EG1311: DESIGN AND MAKE

B03 TEAM 4

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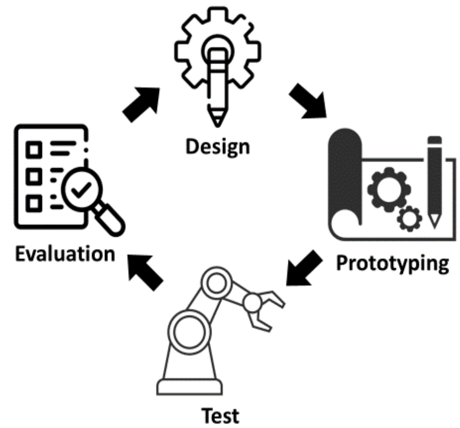
1. Introduction

This project aims to collaboratively build a self-powering robot with a catapult that can navigate and overcome an obstacle course, and subsequently return to the starting point. We used tools such as C++ for programming our robot in Arduino, and Fusion360 to create Computer-aided Design (CAD) models for our robot. We have also adopted the following 4-step cyclic approach in building the robot:

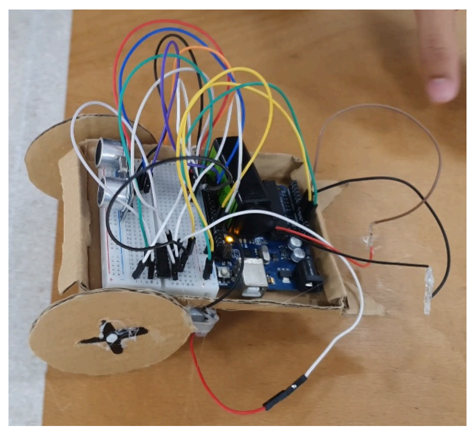
1. Design: Based on the robot requirement, and our findings from the evaluation phase, we generate ideas to address the prototype's shortcomings while enhancing its current strength.
2. Prototyping: We take the designs generated previously and implement them into our prototype.
3. Test: We test our robot with the obstacle course extensively and record observations during its performance.
4. Evaluation: With the observations, we identify the strengths and shortcomings of our current prototype.



This report will discuss our thought process in our approach and how we overcome our challenges.

2. Design, Prototyping, Test And Evaluation

2.1 Template Project



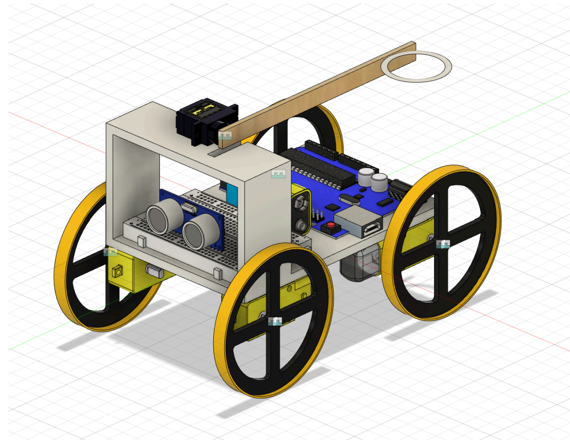
Objective: To develop the correct code and wiring such that the robot can travel and stop before the wall.

Strength: The robot can travel and stop before the wall. This means that the circuit and Arduino code for travelling and halting are correct, and therefore could be used for future designs.

Shortcomings:

- The robot is unable to overcome the bump and ramp due to the lack of friction between the wheels and the ground, and the insufficient torque by the 2 motors. This can be deduced when the wheels are spinning but the robot is not moving forward.
- The wheels are also not large enough as the wheels are not in contact with the ground when crossing the obstacle.
- The cardboard exhibits low durability and is too thin to support the other components, leading to deformation after a few test runs.
- The robot is not travelling in a straight line, due to the unequal distribution of weight, and the poor management of wires, causing it to rub against the wheels and the ground. Hence the length of wire should be reduced and properly bundled up to prevent the former from happening.

2.2 Design 1 (4 Motors)



Objective: To overcome the bump, ascend the ramp, stop in front of the wall and reverse by leveraging our observations from the template project. Additionally, this establishes the foundational design for future improvements of the robot.

Arduino Code: Besides the code in the template, we have added new codes to control the servo motor for the catapult's movement. It is programmed such that the servo motor will turn 90 degrees to throw the ping pong ball once it stops in front of the wall. Furthermore, a new code is implemented to reverse the direction of rotation of the motor once the robot reaches the wall by reversing the polarity of the circuit.

Ultrasonic Sensor & Catapult: The ultrasonic sensor measures the distance from the wall and we have set the stopping distance at exactly 5 cm to meet the obstacle course requirement. The catapult consists of 2 ice cream sticks connected, with a ball holder made up of dried glue and masking tape. Since the ping pong ball is light, the dried glue is strong and sturdy enough to withstand the ball without itself deforming when it is thrown. Moreover, we ensured that the masking tape is long enough so that more than half of the ball is inside the holder, preventing it from dropping out. Applying the formula of Moment (torque = force x moment arm), the 2 ice cream sticks help to extend the arm, enabling the ball to be thrown further and higher. These materials not only allow the catapult to be light but also ensure a dependable launch.

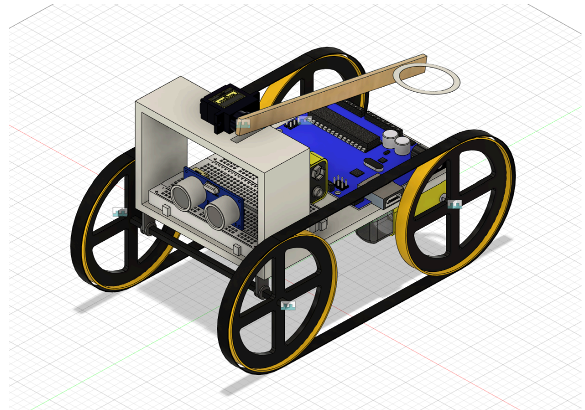
Body: We have used a 10cm x 12cm polypropylene board as it is a more durable material as compared to cardboard for the base. The dimension is sufficient to fit all the components such as the Arduino, breadboard and battery. To prevent any movement of the components, we used tape and glue guns on the slippery surface to secure them to the base and prevent sliding.We have also elevated the catapult by adding an elevated platform of 4cm at the front of the robot. This helps to prevent the robot from toppling as the catapult and the centre of gravity(CG) is in the middle. A small slit is cut out to allow greater movement of the ice cream stick. A rectangular space was also cut at the base's centre to reduce weight and manage motor wires more effectively and neatly.

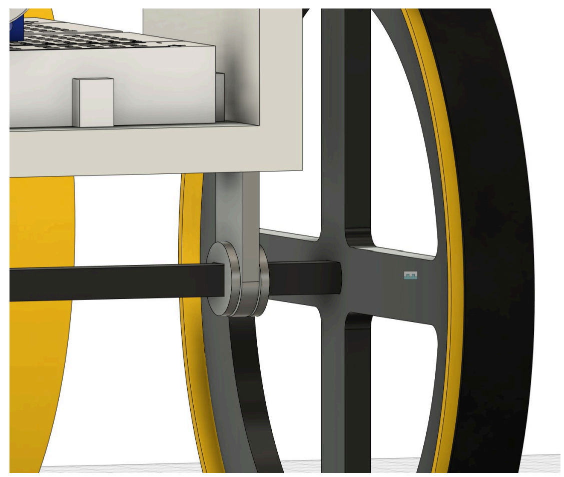
Motors & Wheels: The use of 4 motors compared to 2 increases the robot’s torque and contributes to its increased stability. Acrylic wheels are used as it is a more sturdy material. They were printed with a diameter of 8 cm, with 4 quarters removed to ensure it was big enough to overcome the bump and reduce weight. We have also added rubber bands at the circumference of the wheel to increase friction for the wheels. We did not use pulse-width modulation to control the speed as it is not necessary. Instead, we just maintained a constant speed throughout

Strength: It can complete all the obstacles in the course, hence achieving the set objectives.

Shortcomings: The robot's weight is heavy due to the use of 4 motors. We can consider removing some motors in future prototypes to lighten the robot.

2.3 Design 2 (2 Motors)





Objective: To reduce the robot's overall weight while ensuring that the robot can pass all the obstacles.

Arduino Code & Circuit: No change from the previous design. We have removed the power and ground wires of the front 2 motors.

Ultrasonic Sensor & Catapult: No change from the previous design.

Body: No change from the previous design. We have examined and concluded that this is the smallest possible size for the base as it perfectly fits all the components in there, leaving only a small hole between the Arduino board and breadboard for wires from the motors to come up. The battery is placed at the centre and slightly to the front to allow the CG to always remain in the middle to prevent toppling.

Motors & Wheels: We have removed the front 2 motors from our robot and replaced them with 2 free-spinning wheels. As the motor is one of the heaviest components, reducing the number can significantly reduce the overall weight. The wheels are connected via a shaft placed within 2 hollow holders that are made of acrylic on either side of the robot. Acrylic is used as a sturdy and smooth material is required to allow the wheels to spin smoothly without it deforming. To prevent the shaft from shifting around, we have fixed the shaft's position firmly with 2 circular acrylics at each holder. To ensure all the wheels turn at the same frequency, we adopted a tank design whereby an anti-slip mat is placed around the 2 wheels. This was because, without the slipmat connecting both wheels, the front wheels would not be able to pull the robot up the slope. The wheels used in this design are the same as the previous one.

Strength: The robot managed to overcome all the obstacles except the ramp.

