FINAL PROJECT: AGOJIE ROBOT ASHESI UNIVERSITY

INSTRUCTORS: HEATHER BEAM, NICHOLAS TALI

TEAM 4 | 5/24/23 | INTRODUCTION TO ENGINEERING

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ACKNOWLEDGEMENTS

As Team_4 from cohort B, we are truly grateful to our instructors Doctor Heather Beam and Nicholas Tali for taking us through the course, being approachable and assisting us whenever we needed assistance. We are also grateful for the maximum guidance we received as we did our project. To our lovely FIs, Michael Boateng and David Asare, we have nothing else except for gratitude for sparing your weekends and stretching your limits to give us unwavering support. To Peter and Nana K, the workshop tasks would have been impossible without you. To everyone else who contributed to the success of this project, we extend our heartfelt vote of thanks and may the Lord continue to bless you.

To God Almighty, we give you praise for making this possible.

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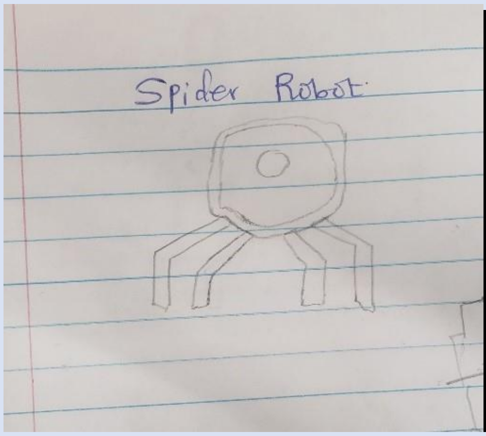
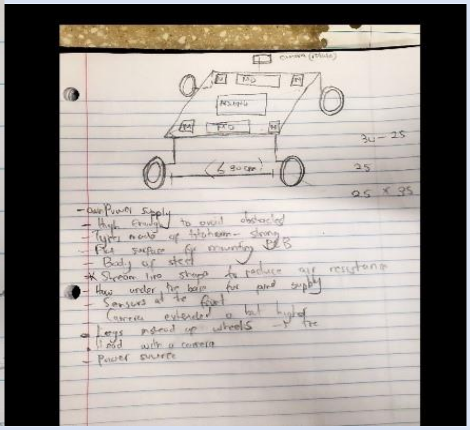
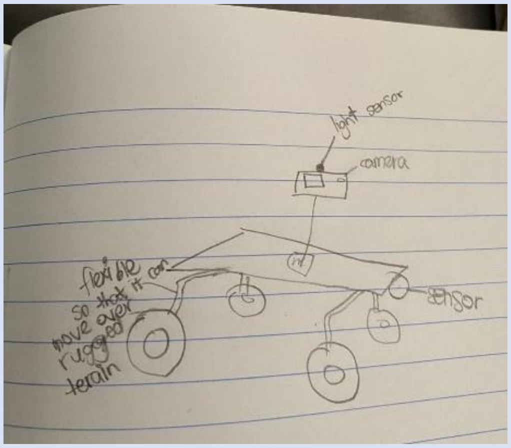
1.1 DESIGN

During our first meeting, each group member drew or scribbled their ideas on paper. Then, based on the general structure of the robot, we classified each proposal. We came up with three categories: spider robot, elevated platform robot, and attached platform robot. We then devised a fourth category concept, the multi-layered robot. Following that, we employed a Pugh-chart for the structural shapes we produced based on criteria, and we decided on the multi-layered robot with an elevated platform based on the Pugh-chart outcome. Attached are a few sketches that we came up with. All sketches were not attached since some had a similar idea.







Mechanical Sub-system evaluation

Criteria	Datum	Option 1	Option 2	Option 3	Option 4
	Perseverance Robot	Spider Robot	Raised platform robot	Attached platform robot	Multi-layered robot
Ability to move over rugged terrain.	0	+1	+1	-1	+1
Take pictures of surface features.	0	0	0	0	0
Ability to avoid obstacles	0	+1	0	-1	0
Speed of the robot.	0	-1	+1	0	+1
The shape of the robot to reduce the effects of air resistance.	0	0	0	+1	-1
Ability to hold all the components.	0	-1	0	0	+1
Total	0	0	+2	-1	+2

According to our Pugh chart evaluation, the raised platform robot and multi-layered robot ideas both have a score of +2. As a result, we decided to combine both by creating a multi-layered robot with the first layer raised above the ground.

Electrical Sub-System Evaluation

Micro-controller

Criteria	Datum	Option 1	Option 2	Option 3
	ATMEGA328P	MSP430x12x	AT89C51AC3	8051 Microcontroller
Ability to accommodate for all components	0	0	+1	+1
Ability to fit on printed circuit board with other components	0	0	-1	-1
Ability to store enough information	0	-1	+1	-1
Power supply required	0	+1	+1	0
Ease of programming	0	-1	-1	-1
Total	0	-1	+1	-2

Although the AT89C51AC3 has a higher score than the others in our Pugh-chart analysis of the micro-controllers, we ultimately chose to use the ATMEGA328P micro-controller because it was the one that was provided for the robot.

Distance sensors

Criteria	Datum	Option 1	Option 2	Option 3
	Ultrasonic	Laser distance sensor	IR Sensor	Time of Flight (ToF)
Should operate at a high level of accuracy	0	0	+1	+1
Should be able to detect obstacles with complex shapes	0	+1	-1	-1
Should be able to process data fast	0	0	+1	-1
Ability to function at very low temperatures	0	0	-1	0
Suitability for long range sensing	0	0	+1	+1
Total	0	+1	+1	0

Both the Laser distance sensor and the IR sensor received a +1 from the Pugh-chart evaluation, but for the work we want the robot to do, we chose the ultrasonic sensor because it was also given for us and is easily accessible.

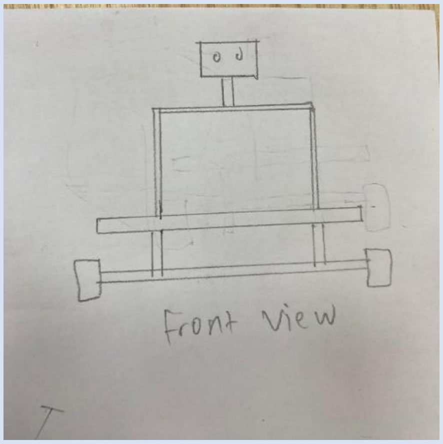
Bluetooth Module

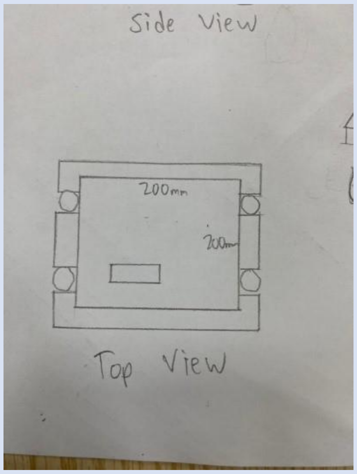
Criteria	Datum	Option 1	Option 2	Option 3	Option 4
	HC-05	Blue SMiRF	BLE Mini	HC-06	BLE link Bee
Ability to communicate with other Bluetooth devices	0	0	-1	-1	+1
Ability to transmit data between devices quickly	0	0	0	0	-1
Ability to detect weak signals	0	0	+1	0	+1
The amount of power that the module uses to transmit its signals to other Bluetooth devices.	0	0	-1	0	-1
Maximum distance over which it can communicate with other Bluetooth devices.	0	-1	+1	-1	0
Total	0	-1	0	-2	0

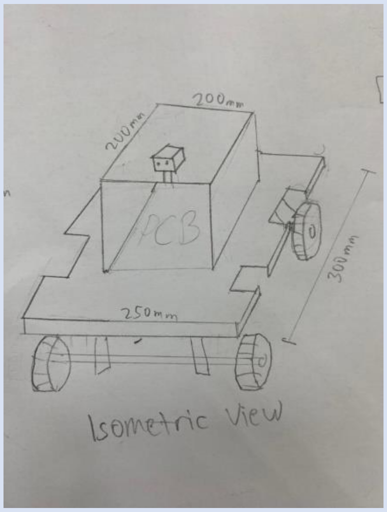
According to the Pugh Chart Evaluation of Bluetooth Modules, both the BLE Mini and the BLE Link Bee have an overall score of 0. We were able to create a list of criteria for each of their functionalities and capacities using the datasheets for each of them. Both the BLE Mini and the BLE Link Bee perform similarly to the given model HC-05, but better than the other two variants Blue SMiRF and HC-06. Hence, we opt for the HC-05 Bluetooth model.

