NURSIE

SUBMITTED BY

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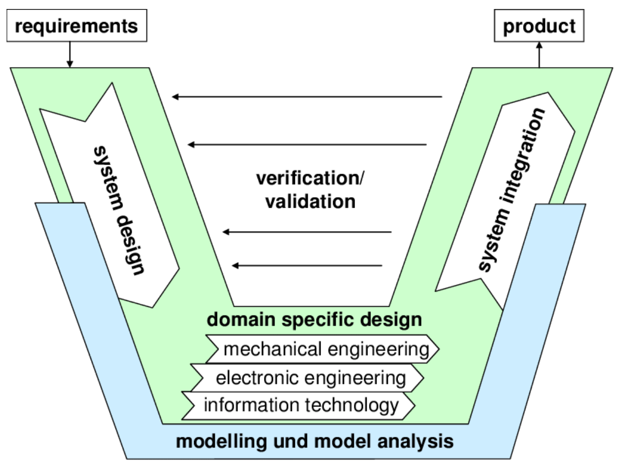
ABSTRACT

This report’s contents include a project description of the semi-autonomous nurse robot that we designed, as well as its mechanical design and working drawings needed for manufacturing, the needed electrical and mechanical components, stress analysis, actuator sizing, software architecture, and finally, a real photos for the robot and environment and link for the Full code.

INTRODUCTION

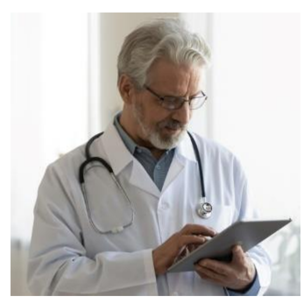
The project concept involves an initial product design phase, where the needs of various users are analyzed, and a specific need is targeted. Subsequently, the product is assessed from a business perspective, and a business model is developed.

The creation of physical system models and the application of control schemes for the development of control systems will occur within the VREP Simulation environment. Physical models will initially be crafted using SOLIDWORKS or Inventor software, and later imported into the simulation environment. We will then engage in the actual construction of the robot by manufacturing its various components, exploring different manufacturing techniques, integrating purchased parts, and testing software modules in real-life situations.



1. FUNCTIONALITY

A medical assistant robot is designed to aid doctors by semi-autonomously navigating through hospital rooms and efficiently collecting patient information via QR-code. This innovative robot is equipped with sensors and navigation capabilities to accurately maneuver around the hospital environment with line path.



It can access electronic health records and gather relevant patient data through a secure interface using raspberry pi. By doing these tasks, the assistant robot saves time for doctors, allowing them to focus on more critical aspects of patient care and improve overall healthcare efficiency.

2. PROJECT DESCRIPTION

The idea of the robot is inspired by realizing the amount of time doctors & nurses waste to get into rooms to know the current state of the patient. Instead, the doctor can ask our nurse to go to a specific room to scan patient's QR code and send it to the Doctor via Wi-Fi. Each patient's room will contain a QR code, containing each patient's information and health updates that will be detected and scanned by the robot, it will follow its path to reach that room. After, it returns to its original position waiting for the next doctor request.

In order to make it as user-friendly as possible, we created a design that is suitable for its purpose, small, compact, free of sharp edges and exposed wires to be as safe as possible & light in weight, In addition, it has the sensors it needs to detect and avoid obstacles.

3. ELECTRICAL COMPONENTS

Our robot consists of various electrical components that work in harmony together to produce the required functionality.

3.1. Arduino Mega

The Arduino Mega serves as our main controller that reads the line follower sensors and obstacle detection sensors, then sends the required speeds to each motor. It also communicates with the raspberry pi to notify it to start and stop the camera functionality.

3.2. Arduino Uno

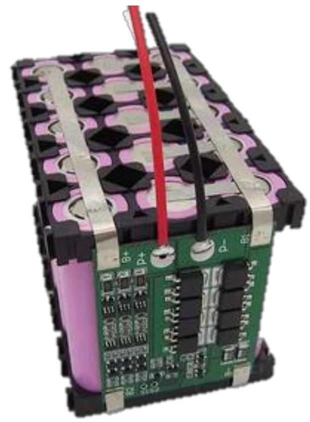
We have 2 Arduino UNOs that serve as PID controllers for each motor, their function is to read the motor speed from our magnetic encoders (AS5600), therefore control the motor speeds.

3.3. Molly PCB Arduino

We have a custom-made PCB that serves as a battery indicator using 4 LEDS which indicates the charge level of the battery.

3.4. LM2596S DC-DC Converter

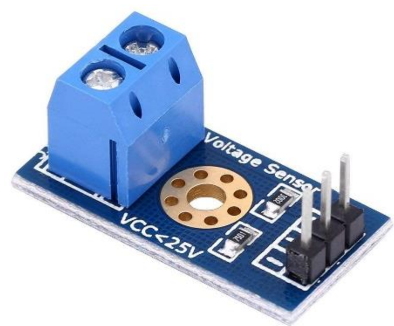
This buck converter is responsible for converting 12V from battery to 5V to the raspberry pi, it’s also used to produce 5V for some sensors such as the obstacle detection sensors.



3.5. Lithium Battery Pack With BMS

This is our main source of power, a custom-made 12V battery having a 3S,5P configuration with a Battery Management System for protecting the battery and all electrical components.

3.6. Voltage Detection Sensor

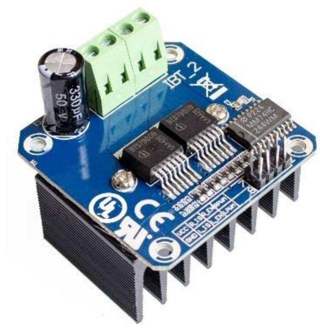


This sensor is used to measure the battery output voltage, and the reading is sent to the PCB Arduino to indicate the battery level to the user using LEDS.

3.7. DC 775 Motor

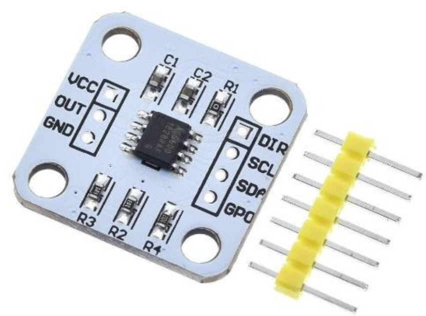
This is our DC motor, it has the capability to operate at 24V 15000 RPM, but we are only operating with the installed battery of 12V.

3.8. BTS 7960 Motor Driver



This is our motor driver for our DC motors (of a rated consumption 10.2 amperes), while a normal H-Bridge(L298n) can only supply 2 amperes which is insufficient for our motor's current consumption.

3.9. AS5600 Magnetic Encoder



This is our 12-bit magnetic encoder, it is used to measure the motor speed with high precision to perform PID control on our motors. They communicate to our ARDUINOs using I2C communication.

3.9. Raspberry Pi

This raspberry pi is responsible for operating the camera and scanning the QR codes, it also communicates with the GUI via wireless communication, and also communicates with the Arduino Mega.

3.10. Emergency Push Button

The emergency push button acts as a kill switch in case of any emergency to shut off the robot and separate the power supply from the circuit, it has a capacity of 10A which is optimal for our circuit.

3.11. Sharp IR

This IR sensor is used to detect any obstacles in front of the robot ranging from 10-150 cm.

3.12. Proximity Infrared Sensor

This sensor is used for detecting any obstacles on the sides of the robot.

3.13. Red Switch

The red switch is used to turn on/off the robot, to separate the power supply from the circuit.

3.14. Terminal Blocks

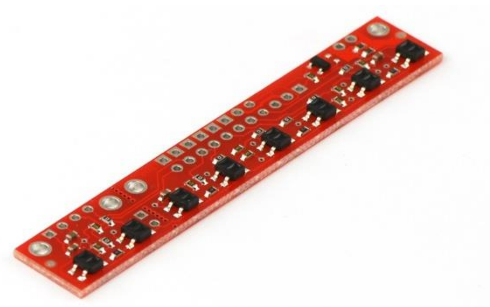
Terminal blocks are used as connecting nodes instead of previously used breadboards, and it has a capacity of 15A and 600V.

3.15. Female DC Jack

This DC jack acts as our charging port to charge the battery pack.

3.16. QTR-8RC Reflectance Sensor Array

It's a sensor that consists of 8 IR sensors used to detect the line path and connected to the Arduino Mega to guide the robot.

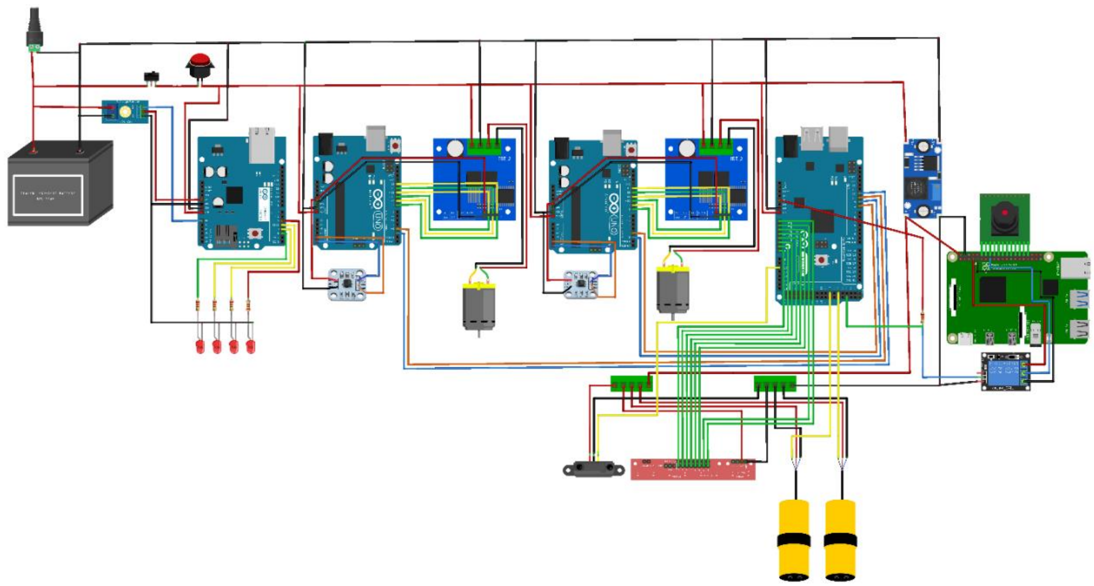


3.17. LEDS

Multiple LEDS are used to indicate the battery level.

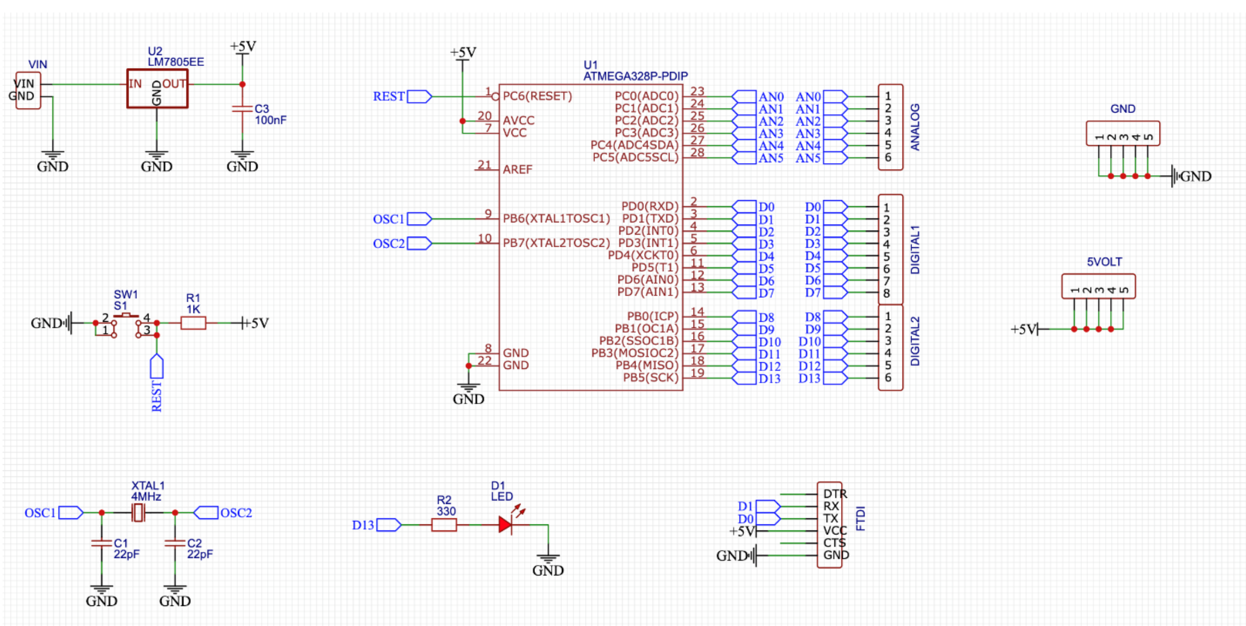
4. ELECTRIC CIRCUIT

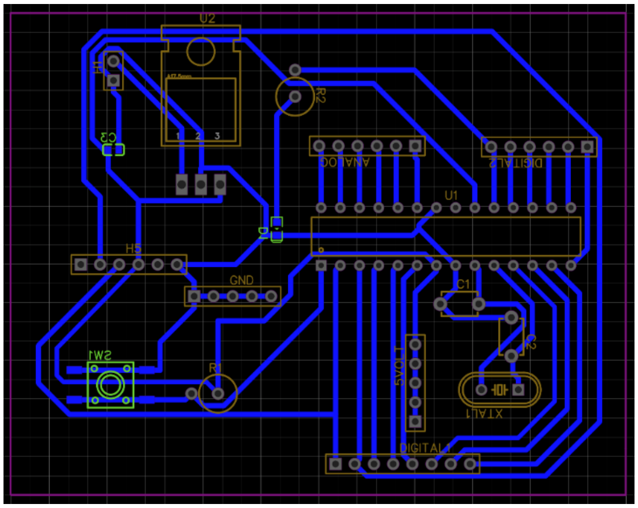
This is our circuit diagram for the full project.

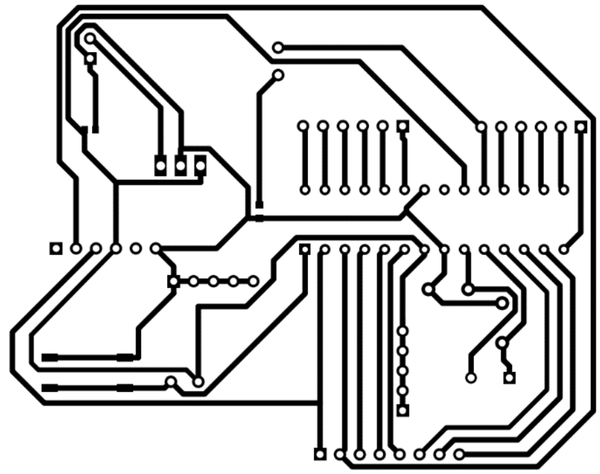


5. PCB LAYOUT

This is our custom-made Arduino PCB schematics.

