KING MONGKUT'S INSTITUTE OF TECHNOLOGY LATKRABANG
SCHOOL OF ENGINEERING GROUP OF
ROBOTICS & AI

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PHYSICS - I LABORATORY, 3D DRAWING
COMPUTER PROGRAMMING FOR RAI

FINAL PROJECT

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DATE OF SUB.:18/12/2022

Abstract

Lorem ipsum dolor sit, this text means nothing, we just use it to fill in the gap. Actually we should change it to something more interesting like a quote or so. Despite all that nonsense, we are making a robot. A robot with a shooter and a gripper. Many designs of this have flown on the internet, but I assure you that our design isn't like everything you have seen. This is the summary of our project. The papers will include all our work process, our inspiration and how we imagine, built it, and perfect it in these pages. We hope you find it interesting and fascinating to read about. Thank you.

We also apologize in advance for errors that we may have made.

With all due respect, Varit R.

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Purpose

1. To understand cooperation in working as a group with friends in other sections.
2. To have a better understanding of C, Python, programming, design, and also 3D printing, and laser cutting.
3. To get a glimpse of how a real project is done, core value, making, testing, and improving.

Project Scope

1. Make a robot with a shooter which can shoot at a target at any point in 180 degrees of angular displacement.
2. Make a robot with a gripper that can pick and place an object from point to point, Also reload the gun automatically and have a desirable height length.
3. Make a line-following robot that is efficient enough to run smooth, fast, and reliable.

Theory

1. Projectile

1.1. Projectile motion is a two dimensional-motion when the object is thrown into the air which acts upon gravity. Also in projectile motion the object

1.2. moves in a parabolic path which is known as trajectory.

1.3. According to Galileo’s theory, he describes that the motion in a projectile is composed of two parts which are horizontal and vertical velocity.

2. Elasticity of rubber

Rubber being hit by force will cause the rubber to stretch or shrink. But when removing that force, the rubber will go back to how it was before. But if done with a force that exceeds the value that the rubber will maintain its elasticity. Tires will not go back to the way they were before.

3. Torque

Torque is the measurement of force which causes something to rotate around the point.

Torque (Nm) = force (N) * length (m)

4. Function

4.1. Function is a block of code that performs a specific task.

4.2. Dividing a complex problem into small components improves the program's understandability and usability.

5. Loop statement

Loop statement is for repeating situation and recurrence situation which chand value or condition

Background research

1. Straight Bevel Gear

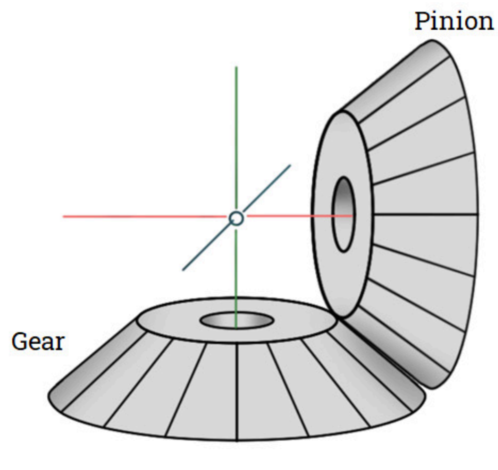


Figure 1.1 - Meshing of Pinion and Gear

Figure 1.2 - Straight Bevel Gear

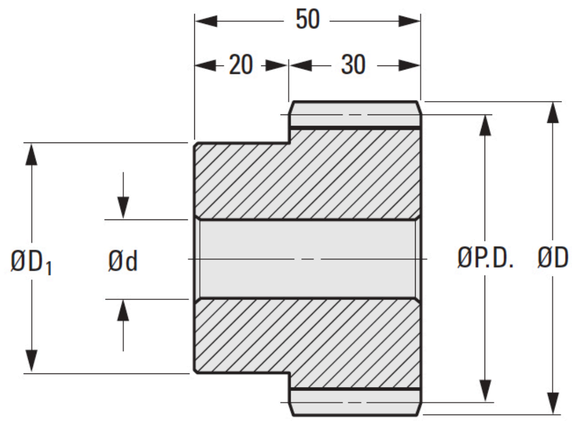


Figure 1.3 - ANSI metric module 3

In order to transform the angular motion of the side which is connected to the motor to the bottom one which is horizontal on the ground and perpendicular to the first one. Both the first and the latter gear would have to be changed to a bevel gear to connect to each other. The pinion bevel gear the ANSI metric module 3 is used.

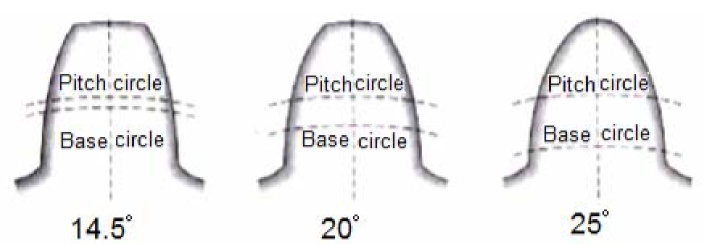


Figure 1.4 - Gear Tooth Profile for different Pressure Angles

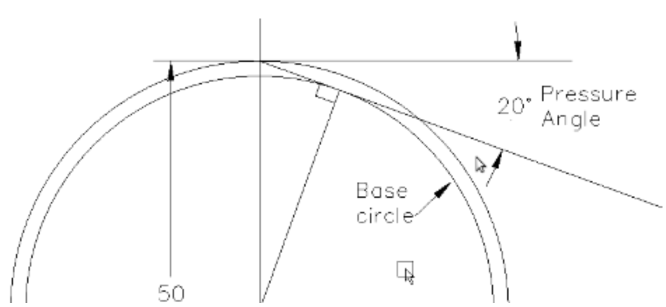


Figure 1.5 - Pressure Angle of gear

Figure 1.4 illustrates how the variations in radius of the pitch circle and the base circle are proportional to the magnitude of the angle. WIth the angle of 14.5 is applied. Our radius calculated was 25.84 mm from the center and it is proportional to the length of the gear holding part.

2. Rail

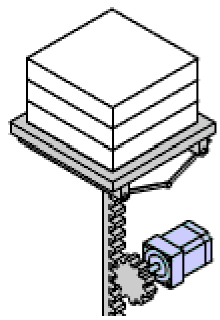


Figure 2.1 - Load Elevator

The rail is used in the gripping part for gripping the object which would be on top of the wall. Also to put the object into the gun chamber. We lift the gripper part up and down the rail by a motor at the bottom connected to a circular roller which would curl the string as the gripper part is pulled. And when the string is released we use gravity to propel the gripper part down from the top. The wire on both servo and motor also got a new proper wire which is to lengthen the wire so when the front part including the gripper is revolving the string won't be curl up.

3. Gripper

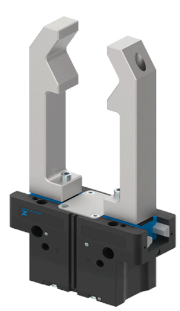


Figure 3.1 - 2 Jaw Gripper

Gripper is a part that was created to simulate the motion of a human hand, the most important feature would be to grip stuff and maneuver it around. Many gripper designs have been considered through the core value process. Kirigami, Over the top gumball machine gripper and suction pneumatic. As we have precipitated our thoughts and decided on this design which is side gripping. Due to the fact that it is easy to design light weight and has a capability of gripping more weighted objects.

4. 3D printing

4.1. Infill

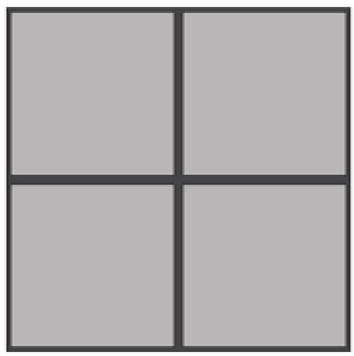


Figure 4.1 - 10% infill density

Based on the research, As figure 4.1, we consider 10% to be quite light and strong, so many parts in the manual robot use this percentage but overall we have used 7-15% in the robot due to many parts requiring more strength with more weight and vice versa.

4.2. Grid Infill

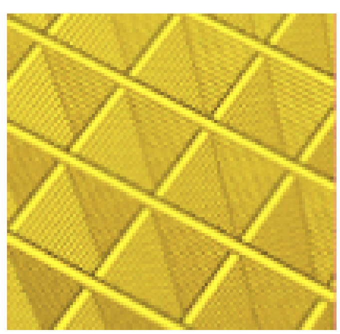


Figure 4.2 - Grid Infill patterns

The grid fill pattern is a strong 2D fill that creates a grid in each layer of the print. The grid infill is similar to the line infill. But line infill only prints in one direction per layer. Each layer of the grid infill has 2 direction lines.