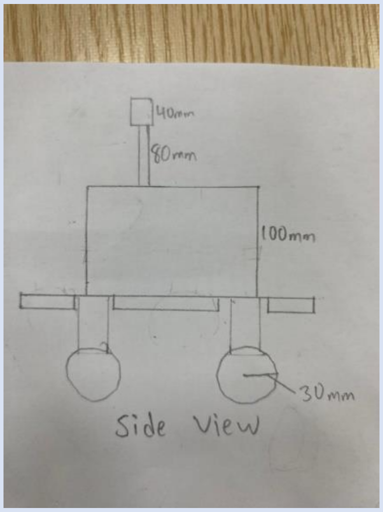
1.2 PROTOTYPE: LOW-FIDELITY PROTOTYPE

SKETCH OF FINAL IDEA WITH VARIOUS VIEWS

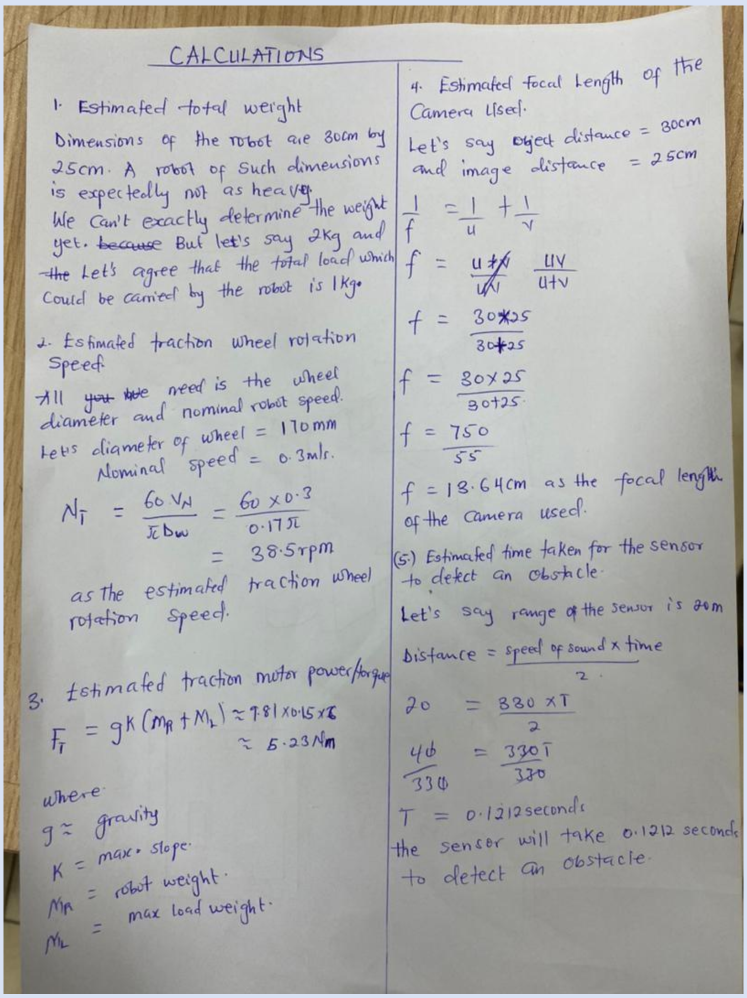








CALCULATIONS OF HOW AGOJIE ROBOT WILL WORK/OPERATE



CALCULATIONS

1. Estimated total weight

Dimensions of the robot are 30cm by 25cm. A robot of such dimensions is expectedly not as heavy. We can't exactly determine the weight yet. ~~because~~ But let's say 2kg and ~~the~~ Let's agree that the total load which could be carried by the robot is 1kg.

2. Estimated traction wheel rotation speed

All ~~you~~ ~~we~~ need is the wheel diameter and nominal robot speed.

Let's diameter of wheel = 170mm

Nominal speed = 0.3m/s.

$$N_T = \frac{60 V_N}{\pi D_w} = \frac{60 \times 0.3}{0.17\pi} = 38.5\,\text{rpm}$$

as the estimated traction wheel rotation speed.

3. Estimated traction motor power/torque

$$F_T = gK(M_R + M_L) \approx 9.81 \times 0.15 \times 6 \approx 5.23\,\text{Nm}$$

where

$g \approx$ gravity

K = max. slope

M_R = robot weight.

M_L = max load weight.

4. Estimated focal length of the camera used.

Let's say object distance = 30cm and image distance = 25cm

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$f = \cancel{\frac{u+v}{uv}} \quad \frac{uv}{u+v}$$

$$f = \frac{30 \cancel{+} 25}{30 \cancel{\times} 25}$$

$$f = \frac{30 \times 25}{30 + 25}$$

$$f = \frac{750}{55}$$

$f = 13.64$cm as the focal length of the camera used.

(5.) Estimated time taken for the sensor to detect an obstacle.

Let's say range of the sensor is 20m

$$\text{Distance} = \frac{\text{speed of sound} \times \text{time}}{2}$$

$$20 = \frac{330 \times T}{2}$$

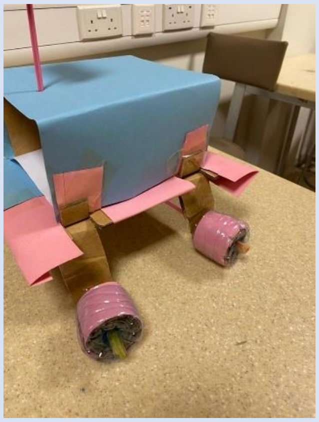
$$\frac{40}{330} = \frac{330T}{330}$$

$T = 0.1212$ seconds

the sensor will take 0.1212 seconds to detect an obstacle.

<u>Materials Use</u>

- Straws
- Sticks
- Cardboard
- Boxes
- Cellotape
- Plastic water bottles
- A4 Sheets

The above images showcase the prototype that we constructed using paper boxes, paper cardboards, straws, bottles, A4 sheets, pins, tape, wooden sticks, etc. The printed circuit board is 20cm x 20cm. It is the same size as the arch on the lower platform, and it will be roofed by the hood/arch. The camera will be attached to the hood/upper platform. The light bulbs will be attached to the little platforms in the middle of the structure. We did an initial sketch of our idea of the robot, but as we were building the prototype, we decided on some extra aesthetics, so we ended up cutting small rectangles from the full frame, and luckily, it ended up helping us to hold up our structure. Our initial idea was to hold the top platform up with straws, but we saw that, even while putting sticks into the straw, they were not stable enough. Therefore, we decided against it and went for a more closed structure. We planned on using straws to connect the bottle pieces to the frame of the robot for wheels, but we encountered some complications, and as a result, used cardboard below the frame, and used straws to connect one tire to another. With our current idea of the tires, they were not stable, so we decided to extend some of the straws. The major thing that we learned from the whole process is that it will not always go to plan, but iteration is good, and goes quite a long way in producing a much better design.

The top platform will be plexiglass, and it will be connected to the two vertical platforms using the jigsaw method. The vertical platforms will be connected to the base using jigsaw. The base will have holes for the wires of both the motor and the LED to be connected to the PCB. The sensors may have holes in the top platform for the ultrasonic sensors to be able to connect them to the PCB.

1.3 3D MODELS

Using our low fidelity prototype as a guide, we made a solid works model. When we were making our solid works, we took into consideration the specifications of our robots one of the specifications was the robot should be raised be raised to enable it rugged terrain. We also considered the dimensions of our solid works.

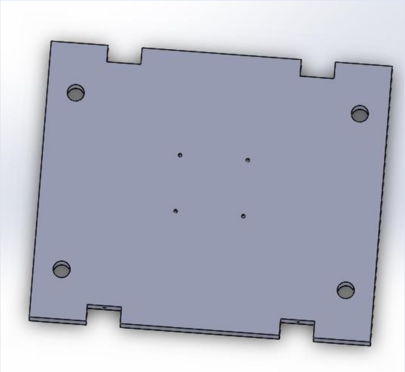
When developing the SolidWorks model, we paid close attention to the dimensions. We made sure to include provisions for mounting and attaching various components to the robot. This thoughtful approach ensured proper placement and alignment of the components, enhancing the robot's overall functionality and efficiency.

In terms of assembly, we thought through the best methods for attaching the parts together. Since the plexiglass material was not thick enough to use screws or nails, we came up with a clever solution. We created jigsaws that allowed for easy attachment of the parts, maintaining the robot's structural integrity while simplifying the assembly process.

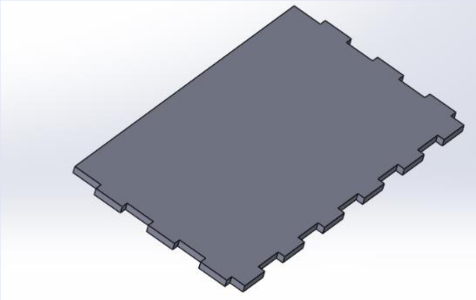
Throughout this project, we gained a deep understanding of designing advanced robots. By combining functionality with careful planning, we have created a remarkable SolidWorks model that demonstrates both elegance and efficiency.

Our commitment to excellence is evident in every aspect of this project. From considering intricate design details to implementing innovative assembly methods, we have produced sophisticated and resilient robots that have the potential to revolutionize the field of robotics.