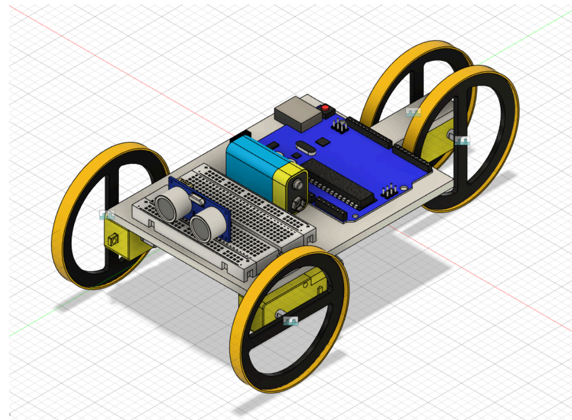
Shortcomings: The robot could not overcome the ramp as it flipped when it went down the slope. This was because the weight distribution was too loft-sided. Even after we placed the battery at the front of the robot, the weight was still not balanced, causing the robot to flip when it crossed the ramp. Therefore, we would need to focus on the weight balance for future prototypes.

2.4 Design 3 (3 Motors)

Objective: To pass all the obstacles with the use of three motors while ensuring that the CG remains well balanced.

Arduino Code: No change from the previous design.

Ultrasonic Sensor & Catapult: No change to Ultrasonic Sensor. We did not include the catapult in this design as we would like to focus on getting the robot past the ramp and bump first.



Body:
We have extended the rear of the body with 2 sticks by the length of 6cm so that we can place the third motors and wheels there. We used two sticks because a single stick wasn't strong enough; it would bend downward, leading to the deformation of the entire structure.

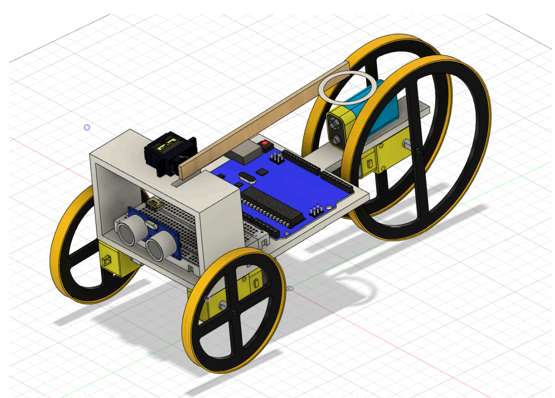
Motors & Wheels: Due to the lack of torque from the previous design, we have added a motor at the rear. This is also to ensure a better weight distribution where the weight difference at the front and back is more equal. We changed our wheels to have 2 semicircles being cut out instead of 4 quarters as we learnt that acrylic is a strong material and it is possible for us to further reduce the weight of the robot by cutting out more volume. We used these wheels and connected them to each side of the front motors and both for the rear motors. This will allow the robot to be more stable as compared to just having one wheel at the rear.

Strength: The robot was only able to travel straight, halt in front of the wall and reverse back to the original position.

Shortcomings: The robot could not overcome the bump and ramp. This was because the longer body and the shorter wheels resulted in the robot being stuck at the bump and the top of the ramp, while the wheels lost contact with the ground. Hence, we have to either decrease the length of the body or use bigger wheels in our next design.

2.5 Design 4 (Final Design)

Objective: To complete all the obstacles in the course with the use of 3 motors and to ensure consistency in the completion.



Arduino Code: No change from the previous design.

Ultrasonic Sensor & Catapult: We have added back the catapult and its elevated surface. Since we also observed that the ping pong ball may be stuck to the holder occasionally, we smoothened out the hoop made of glue guns with sandpaper.

Body: No change in the body.

Motor & Wheels: We have replaced the rear wheels with one that had a diameter of 12 cm. The smaller wheels at the front and the larger ones at the back, helped the robot to pass all the obstacles smoothly, as there will always be wheels in contact with the ground all the time. We also replaced the front two wheels with those from Design 2. Considering that the CG is located at the front of the robot, resulting in higher pressure on the front two wheels, we opted for Design 2 wheels due to their sturdiness compared to those in Design 3.

Strength: Our robot is able to complete the obstacle course consistently with the use of 3 motors.

Day of Assessment: Before the actual graded run, we did 3 trial runs to ensure our robot's consistent performance. We completed the obstacle with a weight of 292g, the lightest in our lab. However, we remained proactive and sought ways to reduce the robot's weight. Firstly, we trimmed off parts of our base and the elevated platform to minimise mass. Next, we removed one of the rear wheels but this led to instability and the robot toppling while going up the ramp. Hence, we added more sticks to reinforce the connection between the body and the rear motor. Through further adjustments and test runs, we finally managed to lower the robot's weight further. Our biggest takeaway came from observing how other teams have designed their robot. We were particularly impressed by some creative mechanisms, such as the use of a rubber band cannon launcher to shoot the ping pong ball over the wall and the implementation of jagged wheel designs to enhance friction. These cross-learning experiences help introduce other ways on how we can design the robot and if given the opportunity again, what else we can do to improve it.

3. Conclusion - Lessons Learnt

Importance of Test and Evaluation: Through rigorous testing, we were able to identify and address the limitations and shortcomings of our design. The feedback allowed us to explore innovative ways of troubleshooting and optimising our robot. The iterative nature of our testing and evaluation process not only brought to light potential issues but also allowed us to implement substantial improvements. Ultimately, each test became a stepping stone, revealing insights that helped us refine our robot, transforming challenges into opportunities for improvement.

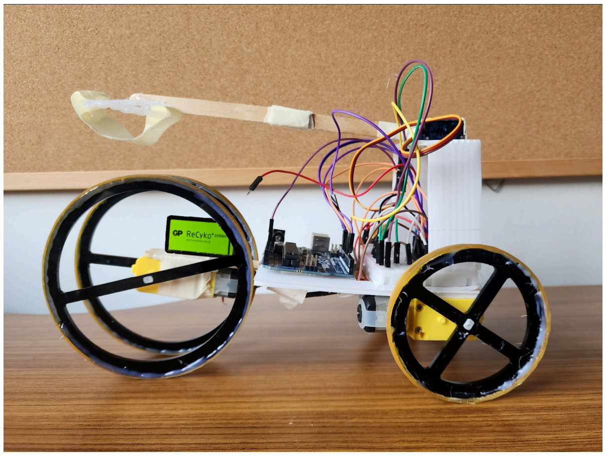
Emphasis on Design: What sets our project apart is that our group managed to complete the obstacle course with the first prototype. This is because we spent an extensive amount of time brainstorming, and researching on the design we should adopt. It was through many rounds of playing devil's advocate and thorough evaluation that we could all reach a consensus on the design that we believed would work before we entered prototyping. Hence, we have learnt the importance of designing and how a good design process will help to speed up the progress of the project.

Keeping Track of Progress: To monitor our progress effectively, we took photos and meticulously documented every detail. This practice enabled us to backtrack and refer to our earlier work in situations where issues emerged or when we recognised that the prior approach was better. This streamlined our workflow and prevented time lost.

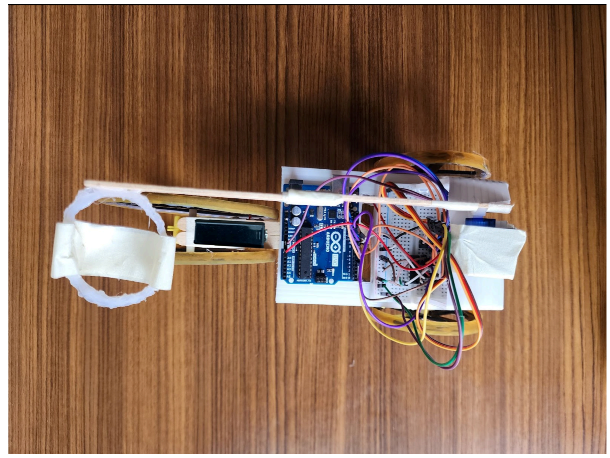
Teamwork: The success of our robot is a collective effort of all team members. We implemented a strategy of task delegation which significantly enhanced the pace and efficiency at which tasks were accomplished. When faced with problems, our collaborative problem-solving approach led us to innovative solutions. Overall, the supportive environment in our group encouraged open communication, making it easier to overcome challenges.

