Design and development of a multifunctional robotic walker

Group 40 | Progress Review II Presentation

Team members

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Supervisors

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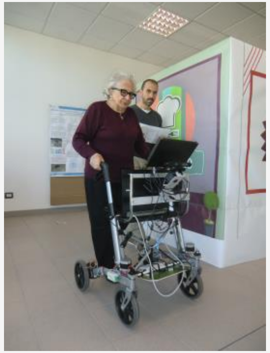
Main Functionalities

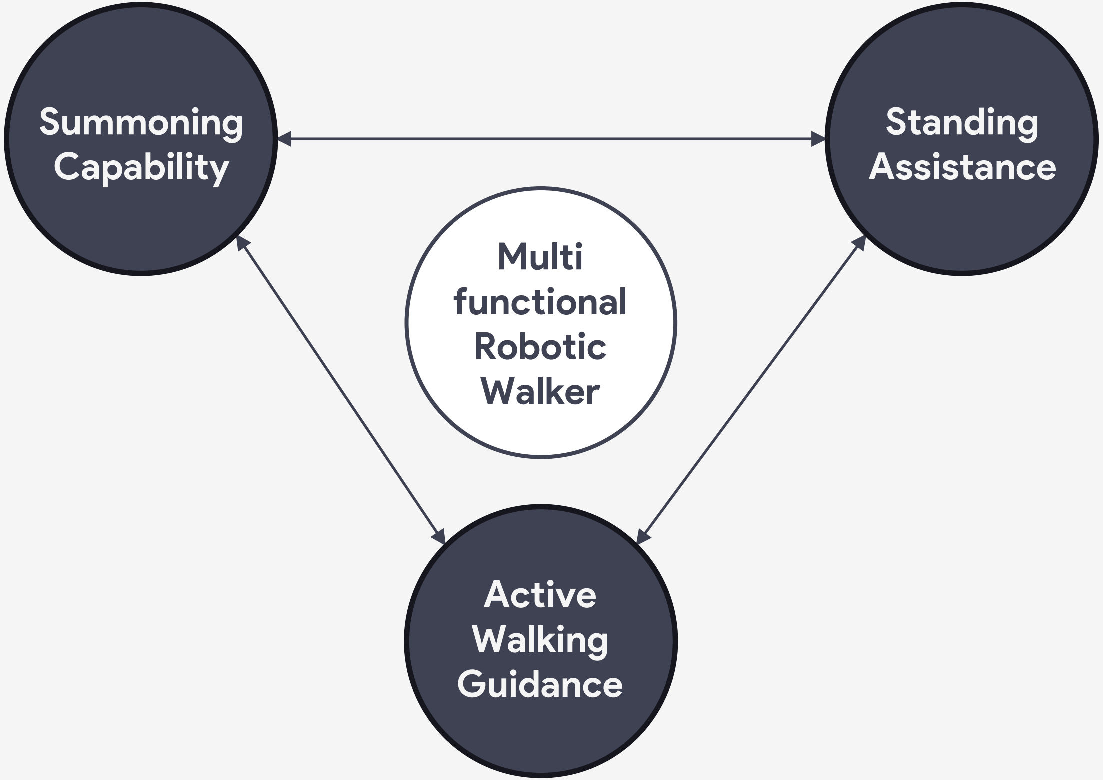


1. **Summoning Capability**
Autonomously navigates to user's location without relying on Indoor Positioning Systems (IPS)

2. **Sit-to-Stand Assistance**
Adjusts operating height suiting to the user
Gently and safely elevates the user from a sitting position
Ensures optimal ergonomic positioning

3. **Active Walking Guidance**
Provides Real-time guidance and support
Adapts movement to user's pace
Detects Emergencies to mitigate fall risk

System Overview



System Overview

Summoning Capability

- User not in visible range - Sound Source Localization
- User in visible range – Gesture Recognition and Depth Estimation
- Obstacle avoidance and path planning – LiDAR based SLAM

System Overview

Standing Assistance

- User Standing Estimation – Computer Vision (Coarse adjustment)
- User holds on to armrests
- Linear Actuator raises armrests to predicted height
- Force sensors limit exceeding operating height (Fine adjustment)

System Overview

Active Walking Guidance

- ❑ Force Sensing Resistors track intuitive user intentions to move or to stay stationery
- ❑ Adapts movement to user's pace
- ❑ Notifies user of obstacles in path
- ❑ Detects Emergencies by applied force

1. Study the existing problems associated with mobility and **identify key focus areas** and **research gaps.**
2. Design and development of an **appropriate mechanical structure** for the platform of the walker.
3. Development of the **autonomous navigation system, walking guidance system**, and **standing assistance system** of the walker.
4. **Testing and validation** of the developed robotic walker.

Objectives

Progress of objectives

Completed

In Progress

Objective I

Literature Review

Objective II

Mechanical Structure

Design Calculation

Differential Drive Kinematics

3D Design

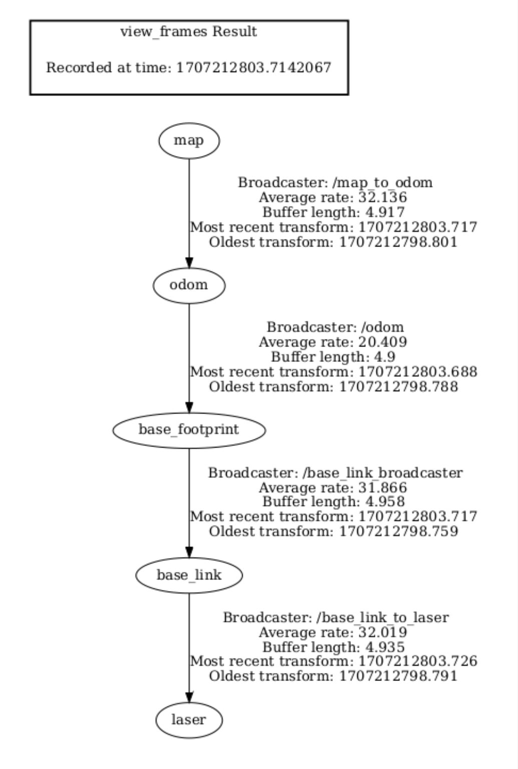
Structural Simulations

Fabrication


Autonomous Navigation
Testing Platform Fabrication
Motor Control & Odometry
SLAM
Sound Source Localization
Stereo Vision
Depth Estimation
Sit-to-stand Assistance
Human Height Estimation
Stand-to-sit Actuation
Walking Guidance System
FSR Calibration and Velocity Mapping
State Identification
Objective III
Testing & validation
Designing experiments
Autonomous Navigation
Sit-to-stand Assistance
Walking Guidance System
Integrated System
Objective IV

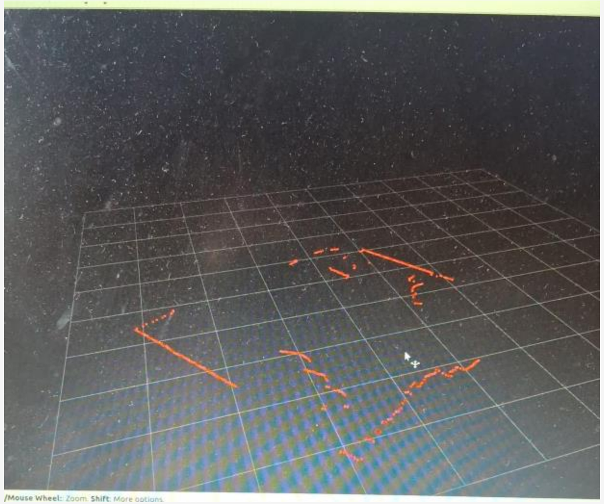
Annexes

Simultaneous Mapping and Localization (SLAM)