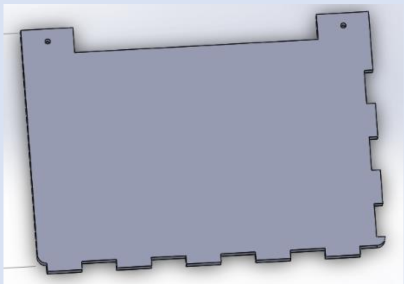
Individual Parts



Base of robot

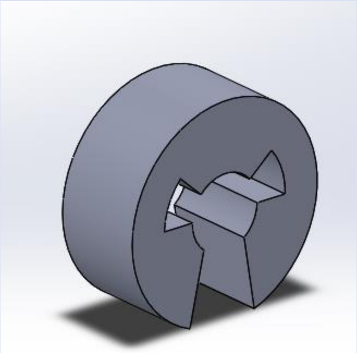


closure for base

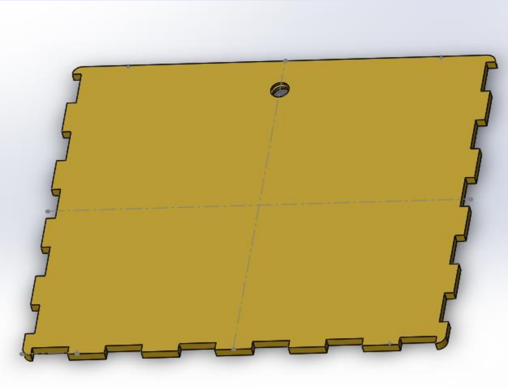


Side of the robot

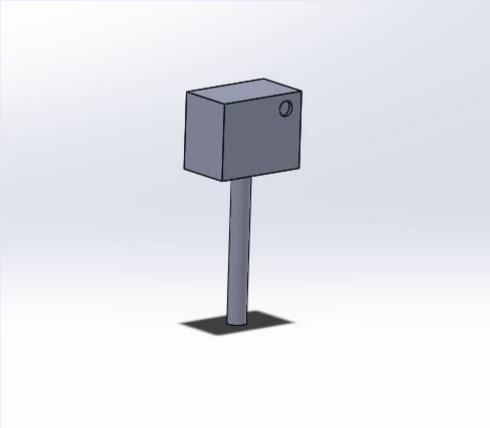
Tyre Connector



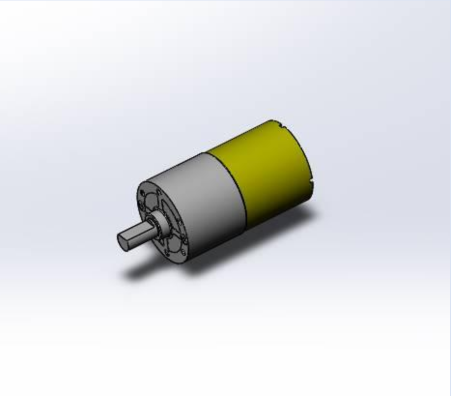
Circlip/ C-Clip



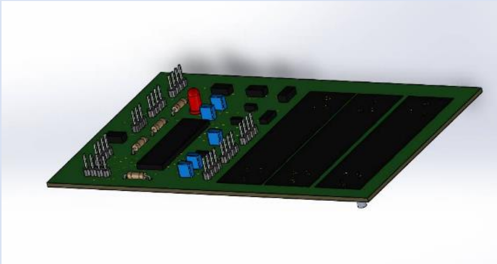
Top of Robot

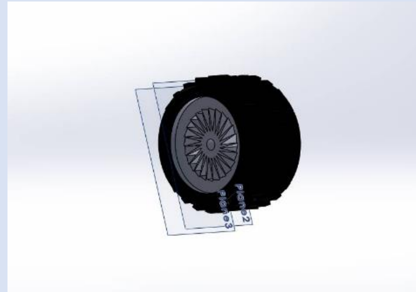


Camera Mount



Motor

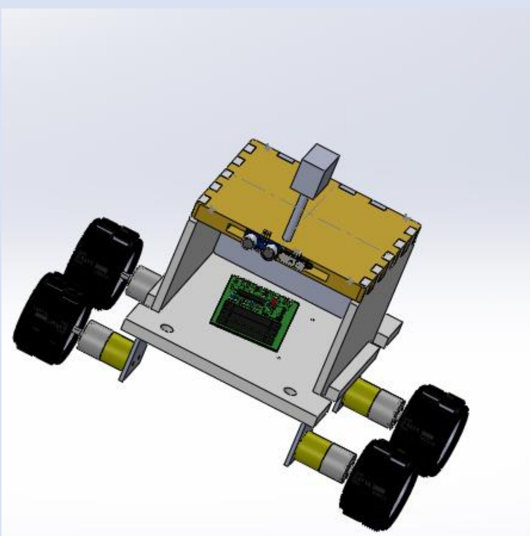




The PCB

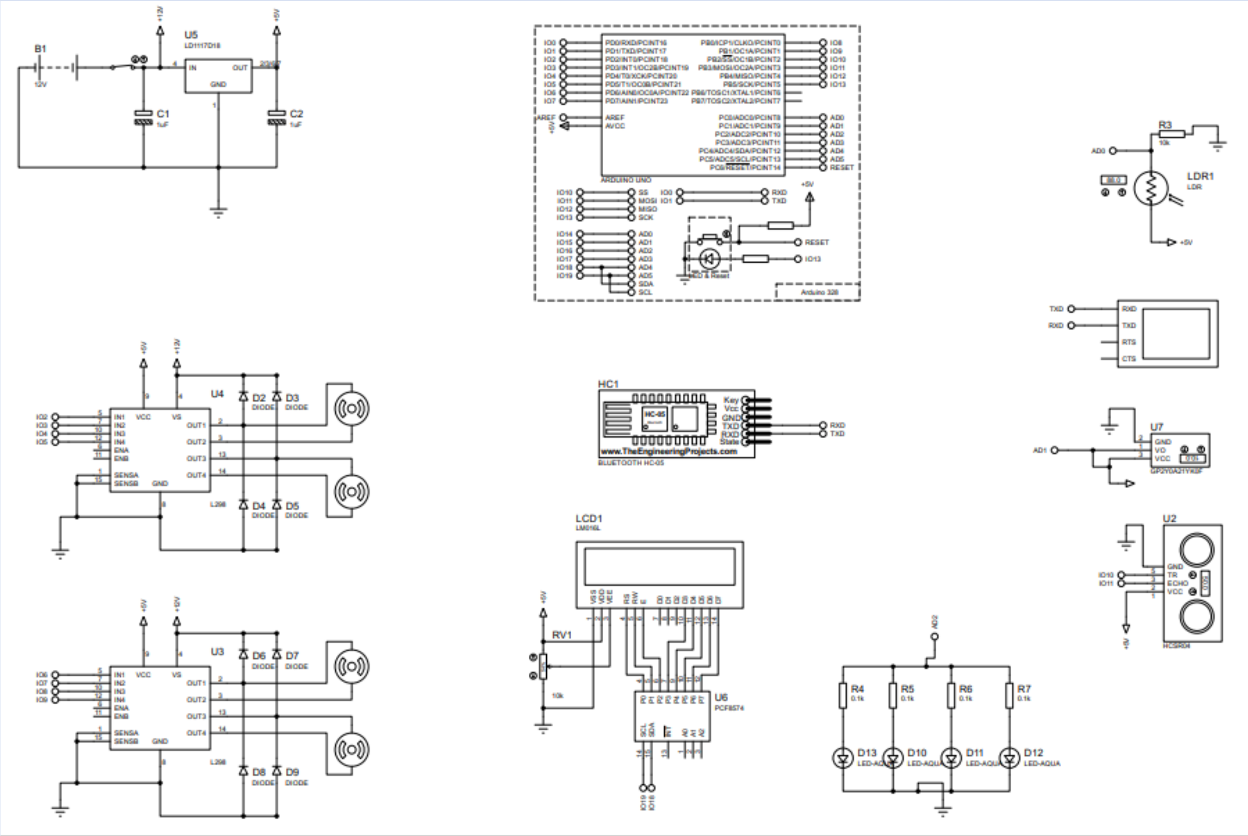
The Tyre

The Assembled Robot

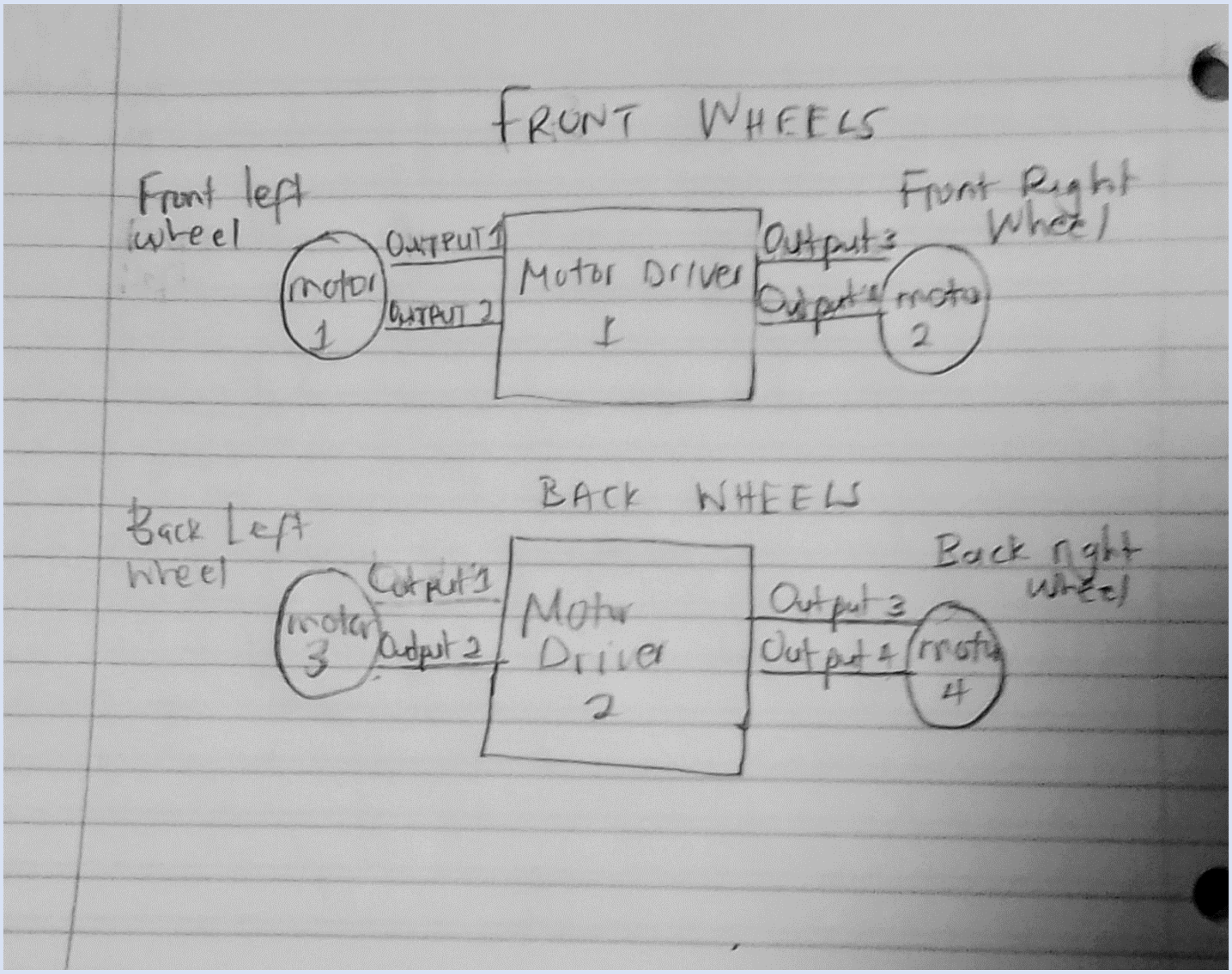


1.4 ELECTRONIC SIMULATIONS

In Proteus, we chose the A3 (15 by 10 inches) sheet size in order to fit in all our components. We designed the electronics of the entire robot in Proteus as shown in the layout below. For each component that we placed, for example, the Light Dependent Resistor (LDR), we would write the code for it in Arduino.



