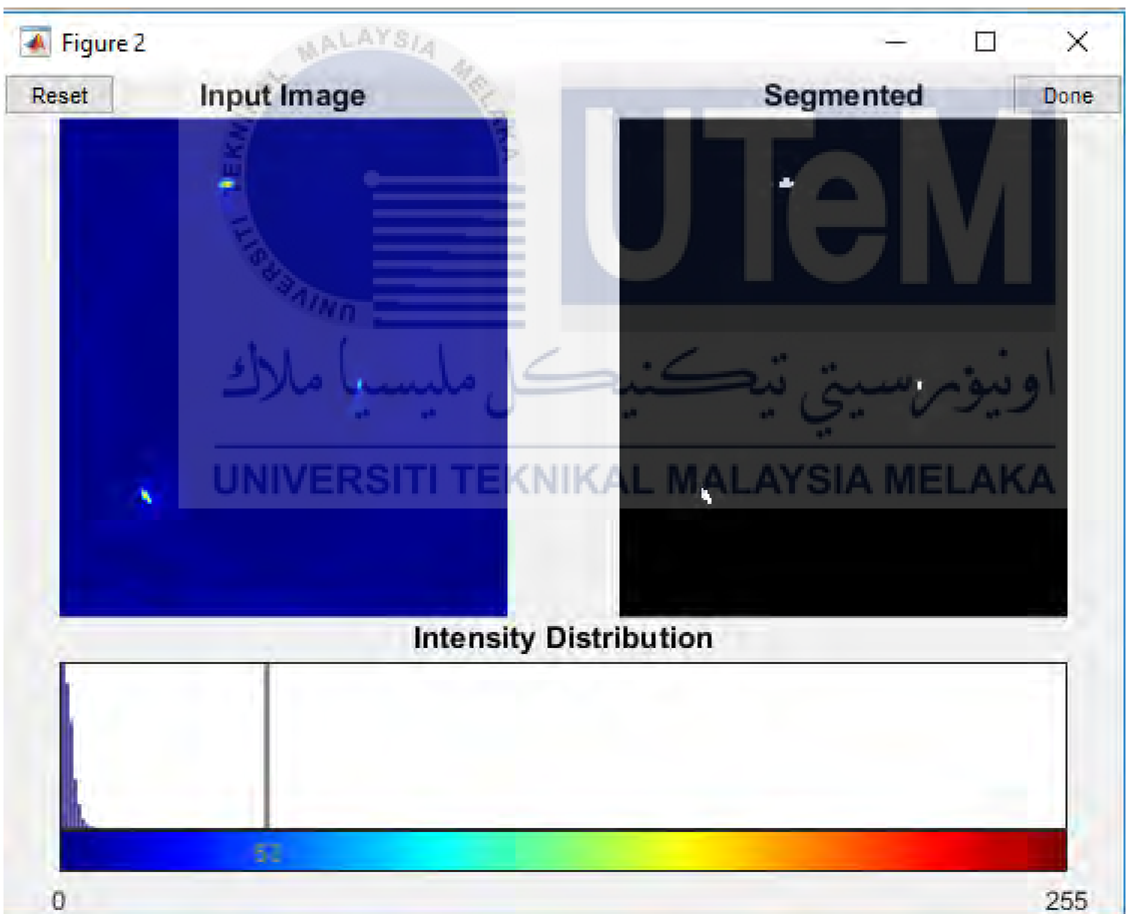


Figure 3.24 Matlab Thresh tool for threshold purpose.

3.6.4 Morphological Operation

1. Image Segmentation

To create a background approximation image, removal all the foreground using morphological opening was used. This operation removes objects that cannot completely contain the structuring element. To exclude the holes on internal pipe surface done before from the image, the structuring element must be sized so that it cannot fit entirely inside a single hole. 'Strel' function is used to create a disk-shaped structuring element with a radius of 15. Later, the operation of subtraction of image with background will produce the uniform background for next process. Below is the background approximation image as a surface from the input image to see where illumination varies; -

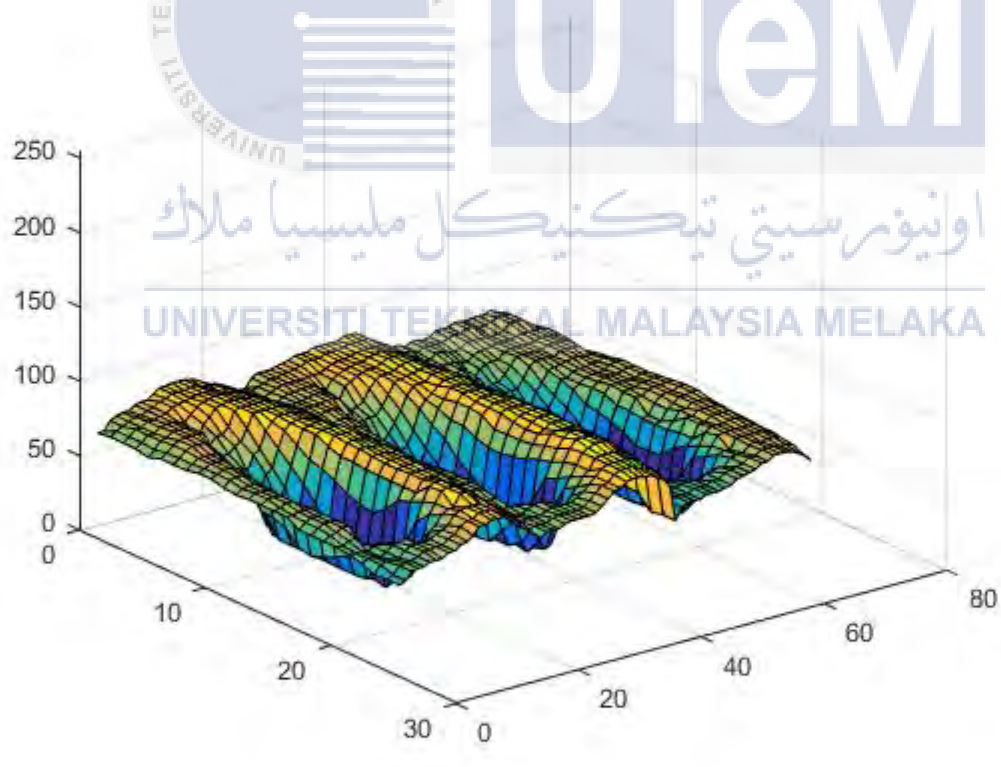


Figure 3.25 Surface of image background

2. Small Object Removal (*area opening*)

In this process, student removes all connected components (objects) that have fewer than needed pixels from the binary image previously created, then producing another binary image that is clean. The default connectivity is 8 for two dimensions, 26 for three dimensions, and maximum value of pixel need to be stated in other instruction for higher dimensions.

