Leaf Collection Robot

Group 4 06/11/2025

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Background



- **28 million tons** of leaves dropped each year of the total **40.2 million tons** leaf biomass posing a major problem

- Around **30.6 million tons of yard trimming** each year, A **quarter of it is from fallen leaves**. And these trimming account for **13.5% of total solid waste**

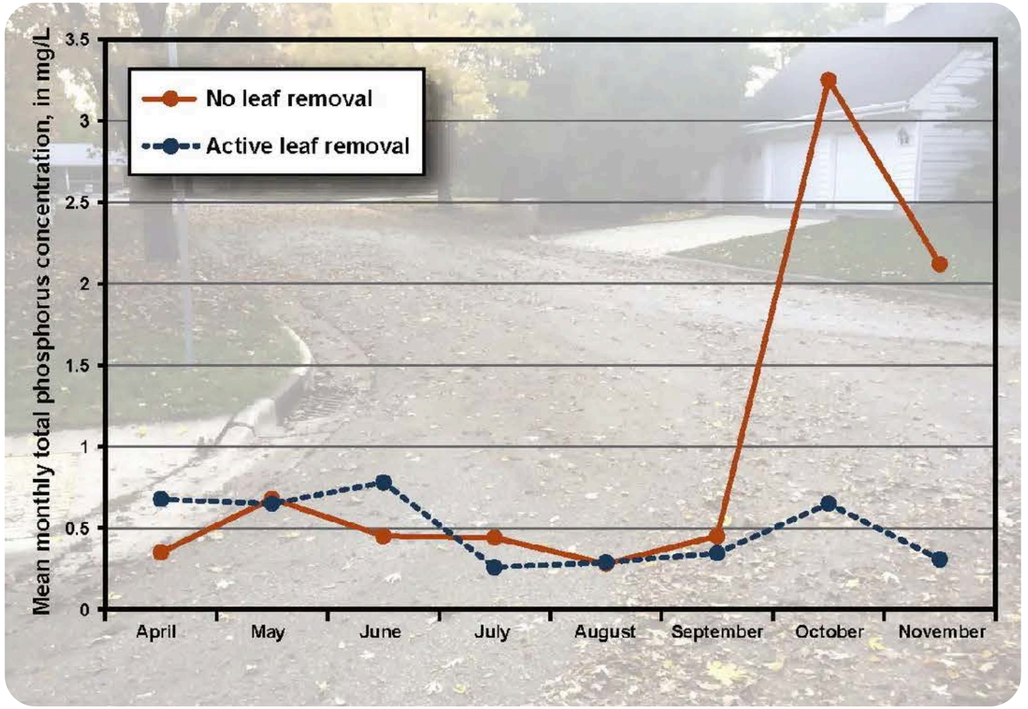
- Leaves are rich in nutrient values and can affect water quality if not dispose correctly.

Background



- Leaves contain a huge amount of nutrients (N-P-K) worth around **551 million dollars per year**. Poor leaves management can cause huge financial loss
- 22 states in the US have regulations for disposing off yard trimmings showing that it is a major problem
- As these leaves are rich in nutrient values, they can affect water quality and nutrient cycles if not disposed off correctly

Background



- Fallen leaves increase concentration of dissolved phosphorus, which can cause problems as seen in the graph.
- Creates problems such as increased algae and eutrophication

Related Works

- Natsu and Hisashi introduced an autonomous blower robot capable of cleaning fallen leaves using real-time navigation and obstacle detection.
- Zhang proposed a small-scale leaf collection and recycling vehicle that utilized mechanical collection and crushing mechanisms.
- Hsia developed a smart leaf-blowing robot integrating deep learning and navigation modules, showing the potential of combining robotic motion with sensor-driven intelligence.
- Miao, Zhang, and Wang presented a method for detecting fallen leaves and cleaning roads using mobile robots equipped with LiDAR-based mapping.

Problem

01

Large amount of leaves near the HM building

02

Takes a lot of manual labor to clean

03

Most leaves doesn’t get disposed properly

04

Existing autonomous leaf collecting robots are expensive

Objectives

01 Automate the leaf collecting process

02 Navigate the robot autonomously or manually

03 Effectively map the area using LiDAR

04 Develop a roller and storage system that can collect and store leaves.

05 Design and build an electronic system for motor control, power regulation and communication between components

Scope

01 Operate on flat surfaces, such as grass lawns

02 Collect dry or slightly moist leaves

03 Autonomous navigation using a predefined LiDAR based map of up to 12 meters

04 Avoid obstacles using LIDAR

05 Operate in normal weather conditions

Expected Outcomes

01 Reduces manual labor for leaf collection through autonomous and LiDAR-based navigation.

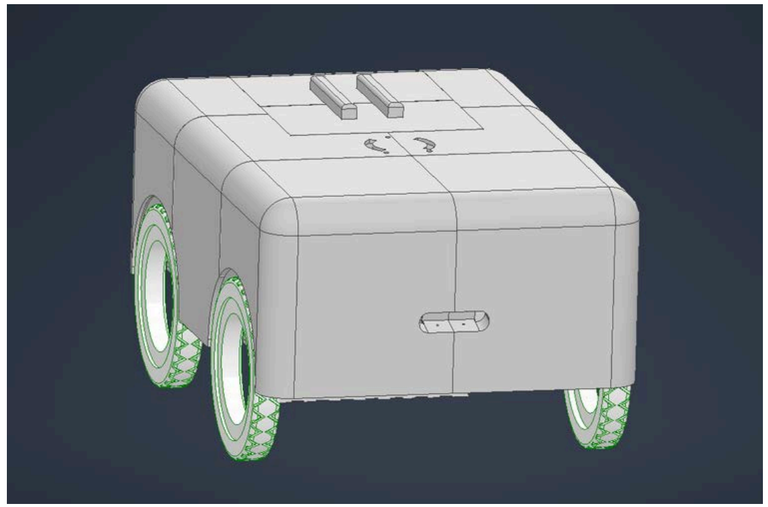
02 Provides a low-cost alternative to expensive commercial autonomous leaf collectors.

03 Modular hardware and ROS2-based architecture allow future upgrades

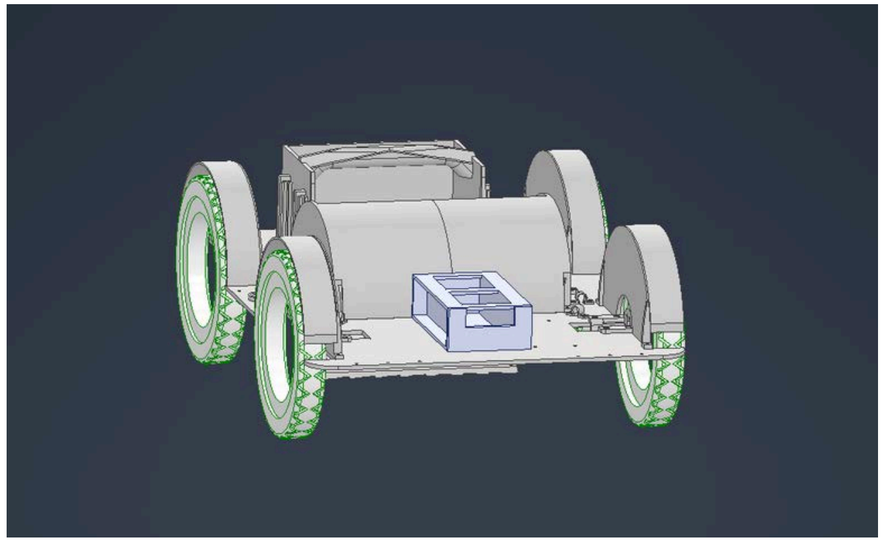
04 Enhances practical learning in robotics, control systems, and embedded software.