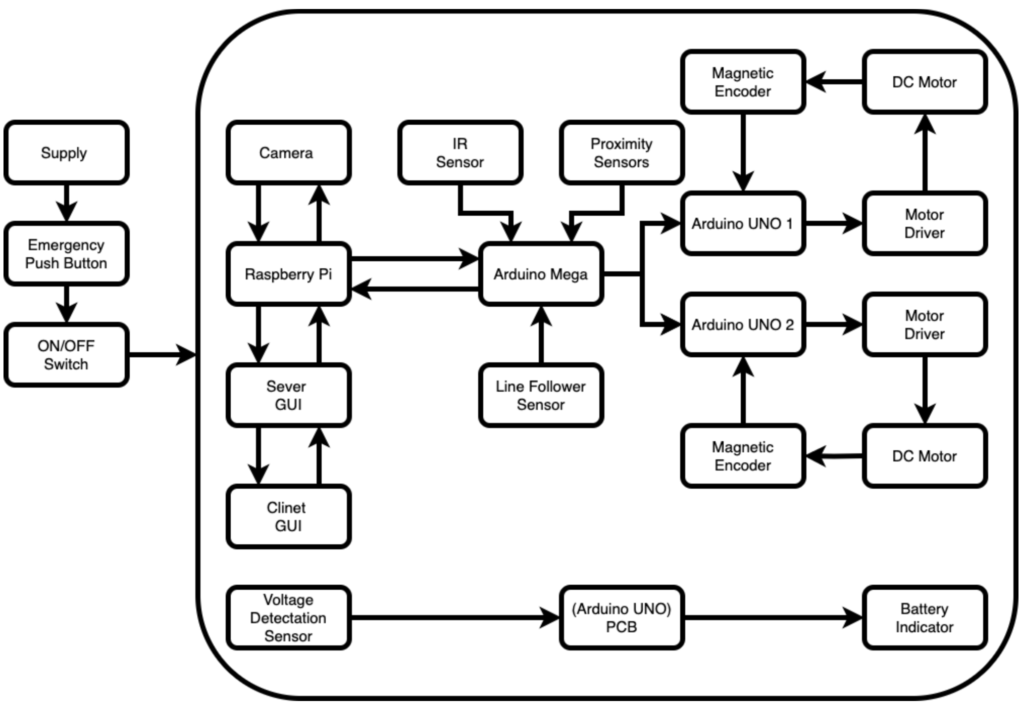






6. BLOCK DIAGRAM

This Block diagram represents our whole system as hardware/software connections.

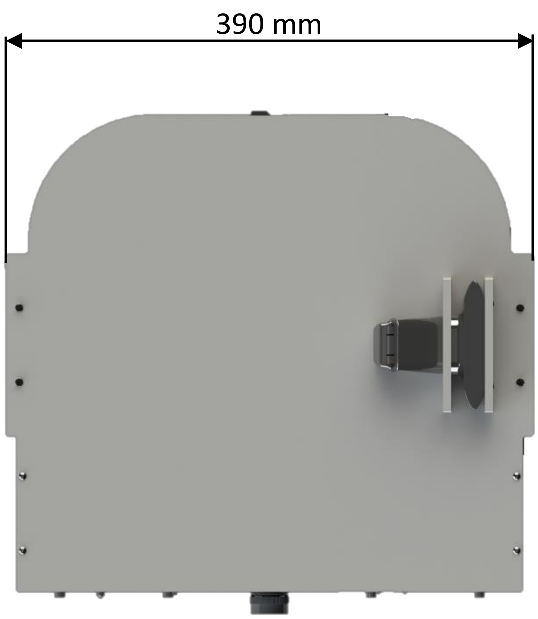


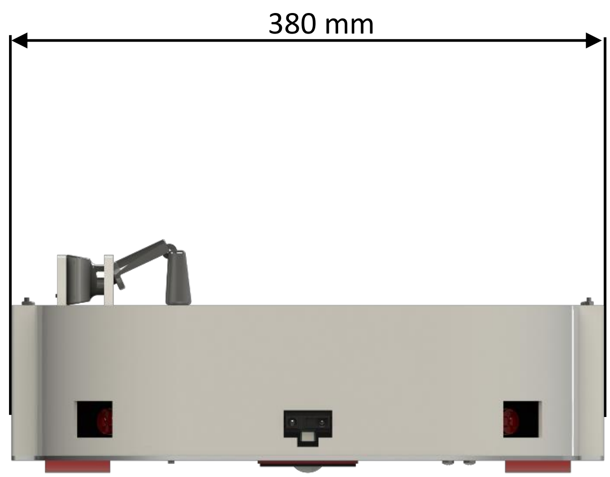
7. MECHANICAL DESIGN

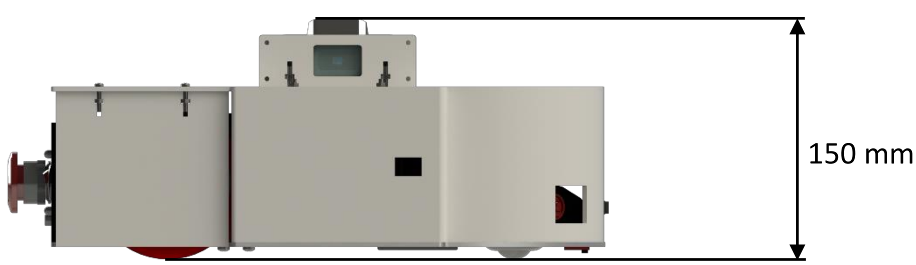
Our robot specializes in being a very compact tri wheel design which allows for low overall dimensions therefore improving our maneuvering capabilities, and allows for lower storage space for the robot, and finally lower overall weight.

Its sleek design and cover fits in any hospital environment with no sharp edges, and friendly looking for kids and adults. It is mainly created from aluminum and acrylic.

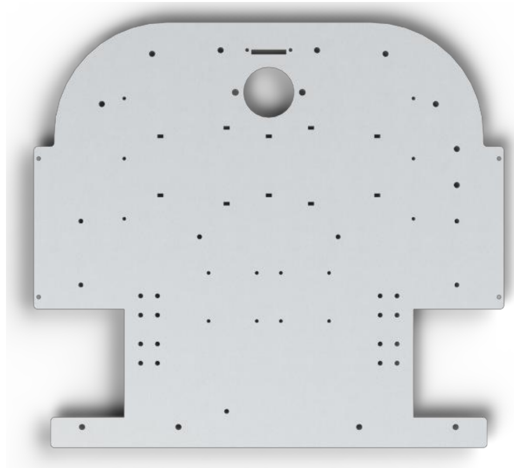
7.1. OVERALL DIMENSIONS







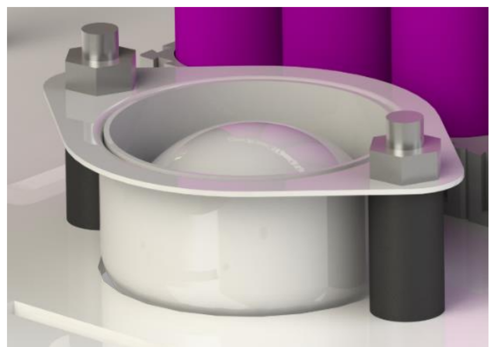
7.2. CHASSIS



The chassis is made from 3mm Aluminum metal and manufactured using metal laser cutting.

The chassis serves as the foundation of our robot, it holds everything in place and supports the entire weight of the robot. All components are fixed on the chassis using bolts, nuts, and L brackets.

7.3. CASTER WHEEL

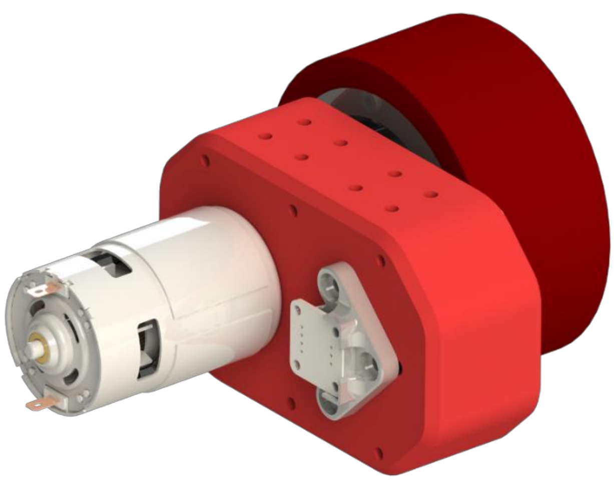


A caster wheel is used as our third wheel, we chose this wheel specifically as it can rotate in all directions without influencing the robot's maneuvering while taking turns.

The caster wheel is fixed using bolts and a spacer to ensure that the vehicle is level and has a constant liftoff distance from the ground that doesn't change due to any vibrations.

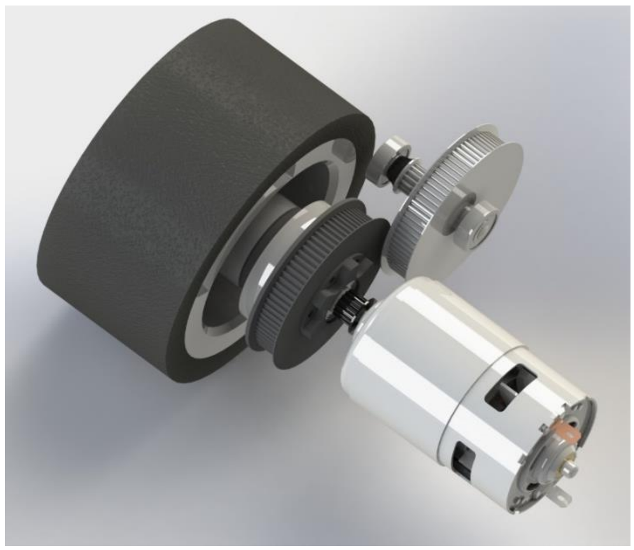
7.4. WHEEL ASSEMBLY

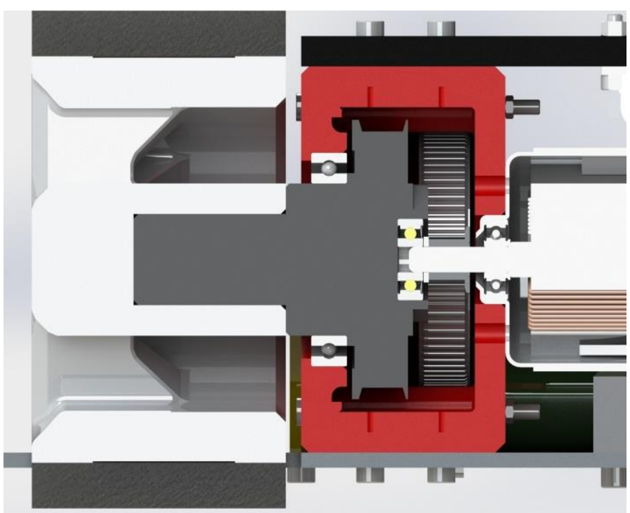
Our wheel assembly consists of a DC motor, magnetic encoder, 3D printed pulley and GT2 belt gearbox, and finally a polyurethane wheel.

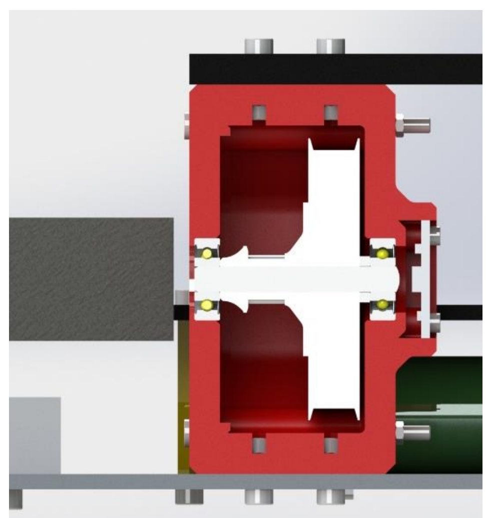


7.5. Reduction Gearbox

A high reduction ratio gearbox is used as the DC motor rotates with a speed of 15000 RPM which needs to be slowed down to be properly used I our robot, the gearbox is made of pulleys and belts to provide low noise during operation, it consists of 2 stages and bearings to provide smooth frictionless rotation.

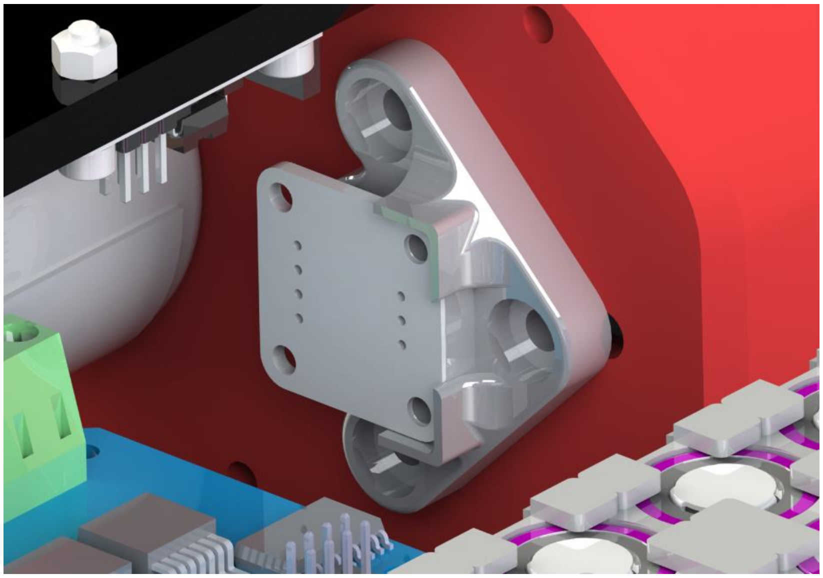




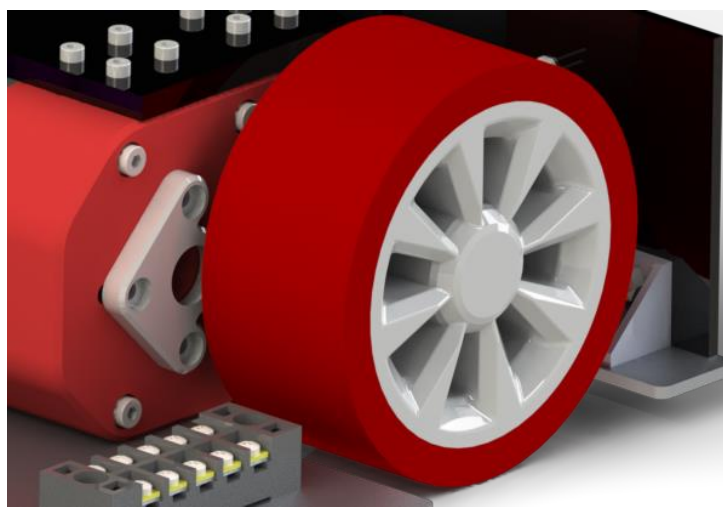


7.6. Magnetic Encoder

A 12-bit magnetic encoder is used on the rotating shaft to ensure high precision and accurate readings.



7.7. Wheel

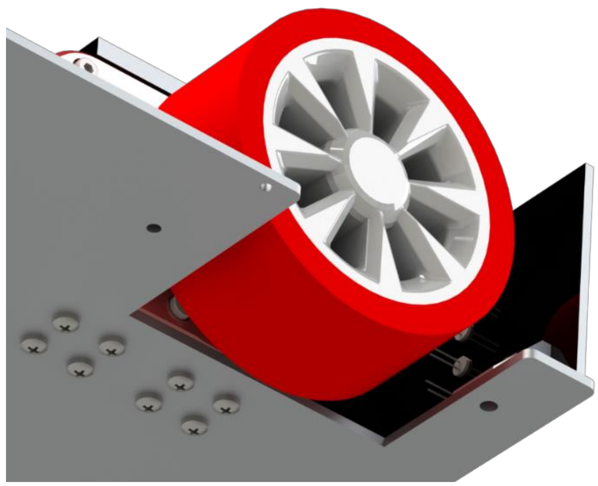


Our wheel is handmade from a mixture of silicon and glycerin casted in a pre-manufactured mold and left to be cured in a 13hrs period to reach the required hardness, and providing a very high traction and freedom of dimensions when creating the wheel.