4. Appendix

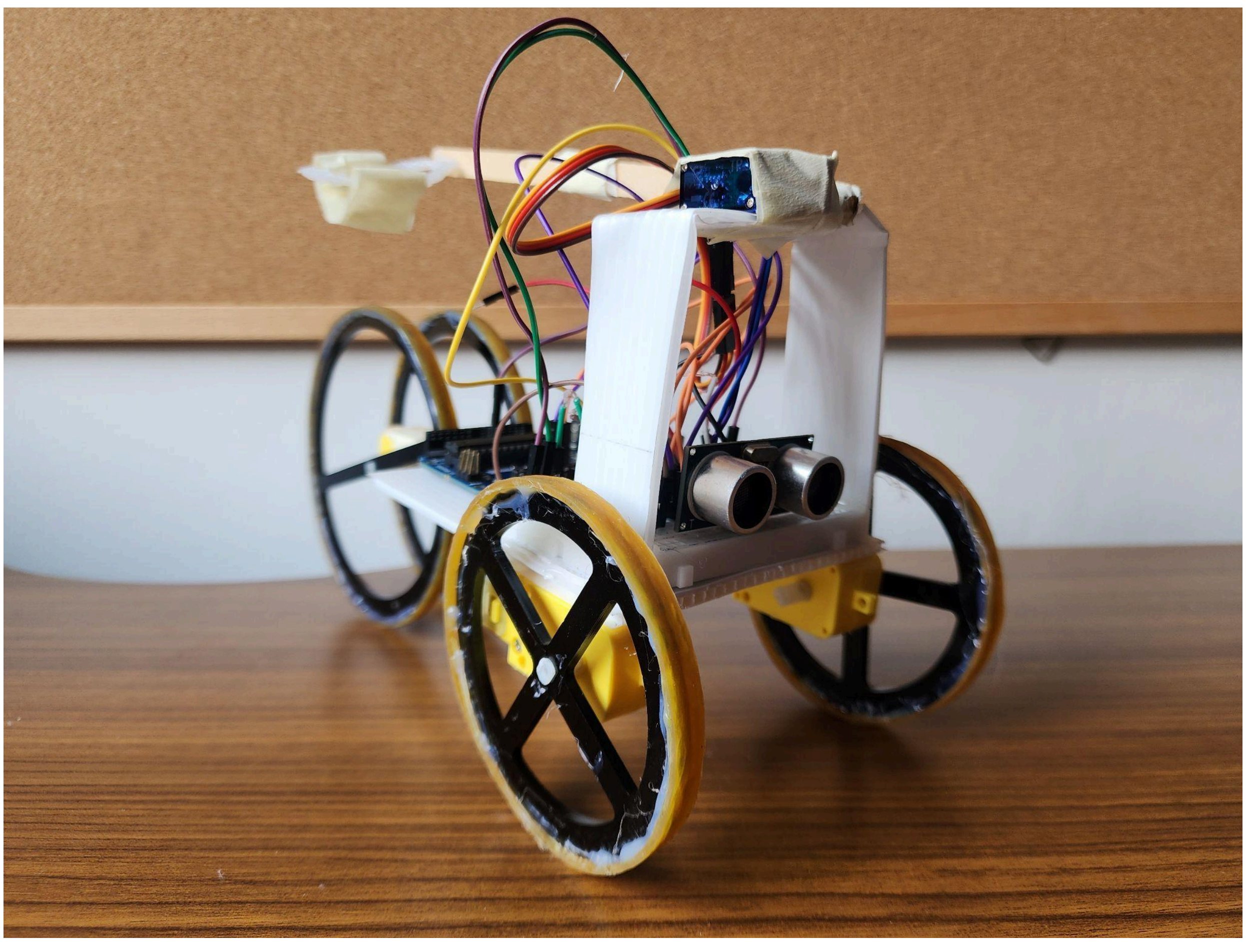
4.1 Photography Of The Final Physical Robot



