FABY

A TELEPRESENCE ROBOT

for

FABLAB

Team Members

SUBHAM AGRAWAL

MOHAMMED MAARUF VAZIFDAR

PRATIK BHUJBAL

MAITREYA KULKARNI

RISHABH VERMA

KRISHNA SAYORI DEB

VIRAL PANCHAL

JOSEPH JOEL

Under the guidance of

RANJITH PILLAI R

(M.E, Assistant Professor, Department of Mechatronics Engineering)

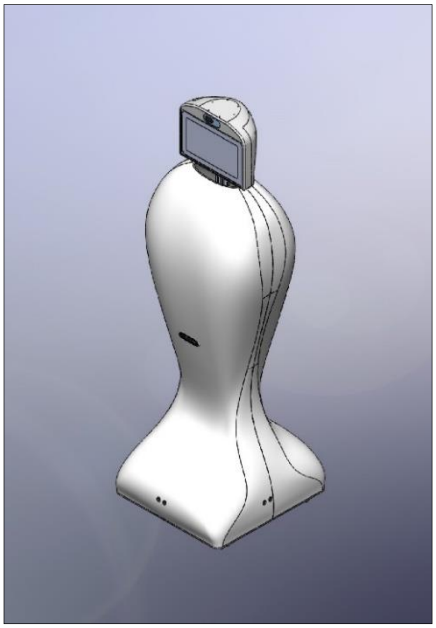
S.R.M. Nagar, Kattankulathur, Kancheepuram District

MECHANICAL

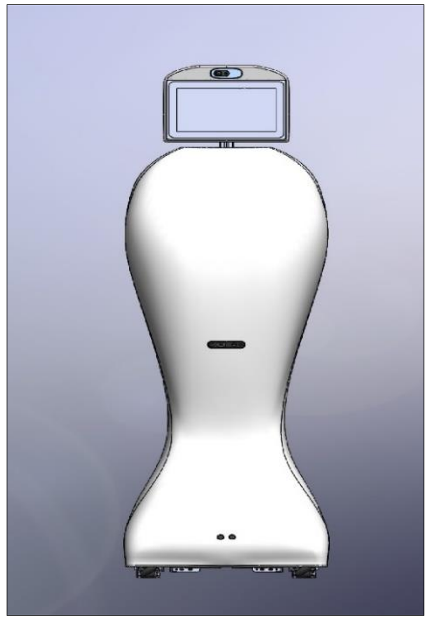
Images list:

1.1 – Isometric view
1.2 – Front view
1.3 – Side view
1.4 – Back view
1.5 – Chassis made using profile channel
1.6 – Aluminum profile channel sectional view
1.7 – Drive isometric view
1.8 – Drive side view
1.9 – Drive top view
1.10 – Drive front view
1.11 – Motor side view
1.12 – Motor front view
1.13 – Motor isometric view
1.14 – Wheel side view
1.15 – Wheel front view
1.16 – Wheel isometric view
1.17 – Motor mount and coupler with motor and wheel assembly
1.18 – Motor mount isometric view
1.19 – Motor mount front view
1.20 – Motor mount side view
1.21 – Coupler isometric view
1.22 – Coupler sectional side view
1.23 – Coupler side view
1.24 – Coupler front view
1.25 – Battery pack front view
1.26 – Battery pack isometric view
1.27 – Display isometric view
1.28 – Display front view
1.29 – Display side view
1.30 – Display back view
1.31 – Display top view
1.32 – Display/ microphone sensor module view
1.33 – Outer Body complete isometric view
1.34 – Outer body front part isometric view
1.35 – Outer body back part isometric view
1.36 – Depicting center of gravity in the robot
1.37 – Render 1
1.38 – Render 2
1.39 – Render 3
1.40 – Render 4

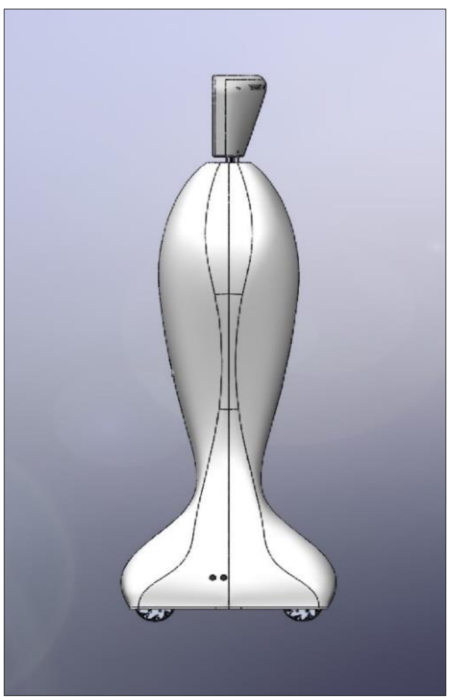
1. **Overview:**
   Using SolidWorks as our CAD software, the complete design of the Telepresence robot is developed.



Img 1.1



Img 1.2



Img 1.3

Img 1.4

Above are the images of the telepresence robot from different views.

2. **Dimensions:**

Length: 450 mm
Width: 500 mm
Height: 1475 mm

Weight: 18 kgs (Approximate)
No. of wheels: 4

3. **Chassis:**

The chassis is made of Aluminum profile channel of grade Series 6063 which has the mechanical properties as below;

Young's modulus (E)	68.3 GPa (9,910 ksi)
Tensile strength (σ_t)	145–186 MPa (21.0–27.0 ksi)
Elongation (ε) at break	18-33%
Poisson's ratio (v)	0.3

The profile channel used makes it easy to modify positioning of sensor mounts in practical test and also helps maintain the tensile strength of the link without having the need to drill new holes in the channel to mount the sensors or electronics.

Chassis dimensions: (img 1.5)

Length: 230 mm

Width: 290 mm

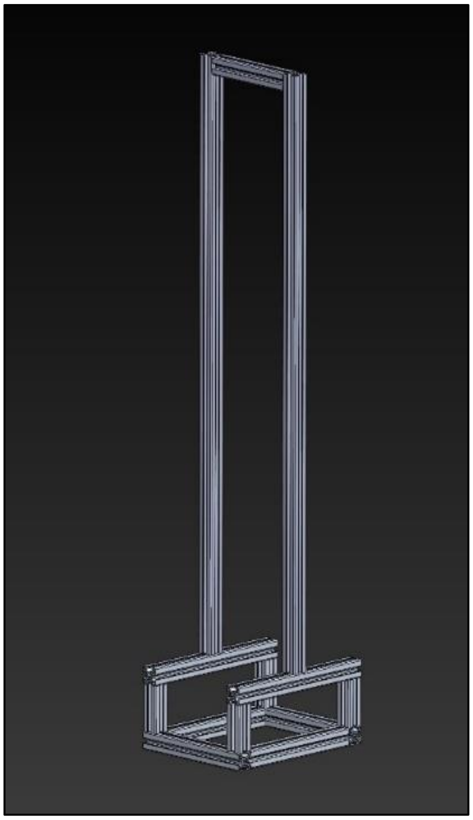
Height: 1140 mm

Chassis weight: 3.4 kgs

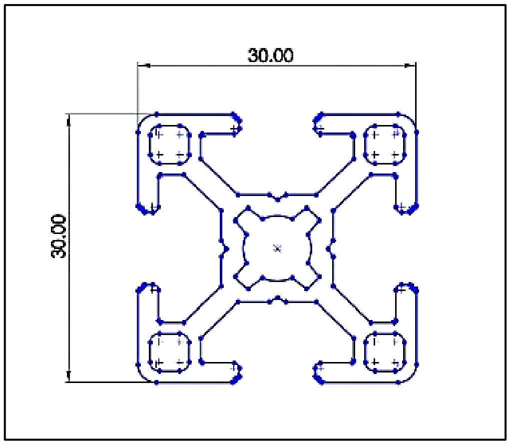
Channel Sectional dimensions: (img 1.6)

Length: 30 mm

Breadth: 30 mm



img 1.5



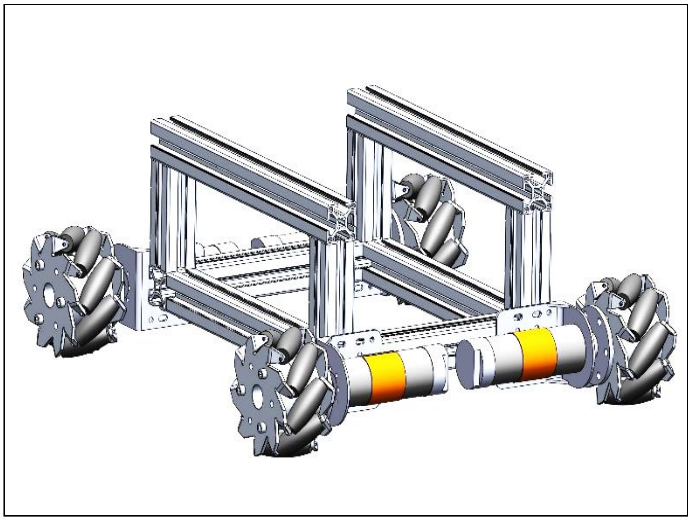
img 1.6

4. **Drive:**

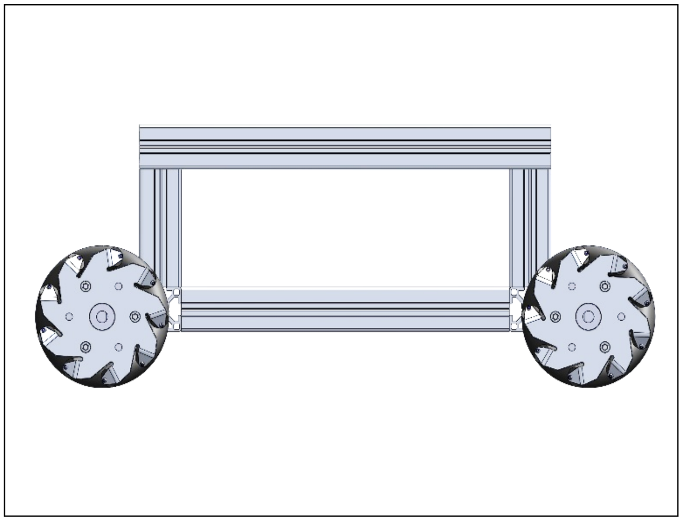
Drive Design: 4-wheel drive.

Drive extreme length: 400 mm

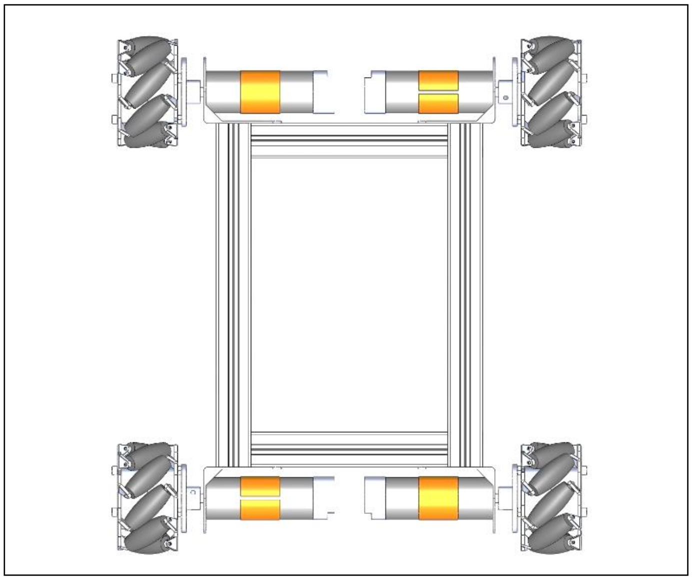
Drive extreme breadth: 450 mm



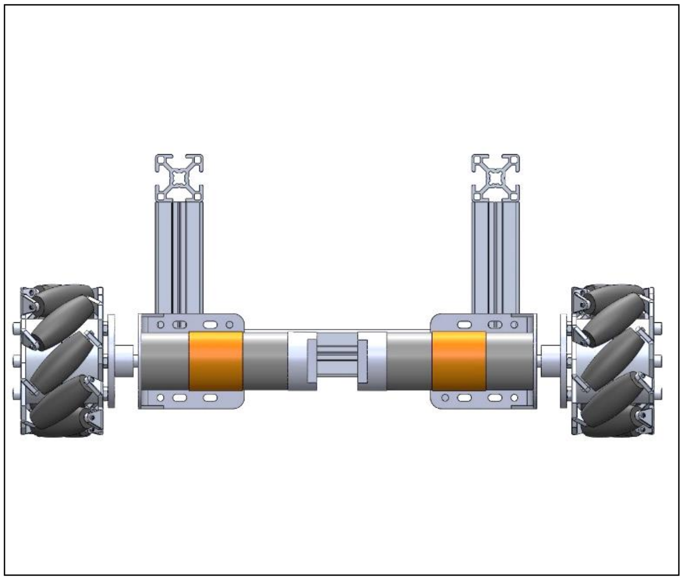
Img 1.7



Img 1.8



Img 1.9



Img 1.10

Above are the images of the base drive from different views.