3. Noise Removal

Noise is unwanted elements in image that reduced the quality of the image itself for instance internal and external noise. Noise removal in image processing is necessary as noise will contribute to difficulties in image compression and image analysis. In this image pre-processing, since the pipe used is white in color, student using wiener filter to remove the noise. Wiener filter is used in the project filter for noise of constant-power ("white") additive type, image dilation and erosion process. Below is the comparison on when the input image of pipe is added with Gaussian noise, and later being filtered using Wiener filter: -

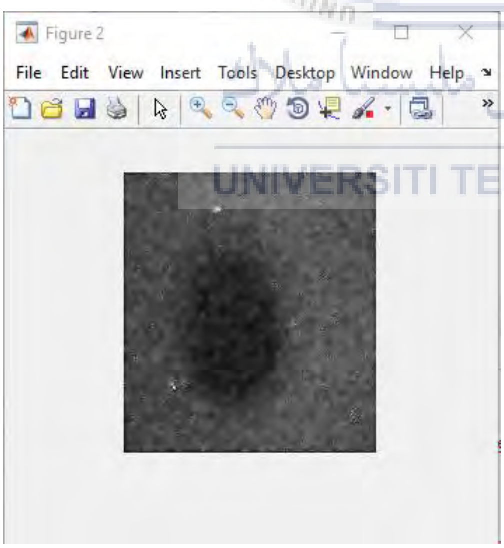


Figure 3.26 Image after filtered

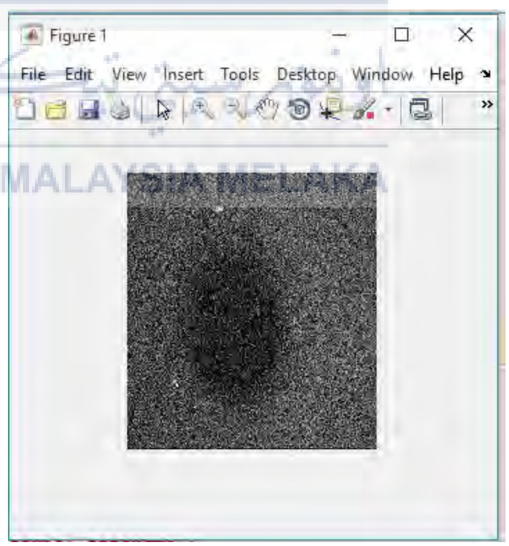


Figure 3.27 Image with Gaussian noise

3.6.5 Image Analysis

1. Label 4 connected components in 2-D binary image

In this project, student label the pre-processed binary image using this process. First from the binary image, a label matrix using 4-connected objects created. Then the coordinate of corresponding label matrix can be determined from this label matrix. The example of the process is as follow: -

1) Create small logical binary image (BW).

```
BW = logical ([1    1    1    0    0    0    0    0
               1    1    1    0    1    1    0    0
               1    1    1    0    1    1    0    0
               1    1    1    0    0    0    1    0
               1    1    1    0    0    0    1    0
               1    1    1    0    0    0    1    0
               1    1    1    0    0    1    1    0
               1    1    1    0    0    0    0    0]);
```

2) Create label matrix (L) by 4 connected components.

```
L =

     1    1    1    0    0    0    0    0
     1    1    1    0    2    2    0    0
     1    1    1    0    2    2    0    0
     1    1    1    0    0    0    3    0
     1    1    1    0    0    0    3    0
     1    1    1    0    0    0    3    0
     1    1    1    0    0    3    3    0
     1    1    1    0    0    0    0    0
```

3) Row (r) and column (c) coordinates of the object labeled "2".

```
r c =

     2    5
     3    5
     2    6
     3    6
```

2. Measure properties of image regions

Next is the image region properties measurement for the labeled binary image where area, eccentricity and bounding box. In Matlab, area specifies the actual number of pixels in the region. On the other hand, eccentricity measured of the ellipse that has the same second-moments as the region as the ratio of the distance between the foci of the ellipse and its major axis length. The value is between 0 and 1. Meanwhile, bounding box defined as minimum bounding or enclosing box for a point set (*S*) in *N* dimensions represent the box with the smallest measure (area, eccentricity) within which all the points lie.

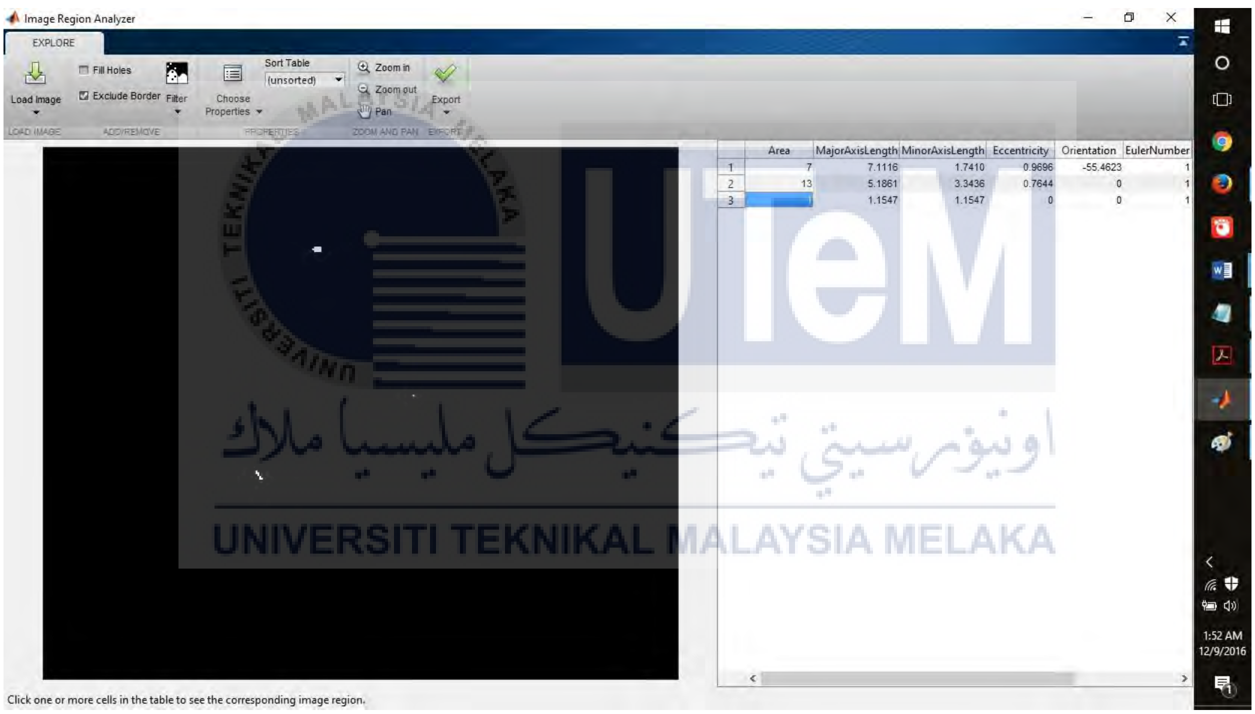


Figure 3.28 Image Region Analyzer Toolbox

CHAPTER 4

RESULT AND DISCUSSION

4.0 Determining the Initial Start of the DC Motor

Whenever the circuit is started, as the potentiometer is turn slowly from 0, there are humming sound in the motor, and this is as result of not enough power for the dc motor to start spin. The advantages of estimate the initial speed for motor to start spin are smoother and time saving operation can be achieved. By observing the serial monitor, student observe that above 130 motor speed, the motor is start spinning as Figure 4.0 and Figure 4.1, meanwhile at Figure 4.2 and Figure 4.3 is the opposite. As result, student decided to put the motor speed as 130 in the coding as the Figure 3.17 below: -

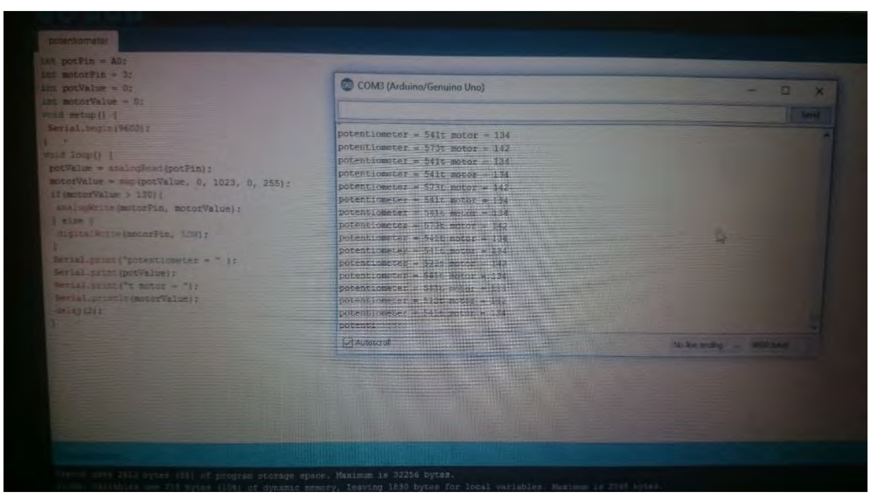


Figure 4.0: Serial Monitor observation for the initial speed for DC motor to spin for motor speed above 130.