The wheel rubber is attached to a 3D printed rim that is attached to the gearbox using 6 bolts.

7.8. Gearbox Fixation

The gearbox is fixed to the chassis using 8 M4 bolts, and inside the gearbox there are fixed nuts that is used to fix the M4 bolts.

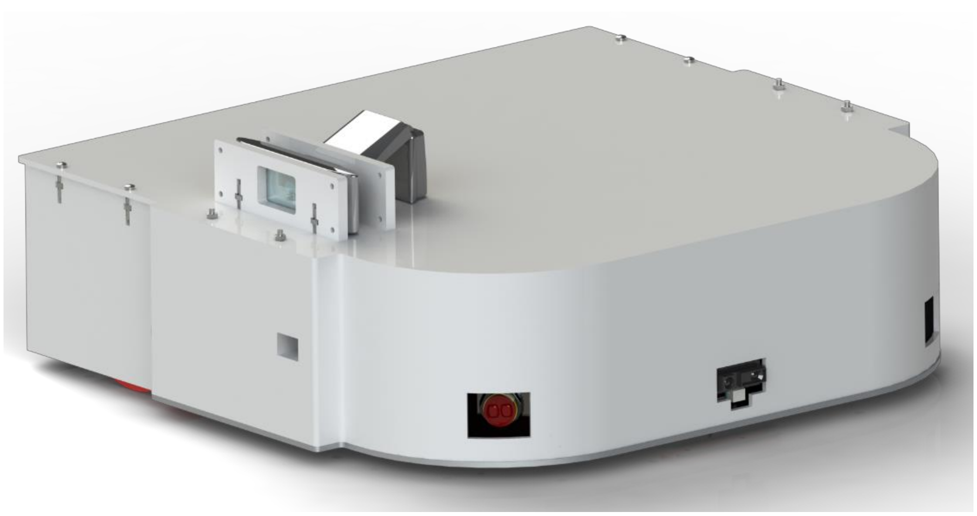


7.9. COVER

The cover's purposes are to cover the robot and isolate all its components from the outside world, it holds the camera in its place, and finally it gives the robot a more appealing and themed look.

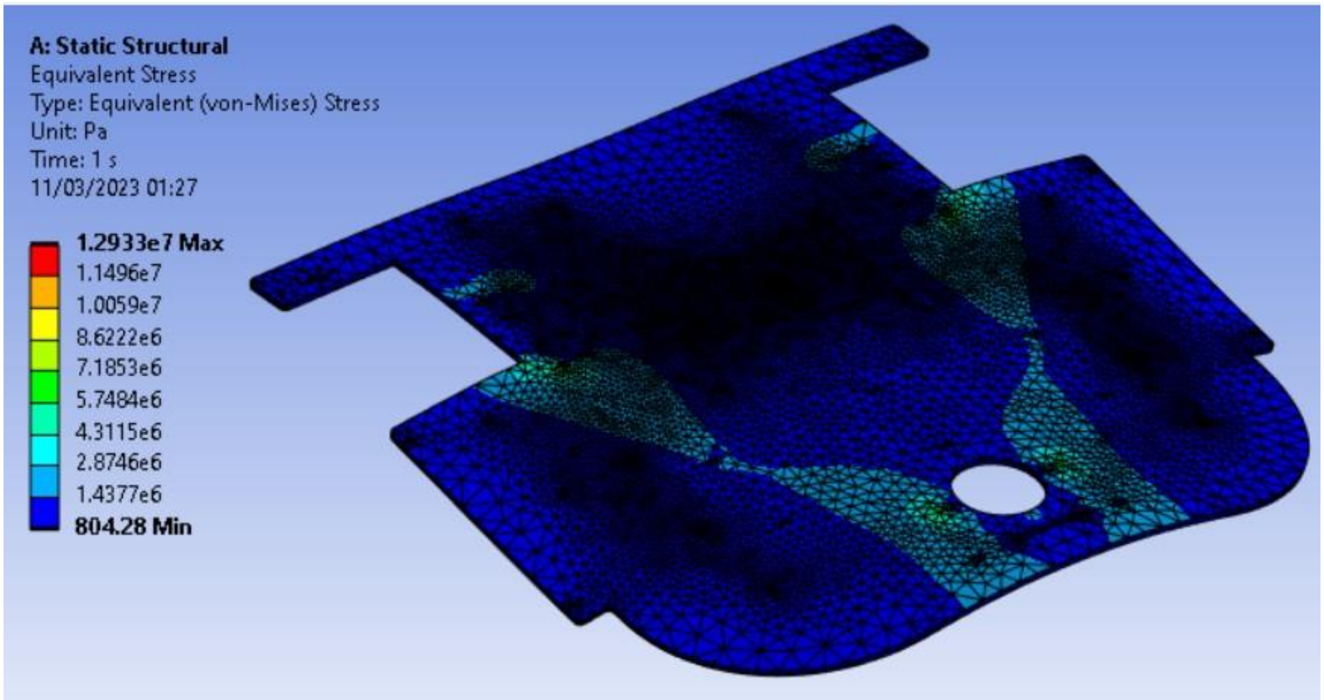
The cover is constructed of multiple acrylic layers laid on top of each other, fixed using M4 bolts to the chassis, and the camera is fixed to the top of the cover.

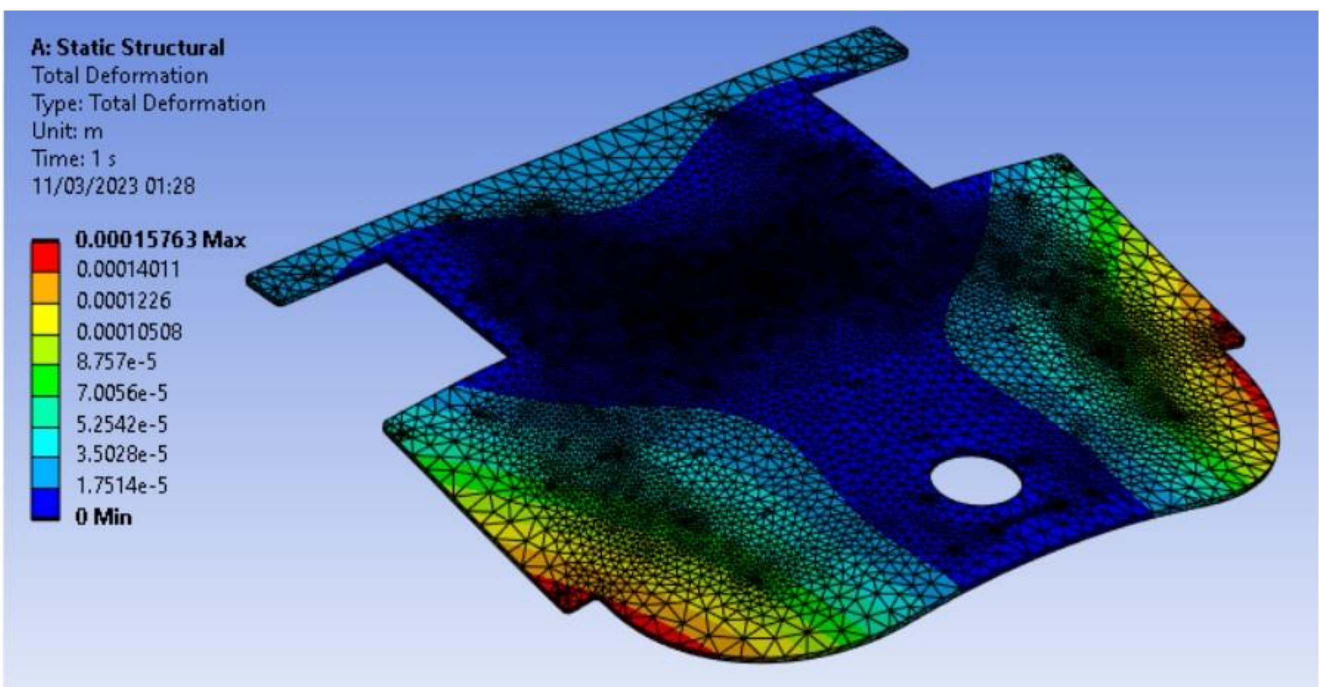
The cover is painted white to give it a nurse-like theme.