05 A fully functional prototype capable of autonomous mapping, navigation, and leaf collection

Hardware Design

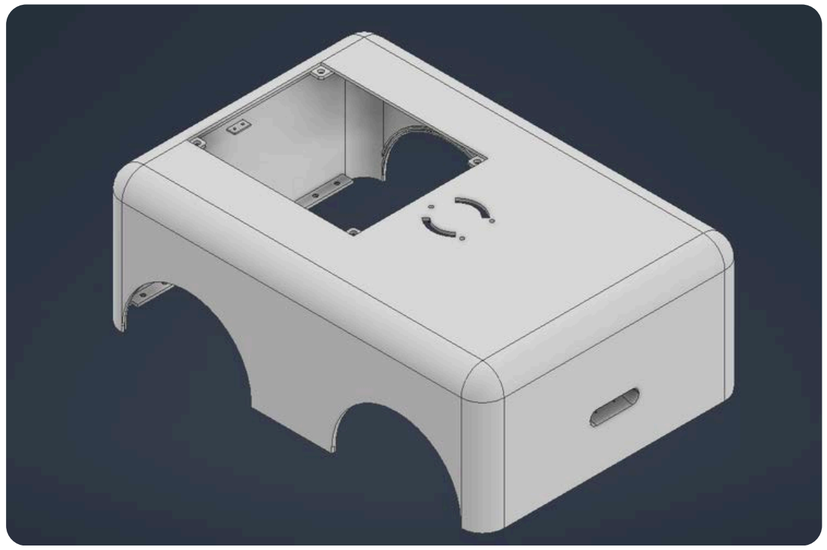


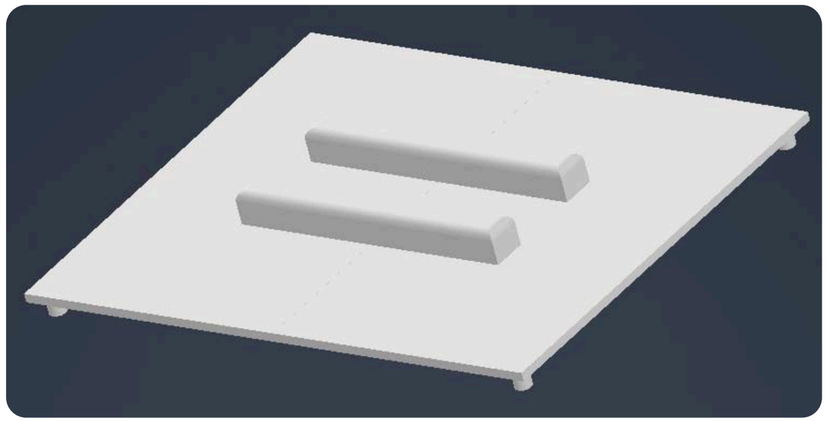
With cover

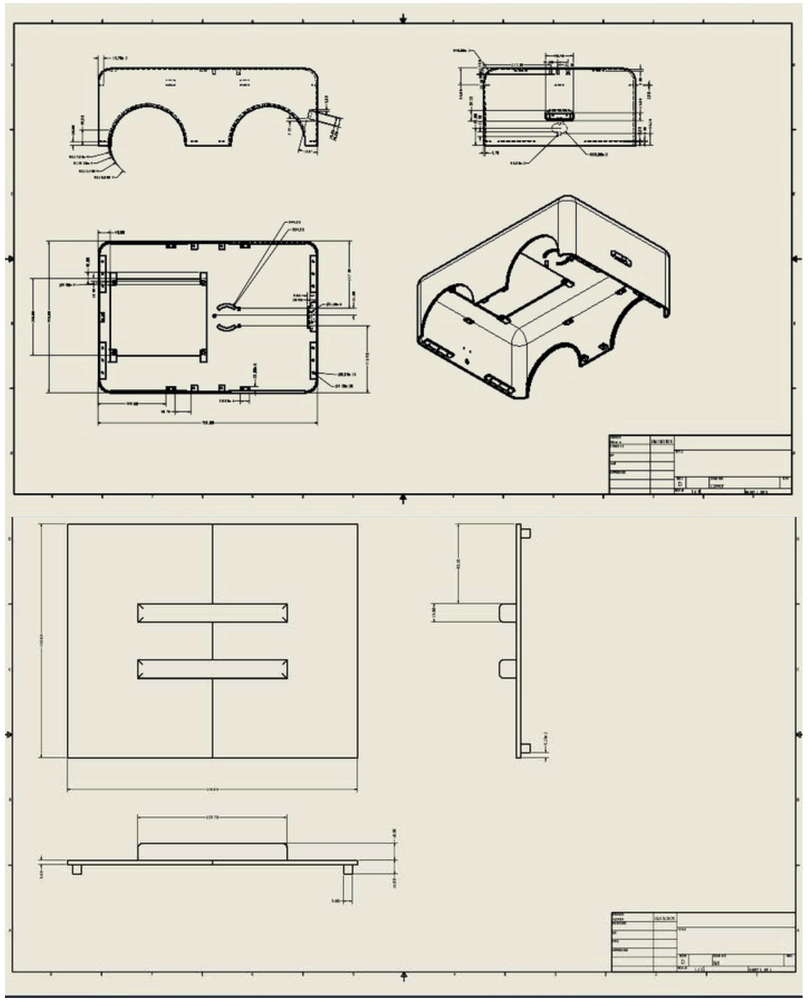