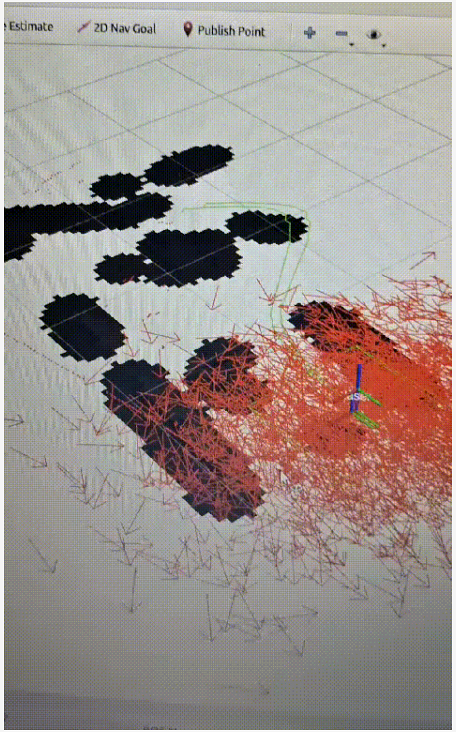
Transform Tree

Lidar with Arduino Adapter

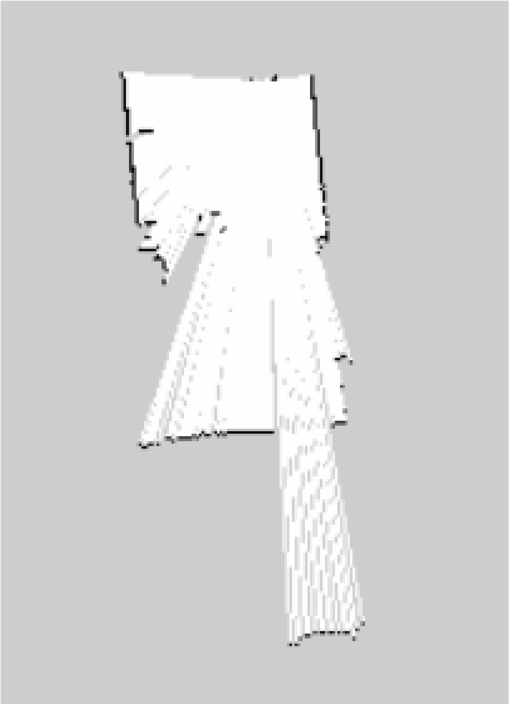


Laser Scan Visualized

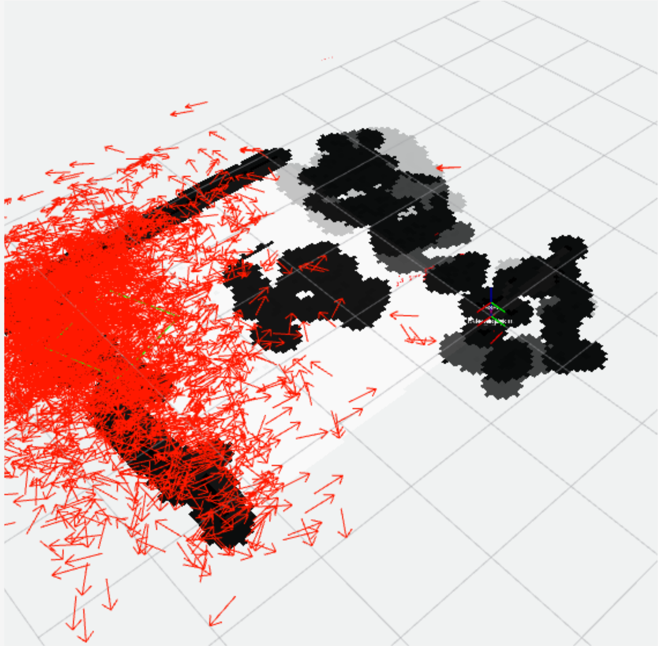
Simultaneous Mapping and Localization (SLAM)



Cost Map and Local & Global Paths
(Dijkstra Algorithm)

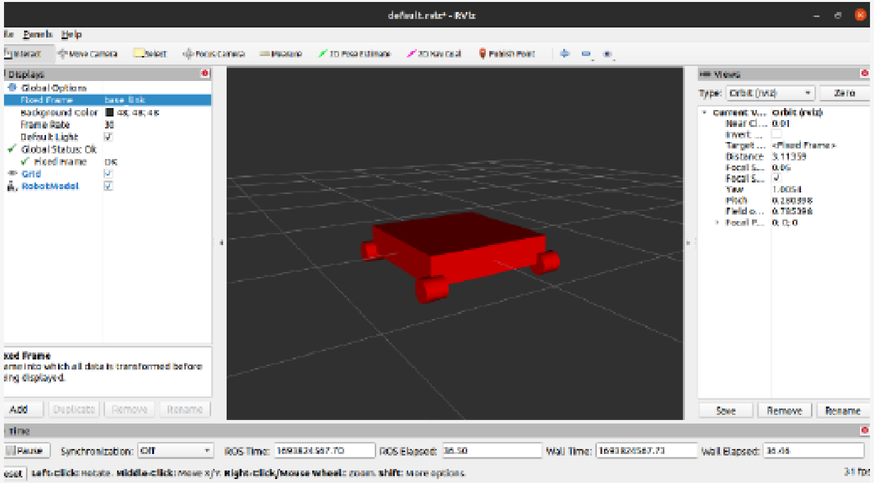


Mapping Results

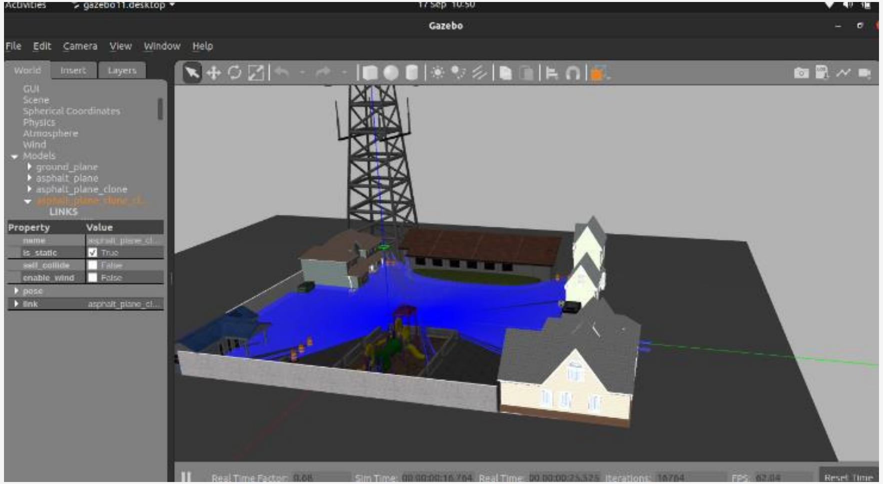


Localization Results

Simultaneous Mapping and Localization (SLAM)



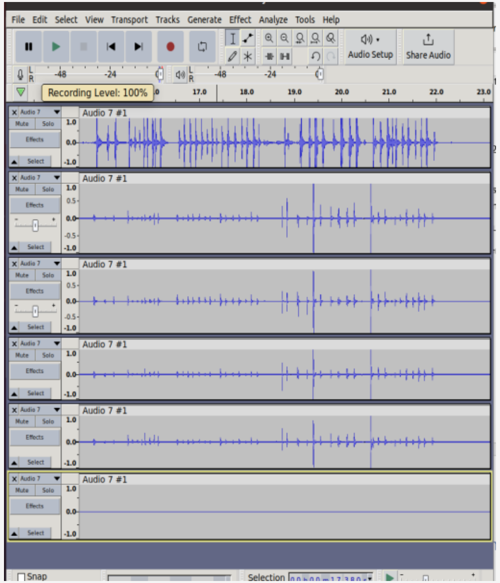
Robot visualization on RViz



Robot spawned on Gazebo with LiDAR Running

Virtual Simulation of Navigation Stack

Sound Source Localization



6 Channel Signal Capture
Visualized on Audacity

```
pesala@Ubuntu:~/usb_4_mic_array/usb_4_mic_array$ gedit DOA.py
^C
pesala@Ubuntu:~/usb_4_mic_array/usb_4_mic_array$ sudo python3 DOA.py
[sudo] password for pesala:
55
55
55
306
306
54
55
55
41
59
36
326
199
332
332
332
^Cpesala@Ubuntu:~/usb_4_mic_array/usb_4_mic_array$
```

Direction of Arrival

```
//////////////#################333
goal.target_pose.header.frame_id = "/map";
goal.target_pose.header.stamp = ros::Time::now();
goal.target_pose.pose.position.x = 2.44;
goal.target_pose.pose.position.y = -0.55;
goal.target_pose.pose.orientation.z = -0.68;
goal.target_pose.pose.orientation.w = 0.73;
```

Goal Setting using Sound
Source Localization

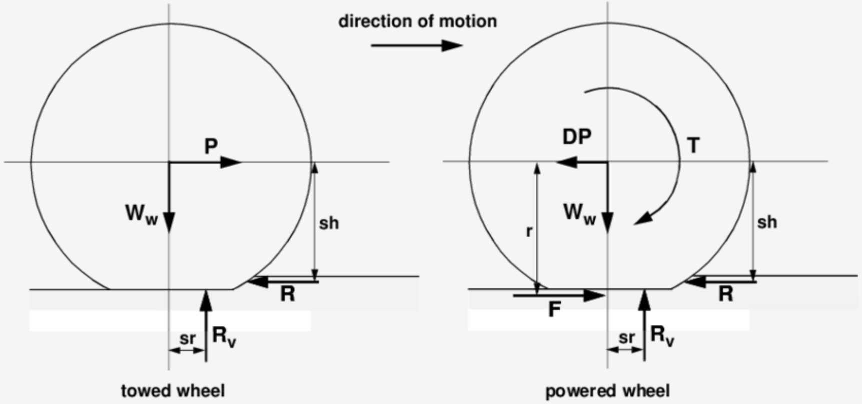
Design Calculations

Design Requirements

- Desired maximum speed 2 $m.s^{-1}$
- Desired maximum acceleration 0.5 $m.s^{-2}$
- Maximum payload 80 kg

Drivetrain Parameters

- Mass of the chassis 15.5 kg
- Mass of a wheel (m_w) 3.75 kg
- Total mass of the walker (m_t) 103 kg
- Wheel diameter 170 mm



Torque Equation

$$T_{total} = T_f + T_i + T_{rolling,active} + T_{rolling,passive}$$

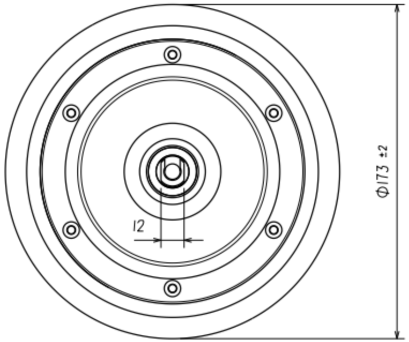
Maximum torque required by the motor was found to be 3.12 Nm

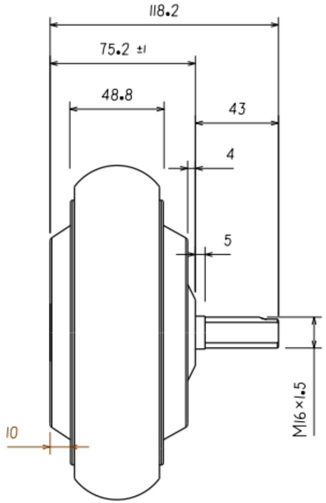
Power Equations

$$P = V.I$$
$$P = T.\omega$$

Maximum power and current required for the application is 65.34W and 2.72A.

