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PSM TITLE:

DESIGN OF ROBOTIC STRUCTURE FOR PEOPLE WITH DISABILITIES FOR EATING AND DRINKING MOTION (EATING)

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DESIGN OF ROBOTIC STRUCTURE FOR PEOPLE WITH DISABILITIES FOR EATING AND DRINKING MOTION (EATING)

MOHD QUSYAIRI BIN BADRUL HISHAM

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronic Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

“ I declare that this report entitle “Design of Robotic Structure for People with Disabilities for Eating and Drinking Motion (Eating)” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree”

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ABSTRACT

Robotic arm is a mechanical arm which is programmed to function like a human arm. This project proposes the design of robotic arm for disabilities people for eating propose. This robot can help the disabilities people to eat and at the same time minimize the works of nurses. The objective of this project is to design and construct the robotic structure for disable people to eat and to analyze the performance of the robot in term of repeatability and accuracy. There are 4 journals that have been study when doing this project. Based on the literature review, the robot is designed part by part and the degree of freedom is decided. The robot is constructed after the components and the control system of the robot is decided. The experiment to analyze the performance of the robot in term of accuracy and repeatability have been carried out after the robot is constructed. In designing the robot, CAD software (SolidWorks) is used. The part's design and the assembly of the robot's parts is done by using this software. For the electrical design, Proteus software is used. The robot have 4 degree of freedom that are base, shoulder, elbow and wrist. The microcontroller for the robot is Atmega328 and Arduino Duemilanove is used to control the servo motor that is by coding the PWM into the Arduino. Experiments to analyze the performance of the robot in term of repeatability and accuracy have been carried out on this semester in PSM II. The result of the experiment is to show that the robot is able to handle a continuous movement repeatedly, and to show that how much the accuracy of the robot when lifting a load without strayed away from the original position.

ABSTRAK

Tangan robotik adalah tangan mekanikal yang mana telah diprogram untuk berfungsi seperti tangan manusia. Tujuan projek ini adalah untuk mereka tangan robotik kepada orang-orang kurang upaya bagi tujuan makan. Robot ini dapat membantu orang-orang kurang upaya untuk makan dan pada masa yang sama dapat mengurangkan beban atau kerja-kerja jururawat. Objektif projek ini adalah untuk mereka dan membina struktur robotik untuk orang kurang upaya untuk makan dan juga untuk menganalisis prestasi robot dari segi kebolehulangan dan ketepatan. Terdapat 4 jurnal yang telah dirujuk semasa melakukan projek ini. Berdasarkan jurnal-jurnal tersebut, reka bentuk robot telah dilakukan sebahagian demi sebahagian dan tahap kebebasan robot diputuskan. Robot ini telah dibina selepas komponen-komponen dan sistem kawalan diputuskan. Eksperimen untuk menganalisiskan prestasi robot telah dijalankan selepas robot siap dibina. Dalam mereka bentuk robot, perisian CAD (SolidWorks) telah digunakan. Semasa mereka bahagian-bahagian robot dan pemasangan bahagian-bahagian ini, perisian SolidWorks telah digunakan. Untuk bahagian elektrik pula, perisian Proteus telah digunakan. Robot ini mempunyai 4 tahap kebebasan terdiri daripada bahagian tapak, bahu, siku dan pergelangan tangan. Mikropengawal untuk robot ini adalah Atmega328 dan Arduino Duemilanove digunakan untuk mengawal motor servo dengan mengkodkan PWM kedalam Arduino . Eksperimen untuk analisis prestasi robot dalam jangka kebolehulangan dan ketepatan telah dijalankan pada semester ini dalam PSM II. Keputusan eksperimen ini adalah untuk menunjukkan kebolehan robot ini untuk mengedalikan pergerakan berterusan berkali-kali, dan untuk menunjukan berapa banyak ketepatan robot apabila mengangkat beban tanpa menyimpang jauh dari kedudukan asal.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

This project deals with an assistive robot arm system for severe physical disabilities. The number of physical disabled people in Malaysia is quite high, the statistic shows that the physical disabled people that have register as disabilities "Orang Kurang Upaya (OKU)" in Malaysia is 123,346, that is about 34.3% from the number of disabled people [1]. As we all know, the number of nurse cannot compete with the number of patient in the hospital, the statistic show that the number of population for nurse only 1:559, which is decrease from years to years [2]. According to statistic from Malaysia Health Ministry, the number of nurse and ratio of population to pharmacists from year 1999 to 2006 are shown on Table 1.1.

Table 1.1: Number of Nurse and Ratio of Population to Phamacists 1999-2006

Year	Num. of Nurse	Population to Nurse Ratio
1999	23236	977
2000	31129	747
2001	33295	721
2002	35280	695
2003	36784	681
2004	40220	636
2005	44120	592
2006	47642	559

The nurse cannot entertain the patient because there are too many of them (patients). Using the robot, some of the patient doesn't have to trouble the nurse when they want to eat, so the nurse can focus on the other patient that required more attention.

1.2 Problem statement

1.2.1 Cost:

As we know, the cost to make a robot is not cheap. The entire factors that can make a waste when doing this project have been list. The first one is the selection of material. In order to minimize the loss, the material have been decided and the quantity of the material that will be use have been check, this robot will use aluminum and Perspex for the arm, and a spoon will be attach directly to the arm of the robot. Secondly, this robot will use a radio control (RC) Servo motor which is among the cheapest servo motor in that types.

1.2.2 Material Selection:

One of criteria need to make the arm of the robot is light in weight but at the same time strong and long lasting. Otherwise, the servo motor will not able to pull up the arm and perform the desired turning degree. Some of the material that can be consider to be used as the arm are perspex, carbon fiber, aluminum, plastic polymer. The materials also need to anti rust so that it can have a longer life spam. The other aspect that should be considered are the overall cost, availability of the materials and flexibility to be shaped. Among the materials that have considered earlier, aluminum and Perspex seem to fulfill the entire requirement needed.

1.2.3 Design The Mechanism and Fabrication Of the Robotic Arm:

The problem in this part is how the servo motor needs to be place and attach in the right position and section or joint to achieve the desired turning degree. In order to complete this project the robot need to be able to attach to each part, for example between the elbow and the wrist. Other than that, the combination of the arm component should be considered in order to achieve the desired degree of freedom. The connection of the link or arm will determine whether the robot can go to the end point that has been set or not. Solidwork software will be used to draw and simulated the mechanical design of the robot. The troubleshooting in the design will be done to improve the robotic arm. With this, the robot can be more reliable.

1.2.4 Circuit Design and Software Programming:

The robot will used the electronic part to control the movement of the arm. This will be done by controlling the rotation of the servo motor. In order to do that, the Arduino Duemilanove is used to control the servo motor, the electronic circuit and the programmed coding will be done by using the Proteus and Arduino software. The power supply to the arduino and the servo motors need to be done separately to ensure the components will not damage and have a better performance.

1.3 Objective

The objectives of this project are:

1. To design and construct the robotic arm structure for people disabilities for eating purpose.
2. To analyze the performance of the robot in term of repeatability and accuracy.

1.4 Scope of the Project

The scopes of this project are:

i. The degree of freedom for the robot is 4 or less.
ii. The actuator for the robot is RC servo motor
iii. The materials that will be used are aluminum and Perspex.
iv. The robot needs to be placed in a known position (fix position).
v. The patient should be able to move at least a finger to push the button.
vi. The plate or bowl need to be placed in a fixed position.
vii. The microcontroller used is Atmega328 (used in Arduino Duemilanove).
viii. The software to design the mechanism is SolidWorks.
ix. The coding of the robot will use the Arduino software and the proteus will be used to design the electronic part.
x. The food is only limited to the porridge only.

CHAPTER 2

LITERATURE REVIEW

Literature review is where the ideas and the example of past journals is used as a guide when carried out this project. All the methodology of experiment, the design and so on can be used to complete the project and gets the ideas to improve the project.

2.1 Material used

Basically the material used for the robot must be a strong and long lasting material. The reason is do that the robot is strong and stable. Based on all the literature review that has been study, aluminum is used as their material selection. Aluminum is easy to be shape but at the same time strong. Another material that can be used is Perspex. Perspex a transparent thermoplastic, this material is light in weight and can be easily be cut into shapes. There are also other material that have been used like low foamable vinyl chloride, balsa wood and carbon plate [3]. Stainless steel [4] is also use as part of the robotic arm.

2.2 Actuator

There are two types of actuator used to move the robot, that is servo motor and DC motor. DC motor is continuous motor and it is fast, about 5000 rpm. The advantage of DC is it cans senses current flowing through output and the disadvantage is with a voltage lower than 8V is functional [7]. To control the DC motor, H-bridge is needed. The second actuator is servo motor. Servo motor is widely used to control the robot's movement nowadays. This is because the servo motor is easy to control. Besides been small, the servo motor has high torque, because it has gear in it. Some servo motor can be modified to rotated 360 degree [8].

2.3 Controller

There are lots of methods to control the robotic arms because of the advance technology nowadays. There are head-controller interfaces, eye-controller interface, vision-based interface, Electromyogram (EMG) [3], CRT display and mouse click (PID) [4], and using a touch sensor on the cheek [5]. There is also the use of GSR sensor to control the robot [6]. All of this is to enable the disabilities people to gain control of the robot. Figure 2.1 show the example of controller used [3].

Figure 2.1: Example of Controller

2.4 Degree of Freedom

Degree of freedom (DOF) is the number of values in the final calculation of a statistic that are free to vary [9]. The robotic arm usually consists of wrist, shoulder, elbow and wrist. The degree of freedom of the robot is depends on the purpose of the robot, but the lower the number of degree of freedom, the greater the limitation of the robot. The robot can be move in linear motion and rotated motion. There is also 1DOF robot [4]. Figure below is the example of 1DOF robot.

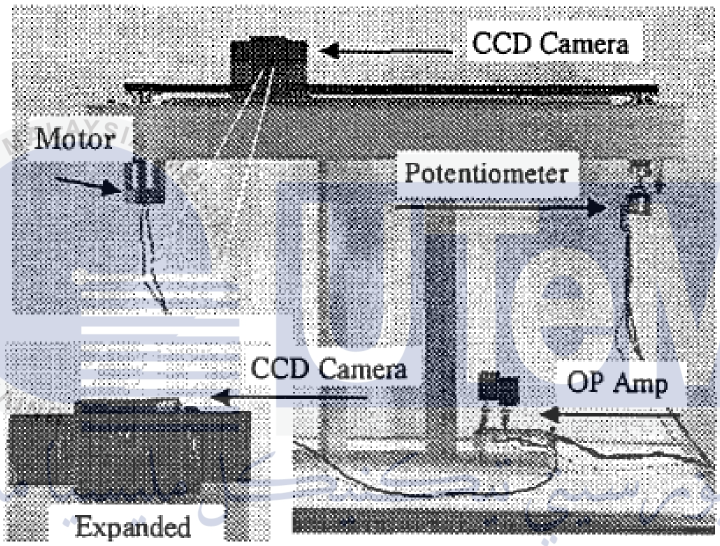


Figure 2.2: One DOF robot

2.5 Microcontroller

Microcontroller is a device that is similar to a small computer. It consists of memory, processor core and programmable I/O peripherals. Microcontroller is used in the robot to control the motor using codes. One of the example is to control the servo motor using PWM. The coding can be create and the compile it into the microcontroller chips. There are lots of features in microcontroller. Eg: analog-to-digital converter (ADC), pulse width modulation (PWM), URAST and so on. Different microcontrollers have different bits. AT91SAM have 32-bits [3].

2.6 Propose Method

In the project of robotic arm to aid disabilities people to eat, there are a few experiments can be done to test the robot in term of its performance. The robot can be test in term of time taken to pick up food and to change the utensil [3]. Besides that it can also be test in term of eating ratio, remained food ratio, spilled ratio and scooping number [5]. To do the test, prototype can be used [4]. The reason to use the prototype is that it's cheaper and easy to build.

	JOURNAL 1- A Mobile Robotic Arm for People with Severe Disabilities	JOURNAL 2: Robotic Food Feeder	JOURNAL 3: Development of Feeding Support System and Its Quantitative Estimation	JOURNAL 4: Human Interface Using PC Display With Head Pointing Device
Propose Method	Test in term of time taken to eat and change utensil	Test using a prototype(1DOF) in term of accuracy of the robot	Test in term of eating ratio, remained food ratio, spilled ratio and scooping number	Test the operation and controller of the robot using CCD camera, and experiment of using GSR sensor
Control Method	Head-controller interface, Eye-controller interface, Vision-based interface, Electromyogram (EMG)	CRT display and mouse click. PID	Using a touch sensor on the cheek.	PI
DOF	7	3	4	5
Type of Motor	Servo motor (controlled by pulse width modulation)	DC motor	DC motor and potentiometer	DC motor and Potentiometer
Microcontroller	AT91SAM7S256, Atmel	Not stated	Not stated	Not stated
Dimension	36 cm X 25 cm X 9 cm (folded)	15cm X 10cm X 5cm	500 mm X 600 mm	14cm X 13cm X15cm
Weight	5 kg with two batteries	4..6kg	Not Stated	Not stated
Materials	Aluminum (mainly), low foamble vinyl chloride, balsa wood, carbon plate	Aluminum and stainless steel	Aluminum	aluminum
Advantage	mobile, light, small, low power	Easy to used, accurate	Including the table, prevent food spills, possible to eat various type of food,	Can control using the patient emotional, advance technology
`	Need to have computer to control.	Still under development, only test with one degree of freedom, need to have computer	Difficult to carry around, too big	Still under development

Table 2.1: Comparison of Journals

2.7 Conclusion of Literature Review

As a conclusion, the robotic arm for this project will used aluminum and Perspex for the body parts. The actuator to control the movement of the robot is RC servo motor because it is accurate and has a high torque. The robot is control by using a switch where it should automatically move to pick up food at fixed position. Besides that, the degree of freedom for the robotic arm is 4 or least. This is to reduce the cost to buy the materials needed to build the robot. ATmega328 is used as a microcontroller of the robot because it has enough port to control all the servo motors in the robot. Lastly, to test the performance of the robot, this project will setup two experiments. The first is to analyze the accuracy of the robotic arm in term of error in the degree to complete the tasks and the ability to perform a movement with and without load. Second is to analyses the repeatability of the robotic arm, where the robot will do a repeated tasks and the last position of the robot is measured.

CHAPTER 3

METHODOLOGY

Methodology of the project is the step or procedure to complete the objective of the project. For this project, there are 2 objectives, to design a robotic arm and test its performance in term of accuracy and repeatability.

3.1 Flow Chart of Methodology

The flow chart of the project is shown on Figure 3.1. The flow chart of the methodology is based on the objective of the project. The step after study the literature reviews is designing the robotic arm and decides the degree of freedom of the robot. When it is complete, the component and system control for the robot is been consider. If it is decided, the construction of the robot can be preceded. After the prototype is been constructed, the analysis of performance based on repeatability and accuracy will be carried out.