A: Motors

Motor type: Planetary Geared DC motor

Motor specification: PG36M555-26.9K

Torque: 72.5 N-cm

Gear ratio: 26.9 : 1

Motor body diameter: 39mm

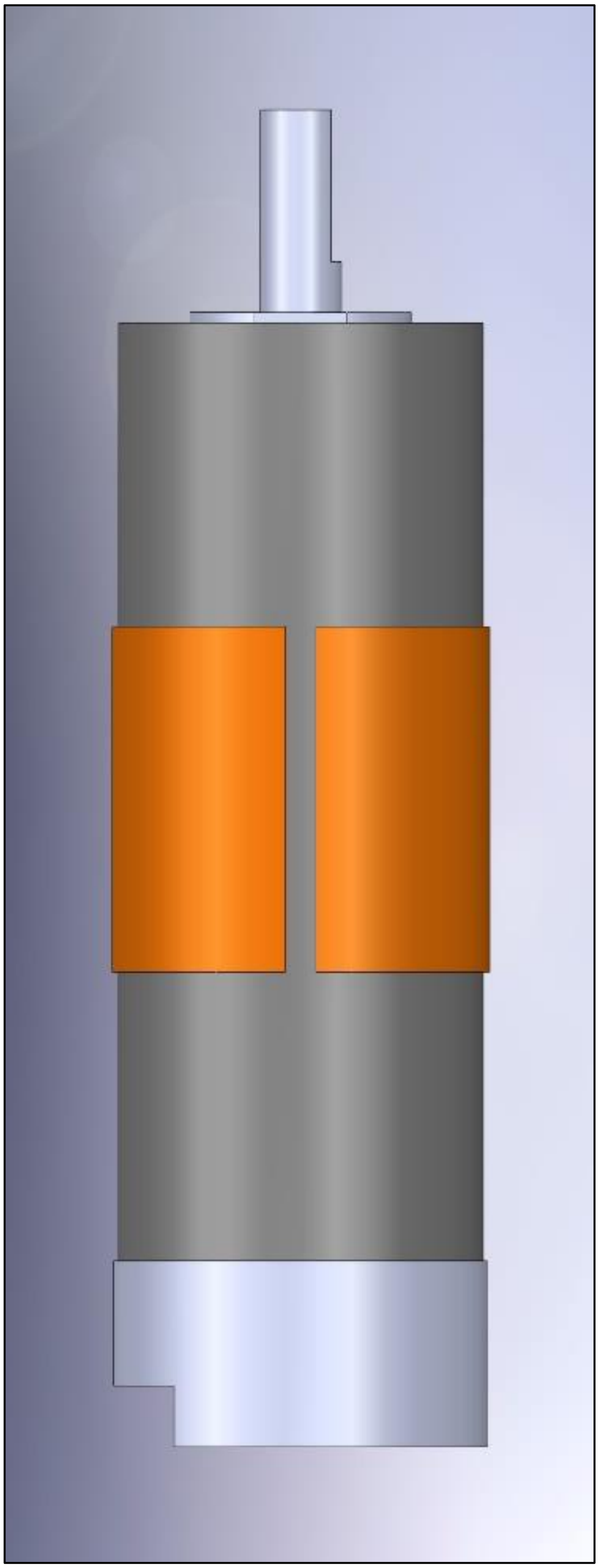
Motor length: 90mm

Shaft diameter: 8mm

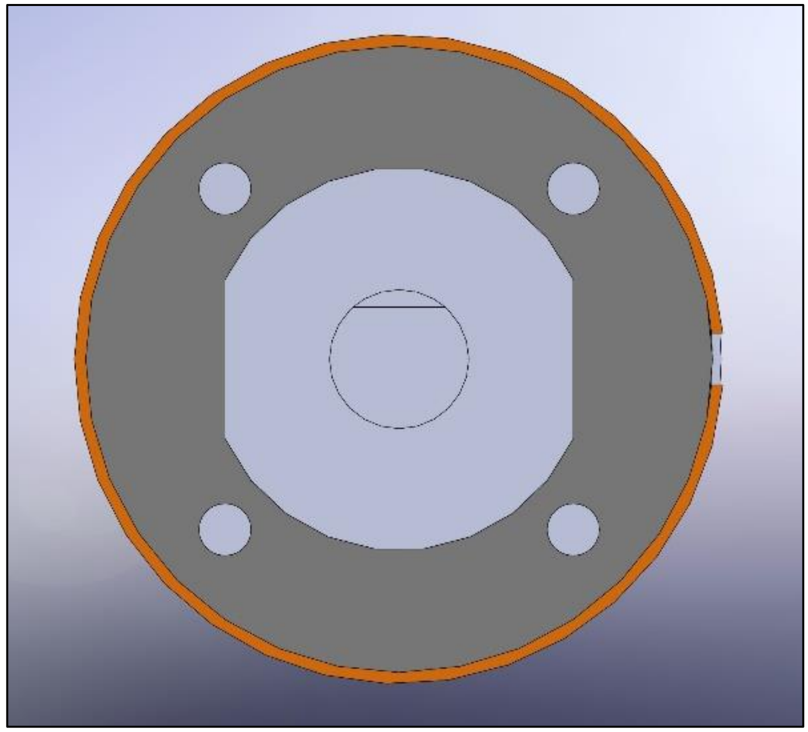
Shaft length: 20mm

Shaft type: D-type

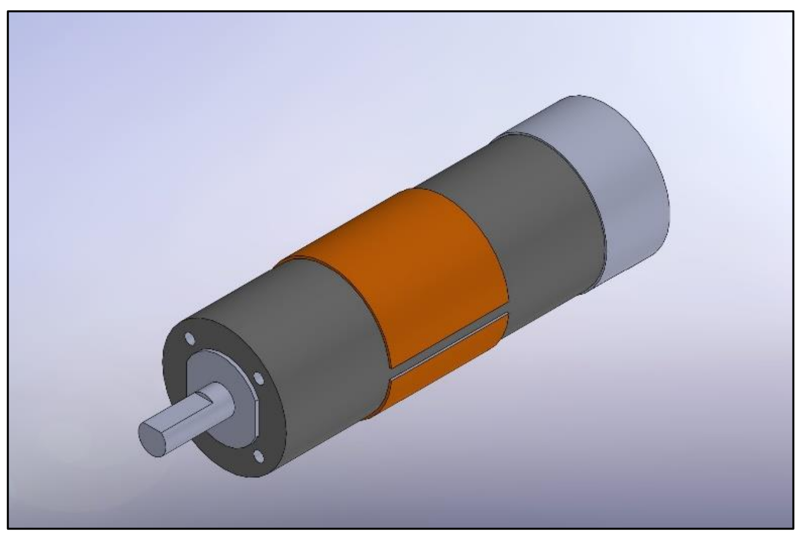
Motor weight: 0.419 kg



Img 1.11



Img 1.12



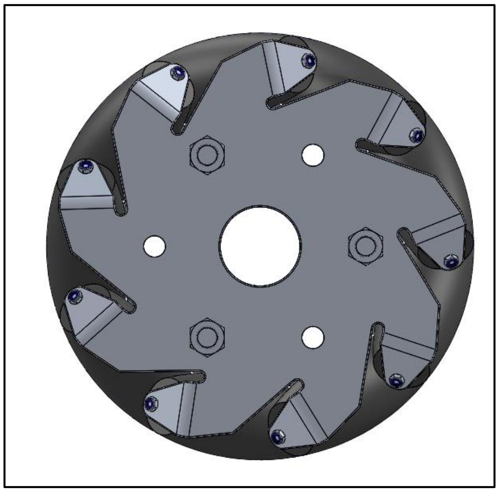
Img 1.13

B: Wheels

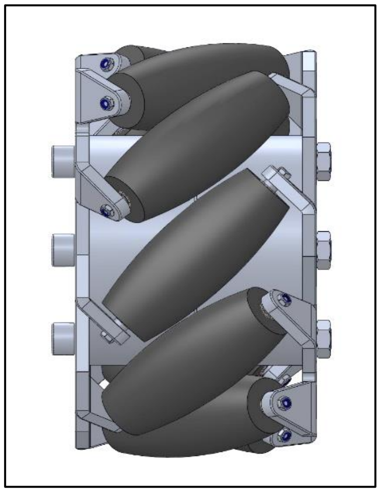
Type of wheel: Swedish Mecanum wheels

Diameter of wheel: 100 mm

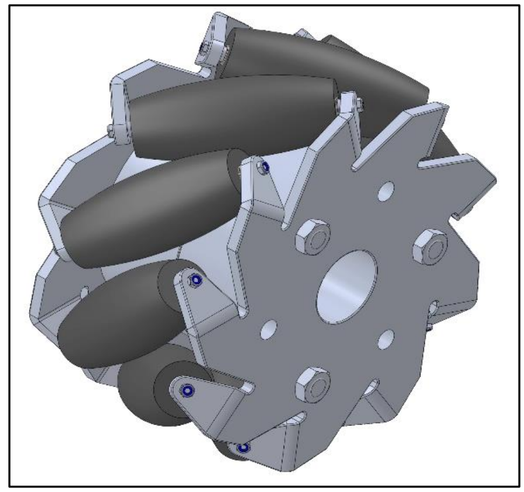
Width of wheel: 52mm



img 1.14



img 1.15

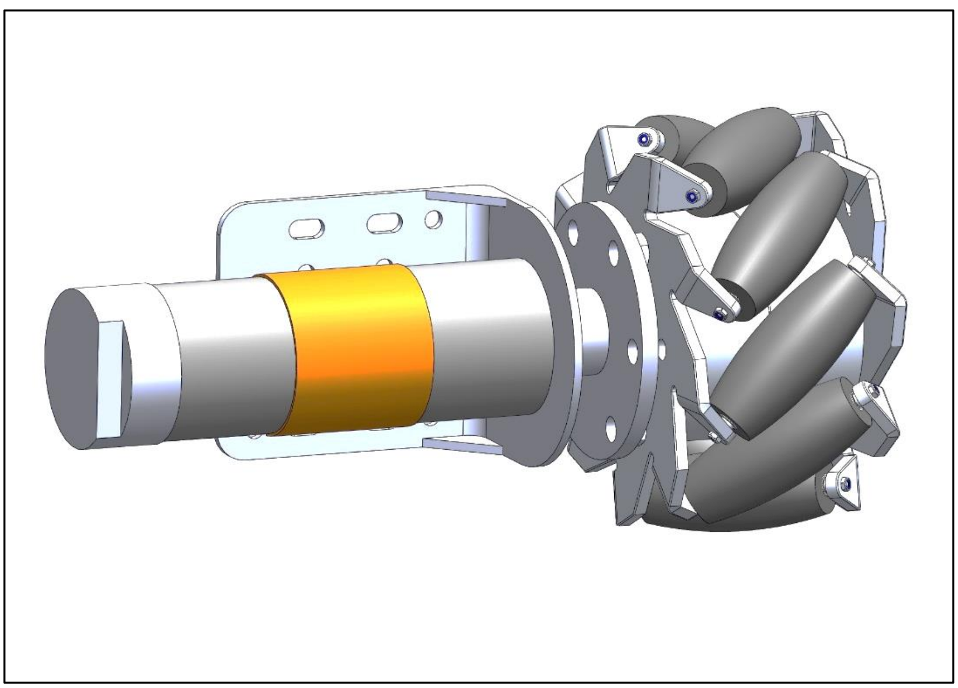


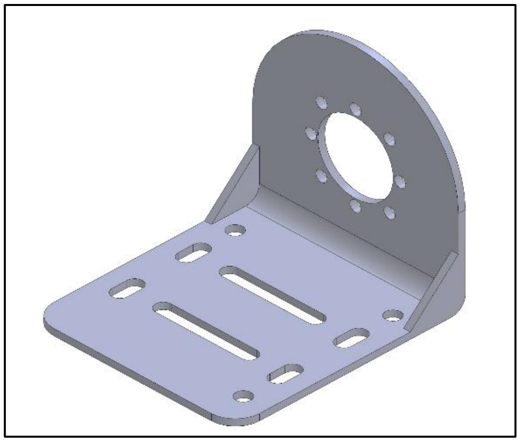
img 1.16

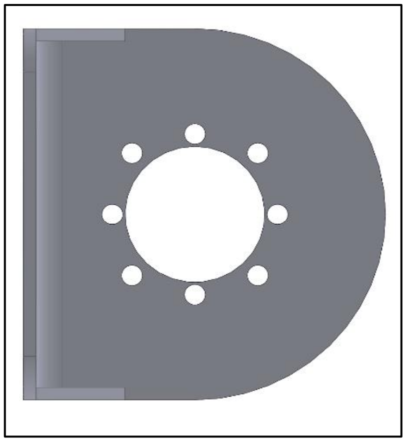
Swedish Mecanum wheel has 3 degrees of freedom and this allows the robot to travel in a diagonal direction when required. Thereby preventing the necessity to make several turns to reach the goal destination point.