Selected Motor Datasheet





Rated Voltage	Power	Rated Torque	Maximum Torque	Rated Speed	Maximum Speed	Rated Phase Current	Max Phase Current
24V-48DC	350W	8N.m	16N.m	200RPM	300RPM	8A	16A
Wheel Diameter	**Weight**	**Shaft Type**	**Encoder**	**Tire**	**Brake Type**	**Protection Level**	**Suggested Load**
170mm	3.75KG	Single shaft	1024/2500/4096-wire magnetic encoder	Rubber	Electric brake	IP65	150KG

Power Wire			
Pin	1	2	3
Color	Blue	Yellow	Green
Signal	Power Wire W	Power Wire U	Power Wire V

Signal Wire							
Pin	5	4	3	2	1	8	7
Color	Blue	Green	Yellow	Red	Black	Purple	White
Signal	Hall V	Hall U	Hall W	+5V	GND	Encoder A+	Encoder B+

Temperature Sensor	
NC	NC
Brown	Grey
Thermistor +	Thermistor -

ZLTECH®	Design change	1		View		Design:	Date:	Company Name: **ShenZhen ZhongLing Technology Co., Ltd**
		2				Proofread:	Date:	Product Name: **Hub Servo Motor**
		3						
		4		ERP:		Approve:	Date:	Product P/N: **ZLLG65ASM250-4096 (Single shaft)**

Differential Drive Kinematics

Three types of motion are possible with a differential drive robot and they are,

- Forward/ backward motion
- Turning in an arc
- Point turn

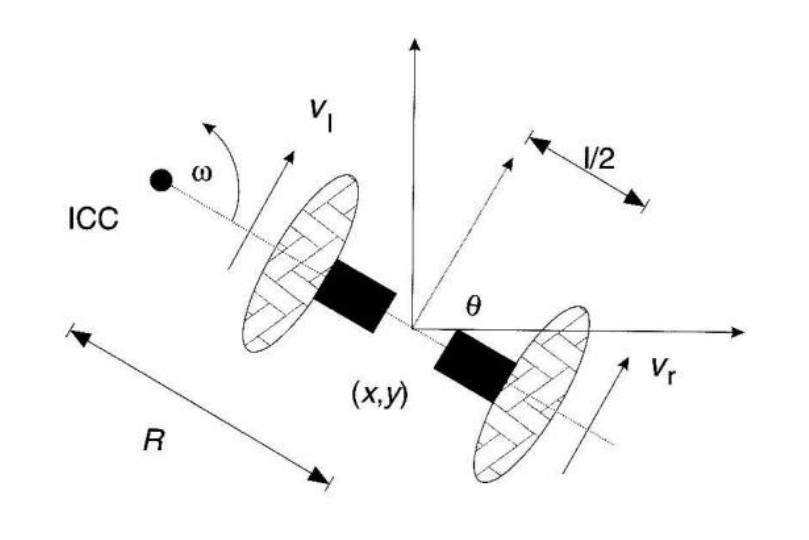
<u>Determining Wheel Velocities</u>

V(t) – Linear Velocity of the robot
ω(t) – Angular Velocity of the robot

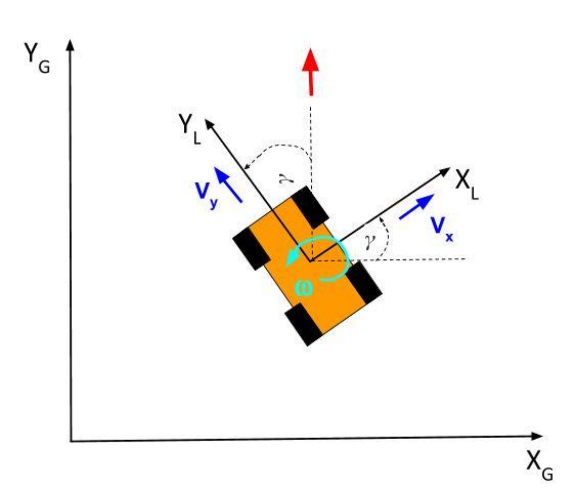
$$V(t) = \frac{V_l(t) + V_r(t)}{2} \qquad \omega = \frac{V_r - V_l}{l}$$

$V_l(t)$ = V(t) – (ω(t). l)/2

$V_r(t)$ = V(t) + (ω(t). l)/2



Differential Drive Kinematics



Position Estimation

$$pose = \begin{bmatrix} x(t) \\ y(t) \\ \theta(t) \end{bmatrix}$$

$$x(t) = \int_0^t V(t)\cos[\theta(t)]\,dt$$

$$x(t) = \frac{V_r + V_l}{V_r - V_l}\,\frac{l}{2}\,\sin[\frac{V_r - V_l}{l}t]$$

$$y(t) = \int_0^t V(t)\sin[\theta(t)]\,dt$$

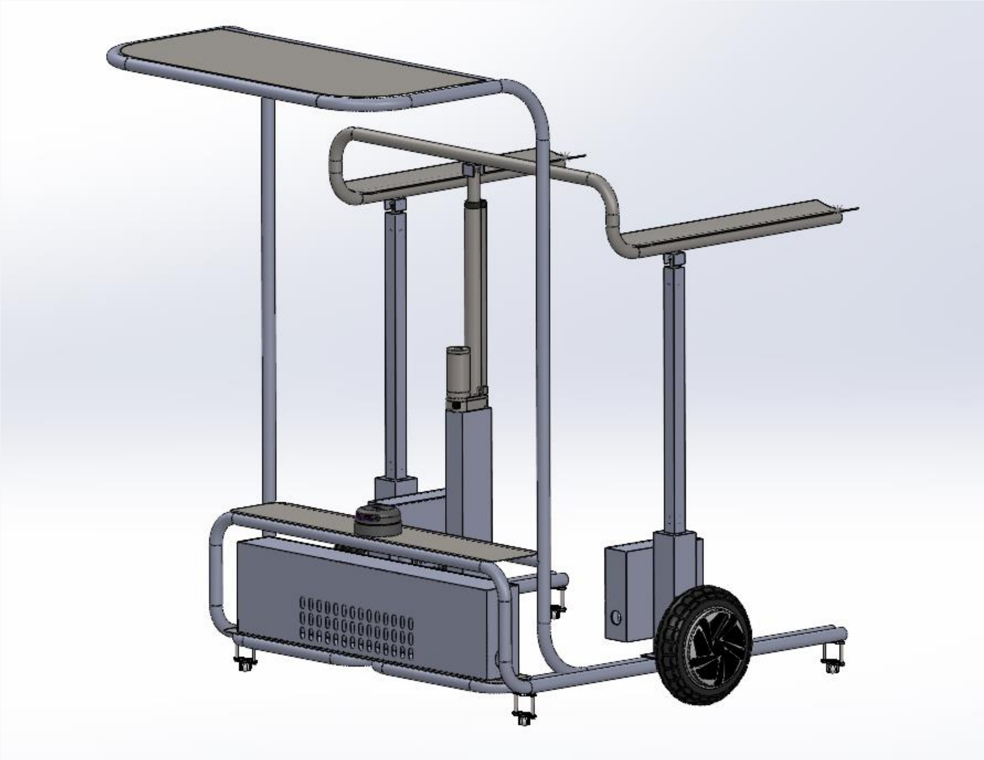
$$y(t) = -\frac{V_r + V_l}{V_r - V_l}\,\frac{l}{2}\cos\left[\frac{V_r - V_l}{l}t\right] + \frac{V_r + V_l}{V_r - V_l}\,\frac{l}{2}$$

$$\theta(t) = \int_0^t \omega(t)dt$$

$$\theta(t) = \frac{V_r - V_l}{l}t$$

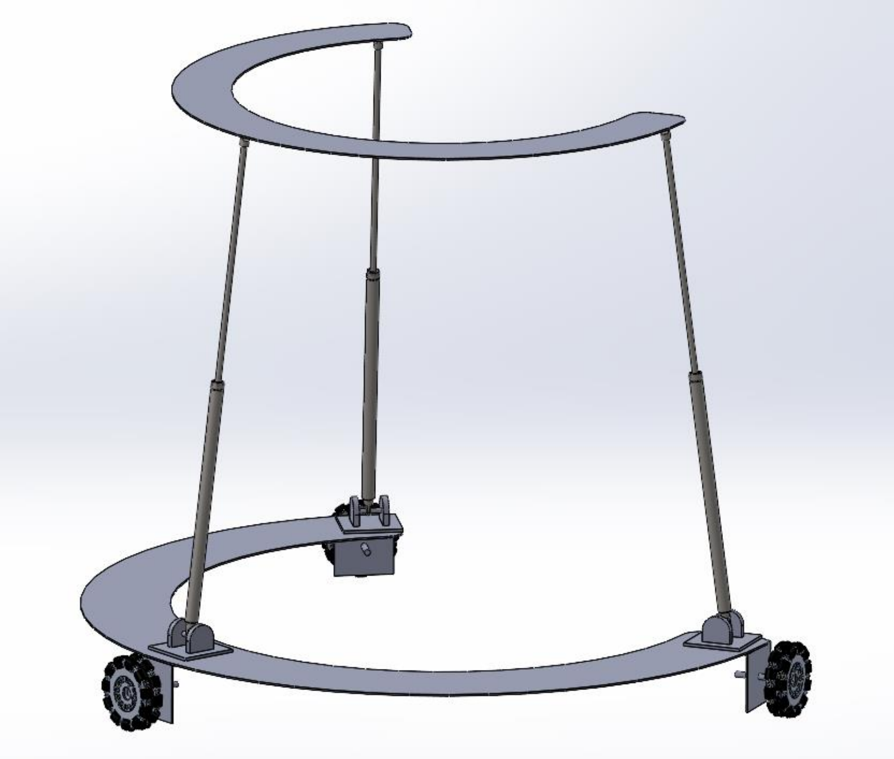
3D Design

Conceptual Design 1
(Differential Drive)