4.3. Support

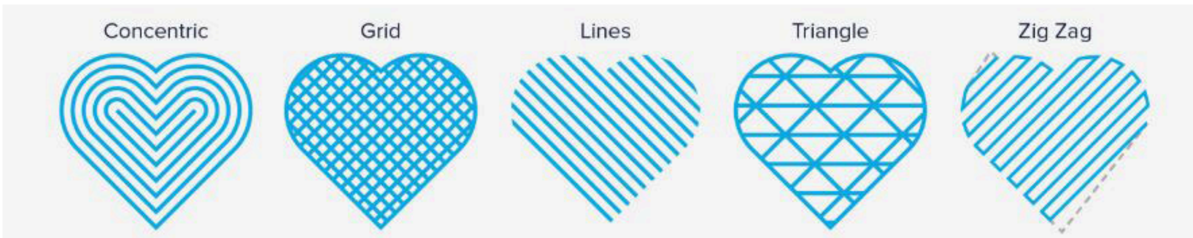


Figure 4.3 - Support patterns

The support structure is the added part that supports the overhanging structure when slicing the model, which needs to be removed after printing. Support patterns which we select is Line, for the reason that it’s easy to remove and fast to print in limited time. Line support pattern is also used in printing standard objects because of its medium strength and medium weight.

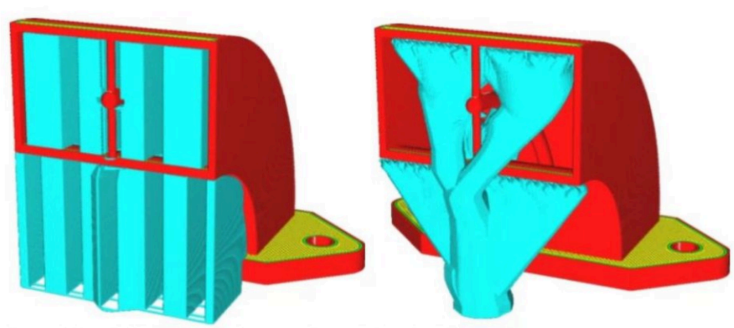


Figure 4.3 - Tree Support

Tree support is another type of support that we had used, tree support is easier to get rid of in many cases. For a difficult overhang that would have consumed much more filament, tree supports are an alternative and a better way of approaching this type of overhang.

4.4. Polylactic acid (PLA)

Figure 4.4 - Polylactic acid

Polylactic acid made from organic material like cornstarch and sugarcane, and maize. When burn releases fumes that are mostly Lactide into the air. Compared to the other materials PLA is considered non-toxic, however the long term effect is unknown. Other filament types are also taken into consideration. PETG, ABS would have more strength, and tolerance. TPU would have great elasticity for many applications.But, many of them release a toxic fume and have a hassle in printing and calibrating.

5. SCREW M3 - 3mm diameters; for connecting other part in the robot

Figure 5.1 - Size of screw M3

M3 screw is the main type of screw that we use in this project, because of its perfect size to many electronics, and also easy to find.

6. SCREW M4 - 4mm diameter; for connecting stepping motors

Figure 6.1 - Size of screw M4

M4 screw is also used in our project, to connect blue motor(Encoder motor), M4 screw is needed, however M4 screw is not suitable for many electronic instruments hence M3 is used more in this project.

Methodology

1. Core value and Brainstorm

Before starting everything the role has to be distributed equally among us three, we started by listing what we have to do, slide, report, calculation, design, test, coding. Finn will take on design and calculation as a basis, and some coding too. Tantan will do the coding and the slide. Testing and reports would be done mostly by juniors. From another perspective, Finn would be the creative, Tantan as the strategy, and junior and the failsafe.

2. List of components

2.1. Auto (Line-following robot)

2.1.1. Arduino UNO

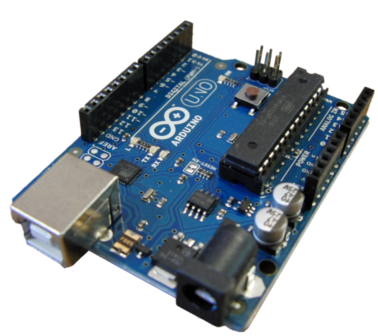


Figure 2.1.1 - Arduino UNO

Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs. We chose this microcontroller in this module because Arduino UNO uses a simplified version of C/C++ language which is easily adaptable, also in scope of our programming class.

2.1.2. Sensor Shield v5.0

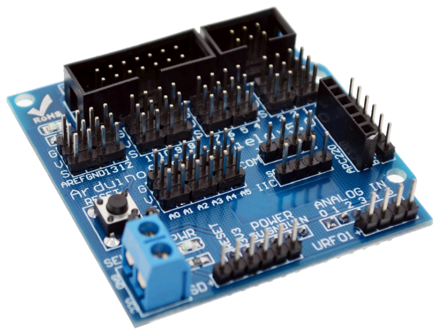


Figure 2.1.2 - Sensor Shield V5.0

The Sensor Shield v5.0 provides an easy way to connect sensors, servos and RS485 devices to Arduino boards. The robot which has to use a lot of many types of sensor, This board helps us to connect every part together easier.

2.1.3. Motor driver (L298N)

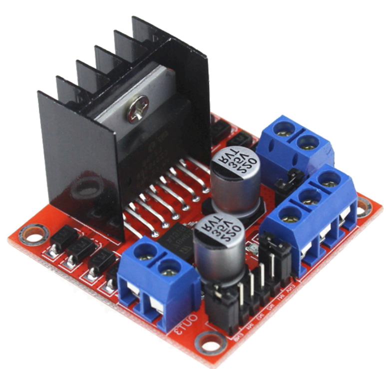


Figure 2.1.3 - Motor driver (L298N)

Motor driver (or L298N) is a high voltage and high current motor drive chip which receives TTL logic signals. We used it to control the rotating direction in DC motors.

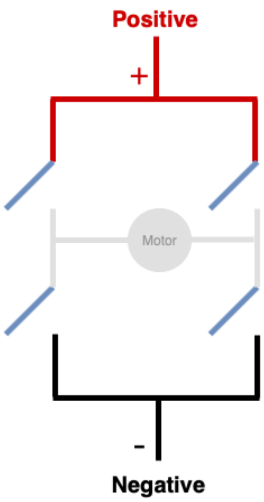


Figure 2.1.3.1 -

Positive and Negative point of Motor driver

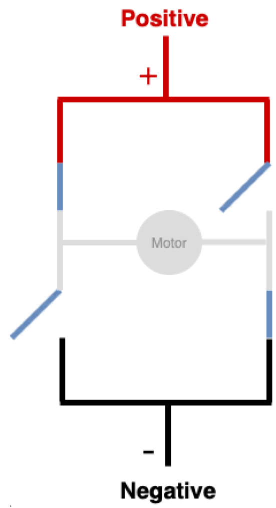


Figure 2.1.3.2 -

Motor driver rotate clockwise

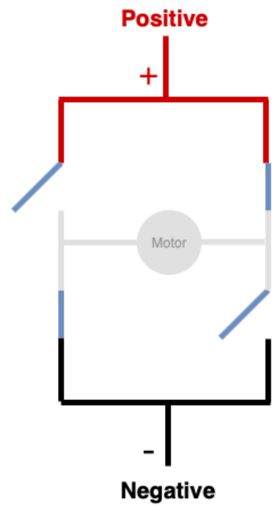


Figure 2.1.3.3 -

Motor driver rotate anti-clockwise

From Figure 2.1.3.1, Motor Driver has 4 switches which are used to control DC Motor. Reference from Figure 2.1.3.2, The positive is applied to the left side of the motor and the negative is applied to the right side. In this case, the motor will rotate clockwise. Last at Figure 2.1.3.3, the positive is applied to the right side of the motor and the negative is applied to the other side. In this case, the motor will rotate anti-clockwise.

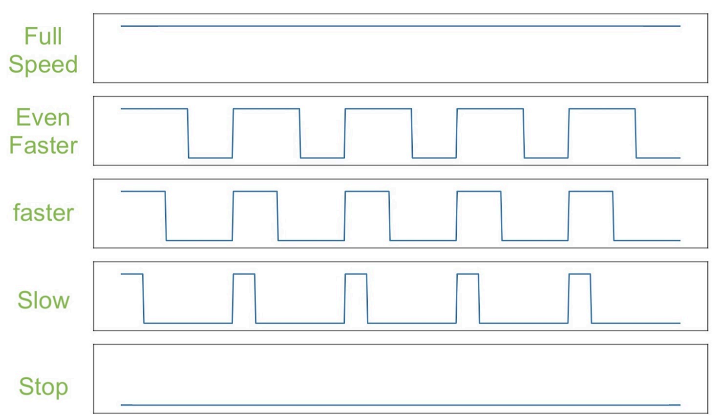


Figure 2.1.3.4 - Pulse Width Modulation (PWM)

The speed of the motor is determined by the width of the PWM pulse sent to the enable input of the L298N motor driver. The wider the pulses, the faster the motor will spin. Thus, PWM is used to control speed.