Without cover

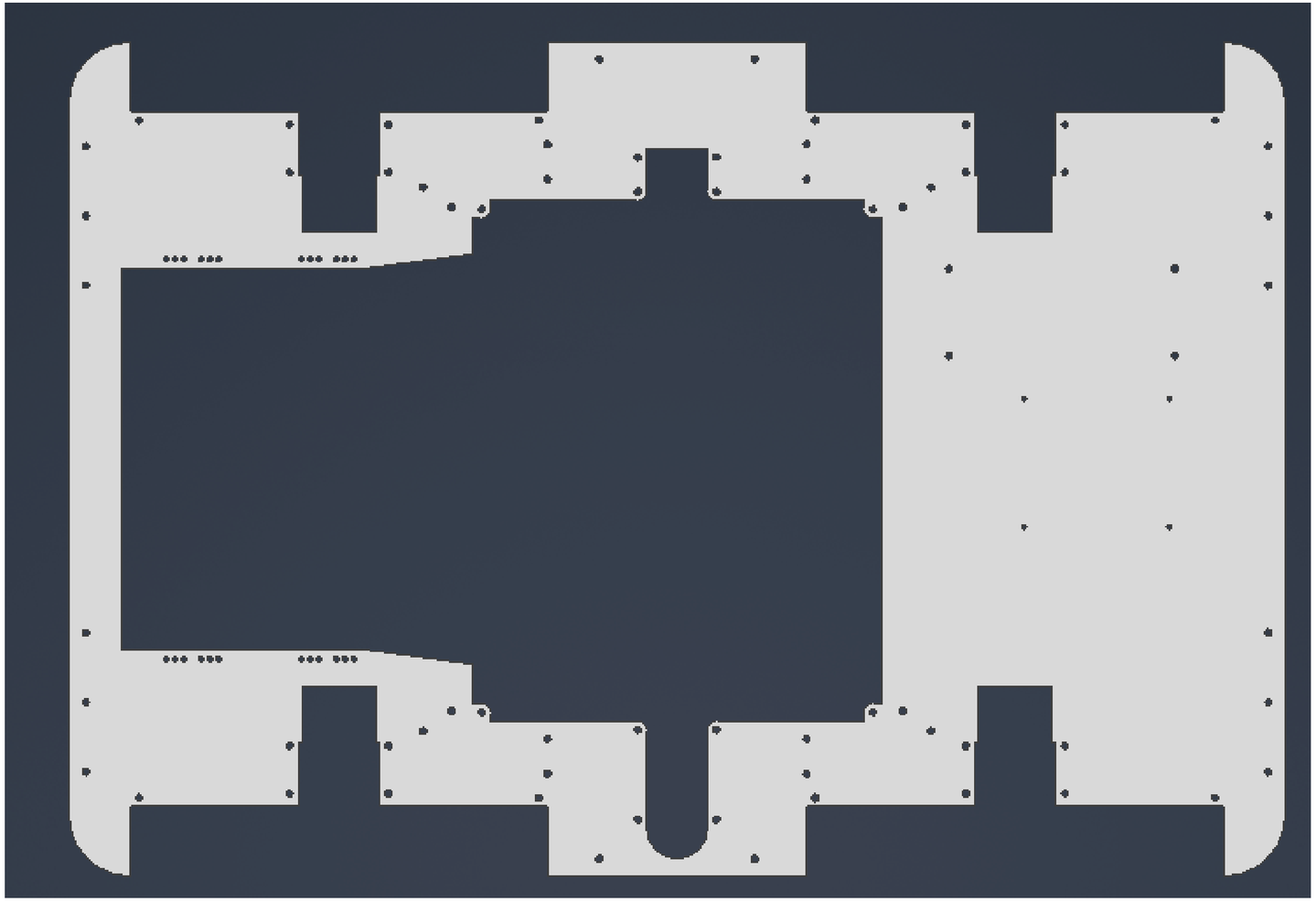
Cover & lid



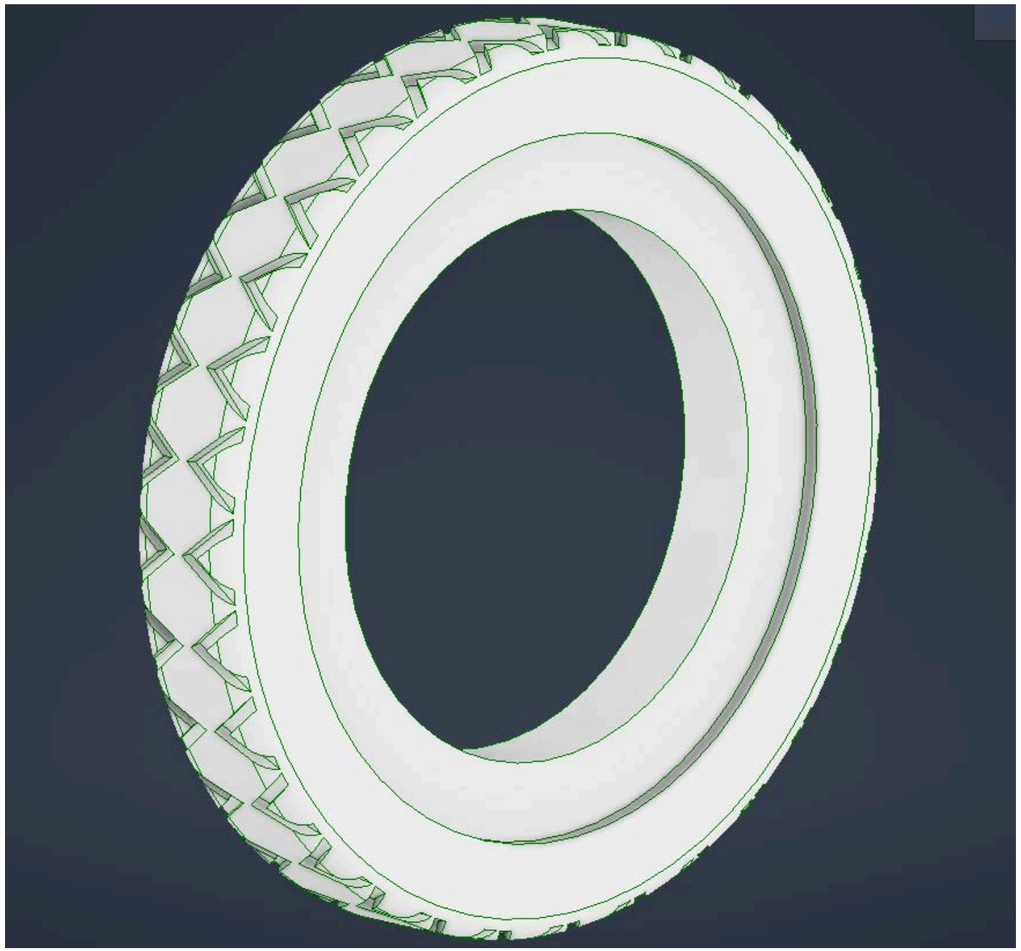




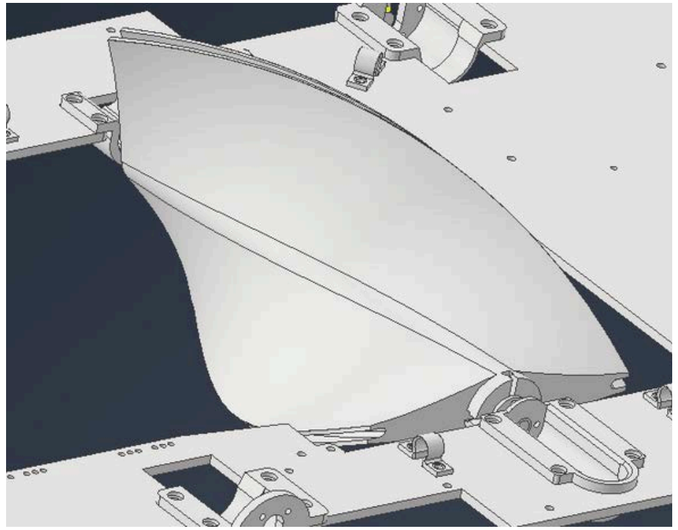
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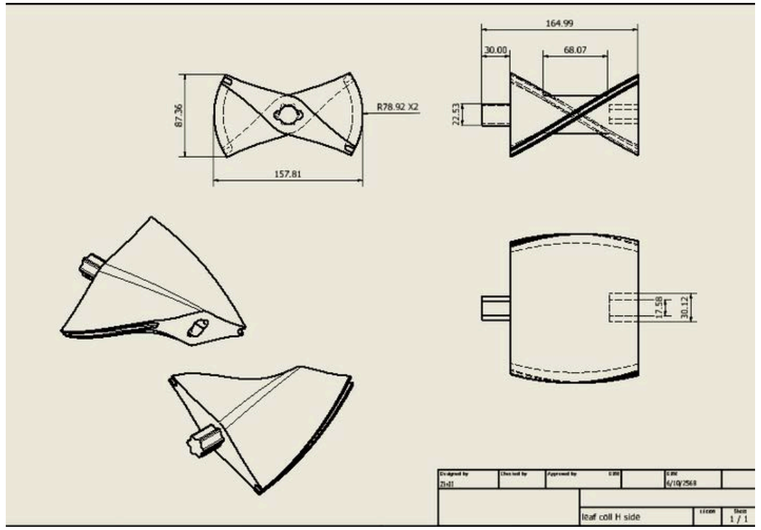