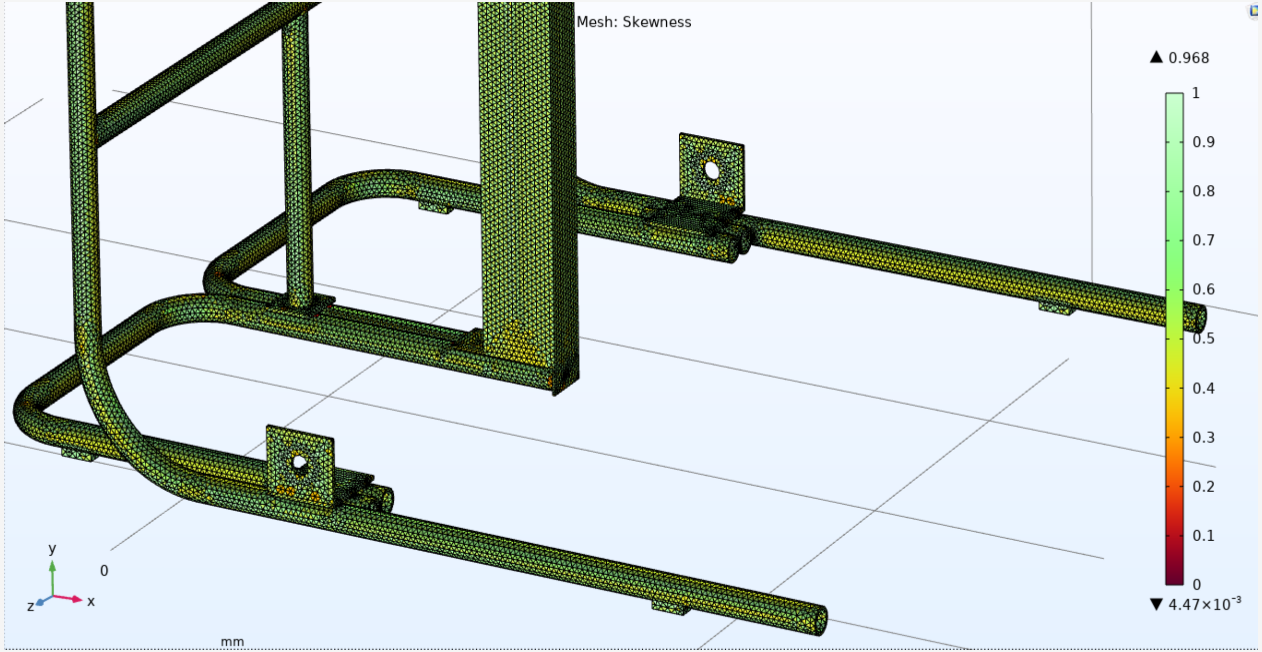
3D Design

Conceptual Design 2
(Holonomic Drive)



Structural Simulations

Meshing



Complete mesh

Mesh vertices: 713556

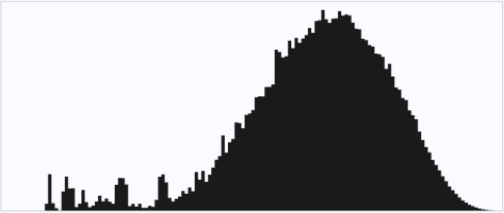
Element type: All elements

Tetrahedra:	3688382
Triangles:	656247
Edge elements:	27051
Vertex elements:	454

Domain element statistics

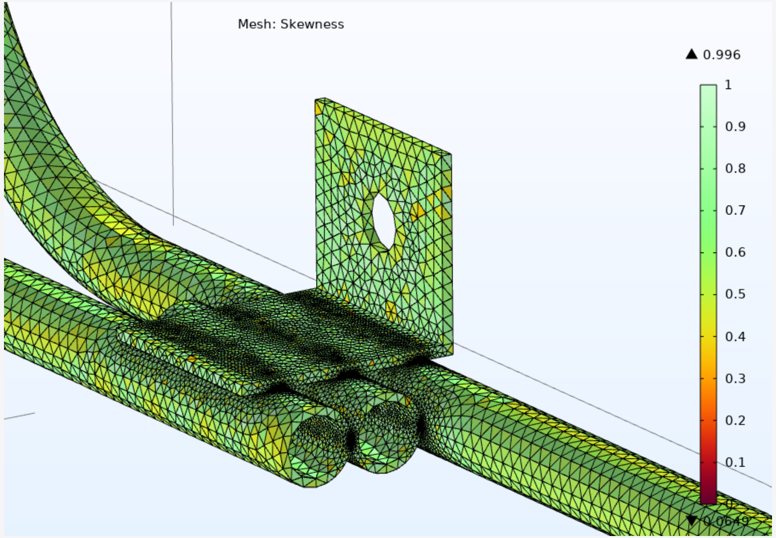
Number of elements:	3688382
Minimum element quality:	0.06487
Average element quality:	0.6275
Element volume ratio:	1.154E-7
Mesh volume:	1942000.0 mm^3