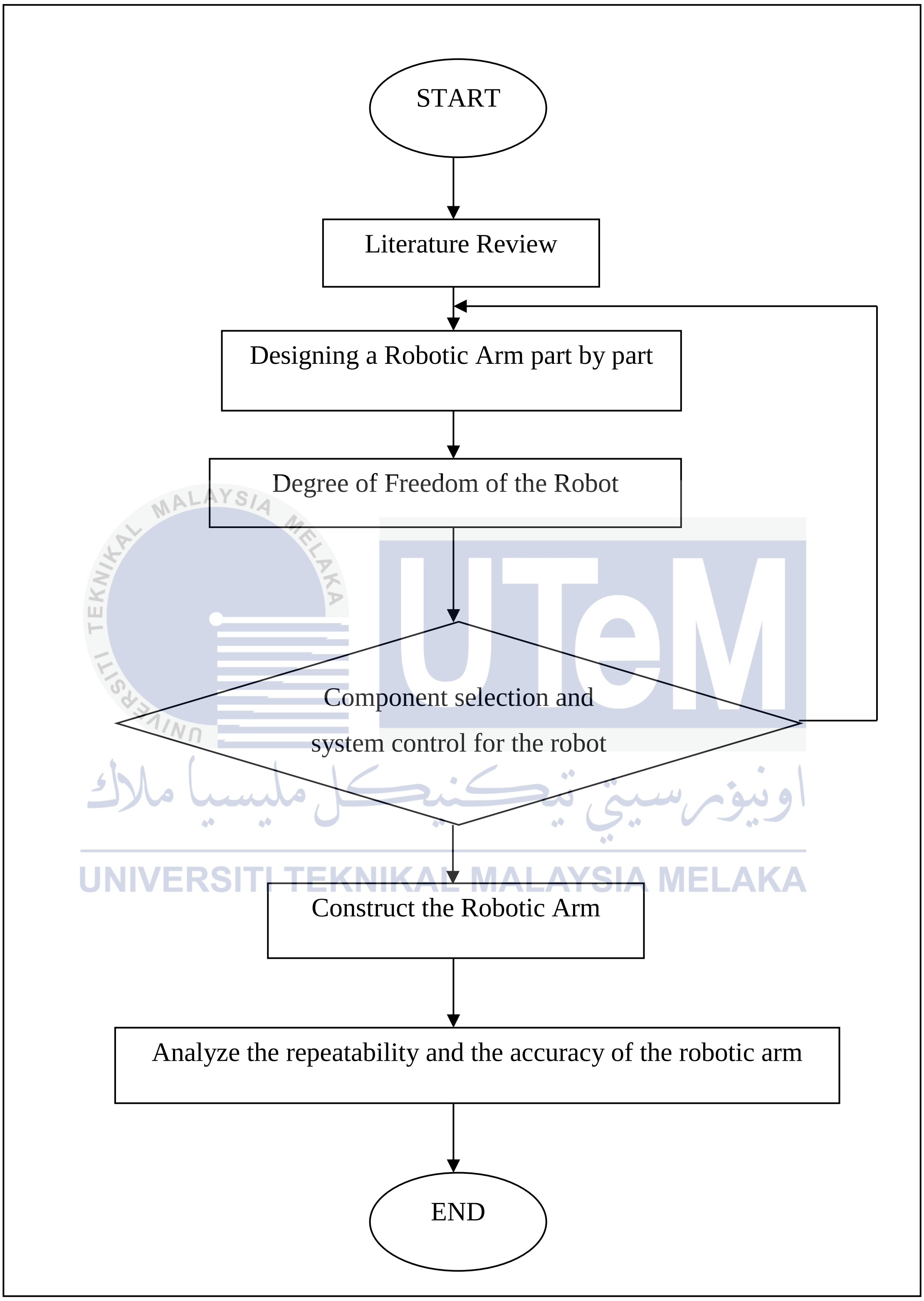


Figure 3.1: Flow Chart of Methodology

3.2 Designing a Robotic arm parts

The design of these robotic parts is by using SolidWorks software. The robotic arm has 4 parts, the servo holder, the U-joint, the base and the rod. The SolidWorks software can show the 3D view of each components and the dimension of each part can be shown as well. The CAD drawing of the complete robot is shown on figure 3.2 and 3.3. Figure 3.4 show the complete assemble of the robot.

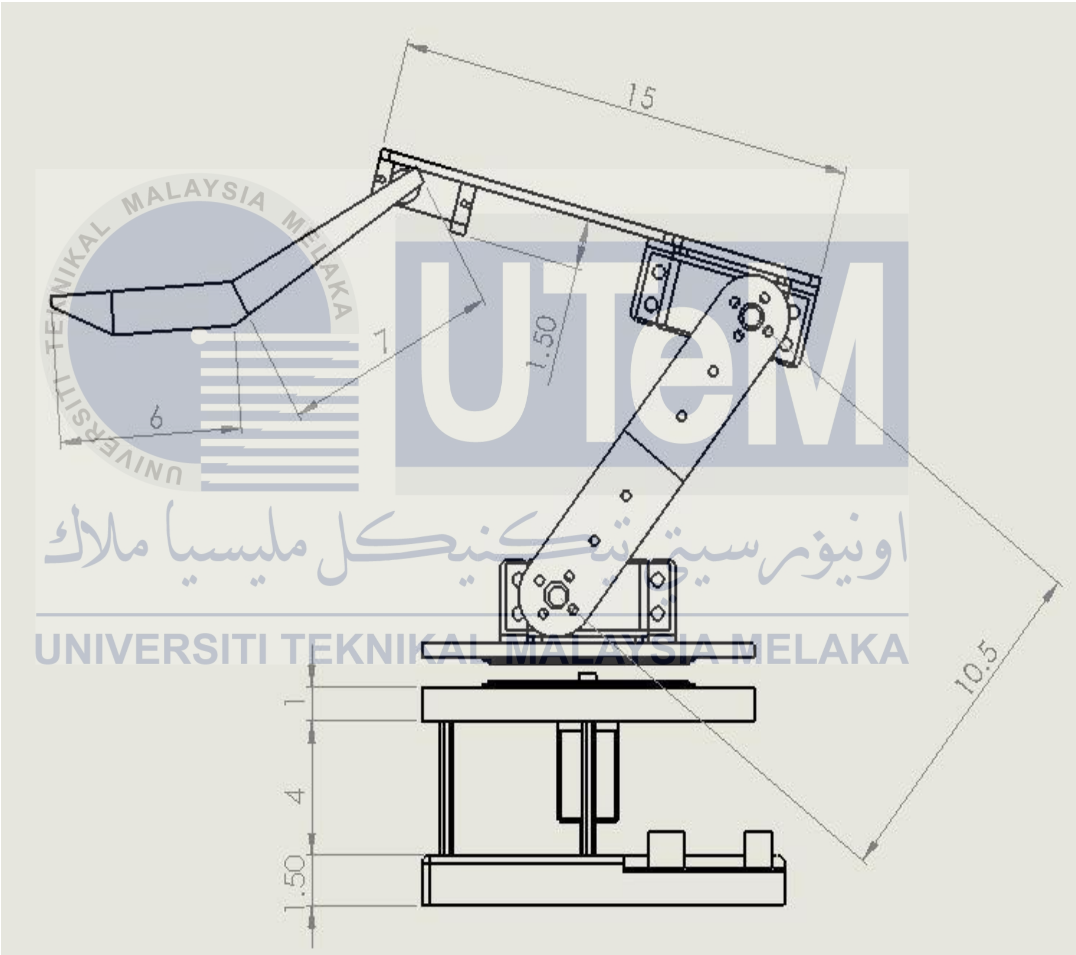


Figure 3.2: Front view of the robot

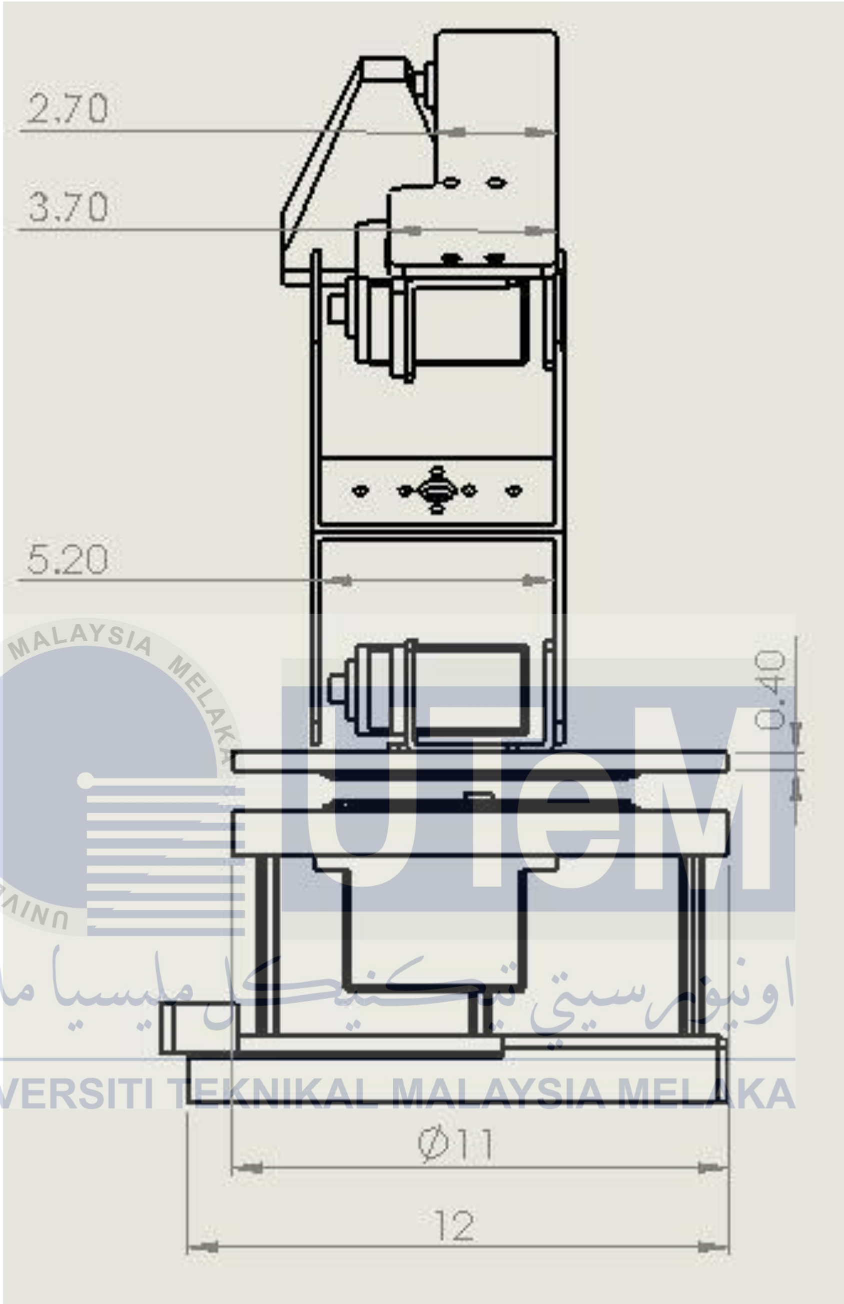


Figure 3.3: Side view of the robot

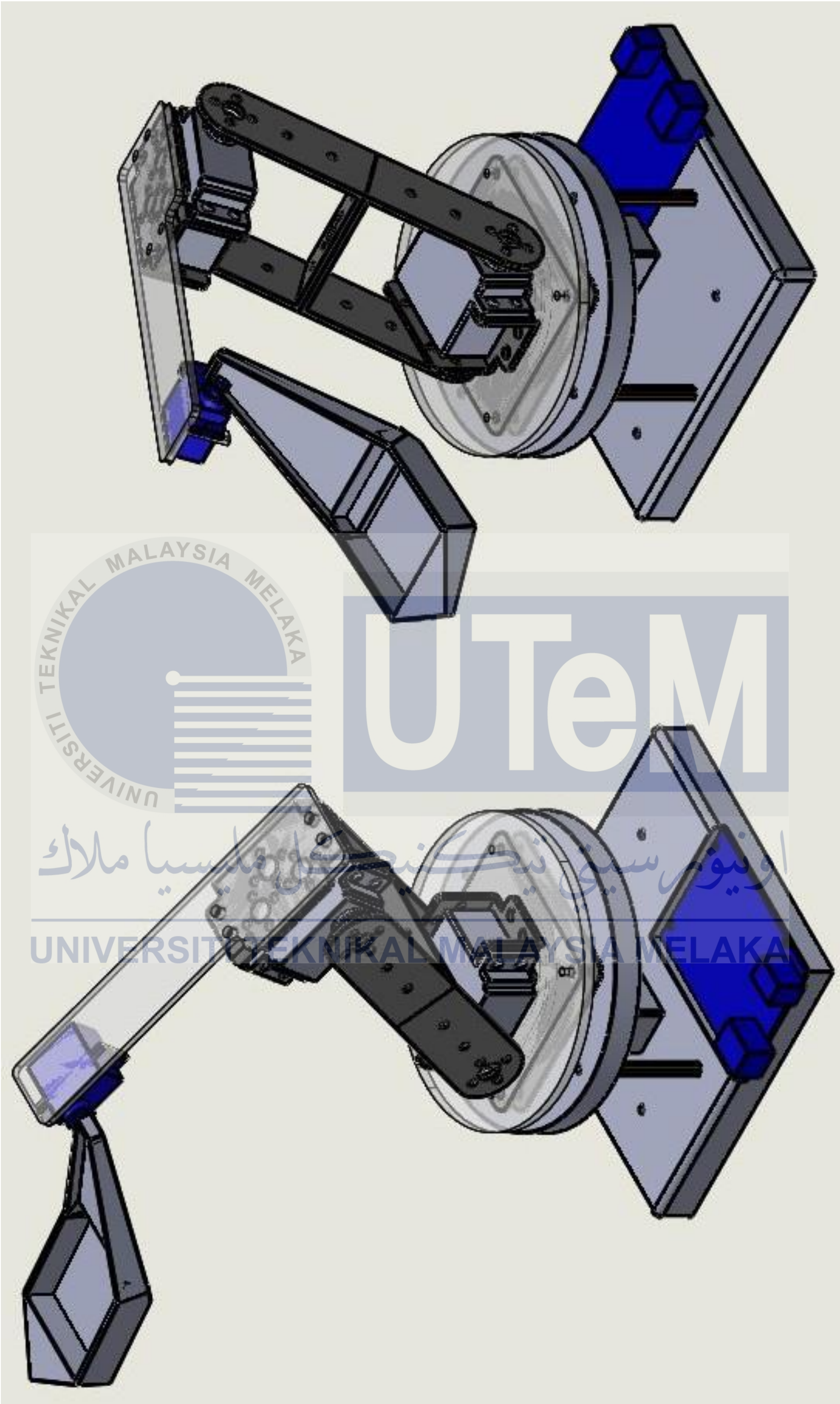


Figure 3.4: Design concept of the robot

3.2.1 Servo Holder

Figure 3.5 show the servo holder, the function of the servo holder is to hold or attach the servo motor to it. It is also to protect the servo motor. The material of the holder is aluminum, which light in weight but at the same time is a strong and not easy to break.

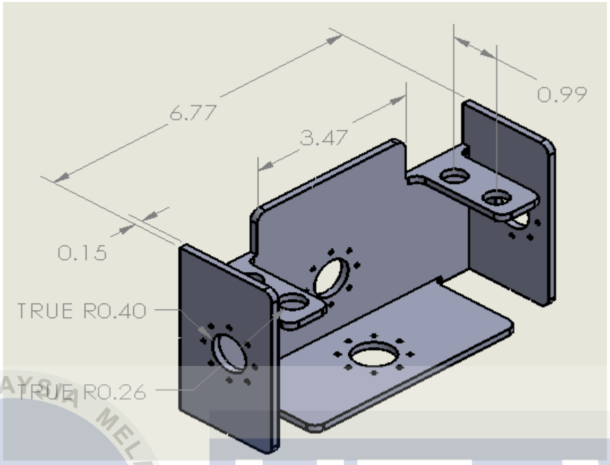


Figure3.5: Servo Holder

3.2.2 U-Joint

U-joint is function to connect with the servo holder. It can move or drive by the servo motor if attach in the right position. The u-joint also can be attached to the rod. The material for the u-joint is aluminum. Figure 3.6 shows the design of U-joint.

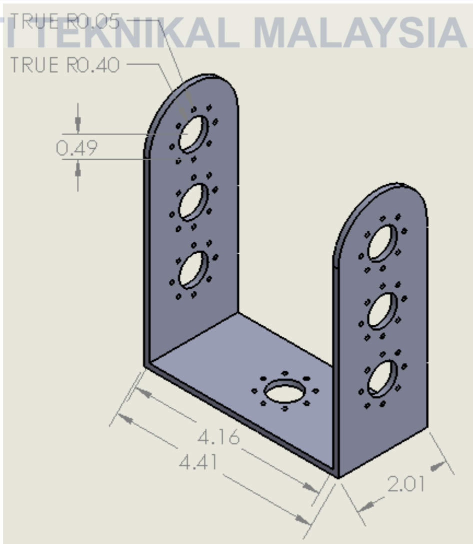


Figure 3.6: U-Joint

3.2.3 Base

The base function is to support the weight of the robotic arm. The base is made heavy in weight and wide in size. The purpose is too made sure that the base is stable. The base is divided into three, the base for the shoulder motor, the upper base and the lower base. The upper and lower base will be connected by 3 rod. The reason the rod is used is to ensure that the servo motor can be place at the base and the arduino can also attach to the base. The shoulder motor base is made from Perspex. This base and the upper base are connected with the rotate bearing. The function of the bearing is to ensure that the base can rotate smoothly. Figure 3.7 show the base design of the robot. The dimension for each part of the base is shown of figure 3.8 to figure 3.