2.1.4. 3-6V Yellow DC Gear Motor

Figure 2.1.4.1 - 3-6V Yellow DC Gear Motor

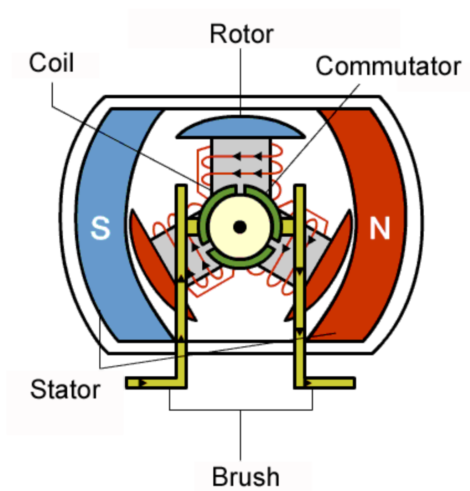


Figure 2.1.4.2 - An operating Brushed DC motor

DC motors are motors that operate on Direct Current (DC). DC motors are available in several different configurations from tiny little motors to absolute huge ones. We use a DC motor to control a robot's wheel direction and also power.

2.1.5. IR Sensor

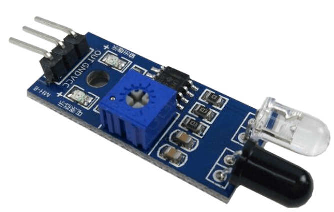


Figure 2.1.5.1 - IR Sensor

An IR Sensor is a device that detects infrared radiation in the environment and outputs an electric signal. We use IR sensors to detect the line and analyze the line in analog value(0-1023).

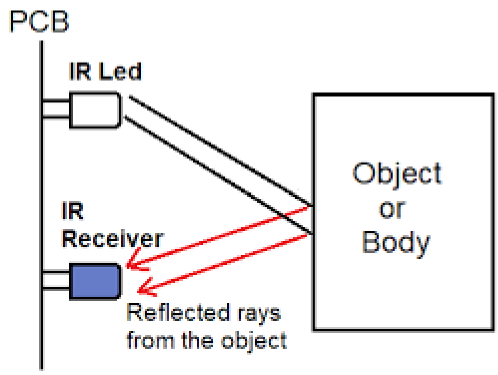


Figure 2.1.5.2 - IR Obstacle Detection Sensor Circuit

From Figure 2.1.5.2, An infrared sensor (or IR Sensor) works by emitting energy that is detected and received by the detector. To obtain the required data, it is further processed through a signal processor. Reflectance and break beam sensors are the best examples of active infrared sensors.

2.2. Manual

2.2.1. Makeblock Controller

Figure 2.2.1.1 - Makeblock Controller

Makeblock bluetooth controllers have 15 buttons and 2 thumbsticks.

Buttons / thumbsticks	Functions
Left thumbstick	Turn left and right
Button R1	Forward
Button L1	Backward

Button 3	Grip
Button 4	Release

Table 2.2.1 : Functions of Makeblock bluetooth controller

2.2.2. Makeblock 180 Encoder Motor

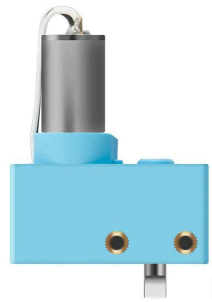


Figure 2.2.2.1 - Makeblock 180 Encoder Motor

The 180 optical encoder motor is equipped with an optical encoder that enables highly precise control with two M4 threaded holes on each of the three sides. Therefore, it can be easily connected to Makeblock's mechanical parts. Therefore, it can be flexibly combined with other parts. The custom materials used reduce noise and guarantee a large output torque.

2.2.3. 3-6V Yellow DC Gear Motor

Figure 2.2.3.1 - 3-6V Yellow DC Gear Motor

2.2.4. Servo

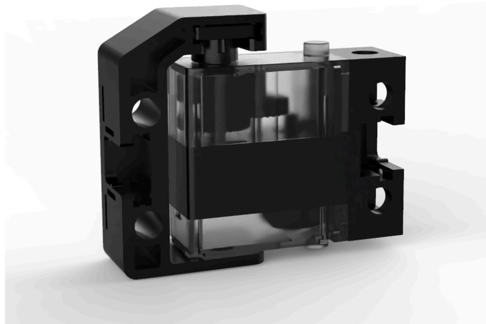


Figure 2.2.4.1 - Makeblock MS-1.5 Servo

The MS-1.5A servo is developed independently by Makeblock. Its dimensions are similar to common 9g servos.

	MS-1.5A servo	Earlier 9g servos
Servo hub mounted before delivery	Yes	No
Supporting quick fitting	Yes	No
Compatible with Makeblock metal parts and Lego blocks	Yes	Yes, but adapter brackets required
Physical limit	No (The circuits are redesigned to better protect the servo and thus ensuring longer service life.)	Yes

Table 2.2.4.2 - Function of MS-1.5A servo compare to 9g servos

Figure 2.2.4.2 - Makeblock Digital Servo

2.2.5. Cyber Pi

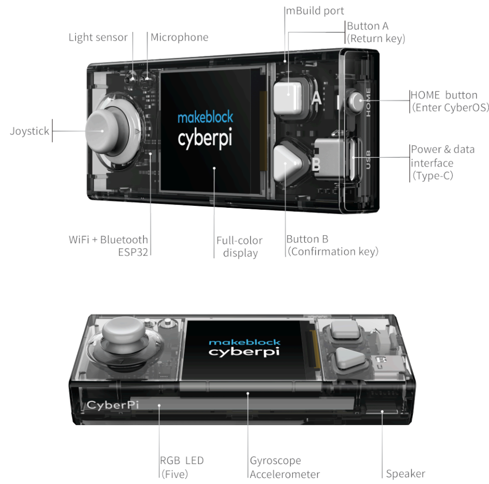


Figure 2.2.5.1 - Cyber Pi

Cyber Pi is a main control board with a compact structure and built-in ports.

2.2.6. mBot2 Shield

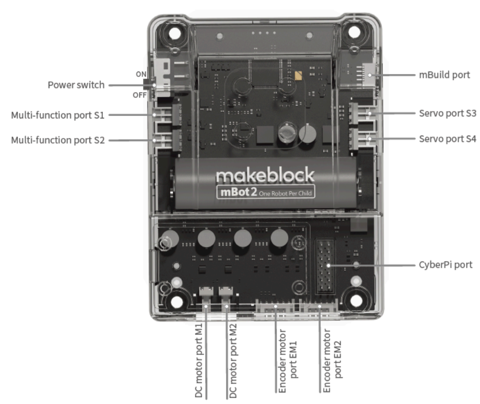


Figure 2.2.6.1 - mBot2 Shield

mBot2 Shield is equipped with a built-in rechargeable lithium-ion battery that can supply power for CyberPi. With the multi-function, servo, and motor ports, it can drive motors, servos, and LED strips.

3. Design

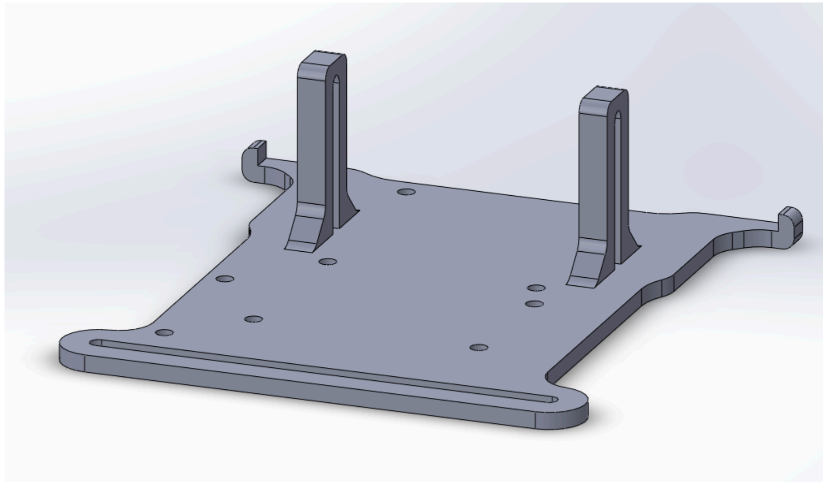


Figure 3.1 - Auto robot bottom plate.