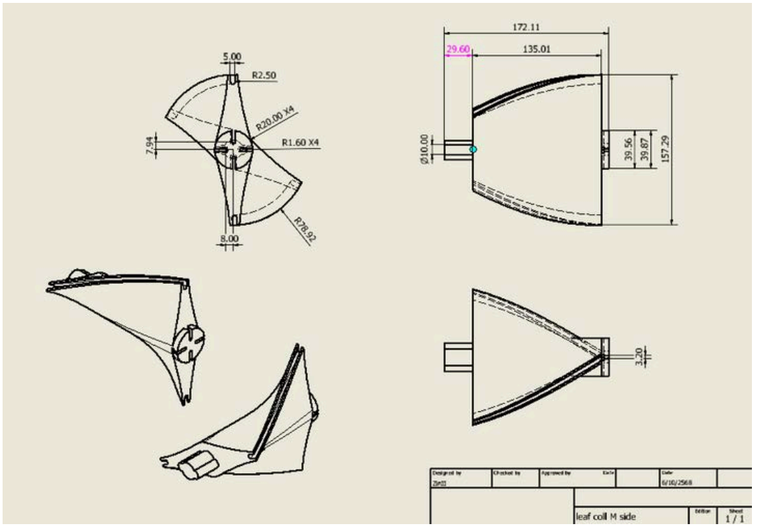
Wheel

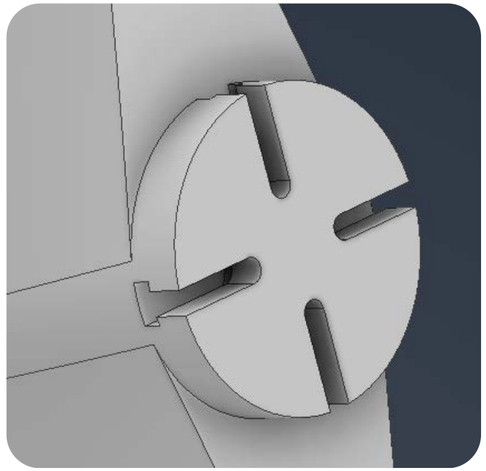


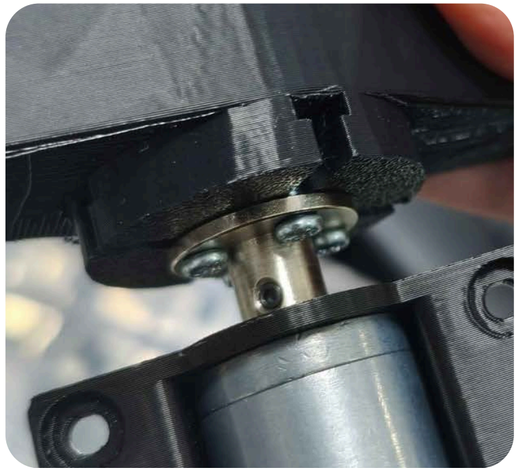
Roller

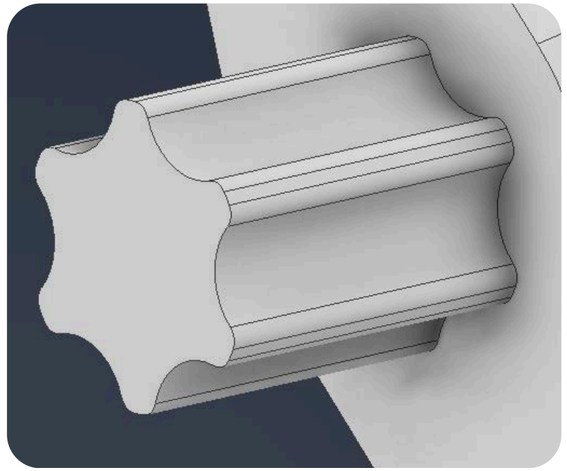


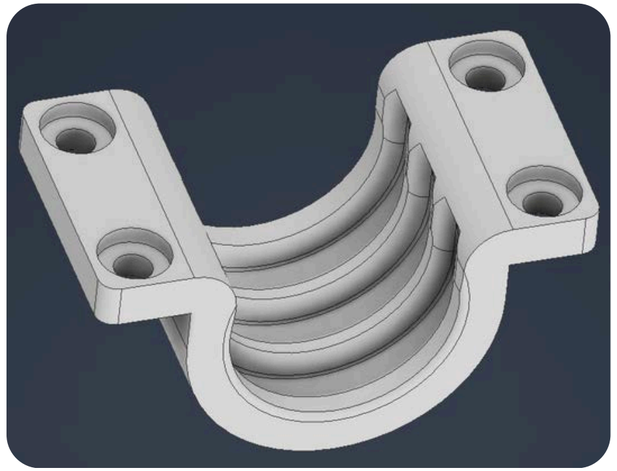

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leaf coil M side
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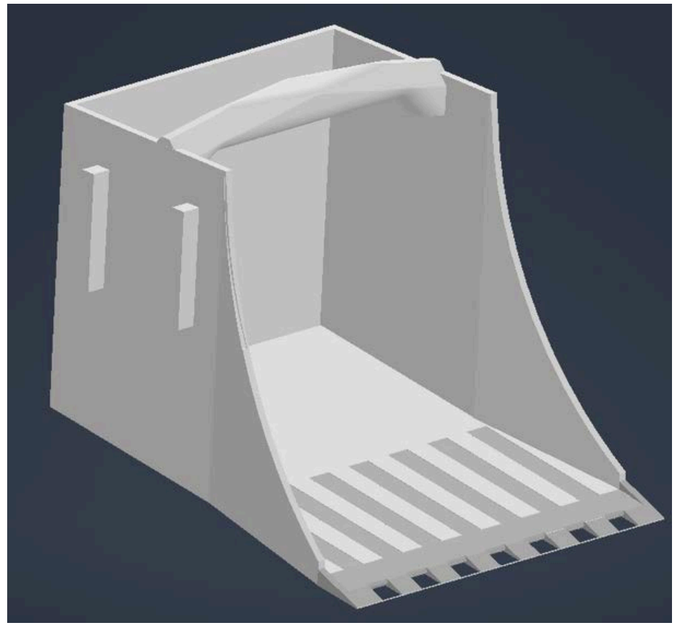