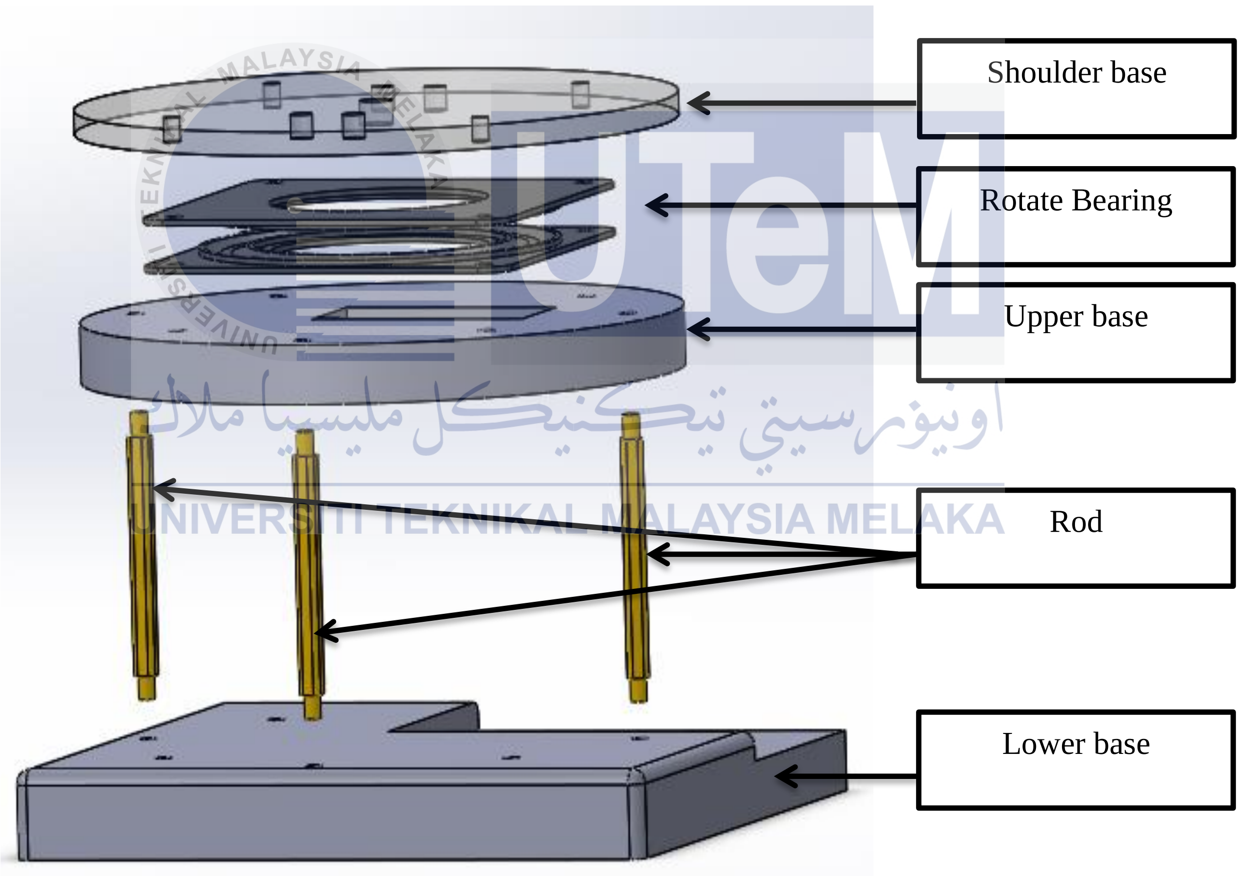


Figure 3.7: Bases of the Robotic Arm

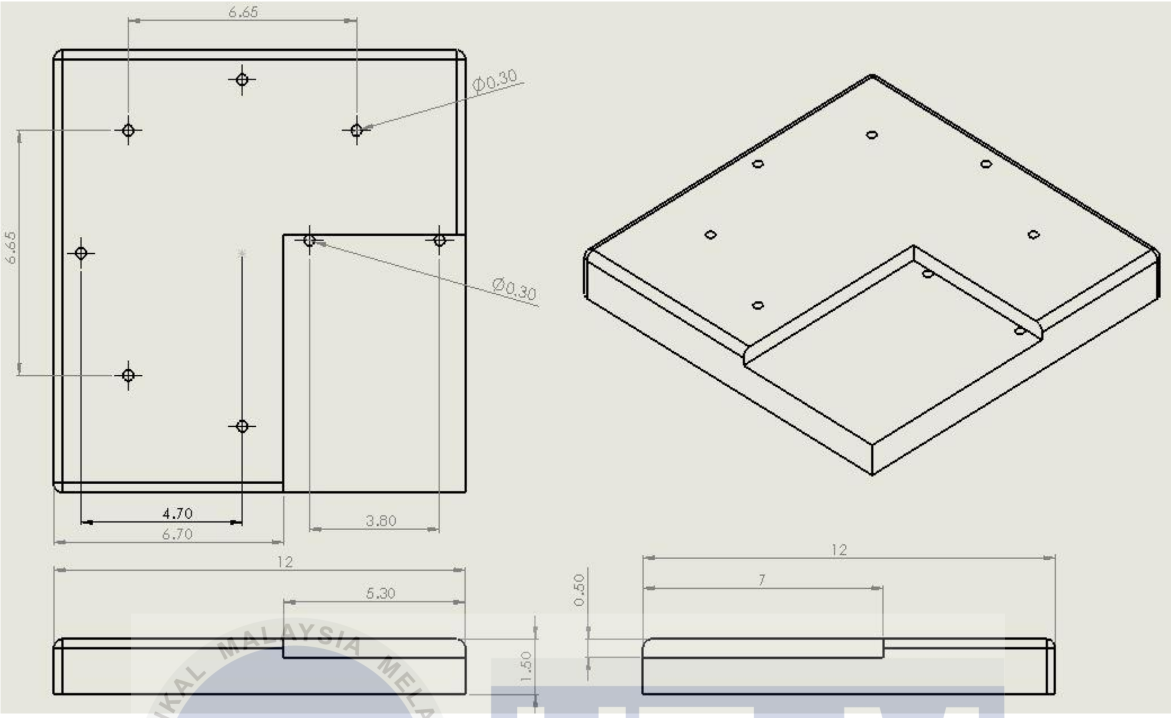


Figure 3.8: Lower base

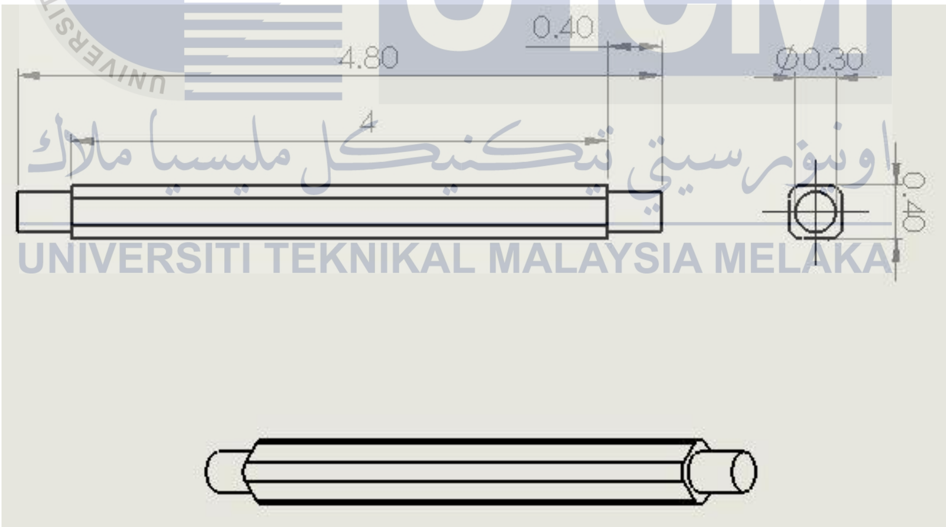


Figure 3.9: Rod

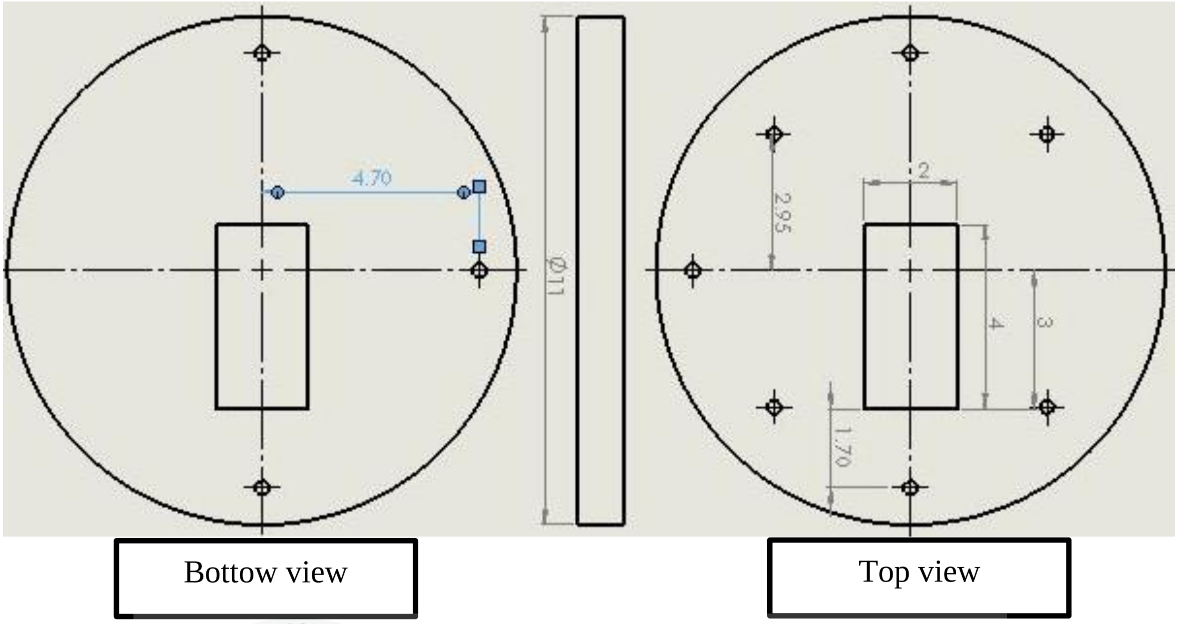


Figure 3.10: Upper base

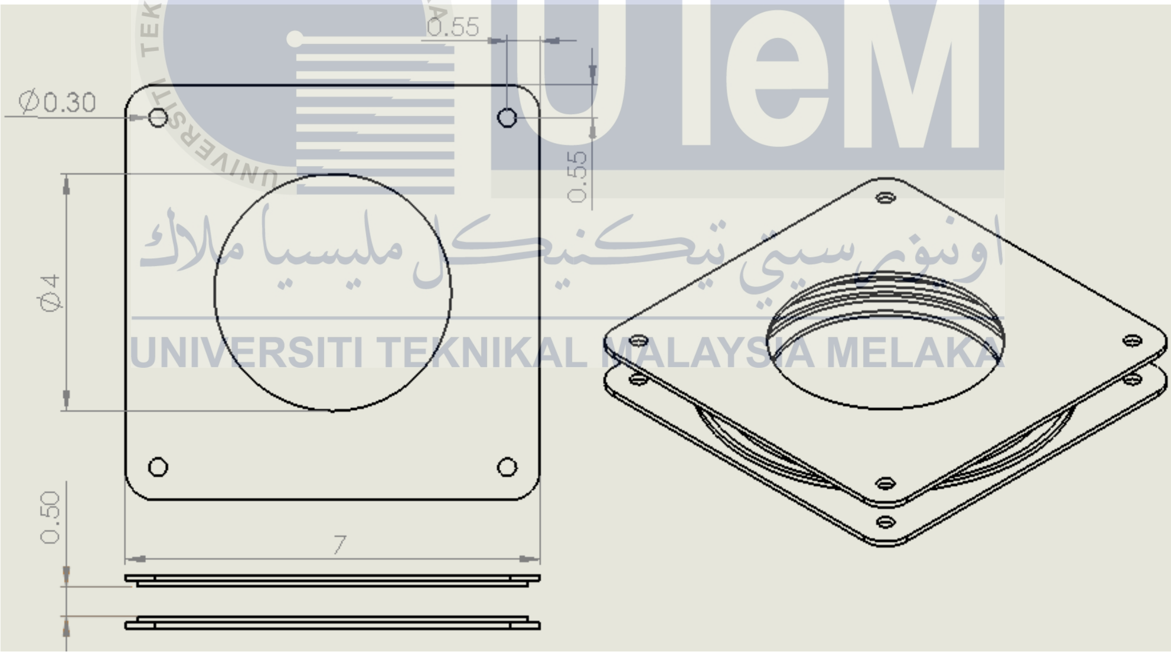


Figure 3.11: Rotate Bearing

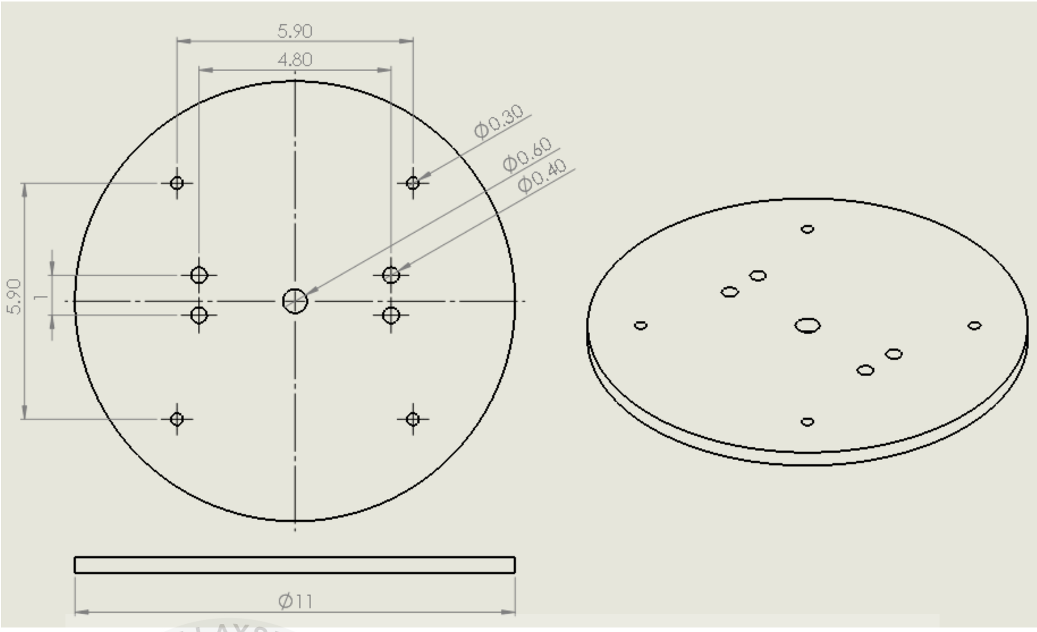


Figure 3.12: Shoulder motor base

3.2.4 Arm

Arm is used as a connector. The arm is a linker of the robot, the length is about 10 to 15cm. Material of the arm is Perspex, it is because the Perspex is light in weight, long-lasting, cheap and easy to shape. The arm needs to be light in order to reduce the weight of the burden that the servo motor will lift. Figure 3.13 show the design of arm.