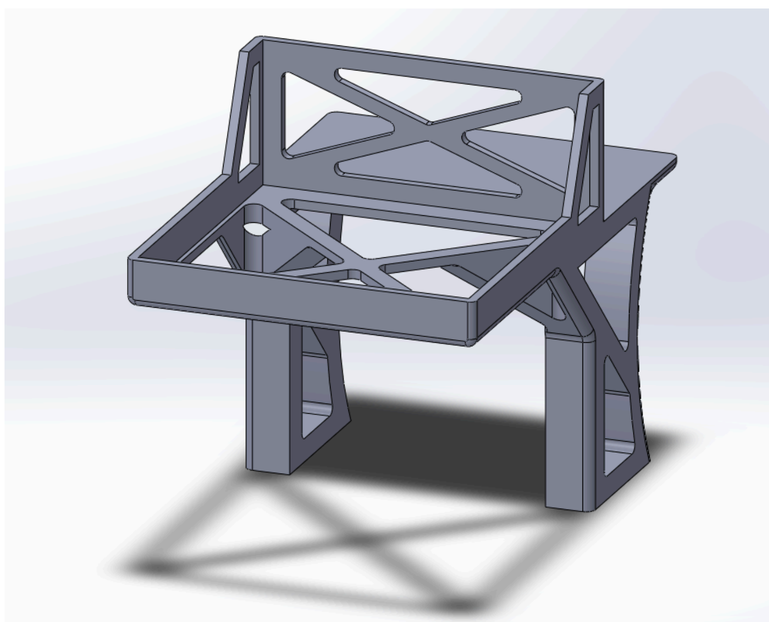


Figure 3.2 - Upper part of auto robot.

For our auto design, while designing we only keep two things in mind, the first sensor has to be as far away as possible from the center of movement, this will increase the robot precision in tracking the line. Another thing is to make our robot as low and wide as possible for stability in tracking the line. Size of the robot also has to be approached carefully due to small size restrictions. Hence our robot is very small.

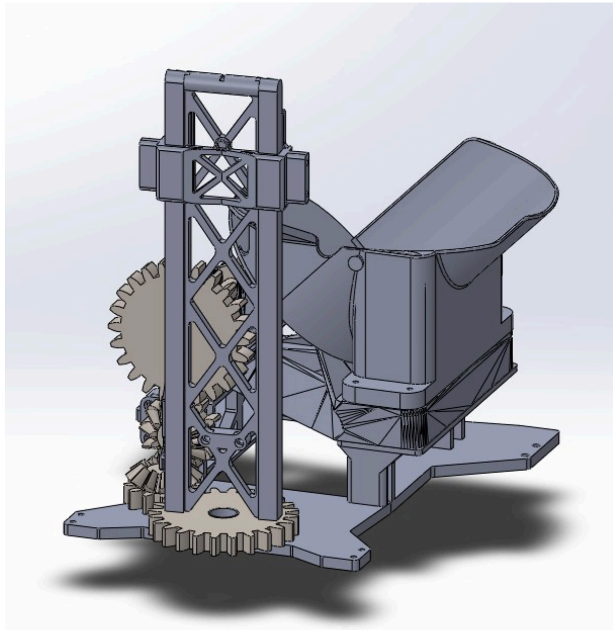


Figure 3.3 - Isometric view of manual CAD

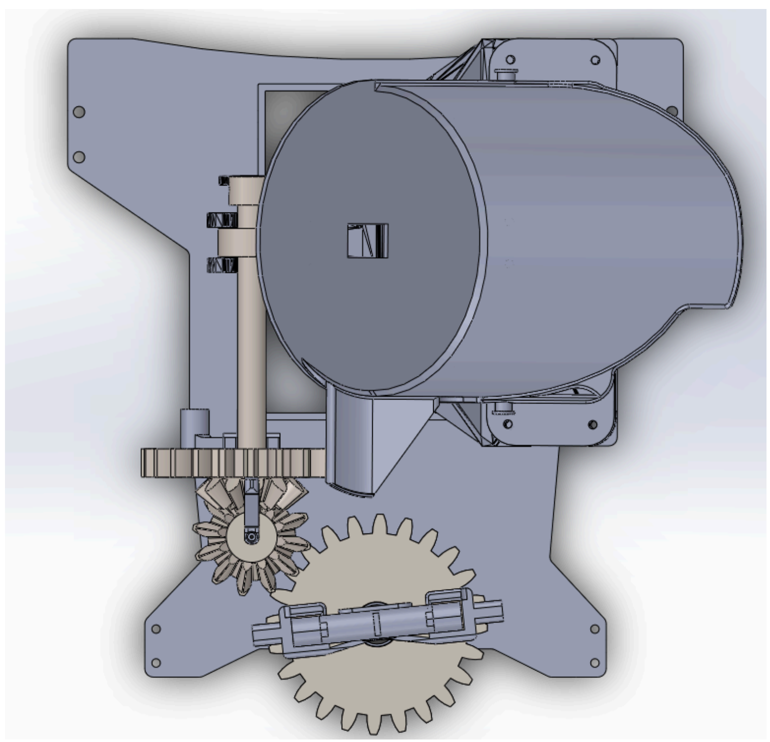


Figure 3.4 - Top view of manual CAD

By using CAD we can design and simulate most movement and how the mechanism would have behaved beforehand. To minimize the error in 3d printing we added clearance and also did many test prints on small parts to prevent error in the bigger part.

Since we have to grab objects from both high and low we had decided on making a lift, for the gripping arms. Our grip would be pulled by a motor which connected to a string and the arm parts. This means that by pulling the motor we could move the whole front section up and by letting go of the string gravitational energy will pull it back to the origin.

For the shooter, we are inspired by a tank. By research we have seen that there are many designs for a shooter mechanism using catapult mechanics. However, we would want our shooter to be an ordinary one, hence, we decided on a gun base design of a tank. Unfortunately, the object we have to shoot is too big for comfort, therefore it makes what is supposed to be a long and small gun alike turn into a mortar shape.

Lastly, our base got inspired by a cow head, however, by the time we finished it, other people already interpreted it as a transformer head.

4. Manufacture

Both Auto and Manual were manufactured by 3d printing. Laser cutting is also an option but since we have a 3d printer at home 3d print is more of a suitable option. There are many pros and cons of each mean, 3d printer is strong and can create many difficult design parts yet it is very slow compared to laser cut, while laser cut is fast but not as strong and can make flat parts, for a difficult and more complex design many flat parts have to be put together.

What is 3D printing?

3D printing, or additive manufacturing, is the process of creating three-dimensional solid objects from digital files.

Creating 3D printed objects is done using an additive process. in the process of adding Objects are created by layering materials. successively until the object is created Each of these layers can be seen as a cross-section of the object.

3D printing is the opposite of subtractive manufacturing. which cuts metal or plastic into pieces, such as a milling cutter

3D printing allows you to create complex shapes using fewer materials than traditional manufacturing methods.

What is laser cutting?

Laser cutting is a process that uses lasers to cut different materials. For both industrial and artistic applications such as engraving.

Laser cutting uses a high-powered laser, which is powered by optics and computer numerical control (CNC), to direct a beam or material. In general The process uses a motion control system to follow the CNC or G-code of the pattern to be cut onto the material. The focused laser beam burns, melts, vaporizes, or is blown by a jet of gas. to leave a high quality surface finish edge.

5. Programming

5.1. Manual Robot

Figure 1.1 : Block diagram for control movement of manual robot

In figure 1.1, when R1 is pressed the motor will propel forward, while joystick LX is also moved, the robot will maneuver accordingly with the turn being proportional to the magnitude of movement on the joystick, and also when L1 is pressed the robot moves backward with the same principle. When All buttons are released the motor stops.

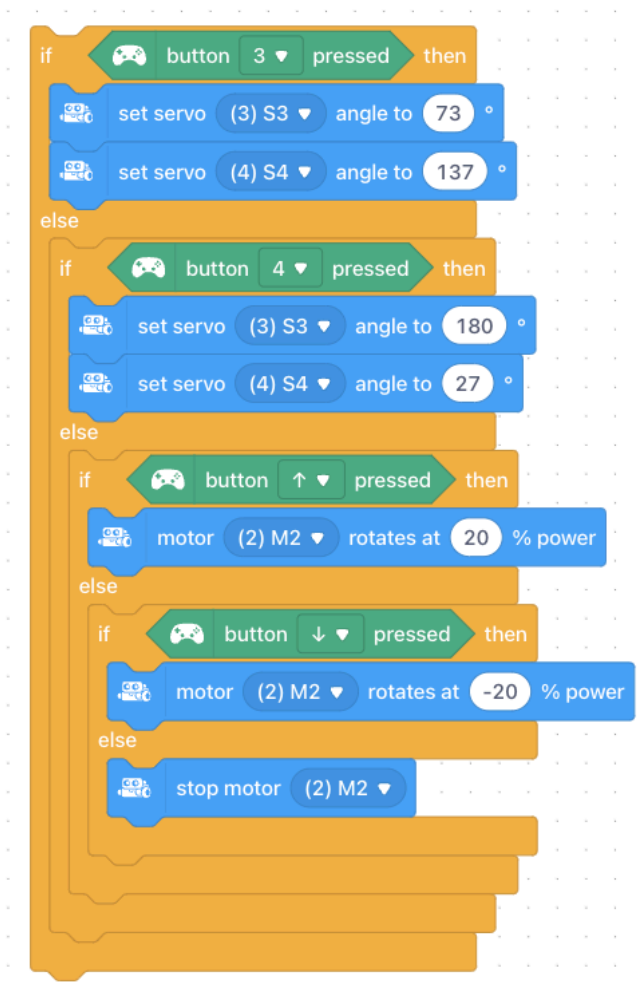


Figure 1.2 : Block diagram for control gripper and rail of manual robot

In figure 1.2, we set a first function to grip the ball by setting button 3 of the controller to control a servo S3 and S4 which is connected with left and right hand of the gripper. When pressed button 3, servo S3 will increase angle to 73 degree and servo S4 will increase angle to 137 degree.