Side View

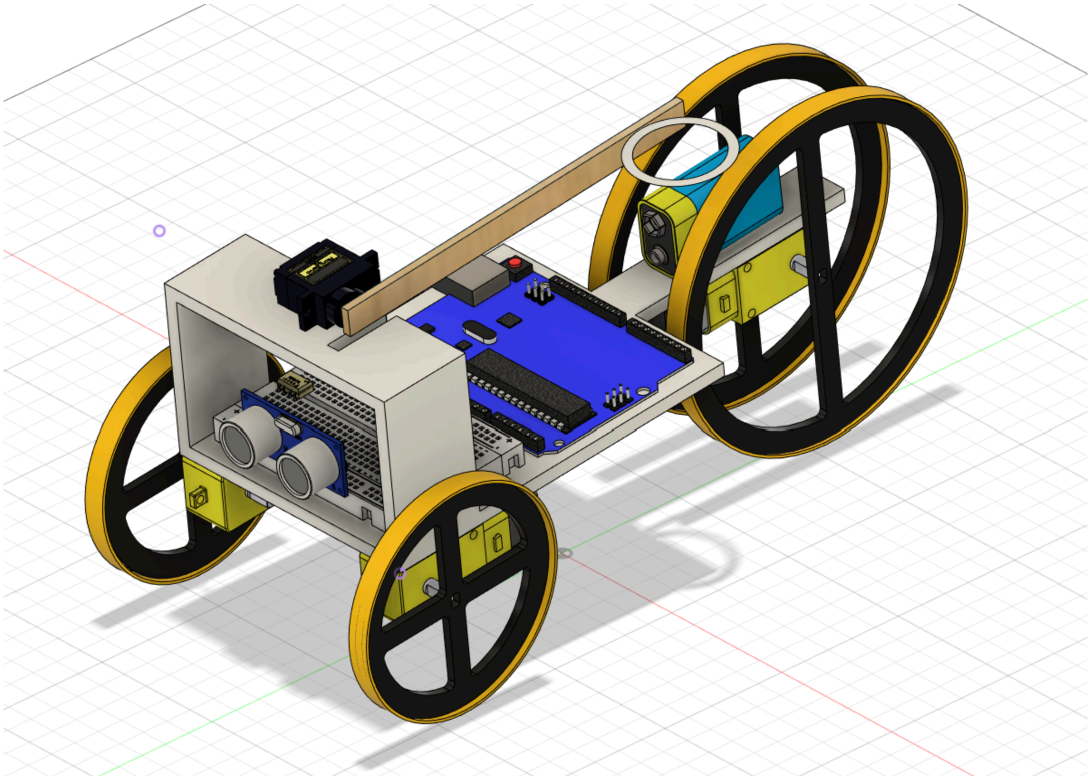


Top View

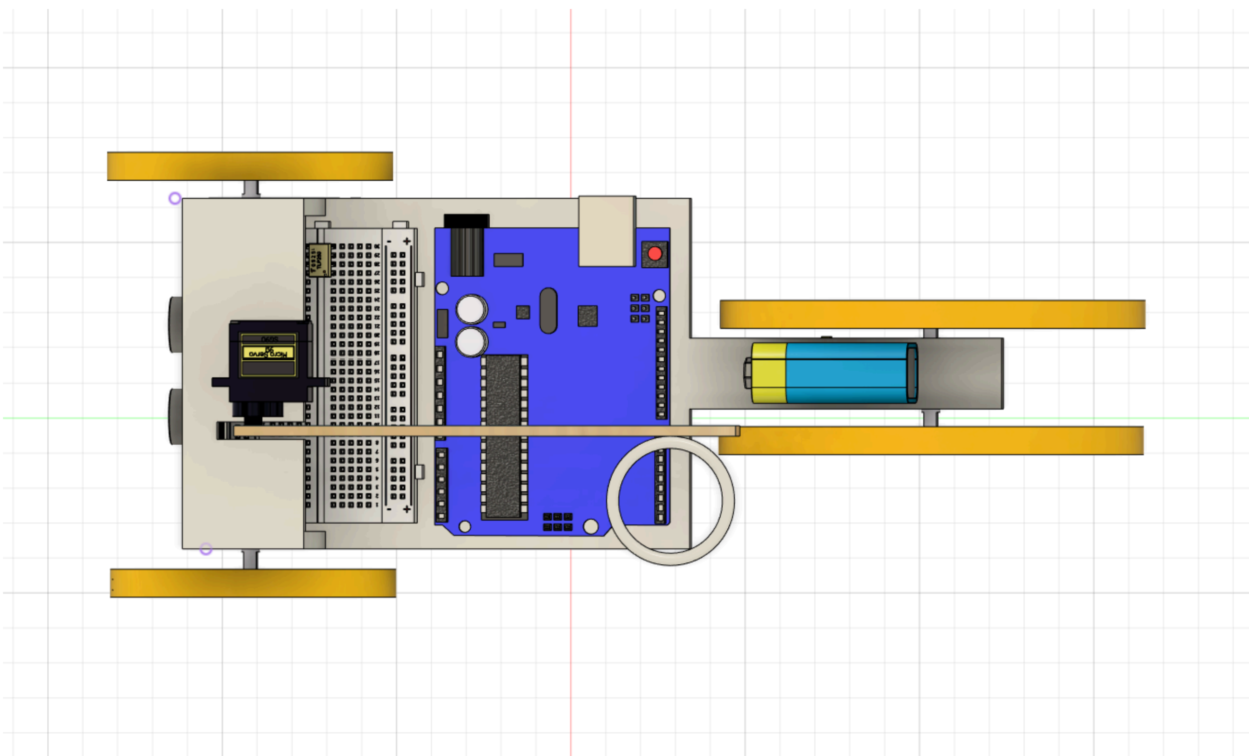


Front View

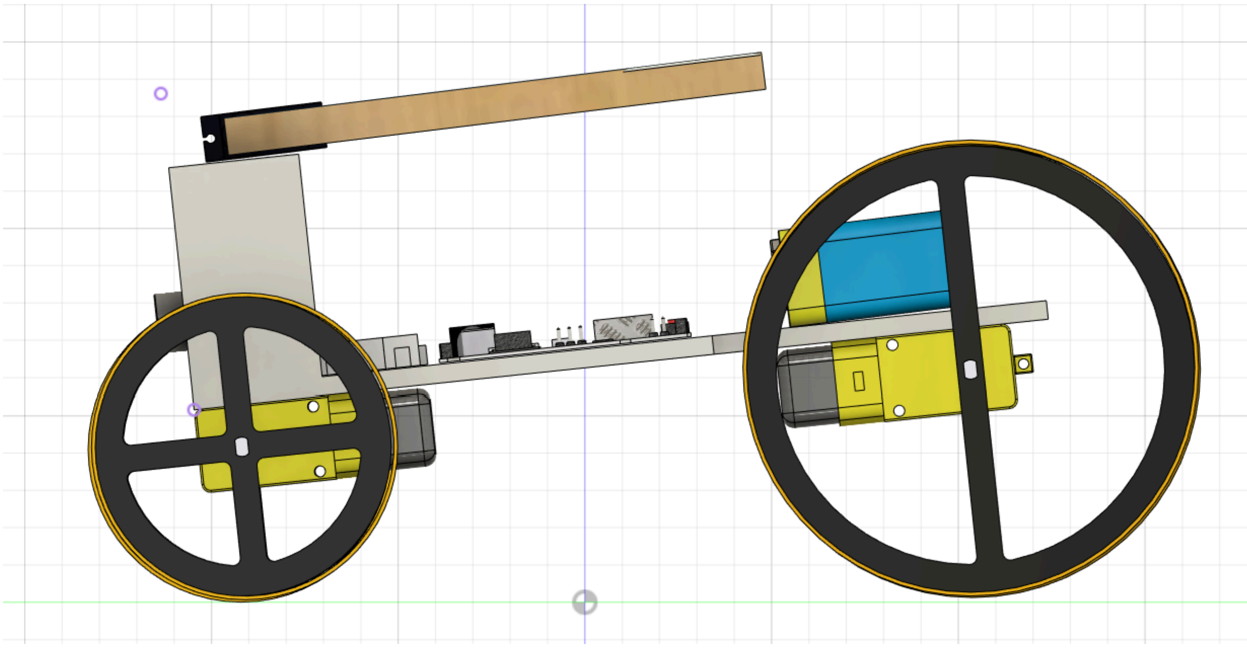
4.2 Cad Rendering Of Final Robot Design



Overall View

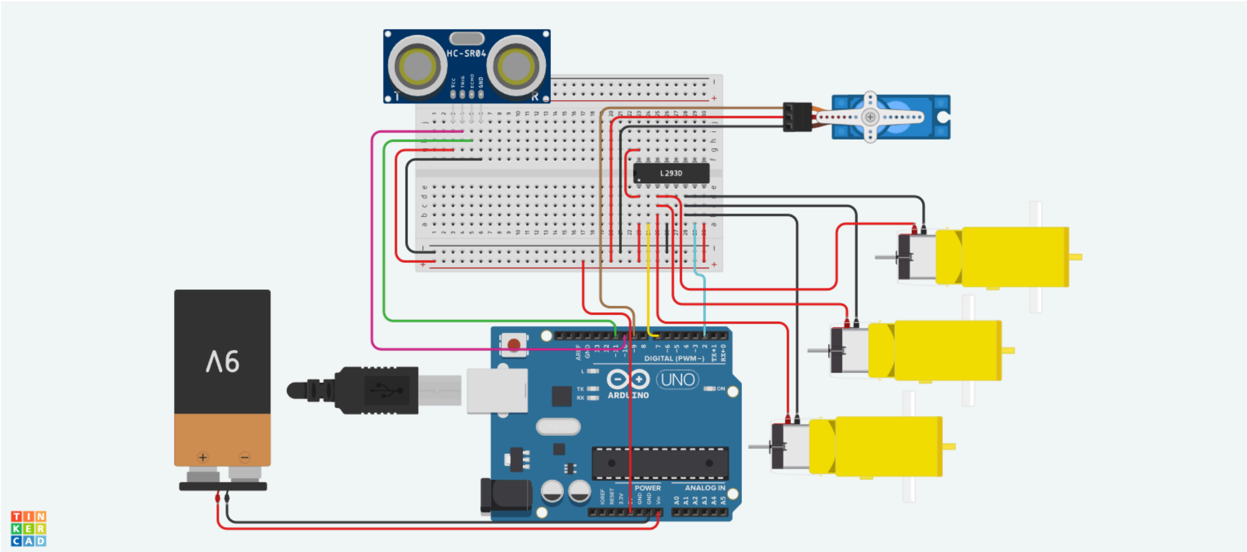


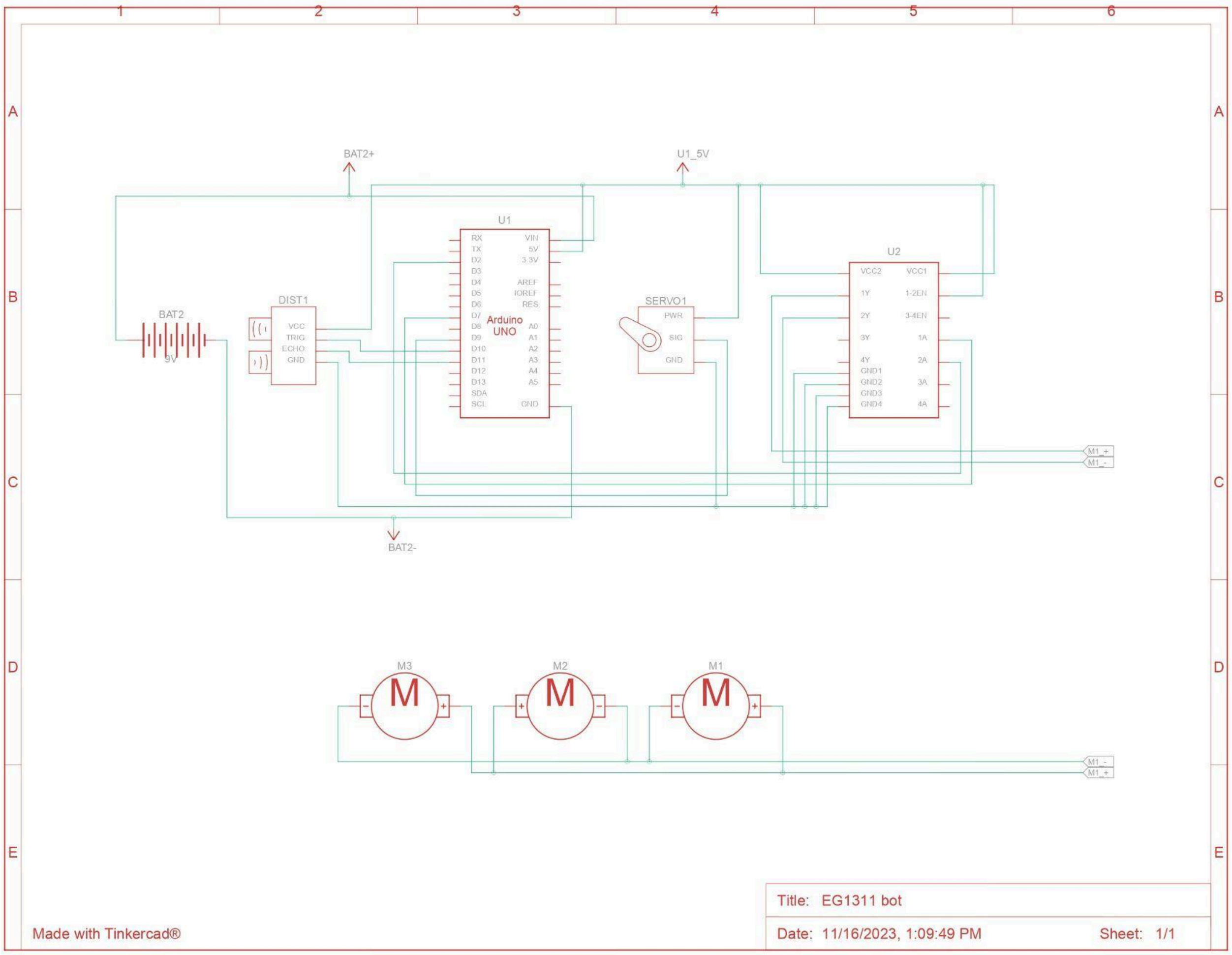
Top View



Side View

4.3 Tinkercad Diagram



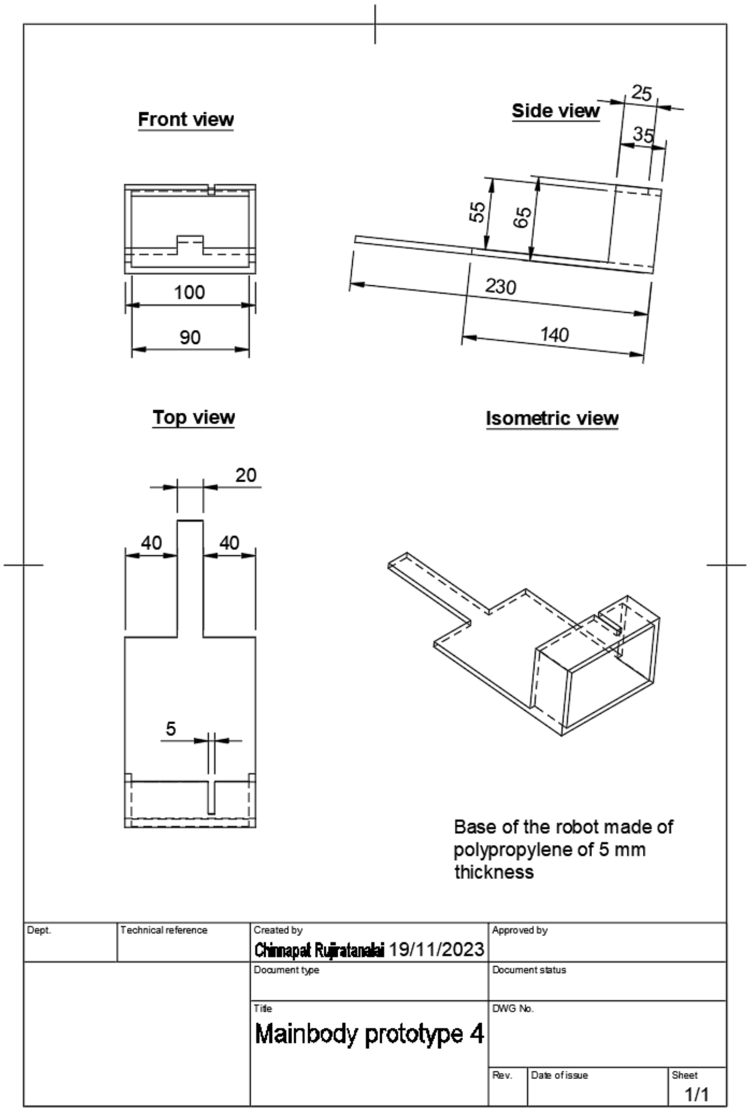


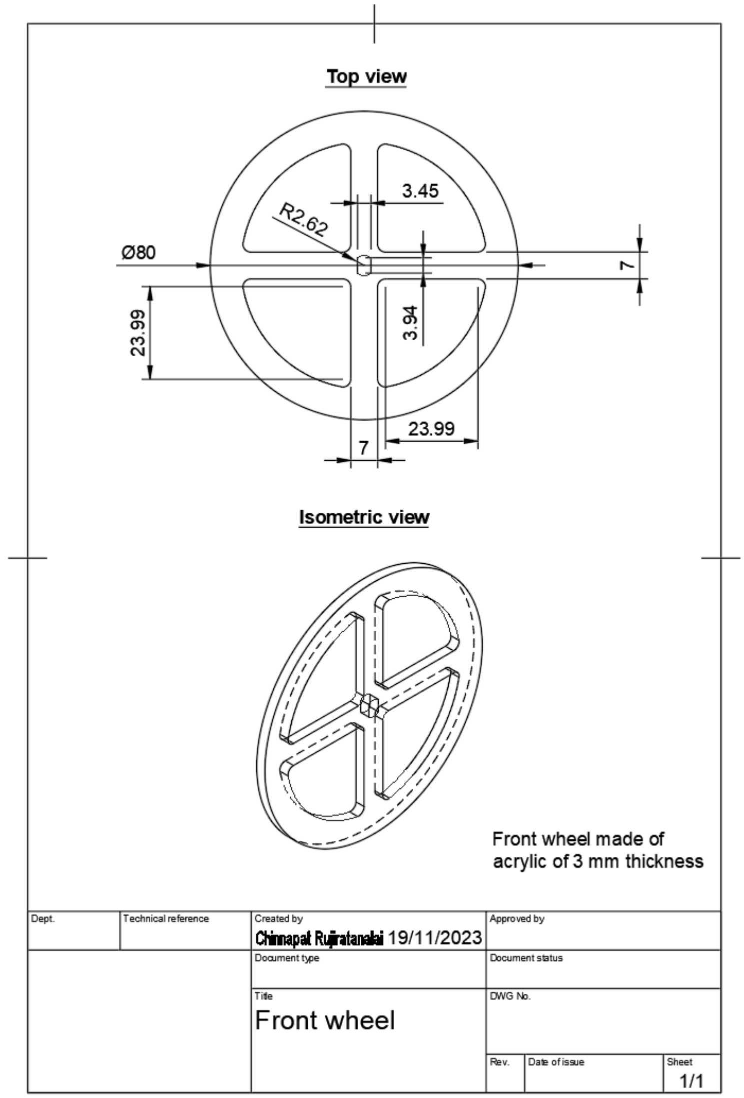
4.4 Arduino Source Code

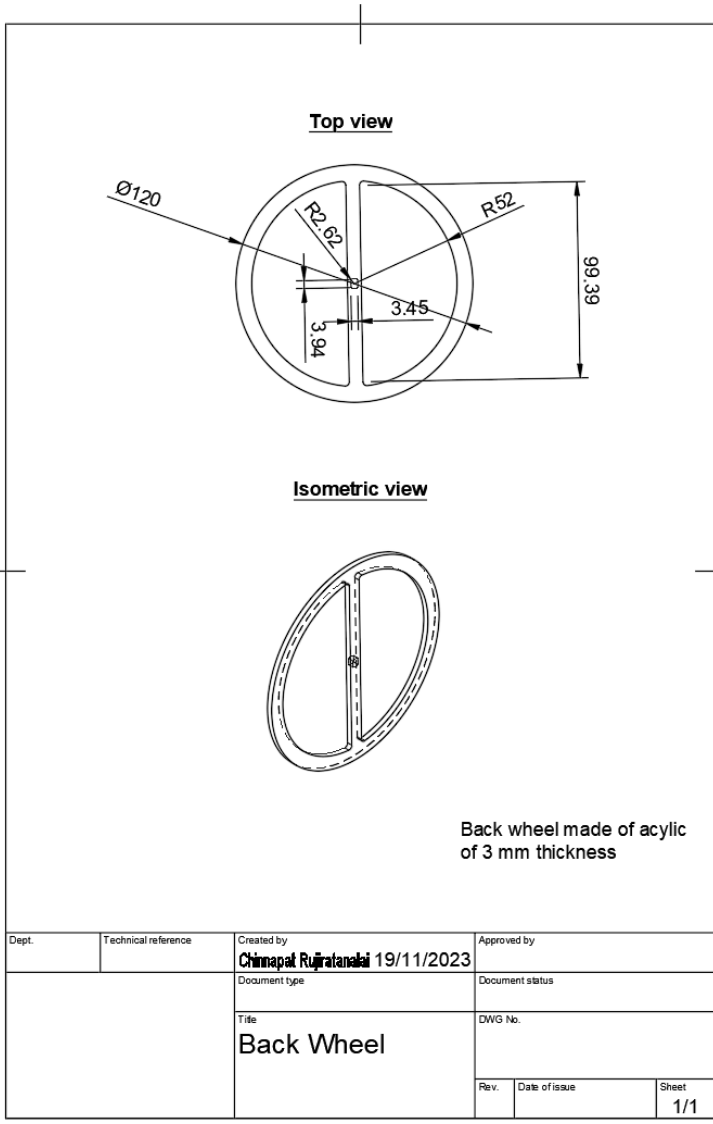
```
#include <Servo.h>


// Constants
int SERVO_PIN = 9;
int MOTOR_GROUND =7;
int MOTOR_HIGH = 2;
int ECHO_PIN = 11;
int TRIG_PIN = 10;
float SPEED_OF_SOUND = 0.0345;
Servo servo;


// Flag
bool reverse = false;


// Changable variable (adjust through testing)
int distance = 8;
int angle = 130;



void setup() {
  pinMode(MOTOR_GROUND, OUTPUT);
  pinMode(MOTOR_HIGH, OUTPUT);
  pinMode(TRIG_PIN, OUTPUT);
  digitalWrite(TRIG_PIN, LOW);
  pinMode(ECHO_PIN, INPUT);
  Serial.begin(9600);
  servo.attach(SERVO_PIN, 600, 2400);