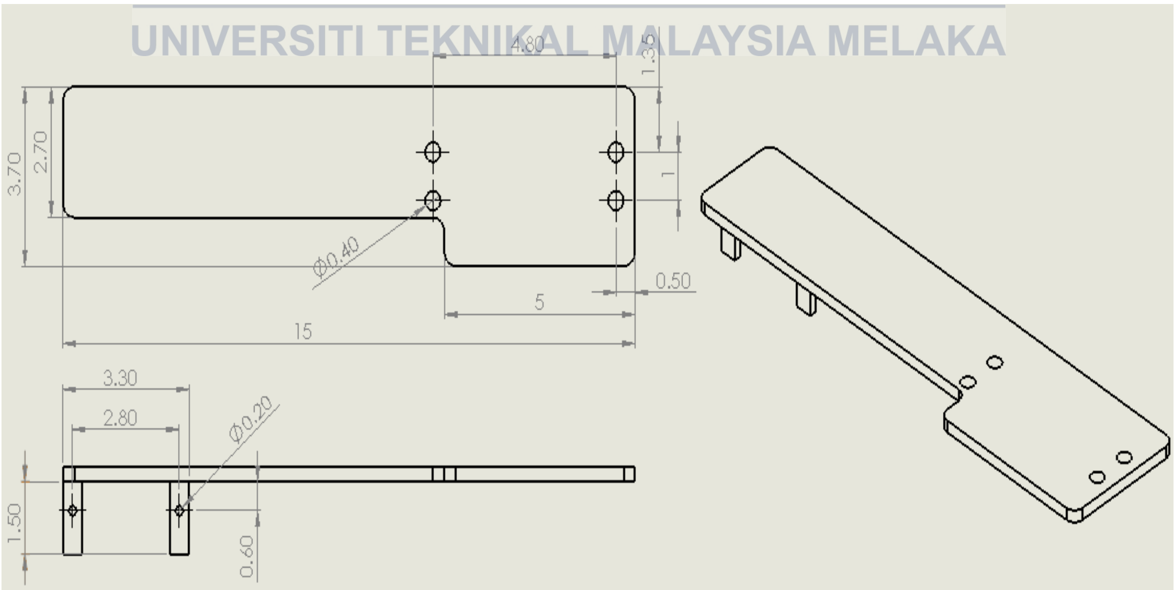


Figure 3.13: Arm

3.3 Force Calculation of the Joint

3.3.1 Moment Arm

The basic equation for the moment calculation is:

Moment=force x distance (3.0)

Moment calculation is used to identify the desired torque of the actuator (servo motor) in order to lift the robotic arm. This can avoid buying a wrong actuator.

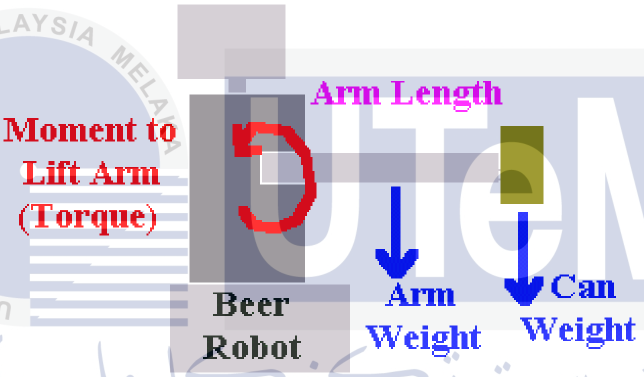


Figure 3.14: Beer robot

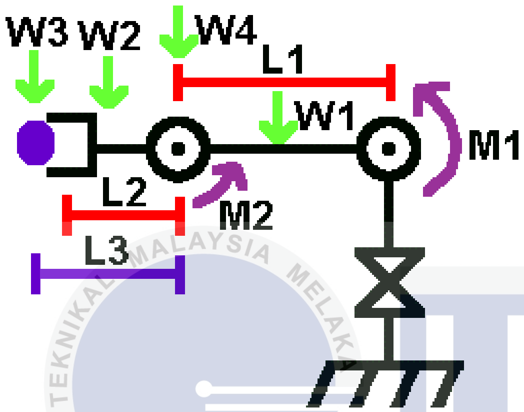
In order to calculated the desired torque of the motor in the Figure 3.14 by using equation 3.0.

Moment = (Can weight x arm length) + (arm weight x arm length/2) (3.1)

The arm length is divide by two is because the weight is distributed thought out the entire arm. Theoretically, all the force across the arm is combine and applying it to the center of mass of the robot arm. The center of mass is estimate to be the midpoint of the robot arm. The center of mass may not be at the midpoint of the arm, to find the center of mass, the arm must be balance and measure it using a ruler.

3.3.2 Force Calculations of Joints

The force calculation is done in order to select a suitable motor's torque for the robot. In motor selection, a few thing need to be consider. First, the motor need to be able to support the weight of the robot arm. Second, the motor need to be able to lift the materials that the robot will hold. Figure 3.15 show example of 2 DOF robot's free body diagram. The robot arm stretched out to its maximum length.



Choose these parameters:

- weight of each linkage
- weight of each joint
- weight of object to lift
- length of each linkage

Figure 3.15: FBD of 2 DOF robot

Using equation 3.0 and 3.1 (moment arm calculation) to find each torque desired at Motor 1, M1 and Motor 2, M2.

Torque at Motor 1:

$$M1= (L1/2 \times W1) + (L1 \times W4) + ((L1 + L2/2) \times W2) + ((L1 + L3) \times W3) \quad (3.2)$$

Torque at Motor 2:

$$M2 = (L1/2 \times W2) + (L3 \times W3) \quad (3.3)$$

Where : L1= length of arm 1

L2= length of arm 2

L3= length from Motor 2 to end point

W1= weight of arm 1

W2= weight of arm 2

W3= weight of object (load)

W4= weight of Motor 2

For 3 DOF robot, the calculation are shown below:

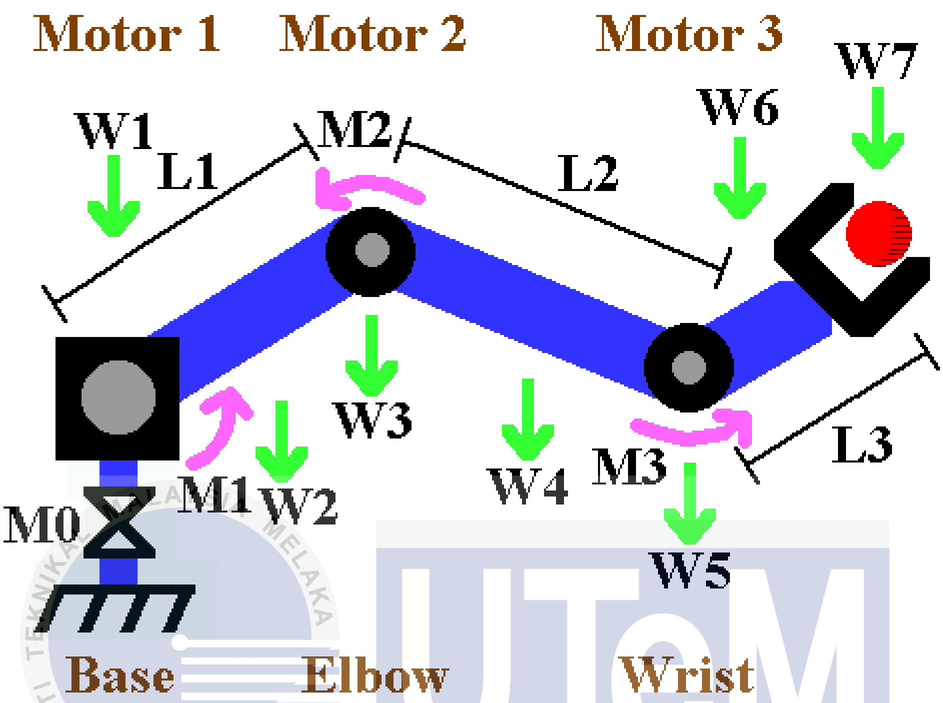


Figure 3.16: 3 DOF robot

M1 = ((L1/2) x W2) + (L1 x W3) + ((L1 + (L2/2)) x W4) + ((L1 + L2) x W5) + ((L1 + L2 + LS/2) x W6) + ((L1+ L2 + L3) x W7) (3.4)

= ((0.105/2) x 0.046) + (0.105 x 0.061) + ((0.105 + (0.11/2)) x 0.019) + ((0.105 + 0.11) x 0.009) + ((0.105 + 0.11 + 0.04) x 0.019) + ((0.105 + 0.11 + 0.13) x 0.01)

= 0.253 Nm

M2 = ((L2/2) x W4) + (L2 x W5) + ((L2 + LS/2) x W6) + ((L2 + L3) x W7) (3.5)

= ((0.11/2) x 0.019) + (0.11 x 0.009) + ((0.11 + 0.08/2) x 0.009) + ((0.11 + 0.13) x 0.01)

= 0.103 Nm

M3 = ((LS/2) x W6) + (L3 x W7) (3.6)

= ((0.08/2) x 0.009) + (0.13 x 0.01)

= 0.0347 Nm

(*calculation is based on http://www.societyofrobots.com/robot_arm_calculator.shtml)

3.4 Component Selection

3.4.1 Arduino Duemilanove R3

An Arduino Duemilanove is a microcontroller board based on the ATmega328. This microcontroller consists of 14 digital input/output pins, a 16MHz ceramic resonator, 6 analog inputs, an ICSP header, a USB connection, and a reset button. Arduino Duemilanove board has everything needed to support the microcontroller. It is used to control the servo motor using the C codes. Figure 3.17 show the board of arduino.

Table 3.1: Arduino Duemilanove Specification

ARDUINO Duemilanove R3 Specification	
Microcontroller	ATmega328
Operation Voltage	5V
Input Voltage (recommended)	7-12V (min 6V max 20V)
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA

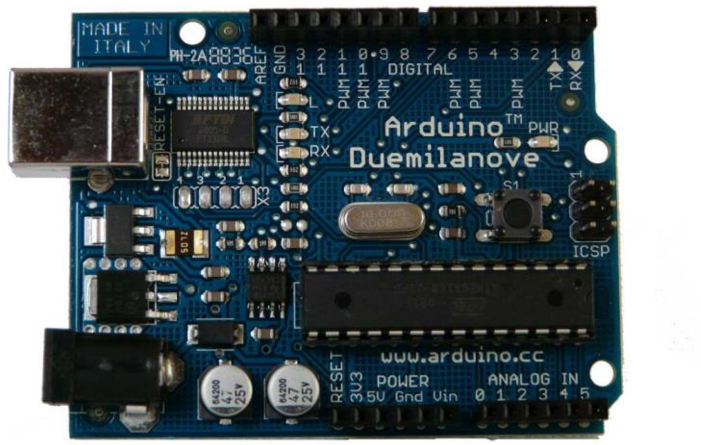


Figure 3.17: Arduino Duemilanove

3.4.2 Servo Motor

Servo motors are DC motors that build in gearing and feedback control loop circuitry. A servo mainly consists of a DC motor, gear system, potentiometer (position sensor) and control electronics. Figure 3.18 show the component of servo motor. DC motor is connected with the potentiometer via a gear system. As the motor move, the potentiometer also rotates. The potentiometer act as a position sensor which will provide a feedback to the system. The change in resistance produces an equivalent change in voltage from the potentiometer. A pulse width modulated signal is fed through the control wire, then the pulse is converted into an equivalent voltage that is compared with that of signal from the potentiometer in an error amplifier. Figure 3.19 show the servo control system.

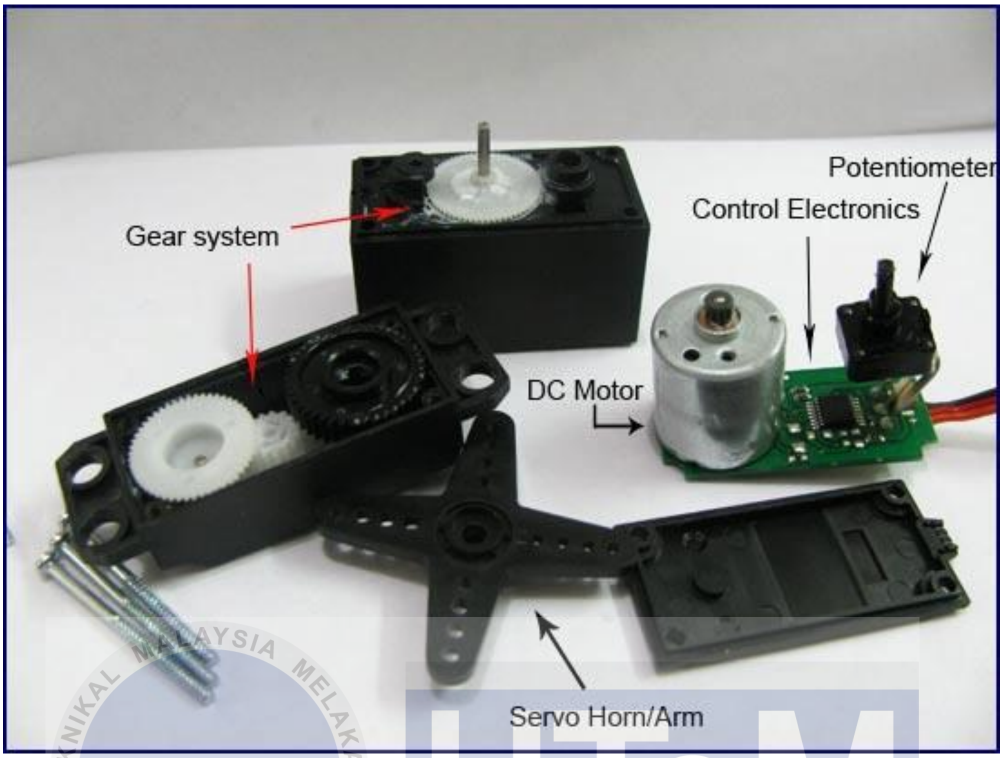


Figure 3.18: Servo Motor Components

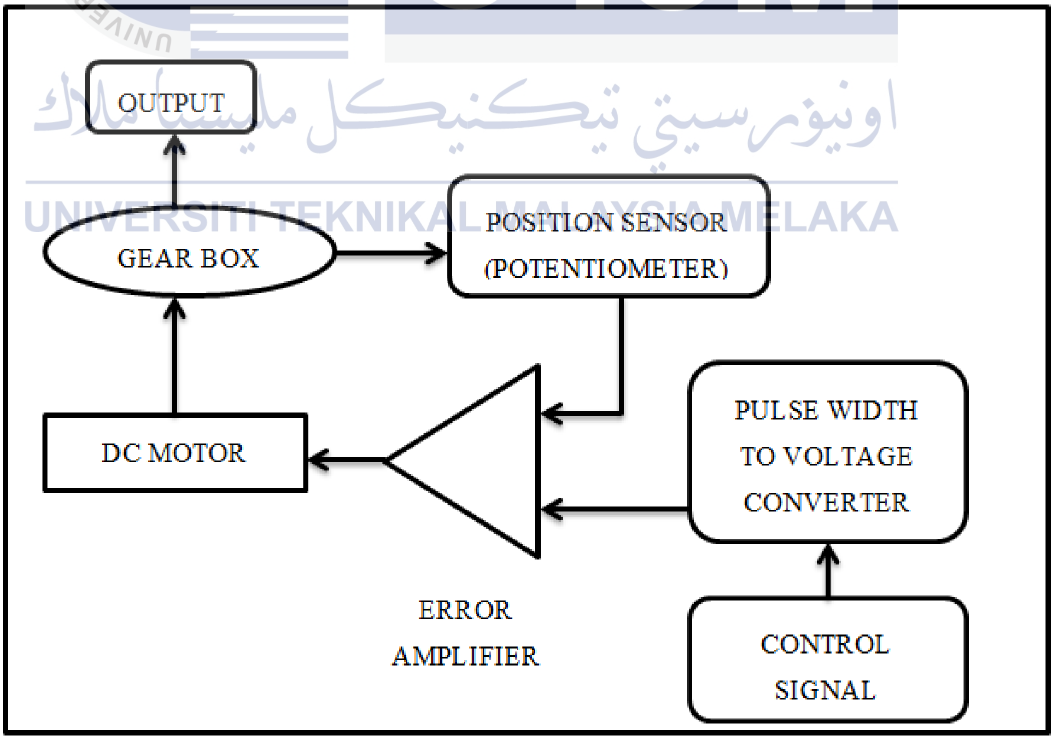


Figure 3.19: Servo Control System

Servo motor is used to move the arm of the robot. Servos have integrated gear and shaft that can be precisely controlled. Normal servos can move from 0 to 180 degrees. Using the servo, the angle of the robotic arm can be set to a precise position. For this project, 3 servo motor will be used to move the robotic arm. In this project three different types of RC servo motor have been used. There are Cytron C40R (Figure 3.20 and Table 3.2), Futaba S3003 (Figure 3.21 and Table 3.3), and micro servo SG90 (Figure 3.22 and Table 3.4),.