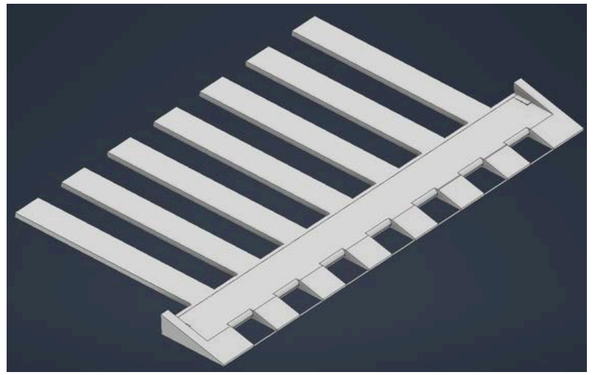


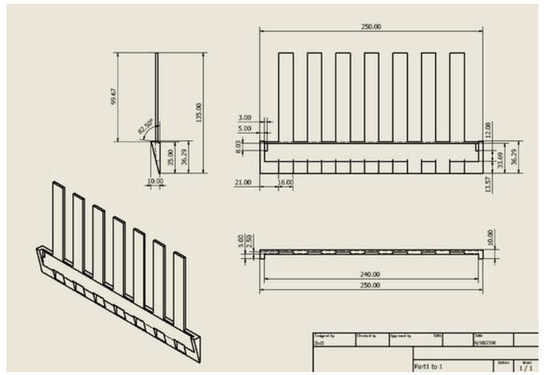


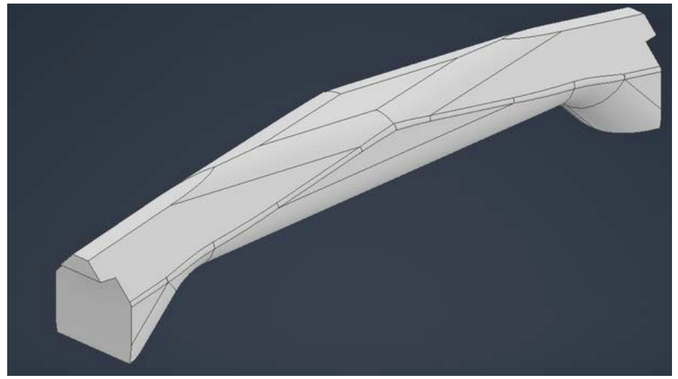


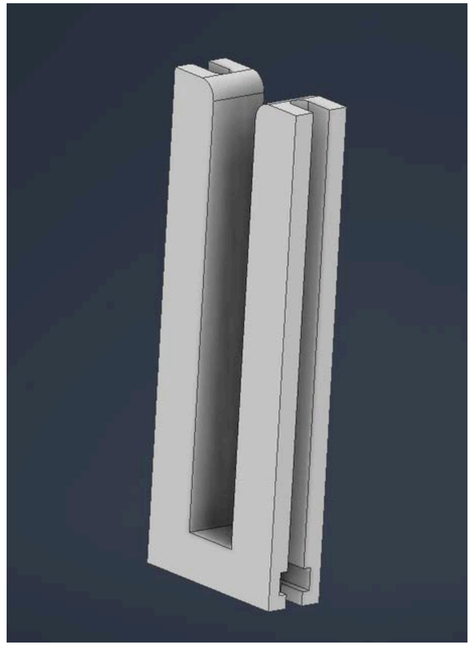
Box

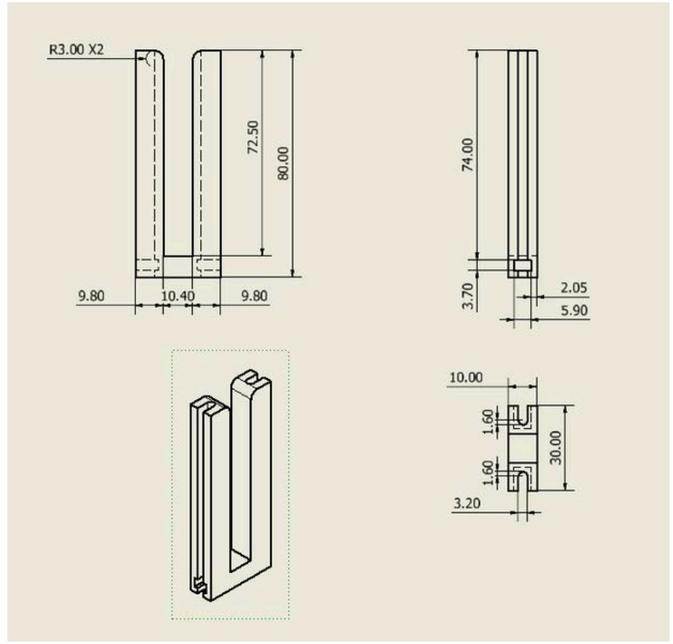




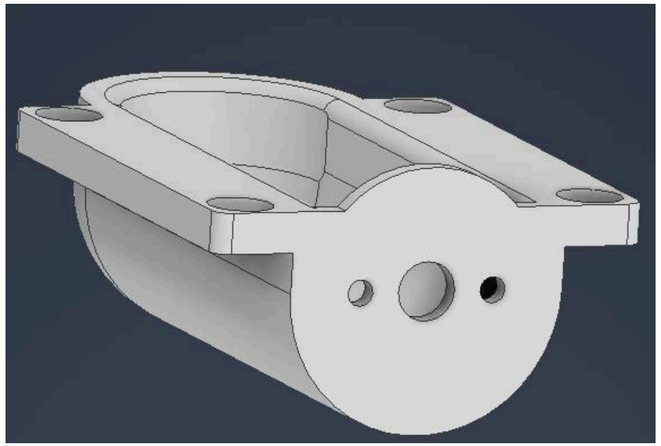

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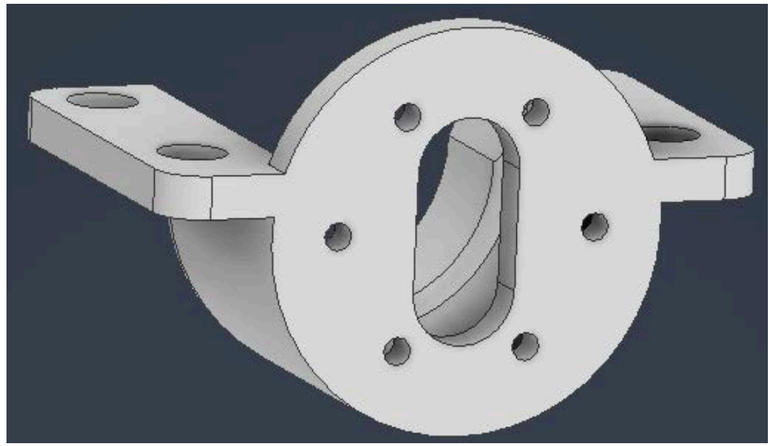


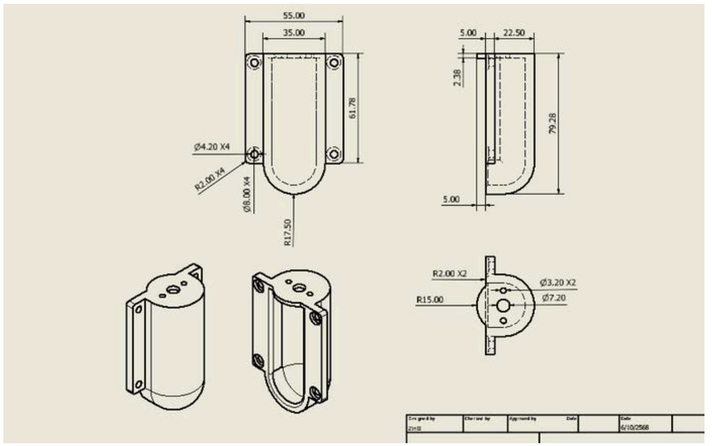


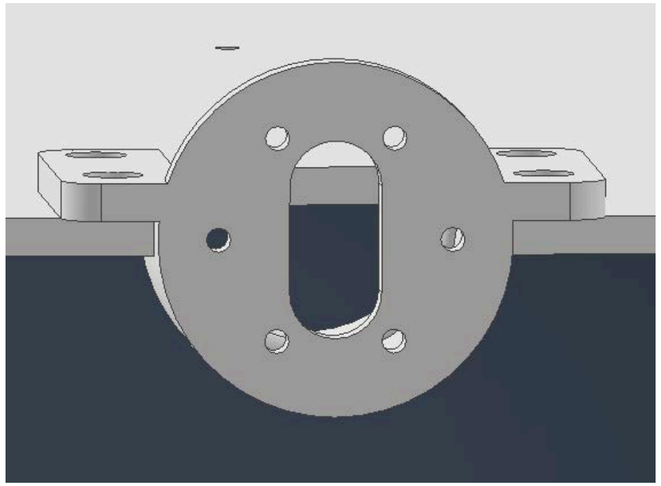

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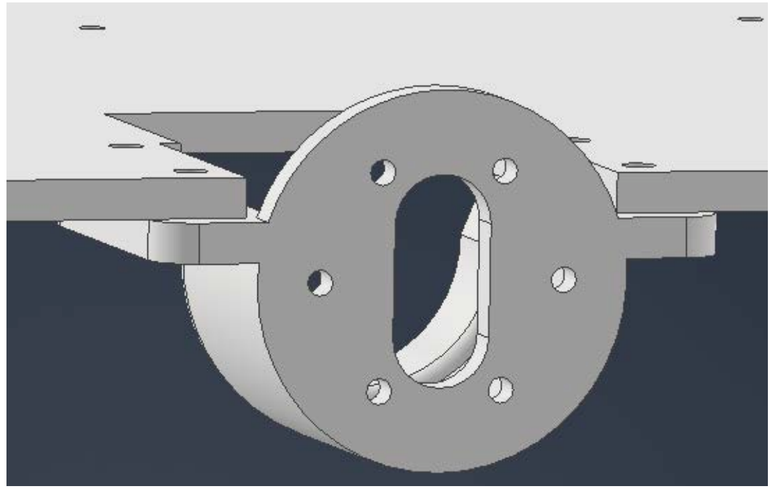
Motor holder