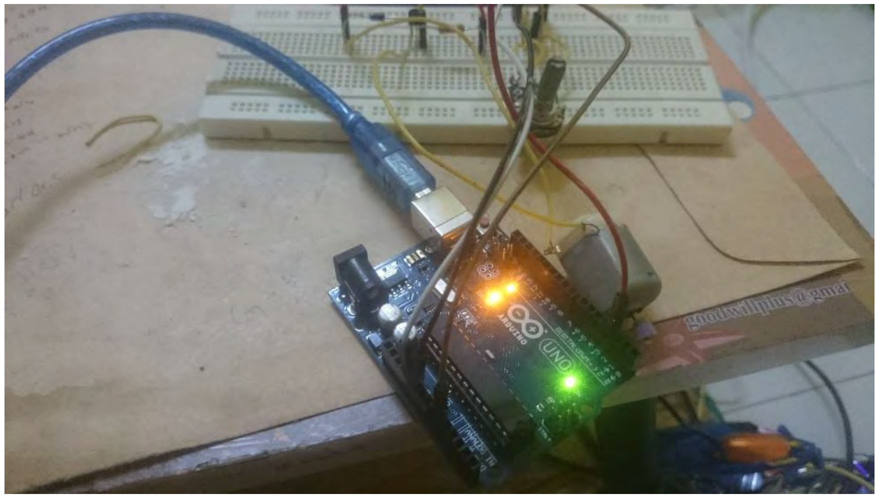


Figure 4.1: DC Motor Spinning at speed above 130

Figure 4.2: Serial Monitor observation for the initial speed for DC motor to spin for motor speed below 130.

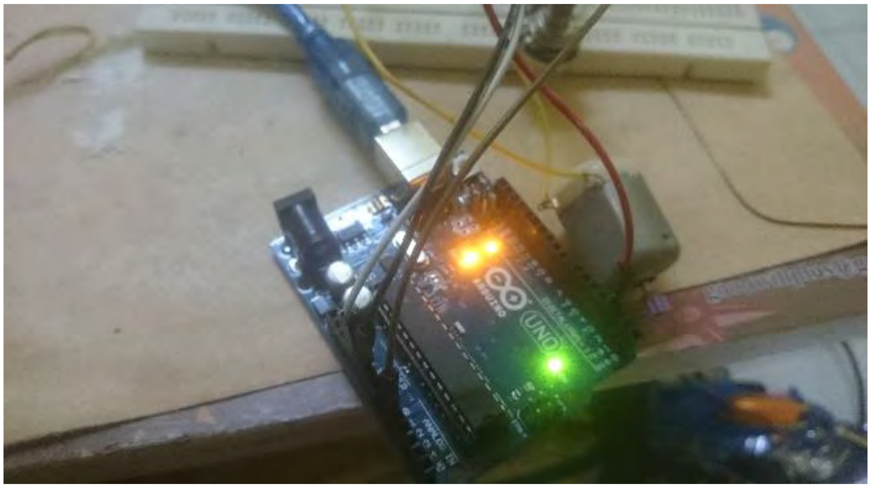


Figure 4.3: DC Motor not spinning at speed below 130

Figure 4.4: Initial speed 130 in motorValue for DC motor to spin.

By implementing the speed control, image processing can be continued in smoother manner as reducing noise from bumping, high speed capture, and blurring in image capturing. Also, over speed in controlling the mechanism may destroy the equipment and bring danger to people surrounding.

4. 1 Image defects location

When above conditions has been met, a figure of image defects location can be display to the user for presentation. The image of the figure is as follow: -

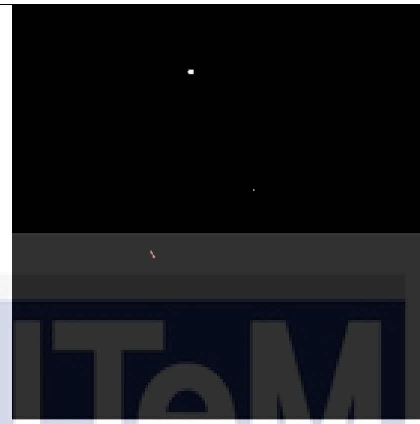
Figure 4.5: The RGB input image with labeled defects locations

Figure 4.6: The binary image with labeled defects locations

4.2 Size Calculation and Display

For area and eccentricity display, student is using the Image Region Analyzer Toolbox by Matlab. This toolbox will help user to display region properties of corresponding element in a binary image such as area and eccentricity. Below is the figure of Image Analyzer Toolbox, defects location and its area and eccentricity display.

Figure 4.6: Defects and Area, Eccentricity Display

<u>Defect 1</u> Area Eccentricity 7 0.96957	
<u>Defect 2</u> Area Eccentricity 13 0.76442	
<u>Defect 3</u> Area Eccentricity 1 0	

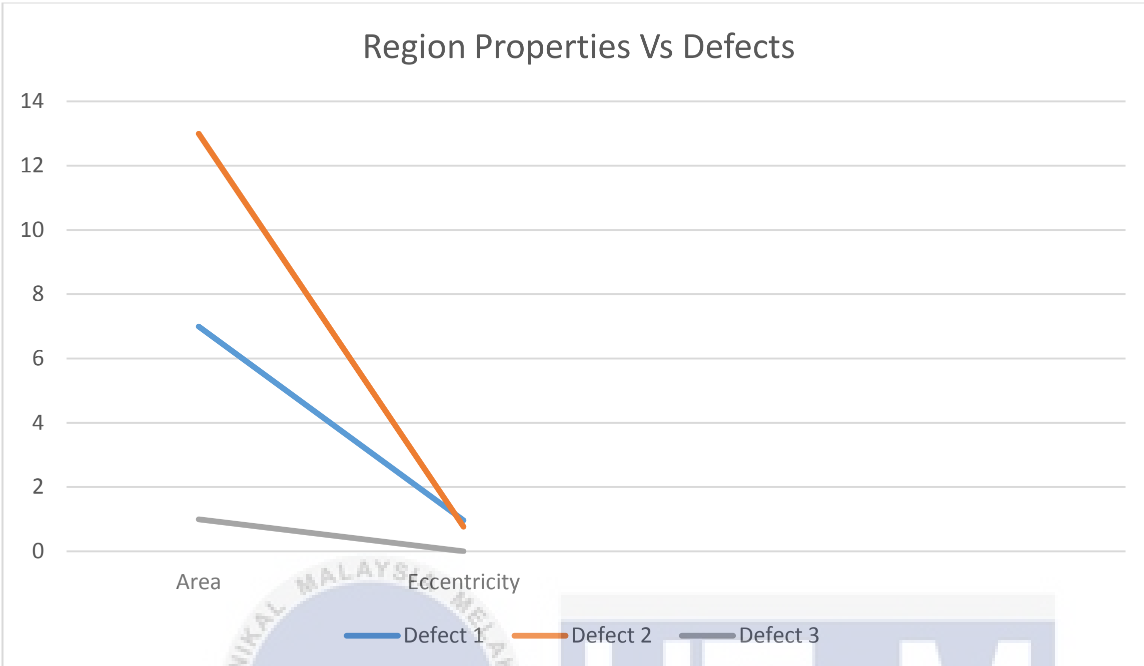


Figure 4.7: Region Properties Vs Defects Plot

From the results and analysis, we can conclude that Defect 1 is a crack, Defect 2 is a crack and Defect 3 is a hole.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter would discuss the overall project's and brief analysis of result with the potential of improvement. In addition, this section emphasizes over the significant parts of the experiment which brought the objectives achievement from the project earlier. The recommendation would be useful for further improvement on the project in the future.