Next, when we press button 4, servo S3 will increase angle to 180 degree and servo S4 will decrease angle to 27 degree. Therefore, the gripper will release the ball. Pressing the up and down buttons will also move the lift up and down, respectively.

5.2. Auto robot

```
#define sval 300 //sensor value
#define dly 360 //delay for black line

void setup() {
  pinMode(10, OUTPUT);  //PWM Pin 1
  pinMode(5, OUTPUT);   //PWM Pin 2
  pinMode(6, OUTPUT);   //Left Motor Pin 1
  pinMode(9, OUTPUT);   //Left Motor Pin 2
  pinMode(8, OUTPUT);   //Right Motor Pin 1
  pinMode(7, OUTPUT);   //Right Motor Pin 2
  pinMode(A1, INPUT);
  pinMode(A2, INPUT);
  pinMode(A3, INPUT);
  pinMode(A4, INPUT);
  pinMode(A5, OUTPUT);
  Serial.begin(9600);
}

void red() { //read IR value
  for (int i = 1; i < 5; i++) {
    Serial.print("A");
    Serial.print(i);
    Serial.print(" : ");
    Serial.println(analogRead(i));
  }
  Serial.println("==================");
  delay(500);
}
```

Figure 5.2.1 - Setup and read line function

```
void motor(int pwr, int pwl) { //motor control function
  if (pwr >= 0 && pwl >= 0) {
    digitalWrite(7, LOW);
    digitalWrite(6, HIGH);
    analogWrite(5, pwr);
    digitalWrite(8, LOW);
    digitalWrite(9, HIGH);
    analogWrite(10, pwl);
  } else if (pwr >= 0 && pwl < 0) {
    digitalWrite(7, HIGH);
    digitalWrite(6, LOW);
    analogWrite(5, pwr);
    digitalWrite(8, LOW);
    digitalWrite(9, HIGH);
    analogWrite(10, (pwl * (-1)));
  } else if (pwr < 0 && pwl >= 0) {
    digitalWrite(7, LOW);
    digitalWrite(6, HIGH);
    analogWrite(5, (pwr * (-1)));
    digitalWrite(8, HIGH);
    digitalWrite(9, LOW);
    analogWrite(10, pwl);
  } else {
    digitalWrite(7, HIGH);
    digitalWrite(6, LOW);
    analogWrite(5, (pwr * (-1)));
    digitalWrite(8, HIGH);
    digitalWrite(9, LOW);
    analogWrite(10, (pwl * (-1)));
  }
}
```

Figure 5.2.2 - motor control function

```
void tt(int pwr, int trn) { //2black line
  while (analogRead(A1) < sval && analogRead(A4) < sval) {
    if (analogRead(A2) < sval && analogRead(A3) < sval) {
      motor(pwr, pwr);
    } else if (analogRead(A2) < sval && analogRead(A3) > sval) {
      motor(pwr - trn, pwr);
    } else if (analogRead(A2) > sval && analogRead(A3) < sval) {
      motor(pwr, pwr - trn);
    } else {
      motor(pwr, pwr);
    }
  }
  ts(pwr, dly, trn);
}
```

```
void tr(int pwr = 200) { //turn right
  ao();
  delay(30);
  motor(pwr, -pwr);
  delay(80);
  while (analogRead(A4) < sval) motor(pwr, -pwr);
  while (analogRead(A4) > sval) motor(pwr, -pwr);
  delay(10);
  ao();
  delay(10);
}

void tl(int pwr = 200) { //turn left
  ao();
  delay(30);
  motor(-pwr, pwr);
  delay(80);
  while (analogRead(A1) < sval) motor(-pwr, pwr);
  while (analogRead(A1) > sval) motor(-pwr, pwr);
  delay(10);
  ao();
  delay(10);
}
```