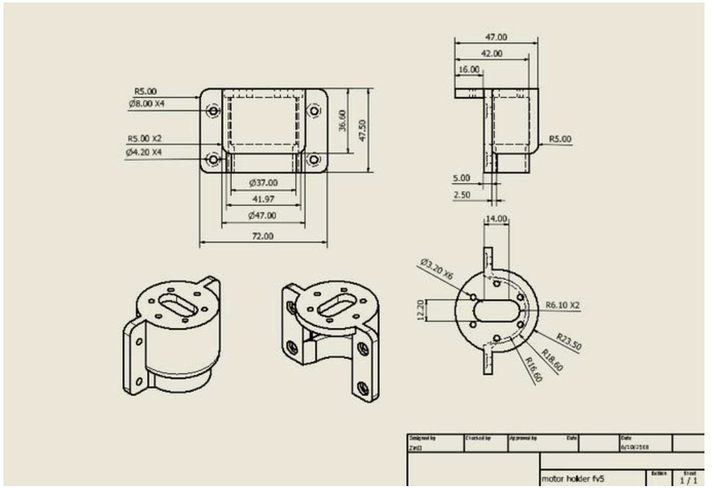




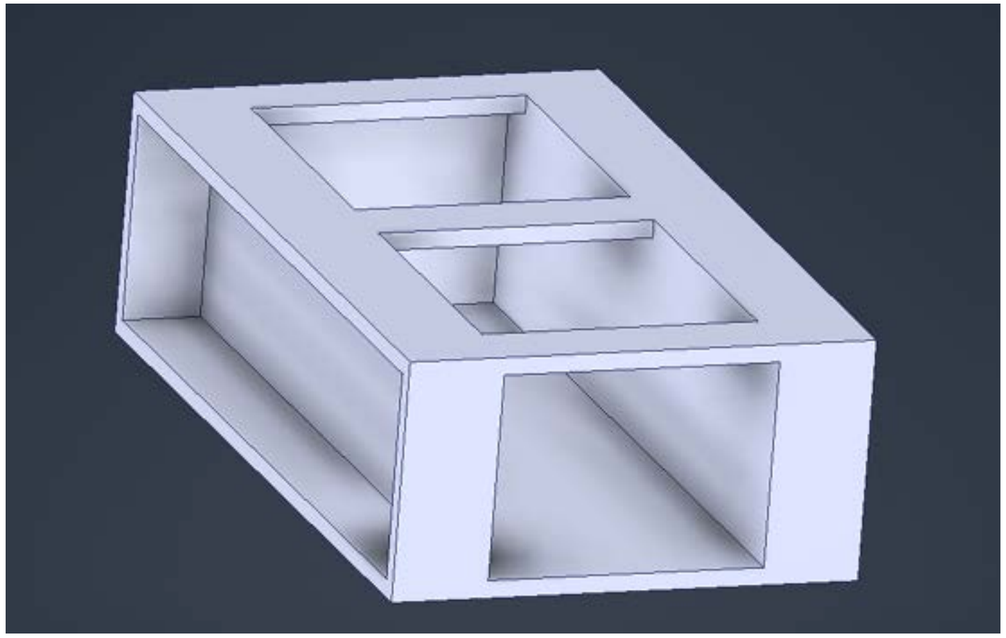


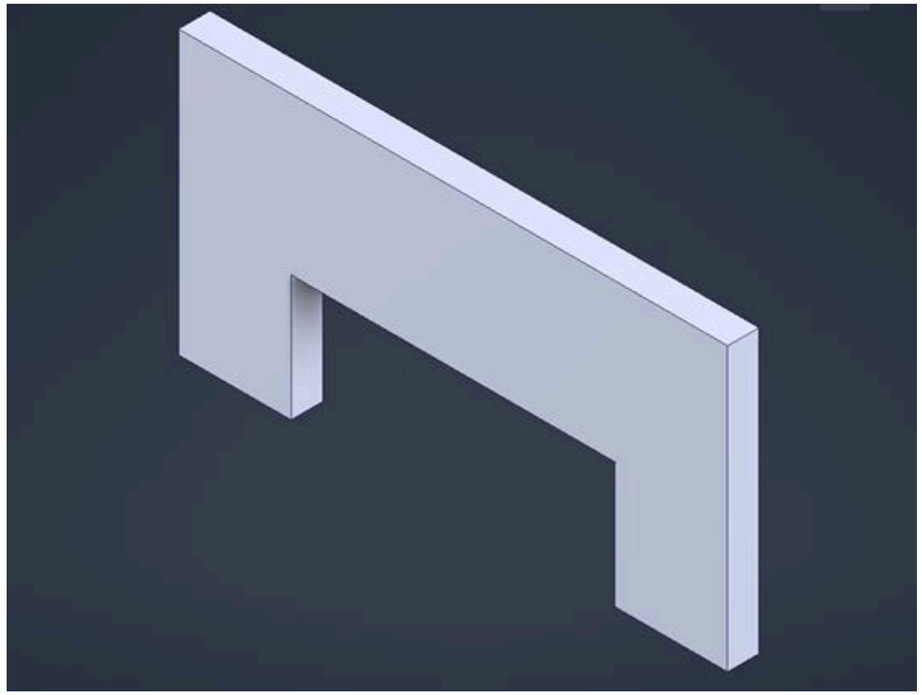




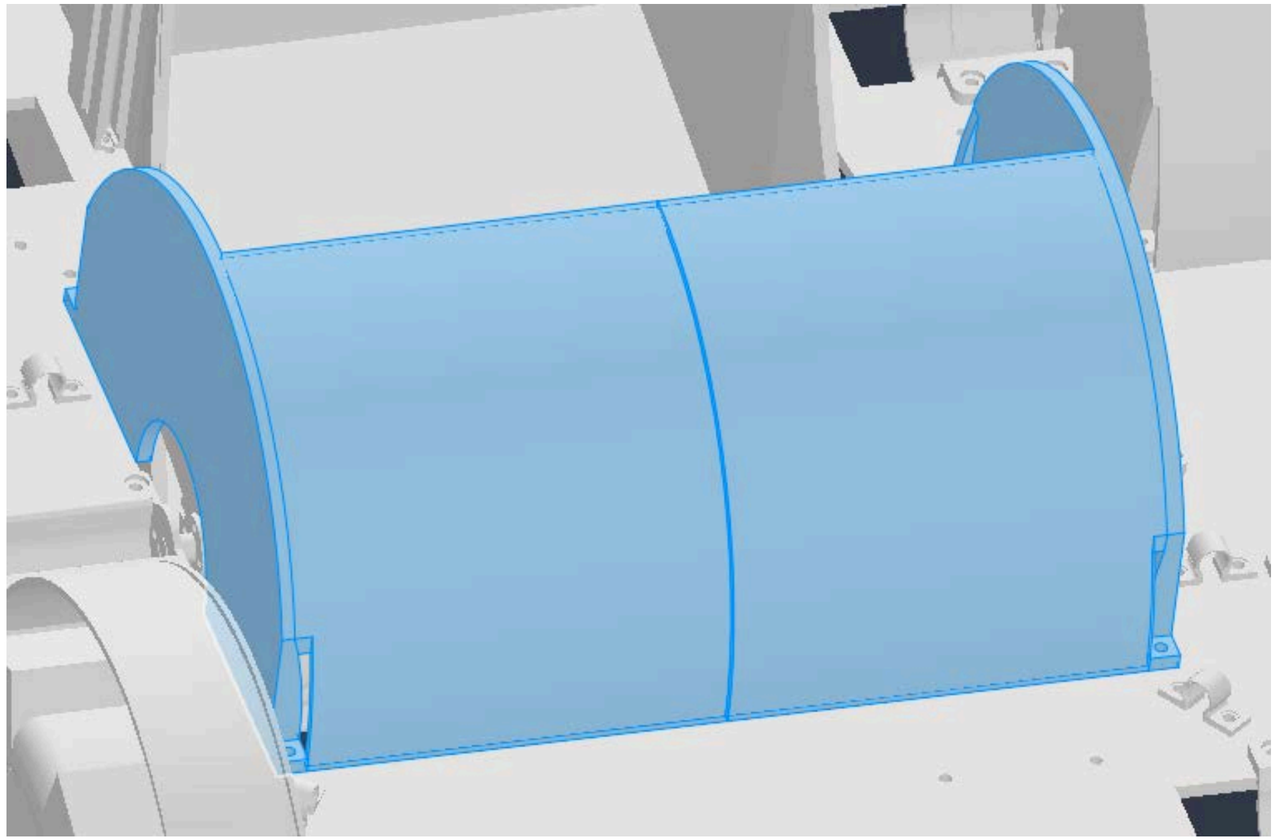


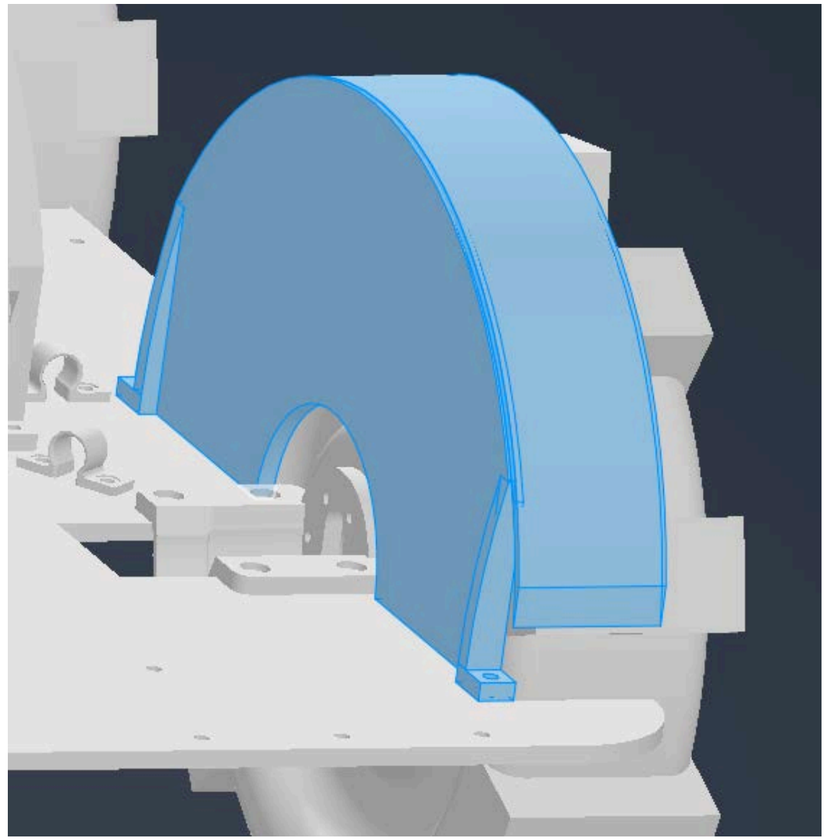
Component Holder





Wheel & Roller cover





Components

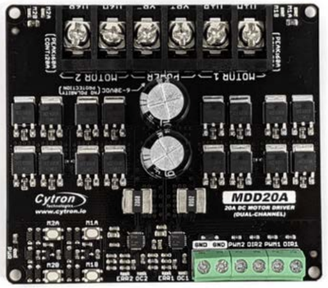
Lidar



Switch



DC Motor Drivers



Depth Camera



ESP 32



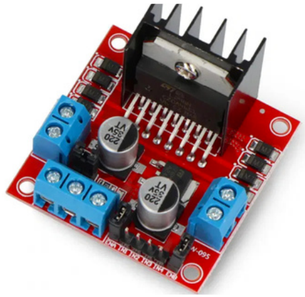
11.1V Lipo Battery



Jetson Nano



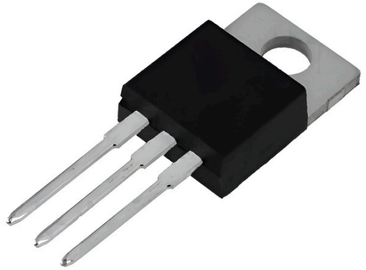
Roller Motor Driver



Encoder Motor



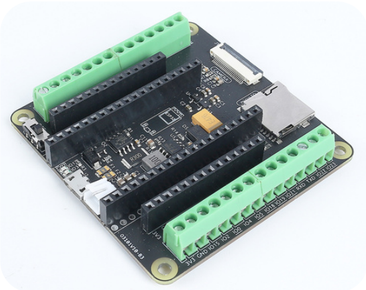
Regulator



DC Motor for Roller



ESP 32 Extender



Software Design

Overview