5. 1 Conclusion

As conclusion, student successfully design an internal pipe inspection mechanism based on vision approach. Student also successfully develop defects detection methods of internal pipe inspection based on vision approach. In addition, student is able to analyze defects in internal pipe system based on surface and size (area and eccentricity). However, a lot of limitation and drawback occurred as follow: -

1. The simulation and experimental results show the location, area and eccentricity of defects, however the actual and resulting values may differ.
2. Results were used to evaluate or classify the defects either it is hole (eccentricity value approaching 1) or crack (eccentricity value approaching 1)
3. The program for image processing part is low in repeatability. It only working in using the UPVC pipe of white in color. The program will not successfully produce the same result if PVC pipe of silver in color is used.
4. Webcam used only be able to capture image of maximum 5MP, so the resolution and quality of image capture are relatively low.

5.2 Recommendation

As recommendation, several factors need be considered for the future project development so improvement can be done such as: -

1. A GUI can be built so that the outcome of the experiment can easier to be displayed and observed.
2. CCTV or high definition surveillance camera can replace the webcam so that the image will be better in resolution and quality.
3. Student can look for existing faulty/damage pipe for inspection or changing the methods used in the Matlab program so that the current pipes can be replaced.
4. As the light intensity and shadow will influence the performance of the project experiment, an operational hour for experiment need to be determined.
5. Surrounding lighting and shadow's existence should be included as parameter in the experiment.

APPENDICES

Full Matlab Program Coding

```
%% GUI Start Menu

choice = menu('IMAGE AQCUISITION OF INNER PIPE SURFACE','Input from
Camera','Exit');

%% get image

if (choice == 1)
    vid = videoinput('winvideo', 2, 'MJPG_320x240');
    preview(vid);

    choice1 = menu('IMAGE INPUT CAPTURE', 'Capture Input Image','Exit');

 %% Image capture

    Image = [];
        if (choice1 == 1) % 'Capture' option from (a)
            Image = getsnapshot(vid);
            Image = imresize(Image,[200,180]);
            testimage=fullfile 'C:\Users\Mohamad
      Naim\Documents\MATLAB\','11.jpg');
            imwrite(Image,testimage);

 %% Image destination folder

            ImagetestPath ='C:\Users\Mohamad Naim\Documents\MATLAB';
        end;

%% Clean up everything
stop(vid);
delete(vid);

%% clear persistent variables
clear functions

end;

%% Image Pre Processing

K = imread('11.jpg');
I = imresize(K,[200,180]);
testimage1=fullfile('C:\Users\Mohamad Naim\Desktop\Pipe Inspection
Development','I.jpg');
imwrite(I,testimage1);
```

```
%% Morphol0gical Opening, image subtraction, image conversion

background = imopen(I,strel('disk',10));
J = I-background;
I2 = rgb2gray(J);
testimage2=fullfile('C:\Users\Mohamad Naim\Desktop\Pipe Inspection
Development','I2.jpg');
imwrite(I2,testimage2);
imshow(I2);

%% Threshold, image conversion, wiener filter, remove small objects

level = thresh_tool(I2);
BW = imbinarize(I2);
BW = wiener2(BW,[5 5]);
BW = bwareaopen(BW, 10);
testimage3=fullfile('C:\Users\Mohamad Naim\Desktop\Pipe Inspection
Development','BW.jpg');
imwrite(BW,testimage3);
figure, imshow(BW);

%% Use feature analysis to identify broken objects

[labeled,numObjects] = bwlabel(BW,4);
stats = regionprops(labeled,'Eccentricity','Area','BoundingBox');
areas = [stats.Area];
minSize = mean(areas) - 0.25 * std(areas);
eccentricities = [stats.Eccentricity];
idxOfDefects = find(eccentricities);
statsDefects = stats(idxOfDefects);


%% Label broken objects

figure; imshow(I);
hold on;
for idx = 1 : length(statsDefects)
        h = rectangle('Position', statsDefects(idx).BoundingBox, ...
            'LineWidth', 2);
        set(h,'EdgeColor',[.75 0 0]);
        hold on;
end

if idx > 3
title(['There are ', num2str(numObjects) , ' defects in the image ']);
end

hold off;

clear functions;
clear all;
```

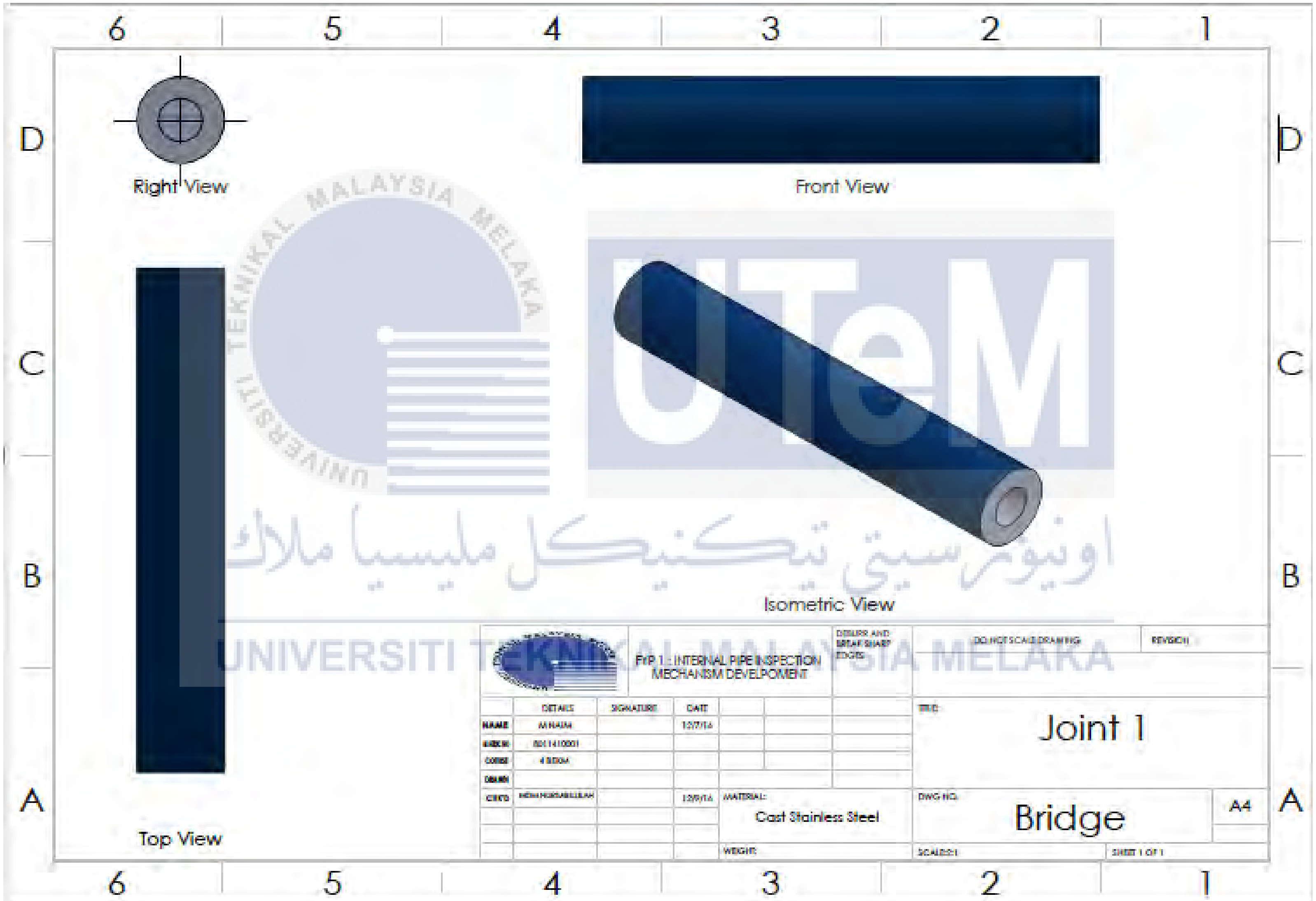
<u>Matlab Coding For Image Binary Class Uint8 to Logical Conversion</u>