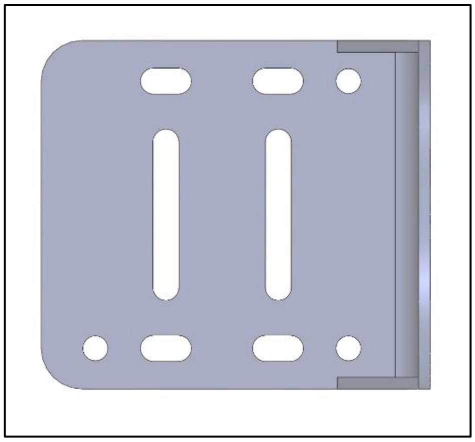
C: Motor mounts and wheel couplers.

- The four motor mounts and wheel couplers used to fabricate are standard and identical.





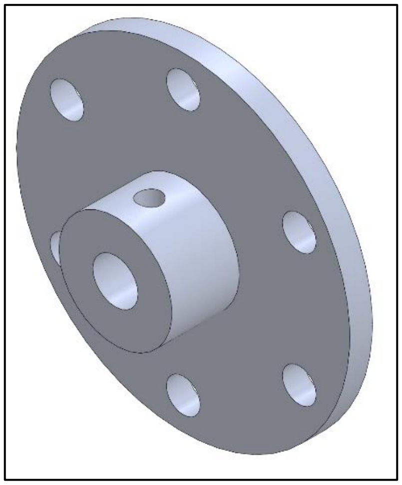


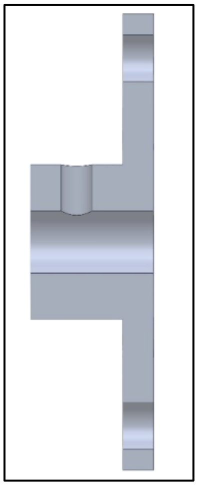


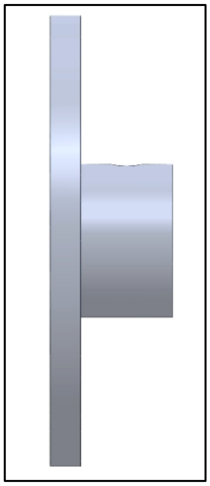
img 1.18 img 1.19 img 1.20

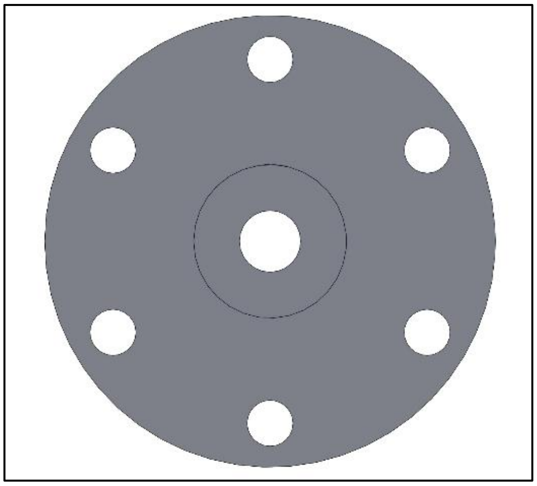
Motor mount specifications:

Material : Mild Steel (MS)	Height : 57 mm
Length : 67 mm	Weight : 0.115 kg
Width : 60 mm	Motor mounting hole dia : 3mm









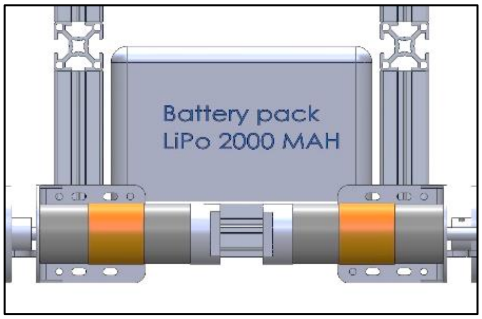
img 1.21 img 1.22 img 1.23 img 1.24

Coupler Specifications:

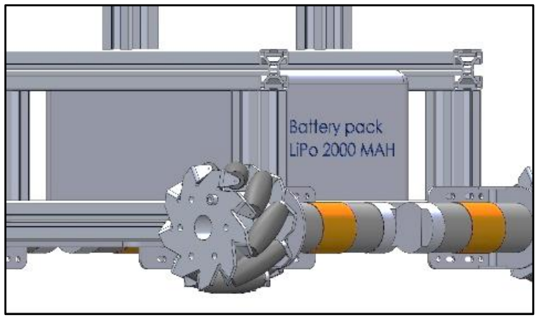
Material: Aluminum grade series 6063	Mounting hole diameter: 6 mm
Outside diameter of flange: 60 mm	No. of mounting holes: 6
Shaft hole diameter: 8 mm	

5. Battery:

The battery is stored at the base of the drive which is enclosed in a pack made using acrylic.



img 1.25



img 1.26

6. Screen:

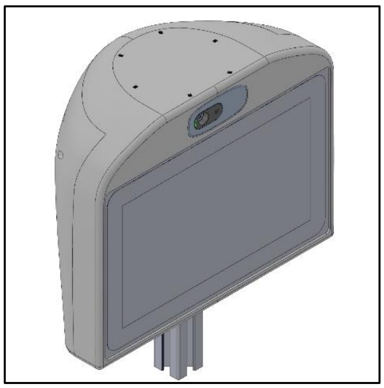
The display for the user interface is mounted on top of the robot. The mounting for the same is 3D printed which houses the screen, microphone module, webcam and Raspberry Pi 4.

Extreme dimensions of the display assembly:

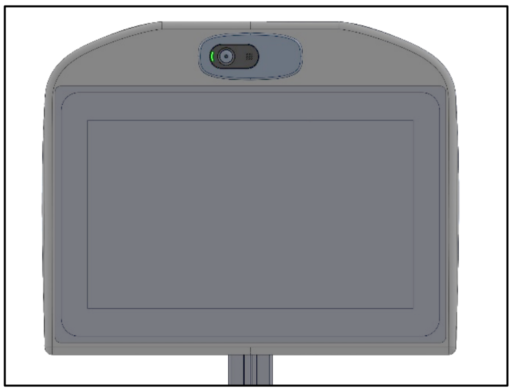
Length: 270 mm

Width: 123 mm

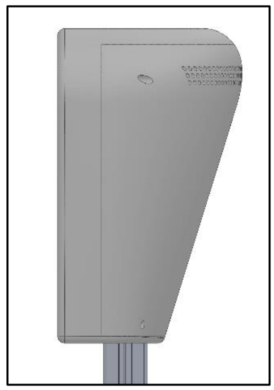
Height: 221 mm



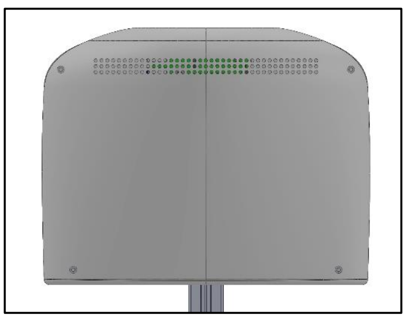
img 1.27



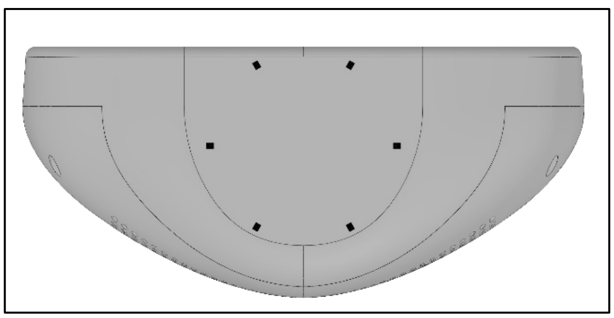
img 1.28



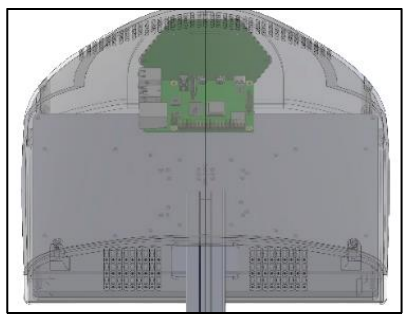
img 1.29



img 1.30



img 1.31



img 1.32

Print Specifications: (As per parameters asked in CURA)

Material: PLA (Polylactic acid)

Infill: 80%

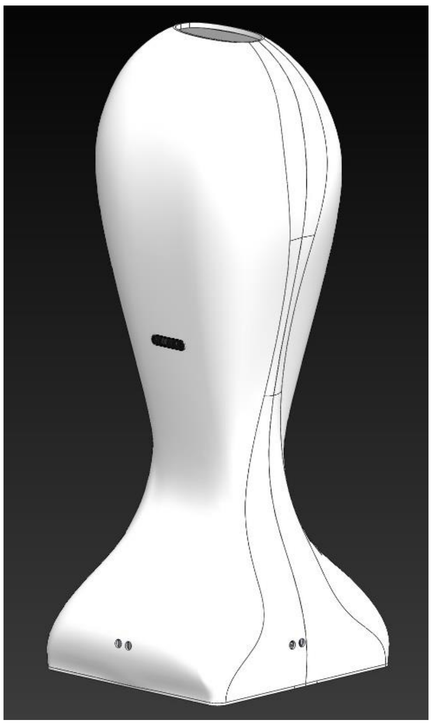
Wall Thickness: 3mm

Generate support: YES

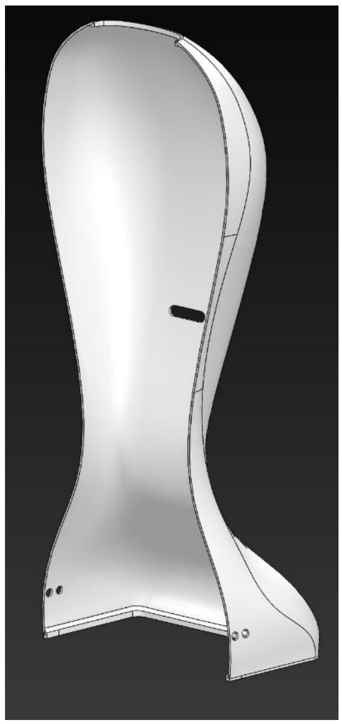
Total weight of the print: 0.41 kgs

7. Body:

The outer body for the telepresence robot is to be 3D printed by PLA (polylactic acid) filament.



Img 1.33



img 1.34

img 1.35

The outer body has a height of 1210 mm (i.e.: approx. 4 feet) and the screen is mounted on top of the body which brings the total height of the telepresence robot to 1475 mm (i.e.: approx. 4.9 feet). This height is efficient for the robot to interact with the guest or user and also preventing the robot from toppling down while in motion.