- ROS2 is used to control the robot, enabling efficient navigation and maneuvering using LiDAR data.
- It provides real time and reliable communication between sensors and actuators
- Works well across different hardware such as ESP32 and Jetson Nano

SLAM - Lidar

Data from LiDAR is used to build a map of the environment, localize the robot and a path is choosen

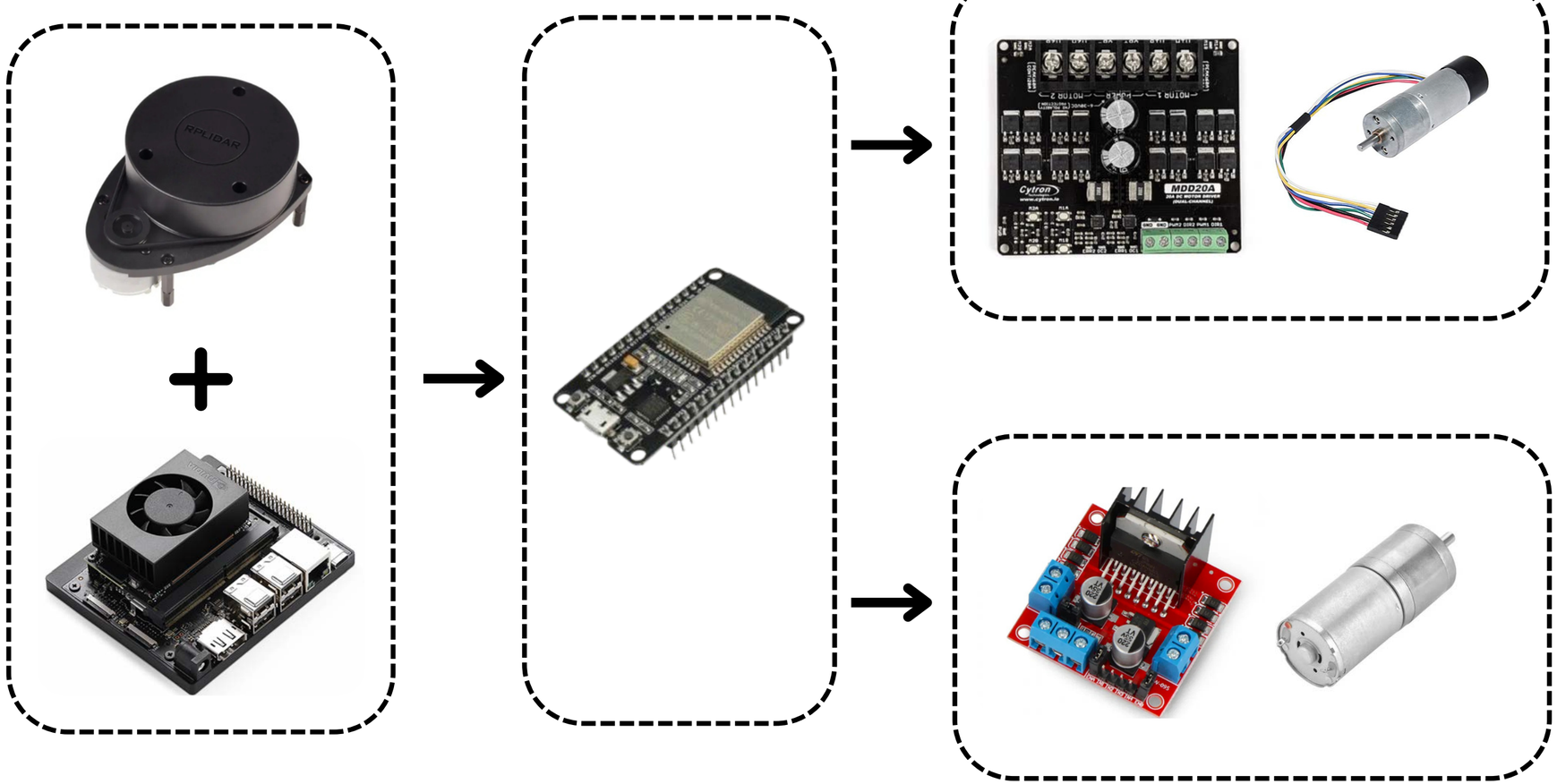
Data Flow

Data is fed from the LiDAR into the ROS2 system for SLAM, velocity data sent to ESP32 for motor control and encoder data used for position estimation

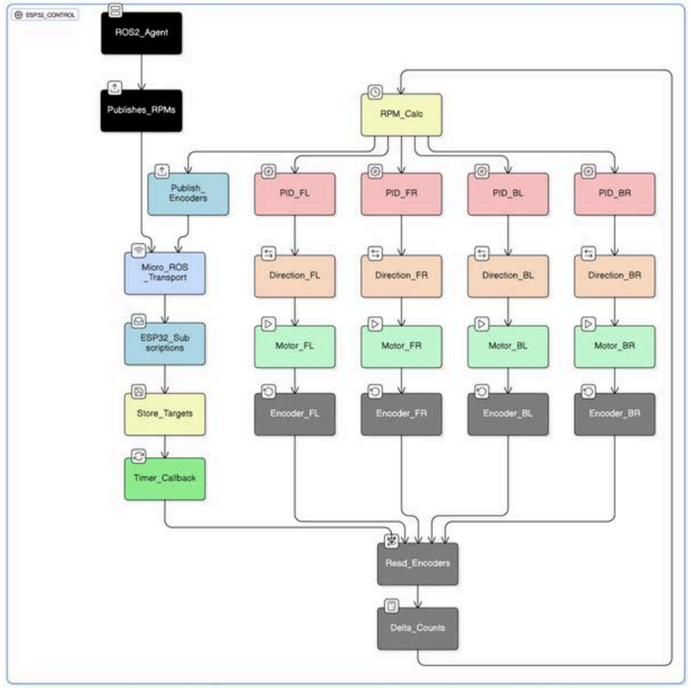
Robot Control

Velocity Information is processed and converted to PWM signals controlling the robot via PID control