  servo.write(0);
}


void loop() {
  // Check if the robot is going back or forward
  if(reverse){
    digitalWrite(MOTOR_HIGH, LOW);
    digitalWrite(MOTOR_GROUND, HIGH);
  } else {
    digitalWrite(MOTOR_HIGH, HIGH);
    digitalWrite(MOTOR_GROUND, LOW);
  }


  // Measure the distance
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);
  int microsecs = pulseIn(ECHO_PIN, HIGH);
  float cms = microsecs * SPEED_OF_SOUND / 2;
```

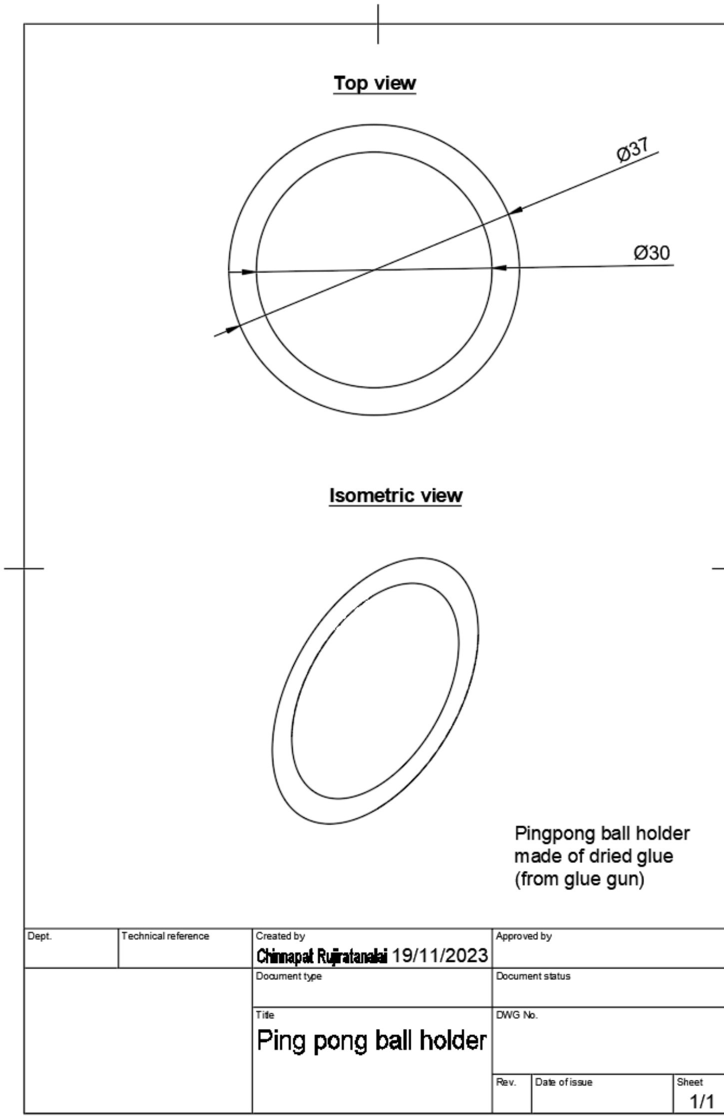
```
  // Print out distance (delete in final product)
  Serial.println(cms);


  /**
  Operation when the robot reach the wall.
  The flag "reverse" so that this only triggered once, and
  to indicate that the robot start going backward
  */
  if(cms < distance && !reverse){
    reverse = true;


    // Stop before the wall
    digitalWrite(MOTOR_HIGH, LOW);
    digitalWrite(MOTOR_GROUND, LOW);


    // Throwing the ball
    servo.write(0);
    delay(200);
    servo.write(angle);
    delay(1000);
    servo.write(0);
  }
}
```