Because of the huge structure the body will be divide into several parts to print based on the bed plate of the 3D printer. Later the assembly will be glued and fastened using strong adhesives and fasteners. The groves and holes for the real sense senor and proximity sensors are provide in the design which can be visualized in the above images.

Print specifications: (As per parameters asked in CURA)

Print material: PLA (Polylactic acid)

Infill: 90%

Wall Thickness: 4 mm

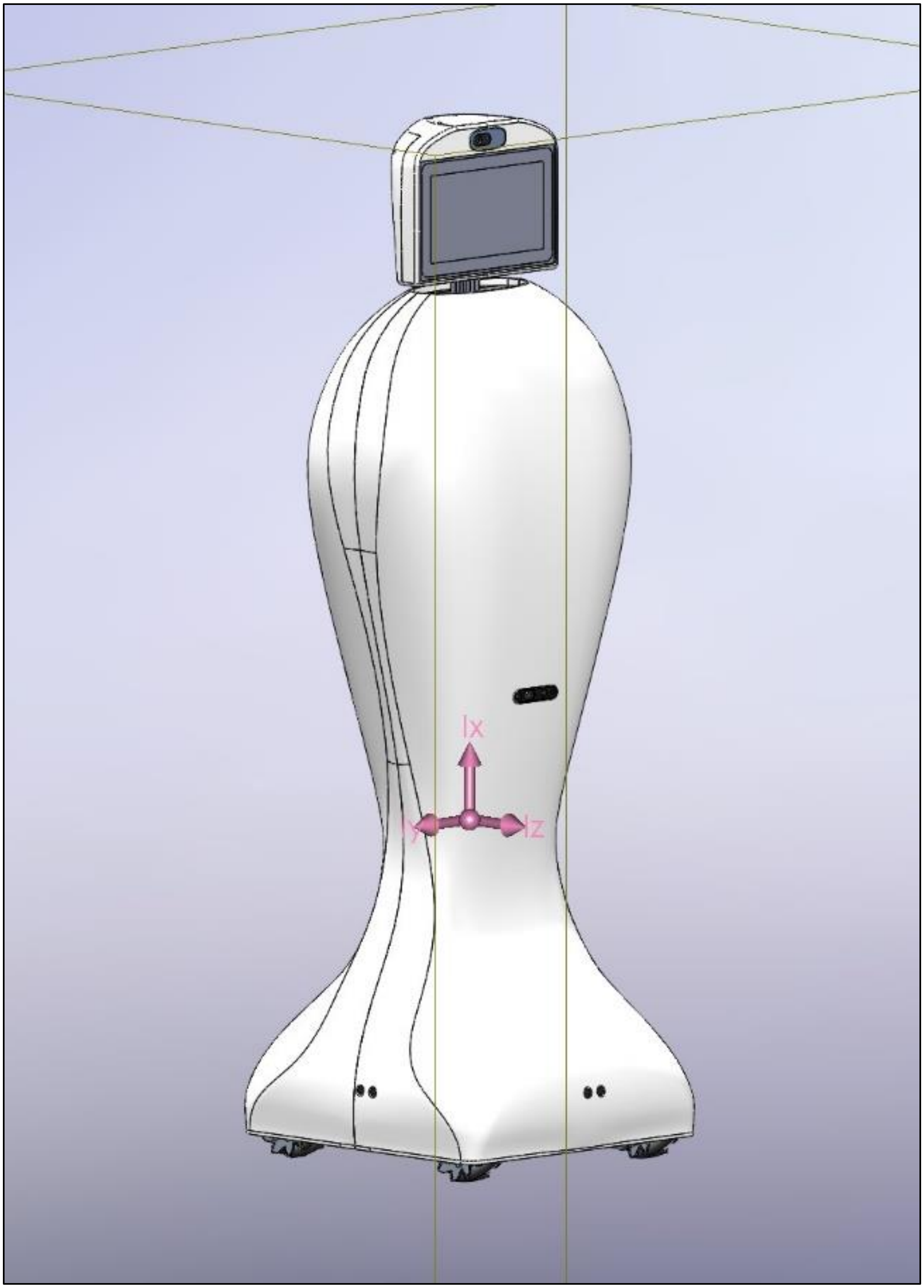
Build plate adhesion type : Brim

Generate support: YES

Total weight of the body : 6.23 kgs

8. Mass Properties of the complete body:

- The Cg (center of gravity) of the robot is at 485mm above the base.
- The total weight of the robot is around 18 kgs.
- Volume of the robot is 12770210.20 mm^3



img 1.36

9. Renders:

Img 1.37

Img 1.38

Img 1.39

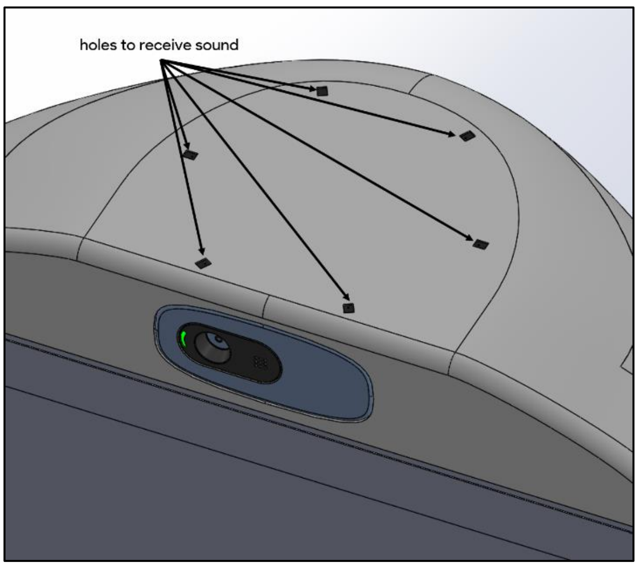
Img 1.40

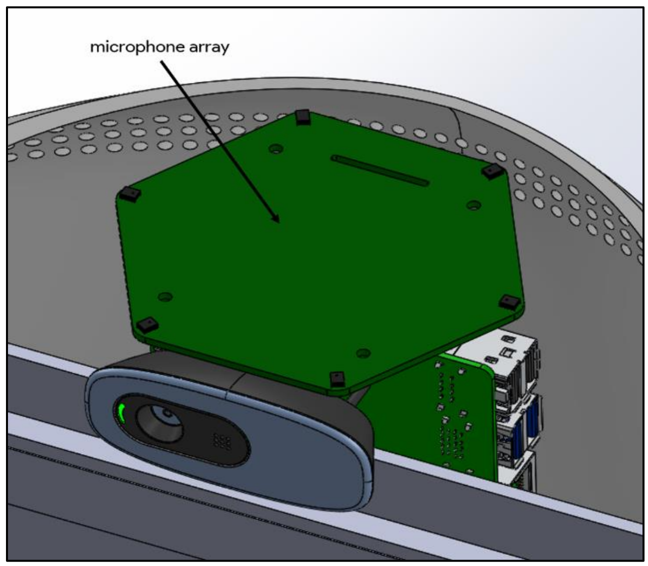
ELECTRONICS

Introduction:

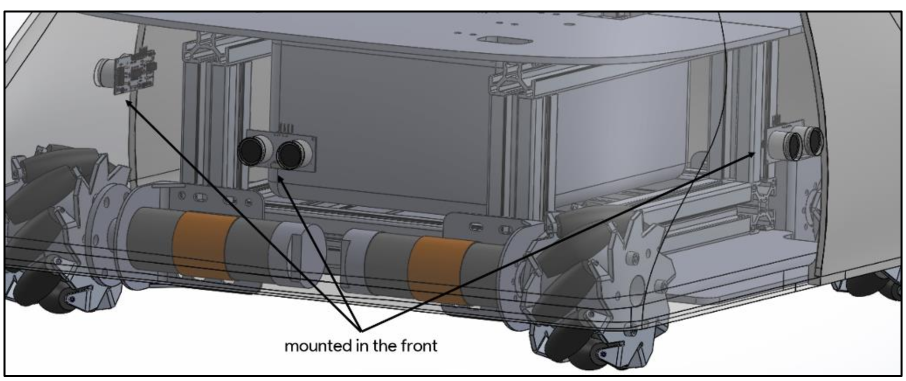
Electronics in a robotic system is a very important part. It is responsible for the powering and controlling all the sensors and actuators. This domain also includes the controllers that runs on the code developed with the data received from the sensors and decides the control action for the movement and interaction of the robot with the surroundings. In this project we have used many sensors to receive data of the surroundings as-well-as from the user since the robot is made specially to interact with members in the facility. This report details all the information about all the sensors, actuators and electronic components used to build this project.

1. **Sensors:**
   a. Microphone array
   The microphone array is used to get voice inputs from the user. This sensor is placed at the top most mart of the robot inside the head cage with holes given on the body to help receive the sound properly. This sensor data is used in the chat-bot feature built for the robot. Power supply for the array is received from the microcontroller.



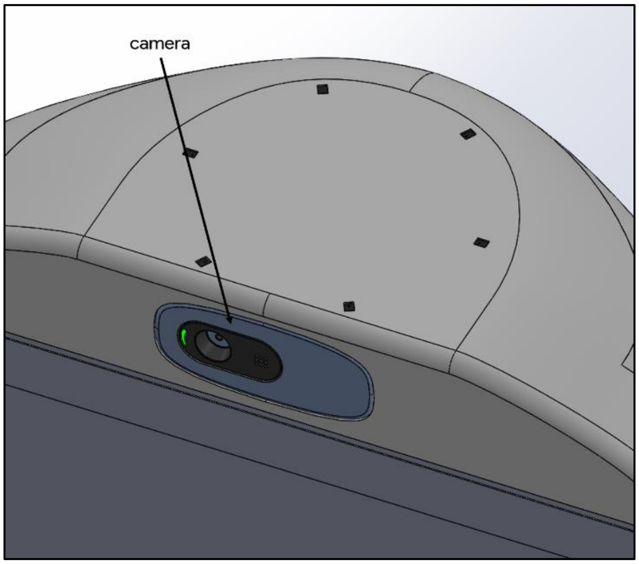


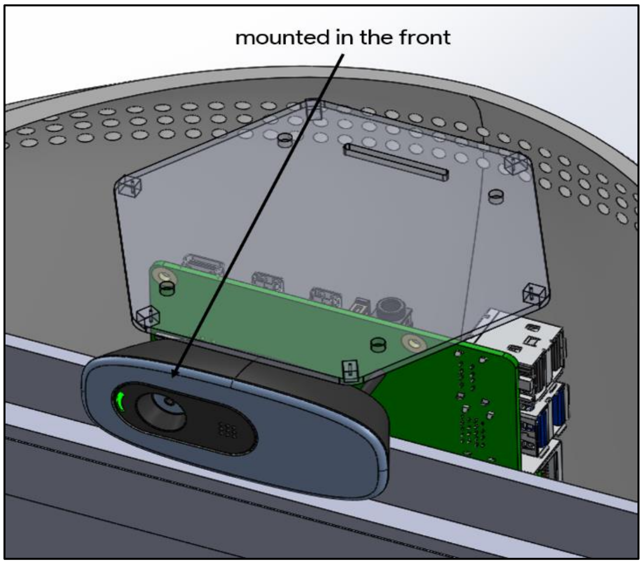
   b. Ultrasonic Sensor
   This sensor is used for detecting obstacle in the path of the robot. They are place in three side on the bottom frame of the robot; front, right and left. A satisfiable threshold is set for all the sensors. When one is triggered the robot will stop and proceed once the obstacle is removed. Power supply for the sensor is received from the microcontroller.