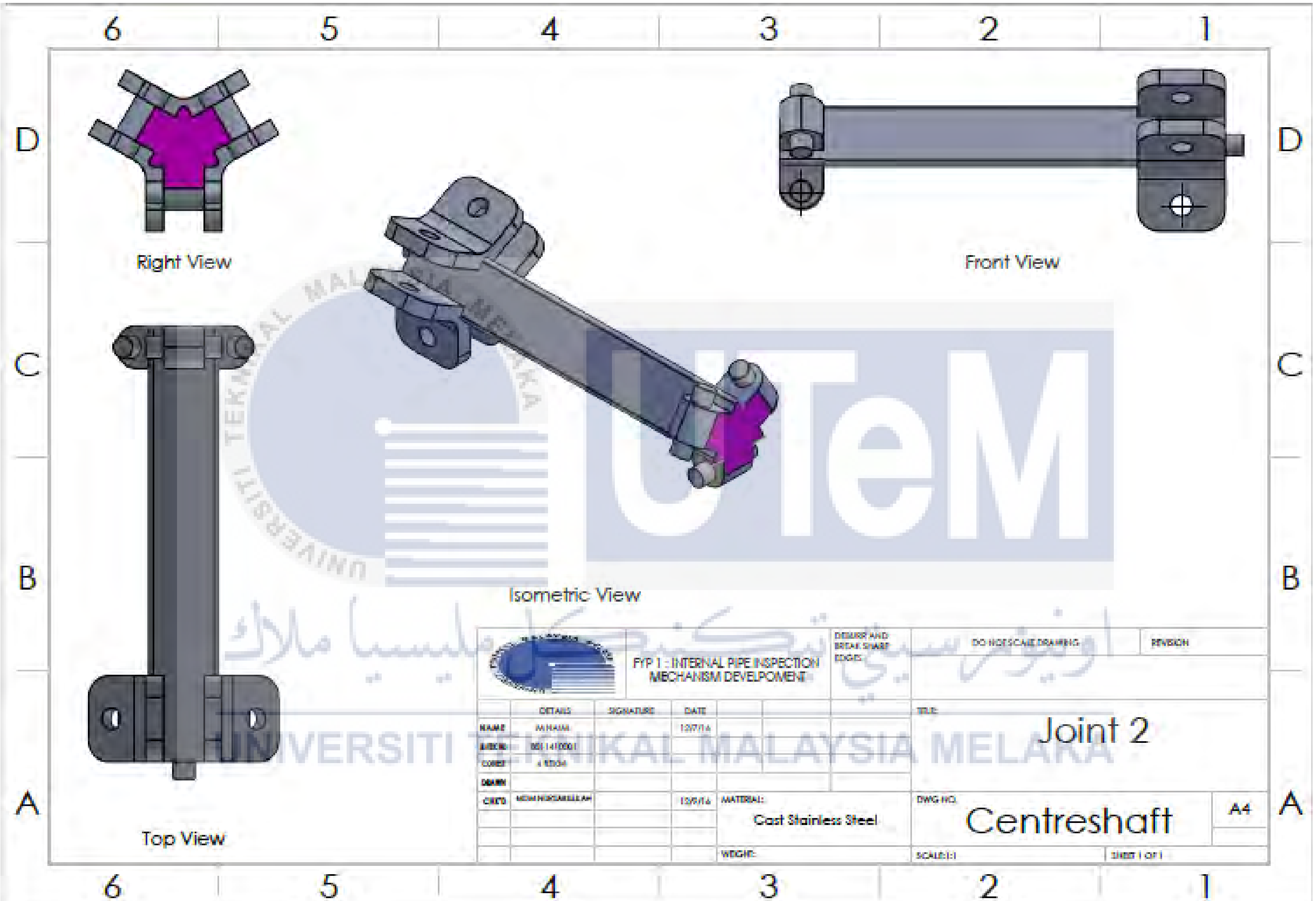
```
I = imread('I2.jpg');
level = graythresh(I);
BW = im2bw(I,level);
imshow(BW)
```

<u>Adruino Coding For Motor Speed control and Initial Speed Start Value)</u>

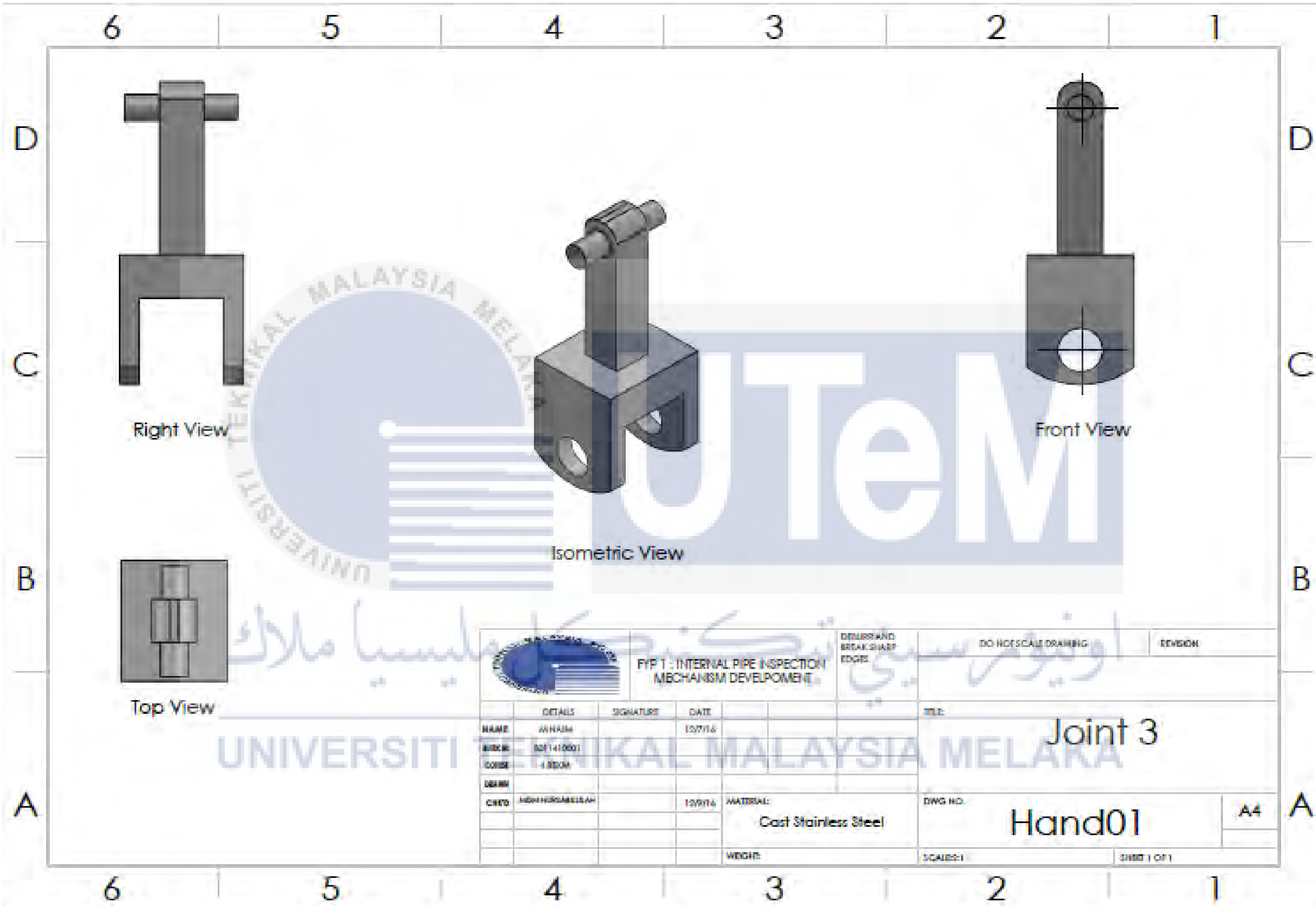
```
int potPin = A0;
int motorPin = 3;
int potValue = 0;
int motorValue = 0;
void setup() {
 Serial.begin(9600);
}
void loop() {
 potValue = analogRead(potPin);
 motorValue = map(potValue, 0, 1023, 0, 255);
 if(motorValue > 130){
  analogWrite(motorPin, motorValue);
 } else {
  digitalWrite(motorPin, LOW);
 }
 Serial.print("potentiometer = " );
 Serial.print(potValue);
 Serial.print("t motor = ");
 Serial.println(motorValue);
 delay(2);
}
```