Figure 3.20: C40R Servo Motor

Table 3.2: C40R Servo Motor Specification

RC C40R Servo Motor Specification	
Type of Gear	Plastic
Speed (sec/60degree)	0.16/4.8V , 0.14/6.0V
Torque (Kg-cm)	6.0/4.8V , 7.0/6.0V(max)
Size (mm)	40.2 x 19.8 x 36
Weight (g)	38
Rotation angle	0 to 180 degree
Pulse Width Range	0.54ms to 2.4ms (estimation)
Designed for “closed feedback”	

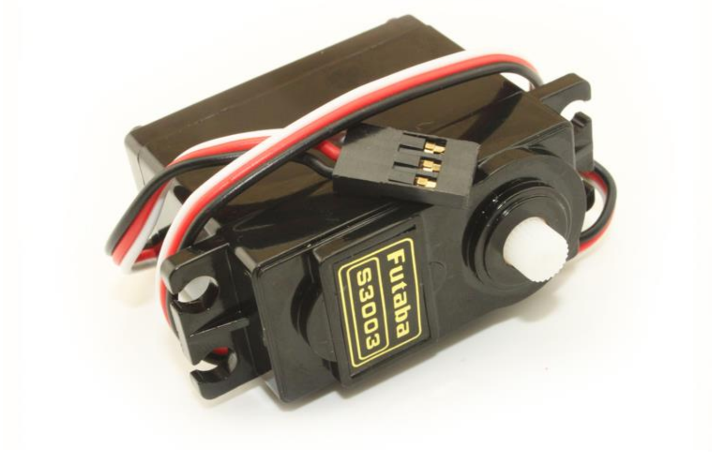


Figure 3.21: Futaba Servo Motor

Table 3.3: Futaba Servo Motor Specification

RC C40R Servo Motor Specification	
Type of Gear	Plastic
Speed (sec/60degree)	0.23/4.8V , 0.19/6.0V
Torque (Kg-cm)	3.2/4.8V , 4.1/6.0V(max)
Size (mm)	41 x 20 x 36
Weight (g)	37.2
Rotation angle	0 to 180 degree
Designed for “closed feedback”	

Figure 3.22: SG90 Micro Servo Motor

Table 3.4: SG90 Micro Servo Motor Specification

RC SG90 Micro Servo Motor Specification	
Type of Gear	Plastic
Speed (sec/60degree)	0.10/4.8V
Torque (Kg-cm)	1.8/4.8V
Size (mm)	23.1 x 12.2x 29
Weight (g)	9
Rotation angle	0 to 180 degree
Pulse Width Range	0.50ms to 2.4ms (estimation)
Designed for "closed feedback"	

3.4.3 Push Button

Push button acted as a switch to make the robotic arm move automatically and scope the food then place near the patient mouth.

Figure 3.23: Push Button

Table 3.5: Push Button Specification

General purpose miniature tact switch
DPST 4 pins
Push ON
Size: 6mm x 6mm
High 1mm
Current: 50mA / 12Vdc

3.5 System Control

The robot can be control by using the push button. When the user pushes the push button, the robot will automatically move to the bowl to pick the food (the position of the plate must be fix at the given position). Then the robot will then carry the food to the user mouth (fix position). The coding for the automatic movement of the robot will be compiled into the Arduino. The coding for the robot will be show on the next sub-topic.

3.5.1 Arduino Coding

The robot is controlled by using an arduino. The code to control the servo motors is compiled into the arduino. Appendix B shows the coding for the robotic arm.

First, the servo motor need to be declare in the arduino, the servos are declare as servo1 (shoulder), servo2 (elbow), servo3 (base) and servo 4 (spoon). The next step is declaring the position for each servo, pos1 for servo1, pos2 for servo2, pos3 for servo3 and pos4 for servo4. The button pin is set on pin 2. Servo1 is set on pin 9, servo2 on pin 6, servo 3, on pin 10 and servo 4 on pin 5.

After that, the button is state that if it is HIGH the robot will perform the movements that have been set. In scene 1, the shoulder and the spoon will move simultaneously in 30ms and wait for 2 seconds. This is where the robot will move the spoon into the bowl. In the scene 2, the elbow and spoon will move simultaneously in 30ms and will wait for 2 seconds. At this movement, the robot will spoon is deep into the bowl to let the porridge enter into it.

Next, the scene 3 will move the shoulder, elbow and spoon simultaneously to the desired angle. This move is to make the robot lift the porridge in the spoon. Scene 4 will rotated the base from 0 to 90 degree and wait for 6 seconds. Within this time, the patient can eat the porridge. After that the robot will rotated back from 90 degree to 0 degree and wait for 2 seconds.

Lastly, the coding will move the shoulder, elbow and spoon. This movement is to make the robot drop back the extra porridge into the bowl.

3.6 Construct the Robotic Arm

When constructing the robotic arm, there will be dividing into two parts;

- Mechanical part
- Electrical part

3.6.1 Mechanical Part

The mechanical part is constructed using SolidWorks. All the parts than have been design will be attached together to see whether the part is fix or can be use or not in the robotic arm. The function of each part have to be functional, if not the robotic arm will have more load and this will affect the accuracy of the robot. To attach each part, function "assembly" in the SolidWorks will be used. During the assembly we can see the connection of each part. The CAD of the whole system is shown figure 3.2, 3.3 and 3.4.

3.6.2 Electrical Part

The electrical part is constructed using the Proteus 8.0 software. First, we need to download the arduino library for Proteus and place it into the Proteus library to enable the arduino in the Proteus. The coding for the arduino will be made using the Arduino 1.5.4 software. The coding will be compiled into the arduino in the Proteus to see whether it is function or not. This method can prevent the damage of the hardware. Figure 3.24 show the circuit of the robot.

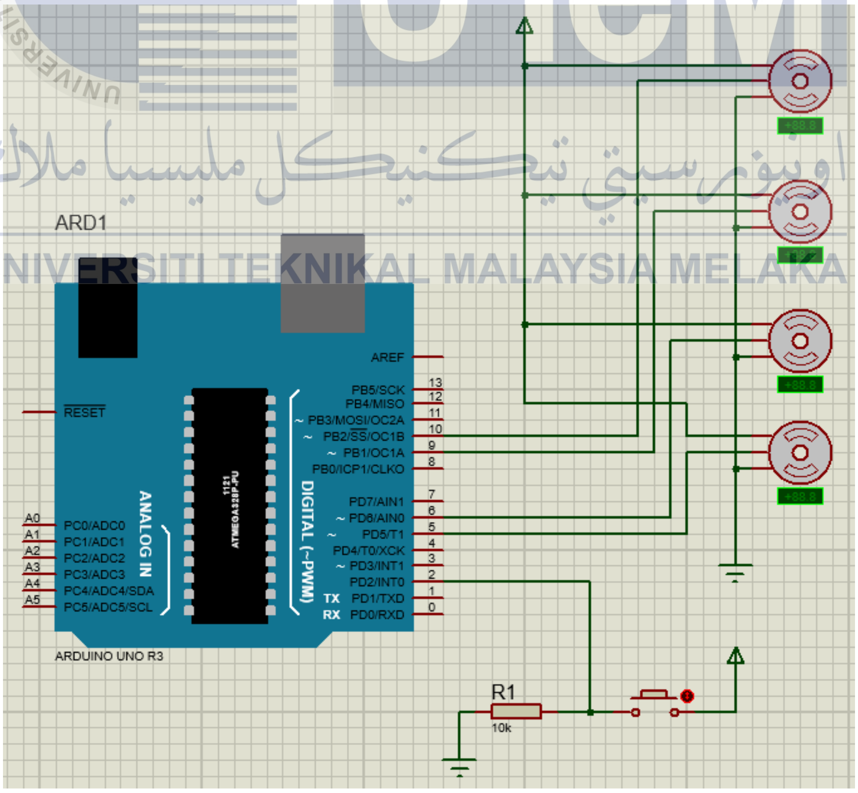


Figure 3.24: Circuit of Robot design using Proteus

3.7 Experiment of the Robotic Arm

3.7.1 Experiment 1

Objective: to analyze the accuracy of the robotic arm

Hypothesis: the servo can rotate from 0 degree to 180 degree, but the rotation may not be accurate due to some error and different torque. Different type of servo can have different accuracy.

Apparatus:

1. Robotic arm prototype
2. Stopwatch, Ruler and protector
3. 3 type of servo (C40R, Futaba S3003, SG90)

Variables:

Constant variable = the pattern of the movement

Manipulate variable = Joint of the robot (different torque)

Responding variable = the error in angle

Procedure:

I. The prototype is place on the fix position.
II. The servo at the shoulder joint is set to 0 degree.
III. The joint move from 0 to 30 degree.
IV. The time taken for the robot finished the movement is measured.
V. The angle at the end point is measured.
VI. Step II to V is repeated 3 times.
VII. Step II to VI is repeated using a different angle from 60, 90, 120, 150 and 180 degree.
VIII. Entire step is repeated at all joint (base, elbow and wrist).

3.7.2 Experiment 2

Objective: to analyses the repeatability of the robotic arm

Hypothesis: the position and the angle of the robotic arm are changing when the robot continuously repeated the movement.

Apparatus:

1. Designed prototype
2. Ruler
3. Protector
4. Camera
5. Tripod

Variable:

Constant Variable = the type on movement

Manipulated Variable = numbers of repeatability of the robotic arm

Responding Variable = the position and the angle of the robotic arm

Procedure:

I. The prototype is set up in fix position.
II. The robot is set to 0 degree position.
III. A picture is taken at the initial position.
IV. The push button is pushed and the robot will move from 0 to 90 degree.
V. A picture is taken at the end point of the movement.
VI. The angle and position is measured using the pictures taken.
VII. Repeat step II and VI for 3 times.
VIII. Repeat all steps at 4 joint of the robot (base, shoulder, elbow and wrist).

CHAPTER 4

RESULT, ANALYSIS & DISCUSSION

Result and discussion is where the data of the experiment is gathered. For this experiment the design of the robotic arm is completed. The robot can pick up the porridge and place it near the patient mouth. The performance of the robot in term of accuracy and repeatability is good, although there is some error but it will not affect the robot to complete the task.

4.1 Result

This section explains the results of this project. The design result of the robotic arm is fabricated. The coding is added into the robot to make control the servo motors at each joint. The result of the design is measured and evaluated according to experiment 1 and experiment 2. The result is tabulated in table form and graph. Based on the results, the performance of the robotic arm is analyzed and discussed.

4.2 Design Result

The parts that have been designed have been assembled together. Robotic arm can be seen in Appendix A. The servo motor is joined together with the servo holder and the U-joint is connected to the servo motor so that it can move. At the base, there will be a motor to move the robotic arm rotationally and are attached together with the rotate bearing to smooth the movement of at the base. The robotic arm will consist of wrist, shoulder, elbow and wrist. Figure 4.1 till 4.3 show the design of robotic arm.

Figure 4.1: Robotic Arm Design (side view)

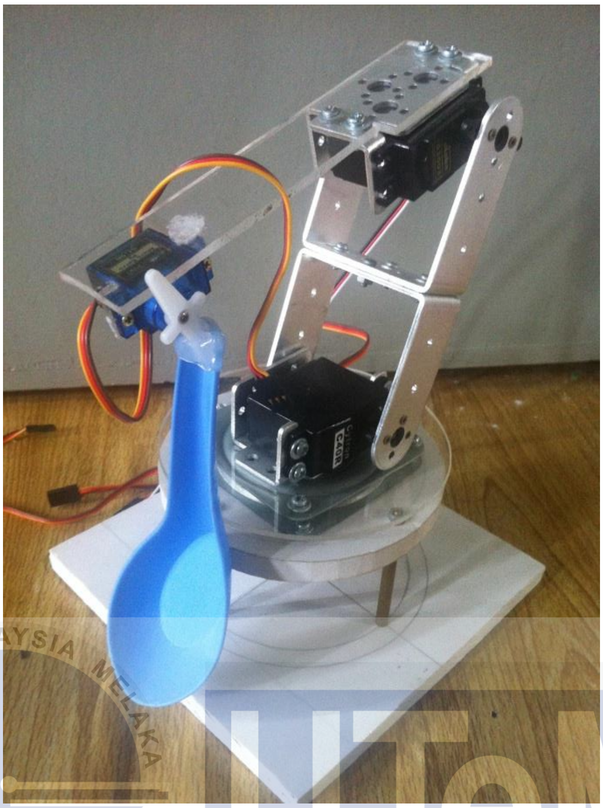


Figure 4.2: Robotic Arm (front view)

Figure 4.3: Robotic Arm (back view)

The figure of robotic arm's part is shown on Appendix C. Table below show the weight of each part.

Table 4.1: Weight of robotic part

Part	**Weight (g)**
2 U-Joint	46
Arm/Linkage	19
Rotate Base	36
Rotate Bearing	80
Base of The Robot	162
C40R Servo Motor	35
Futaba S3003 Servo Motor	38
S90 Micro Servo Motor	9
Spoon	9

4.3 Experiment Result

Show example of table and graph pattern for the experiment.

4.3.1 Experiment 1: Analysis the Accuracy of the Robotic Arm

From the experiment, the robotic arm able to move automatically when the push button is pushed. The experiment analyses the relationship between the total error and the actual position of the robot when it done the movement and time taken to complete the movement. From the grapht (Figure 4.9 and 4.10), the conclusions relate is the bigger the load for the robot to lift, the low the accuracy of the robot. All the step in the methodology is followed and the result is taken. To calculate the error:

Error = Desired Angle – Average Angle of three reading (4.0)

Appendix D shows the experiment of accuracy is been carried out. Table 4.2 till 4.5 shows the result of the experiment.

Table 4.2: Reading at the Base

Angle (Degree)	Reading 1	Reading 2	Reading 3	Average Angle	Error	Average Time (S)
30	29° (1.45s)	28° (1.44s)	28° (1.44s)	28.33°	+1.67°	1.44s
60	59° (3.26s)	59° (3.26s)	59° (3.27s)	59°	+1°	3.26s
90	90° (4.99s)	89° (4.98s)	89° (4.98s)	89.33°	+0.67°	4.98s
120	119° (6.97s)	118° (6.97s)	119° (6.97s)	118.67°	+1.33°	6.97s
150	149° (8.80s)	149° (8.81s)	149° (8.81s)	149°	+1°	8.81s
180	178° (10.27s)	178° (10.28s)	177° (10.27s)	177.67°	+2.33°	10.27s

Table 4.3: Reading at the Shoulder

Angle (Degree)	Reading 1	Reading 2	Reading 3	Average Angle	Error	Average Time (S)
30	31° (1.45s)	30° (1.51s)	31° (1.48s)	30.67°	-0.67°	1.48s
60	61° (3.47s)	61° (3.46s)	60° (3.48s)	60.67°	-0.67°	3.47s
90	89° (5.22s)	90° (5.23s)	90° (5.22s)	89.67°	+0.33°	5.22s
120	119° (7.16s)	120° (7.17s)	119° (7.16s)	119.33°	+0.67°	7.16s
150	150° (8.93s)	149° (8.95s)	149° (8.93s)	149.33°	+0.67°	8.94s
180	179° (11.30s)	179° (11.31s)	179° (11.31s)	179°	+1°	11.31s

Table 4.4: Reading at the Elbow

Angle (Degree)	Reading 1	Reading 2	Reading 3	Average Angle	Error	Average Time (S)
30	31° (1.52s)	30° (1.51s)	32° (1.50s)	30.33°	-0.33°	1.51s
60	60° (3.51s)	59° (3.50s)	60° (3.50s)	59.67°	+0.33°	3.50s
90	88° (5.24s)	90° (5.25s)	89° (5.24s)	89°	+1°	5.24s
120	115° (7.20s)	116° (7.20s)	114° (7.19s)	115°	+5°	7.20s
150	145° (9.01s)	144° (8.98s)	143° (8.99s)	144°	+6°	8.99s
180	176° (11.41s)	175° (11.41s)	175° (11.39s)	175.33°	+4.67°	11.40s

Table 4.5: Reading at the Wrist

Angle (Degree)	Reading 1	Reading 2	Reading 3	Average Angle	Error	Average Time (S)
30	28° (1.37s)	28° (1.36s)	28° (1.37s)	28°	+2°	1.37s
60	59° (3.28s)	59° (3.28s)	58° (3.27s)	58.67°	+1.33°	3.28s
90	90° (5.06s)	90° (5.05s)	89° (5.05s)	89.67°	+0.33°	5.05s
120	119° (7.00s)	118° (6.97s)	119° (7.00s)	118.67°	+1.33°	7.00s
150	149° (8.80s)	149° (8.81s)	149° (8.80s)	149°	+1°	8.80s
180	179° (10.30s)	178° (10.28s)	179° (10.29s)	178.67°	+1.33°	10.29s

From the reading above, Graph Angle vs. Error is produce in figure 4.4.