4.5 2D CAD Drawing For Each Structural Component



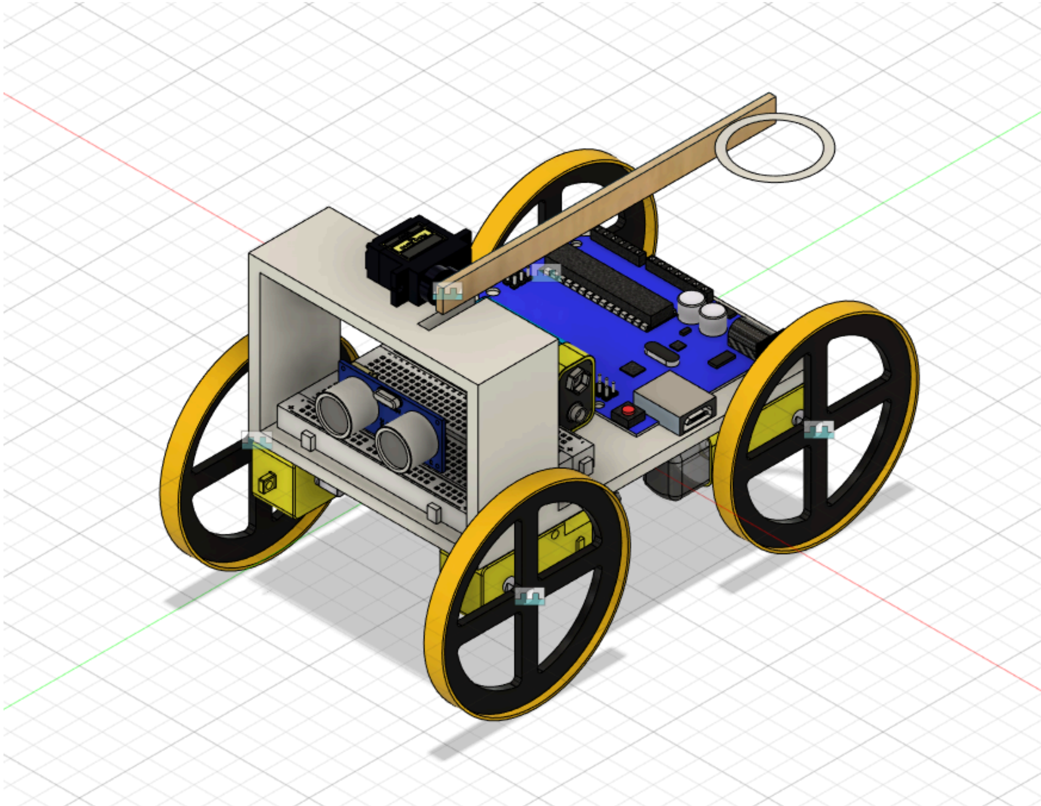



Top view
Ø120
R2.62
R52
99.39
3.45
3.94
Isometric view
Back wheel made of acylic
of 3 mm thickness
Dept.
Technical reference
Created by
Chinnapat Rujiratanalai 19/11/2023
Approved by
Document type
Document status
Title
Back Wheel
DWG No.
Rev.
Date of issue
Sheet
1/1

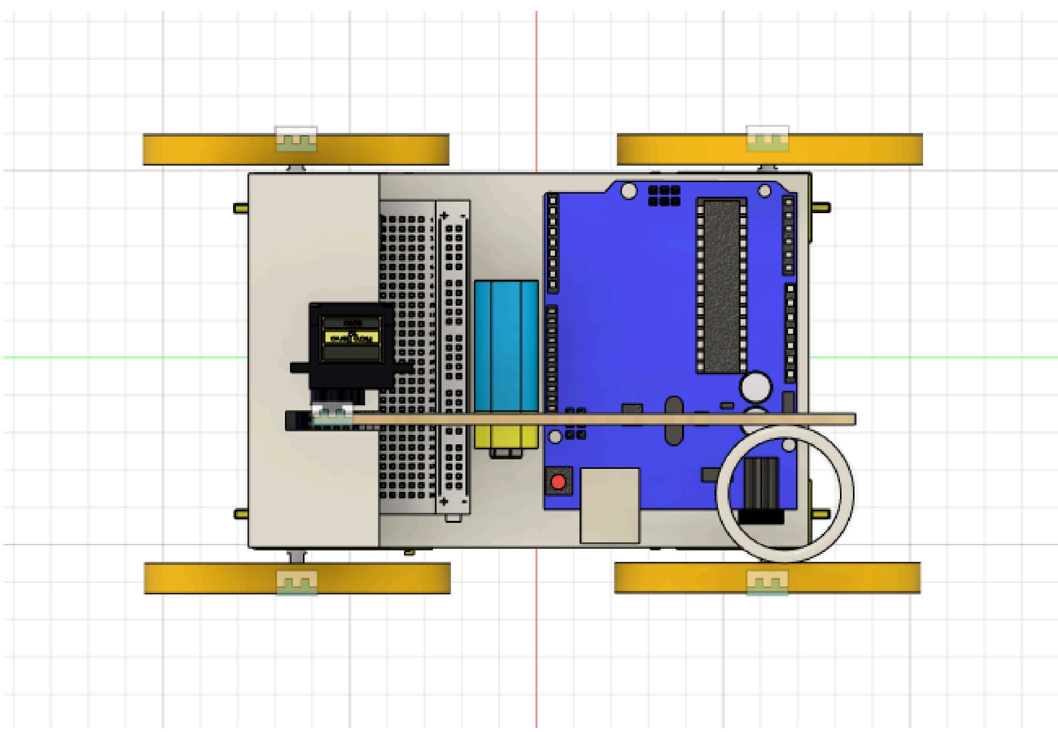

Top view
Ø37
Ø30
Isometric view
Pingpong ball holder
made of dried glue
(from glue gun)
Dept.
Technical reference
Created by
Chinnapat Rujiratanalai 19/11/2023
Approved by
Document type
Document status
Title
Ping pong ball holder
DWG No.
Rev.
Date of issue
Sheet
1/1