Figure 5.2.3 - track and turn function

6. Flowchart

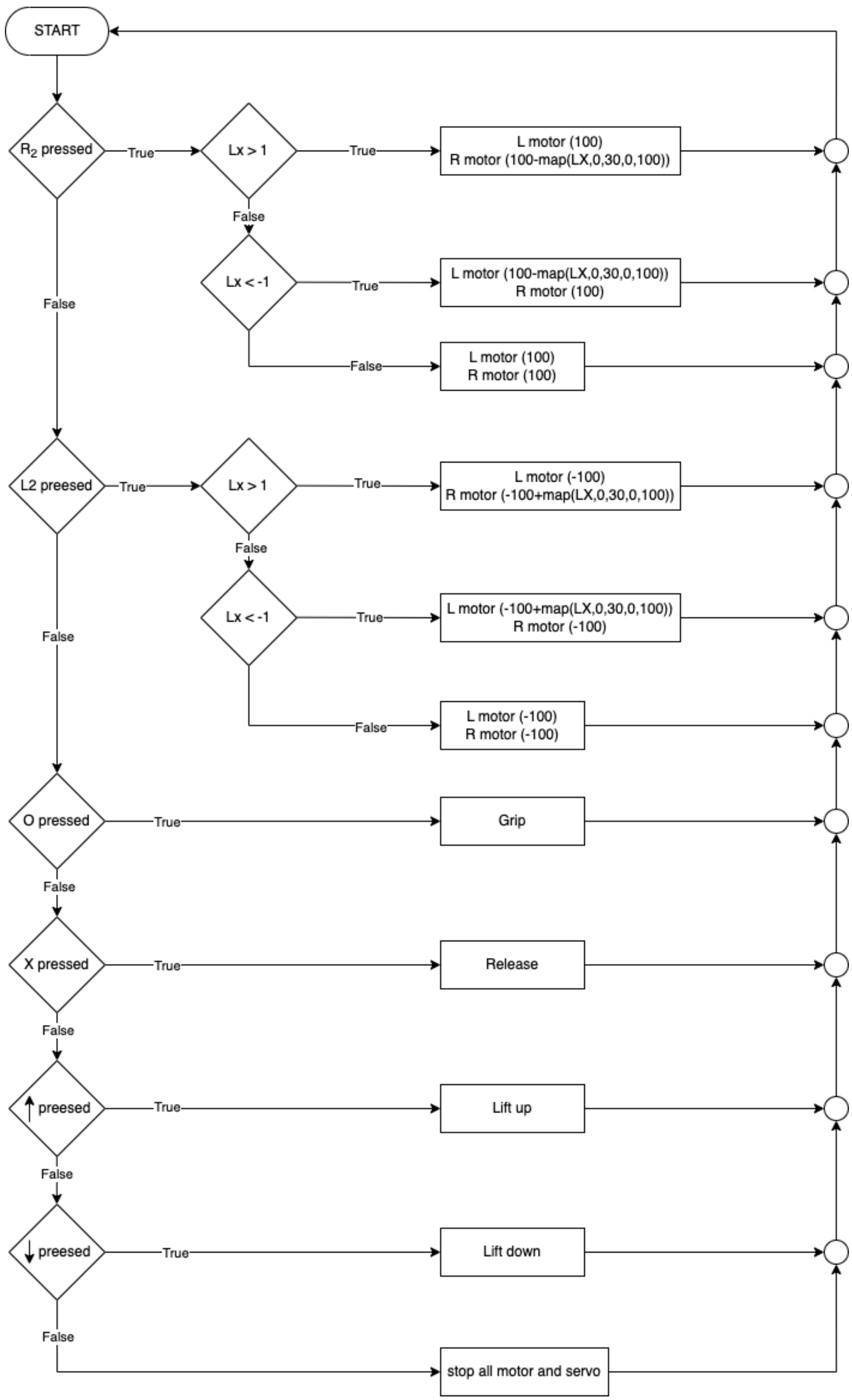


Figure 1.1 : Flowchart of Manual robot

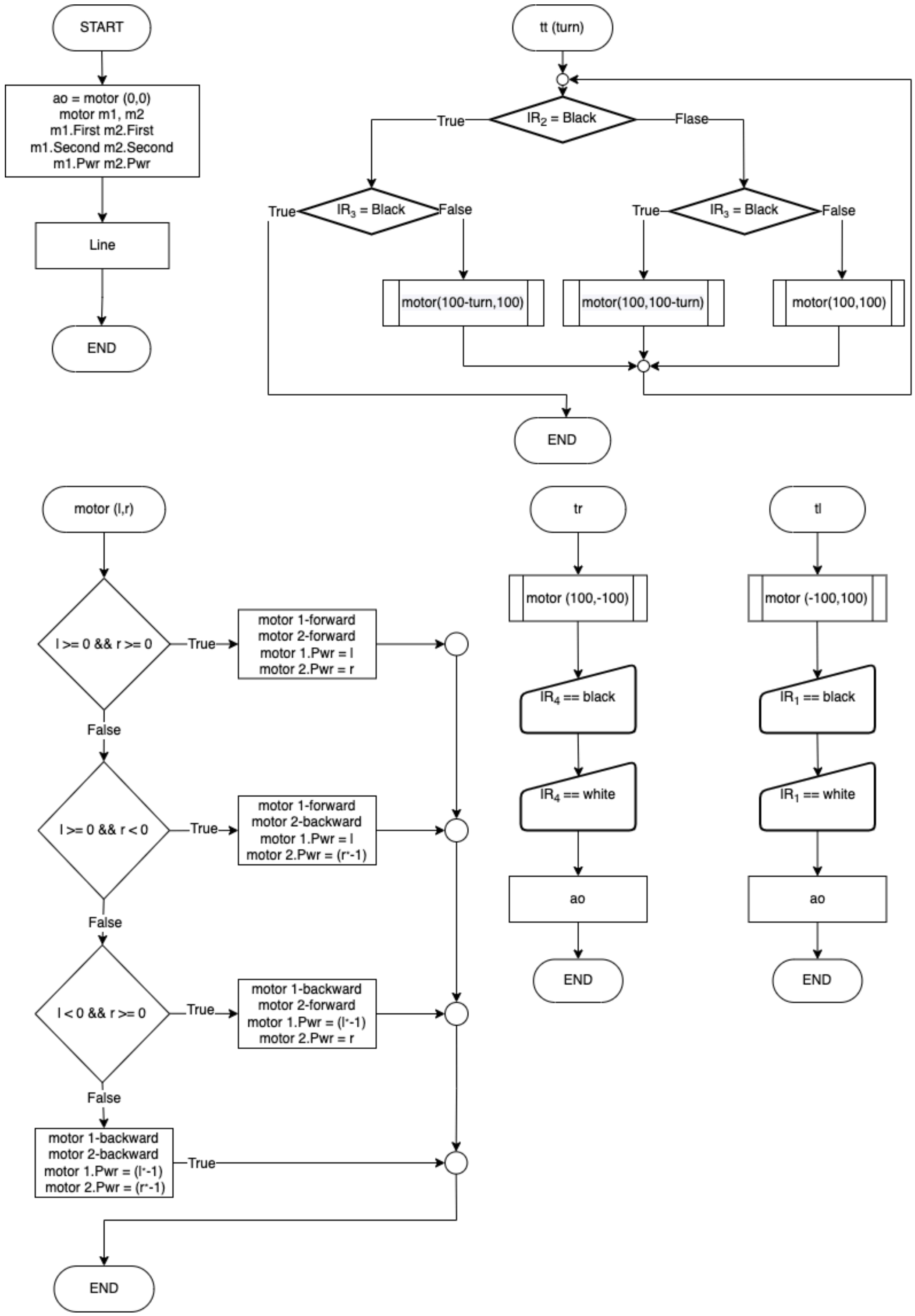


Figure 1.2 : Flowchart of Auto robot

7. Calculation

Calculation 1 - Find velocity of the ball in 2 gantries.

- Displacement = velocity_x x time

  $S = v_x t$

  $v_x = s/t$

  $v_x = (0.45m) / (0.49s)$

  $v_x =$ **<u>0.92m/s ± 0.02m/s</u>**

- Final $v_y^2 = u_y^2$ - 2 x acceleration x displacement

  $v_y^2 = u_y^2 - 2as$

  $0 = u_y^2 - 2(9.8m/s^2)(0.112)$

  $u_y =$ **<u>1.5m/s ± 0.1m/s</u>**

- Final initial velocity by pythagoras theorem is

  $= \sqrt{0.92^2 + 1.5^2}$

  = **<u>1.75m/s ± 0m/s</u>**

Calculation 2 - Find k of the rubber band

- k in this case is a rubber band elastic constant and can be find with $0.5kx^2$

  $0.5(k)(\text{displacement})^2 = 0.5(\text{mass})(\text{velocity})^2$

  $+ (\text{mass})(\text{gravitational acceleration})(\text{height})$

  In this equation you can see that the spring potential energy transforms to mechanical energy.

  $0.5kx^2 = 0.5mv^2 + mgh$

  $0.5k(0.06m)^2 = 0.5(0.044kg)(1.75m/s)^2 + (0.044kg)(9.8m/s^2)(0.10m)$

  $0.5k(0.06m)^2 = 0.074 + 0.043$

$0.5k(0.06m)^2 = 0.117\ 0.004$

$k = (0.117)(2) / (0.06)^2$

$k =$ **<u>61.31N/m ± 3N/m</u>**

Calculation 3 - Find average k(Young's Modulus) from both ball

- 1st k from the green ball = 61.31N/m ± 3N/m
- 2nd k from the yellow ball = 39.59N/m ± 1.93N/m
- Average = $\Sigma X / N$
  = (61.31 + 39.59) / 2
  = 50.451
  = **<u>50.45N/m ± 2N/m</u>**

Calculation 4 - Find torque require

- We know the energy that goes into the spring mechanism can put its energy equal to rational energy.
- $1/2(k)(\text{displacement})^2 = 1/2(\text{moment of inertia})(\text{angular velocity})^2$
  $0.5(k)(x)^2 = 0.5(I)(\omega)^2$
  $(50.45)(0.06)^2 = (mr^2)(\omega)^2$
  $(50.45)(0.06)^2 = (0.0284)(0.039)^2(\omega)^2$
  $0.18162 = 0.0000431(\omega)^2$
  $\omega_{shooter}$ = **<u>64.84rad/s ± 18.97rad/s</u>**

- Then ω_{drive} of the second gear(the drive gear) can be found by
  Angular velocity x Teeths = Angular velocity x Teeths
  64.84 x 24 = ω_{drive} x 12
  ω_{drive} = **<u>129.68rad/s ± 37.94rad/s</u>**

- By $\omega_f^2 = \omega_i^2 + 2\alpha\theta$
  $(129.68)^2 = 0 + 2\alpha(2\pi)$
  α = **<u>1338.24rad/s² ± 783.45rad/s²</u>**

- By knowing the alpha of the drive gear, we can also find torque by applying $\tau = I\alpha$

  $\tau = I\alpha$
  $\tau = (0.0284)(0.039)^2(1338.24)$
  $\tau = 0.057$

τ = **<u>0.06Nm ± 0.03Nm</u>**

- Yellow DC motor could give out 0.08Nm of torque. This means that we only used 75% of its power. If we don't have the gear reduction the motor would be able to handle twice as much torque.

Calculation 5 - Find max weight carrying capacity of the front gripping part

- Yellow motor could handle 0.08Nm
- Torque = radius x Force

  τ = rF

  0.08 = (0.00475)F

  F = 0.08 / (0.00475)

  F = **<u>16.84N ± 3.55N</u>**

- Since T = F and T has to be equal to the weight of all material we can say that

  T = mg : when m is roller mass, gripper mass x2, servo mass x2

  T = (roller + 2gripper + 2servo + M)g

  16.84/9.8 = 0.0145 + 2(0.0054) + 2(0.009) + (M)

  M = 1.675kg

  M = **<u>1.68kg ± 0.36kg</u>**

- This means that for the maximum power input the motor can lift 1.68kg.

Calculation 6 - Find the gear revolution for 1 spin of the gripper part

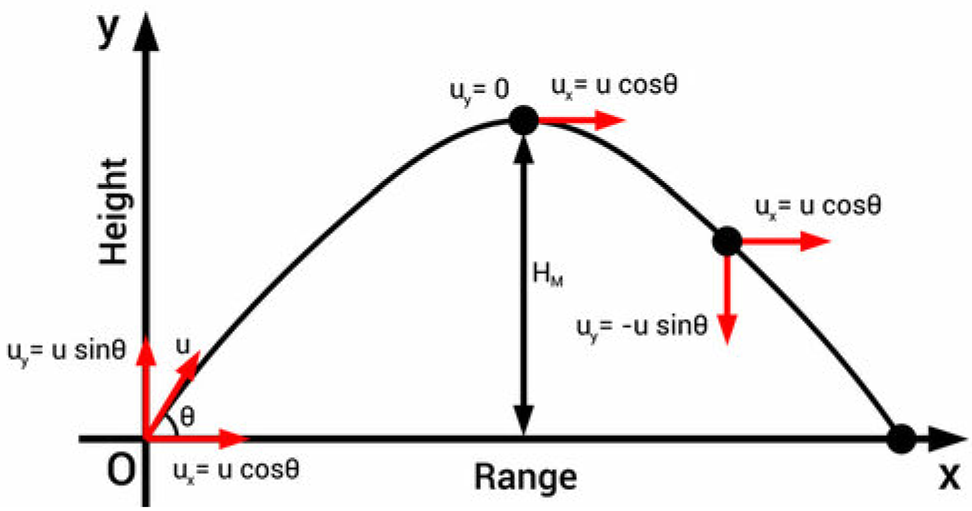
- Angular velocity x Teeths = Angular velocity x Teeths

  R x 12 = 1 Revolution/s x 24

  R = **<u>2 Revolution/s</u>**

  ∴ When the drive gear turn 2 revolutions the big gear would spin just once.