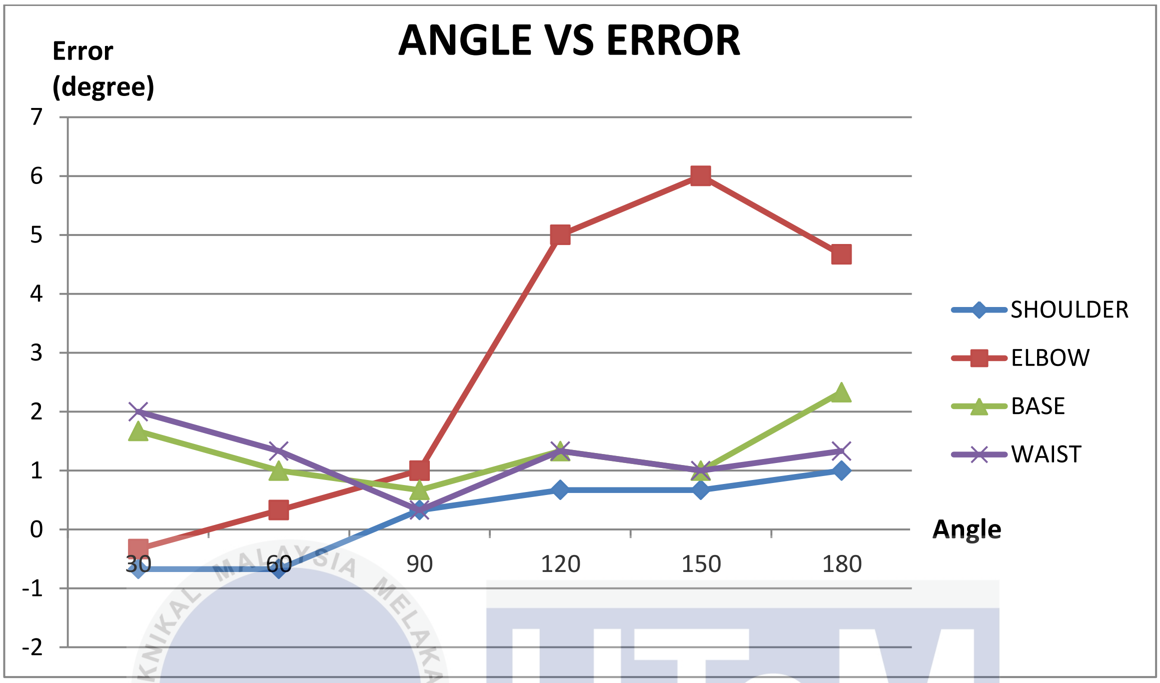


Figure 4.4: Graph of angle vs. error

From the graph taken, there is great error at the elbow compare to other joint. The elbow joint used a Futaba S3003 servo motor which has a torque of 3.2 kgcm to 4.1 kgcm. According to the calculation of torque required at equation 3.5, the elbow need to have 1.05 kgcm. According to the specification of the motor it should be able to lift the arm. The conclusion of the great error at the elbow is because the gear efficiency of S3003 servo is not good enough. The quality of the S3003 is low compare to the C40R servo. S3003 is cheaper compare to the C40R and the torque of C40R is greater compare to the S3003. The base and the shoulder used C40R servo, and the error is less compare to the S3003. The base has an error slightly above the shoulder because the base required moving a greater weight or burden compare to the shoulder. Error for the SG90 micro servo is low and acceptable. The error may occur because of the parallel error when taking the measurement. The reason the futaba S3003 is not accurate is because the servo that have been used on this project is the low quality servo in term of gear efficiency [10]. The gear teeth gap of the S3003 servo used on the robot have a wide gap compare to the original servo, because of that the accuracy of the servo is decrease the servo also attempt to shake a lot. Figure 4.5 show the comparison of coarser teeth between the used servo motor and the genuine Futaba. It has a much smaller number of much coarser teeth. In fact, the output gear has the largest teeth seen in a servo it have adversely affect the operation of the unit once a load is applied.

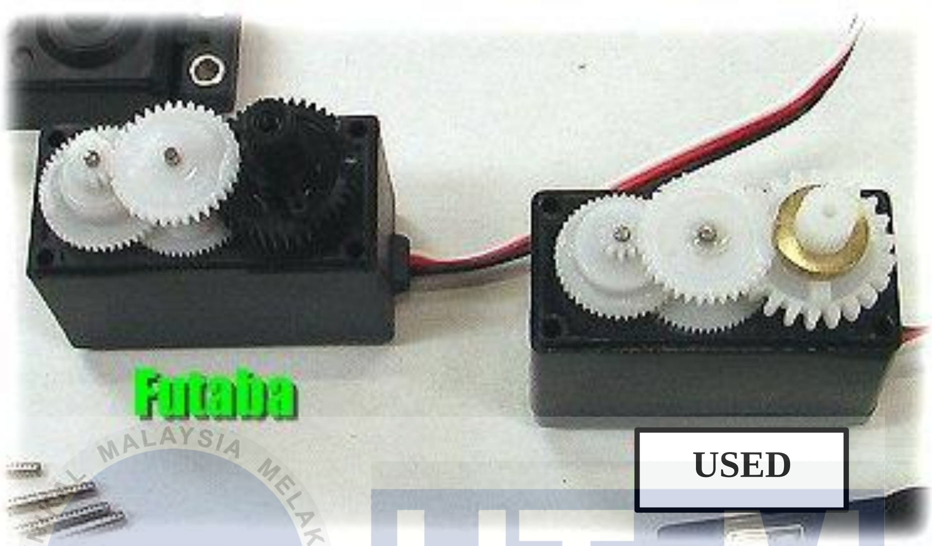


Figure 4.5: The Comparison of Coarser Teeth

4.3.2 Experiment 2: Analysis the Repeatability of the Robotic Arm

From the experiment, the robotic arm able to move automatically when the push button is pushed. The robot moved from 0 degree to 90 degree for 3 times. The experiment analyses the repeatability of the robot. Three pictures of initial position and final position are captured. The picture than will be compared to determine any changes. The camera needs to be static by using a tripod. Appendix E shows the figure of the experiment.

Table 4.6: Base reading for Repeatability

BASE	Initial Position	Final position
Reading 1 (degree)	10^{o}	33^{o}
Reading 2 (degree)	10^{o}	33^{o}
Reading 3 (degree)	10^{o}	33^{o}

The readings show that, the base repeatability is excellent.

Table 4.7: Shoulder reading for Repeatability

SHOULDER	Initial Position	Final position
Reading 1 (degree)	90^{o}	94^{o}
Reading 2 (degree)	90^{o}	95^{o}
Reading 3 (degree)	90^{o}	94^{o}

The readings show that there are slightly misposition at final position, reading 2, at 1^{o}. The repeatability of shoulder is good.

Table 4.8: Elbow reading for Repeatability

ELBOW	Initial Position	Final position
Reading 1 (degree)	14^{o}	5^{o}
Reading 2 (degree)	14^{o}	2^{o}
Reading 3 (degree)	11^{o}	2^{o}

The readings at initial position, at reading 3, there are misposition about 3^{o}. The final position, reading 1, there are misposition about 3^{o}. The repeatability is lower compared to 4 joint but still acceptable. This is because the elbow used a fake Futaba S3003 servo motor [10]. The efficiency of fake S3003 is low compared to original one. The fake S3003 is a low quality servo.

Table 4.9: Wrist reading for Repeatability

WRIST	Initial Position	Final position
Reading 1 (degree)	32^{o}	21^{o}
Reading 2 (degree)	32^{o}	22^{o}
Reading 3 (degree)	33^{o}	22^{o}

The reading at initial position, reading 3, there are misposition by 1^{o} from reading 1 and 2. The final position reading, at reading 1, there are misposition by 1^{o}. The repeatability is considered good.

Calculation of mean square root (MSR):

Base:

$$\frac{(10-10)^2}{3}+\frac{(10-10)^2}{3}+\frac{(10-10)^2}{3}=0 \quad (4.1)$$

$$\frac{(33-33)^2}{3}+\frac{(33-33)^2}{3}+\frac{(33-33)^2}{3}=0 \quad (4.2)$$

Shoulder:

$$\frac{(90-90)^2}{3}+\frac{(90-90)^2}{3}+\frac{(90-90)^2}{3}=0 \quad (4.3)$$

$$\frac{(94-95)^2}{3}+\frac{(95-94)^2}{3}+\frac{(94-95)^2}{3}=1 \quad (4.4)$$

Elbow

$$\frac{(14-14)^2}{3}+\frac{(14-11)^2}{3}+\frac{(11-14)^2}{3}=6 \quad (4.5)$$

$$\frac{(5-2)^2}{3}+\frac{(2-2)^2}{3}+\frac{(2-5)^2}{3}=6 \quad (4.6)$$

Wrist:

$$\frac{(32-32)^2}{3} + \frac{(32-33)^2}{3} + \frac{(33-32)^2}{3} = 0.67 \quad (4.7)$$

$$\frac{(21-22)^2}{3} + \frac{(22-22)^2}{3} + \frac{(22-21)^2}{3} = 0.67 \quad (4.8)$$

Table 4.10: Mean Square Root of Repeatability

	Initial Position (MSR)	Final Position (MSR)
Base	0	0
Shoulder	0	1
Elbow	6	6
Wrist	0.67	0.67

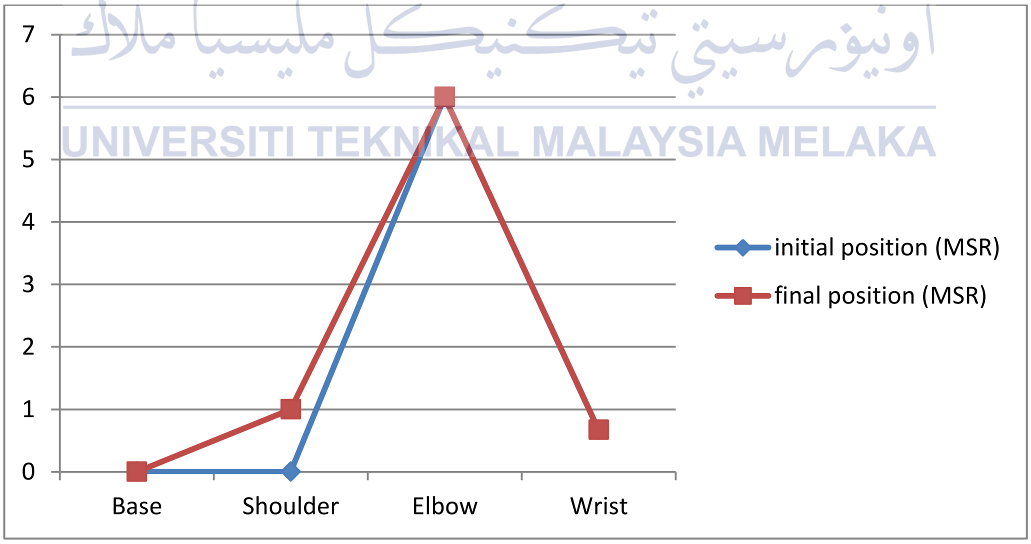


Figure 4.6: Graph of Mean Square Root of Repeatability

The graph shows the mean square root of repeatability of the robot. From the graph, the elbow shows a greater value in MSR, this means that the repeatability of at the elbow is low compare to the others. The second high value in MSR is at the shoulder, this is because the joint at the shoulder have a greatest amount of weight to be lift. The wrist have value of MSR of 0.67 which is lower compare to the shoulder and the elbow. The base have an excellent repeatability out of the entire robot's joint. Although there are a few miss in the repeatability, this will not affect the robot's performance to done the task.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The first objective is to design a robotic arm for disabilities people design and construct the robotic arm structure for people disabilities for eating purpose. The first objective has been achieved. The robot has 4 degree of freedom as mention in scope. In term of controlling the robot, the patients that can move a finger should be able to push the button. The robot will automatically move to pick up the porridge and place facing the patient.

The robot has been design using CAD software (SolidWorks). By using CAD software, the drawing and designing become easier and at the same time, it can show the design in 3 dimension view. Besides, the software can view the motion of the hardware. So the movement of the robot can be analyzed.

Second objective is to analyze the performance in term of repeatability and accuracy. In term of accuracy the robot have a good performance, although the elbow joint have a slightly error in term of accuracy, but it will not affect the performance of the robot to pick up porridge. The robot have a great repeatability performance, according to the test that have been carried out, the result show that the robot can repeat steps without have a major misposition.

All the hardware and circuit have been done and it is according to the Gantt chart.

5.2 Recommendation

To achieve better performance for this system, the controller for the robot can change so that it will suit the patient. The controller can be in term of voice recognition. With this, the patient can just tell the robot to move without moving any part of the body.

The design of the gripper can also be improve, so that there will be more types of food that the robot can pick. The degree of the freedom of the robot can be upgrade, where the arm can be rotated in any direction. It will expand the working area of the robot.

The actuator for the robot can be change, for example the fake futaba S3003 should be replace with the original one to increase the robot performance. The robot can also be added with a control system such as PID control system or forward/inverse kinematic to get a high accuracy and repeatability.

The improved robotic arm system able to helps disabilities people to have a better live. It also will develop Malaysia to achieved Wawasan 2020 vision, as one of develop country with an advance technology.

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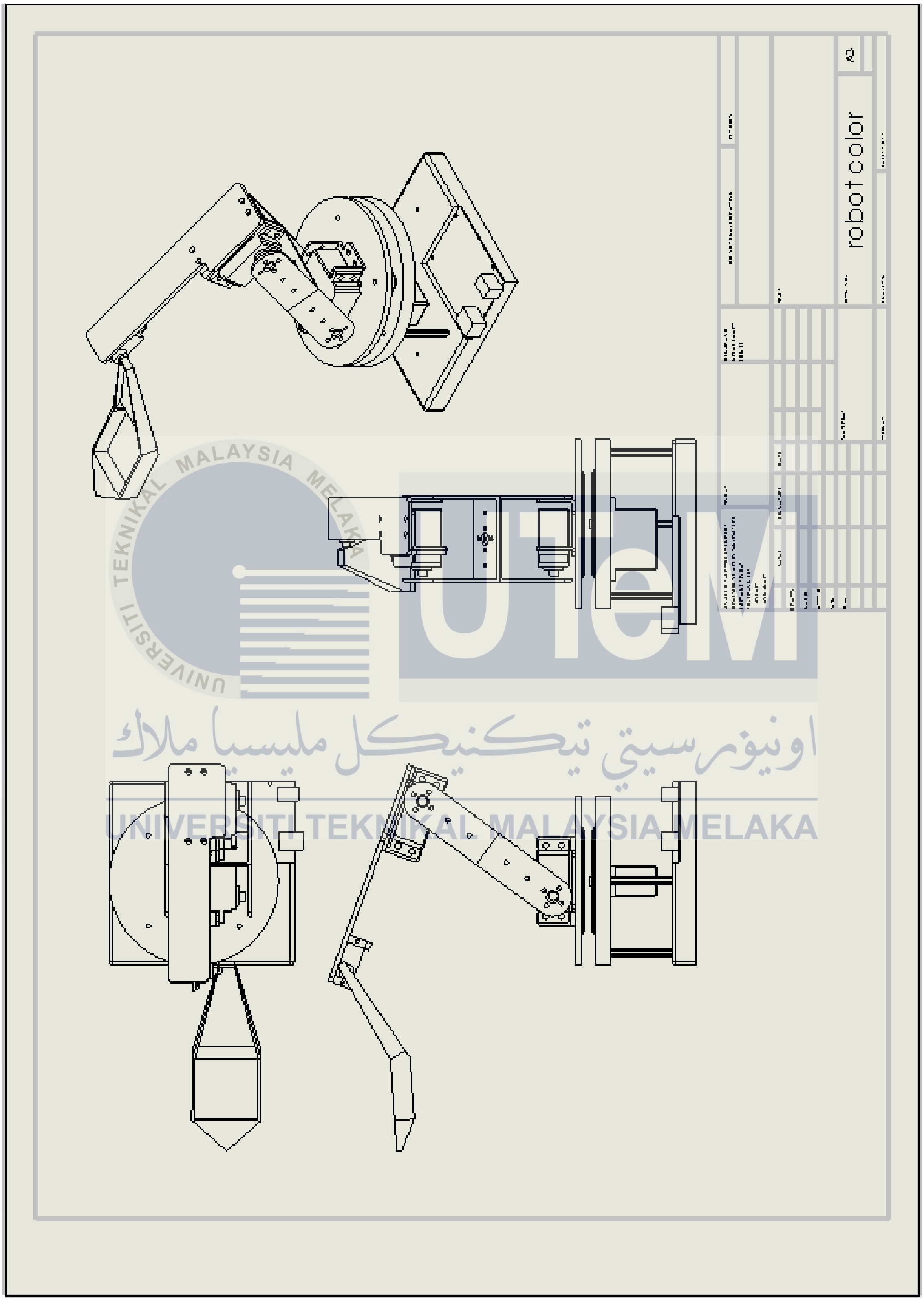
APPENDIX A: DESIGN RESULT