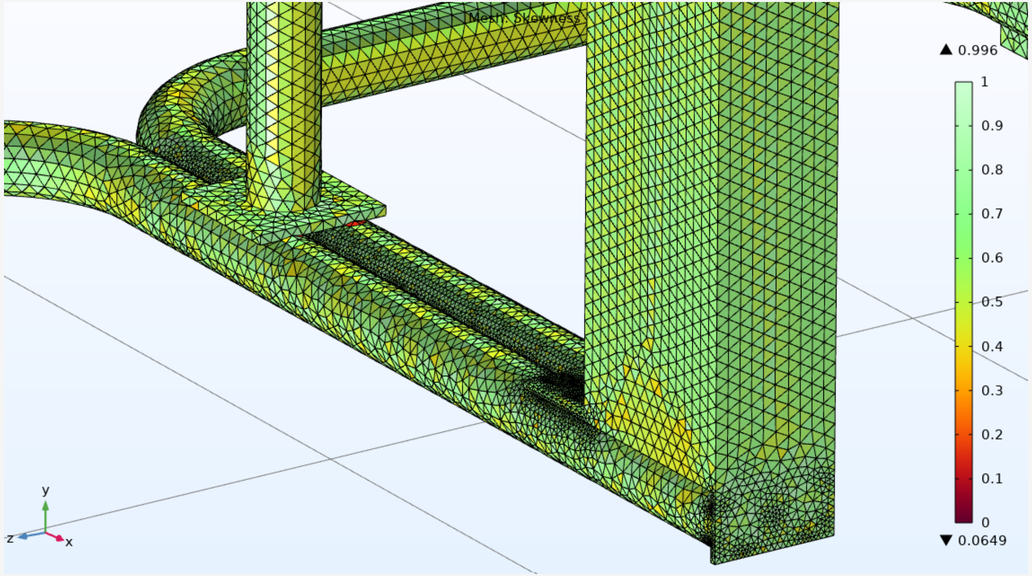
Element Quality Histogram



Structural Simulations

Meshing





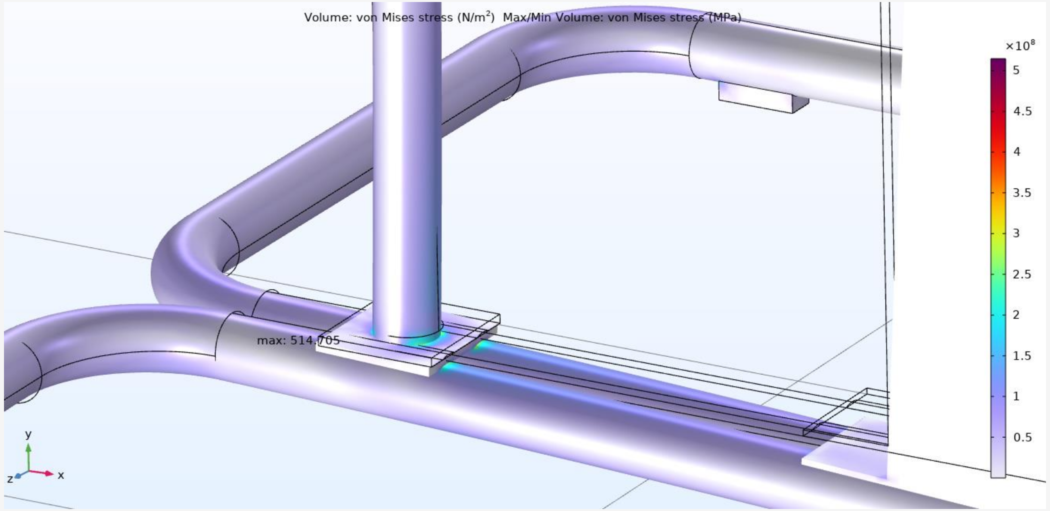
Structural Simulations

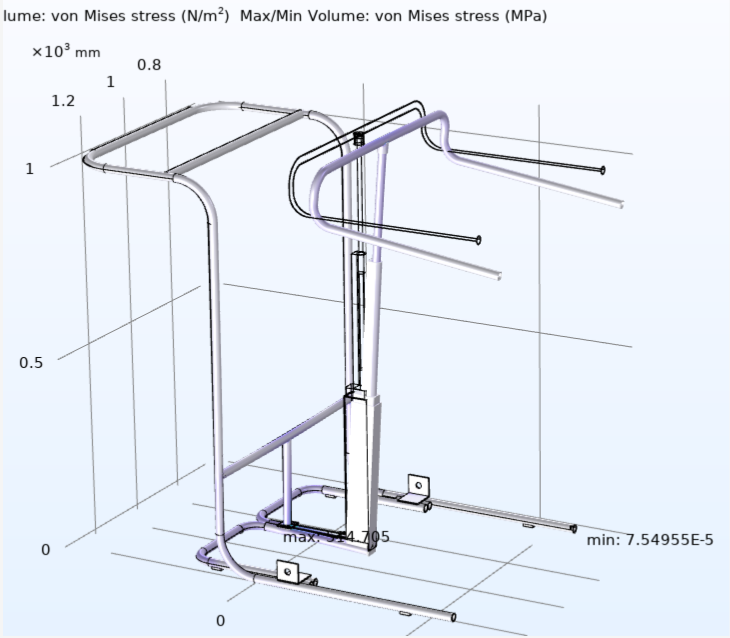
Stress Analysis

Simulation Parameters

- 400 N load on the armrest
- 20 N load on the laptop tray
- Material used – 304 Stainless Steel, 1030 Plain Carbon Steel

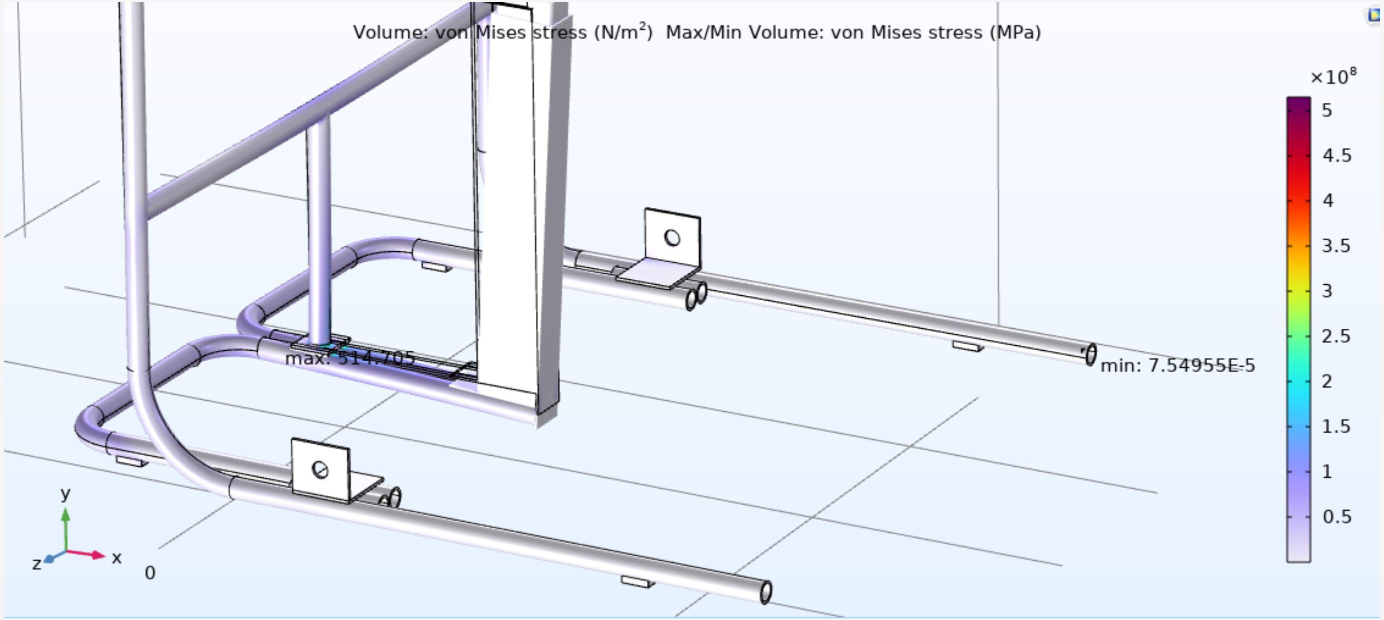
Tensile strength of Stainless Steel- 515 to 625 MPa
Maximum stress obtained in the chassis – 514 MPa





Structural Simulations

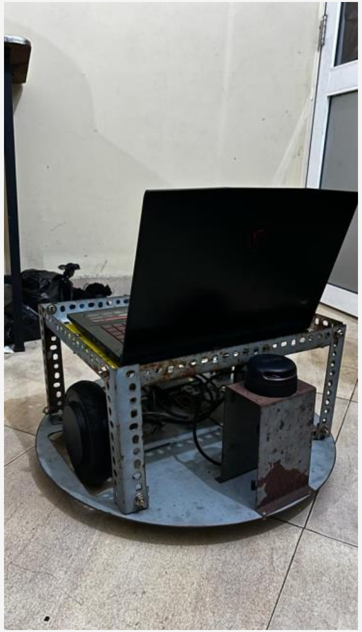
Stress Analysis

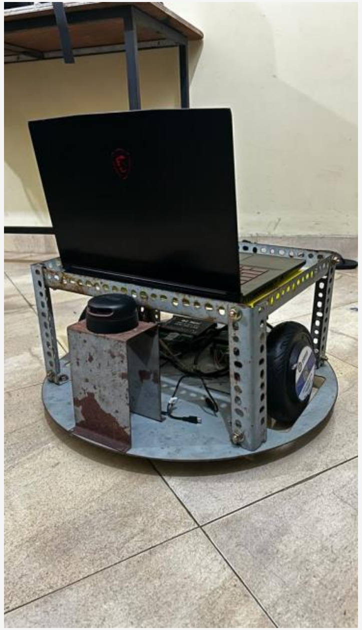


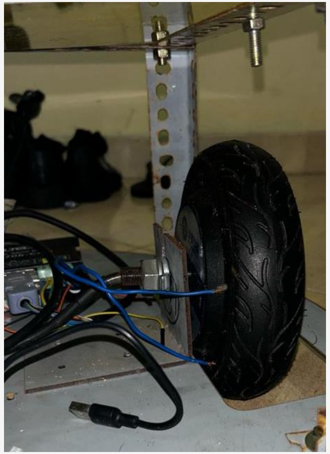
Messages Progress Log **Maximum and Minimum Values**

X	Y	Z	von Mises stress (MPa)
621.78	18.597	679.11	7.5495E-5
-82.938	13.202	1000.5	514.70