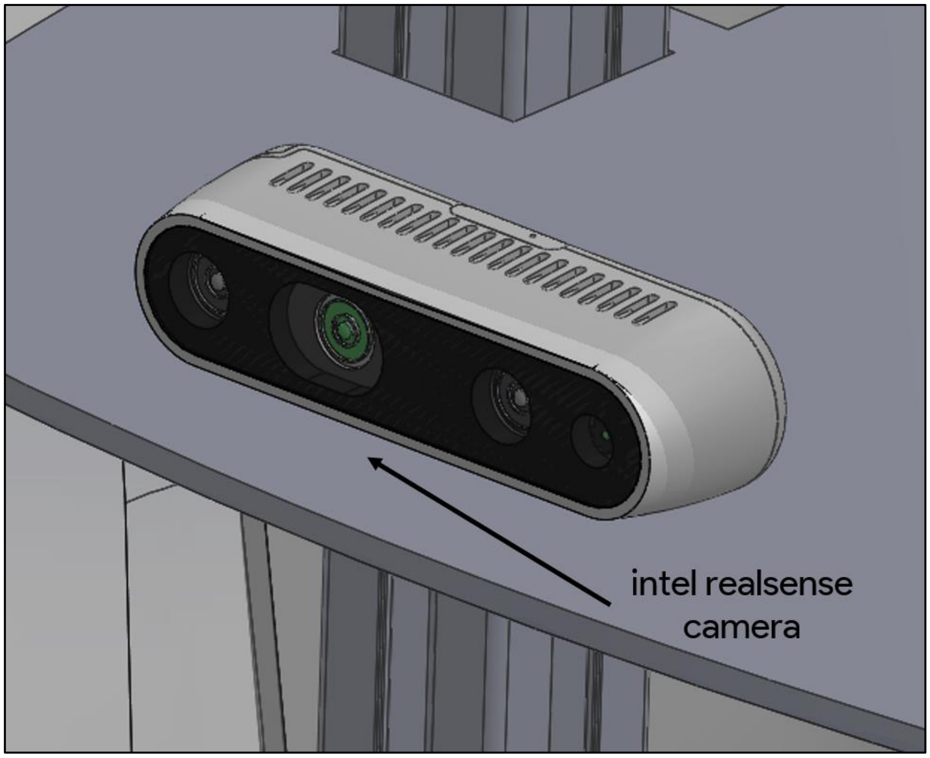


c. Camera

The camera is used for video communication. It is used to interact with the user. Another camera module is used to estimate pose of the robot using machine vision algorithm and markers. Power supply for the camera is received from the USB hub.



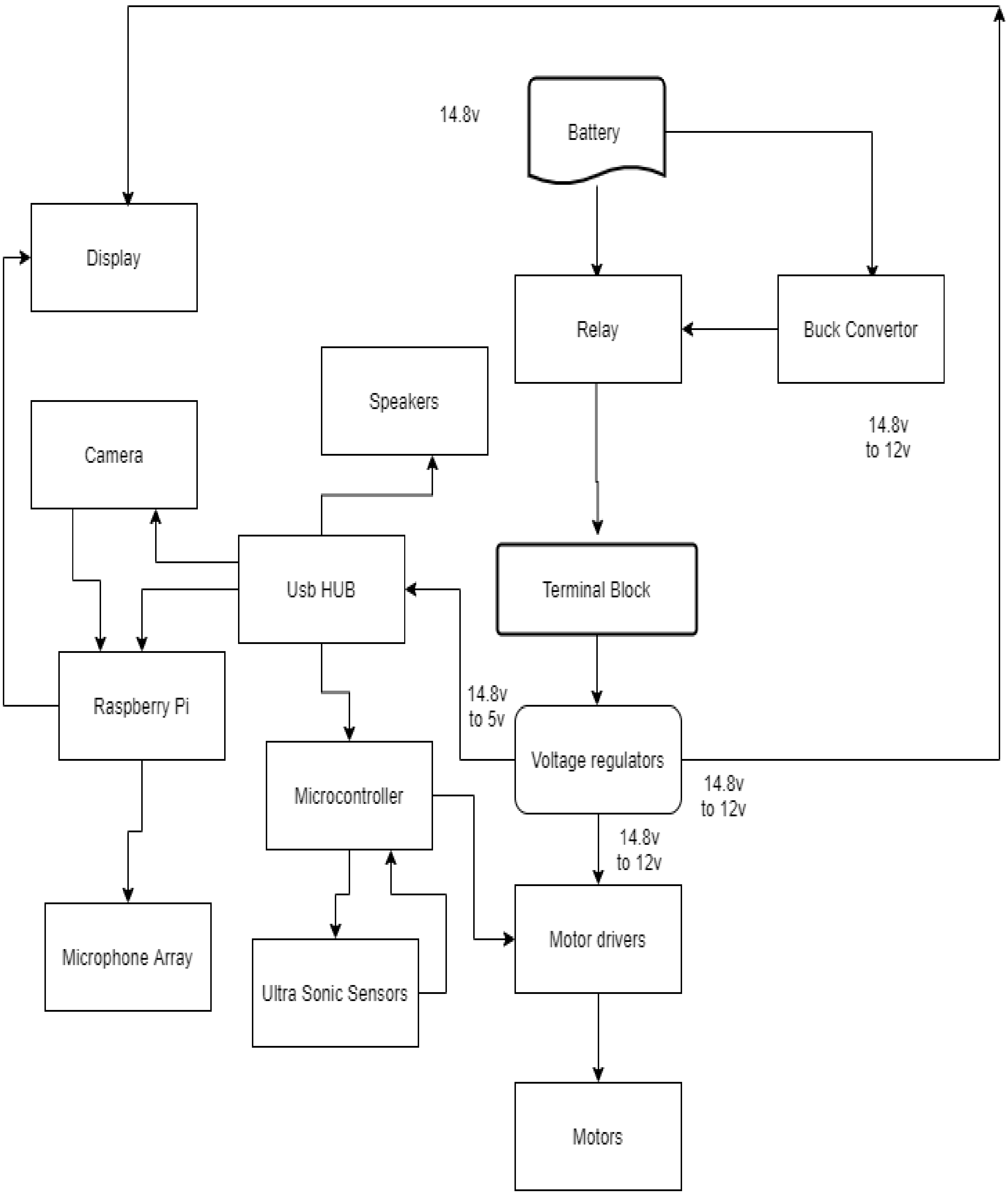




d. Speakers

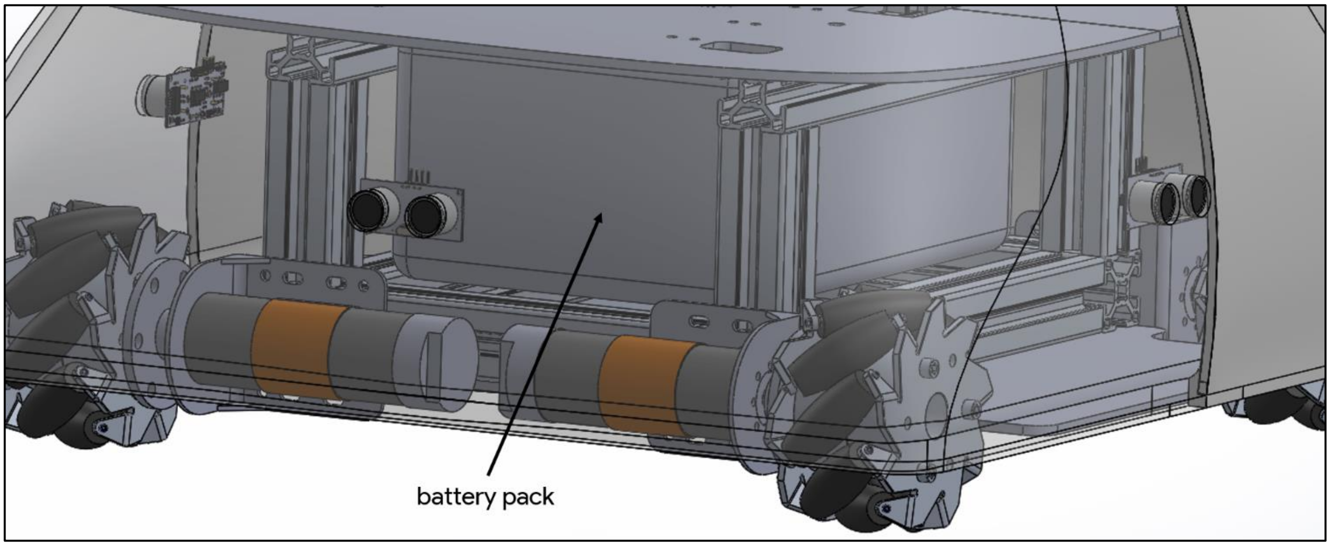
Speakers help the robot speak to the user through voice. It is also used to call out emergencies, battery low indicators, obstacle removal and voice communications and sounds for the infotainment display device. This includes interactive conversation with the built-in chat bot, providing educational content, music and announcements. The speakers are located inside the body of the robot. Power supply for the speakers are received from the USB hub.

2. **Electronics:**
The electronic components and their functions can be described by the flow chart given below.



Electronic Components:

a. Battery
The power supply for the robot is received from a Li-ion battery pack with output voltage of 14.8 V DC. The battery pack is placed in the bottom frame of the robot.



b. Relay
The relay module is used as a kill switch to protect the components used in the robot if any failures occur.

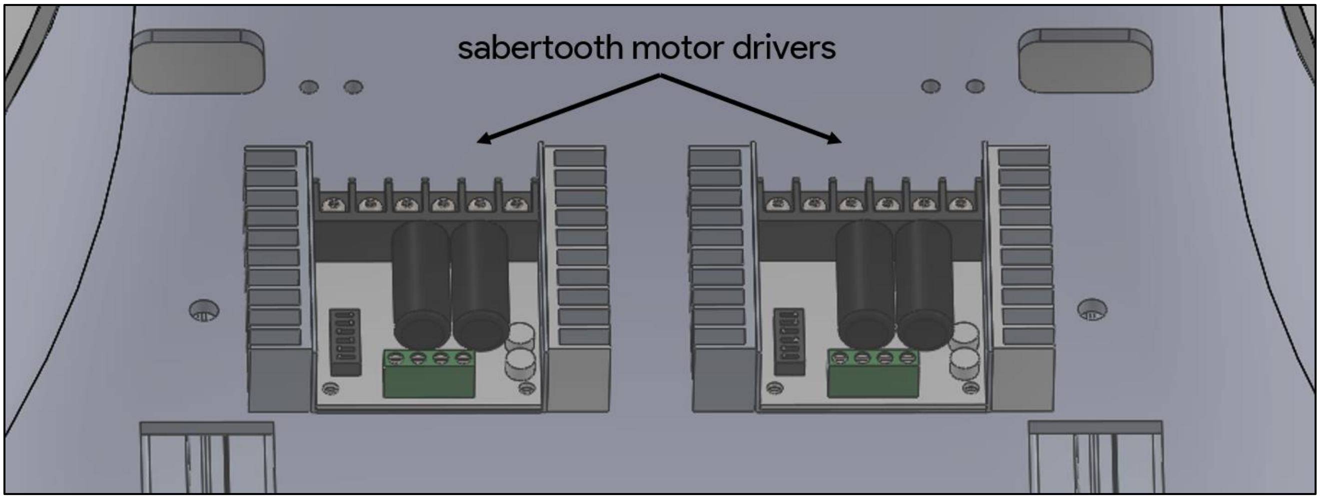
c. Buck converter
The buck converter is used to regulate the battery voltage and covert it from 14.8 V to 12 V. Since few devices in the robot uses 12 V, they can be directly powered without any more converters.

d. Voltage regulators
Electronic devices used in the robot require different voltages to run. Therefore, a voltage regulator is used to convert the voltage to the required stepped-down voltage.
(i) Display: 12 V
(ii) Motor drivers: 12 V
(iii) USB hub: 5 V

e. USB hub
The hub receives 5 V supply which is then distributed to the Arduino controller, speakers, camera and the Raspberry Pi controller. They all receive power through a USB chord.