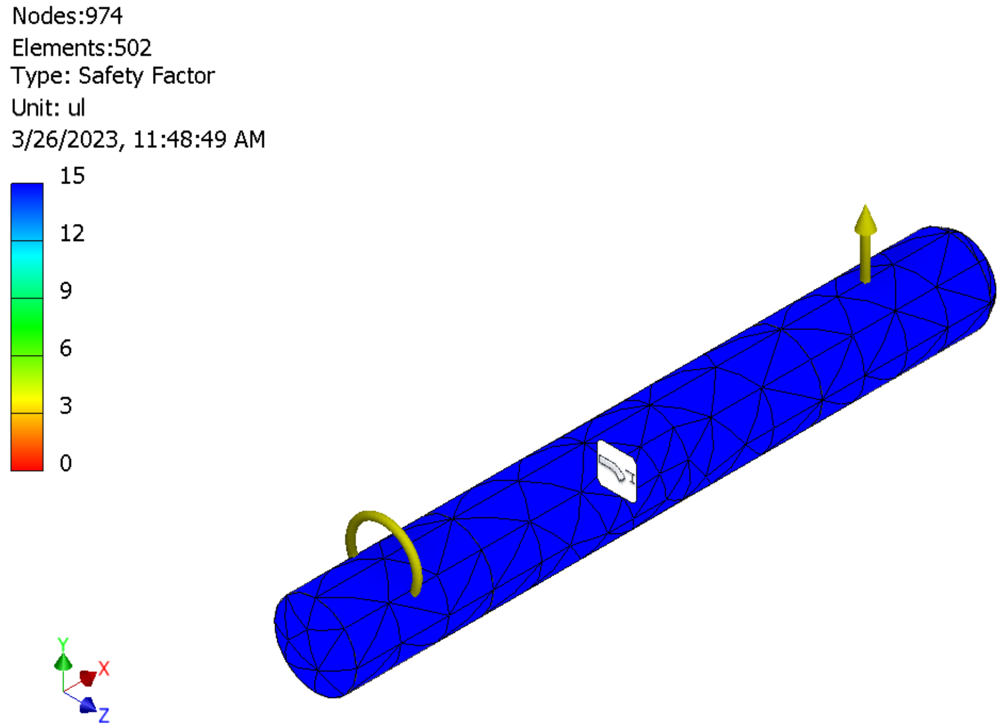
8. Stress Analysis

8.1. Chassis

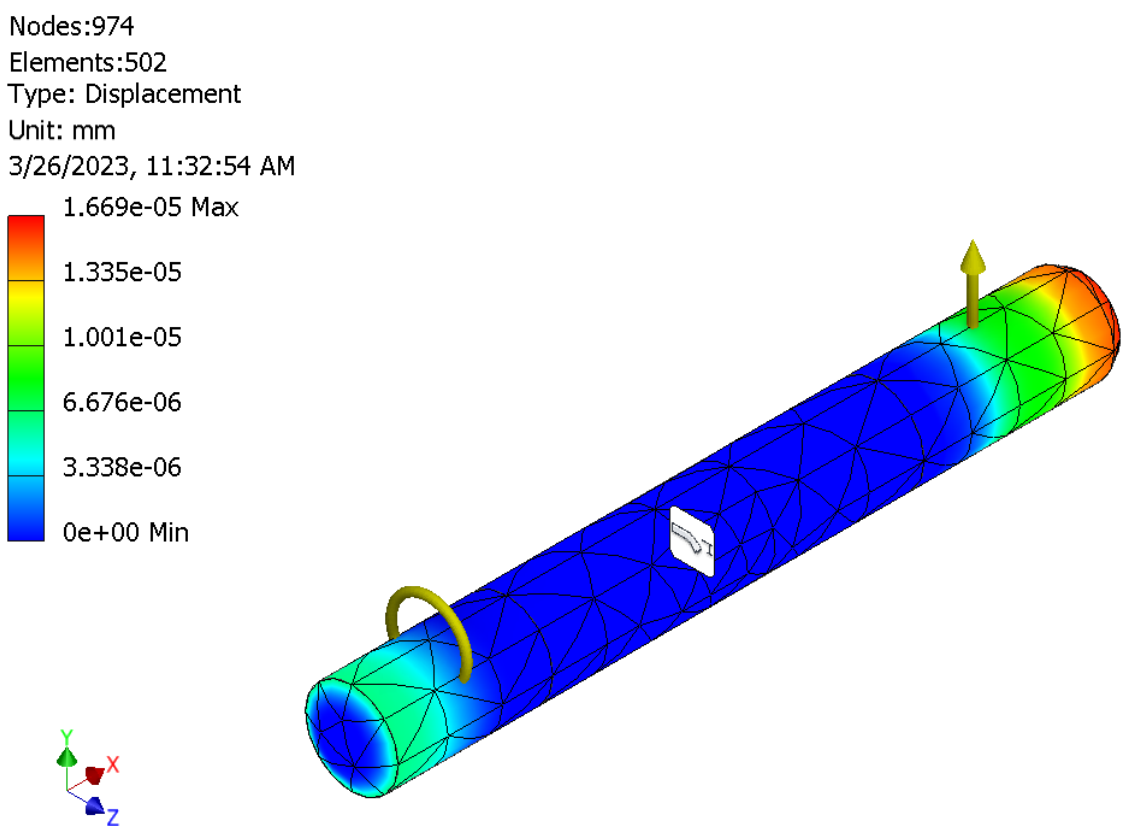




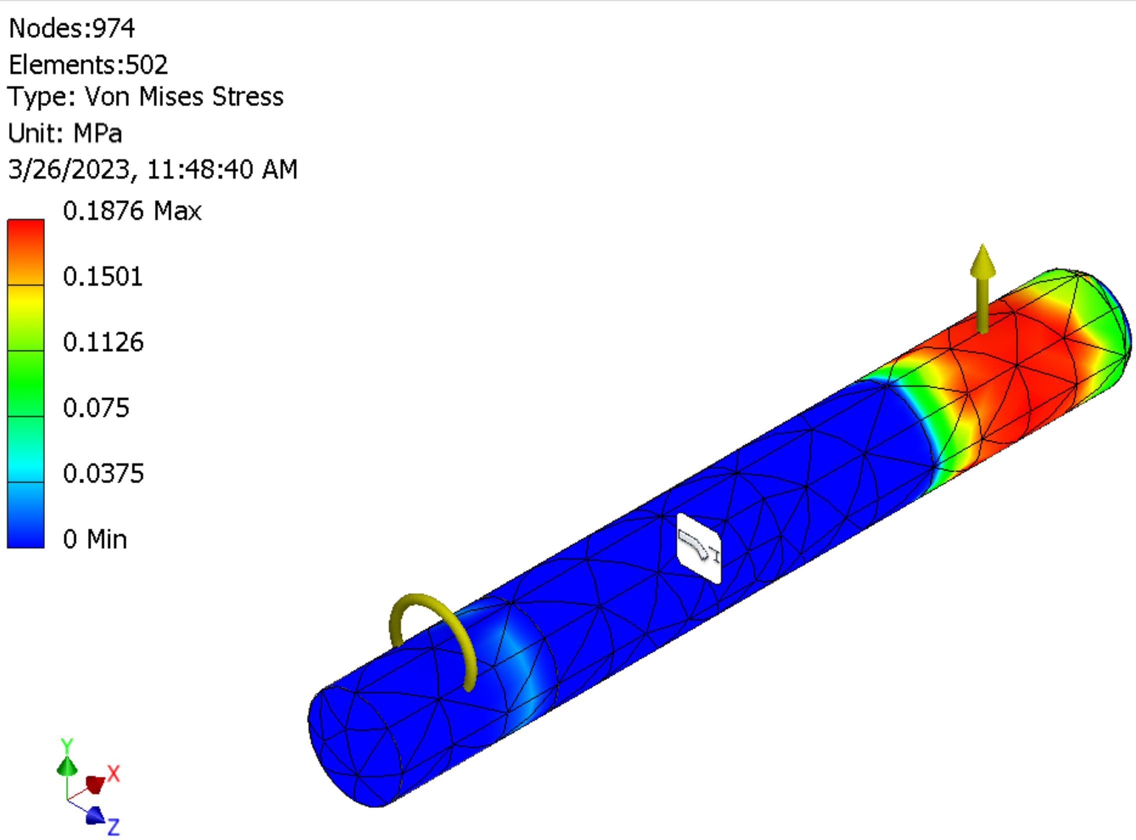
8.2. Shaft



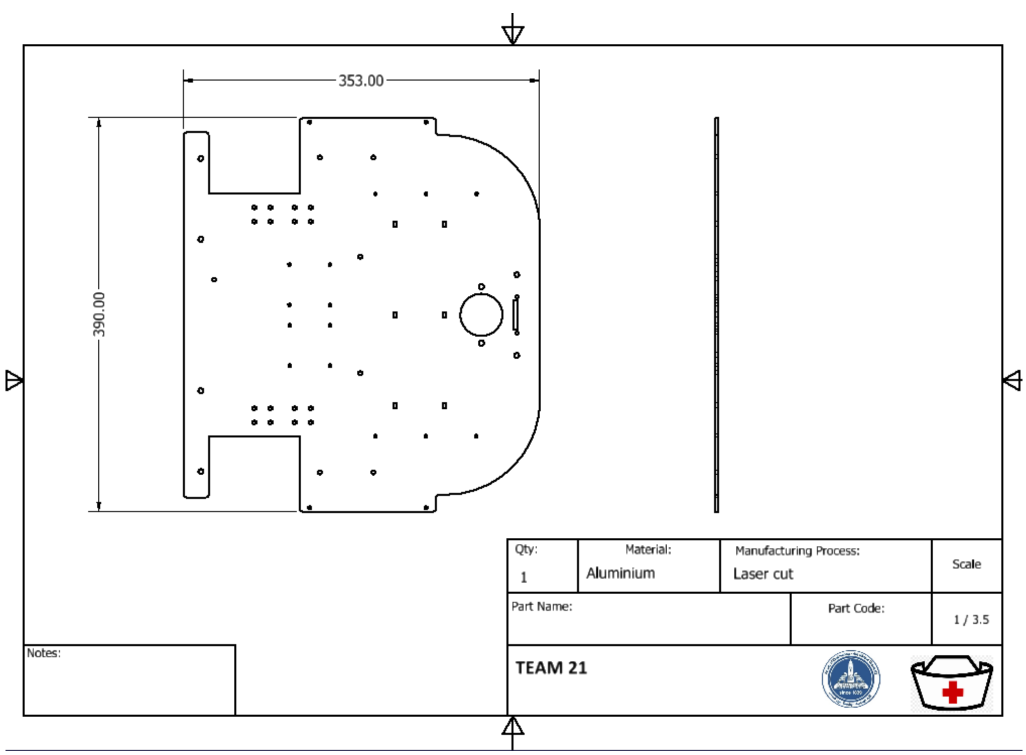
Nodes:974
Elements:502
Type: Safety Factor
Unit: ul
3/26/2023, 11:48:49 AM
15
12
9
6
3
0
Y
X
Z



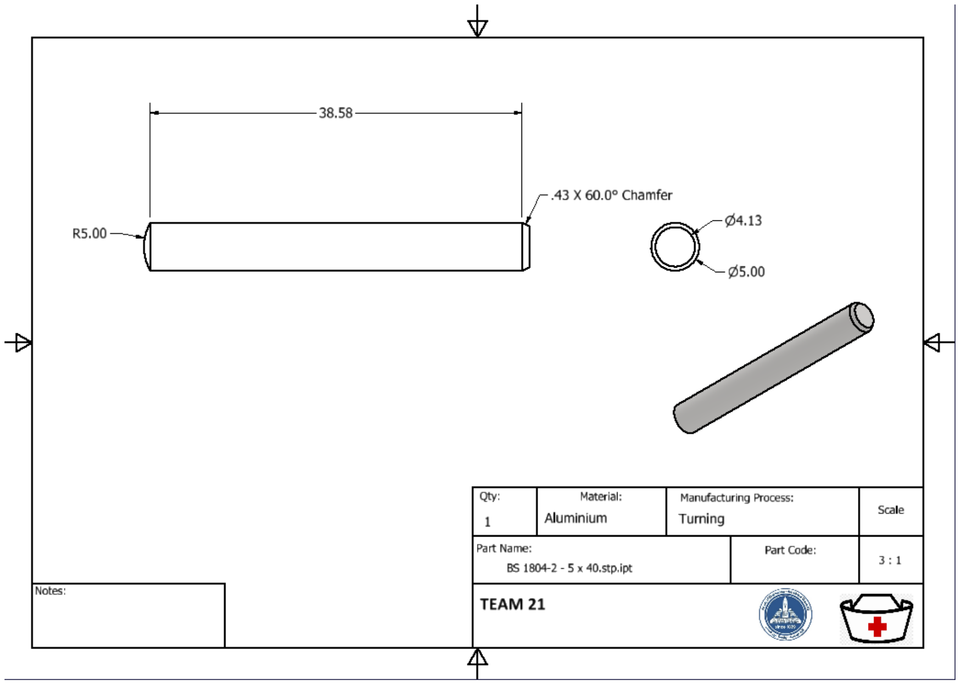
Nodes:974
Elements:502
Type: Displacement
Unit: mm
3/26/2023, 11:32:54 AM
1.669e-05 Max
1.335e-05
1.001e-05
6.676e-06
3.338e-06
0e+00 Min
Y
X
Z



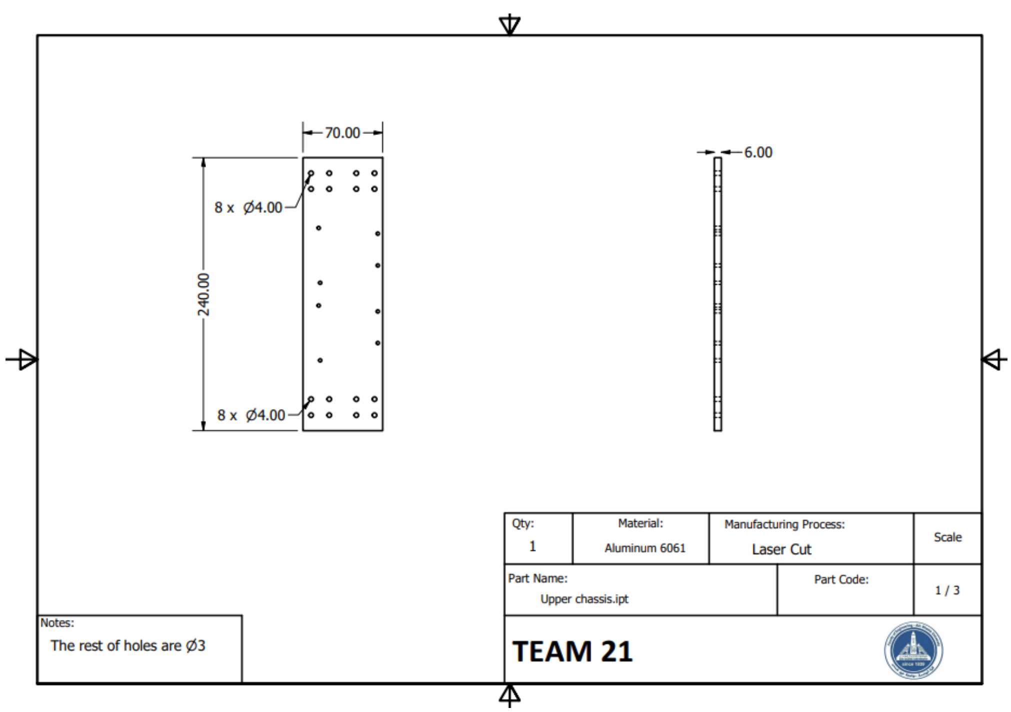
8.3. Working Drawings



(Note that only overall dimensions are put in this working drawing, as this will be manufactured by laser cutting. The working drawing is made for purchasing the sheet metal with the required dimensions)



Note that only overall dimensions are put in this working drawing, as this will be manufactured by laser cutting. The working drawing is made for purchasing the sheet metal with the required dimensions.



9. ACTUATOR SIZING

9.1. Force Analysis

Mass = 7 kg

Fcg = 68.67 N

$\sum F_Z = 0$

$F_{caster} + F_f + F_r = 68.67$ N

at O :

$\sum M_x = 0$

$0.295 \times F_c + 0.075 \times Fw_f + 0.075 Fw_r = 68.67 \times 0.153$

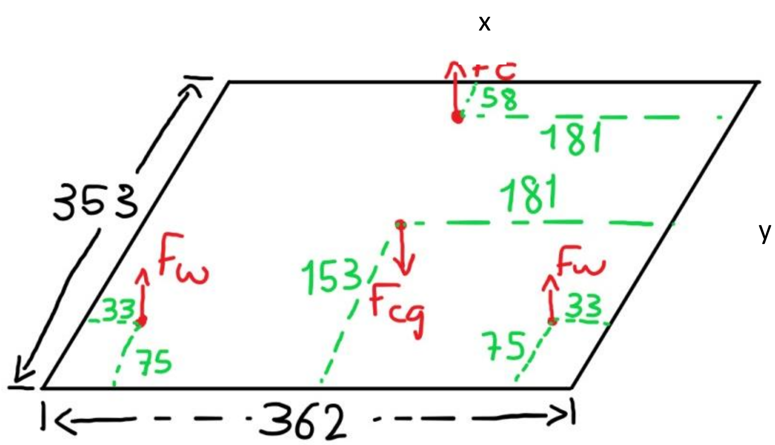


Figure 1 Forces on chassis

$\sum M_y = 0$

$0.181 \times F_c + 0.033 \times Fw_f + 0.329 Fw_r = 68.67 \times 0.181$

F_c = 24.34 N

F_f = 22.17 N

F_r = 22.18 N

∴ Taking Fr for actuator sizing as its larger than Ff

9.2. Torque Due To Resistance

$\boldsymbol{Rolling\ Resistance} = (Coefficient\ of\ rolling\ resistance) * \mathrm{mg}$

C_{rr}	Surface
0.001 - 0.0025	steel wheels on steel rails
0.0015 - 0.0025	bicycle tires
0.006 - 0.01	truck tire on asphalt
0.01 - 0.015	ordinary car tires on concrete
0.03	car tires on tar or asphalt
0.2 - 0.4	car tire on loose sand

Rr = 0.01 × 22.18 = 0.2218 N

$\boldsymbol{Air\ Resistance} = 1/2 * \boldsymbol{Cd}\ (Coefficient\ of\ Drag) \times (Air\ Density) \times (Projected\ Fontal\ Area) \times \boldsymbol{V}^2\ (Robot\ Velocity)$

Af = 0.362 × 0.101 = 0.0366 m^2

Ra = ½ × 0.25 × 1.204 × (0.0407) $\times$ $(0.034)^2$ = 6.4 × 10^{-6}

Tr = F × R = 0.049 × (6.4 × 10^{-6}**+** 0.2218 **) = 0.0109 N.m**

9.3. Torque Due to Inertia

ω =1.256 rad/sec

$\alpha = 0.628\, rad/\sec^2$

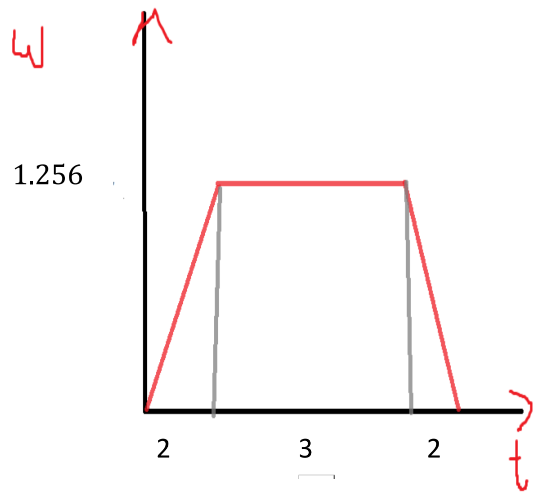


Figure 2 velocity profile

Torque due to Inertia

$\boldsymbol{J = Jmotor + JEq\ Wheels + JEq\ Linear\ Mass}$

$J_{total} = \frac{mR^2}{N^2} + mR^2$

$$= \frac{\left(\frac{22.18}{9.81}\right)(0.049)}{25^2} + \left(\frac{22.18}{9.81}\right)(0.049)$$

$$= 0.11\ Kg.m$$

T = 0.11 × 0.628 $=$ 0.069 N.m

RMS Torque

T_{acc} = 0.069+ 0.011 = 0.08 N.m

T_{dec} = 0.069 – 0.011 = 0.058 N.m

T_L = 0.069 N.m

T rms = $\sqrt{\frac{(Tacc^2 * t1 + Tl^2 * t2 + Tdec^2 * t3)}{t1+t2+t3}}$

Trms = 0.0695 N.m = 0.71 Kg. cm

With safety factor of 1.5

Trms = 1.1 Kg. cm

$\boldsymbol{Tractive\ Effort\ Max}$ = $\boldsymbol{Nactuated\ Wheel * \mu f}$ = 0.4 × 22.18 = 8.87 N

Motor chosen specifications

A reduction ratio of 1: 25 was used to increase the torque to 15 kg.cm.

General Specification:

- Motor Type: 775.
- Operating Voltage: 12~24Vdc. (Nominal 12Vdc).
- No Load Speed: 6,000 RPM @ 12V.
- Rated current (No Load): 0.5A @ 12V.
- Rated Torque: 600g.cm.
- Stall Torque: 4200g.cm.
- Cooling Fan: Internal
- Overall Size: 98x42mm.
- Shaft: Full Round Type Ø5mm.
- Mounting Screw Size: M4.
- Weight: 350g.

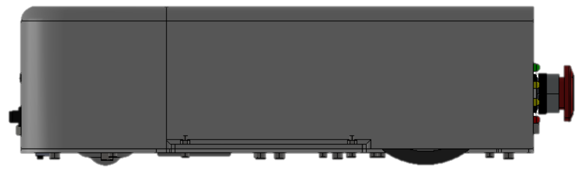
Ball bearing DC motor with built-in cooling fan. High torque with wide operating voltage 6~20Vdc. Suitable for motor tools application and DIY projects.