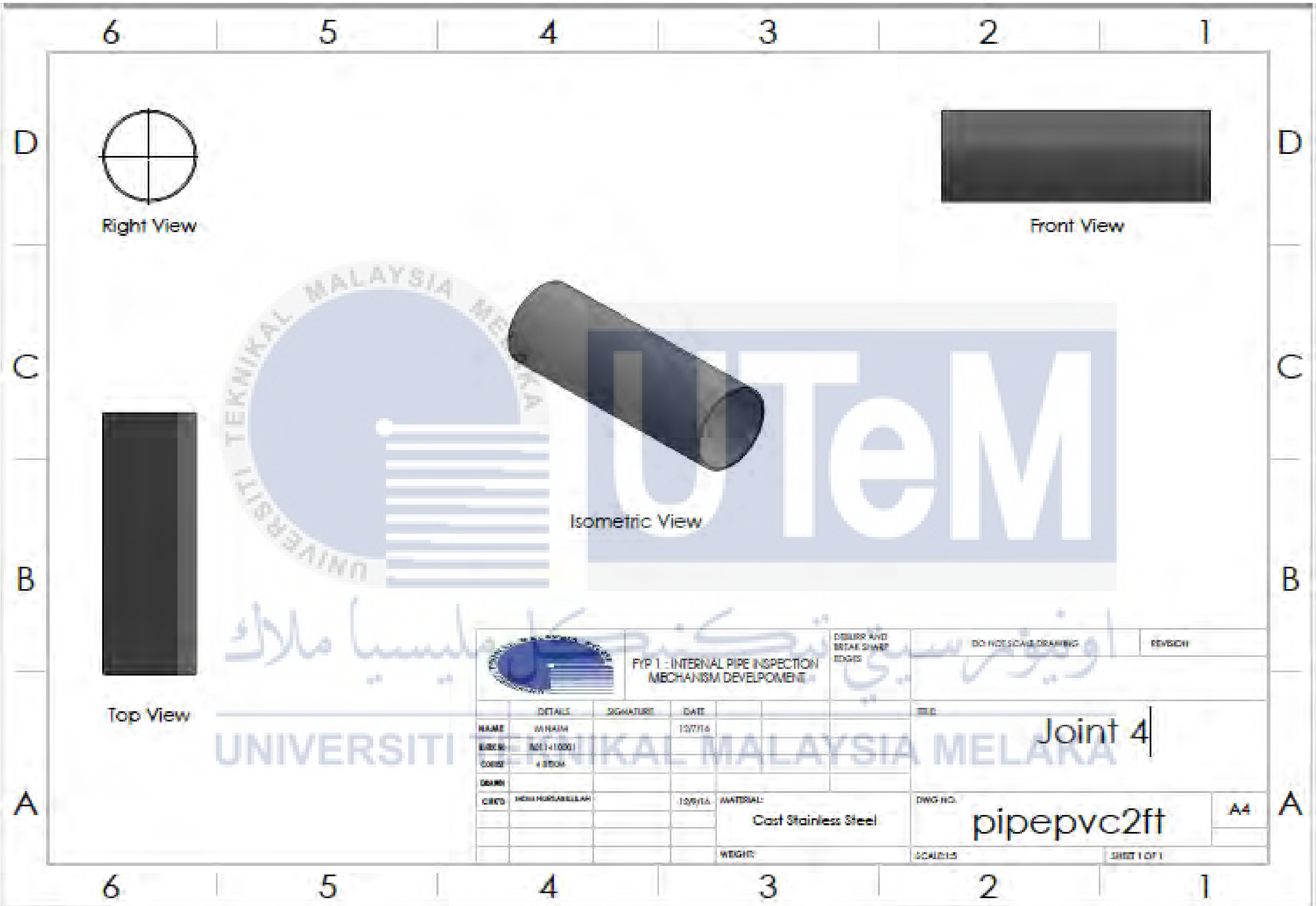
Solidwork Templates For Mechanism Design Sketches