In order to determine which motor driver would drive each wheel, we made a sketch of the robot showing each wheel. We then assigned each pair of wheels on one motor driver as the front or the back wheels such that each motor driver will control the back wheels, and another will control the front wheels.



Sketch to aid drawing

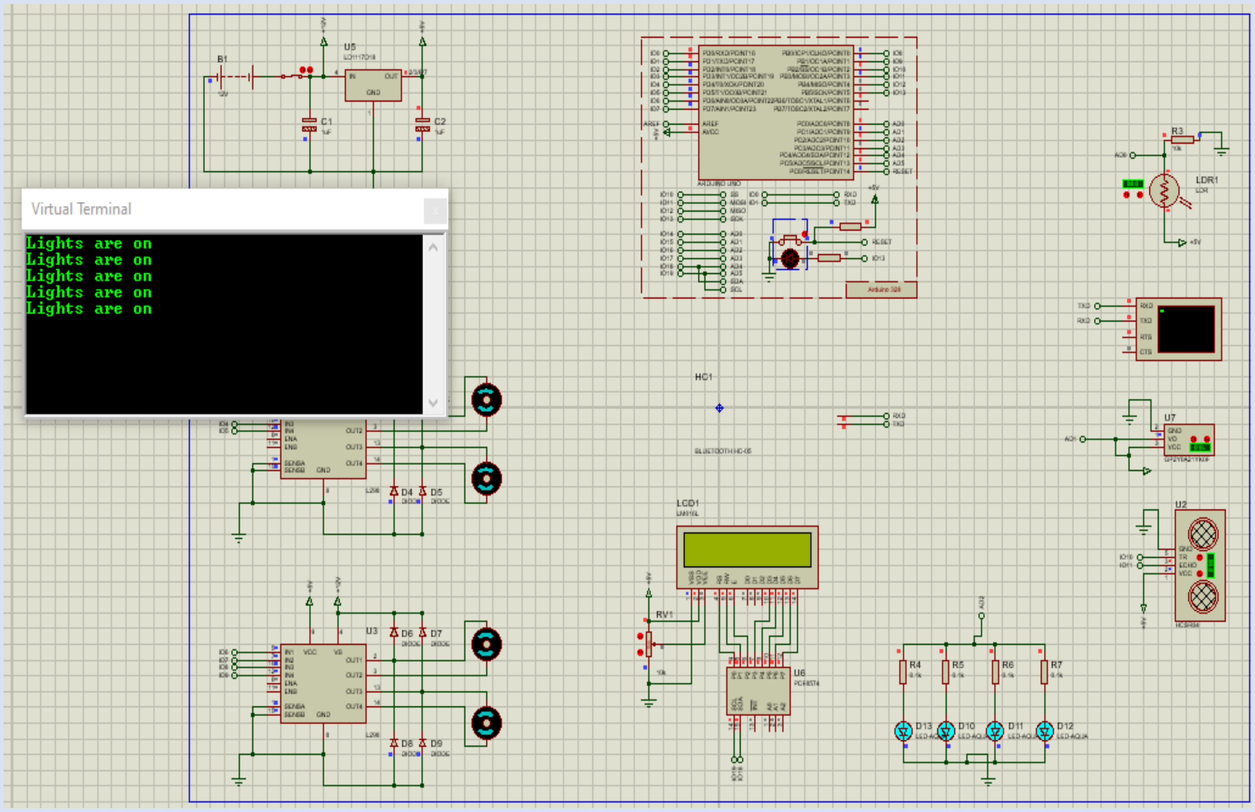
With this picture in mind, we wrote the code for the motors. We had to import a new library for the Bluetooth module since there was no in-built library for the Bluetooth module HC-05. We added LEDs to be the robot's lights and then connected them to one pin on the microcontroller as the pins were now limited. We wrote a code to make the lights switch on and off depending on the input from the LDR; when the LDR detects darkness, the lights will come on, and when the LDR detects light, the lights come on. This information will be printed on the serial monitor.

In our code, most of the movement of the robot was Bluetooth controlled. Characters like ‘F’ and ‘B’ for forward and backward movement would be received via Bluetooth. Once received, the motors’ forward or backward movement function would be called, and the robot would move in that direction.

However, we also included the ultrasonic sensor in such a way that if the character ‘Q’ is received via Bluetooth, the robot would automatically move, avoiding obstacles in the course. The ultrasonic sensor would calculate the distance between the robot and the object, and if the distance is less than 50cm, the function for the left and right movement would be called. The robot would turn left for one second, then right for two seconds to find direction with no obstacle. If the ultrasonic sensor finds no obstacle, the forward function would be called.

For the LCD, we used the module LM016L together with the LCD adapter module PCF8574 as we would use this in the actual making of the robot. The LCD would also display every direction the robot takes; for example, “moving left” indicates that the robot is turning left.

After laying out every component and simulating each individually, we had the layout as shown below. We combined the individual codes and then simulated the whole electronics of the robot.

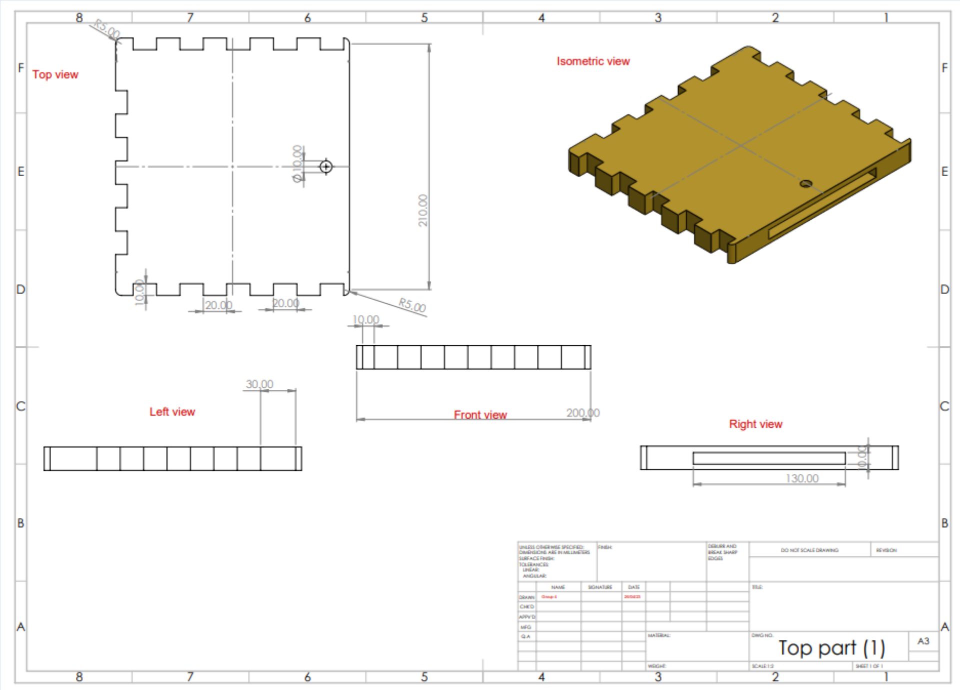


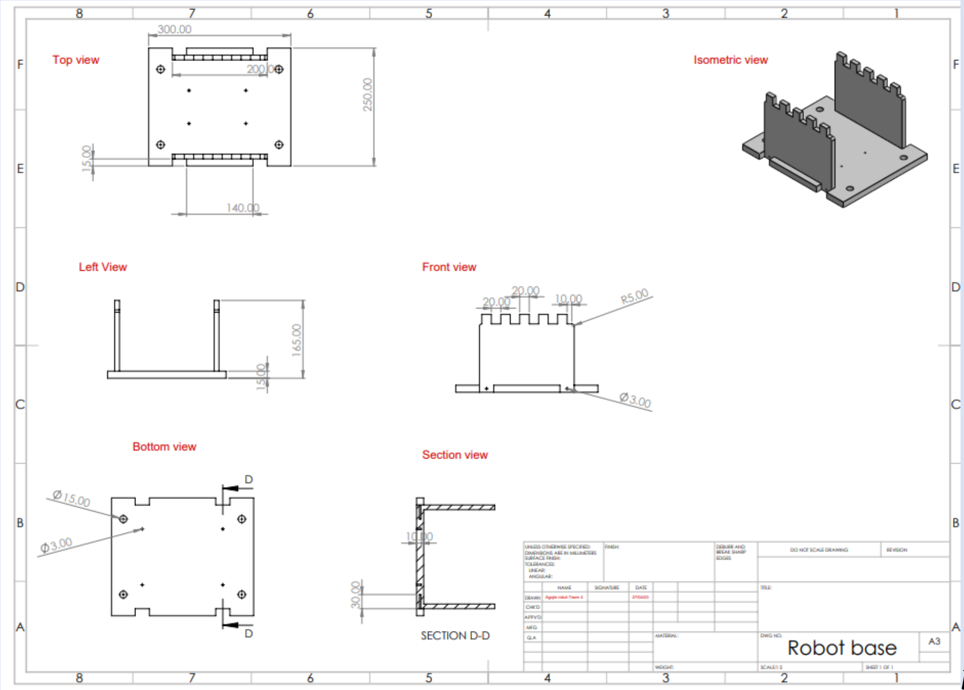
Proteus simulations

1.5 2D DRAWINGS

After creating our solidworks parts, we were required to provide 2D drawings of them including orthogonal views as well as isometric views. To do this we had to create drawing files for each of them and generate various views to show the parts from any direction.