4.6 Cad Rendering Of Design 1 - 3

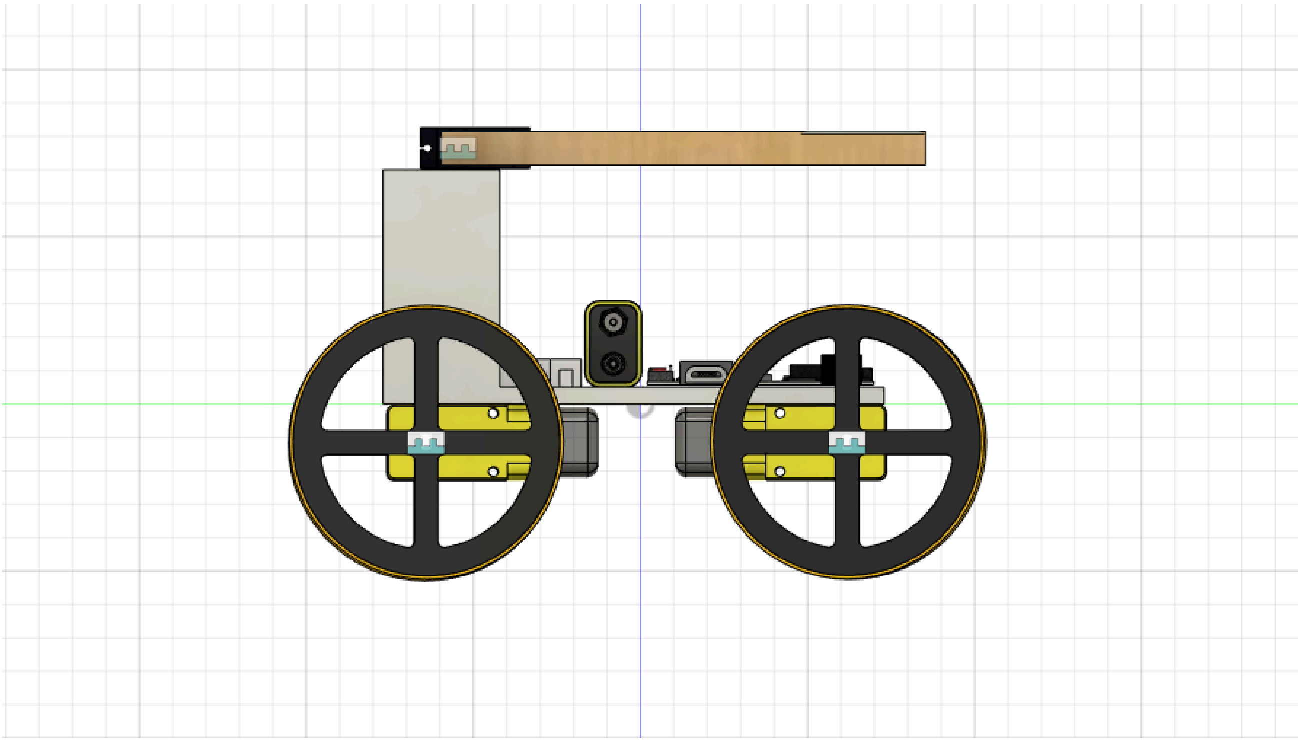
4.6.1 Prototype 1



Prototype 1: Overall View

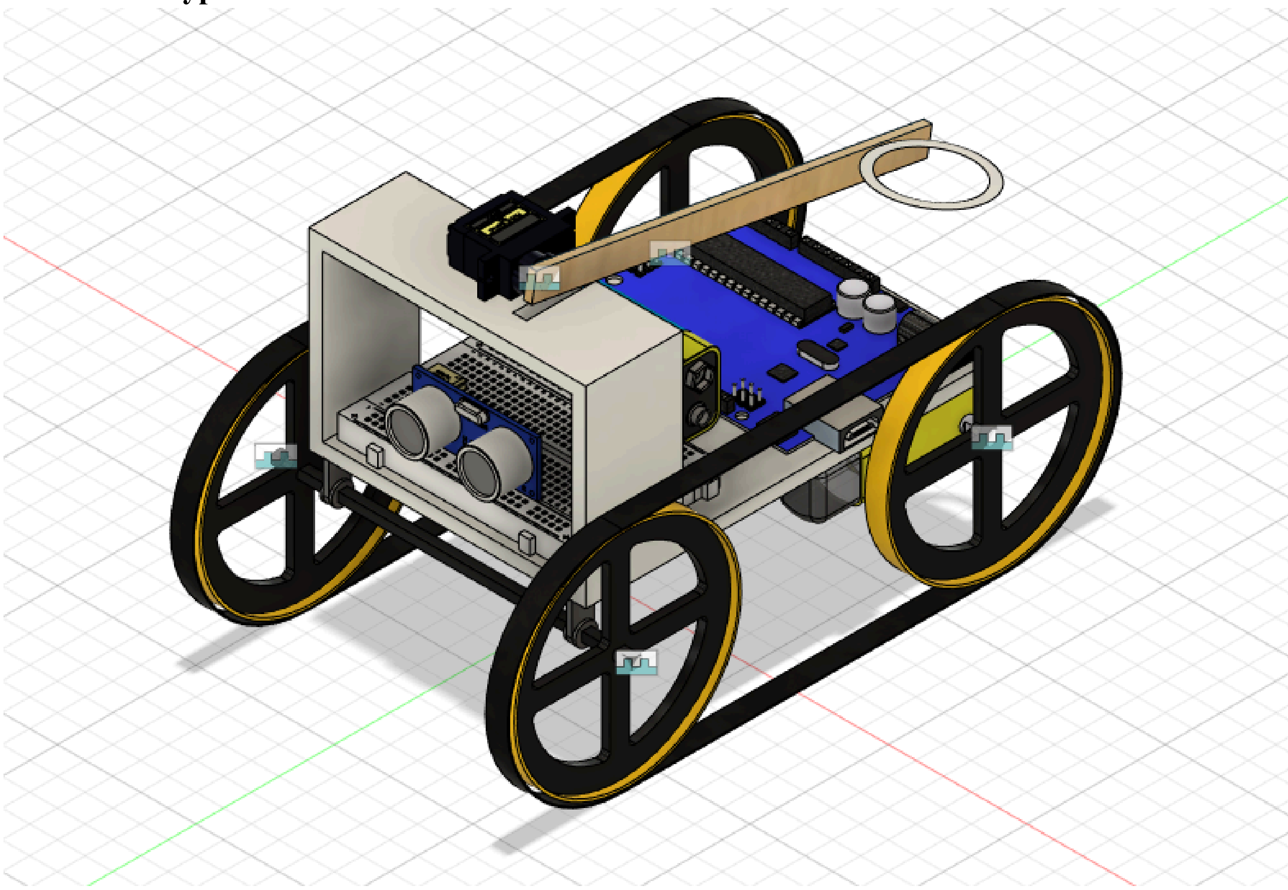


Prototype 1: Top View

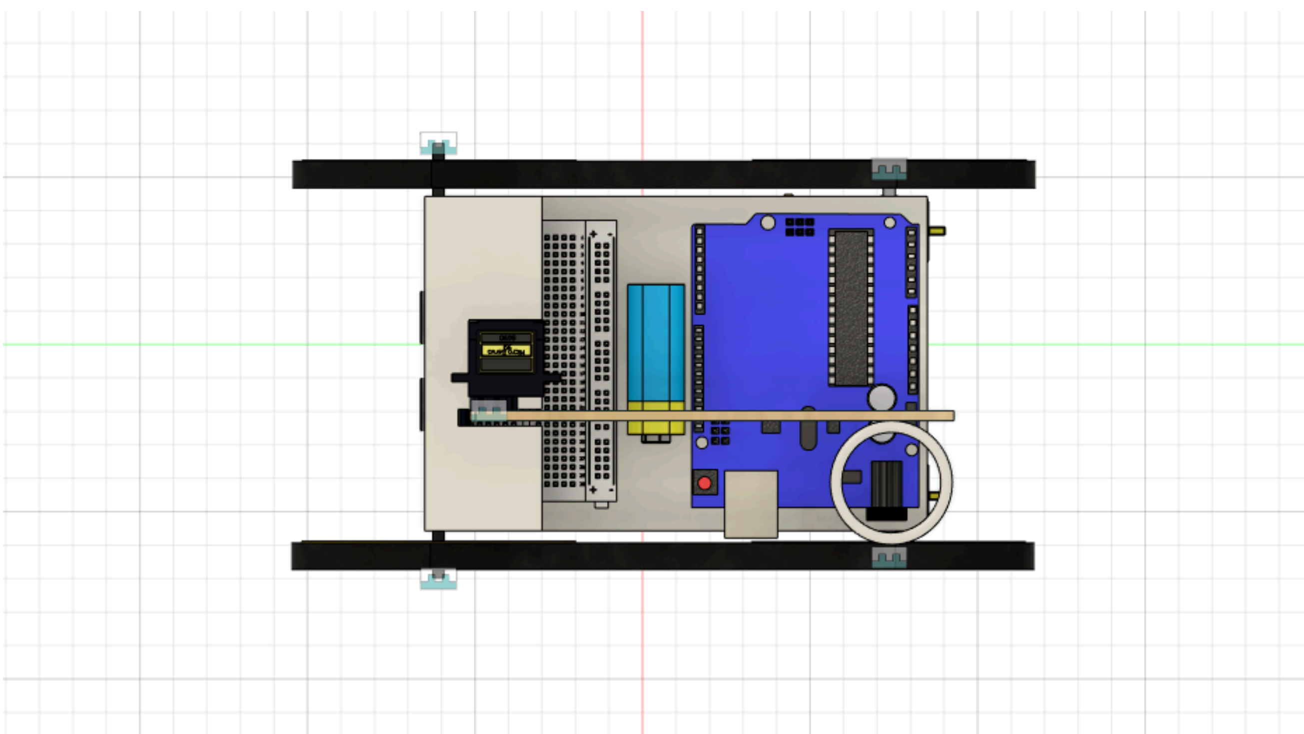


Prototype 1: Side View

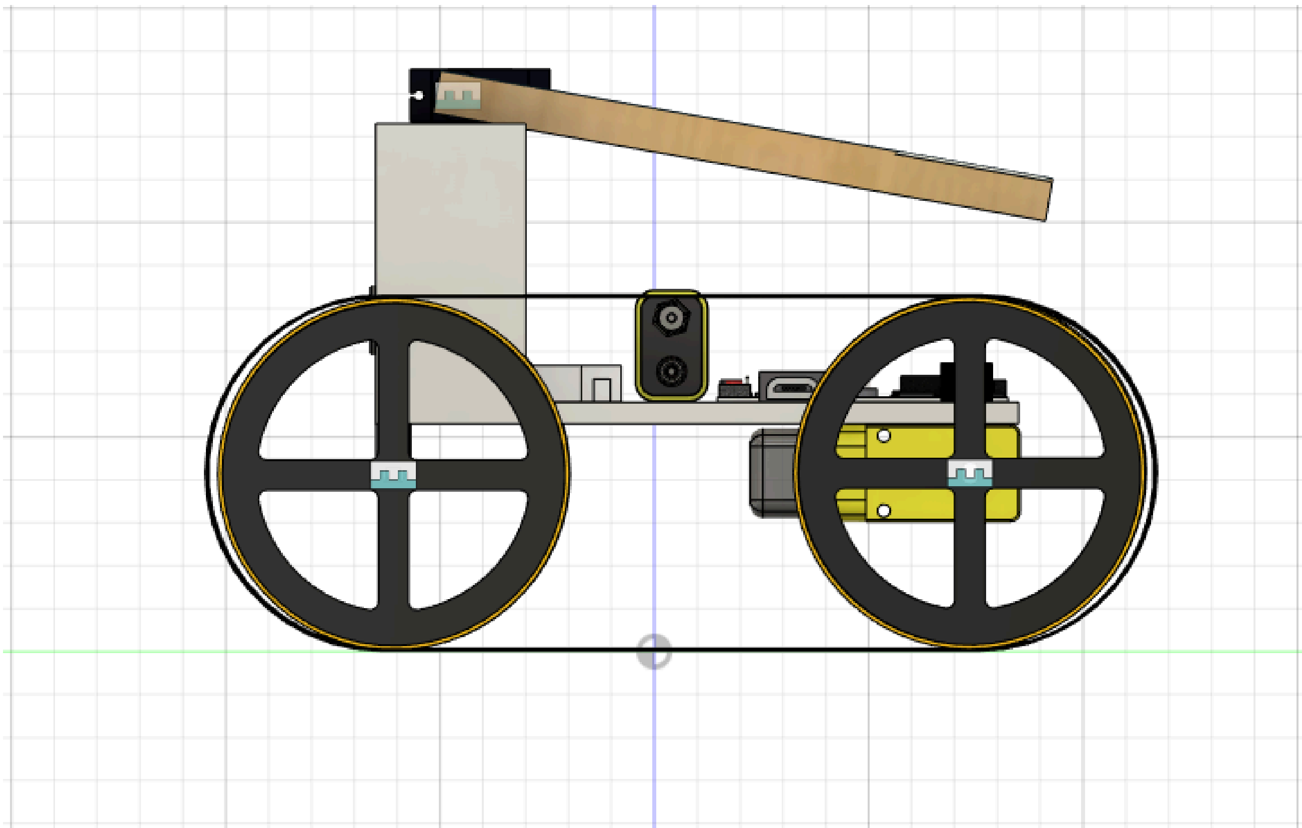