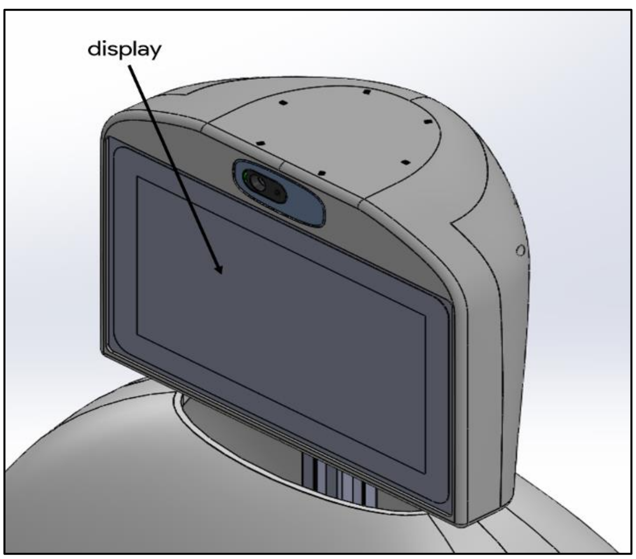
f. Motor drivers
The robot uses two Sabertooth motor drivers for four motors. This motor driver is specifically used because it has support for Mecanum wheels used for the movement of the robot. The drivers run at 12V and receives PWM inputs from the controller. Sabertooth motor drivers provide different modes of operations. For this project we use Mode 1; Analog input mode. Analog input mode takes one or two analog inputs and uses those to set the speed and direction of the motor. The valid input range is 0 V

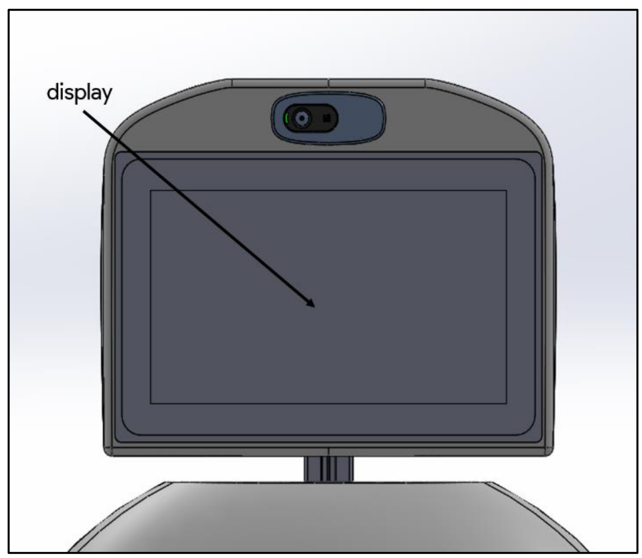
to 5 V. This makes the Sabertooth easy control using a potentiometer, the PWM output of a microcontroller (with an RC filter) or an analog circuit.



g. Display

The display is used to show the robots interactive app which is made for the user. It shows general details of the robot and functions and controls the robot can perform. The display is also used for video communications too. The 10-inch touch display allows the user to command the robot to do actions like, direction to a machine, how to use a machine, contact someone, user-guide for a machine, play songs and many more. It also displays the interaction with the chat bot built for the robot.





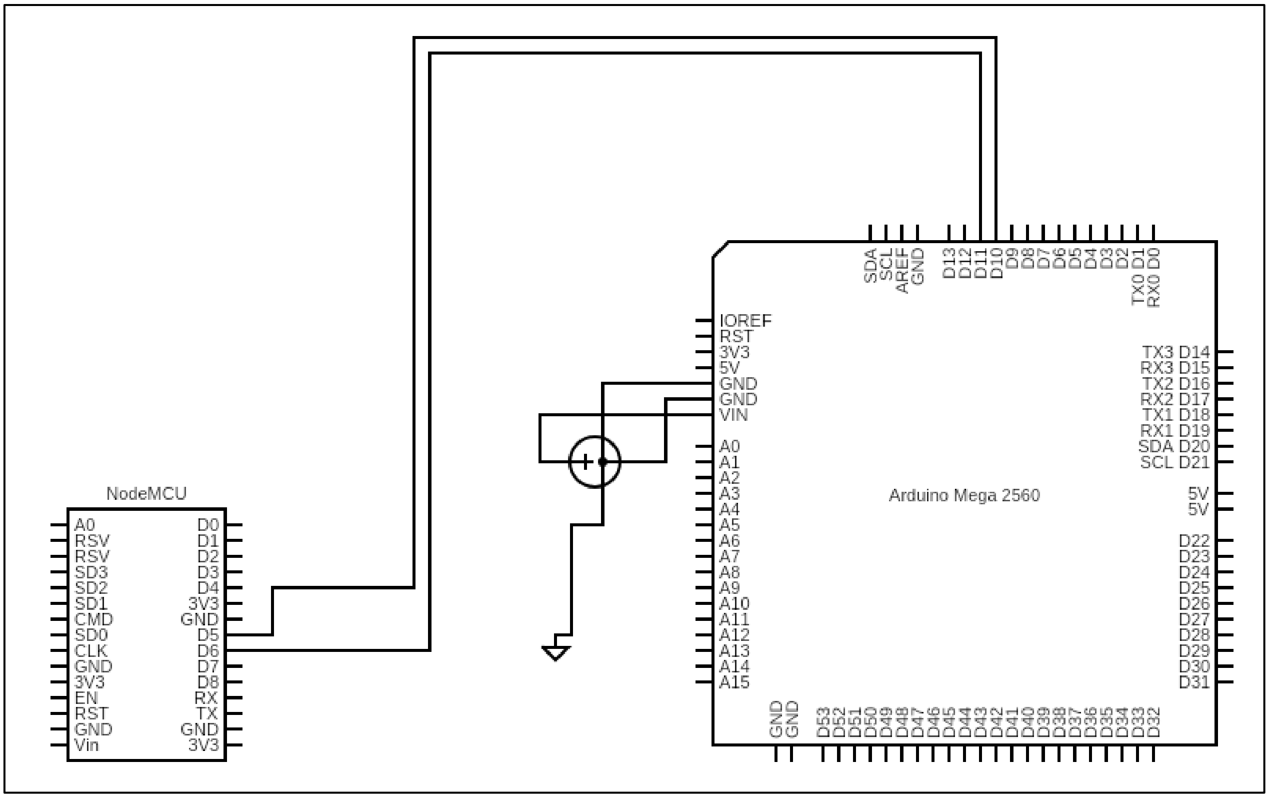
3. **Controllers:**

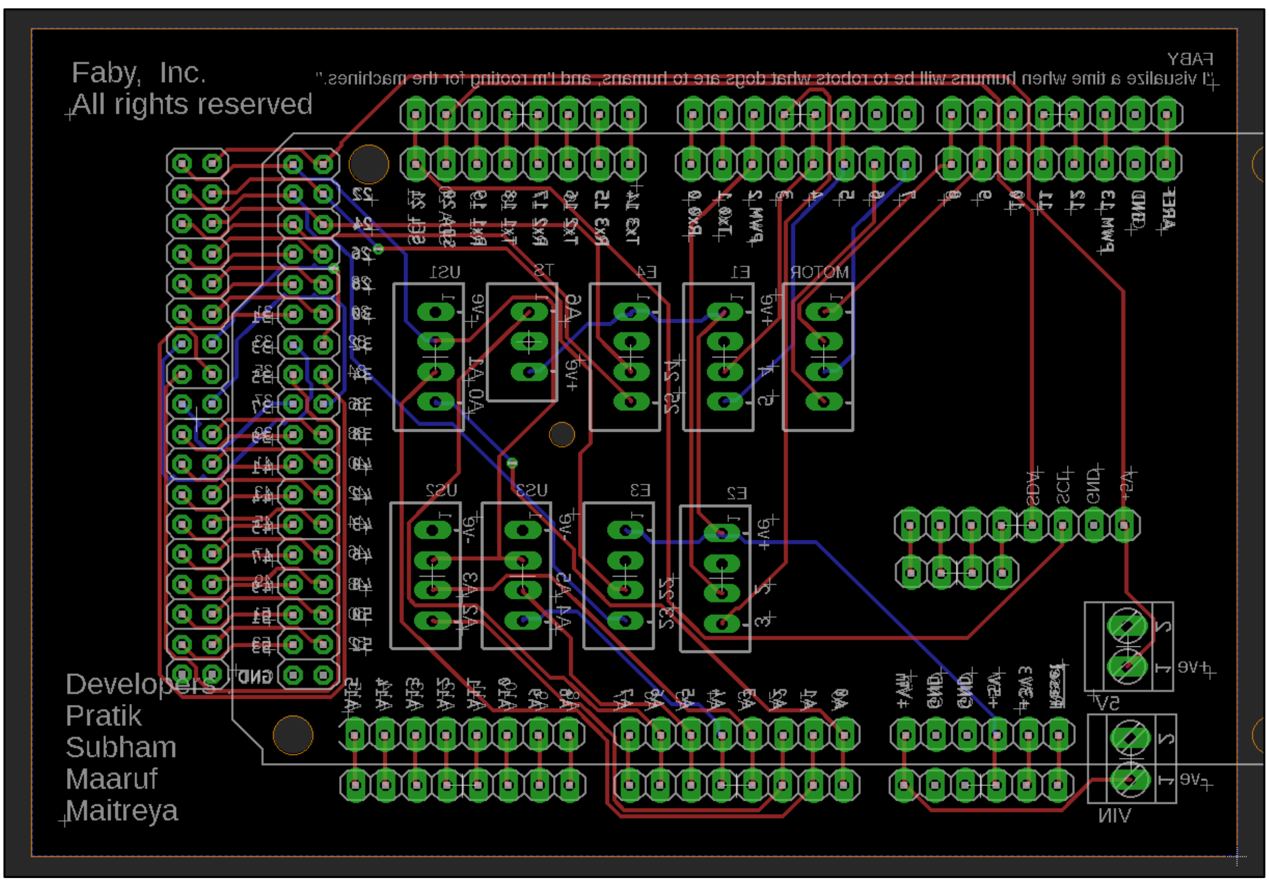
(i) Arduino Mega

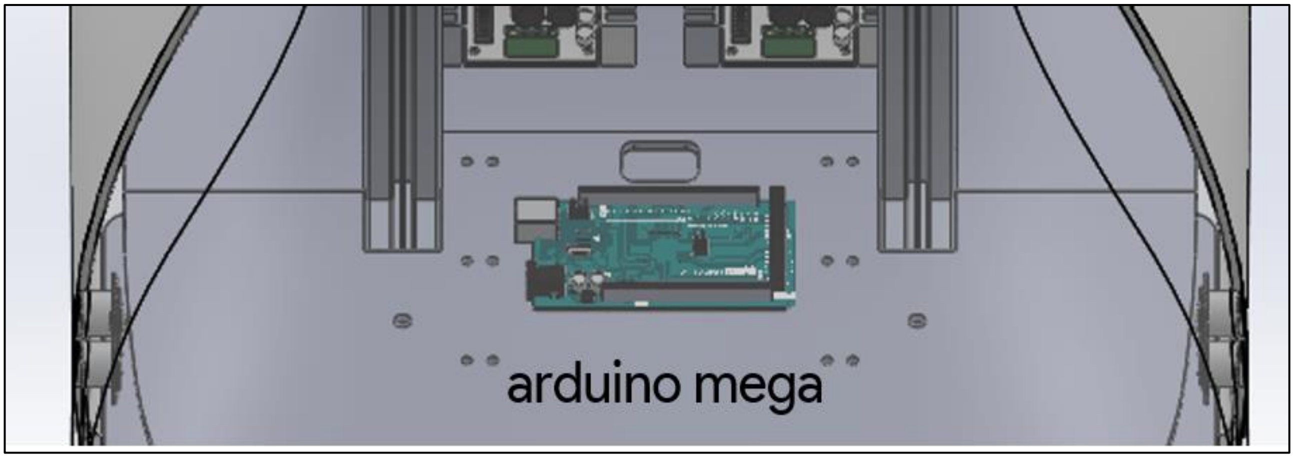
This controller is used for robot locomotion. This controller is used to send PWM inputs to the motor drivers which then move the motors. The controller also receives sensory signal from the ultrasonic sensor to detect obstacles in the path of the robot. The controller is powered from the USB hub. The controller is also attached with a custom-made shield to reduce wiring on the controller. The controller is placed at the base of the robot frame.

Custom Circuit Board:

A custom shield was made for the Arduino controller used in the robot to reduce complexity and jumbling in wiring.