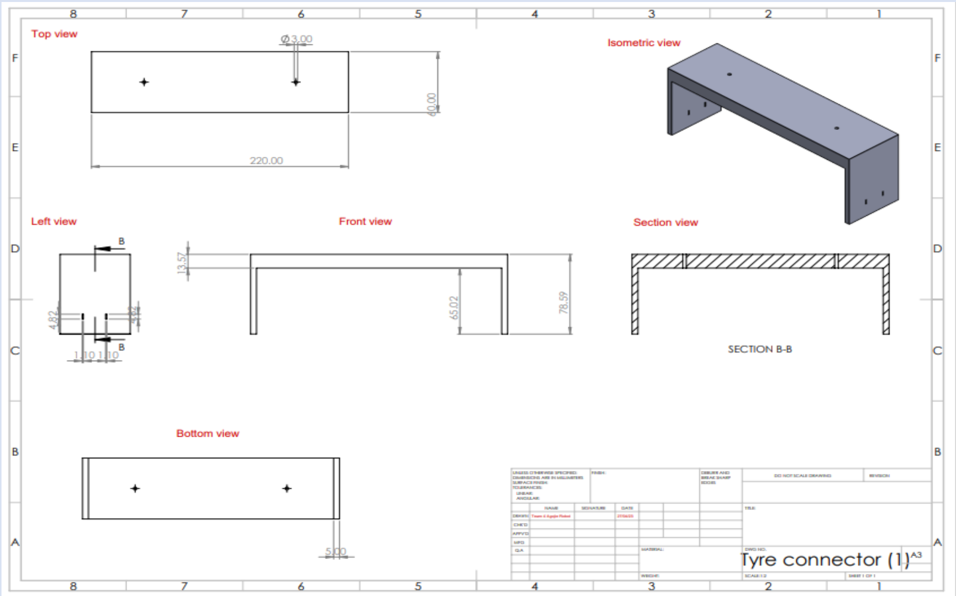
Top part of the Robot



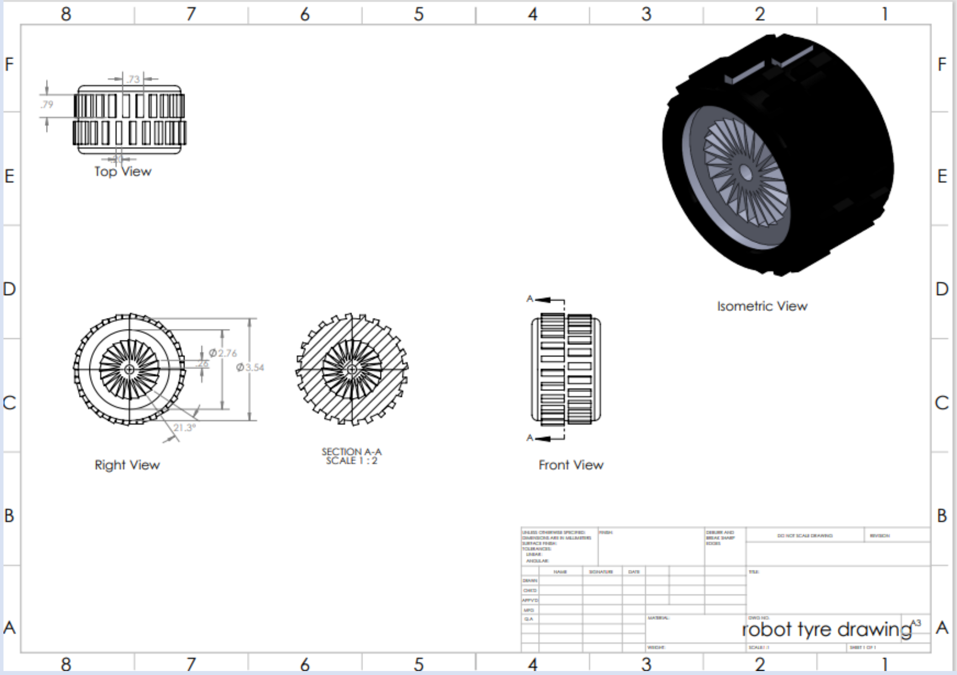


base of the robot

Robot connector

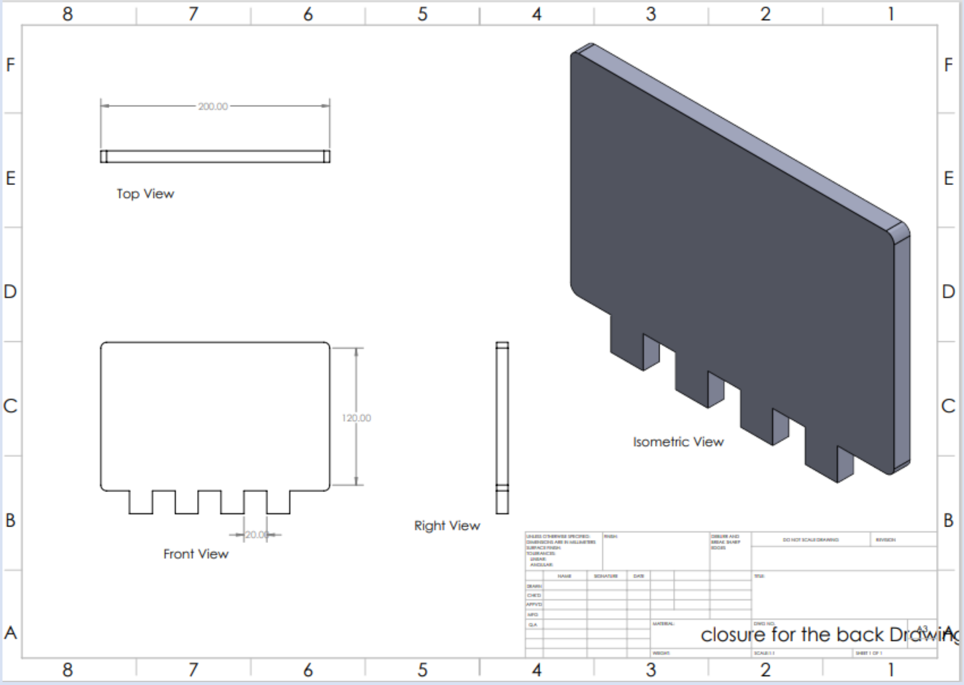


Robot Tyre

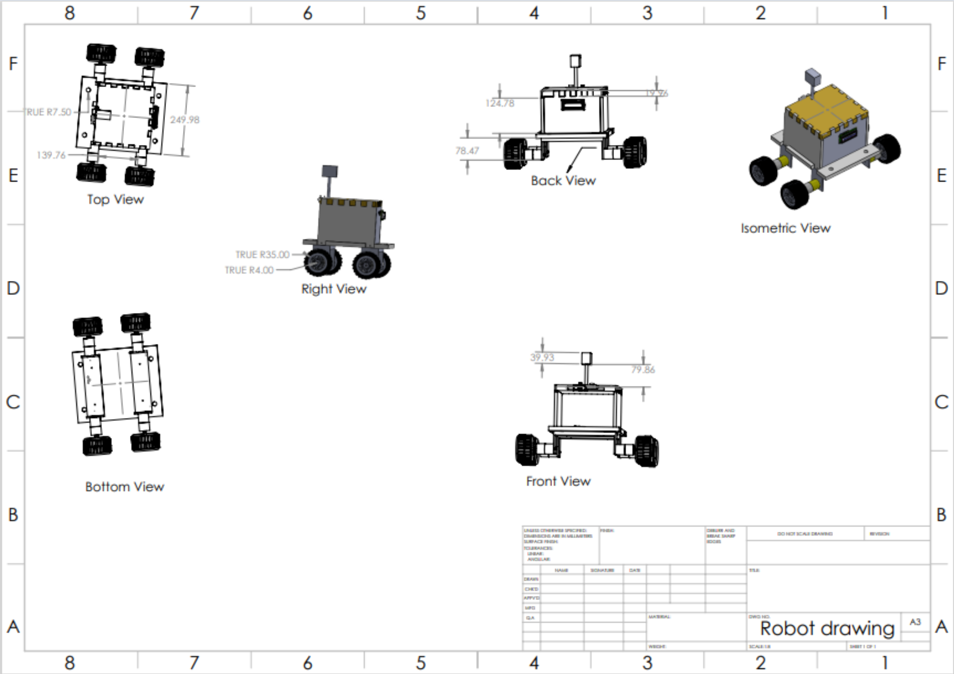


Robot tyre

Closure for the back



Assembled Robot



1.6 FABRICATION OF PARTS

Following our assessment of Solidworks, we carefully selected components for either 3D printing or laser cutting.