4.6.2 Prototype 2



Prototype 2: Overall View

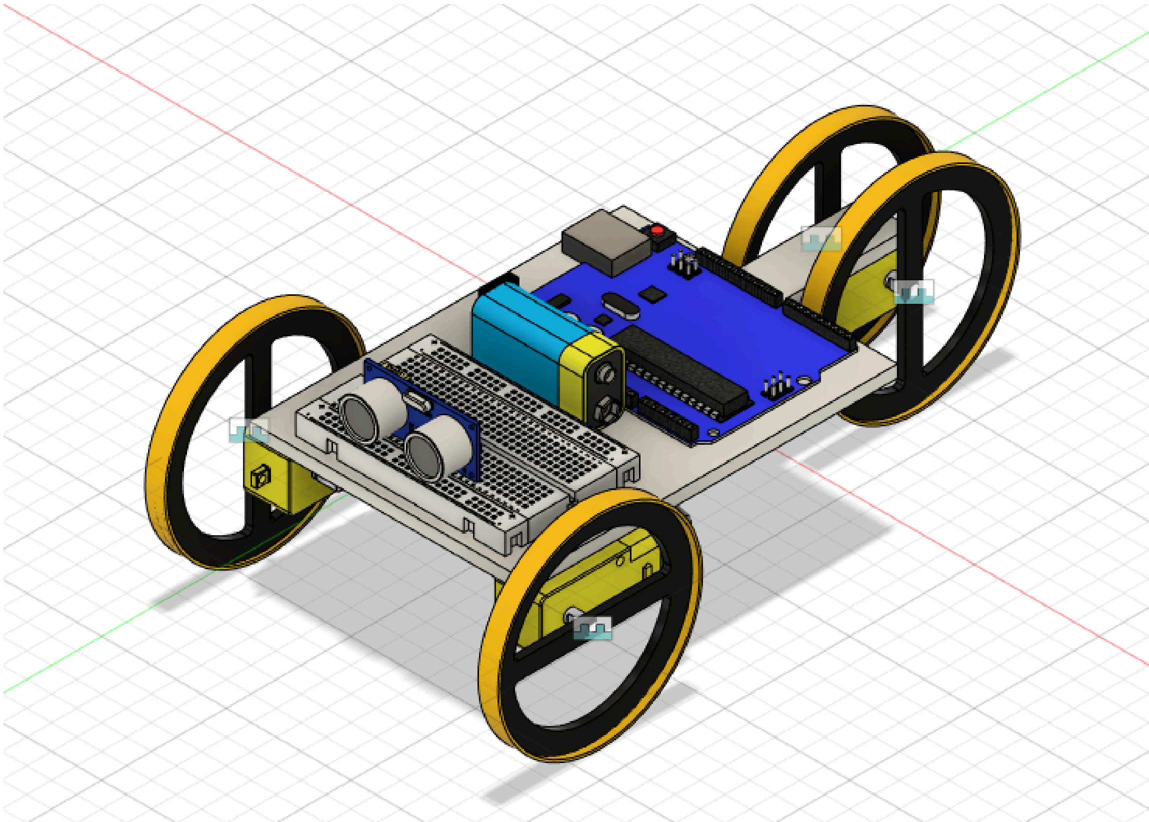


Prototype 2: Top View

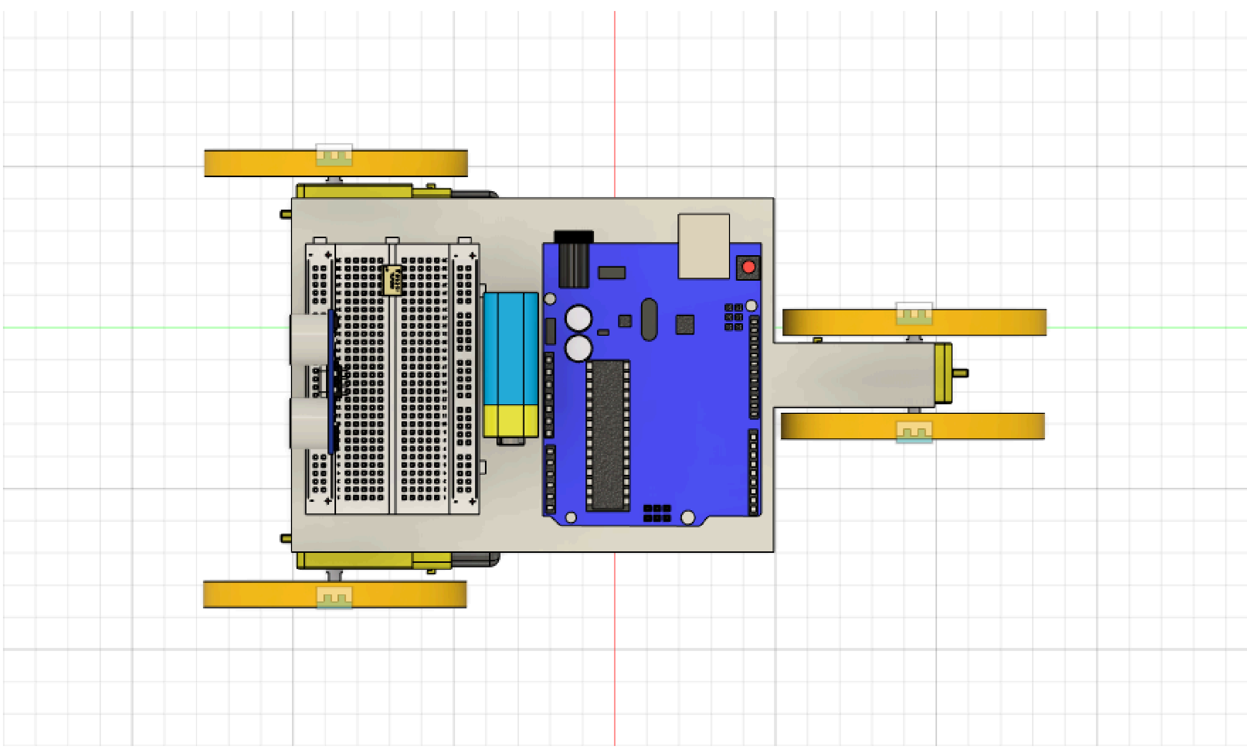


Prototype 2: Side View

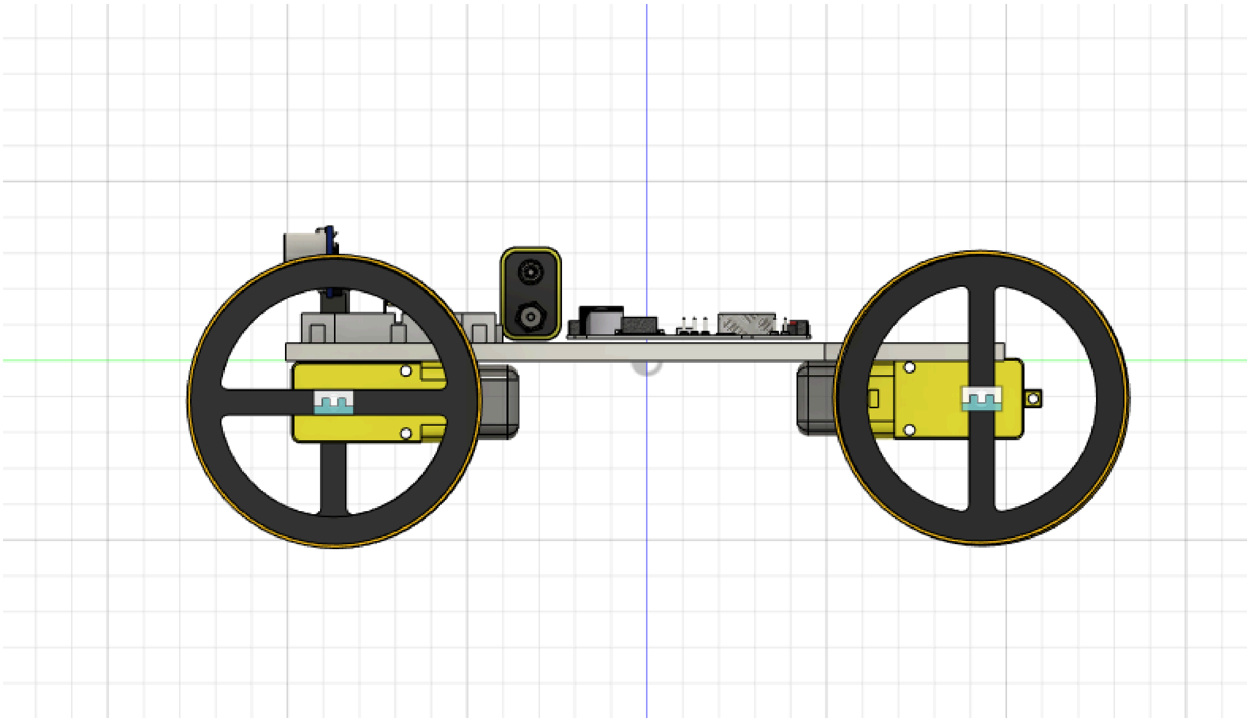
4.2.3 Prototype 3



Prototype 3: Overall View



Prototype 3: Top View



Prototype 3: Side View