APPENDIX B: CODING OF ARDUINO

```
#include <Servo.h>

Servo servo1;  // create servo object to control a servo (shoulder)

Servo servo2;  // create servo object to control a servo (elbow)

Servo servo3;  // create servo object to control a servo (base)

Servo servo4;  // create servo object to control a servo (spoon)

int pos1;      // angle of servo 1 (shoulder)

int pos2;      // angle of servo 2 (elbow)

int pos3;      // angle of servo 3 (base)

int pos4;      // angle of servo 4 (spoon)

const int buttonPin = 2;     // the number of the pushbutton pin

const int ledPin =  11;      // the number of the LED pin

int buttonState = 0;         // variable for reading the pushbutton status

void setup()

{

  pinMode(ledPin, OUTPUT);

  pinMode(buttonPin, INPUT);

  servo1.attach(9);  // attaches the servo on pin 9 to the servo object  (shoulder)

  servo2.attach(6);  // attaches the servo on pin 6 to the servo object  (elbow)

  servo3.attach(10); // attaches the servo on pin 10 to the servo object (base)

  servo4.attach(5);  // attaches the servo on pin 5 to the servo object  (spoon)

}
```

```
void loop()
{
  buttonState = digitalRead(buttonPin);


  if (buttonState == HIGH)
  {
//SCENE 1//
    for (int i=0; i<40; i += 1)
    {
      pos1 = 90 + i + (i/8);        // servo1 from 90 to 135 degrees
      pos4 = 90 - (i/2) - (i/4);    // servo4 from 90 to 60 degrees
      servo1.write(pos1);
      servo4.write (pos4);
      delay(30);                    // waits 30ms for the servo to get there
    }
    delay (2000);                   // waits 2s


//SCENE 2//
    for (int i=0; i<30; i += 1)
    {
      pos2 = 90 + i + (i/3);        // servo2 from 90 to 130 degrees
      pos4 = 60 - i;                // servo4 from 60 to 30 degrees
```

```
  servo2.write(pos2);

  servo4.write (pos4);

  delay(30);                    // waits 30ms for the servo to get there

 }

 delay (2000);                  //waits 2s


//SCENE 3//

 for (int i=0; i<80; i += 1)

 {

  pos1 = 135 - i;               // servo1 from 135 to 55 degrees

  pos2 = 130 - i/8;             // servo2 from 130 to 120 degrees

  pos4 = 30 + (i/4) + (i/8);    // servo4 from 30 to 60 degrees

  servo1.write(pos1);

  servo2.write(pos2);

  servo4.write (pos4);

  delay(30);                    // waits 30ms for the servo to get there

 }


//SCENE 4//

 for(pos3 = 90; pos3 < 180; pos3 += 1)  // goes from 90 degrees to 180 degrees // in
steps of 1 degree

 {
```

```
  servo3.write(pos3);          // tell servo3 to go to position in variable 'pos3'
  delay(30);                   // waits 30ms for the servo to reach the position
 }
 delay(3000);
 delay(3000);

 for(pos3 = 180; pos3 >= 90; pos3 -= 1)  // goes from 180 degrees to 90 degrees // in steps of 1 degree
 {
  servo3.write(pos3);          // tell servo3 to go to position in variable 'pos3'
  delay(30);                   // waits 30ms for the servo to reach the position
 }
 delay(2000);

//SCENE 5//
 for (int i=0; i<30; i += 1)
 {
  pos1 = 55 + (i+i/6);         // servo1 from 55 to 90 degrees
  pos2 = 120 - (i);            // servo2 from 120 to 90 degrees
  pos4 = 60 + i ;              // servo4 from 60 to 90 degrees
  servo1.write(pos1);
  servo2.write(pos2);
```

```
    servo4.write(pos4);
    delay(50);                    // waits 50ms for the servo to get there
  }
 }
}
```

APPENDIX C: WEIGHT OF EACH ROBOTIC PARTS

U-joint combine together

Arm or linkage

Rotate base

Rotate bearing

Base of the robot

C40R servo motor

Futaba S3003 servo motor

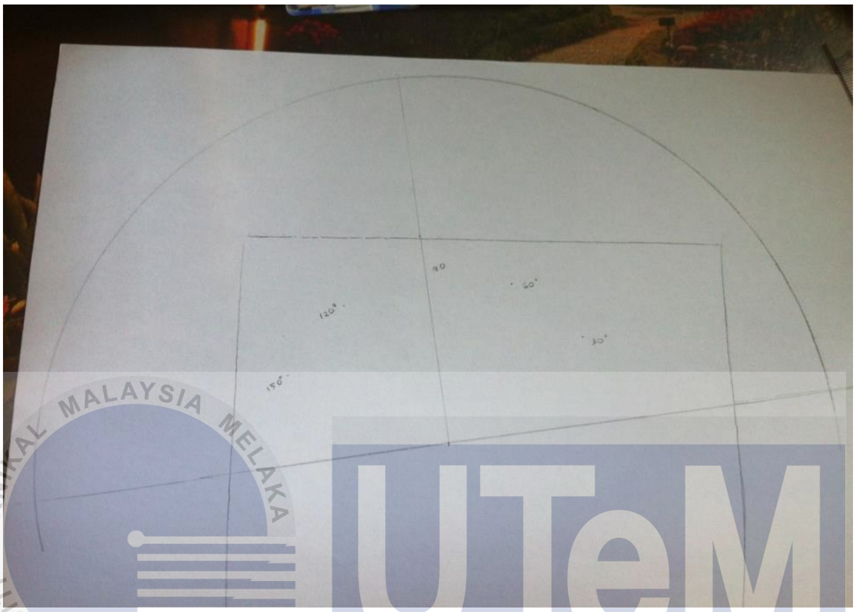
SG90 micro servo motor

Spoon

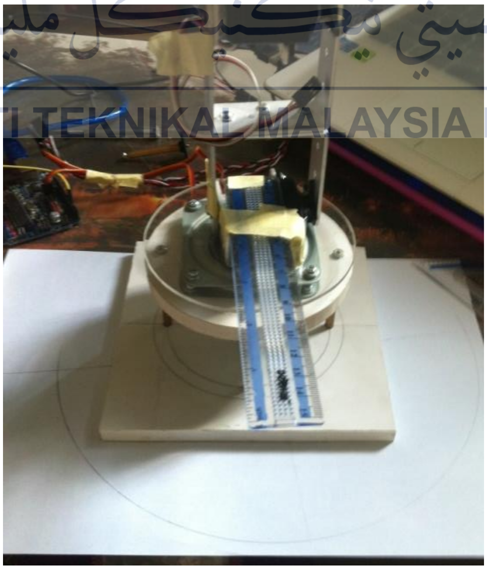
APPENDIX D: ACCURACY EXPERIMENT

<u>Base</u>

Shows how the measurement are taken.

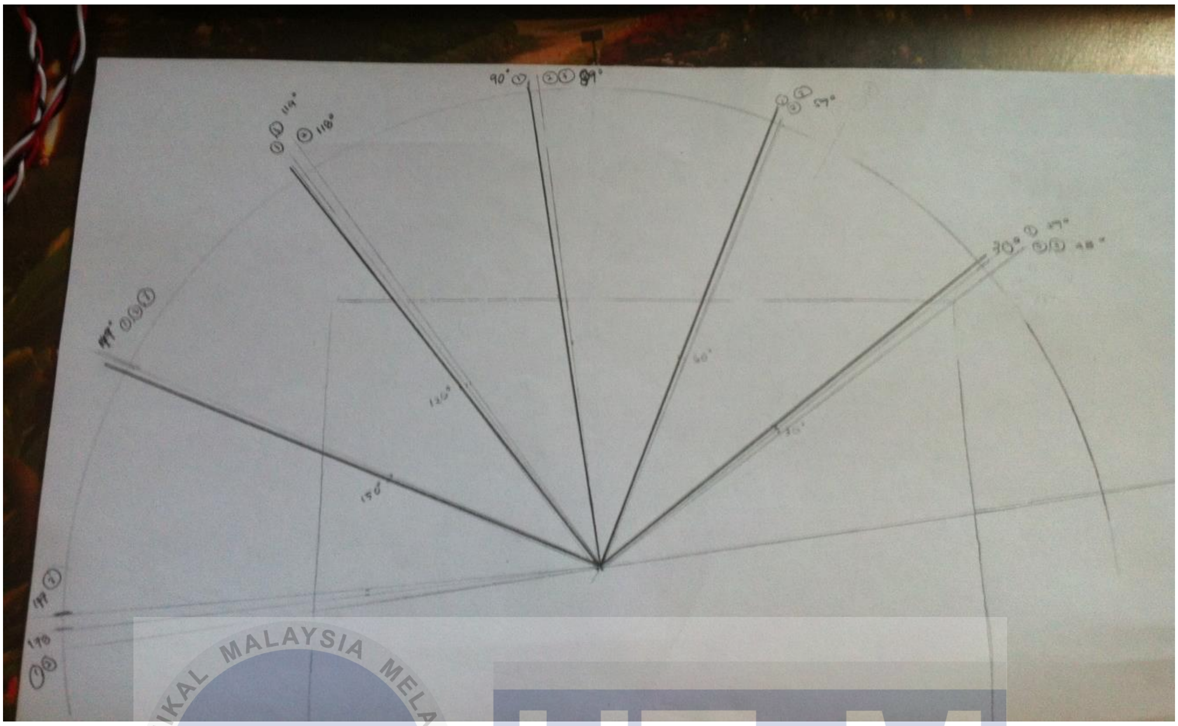


Draw a desired angle on a piece of paper



The robot is place on top of the paper

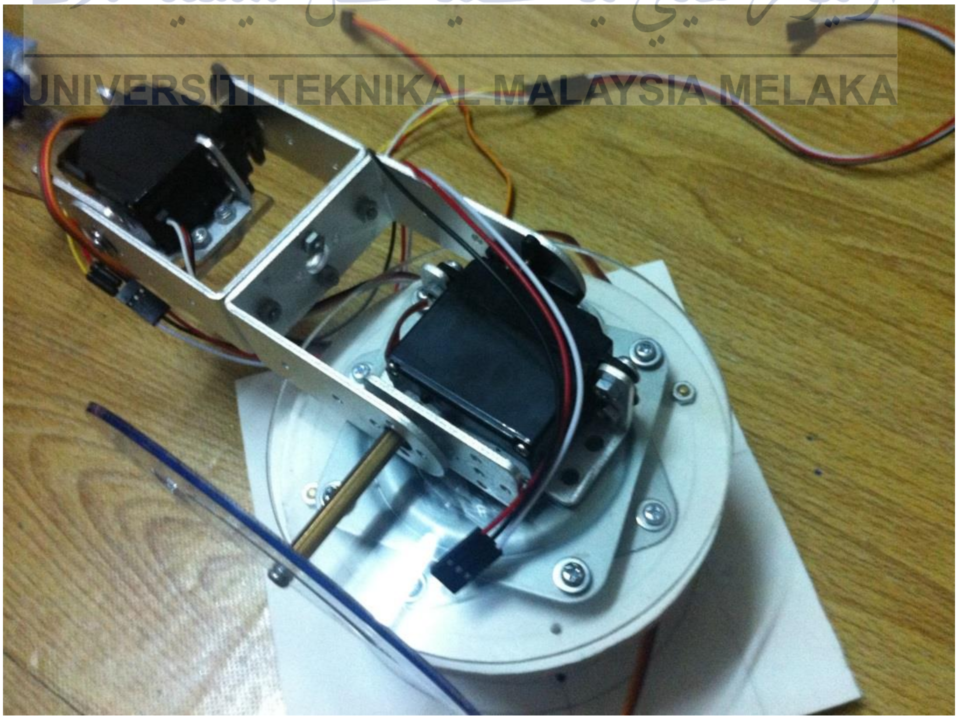
After the robot move, the end point are taken

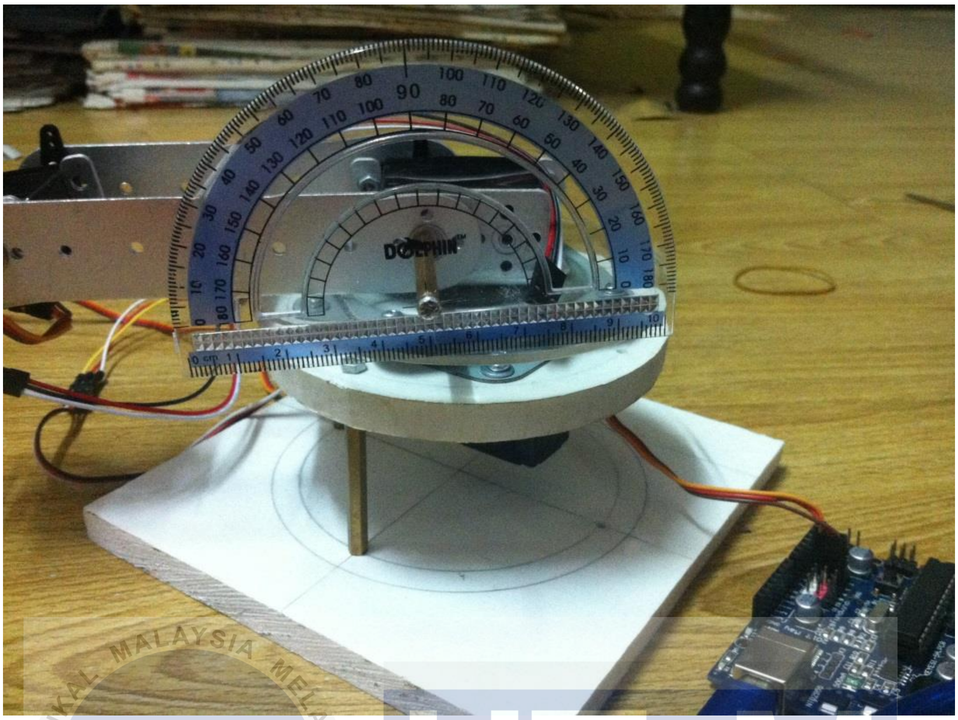


The result taken at the base

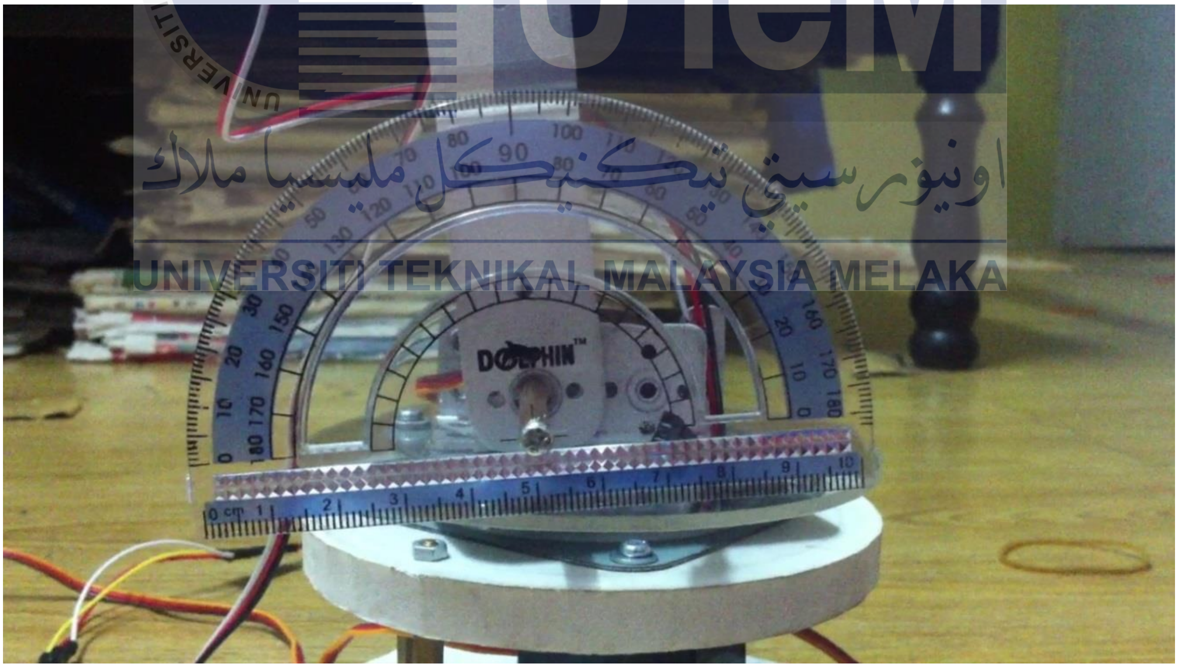
Shoulder

Shows how the measurements are taken at the shoulder.