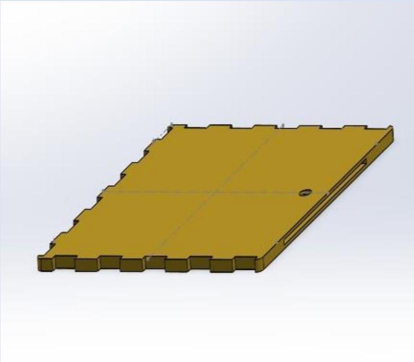
For laser cutting, we included the robot's base, side covers, back cover, top cover, and tyre connectors. These Solidworks files were saved as DXF files and sent to the Boss laser cutter. Before submission, we ensured that unnecessary lines were removed from the parts to prevent unintended cuts.

We also 3D printed the parts that hold our motors to the tyre connectors. This specific component was saved as an STL file since it requires the STL format for 3D printing purposes.

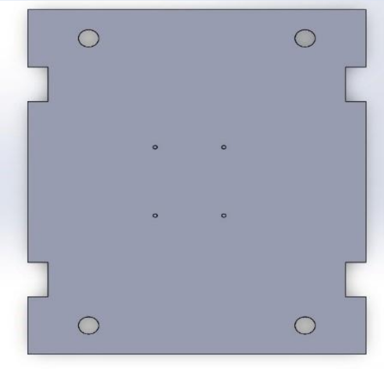
Through these precise manufacturing techniques of 3D printing and laser cutting, we have made significant progress in bringing our project to life, combining careful design with advanced fabrication methods.