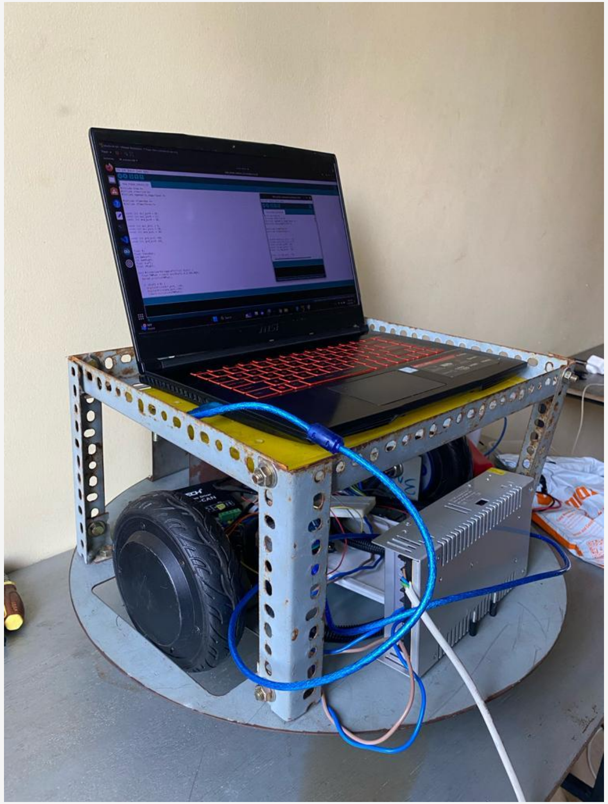
Testing Platform Fabrication





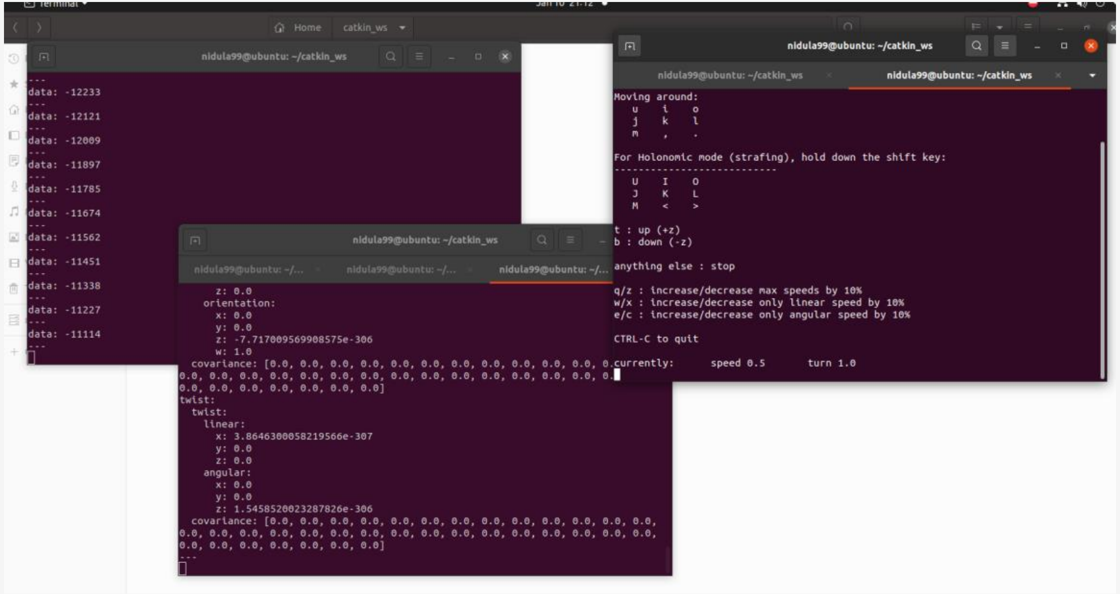


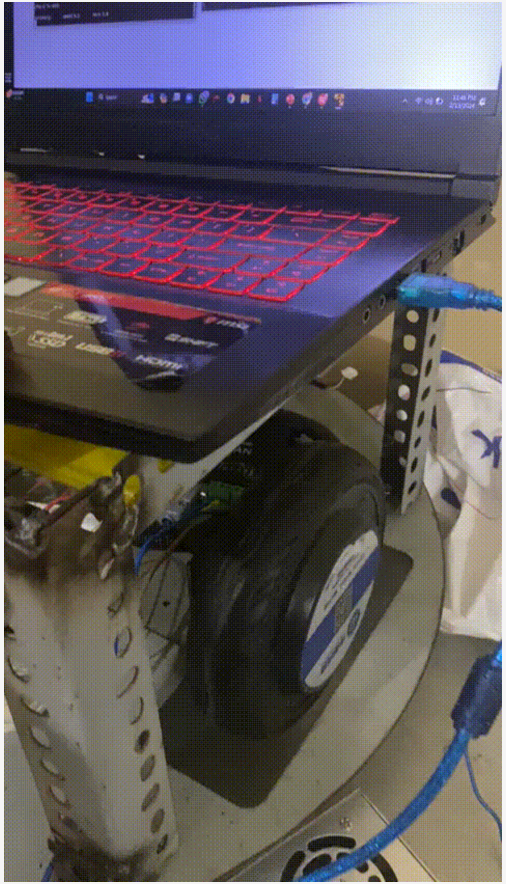
Motor Control & Odometry



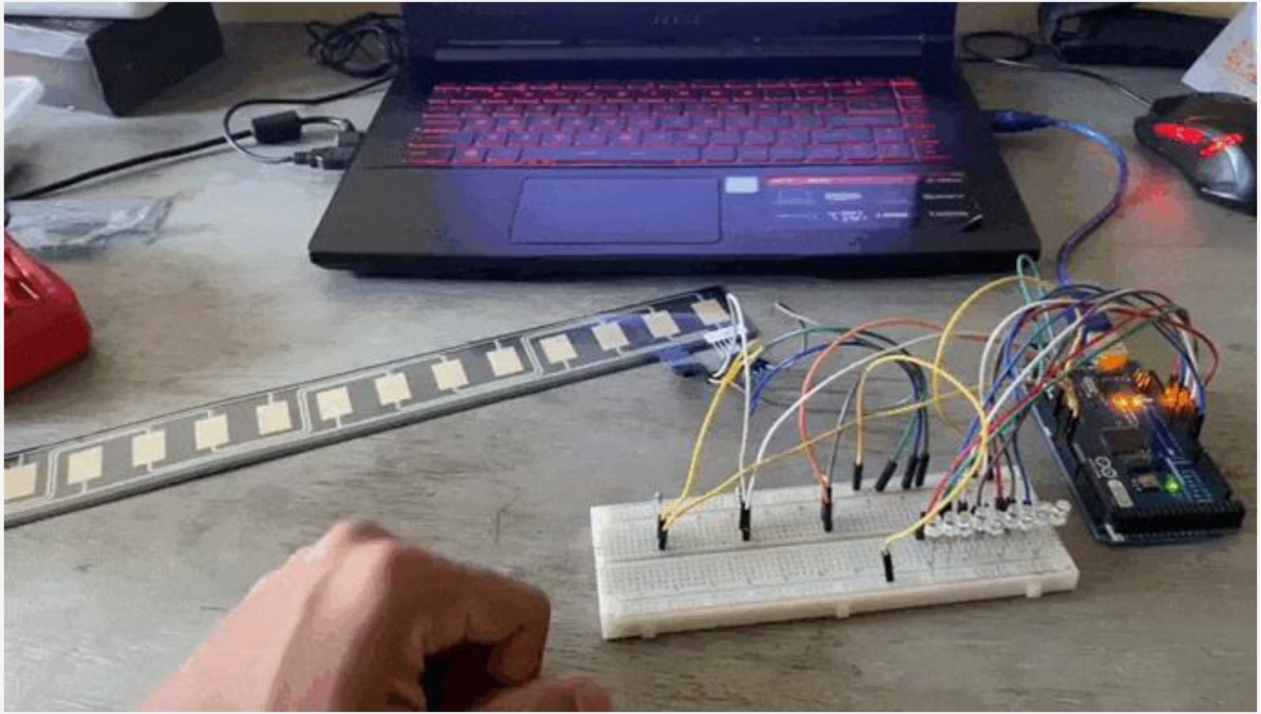
Motor Control & Odometry

Odometry



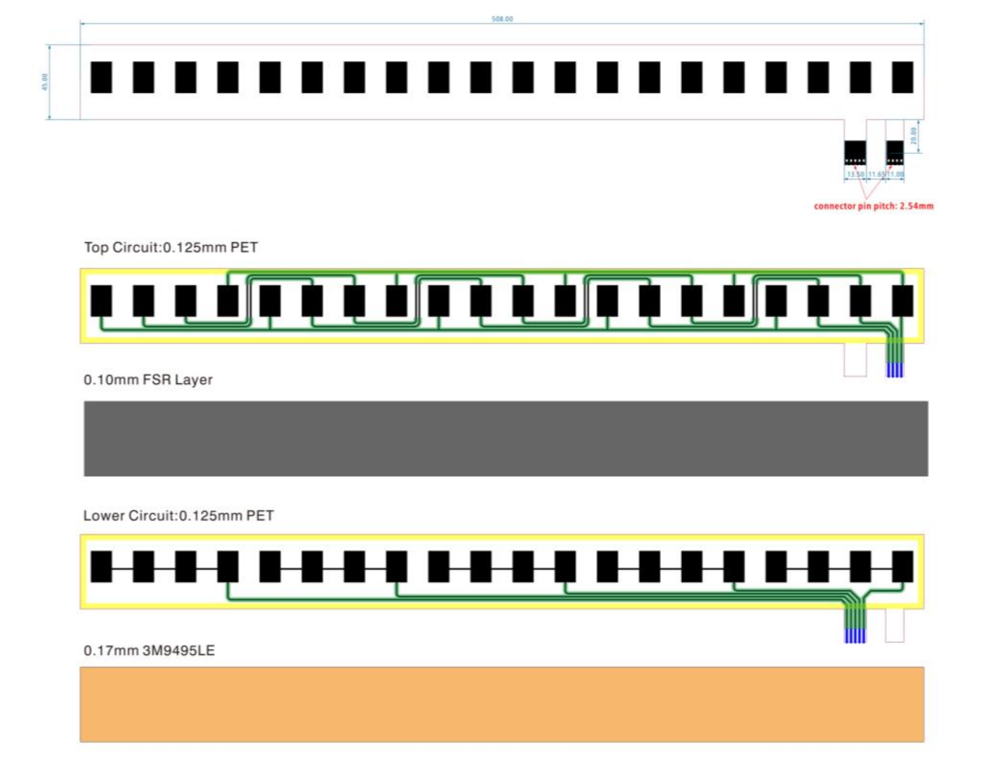


FSR Calibration and Velocity Mapping



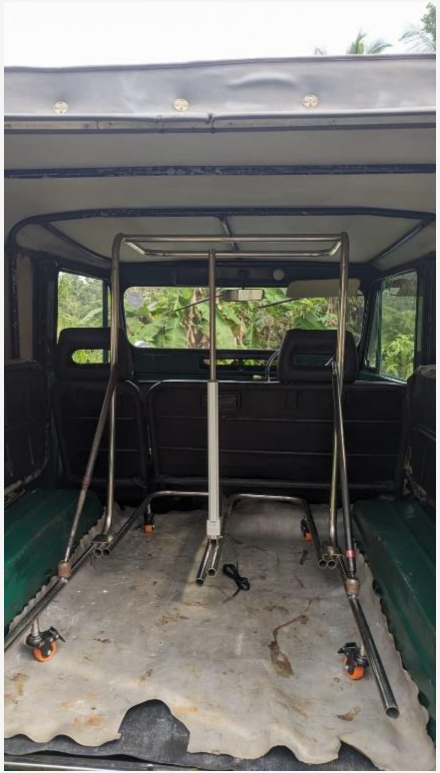
Force-sensitive Resistor (FSR) Calibration