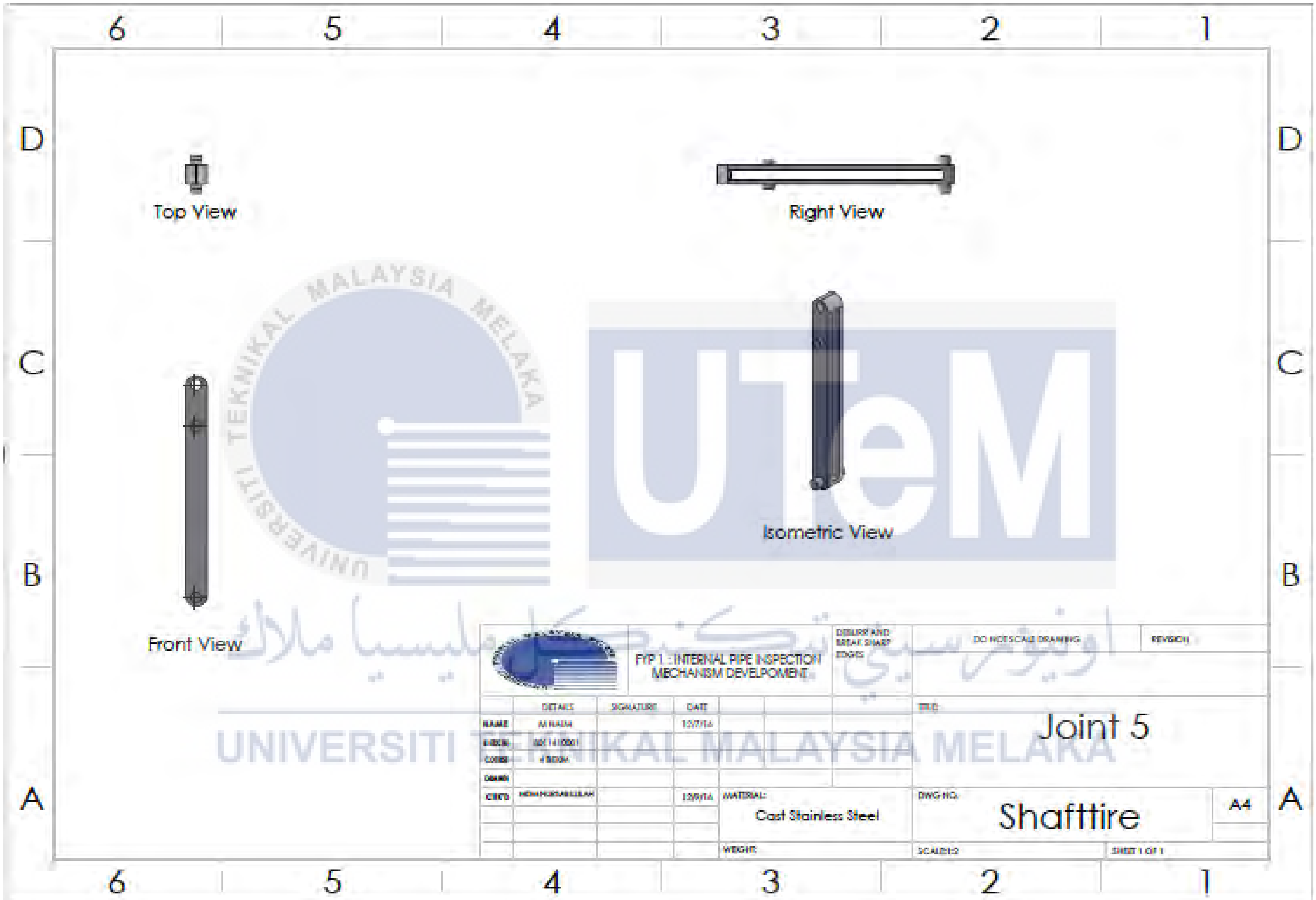


Right View
Front View
Isometric View
Top View
FYP 1 : INTERNAL PIPE INSPECTION MECHANISM DEVELPOMENT
DEBURR AND BREAK SHARP EDGES:
DO NOT SCALE DRAWING
REVISION
DETAILS
SIGNATURE
DATE
NAME
CHK'D
MATERIAL:
Cast Stainless Steel
TITLE:
Joint 2
DWG NO.
Centreshaft
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1

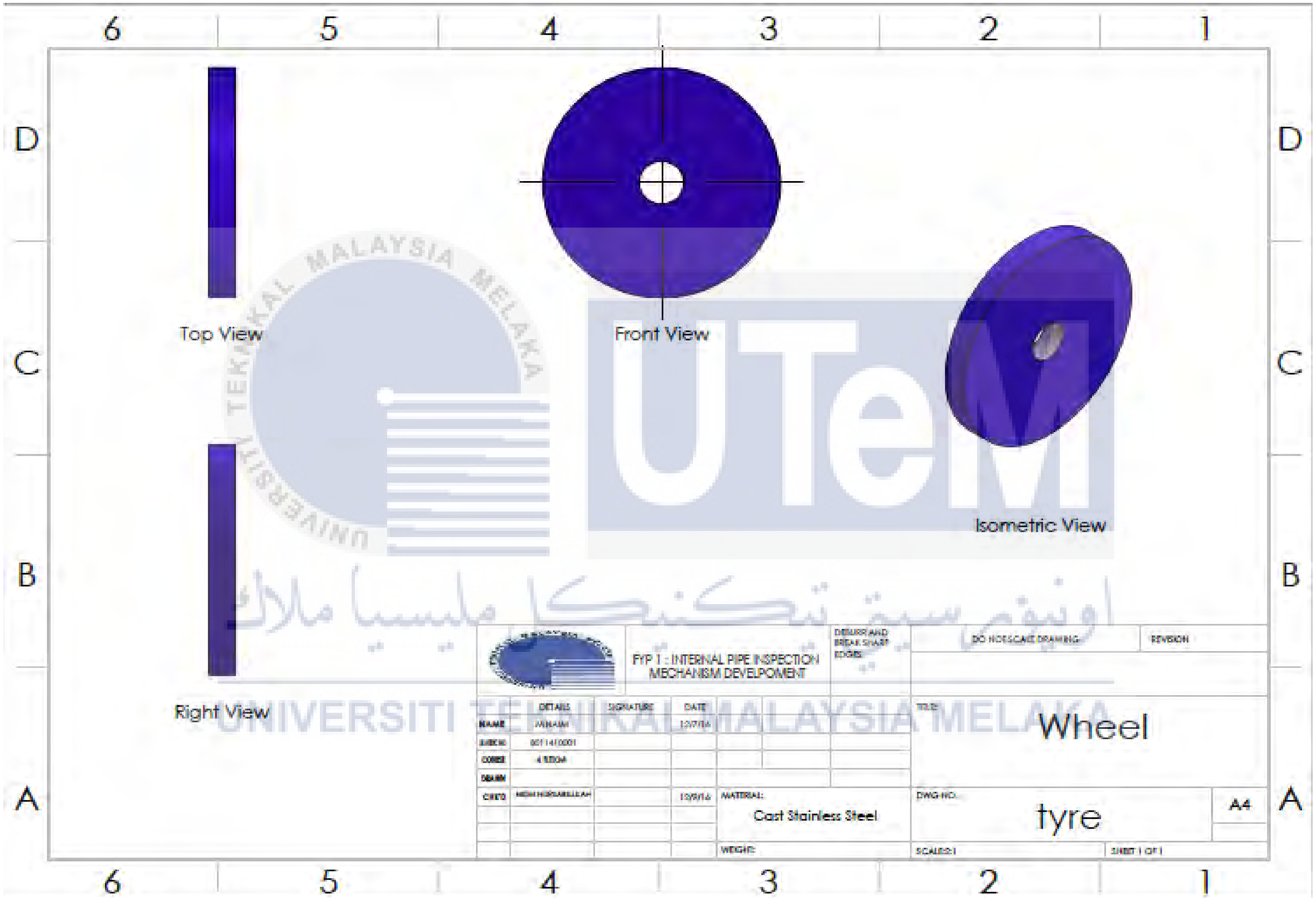

Right View
Isometric View
Front View
Top View
FYP 1 : INTERNAL PIPE INSPECTION MECHANISM DEVELPOMENT
DO NOT SCALE DRAWING
REVISION
DETAILS
SIGNATURE
DATE
NAME
TITLE:
Joint 3
MATERIAL:
Cast Stainless Steel
DWG NO.
Hand01
A4
WEIGHT:
SHEET 1 OF 1