<u>PARTS WE LASER-CUT</u>

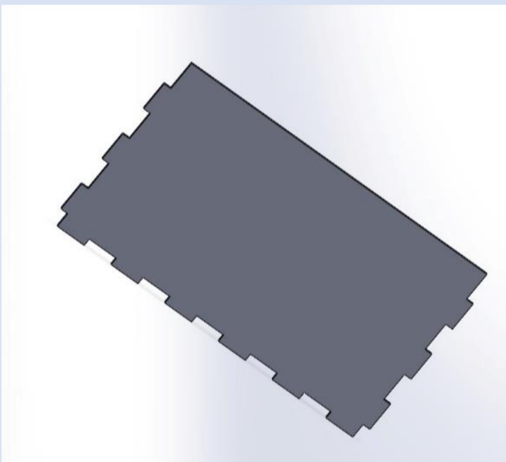
Top Of Robot



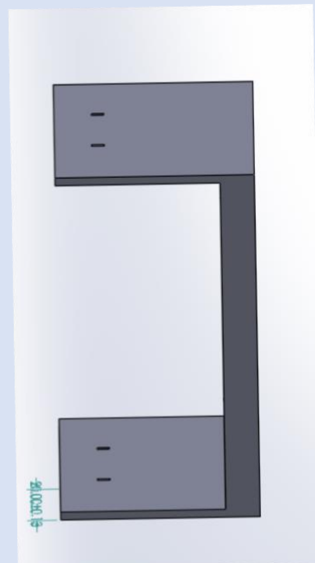
Base of robot



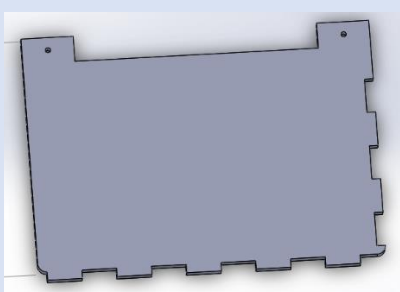
Back Closure of Robot



Tyre connector

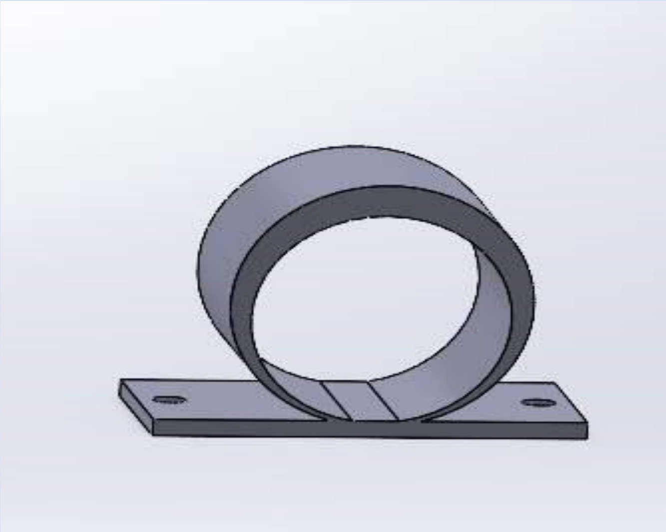


Side of robot



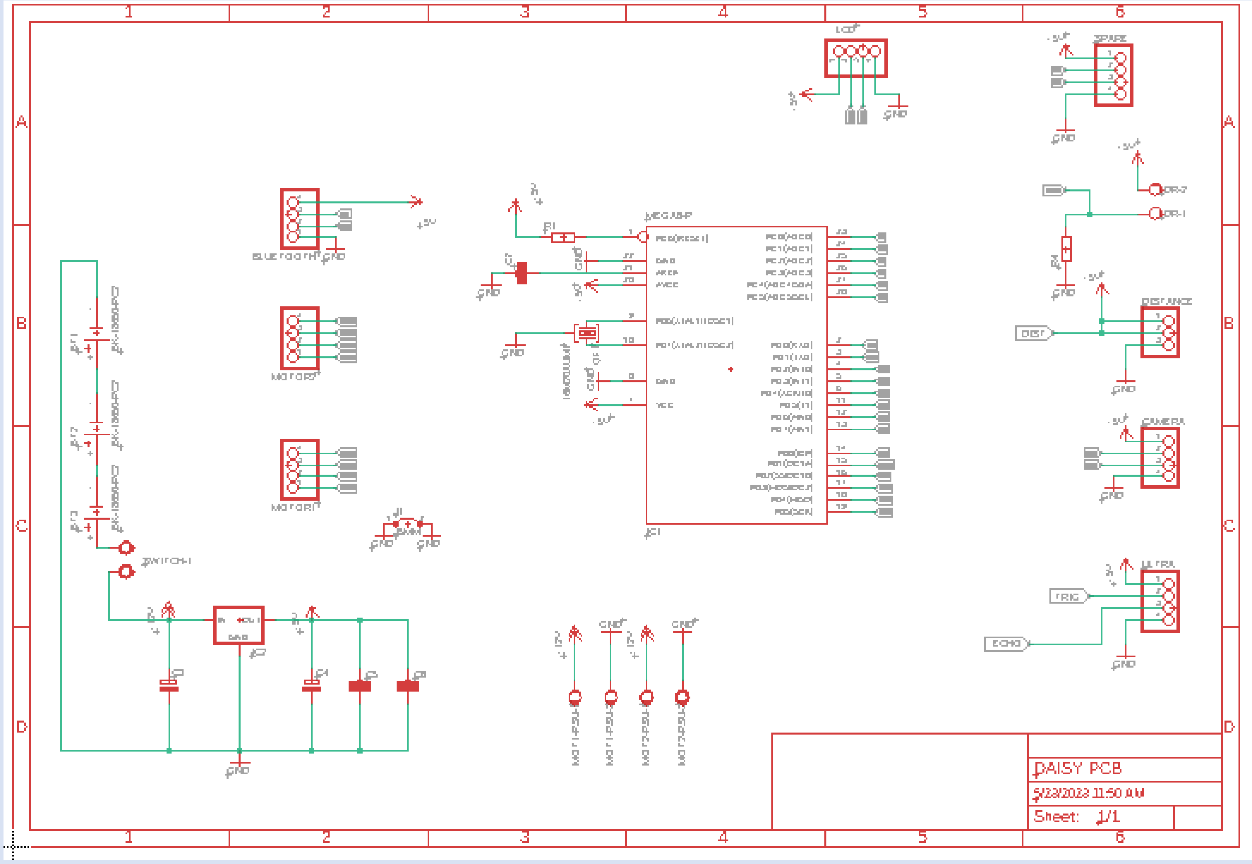
PARTS WE 3D PRINTED

Motor holder



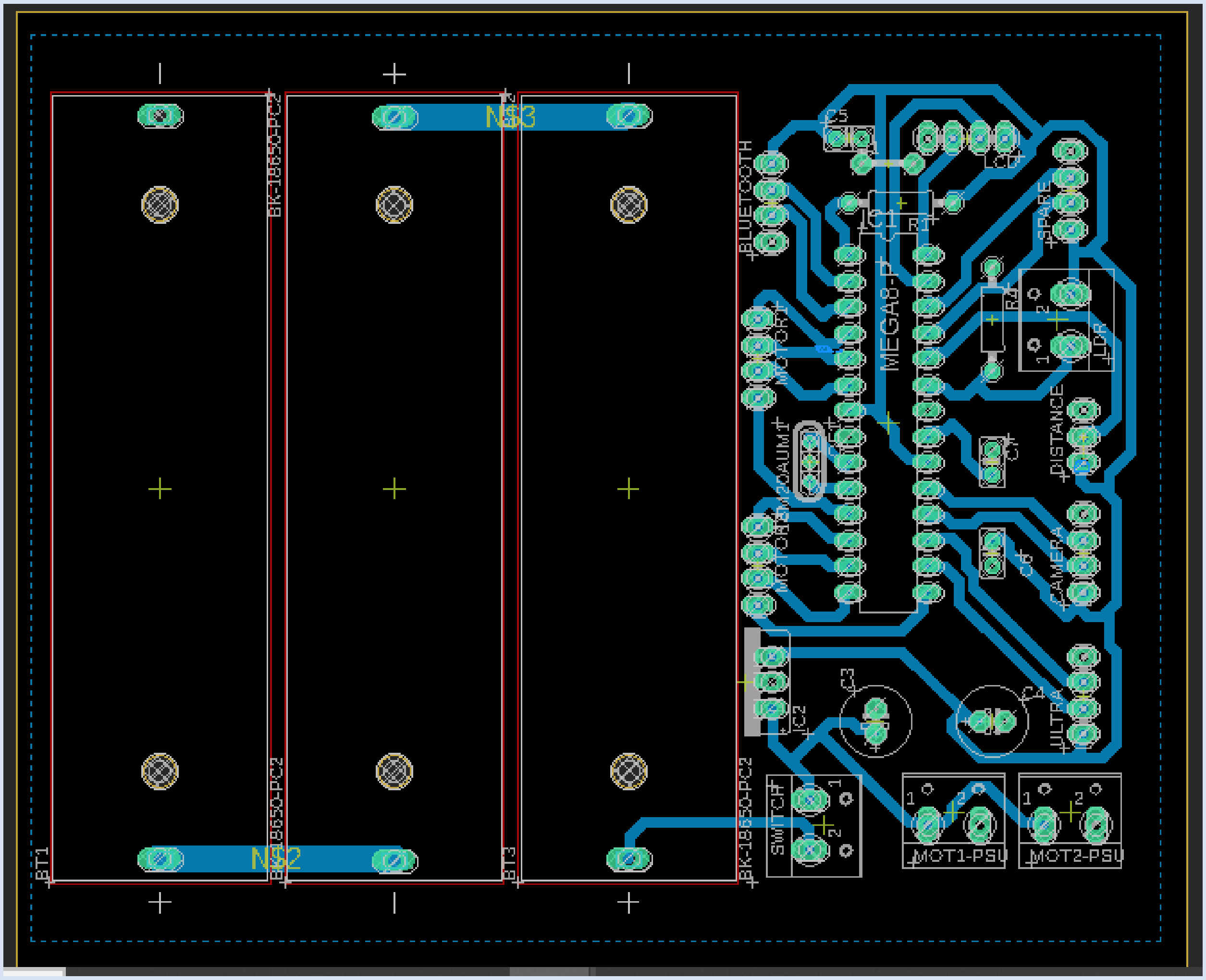
1.7 Printed Circuit Boards

For designing our Printed Circuit Board (PBC), we made use of Autodesk Eagle. We laid out the components as shown in the diagram below. After trying to route the PCB automatically, we did not get 100% routing. So, we included a jumper connection on the part that had not been routed.



PCB layout

Before routing the PCB, we made the trace thickness 40 mils and the clearance for the wire 15 mils. After routing the PCB, we increased the width of the traces from the power supply to 100 mil to reduce overheating on the PCB.

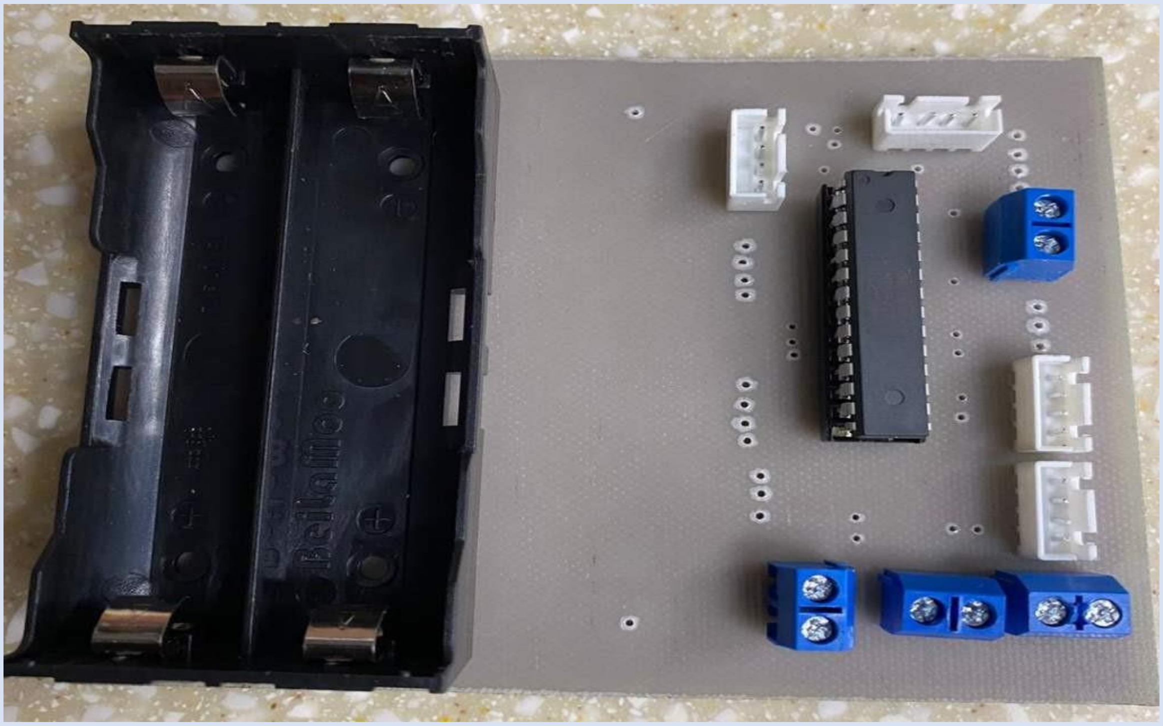


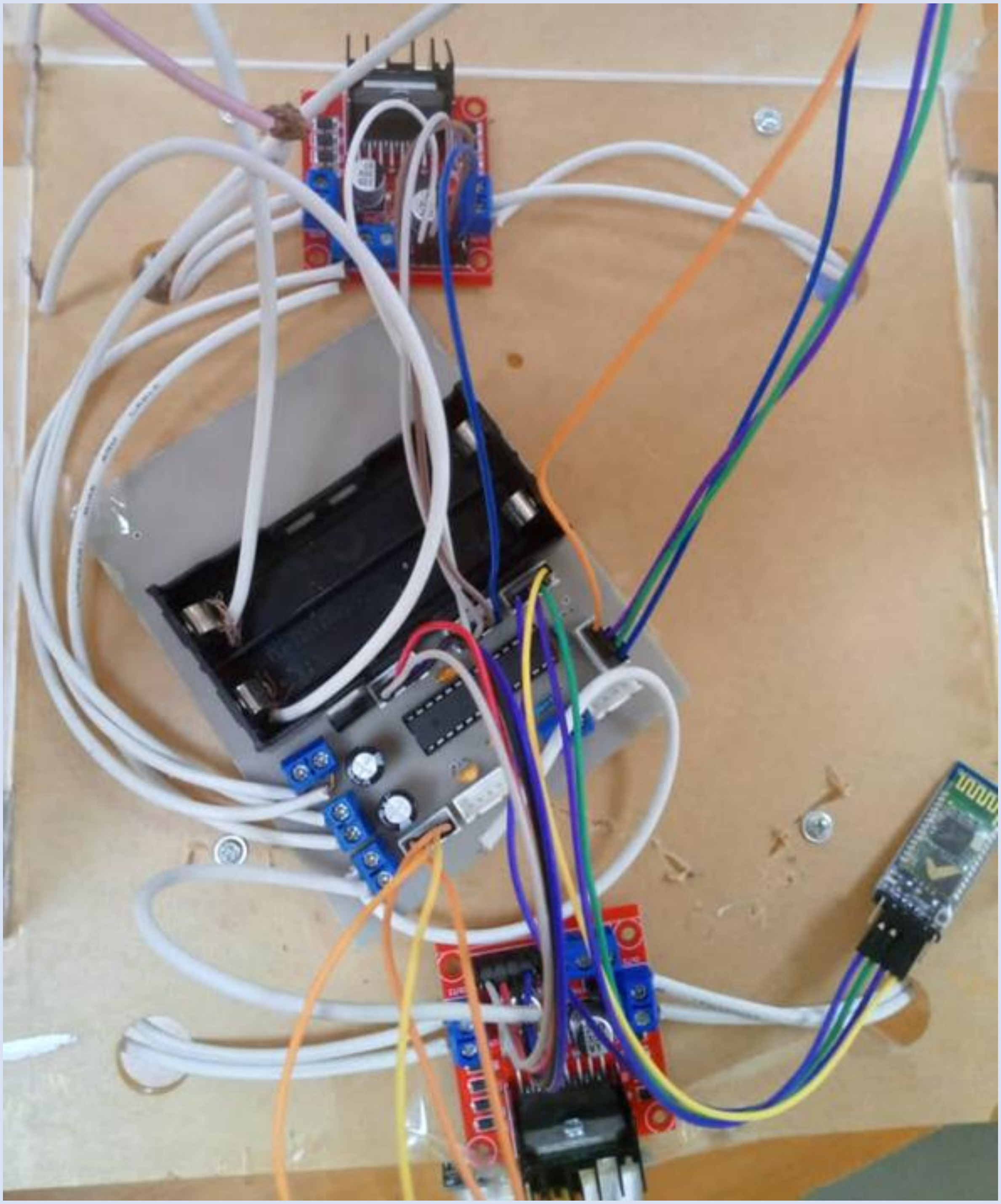
Printed Circuit Board in Autodesk Eagle

We then made the PCB using the “Iron on glossy paper method”. We selected the output in black both from the PCB design software and the printer driver settings. We ensured the printout was made on the glossy side of the paper. We cut the copper board according to the size of the layout (100 * 100 mm) using a hacksaw. Next, we rubbed the copper side of the PCB using steel to remove the top oxide layer of copper and the photoresist layer and allow the image from the paper to stick better.