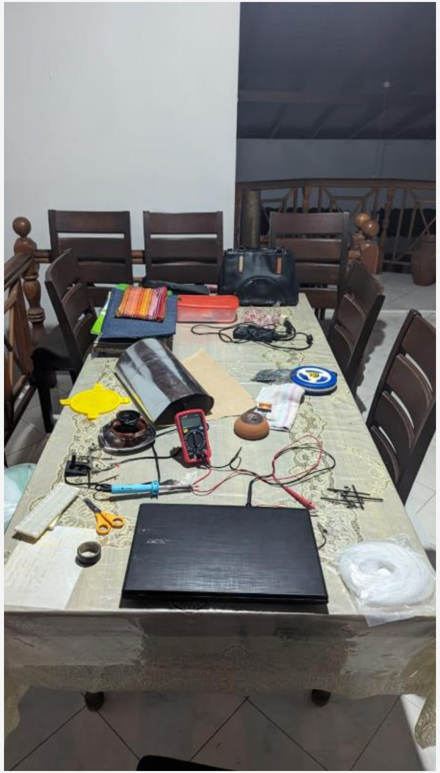
FSR Calibration and Velocity Mapping



Force-sensitive Resistor (FSR) Matrix Arrangement

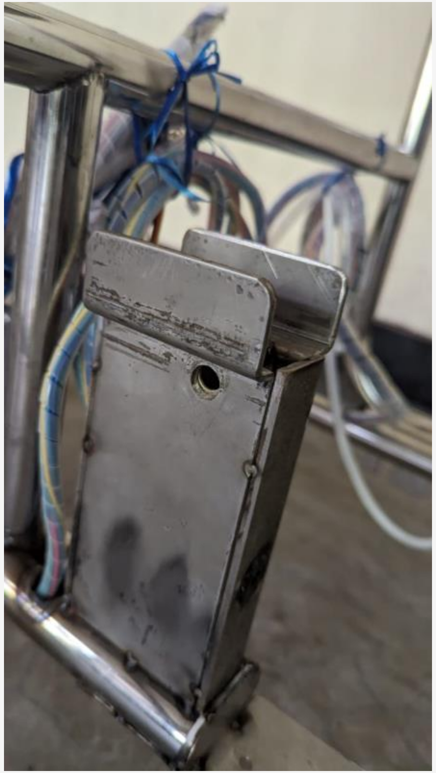
Fabrication



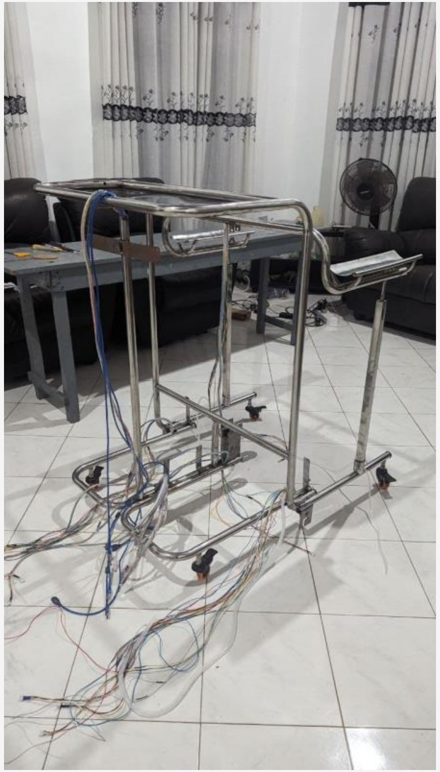


Fabrication

Fabrication



Fabrication

Fabrication

Stereo Vision

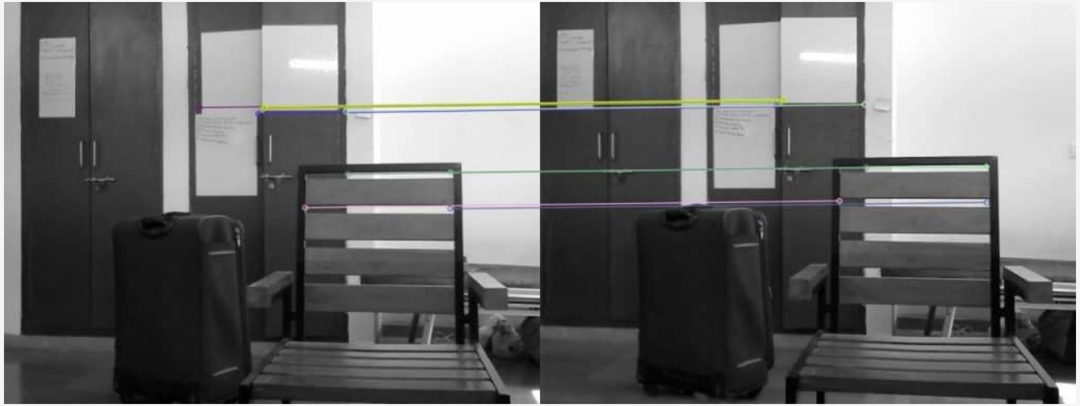
Fabricated Stereo (Binocular) Vision Setup

Checkerboard pattern for Camera Calibration

Stereo Vision

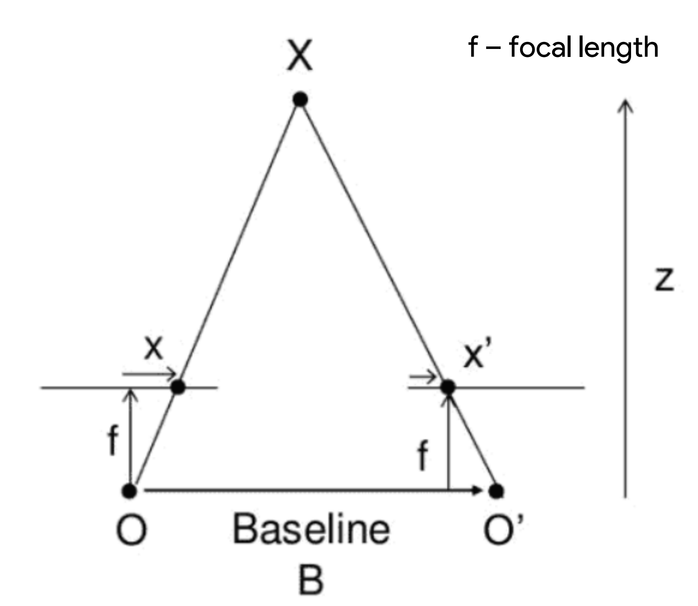
Left and Right Images captured by Stereo Vision Setup

Matching lines between a few corresponding points (Stereo Rectification)



Stereo Vision

Depth Calculation using Disparity



Relationship between
Depth Z and
Disparity (x – x')