8. Results



The diagram illustrates Displacement X and Y which paint the picture for the upcoming table.

The table shows displacement in x, time, and velocity of both balls .

Trials	Green ball			Yellow ball		
	Displacement X	Time	velocity	Displacement X	Time	velocity
1	0.450m±0.001m	0.49s±0.01s	0.92m/s±0.02m/s	0.880m±0.001m	0.42s±0.01s	2.10m/s±0.04m/s
2	0.448m±0.001m	0.47s±0.01s	0.95m/s±0.02m/s	0.871m±0.001m	0.40s±0.01s	2.18m/s±0.04m/s
3	0.451m±0.001m	0.50s±0.01s	0.90m/s±0.02m/s	0.896m±0.001m	0.43s±0.01s	2.08m/s±0.04m/s

The table shows displacement in y, time, and velocity of both balls .

Trials	Green ball		Yellow ball	
	Displacement Y	velocity	Displacement Y	velocity
1	0.112m±0.001m	1.48m/s±0.05m/s	0.188m±0.001m	1.92m/s±0.06m/s
2	0.115m±0.001m	1.50m/s±0.05m/s	0.190m±0.001m	1.93m/s±0.06m/s
3	0.116m±0.001m	1.51m/s±0.05m/s	0.189m±0.001m	1.92m/s±0.06m/s

- Mass of the Green and Yellow balls is 0.0440kg ± 0.001kg and 0.0143kg ± 0.001kg, respectively.
- Average K is 50.451N/m and the torque required is 0.06Nm ± 0.03Nm

- The drive gear has to be turned two times in order to rotate the front part once.
- The maximum load the motor can handle is 1.68kg ± 0.36kg, friction and other resistance force not included.

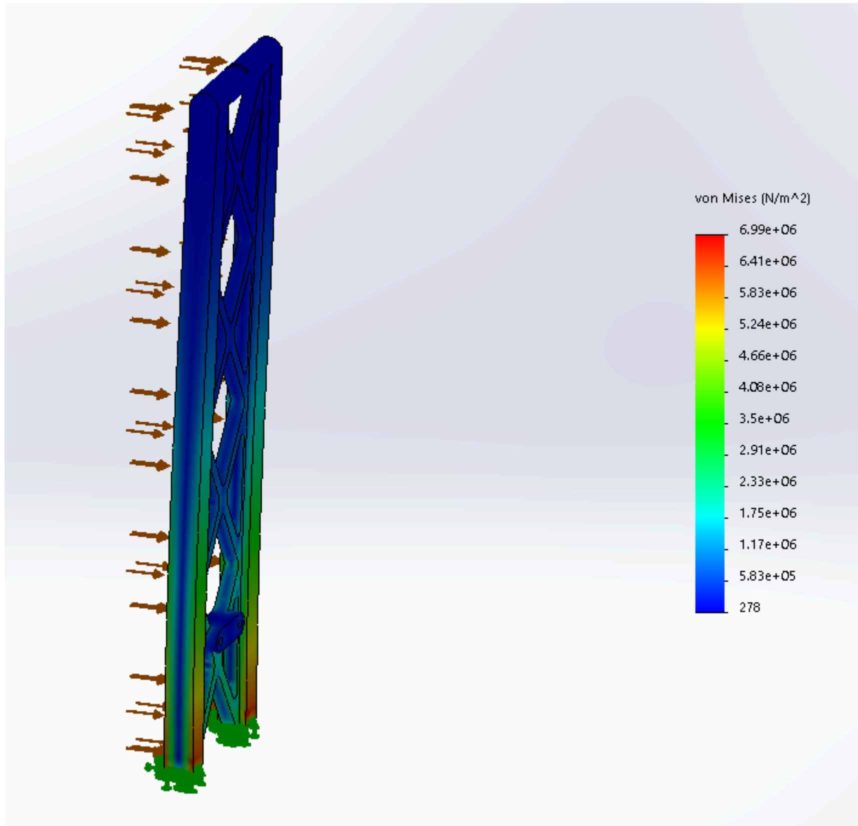


Figure 8.1 - How the rail reacts with a force of ten newtons applied to the tip of the rail.

9. Conclusions

- We only used 4 IR sensors in the auto robot (Line-following), because 4 sensor and 5 sensor line following robots have a minute difference in tracking the line.
- In the manual robot we can see that both balls receive different velocities in both gantries as the result of the mass not the same. Displacement in x direction tends to be more than displacement in Y direction.
- The drive gear has to be turned 2 times in order to rotate the gripper mount. This is due to the fact that the second motor has to turn both the shooter and the gripper part at once in sync. The lack of torque in the motor is overcome by using two gears, one small, and one big. The motor would spin the small gear and will provide more torque into the shooter itself. However, this will also reduce the speed. Because speed is inversely proportional to torque.
- To equally separate the tension in the lift we used 5 strings in order to distribute the tension equally between the tether, this also provides failsafe for the lift, for if the string is rupture and the other string is still in place and ready to be used.
- The yellow DC motor could give out 0.08Nm max torque when provided with the minimum 3v and that is more than enough for our design we only use 0.06Nm torque in turning the shooter part, however with 0.03Nm error the gap is not enough for if the torque calculated was wrong to the extreme. The front gripping part will also use some torque in order to turn but since the gear is stuck on the base loosely friction is very little therefore, we won’t take into account the torque used by the gripping mechanism.
- For the gripper mechanism 1.68kg ± 0.36kg of mass could be easily pulled, however, we can see from figure 8.1 that the maximum stress point lied on the bottom edges of the rail, and exert more force than the rail can handle, By this diagram we know that PLA is not able to hold itself up against a 1kg weight at the top. However in order to find the max weight and height that it could handle an experiment is needed to be performed. But by performing this experiment, many spare parts are needed. Therefore, we decided not to do this, as long as both balls can be picked up this experiment will be excluded from this report.

Improvement

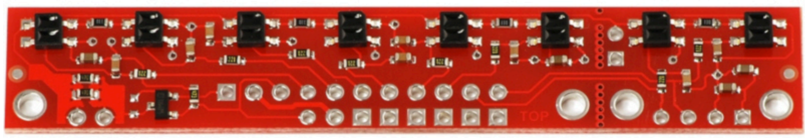


Figure 10.1 - QTR-8RC, Reflectance sensor array

- For an auto robot, if it weren't for the limited electronic uses. QTR-8RC in figure 1.1 would be used. For easier and more stable tracking movement with PID. However since the line following part is very short and covers less percentage than the manual part we had decided to focus more on the manual aspect of the competition.

Figure 10.2 - L293D Motor Drive Shield

- The design would be redesigned from the start. We would prefer a controller board with a motor driver included in the board (ATX2, POPx2, or in figure 1.2) so it would take much less space of our 16x16 size limit. Since the key of making a stable and fast line tracking robot would be to have the sensor far from the center of movement and also to have a short and wide robot.

Figure 10.3 - Bungee cords

Figure 10.4 - Spring

- For the manual section, our gun design is far from perfect due to the lack of time and resources. Giving it more shooting power would be the best option for us, however by putting more than 4 rubber bands into the mechanism. The rubber bands tend to stick together with friction and also curl up on each other so we are limited to 3 rubber bands at max. Finding a new elastic material (Figure 1.3 and 1.4) that has more force and uses less space would be a fantastic addition to our shooter, spring had been considered since the lack of time we could not find the suitable one for the shooter. The spring angle could also be lower from 45° from horizontal to 30°. With the shooter lowered the energy gain by the shooter would be converted more into horizontal movement and less in propel it upward over the chamber.