9.4. Stability in the Longitudinal Direction

$$N_F = mg * \frac{L_1}{L} - \frac{ma * h_{cg}}{L}$$

$$a = g\frac{L_1}{h_{cg}}$$

$$\frac{gL1}{h} = \frac{(9.81 * 0.272)}{0.049} = 51.3\ \frac{m}{s^2} \gg a$$



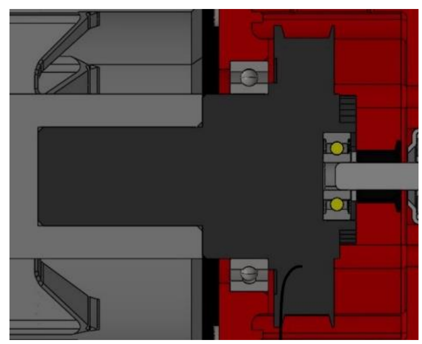
$$\therefore As\ accelaration\ not\ equal\ to\ \frac{gL1}{h}, its\ stable\ in\ the\ longitudental\ direction$$

9.5. Shaft Calculations and Bearing Selection

FA + FB = 22.18

FA (0.0235) +FB (0.0395) = **0.072**

FA = 50.26 N FB = -28.08



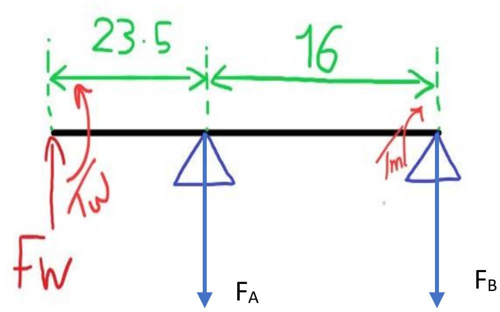
$$\frac{16}{\pi d^3} M \leq \frac{\sigma}{2n}$$

For Al $\sigma = 60\ MPa$

n = 2 , M = 1.175 N.m

d_{min} = 0.0736 m → 7.36 cm

Shaft diameter is >> 7.36 so its safe



9.6. Bearing A Properties

C_{calc} = Fe $\sqrt[3]{life\ in\ million\ revolutions}$

x = 1 , v =1 , $\gamma = 0.25$

$Fe = (Fr \times x\ \times v) +\ \gamma Fa = 50.26 + 0$ = 50.26 N

Expected $l_h = 3\ years = \ 26280\ hrs\ , N = 12\ rpm$

Life In million years = $26280 \times 60 \times 12 \times \frac{1}{10^6} = 18.9$

Ccalc = 50.26 $\sqrt[3]{18.9}$= 133.9 N → 0.133 KN which is less than Cd

$\therefore \boldsymbol{suitable\ bearing}$

9.7. Bearing B Properties

Ccalc = Fe $\sqrt[3]{life\ in\ million\ revolutions}$

x = 1 , v =1 , $\gamma = 0.25$

$Fe = (Fr \times x\ \times v) + \ \gamma Fa = 28.08 + 0$ = 28.08 N

Expected $l_h = 3\ years = \ 26280\ hrs\ , N = 12\ rpm$

Life In million years = $26280 \times 60 \times 12 \times \frac{1}{10^6} = 18.9$

Ccalc = 28.08 $\sqrt[3]{18.9}$= 74.83 N → 0.075 KN which is less than Cd

$\therefore \boldsymbol{suitable\ bearing}$

Performance

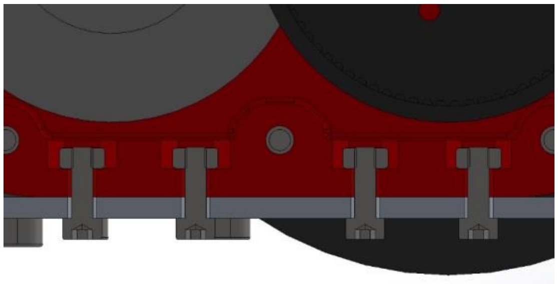
Basic dynamic load rating	1.14 kN
Basic static load rating	0.38 kN
Limiting speed	60 000 r/min

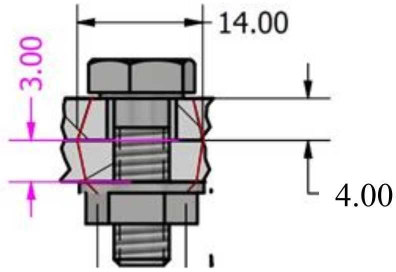
Performance

Basic dynamic load rating	4.1 kN
Basic static load rating	2.9 kN
Limiting speed	9 500 r/min

BOLTS

M3 × 45 , Ac =5.03 mm^3





$b = 8\ mm,$

$b1 = 5\ mm,$

a = 3.6 mm

$L = P1 + P2 + ss_1 + V = 3 + 4 + 0.8 + 5.2 = 13\ mm$

Fmax = 69 N/18 = 3.83 N

$Fmax = \frac{\sigma}{Ac} \rightarrow\ \sigma = 3.83 / 5.03 = 0.76$ Mpa

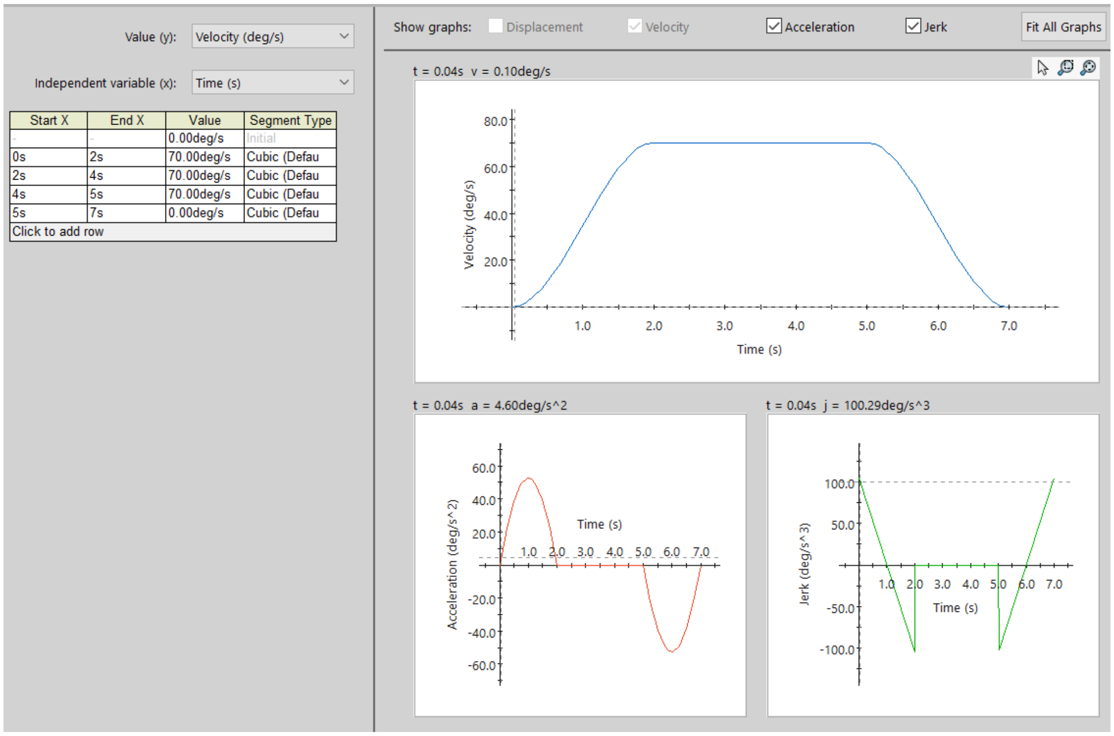
$$\tau = \frac{\sigma}{2} = 0.381\ MPa$$

$$\tau \leq \frac{\sigma y}{2n}, where\ n = 2 \longrightarrow \sigma y = 1.524\ MPa$$

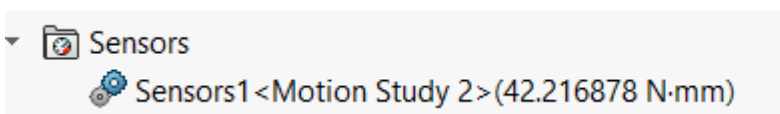
$$\therefore St\ 37\ is\ suitable\ for\ all\ 18\ bolts$$

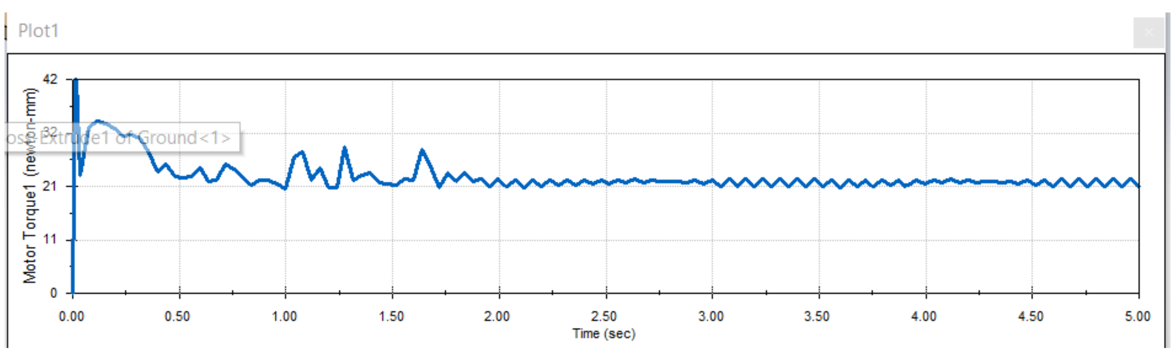
9.8. Actuator Sizing Solid Works

Motion profile



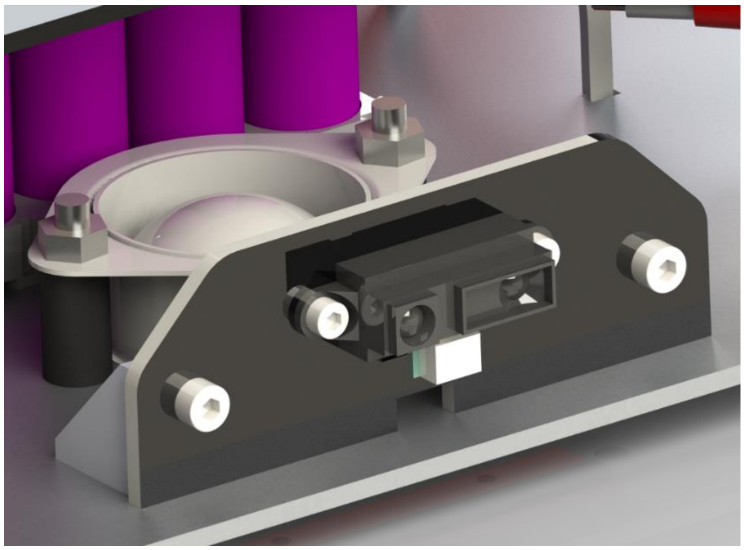
9.9. Plots & results



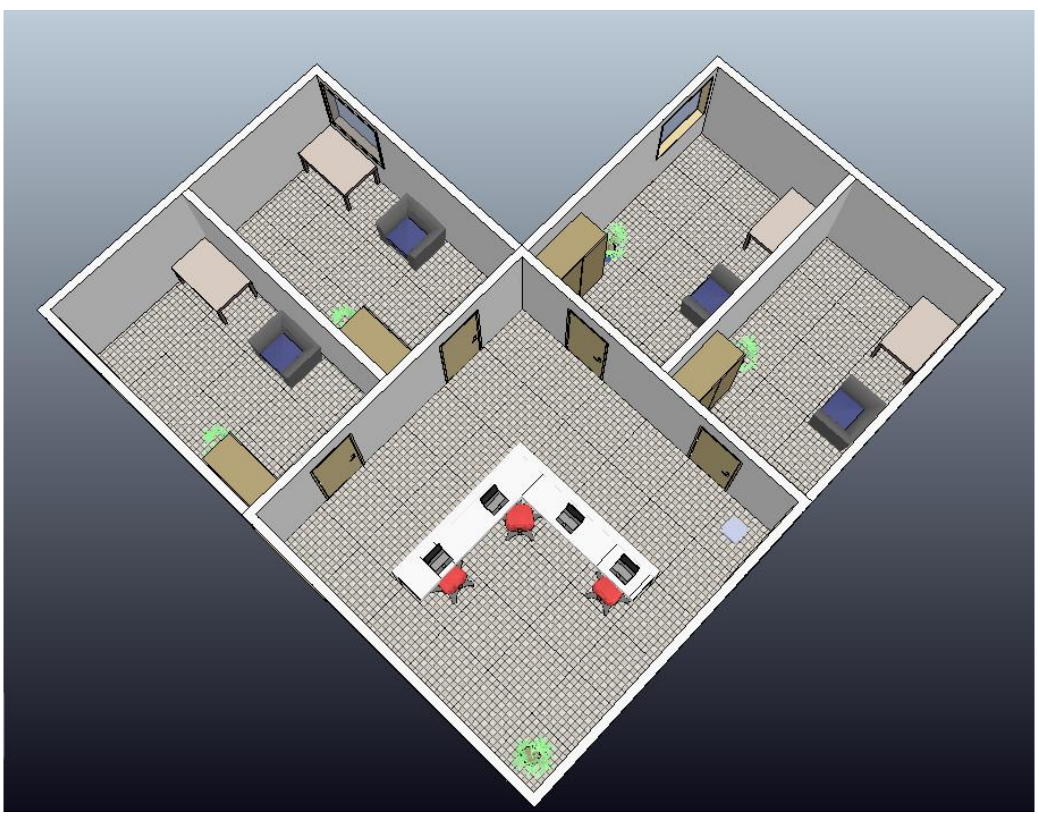


10. SENSORS FIXATION

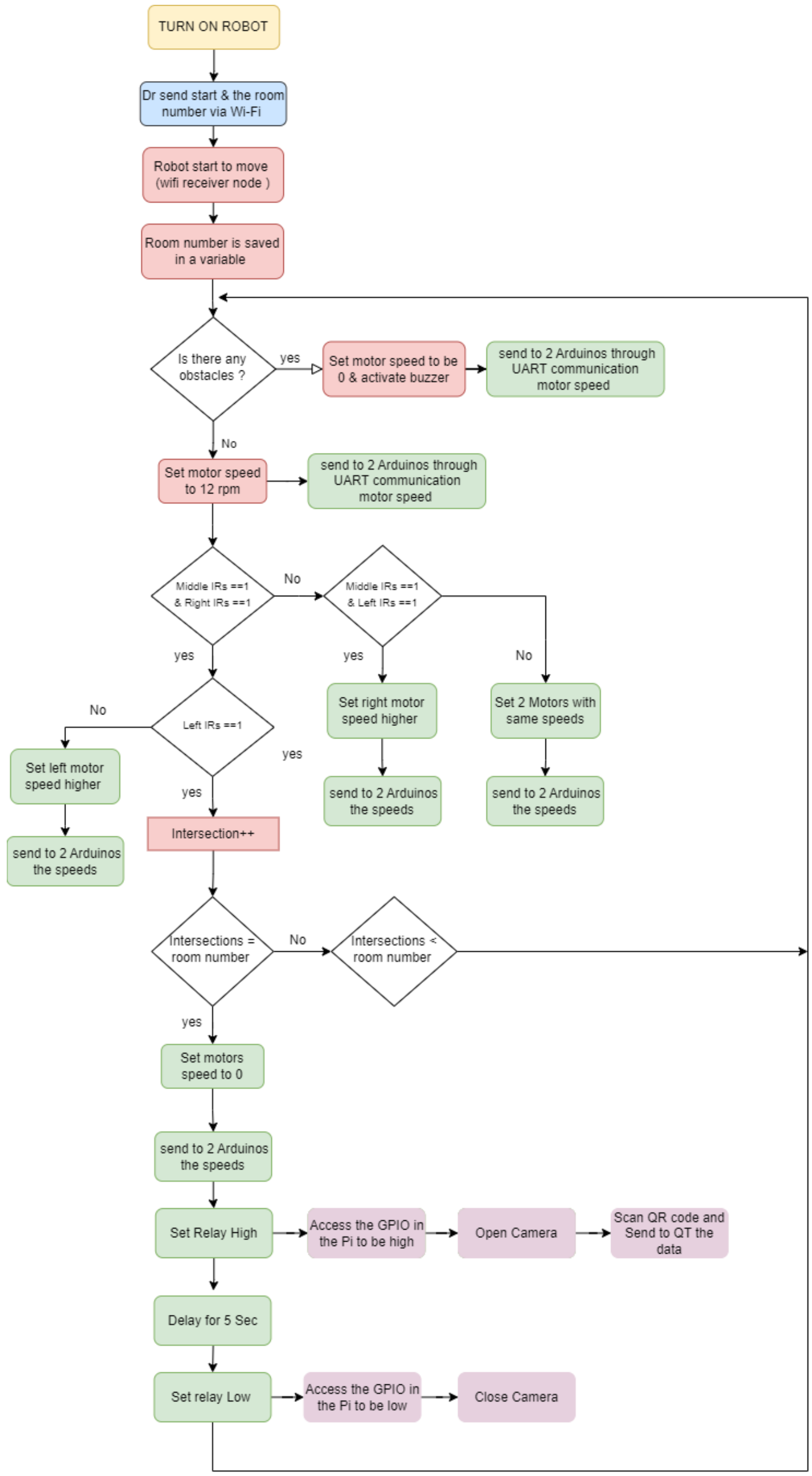
All sensors are fixed on a thin acrylic plate which is fixed to the chassis using bolts and L brackets.