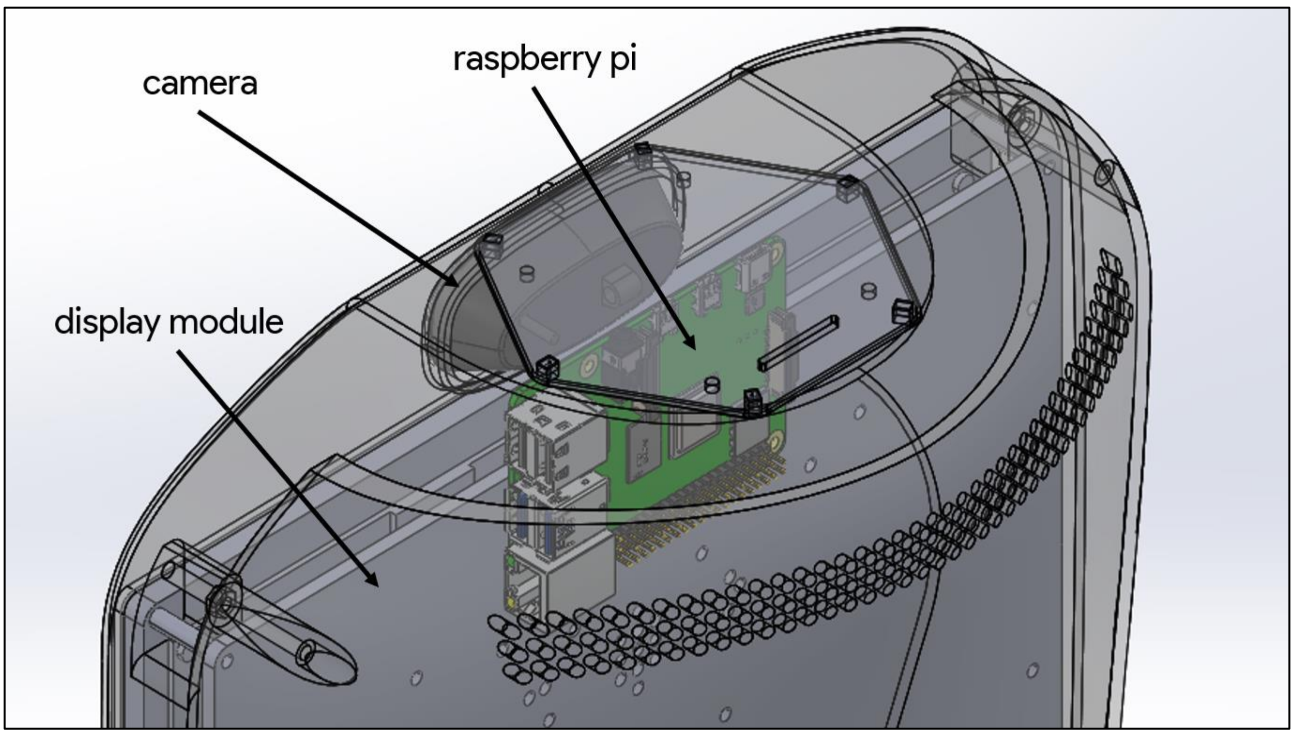






(ii) Raspberry Pi

This controller is used to control the camera, display and the microphone array. All the interactive components of the robot are handled by this controller. It receives it power supply from the USB hub. It is placed in the head of the robot along with the camera, microphone and the display.

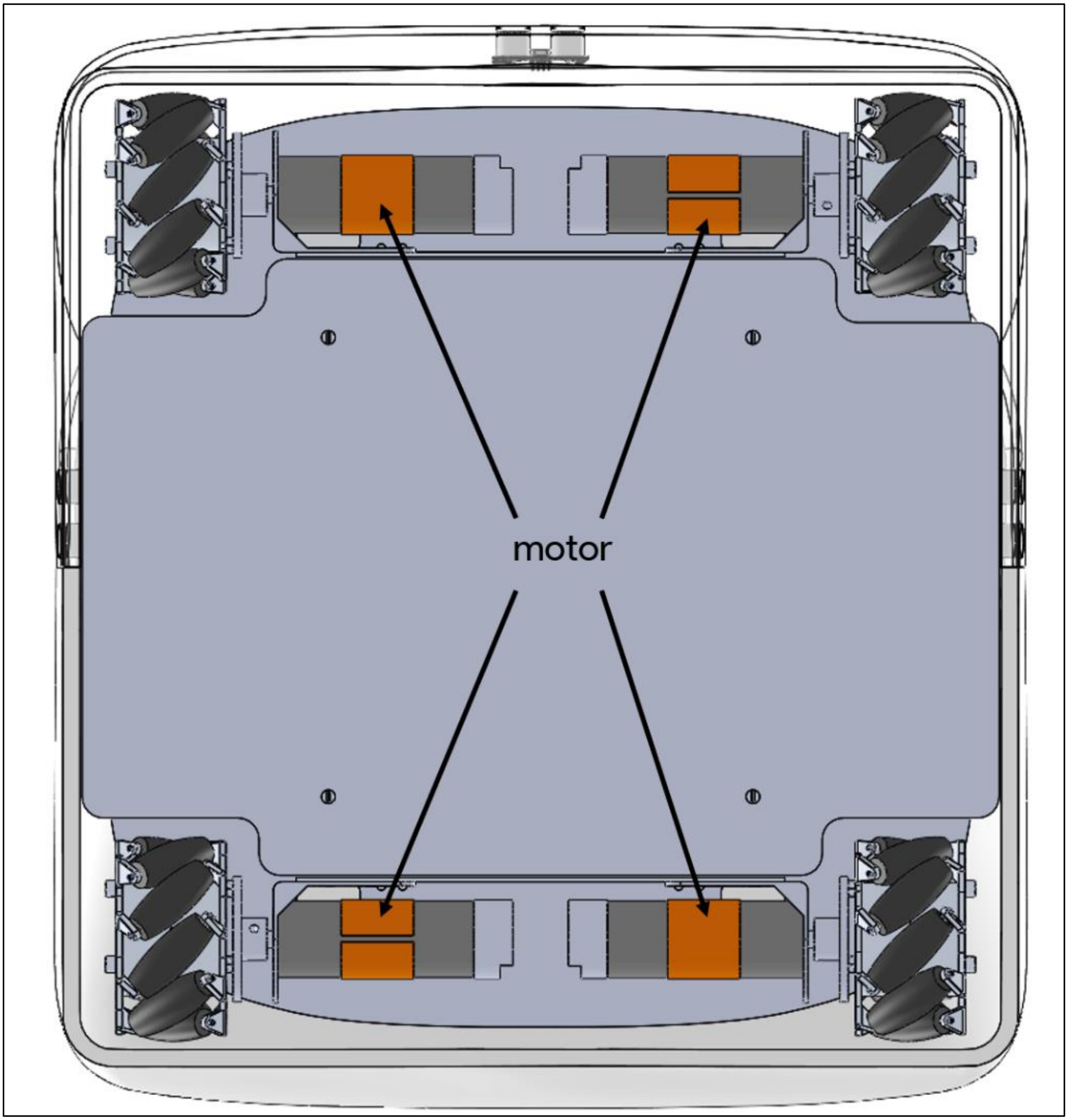


(iii) NVIDIA Jetson Nano

This controller is the most powerful controller among the above mentioned and hence it used for the higher order calculations required to run the program. This controller is used as a mini onboard computer running major algorithms for the path planning of the robot. It also receives heavy sensory data from the Realsense camera which is used for obstacle avoidance and pose estimation of the robot using markers.

4. **Actuators:**

The only actuator used in this robot is motors. Orange Planetary Gear DC Motor with specifications of 12V, speed of 185RPM and torque of 72.5 N-cm is used for driving the robot. This motor was selected considering the performance required by the robot and taking into account the weight of the robot. These motors are coupled with Mecanum wheels which require special control of the motors rather than traditional control of a four-wheel drive. This gives the robot more freedom of movement. The motors have encoders coupled along with them which gives feedback to the Arduino controller.

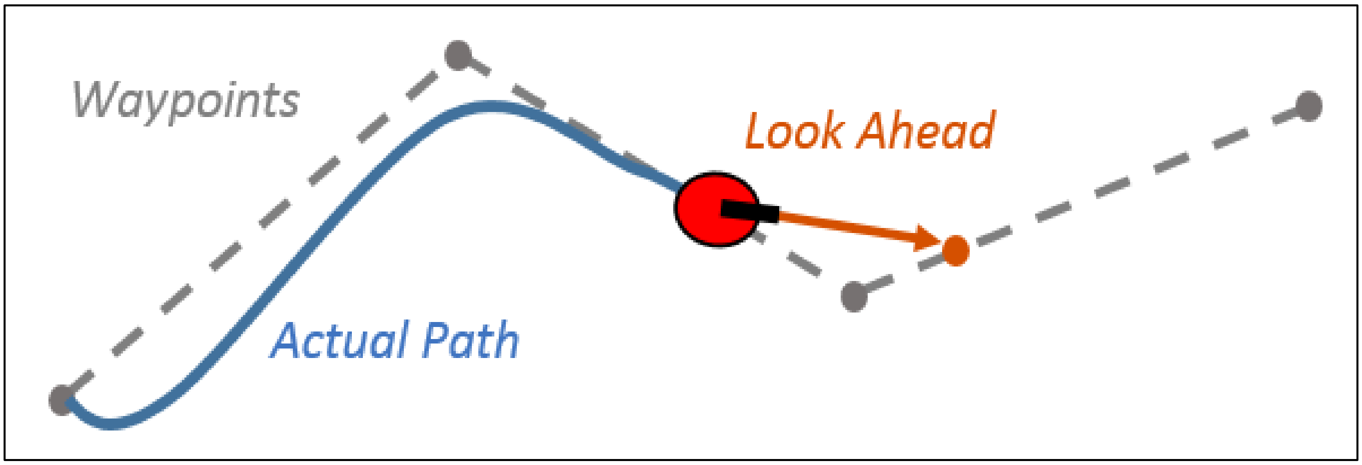


1. **Path Planning**

(i) Pure pursuit controller:

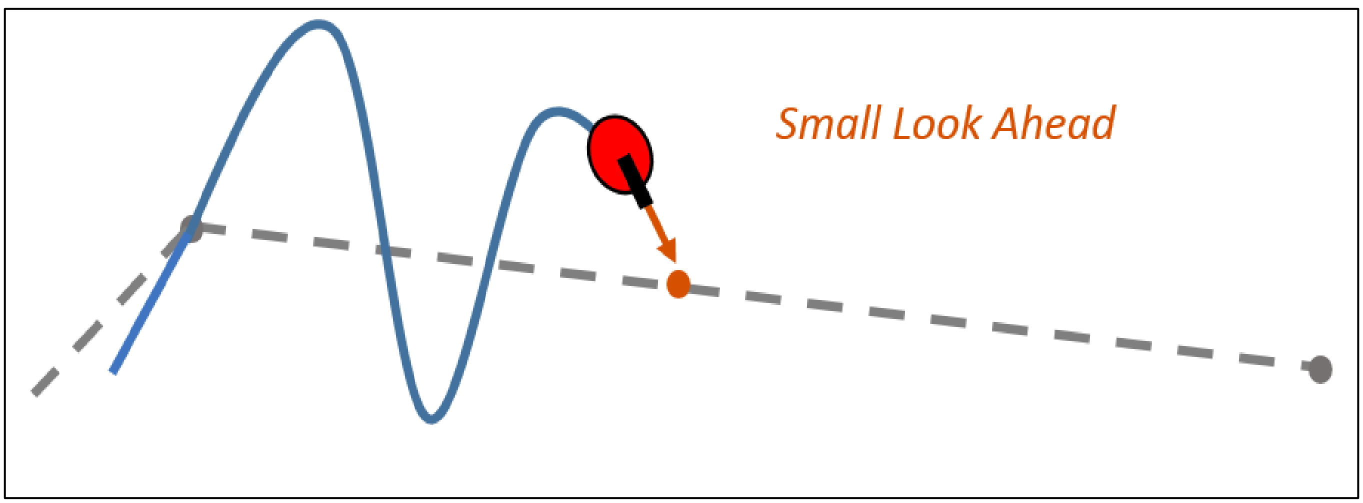
It is an algorithm which calculates the angular velocity required by the robot to reach a point. When the robot reaches the point, the algorithm shifts the point further based on the current position of the robot. This continues till the path is completed. The property LookAheadDistance decides how far the point will be placed. There are certain advantages for this algorithm. The desired linear and angular velocities can be specified.

But there are few things need to be considered for this algorithm. How far the look ahead point should be placed is a question.



Like what is shown above, the robot may not move exactly the way we want in between the current position and the look ahead point. One way of solving this problem is to keep less distance between look ahead point and current distance.