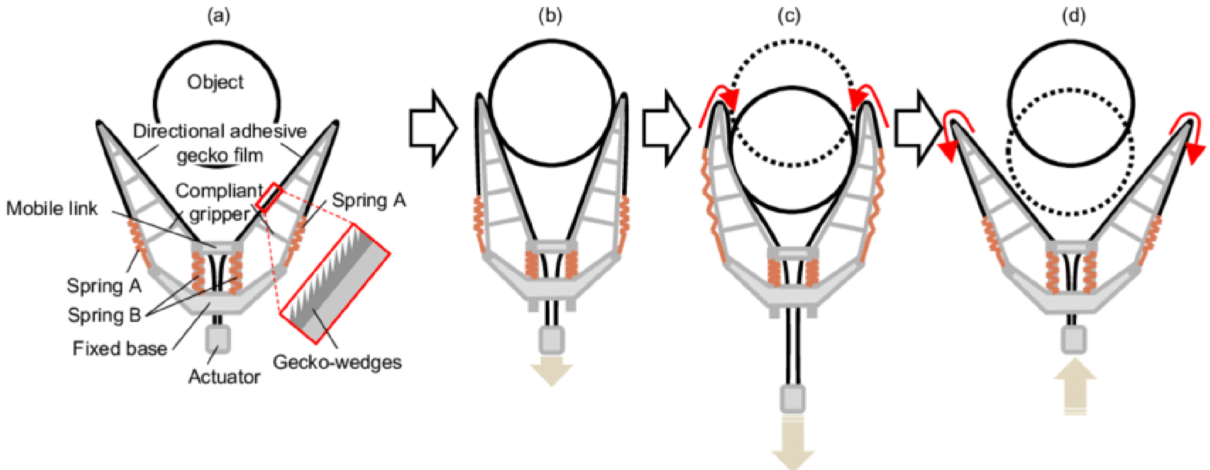


Figure 10.5 - Adaptive Gripper

Figure 10.6 - Pneumatic suction cup

- For our gripper we would have made it more stable and adaptive gripping (Figure 1.5) or pneumatic mechanism (Figure 1.6) would be considered. Our gripper base was limited by the maximum size of the robot, and by increasing the base length both rail and the gripping part would be more stable. Adaptive gripper should be used due to the differ size of the ball, hence adaptive gripper would be more suitable in having more contact points with both balls.

Figure 10.7 - Omni wheel

Figure 10.8 - Mecanum wheel

- The design overall is pretty strong and robust. However, we had missed an opportunity to put omni (Figure 1.7) or mecanum (Figure 1.8) wheels on the robot. By using these two wheel types our robot would have less limited movement and could be significantly faster.

Future work

1. Trash Collecting Robot

Figure 1.1 - Garbage Robot called DustBot in Italy

The Trash Collection Robot is designed to collect solid waste in public places and residential places. Nowadays, a trash collection robot has a high cost and not for everyone. For reference in figure 1.1, In Italy has developed a DustBot which uses a $3.9 million research program. It directly shows that a less developed country will not have an opportunity to have robots that aim to make good hygiene in their city. Therefore, our group decided to improve our manual robot to be a Garbage Collection Robot with lower cost and have a similar function to a high class robot. Our gripper has the potential to be a collecting garbage machine, we could change the shooter in the back to a bin.

2. Logistic

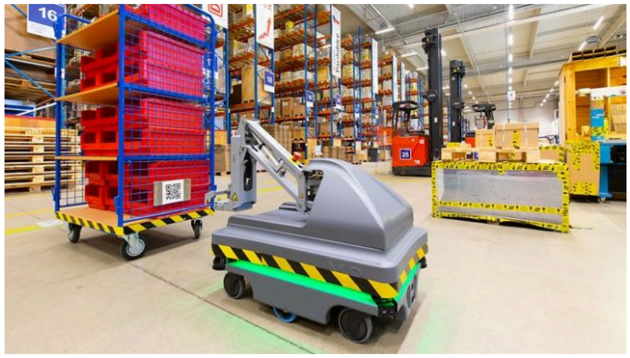


Figure 2.1 - MiR Hook 200 robot in Czech Republic

Autonomous mobile robots (AMR) in logistics will help to detect, transport or pick the object to make operations even more efficient. In figure 2.1, this is the first logistics robot in the Czech Republic into operation called “MiR Hook 200”. This robot helps staff by taking over simple warehouse tasks such as detect and transport trolleys. For our group, we will add a forklift to lift and use grippers to transport. For the rail to move things up and down, we will adjust to be able to lift more weight because we use it in logistics. Our gripper will be redesigned to be able to handle many shapes and be able to lift heavy objects.

3. Forklift

Figure 3.1 - Autonomous forklift

Forklift robot also known as AMR Forklift, forklift robot is a type of robotic driverless forklift that complies with two specific requirements. It must perform autonomous navigation (natural navigation). Natural navigation doesn’t need any type of infrastructure/hardware to localize and navigate the forklift. Next, it must be able to decide autonomously different guidepaths on its own and allow obstacle avoidance.

For our group, we got inspired by an elevator design from a forklift, which means it has the ability to lift something up and down, we can make an elevator system more secure for handling more weight of things, and re-create gripper design for a more flexible curve of gripping various type of object.

4. Fishing

Figure 4.1 - Autonomous fishing pole

Fishing industry could also be automated by our robot, traditional fishing is the most known way of fishing by casting a line and rolling the line back. We could stick the end of the line to a roller in the front part of our robot, the part which used to lift the gripper up and down. So the shooter could be used for throwing the bait far into the sea. We can also wiggle the bait by turning the front part left and right.

5. Fire engine

Figure 5.1 - Fire engine

One of the primary users of fire engine robots is to extinguish fires in dangerous or high-risk environments where firefighters may not be able to safely enter. They can navigate through challenging terrain, locate the source of a fire, and extinguish it using a variety of firefighting techniques. In addition to traditional firefighting tasks, fire engine robots can be used for tasks such as hazardous material heading, search and rescue and disaster response. They can provide valuable assistance to human firefighters and help reduce the risk of injury or loss of life. Our robot could do this task as well. By having the ability to lift objects up and down, we could use the shooter in the back to shoot a ball filled with fire extinguishing material such as potassium bicarbonate, and change the normal tires to track wheels more stable to bear a heavy weight.

6. Weather balloon

Figure 6.1 - Weather balloon being deployed.

Helium is a very limited element on earth, and is used everyday to study the wind speed, temperature, etc. everyday more than 1800 weather balloons are released. Weather balloons are essential for our daily life, we can’t deny that we never use a forecast application in our lifetime. Behind a perfect prediction of the weather, some never even knew that weather balloons are being deployed, and helium is being used. In 25-30 years from now the world will be running out of helium supply. Our group proposed a new way for weather balloons to be deployed, Our shooter mechanism has a potential to be built bigger with other means and material. Instead of pumping a limited resource into weather balloons everyday, we suggest using a shooter-like mechanism to shoot the weather balloons upward and let it glide down while measuring many aspects of the air condition.

7. Radioactive waste management

Figure 7.1 - Robot used for cleaning up nuclear waste.

Nuclear energy is a very efficient means of producing energy in this time of life, however it is not reliable. We have seen many nuclear plants malfunction and leave radioactive waste that is hard to cope with behind. Robots have been used to tackle this problem. Our robot could do this task as well. By having the ability to grab objects from high and low, we could change the shooter in the back to a nuclear management bin, and change the normal tires to track wheels like a tank. We could potentially tackle this task with our robot too, if not consider the damage that the radioactive activities could do on the robot. However by researching more into this field we believe that our robot could be used to tackle this field.

Discussion

1. For an auto robot, we have two rules to follow. First, we put the IR sensor far from the motor for more accurate movement. Second, we have to make a robot light and as short as possible for a stable movement.
2. IR sensors placement. The height of IR sensors needed to be ludicrously low to the ground, hence adjusting the potentiometer is vital, And calibrating for all IR sensors is mandatory for reducing an error in tracking the line.
3. Latency of the arduino uno is about 5ms, delay in conveying some information may occur, this may cause errors when deploying the robot.
4. Battery problems, 1.5v AA Battery can surge down in voltage very quickly after sometimes. The voltage fluctuated a lot and correlated to the inconsistency in the motor throttle. This occurs a lot during our testing period, hence we change normal battery to a rechargeable one which output less voltage. But increases in consistency of the motor speed.
5. IR sensors were mounted too far to the front of the robot. Normally this would have resulted in a good meaning, but with how the fields were placed with many lines stuck very high to each other. We have to move the sensors for some distance.
6. Calculation is very complicated to do. Finding the hound modulus of the spring is already a hassle enough. When we go into finding the torque the error keeps increasing and due to many steps in calculating and many values being added. At last calculation can't guarantee that our robot would have work but by taking the risk and experimenting we can confirm that our calculations have work and the robot works flawlessly.
7. When measuring the length from the end of shooter and falling point, make sure that the final position of the measurement must be measured from the center of the object, or else the final calculation will be faulty.
8. We can't put more k into the system, to simplify, we can't increase the count of the rubber bands. For more than 3 rubber bands, the k started to decrease due to the friction of the rubber and the rubber getting curled up on each other. Therefore by the equation F=kx we know that Force comes from k multiplied by the displacement, so by increasing the displacement, we can also increase the force generated.
9. We designed a place for keeping wires with a lift structure which connected to a string and the arm parts. When we shoot a ball from the end of the shooter. A bevel gear, which connects lift and shooter together, will make wires tangle up. Thus, the lift is stuck and can't continue to rotate..

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