A protector is attach at the shoulder joint



End point, the reading is taken

<u>Elbow</u>

Shows the protector is attach to the elbow in order to take the measurement.

Protector is attach to the elbow joint

<u>Wrist</u>

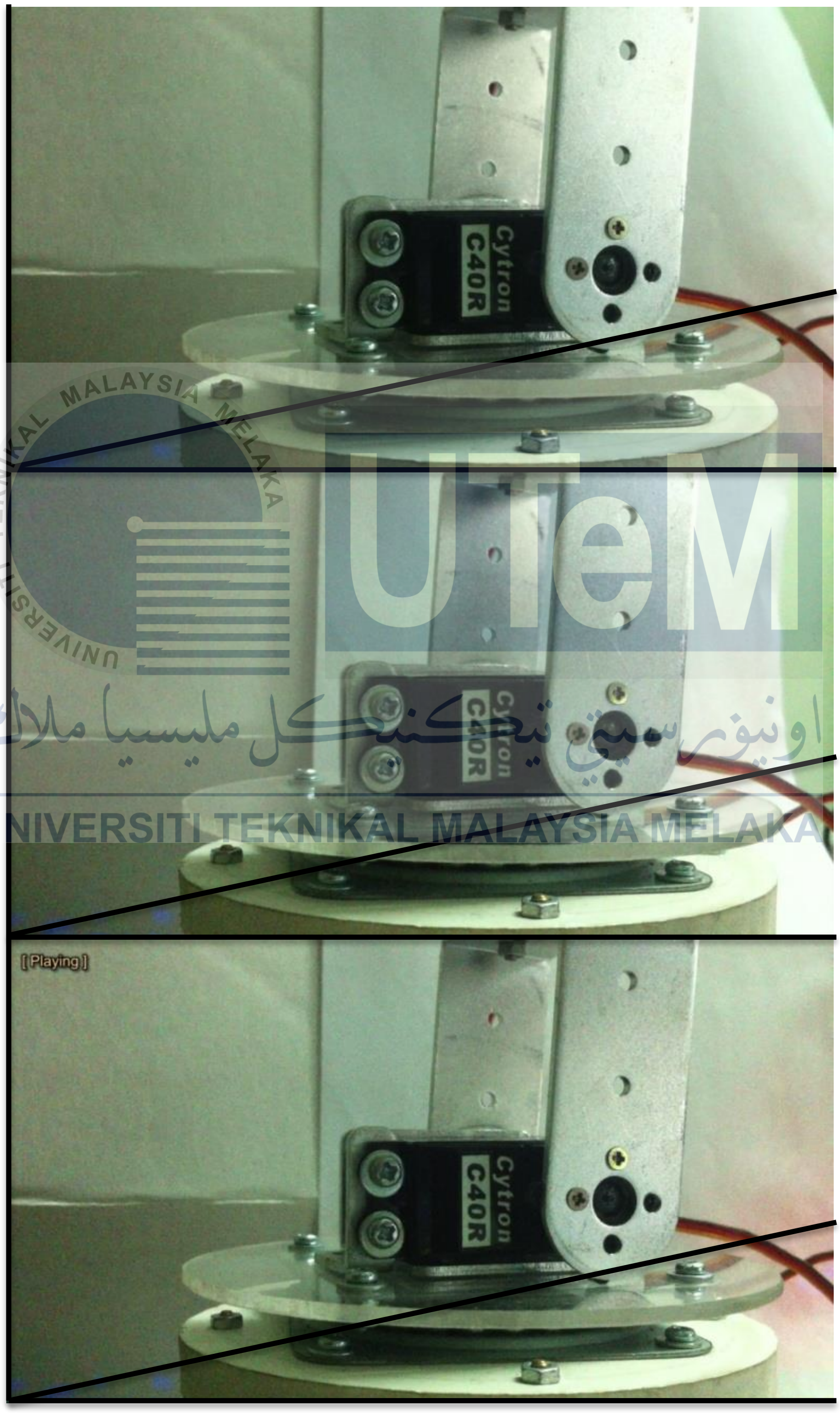
Shows how the protector is attached to the robot

Protector attached to the elbow joint

APPENDIX E: REPEATABILITY EXPERIMENT

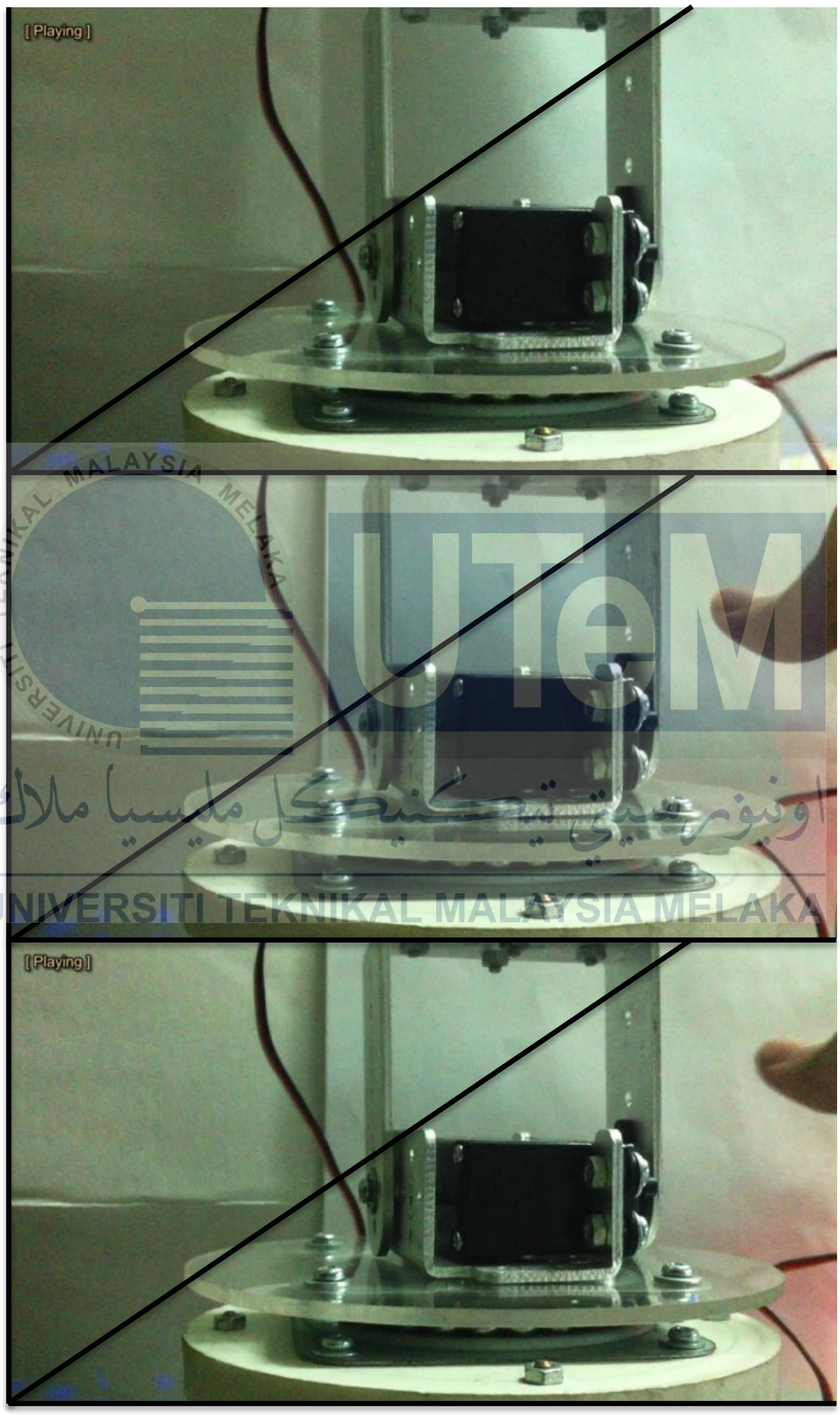
Base

Initial position, 0 degree.



Initial position of base

Final position, 90 degree.



Final position of base

<u>Shoulder</u>

Initial position, 0 degree.

Initial position of shoulder

Final position, 90 degree

Final position of shoulder

Elbow

Initial position, 0 degree.

Initial position of elbow

Final position, 90 degree

Final position of elbow

<u>Wrist</u>

Initial position, 0 degree.

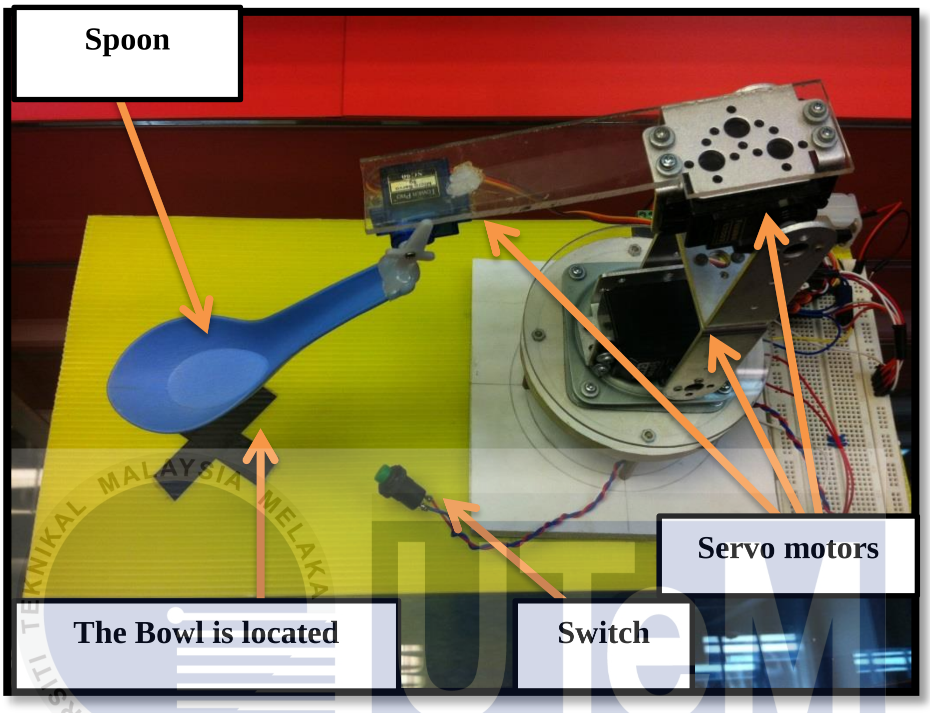
Initial position of wrist

Final position, 90 degree.

Final position of wrist

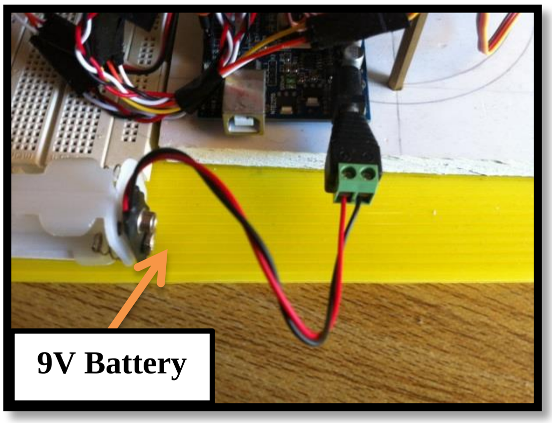
APPENDIX F: USER MANUAL

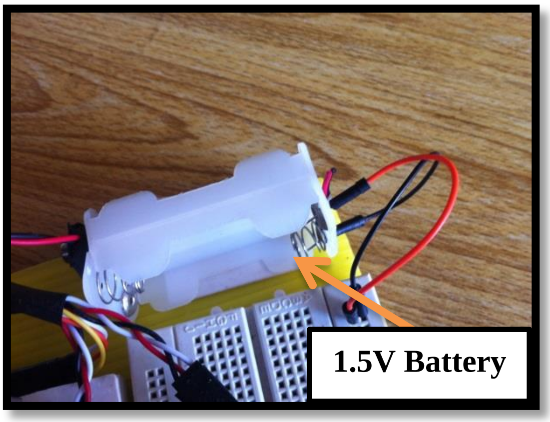
Eating Assisting Robotic Arm, is a robot to help a disabilities people in eating task.



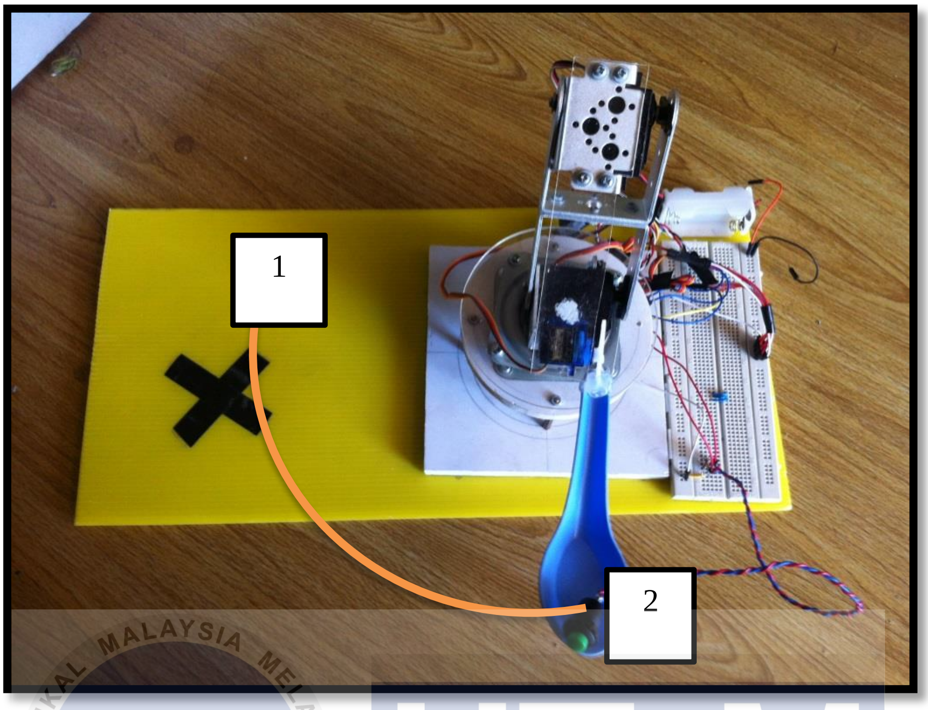
The robot is control by using the switch. To move the robot, push ON the switch and the robot will automatic move to pick up food. Push OFF the switch, the robot will stop at the bowl. The robot is only limited to pick up porridge only.

Get Started:





To power the robot, one 9V battery and four 1.5V batteries are needed.



The robot will move face the patient after its pick up the food. From 1 to 2, and then will go back to 1.

APPENDIX G: GANTT CHART PSM II

Project Plan																		
Week / Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Buy the component needed to make the robot	■																	
Making the robot using Solidwork		■	■															
Make the robot based on design			■	■	■	■												
Adding degree of freedom of the robot			■	■	■	■												
Controlling the robot movement						■	■	■										
Controlling the speed of the robot						■	■	■										
Improving on the design								■	■	■								
Study the servo motors performance								■	■	■	■							
Study the battery suitable for the robot								■	■	■	■							
Analyze the performance of robot in term of accuracy and repeatability								■	■	■	■	■						
Preparation of the report										■	■	■	■					
Sent draft to SV													■					
Repair report													■	■				
Claim for the project														■				
Sent report to Panels															■			
Demo PSM2																■		
Repair final report															■	■	■	
Sent final report, logbook and PDF																		■

APPENDIX H: GANTT CHART OF THE PROJECT

PROJECT PLANNING			
Project Activities	2013	Break	2014

	Sept	Oct	Nov	Dec	Jan	Feb	Mac	Apr	May	Jun
Research and study on topic										
Draft out proposal										
Conduct experiment and collect data										
FYP1 prese ntation										
Hardware design and building										
System building										
Test on hardware and trouble-shooting										
Analysis to hardware performance										
Final presentation										