11. COPELIASIM ENVIROMENT

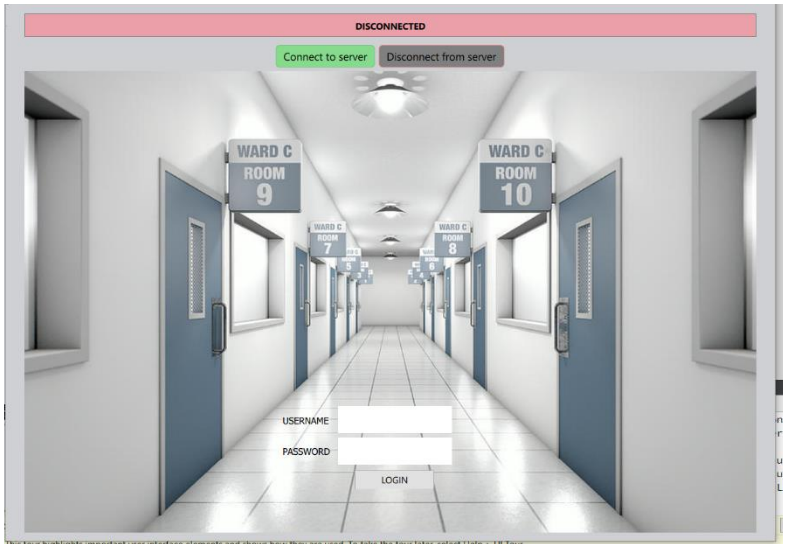


12. FLOWCHART



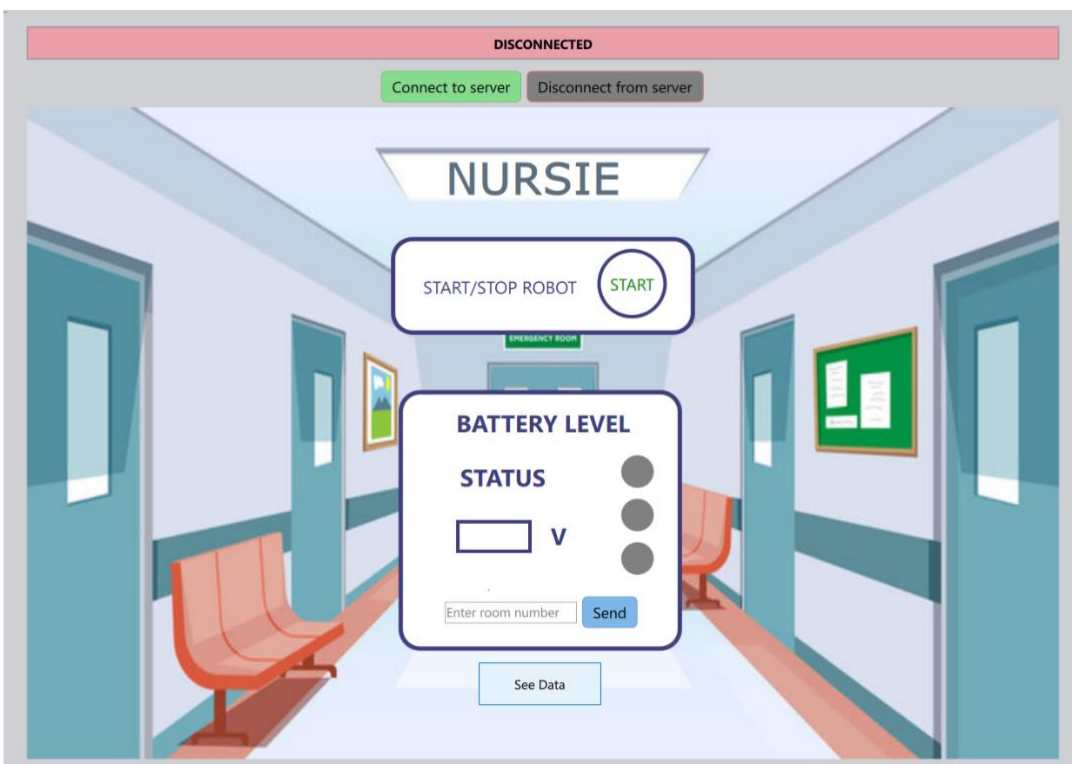
13. GUI SCREENS

13.1. Login screen



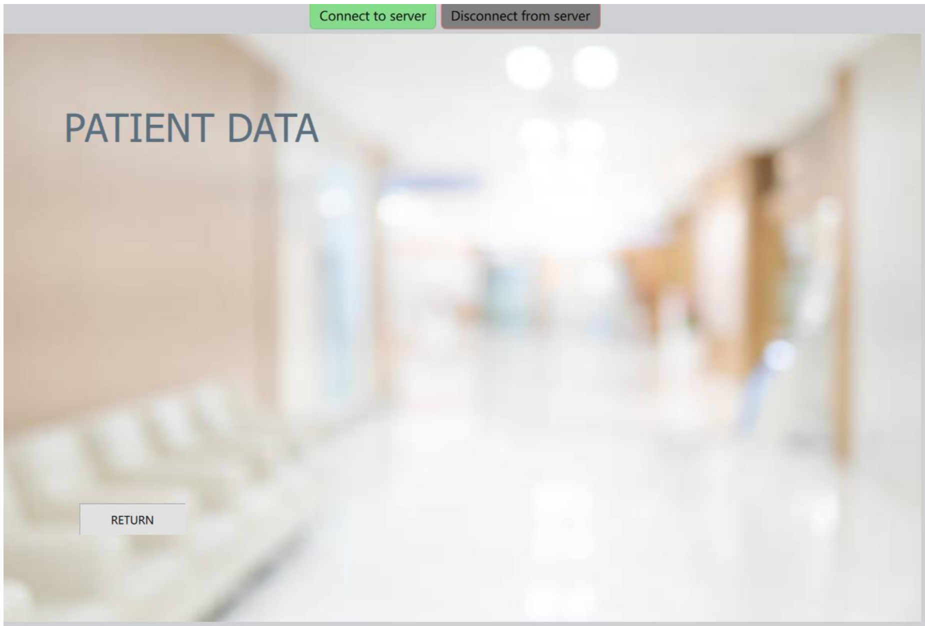
The username and password must be correct to enter main screen

13.2. Main Screen

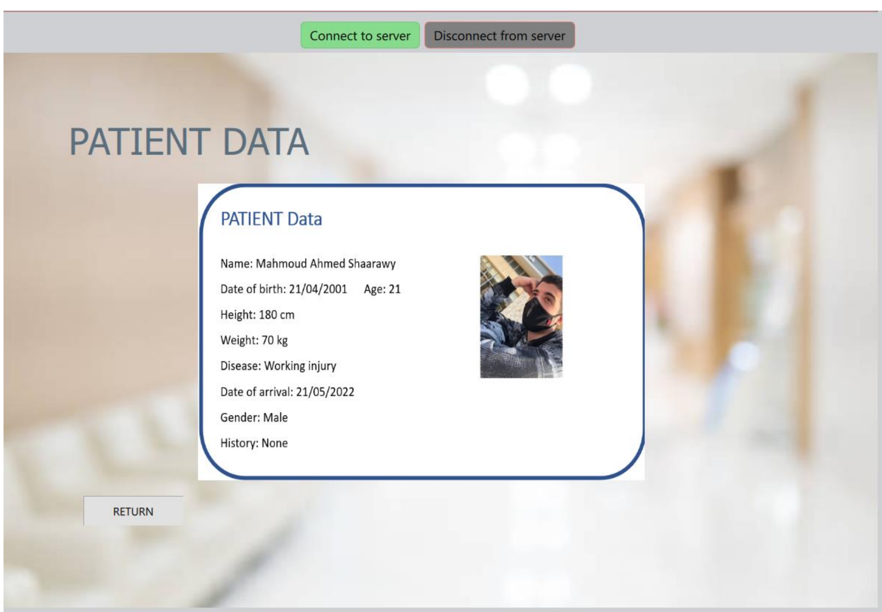


When start is pressed , it sends to server that robot should start . The battery level status is an input from raspberry pi sensor. Finally the doctor must enter the room number so the robot arrives the right destination

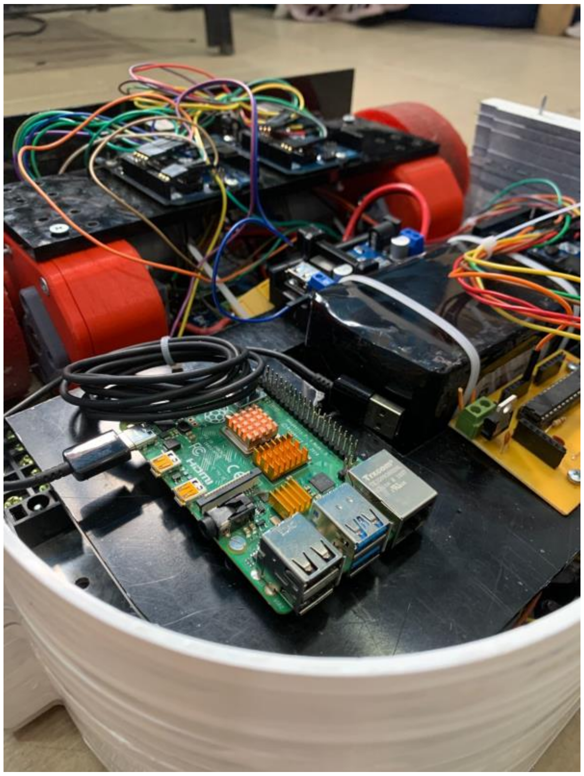
13.3. Data Screen

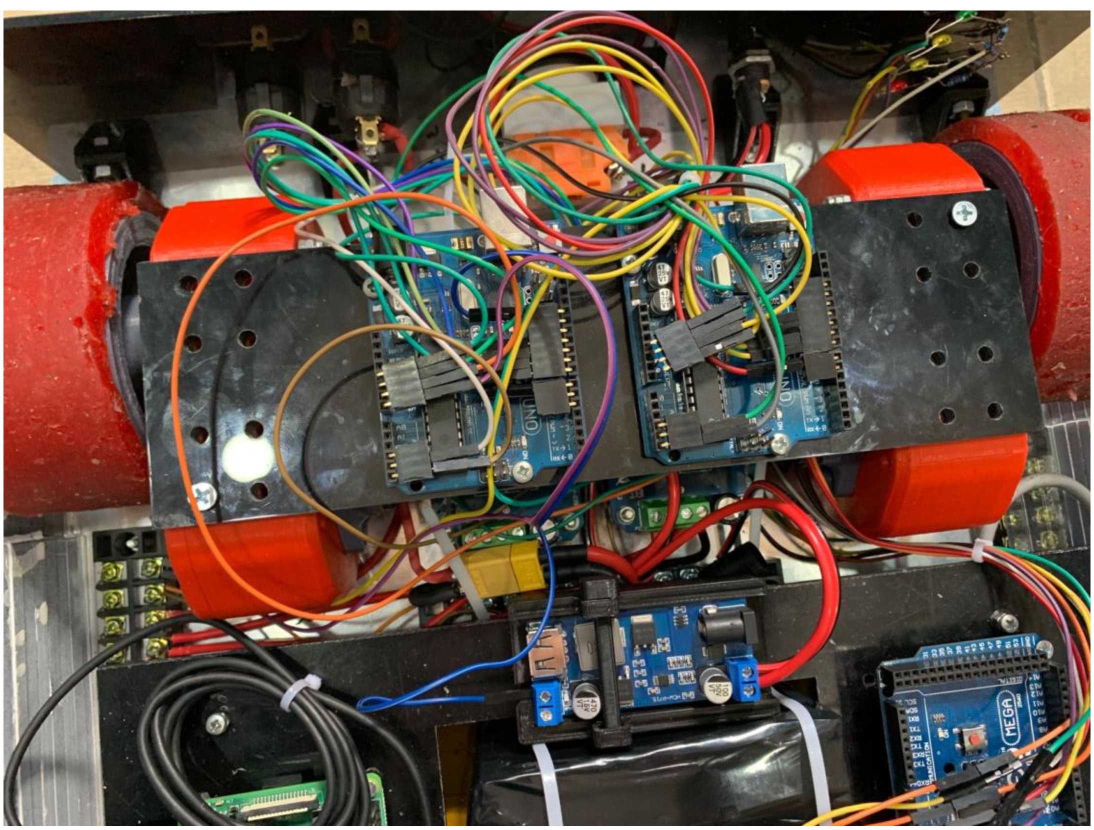


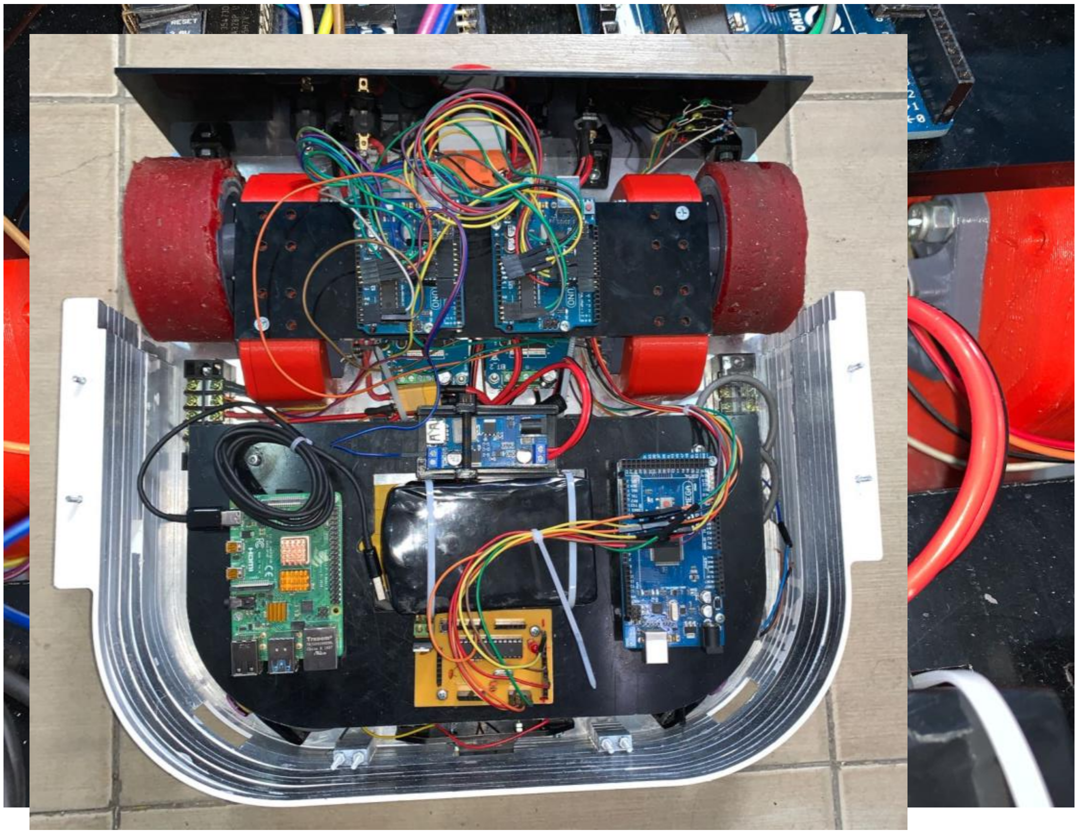
When camera is on:

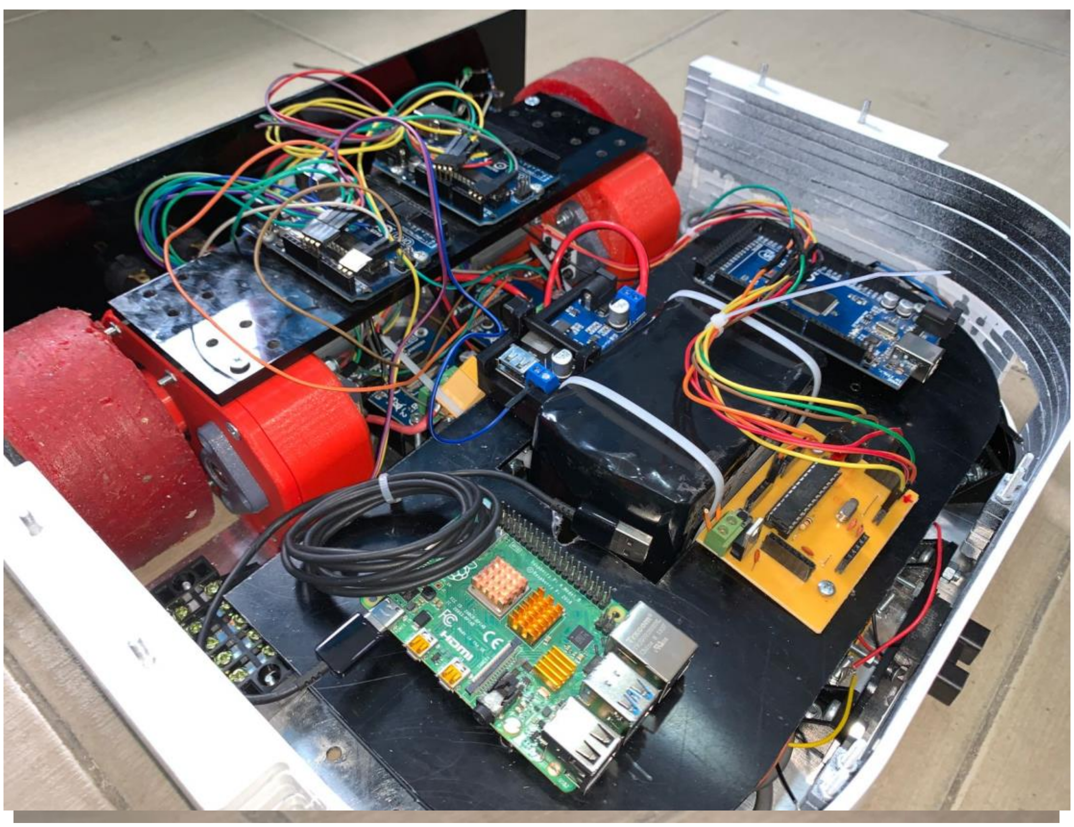


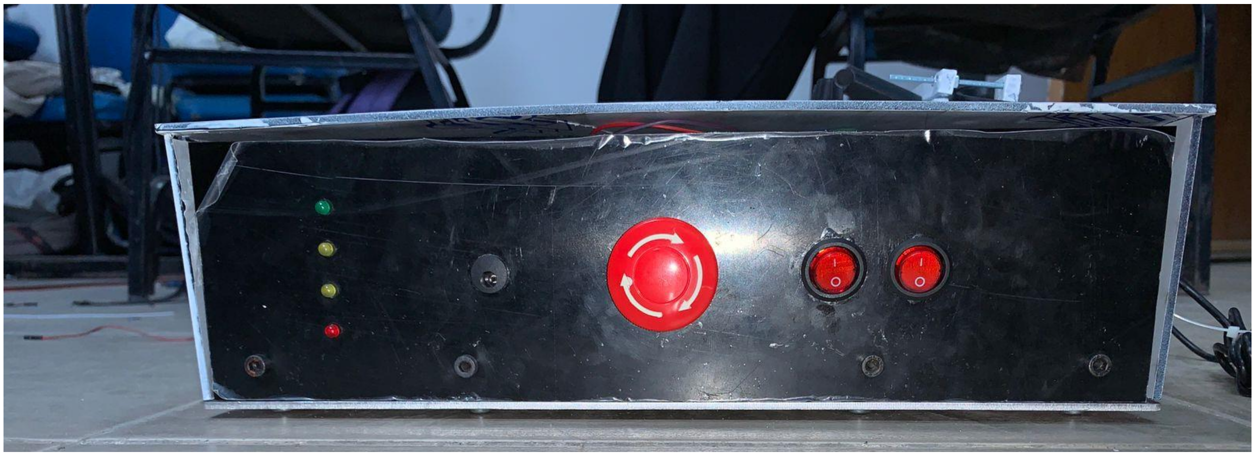
14. PHOTOS IN REAL LIFE

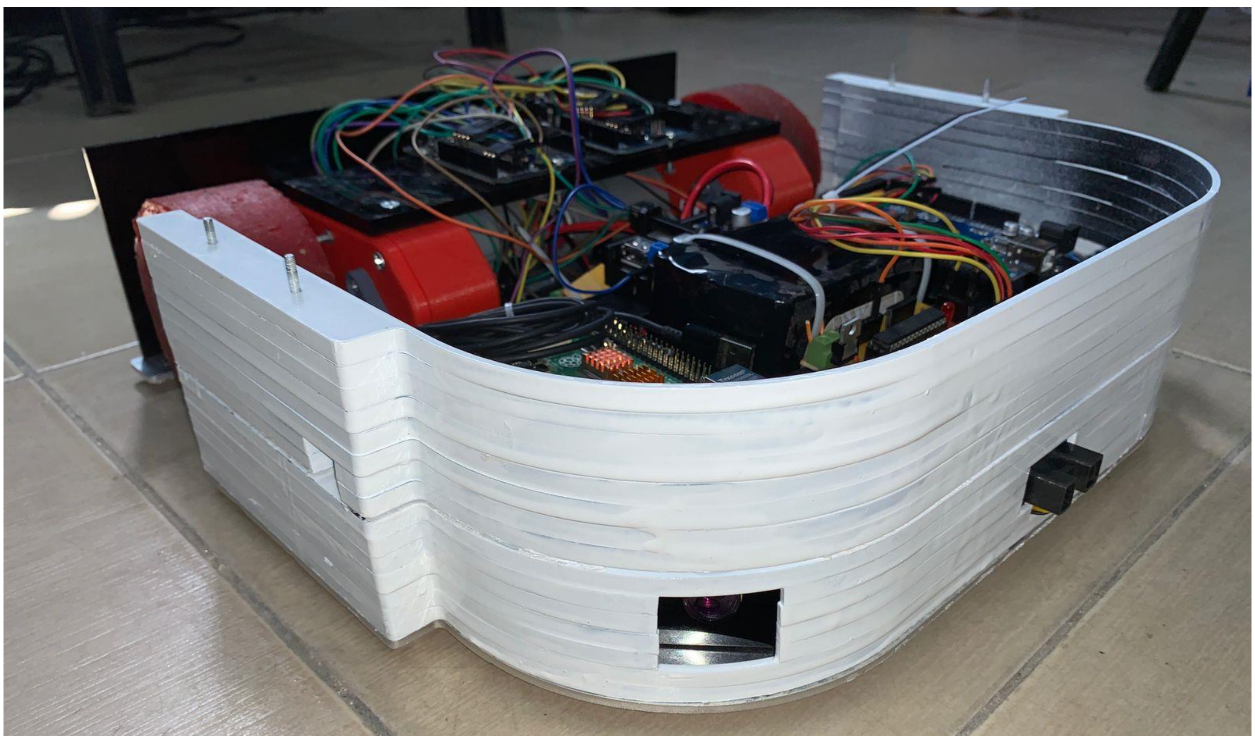


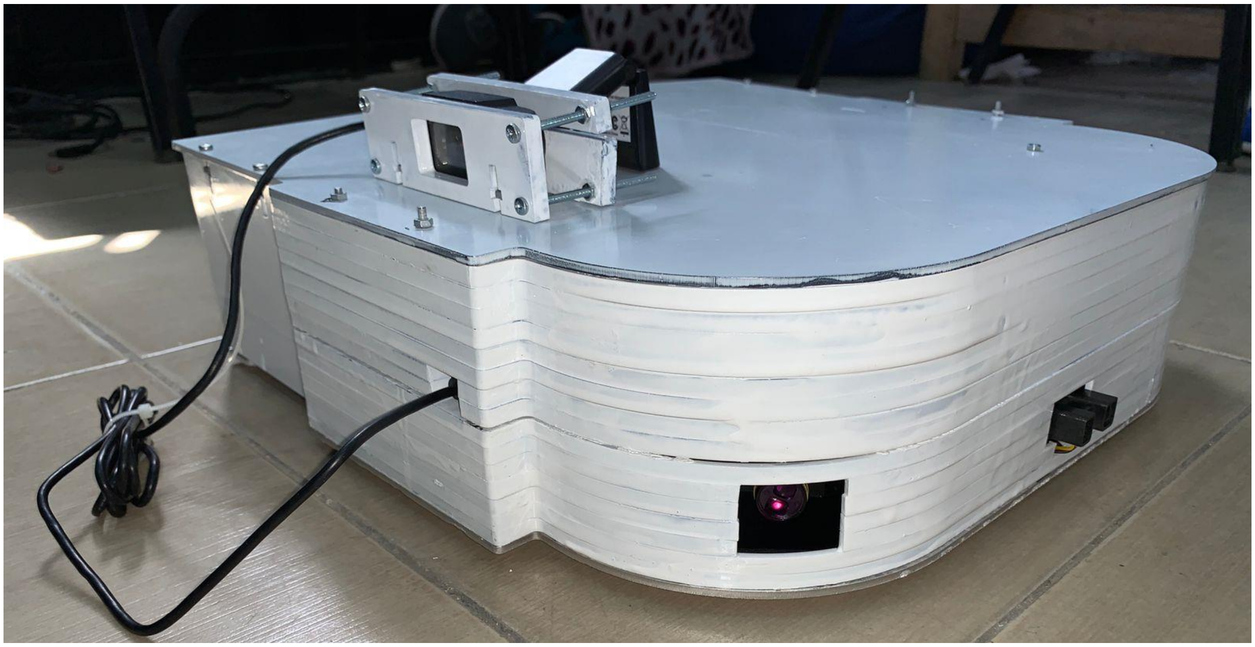


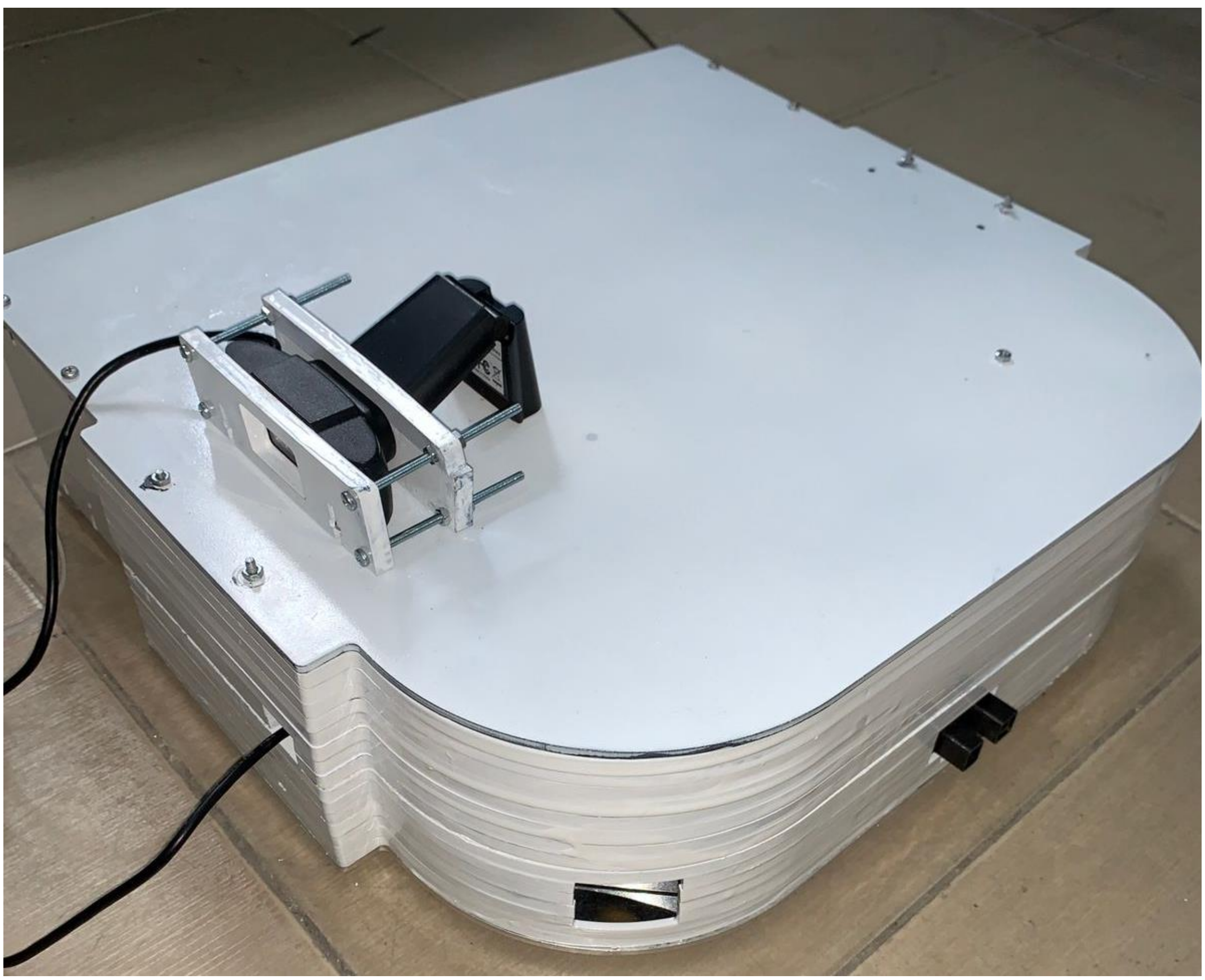




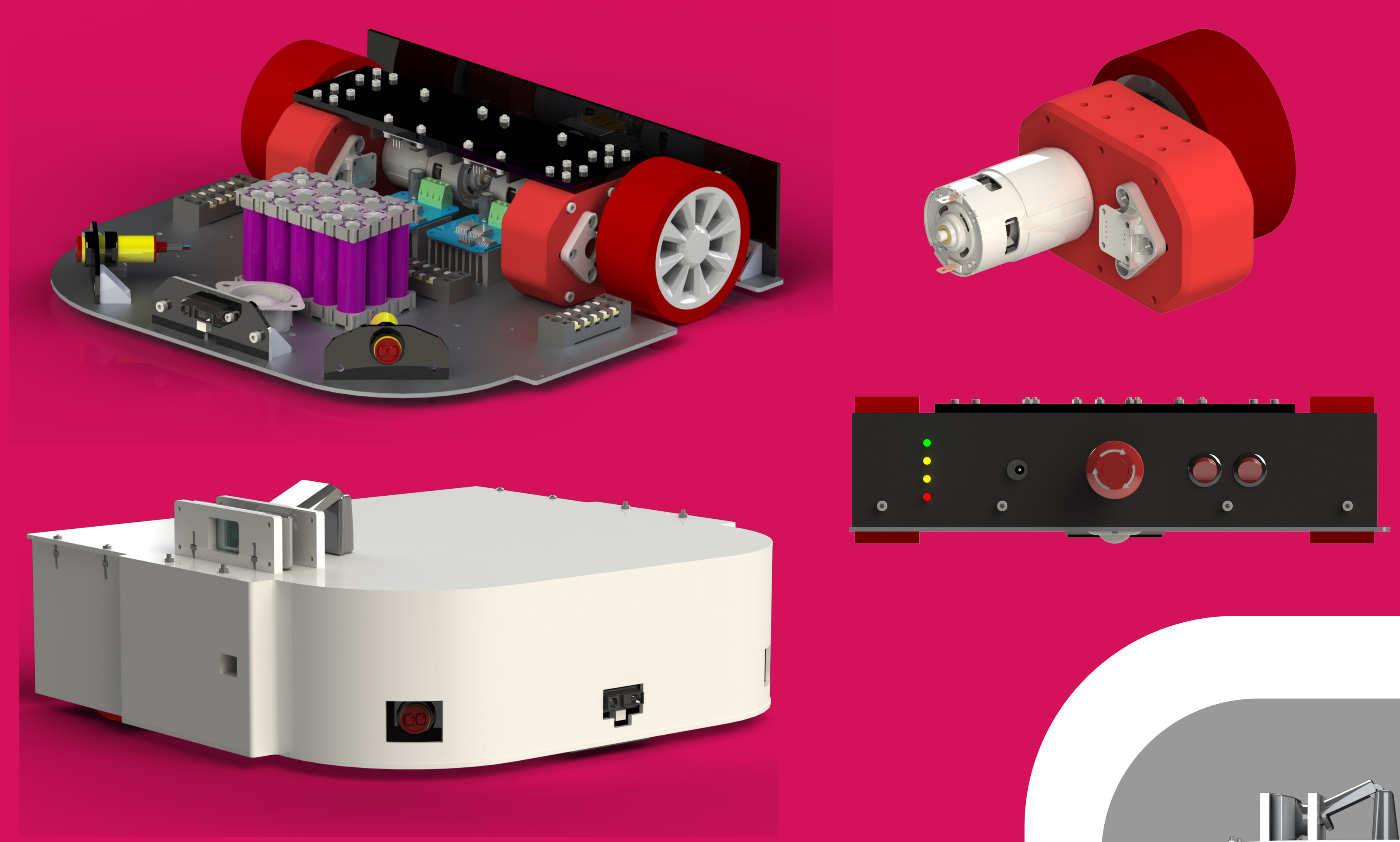




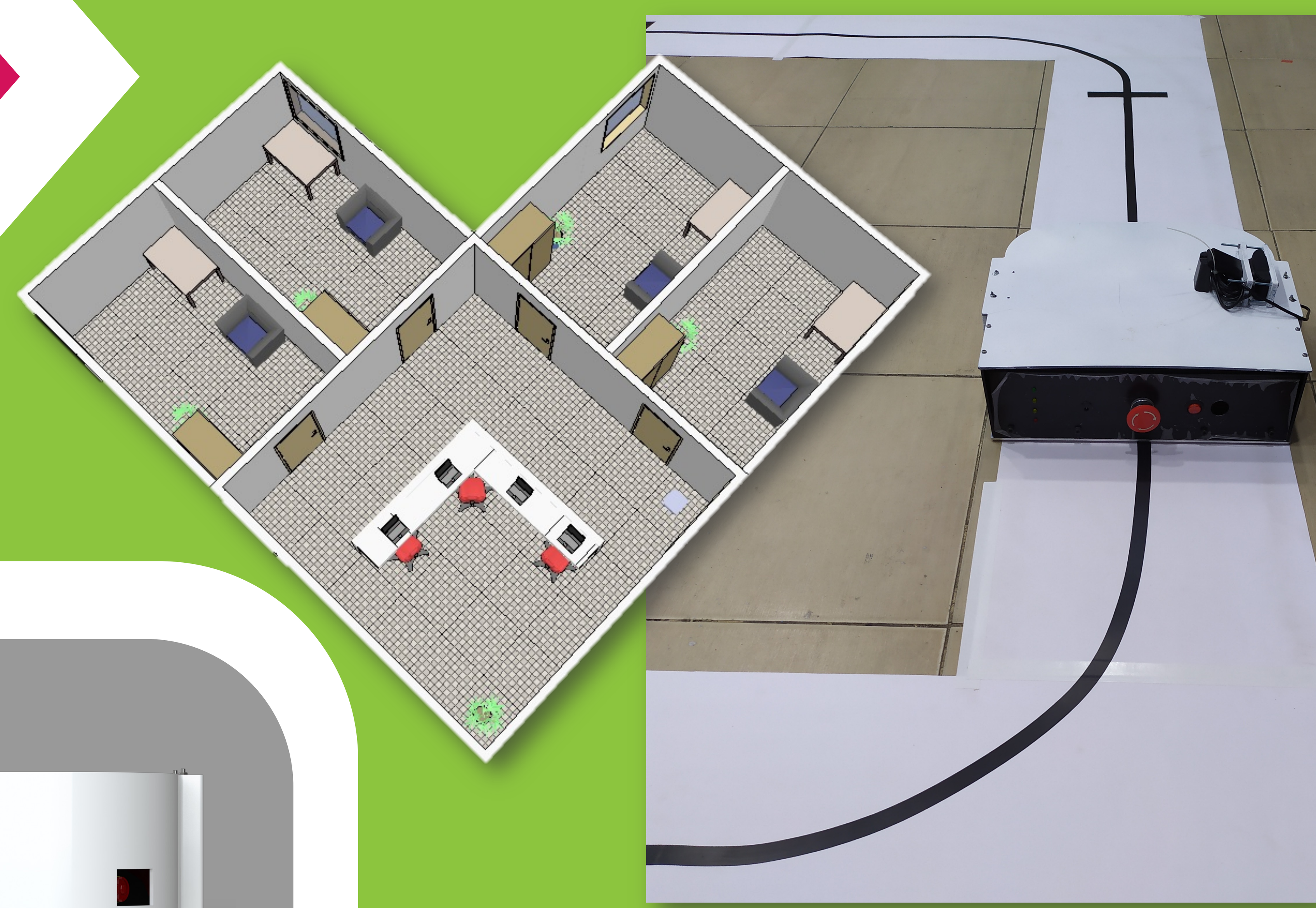


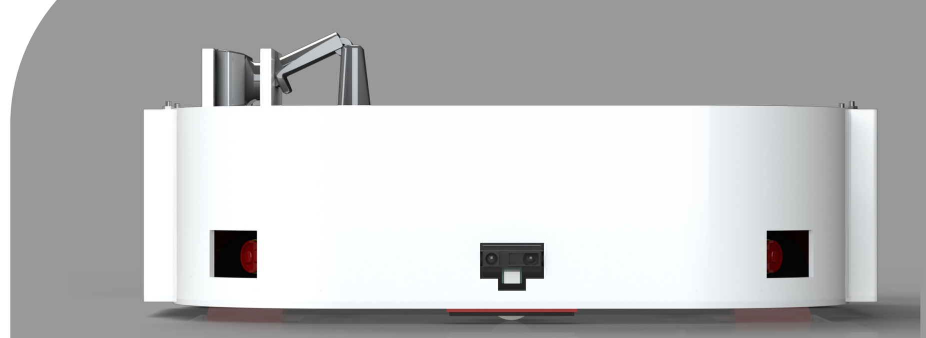


Robot



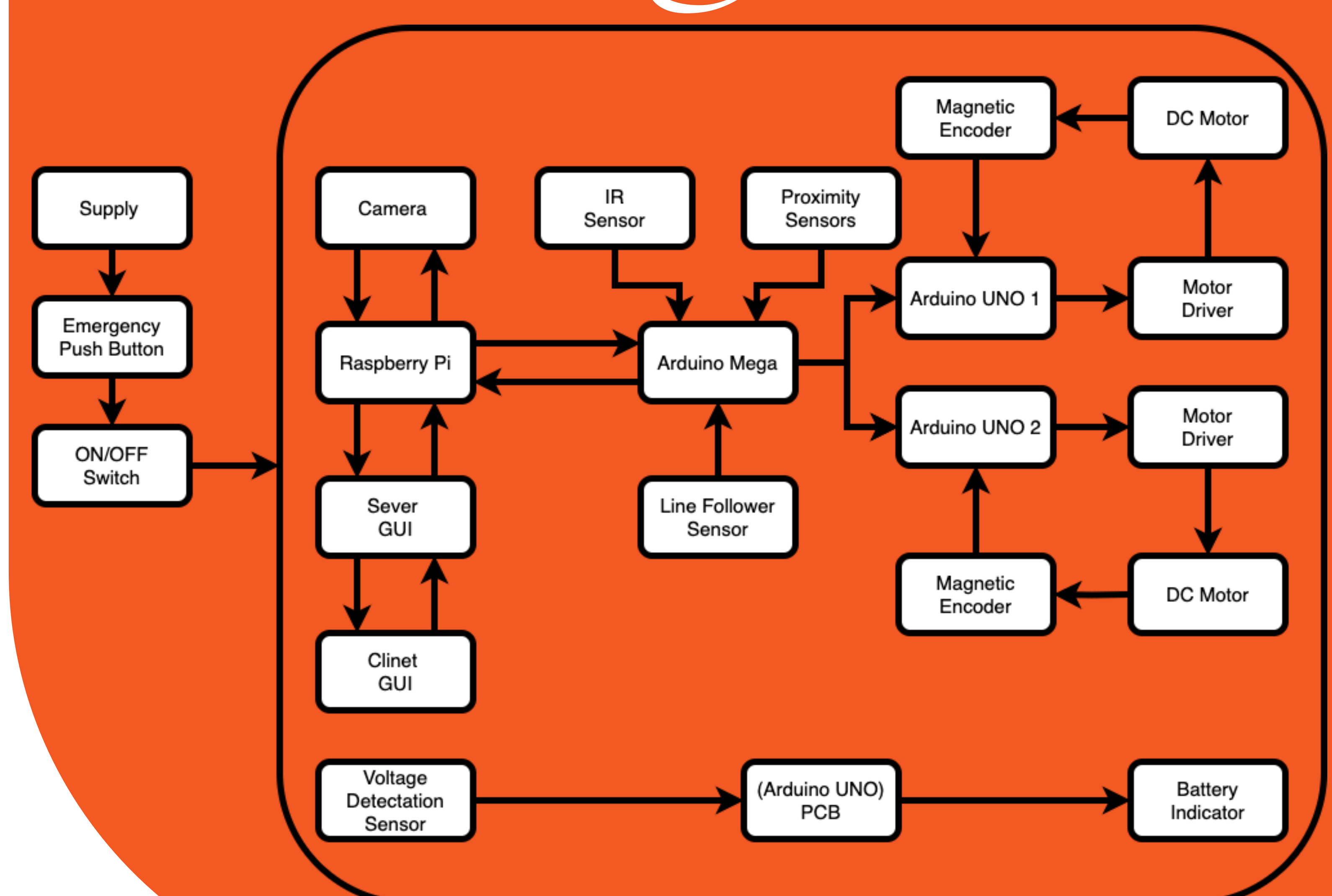
CoppeliaSim



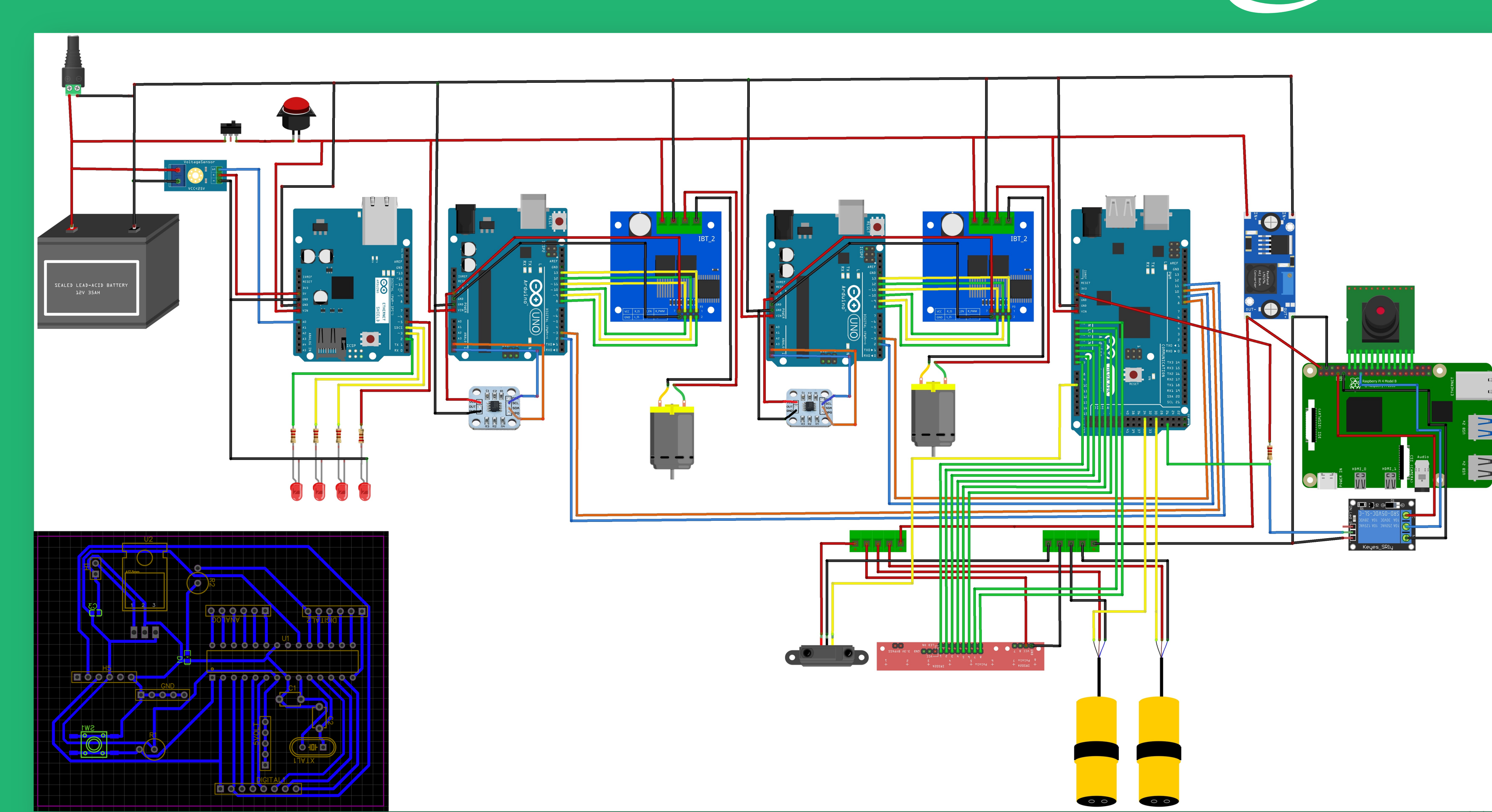


Nursie

B-Diagram



Wiring



Robot Specs

Size:	$(35 \times 39 \times 11)\ cm$
Weight:	$9\ kg$
Time On:	$8\ hrs$
Max Speed:	$3.1\ m/sec$
Charging Time:	$3\ hrs$
Charging Capacity:	$15\ Ah$

Robot Features

- **Vision**
- **Line Following**
- **Emergency Switch**
- **Obstacle Detection**
- **Battery Level Indicator**
- **Wireless Communication**
- **Pulley & Belts Reduction System**
- **Polyurethane Tires for Extra Traction**
- **12-bit Encoders for Precise Positioning**

Team 21