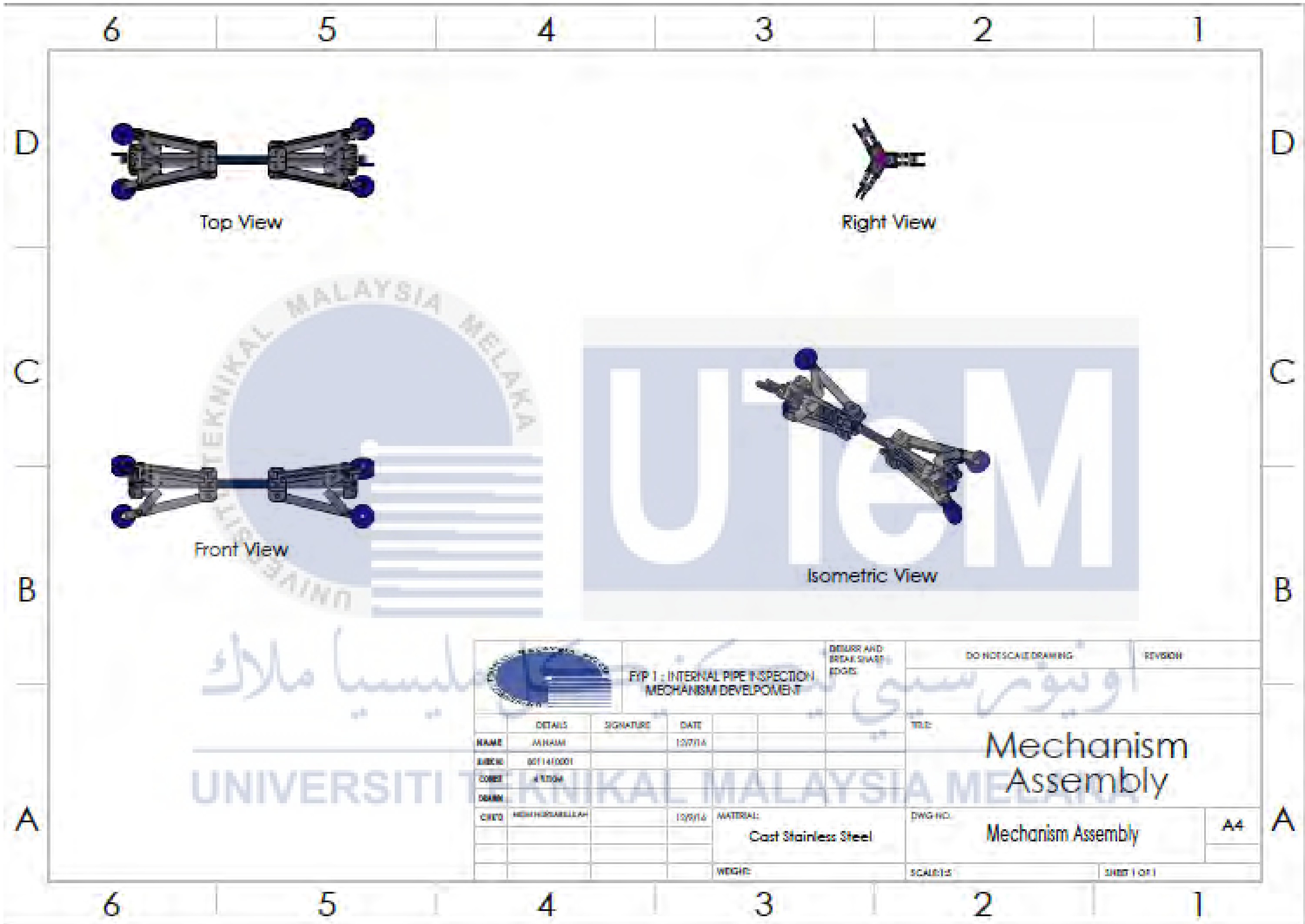


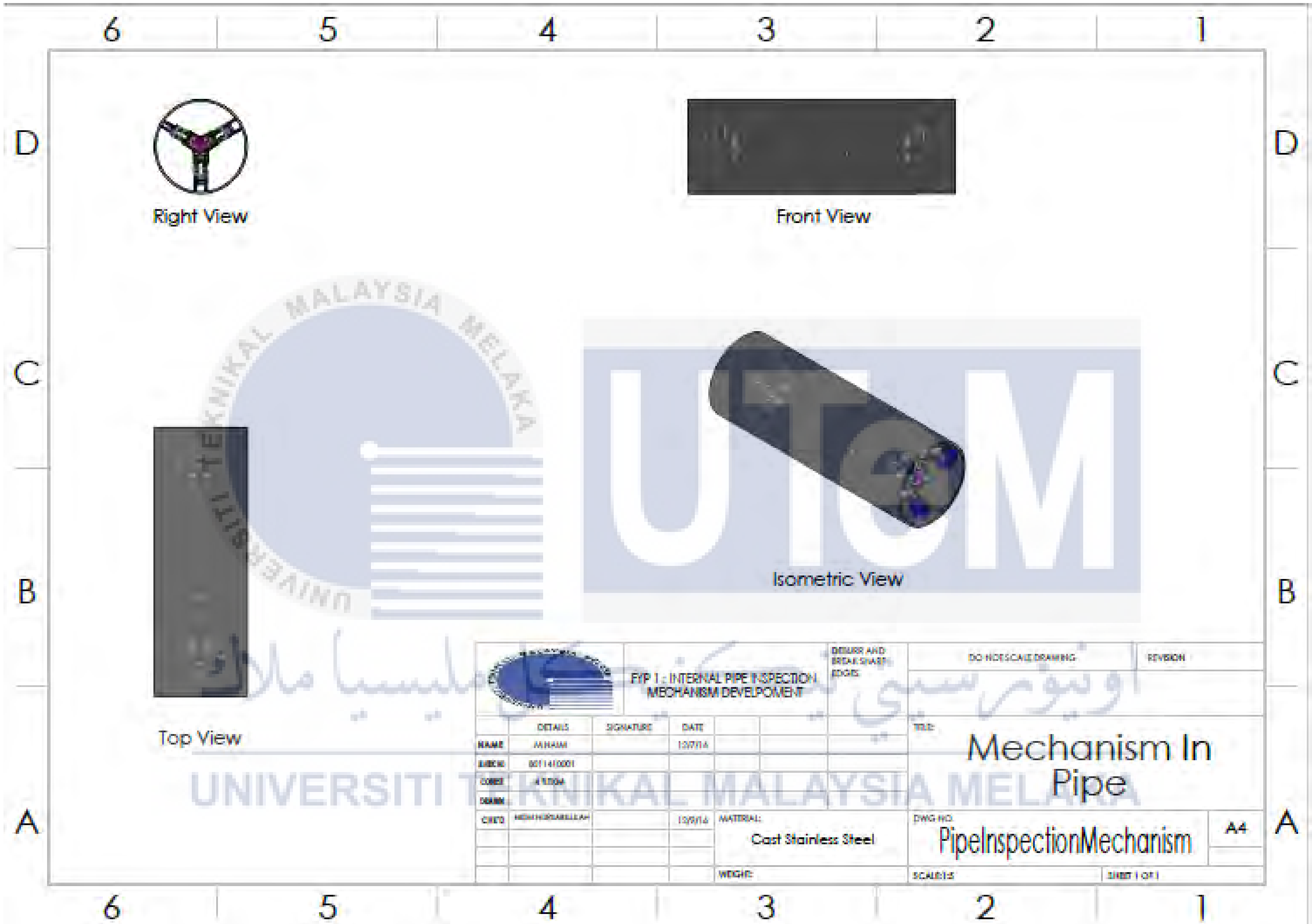
Right View
Front View
Isometric View
Top View
FYP 1 : INTERNAL PIPE INSPECTION MECHANISM DEVELPOMENT
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
DETAILS
SIGNATURE
DATE
NAME
CHK'D
MATERIAL:
Cast Stainless Steel
DWG NO.
pipepvc2ft
A4
Joint 4
WEIGHT:
SHEET 1 OF 1



Top View
Right View
Isometric View
Front View
FYP 1 : INTERNAL PIPE INSPECTION MECHANISM DEVELPOMENT
Joint 5
Cast Stainless Steel
Shafttire
A4


Top View
Front View
Isometric View
Right View
FYP 1 : INTERNAL PIPE INSPECTION MECHANISM DEVELPOMENT
DO NOT SCALE DRAWING
REVISION
DETAILS
SIGNATURE
DATE
NAME
MATERIAL:
Cast Stainless Steel
WEIGHT:
TITLE:
Wheel
DWG NO.
tyre
A4
SHEET 1 OF 1


Top View
Right View
Front View
Isometric View
FYP 1 : INTERNAL PIPE INSPECTION MECHANISM DEVELPOMENT
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
DETAILS
SIGNATURE
DATE
NAME
TITLE:
Mechanism Assembly
MATERIAL:
Cast Stainless Steel
DWG NO.
Mechanism Assembly
A4
WEIGHT:
SHEET 1 OF 1



Right View
Front View
Isometric View
Top View
FYP 1 : INTERNAL PIPE INSPECTION MECHANISM DEVELPOMENT
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
DETAILS
SIGNATURE
DATE
NAME
TITLE:
Mechanism In Pipe
MATERIAL:
Cast Stainless Steel
DWG NO.
PipeInspectionMechanism
A4
WEIGHT:
SHEET 1 OF 1

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