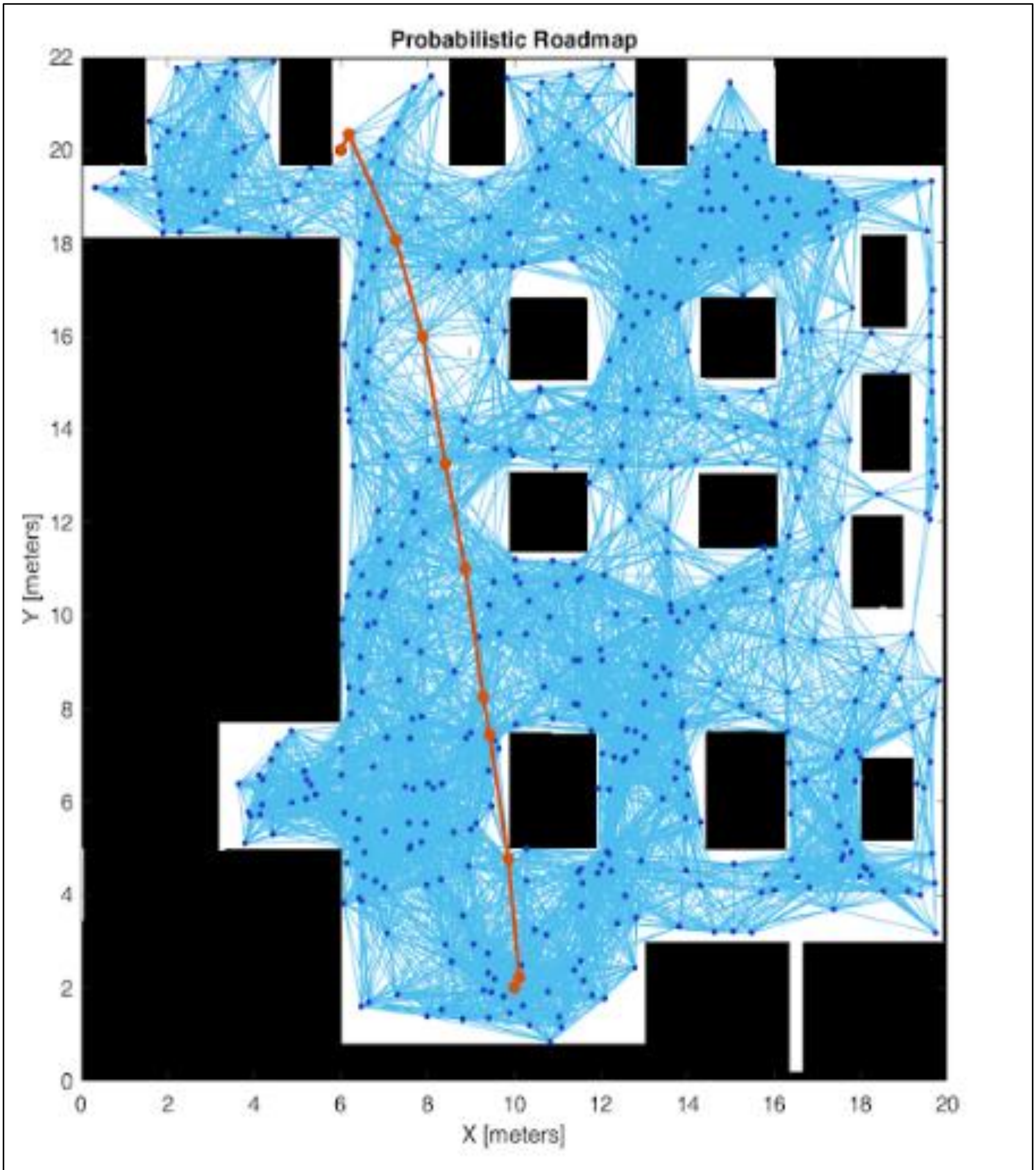
However, the robot may start oscillating along the desired path as shown and to lessen the oscillations, larger look ahead distance can be chosen.



In other words, the look ahead distance should be tuned carefully.

(ii) Probabilistic roadmap (PRM):

PRM is used to find the obstacle free path from starting location to end location. For this, first a environment map is specified. The mobileRobotPRM object uses this map to generate a roadmap with possible path in the map based on free and occupied spaces. Then, the mobileRobotPRM path planner generates nodes throughout free spaces. Nodes are then connected and a path is created which can be found using the findpath method.



(iii) MATLAB code:

In the code, first, the arena image was converted into a binary image. Then, initial coordinates were given. Then, coordinates (x and y) of each destination area in the map were given. Then, trajectory was plotted between the initial location and destination. Then PRM planning was used. It's number of nodes were set along with the connection distance. Then start and end locations were given and the path was figured. Then, using pure pursuit algorithm, a lookahead point was generated. Then the angular velocity for reaching the lookahead point is calculated and the robot is instructed to move.

(iv) For remote control:

For remote control, nodemcu and arduino mega is used. Nodemcu is a WiFi module which is used so that the robot can be controlled from a mobile application. The nodemcu is connected to the firebase to communicate between mobile application of remote control and the nodemcu. The nodemcu is then used to control the arduino for the robot movement. Arduino mega has been used as it has enough digital and analog pins for sensors and arduino mega is a faster option for data transfer.

For the arduino code, for the movement control , loops have been run – moveForward, moveBackward, moveRight, moveLeft , backwardright, backwardleft, forwardright, forwardleft , turnright, turnleft. Ultrasonic sensors have been connected for obstacle avoidance. The distance between robot and any obstacle is obtained using the sensors and if the distance is greater than the set maximum safe distance, then only the robot will move, otherwise it will stop.

2. **Localization**

Localization is the part of robotics which helps the robot recognize its position with respect to the surrounding world. For this project we are using motor coupled, optical encoders the give feedback to the robot controller (Arduino Mega). This data can be imperfect if any slip of wheels occurs during locomotion. Therefore, we also have another system integrated to the robot for localization, which is using markers or beacons.

ArUco markers for localization:
An ArUco marker is a synthetic square marker composed by a wide black border and an inner binary matrix which determines its identifier (id). The black border facilitates its fast detection in the image and the binary codification allows its identification and the application of error detection and correction techniques. The marker size determines the size of the internal matrix. These markers are similar to a QR code but rather simple in comparison. They are especially identifiable markers with an image data that holds a number that describes the marker. With a camera and a machine vision algorithm the marker can be identified and by which the pose of the camera located on the mobile robot can be estimated. These markers can be deliberately placed in the surroundings of the robot. The pose of the all the markers are then fed in the algorithm.
For this project we use the 6x6 markers which has up to a thousand markers in its dictionaries. ArUco markers have a well-defined relation with OpenCV which makes the vision algorithms simple and optimal. Another reason for using two localization methods is to mitigate the issue of kidnapping problem for mobile robots. For our project if the robot is picked and placed in some place, as long as it can identify a marker the robot can recognize its pose.

MOBILE AND WEB APPS

Website

The faby website is made using static html, CSS and JavaScript. Firebase is used for handling when to trigger video chat calls by always checking videorequestFlag in firebase database. If the flag is set then video chat connection is established

The video chat is supported with the use of agora cdn and agora JavaScript file which allows video chat between the website and an app which shares the same agora app id.

FABY App

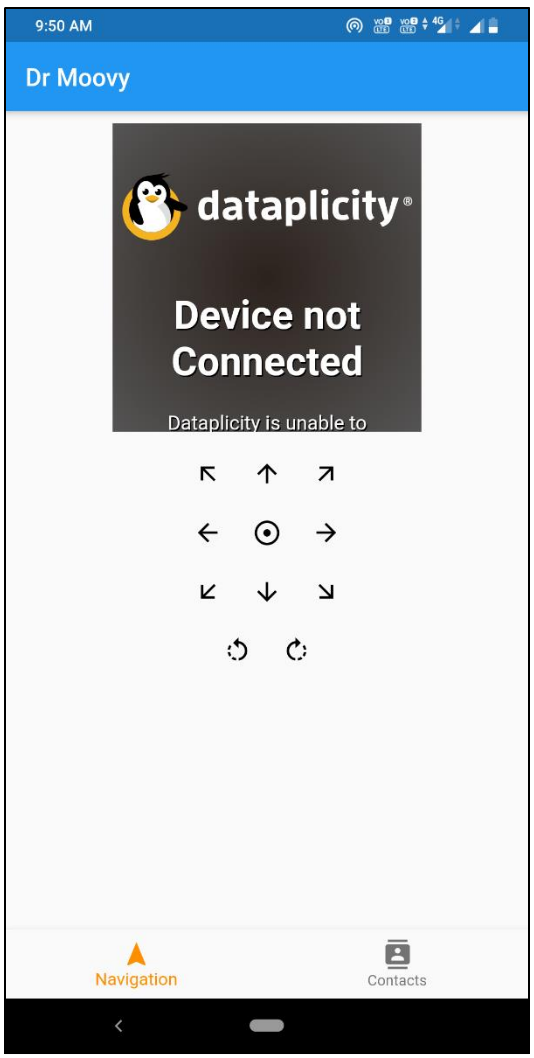
App Structure:

App structure has two major components which can be transitioned between using the bottom navigation bar.

These two components with their functions are as follows:

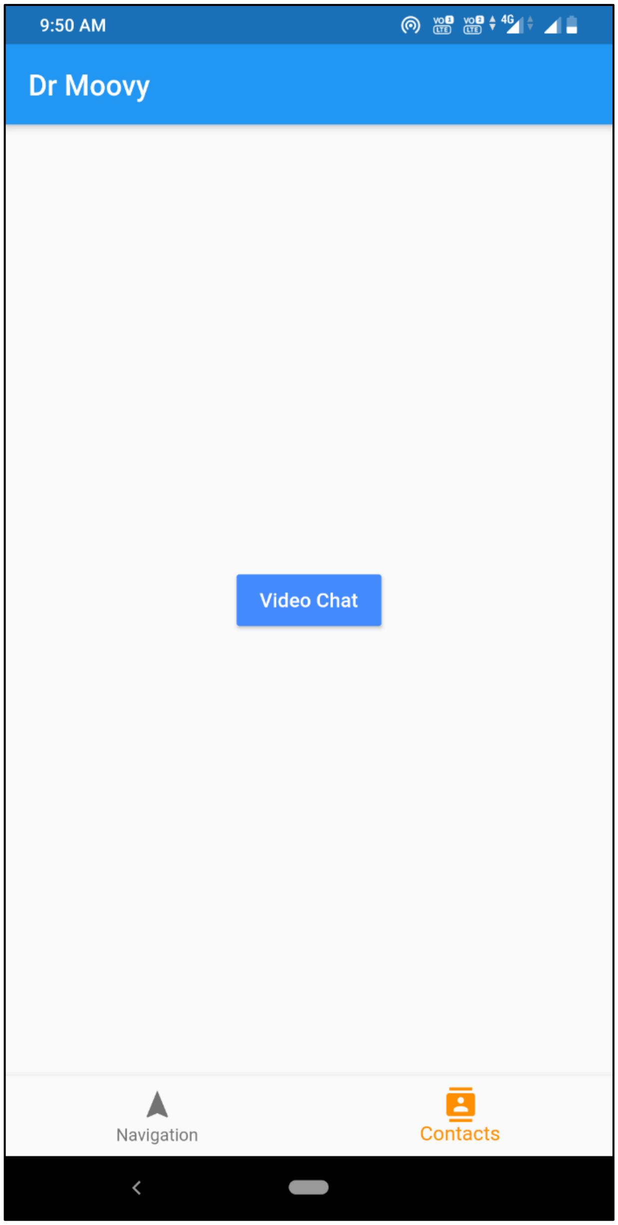
1. Navigation

   App can control the movement of the FABY robot with buttons for each direction as well as for rotation in clockwise and anti-clockwise direction. The feed from robot front screen is shown in the app using a WebView which helps in deciding the further directions.



2. Video Call

The App uses agora video call api which helps in allowing video chats between the person next to robot with the person using this app. A button in video menu can start the video chat.



Backend Logic:

The movement of robot is possible using firebase database which has a direction key the direction key is set by pressing the direction buttons present in the app.

The video chat occurs using agora sdk which is added as a package in flutter using pubspec yaml file and pub commands. It allows video communication between the FABY website and app as they share the same agora id.