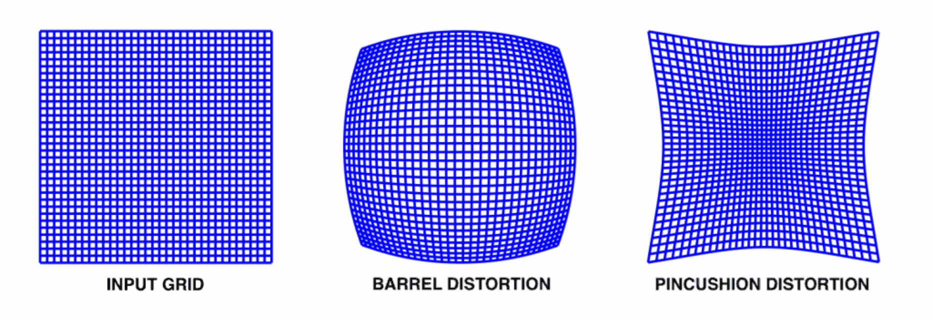
$$disparity = x - x' = \frac{Bf}{Z}$$

$$Bf = M$$

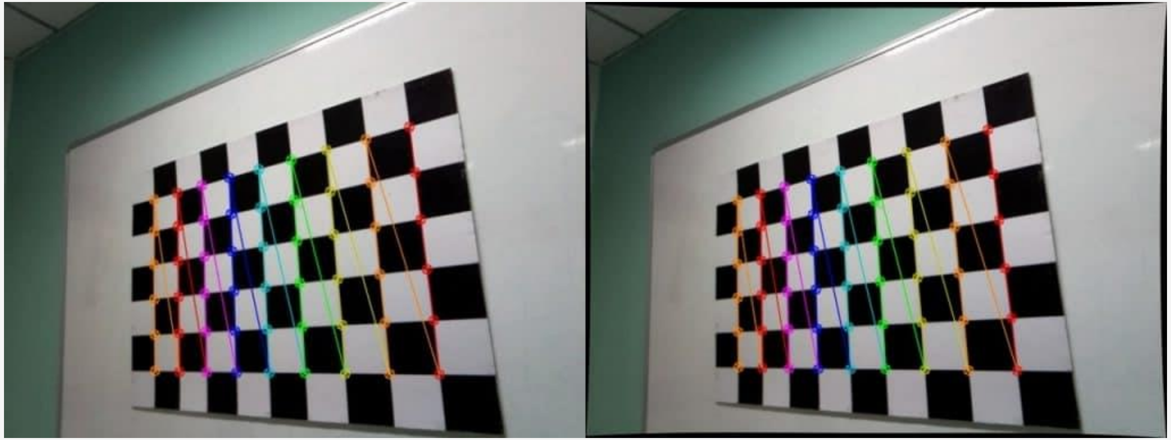
$$Z = M\frac{1}{x - x'}$$

Calculation of depth
from Disparity

Stereo Vision

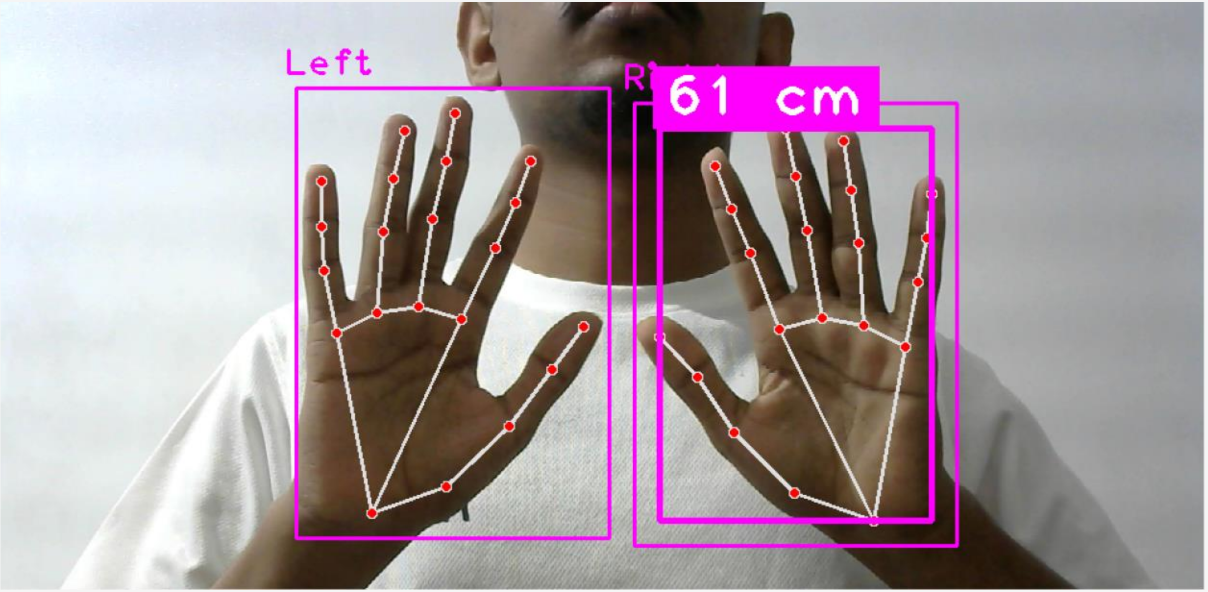


Types of Lens Distortion



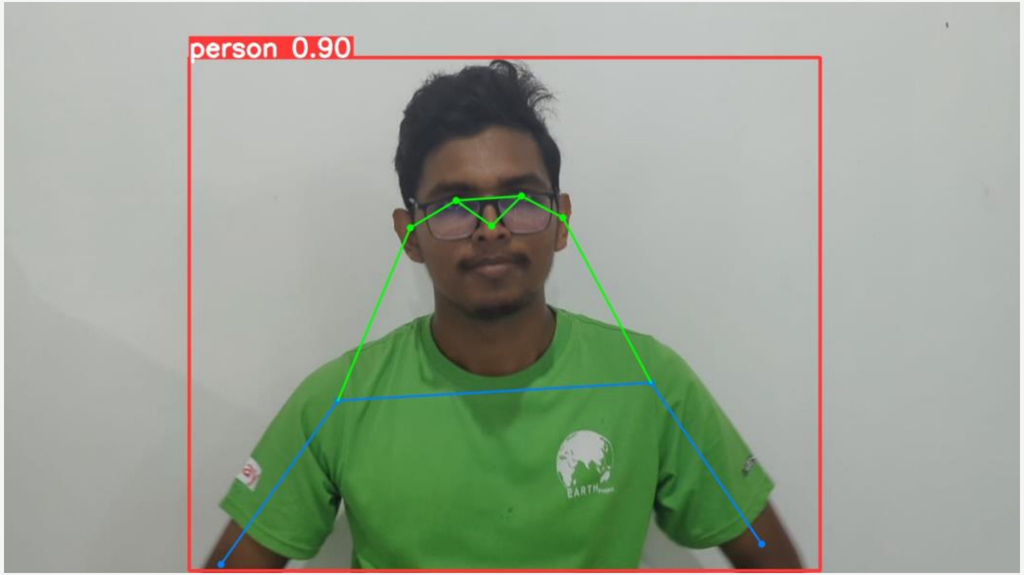
Distorted Image (Left) & Undistorted image (Right)

Depth Estimation



Gesture Recognition and Distance (Depth) Estimation

Stand-to-sit Actuation



Detection of Human Pose Landmarks
using Image Processing
In seated posture

$$f(depth) = k * depth + offset$$

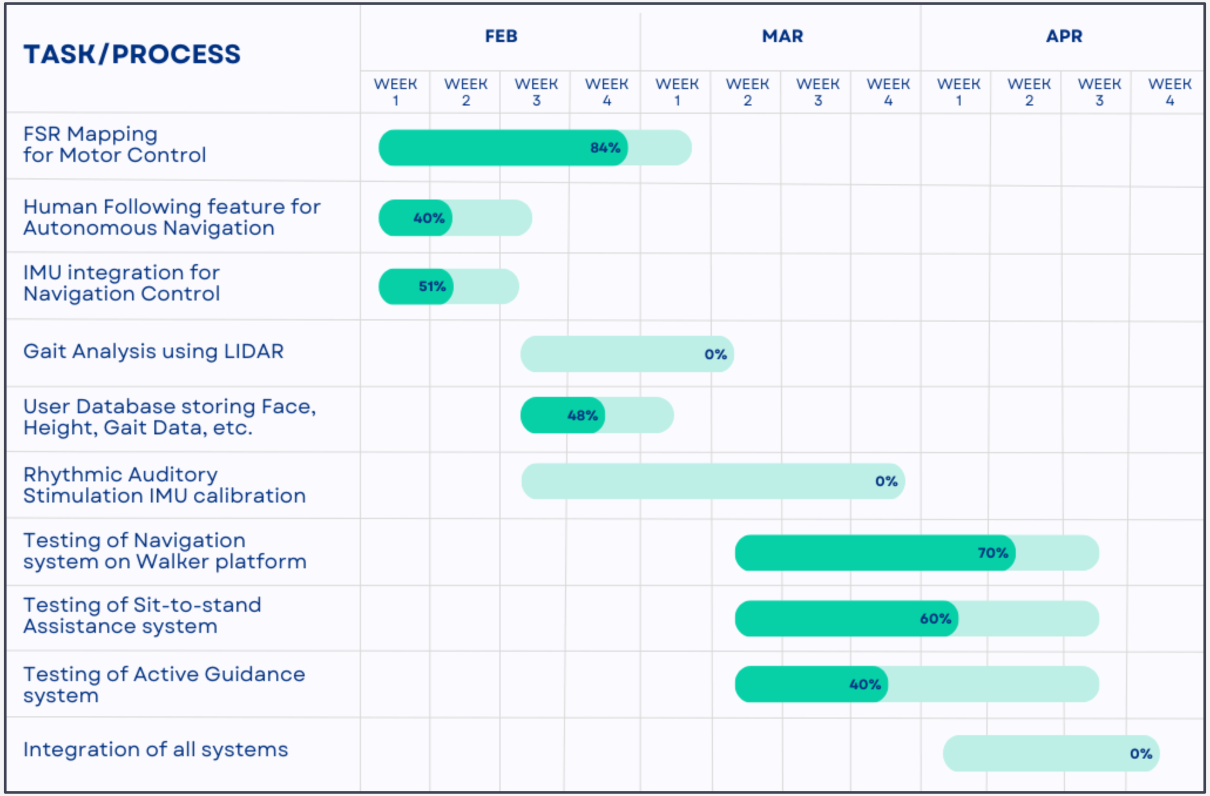
$$head\_size\_cm = f(depth) \cdot head\_size\_pixel$$

$$head\_size\_cm = distancePx(eyes, mouth) * 3$$
$$head\_size\_cm = distancePx(eyes, nose) * 6$$

$$human\_height = 8 \cdot head\_size\_cm$$

Estimation of user operating height by
using anthropometric relations

Future Work


TASK/PROCESS
FEB
MAR
APR
WEEK 1
WEEK 2
WEEK 3
WEEK 4
WEEK 1
WEEK 2
WEEK 3
WEEK 4
WEEK 1
WEEK 2
WEEK 3
WEEK 4
FSR Mapping for Motor Control
84%
Human Following feature for Autonomous Navigation
40%
IMU integration for Navigation Control
51%
Gait Analysis using LIDAR
0%
User Database storing Face, Height, Gait Data, etc.
48%
Rhythmic Auditory Stimulation IMU calibration
0%
Testing of Navigation system on Walker platform
70%
Testing of Sit-to-stand Assistance system
60%
Testing of Active Guidance system
40%
Integration of all systems
0%

Thank you!