We put the board and photo paper together with the back of the photo paper facing upwards and covered this arrangement with a sheet of paper. We heated up the electric iron to the maximum temperature and then pressed the iron on top of the paper for a few seconds before applying a little pressure for 15 minutes.

After leaving the PCB to cool for some minutes, we dipped it into the water to remove the paper. We then dipped the PCB into an etching solution of concentrated HCl with Hydrogen peroxide acting as a catalyst. The HCl reacted with the unmasked copper and removed the unwanted copper from the PCB. We then rinsed the PCB and cleaned it. Afterward, we used a driller to drill the holes for the PCB and mounted the components. We then soldered the components at the bottom of the PCB.





PCB with mounted components

MODIFICATION MADE TO THE DESIGN

- The prototype we made had only two enclosed sides and two were left open, wo we decided that the weather conditions on Mars may not be favorable. So, in our 3D Design we decided that we close all the sides of our robot. This is to ensure that all the electronic components attached to the PCB and other parts of the Agojie robot are safe.

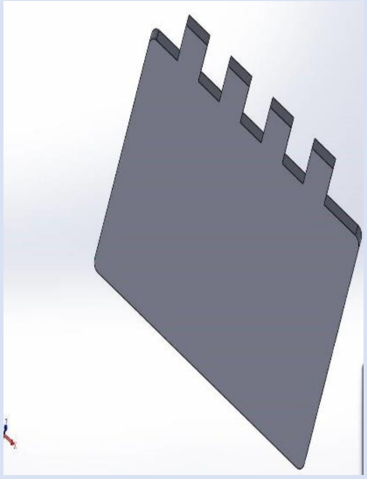
Possible Materials to be used.

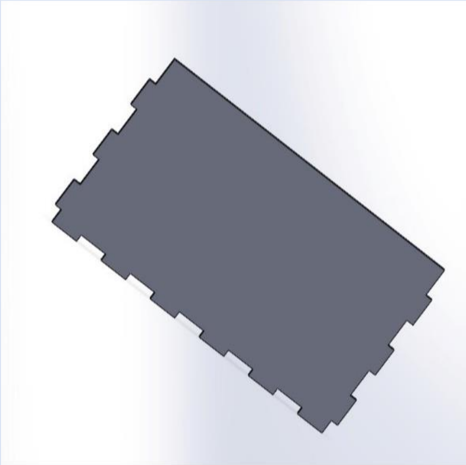
- For our robot we are considering using plexiglass, aluminum, and a little bit of metal. We will use plexiglass of 5mm (about 0.2 in) thickness for the upper body of the structure that surrounds the PCB and other electronic components. The base on which the PCB will be placed will be made of aluminum. The 8mm (about 0.31 in) shafts connecting the wheels are made of aluminum. For the circlips that will fasten the shafts to the wheels, we will use steel.

Attachments Between Materials

- For connections of plexiglass to plexiglass, we will use the jigsaw method such that after printing the parts we can simply fit them together. We will use the 3mm (about 0.12 in) to attach the PCB to the aluminum base of the robots. The aluminum base of the robot will be screwed to the aluminum brackets through which the shafts pass through. The ultrasonic sensor, the sharp distance sensor and the camera will be glued to the front of the robot and the cables that will be connecting them to the microcontroller will pass through a hole to the MCU.

MODIFICATION OF PARTS

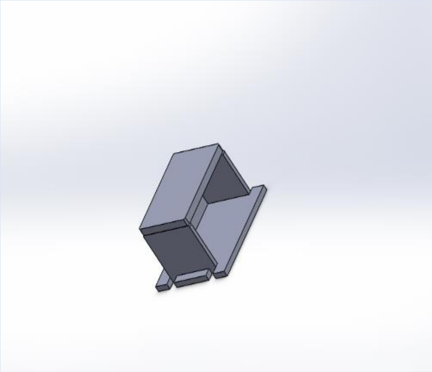


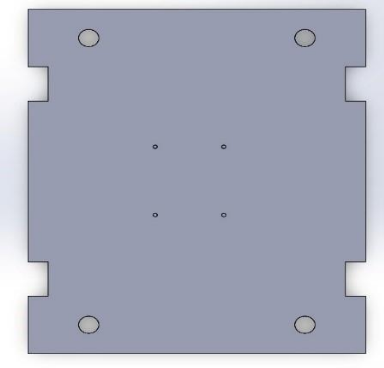


Part Before Part After

<u>Reason for modification</u>

We made the first design without the jigsaws on the sides, we figured that it would be difficult to fabricate the parts after 3D printing and laser cutting them. We also made jigsaws for easy attachment to each other.



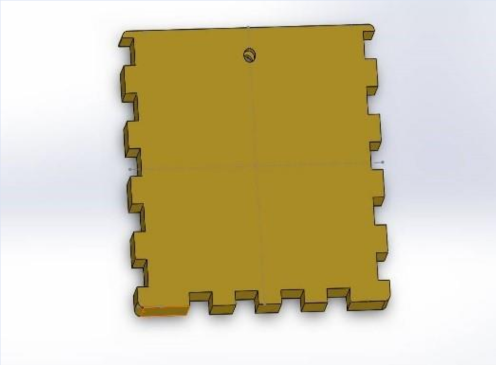


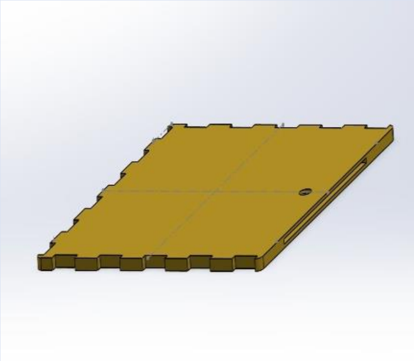
Part Before

Part After

Reason for modification

The first design included the sideboards attached to it. We removed the sideboards so it would be easier to 3D print them.





Part Before

Part After

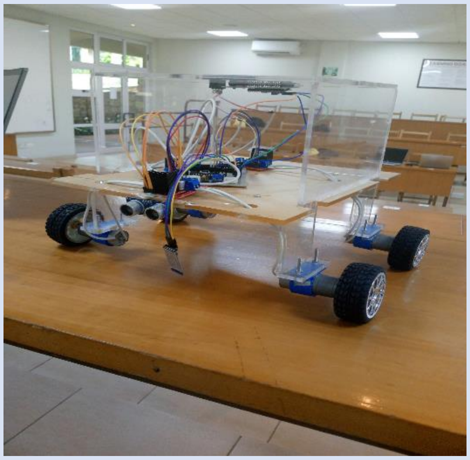
<u>Reason for modification</u>

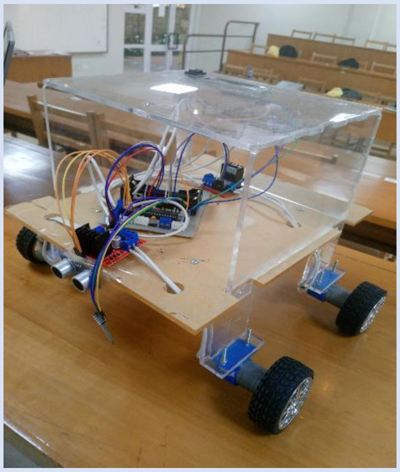
The first design had a thickness of 8mm, and we have changed it to 5mm thickness to match the available resources and I this case the provided plexiglass had a thickness of 5mm.

The Robot

Before

After





Reason for Modification

Initially, the base of our robot was made of wood which we cut and shaped at the workshop. We later changed the material of the base and the tyre connector from wood to plexiglass for a number of reasons. We had made the motor holders from steel, and we 3D printed the motor holder and replaced the steel ones. The first reason is that it was difficult to attach the sides of the plexiglass robot to the wooden base. They were screwed together as shown in the image above, but the attachment was not strong enough, so the robot was unstable as it moved. We decided to laser cut plexiglass and produce the tyre connector and the base of the robot. The second reason was that the robot was too heavy because of the wood we had used. Lastly, besides functionality, we wanted our robot to look much more presentable, and this was for aesthetic reasons.

OTHER APPLICATIONS OF THE ROBOT

1. Taking soil samples from Mars for scientific experiments: The robot can also take soil samples periodically while navigating on Mars's surface. Our current design would have to be modified to include a robotic arm to take the soil samples and a container at the back to store the soil sample.
2. Monitoring criminal activities: It can be programmed to patrol an area and monitor for suspicious activities. The camera can capture live video footage, which can be transmitted in real-time via Bluetooth to a connected device for remote monitoring and analysis. The current design should be modified to include an independent source of power (solar panel) so that it can recharge during the day. The robot should be closed on all sides and all holes should be covered to prevent water from entering and corrupting the electronics inside.
3. Monitoring active volcano areas: For volcano areas, the materials used should have very high melting points which can withstand very high temperatures.eg) tungsten and other ceramics and metals like aluminum oxide, silicon nitride
4. Delivering food: The robot can also be used to do door-to-door delivery of food from the cafeterias and small packages from essentials to students’s hostels at Ashesi University. The robot will include a carrier where the package will be stored. It will also make use of GPS to determine the location of the hostels.

REFLECTIONS/ LESSONS LEARNT

Darryl

“It’s best to think about all of the details beforehand.”

Shadrach

“I learned always to make a plan before you go on into anything.”

Fadzai

“Iteration, if things don't work out we can always go back and make changes that will work out.”

Jessica

“I learned that it's best to work as a team because combined efforts come together to produce the perfect piece.”

Daisy

“The first design isn’t always the best. The first code doesn’t always compile. The first simulation introduces fatal errors. But we don’t lose heart; instead, we get up and go out to draw inspiration from nature, come back, and try again. It’s all part of learning.”

Obadiah

“I’m just speechless!”

REFERENCES

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THE END!