Software Design

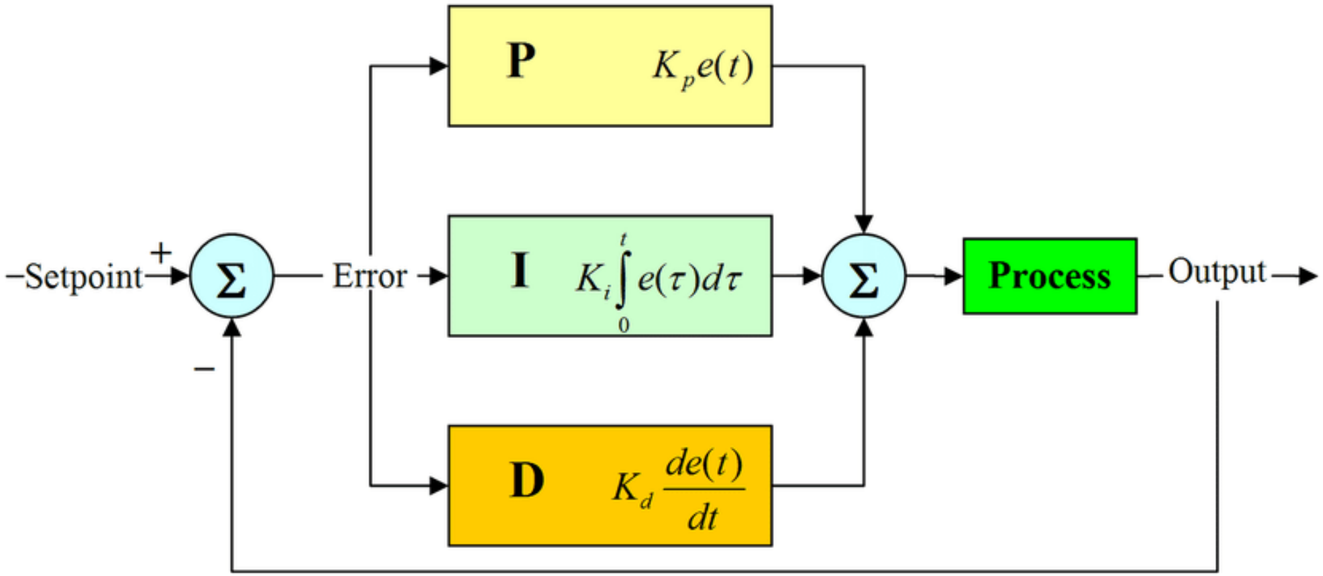


ESP32 Control



- The ESP32 acts as a Micro-ROS node, receiving target RPM commands from the ROS2 Agent via UART.
- It measures the current speed using encoder feedback, calculates the error, and uses a PID controller to adjust the PWM signal to match the target RPM.
- The control loop is optimized with PID gains set to Kp = 0.1 and Ki = 0.02, generating PWM output in the range of -255 to 255.

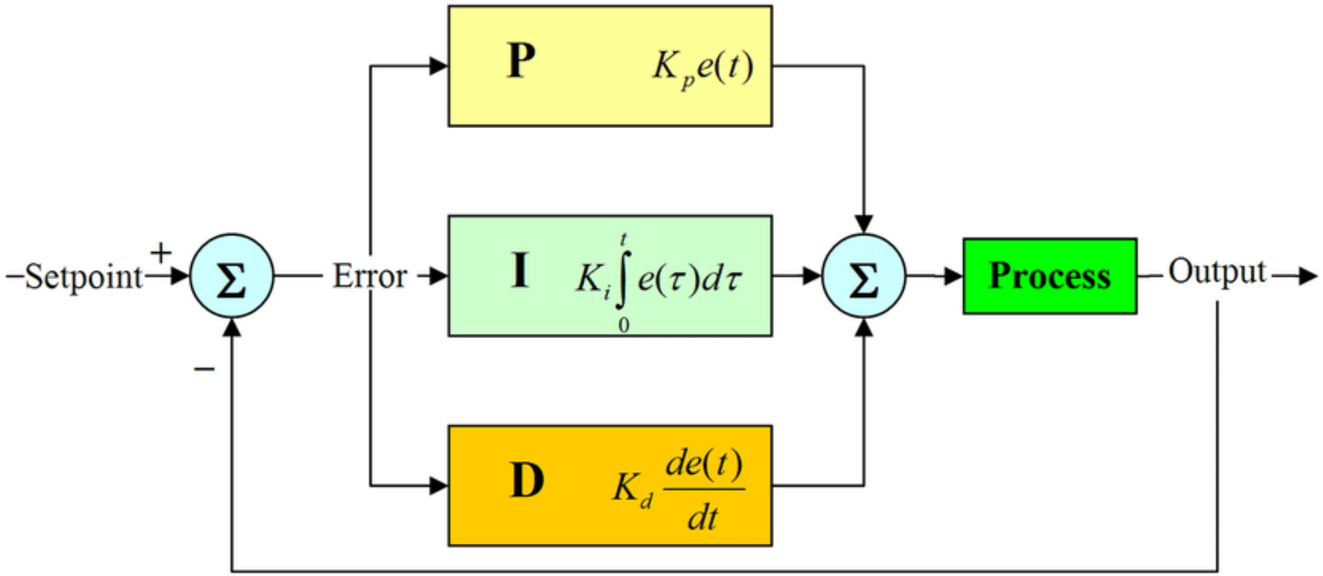
PID



Proportional Integral Derivative (PID) helps the wheels to achieve the target speed by using a PID Correction algorithm

- **Proportional (P):** Reacts to the current error as a quick response
- **Integral (I):** Compensates for past accumulating errors to eliminate the steady-state error
- **Derivative (D):** Predicts future error by checking the rate of change

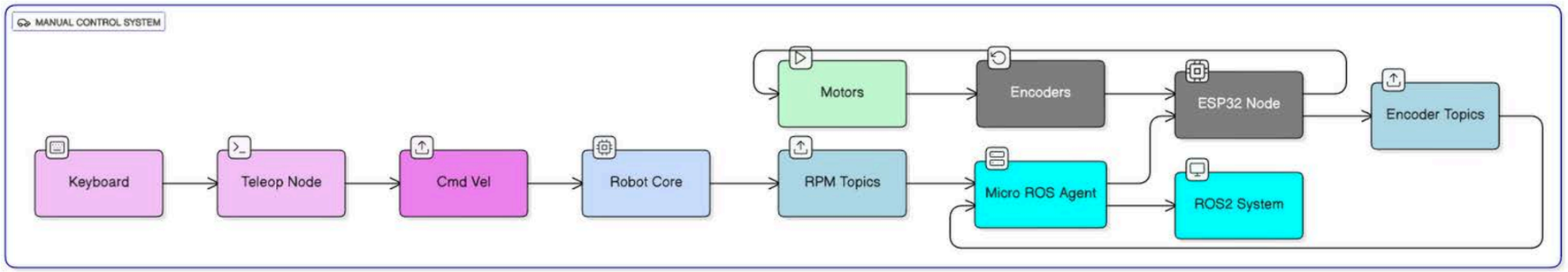
PID



Proportional Integral Derivative (PID) helps the encoder motor achieve the desired RPM by using a PID Correction algorithm

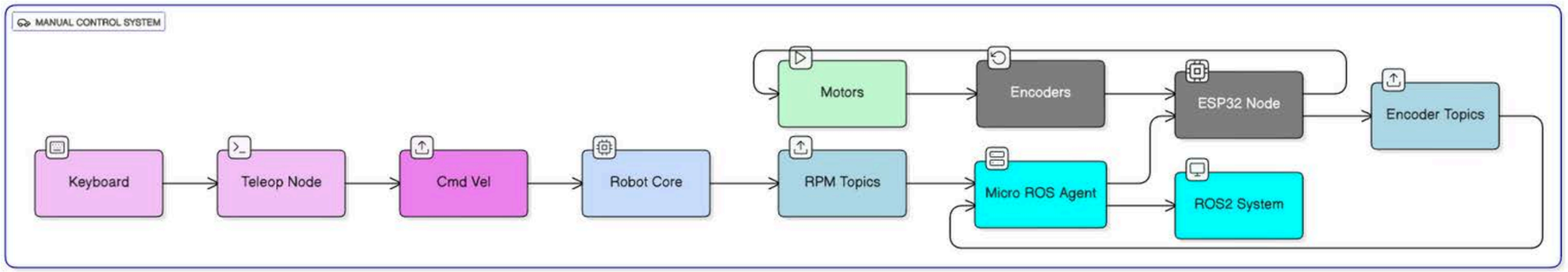
- **Target setting:** The robot system determines the Target RPM (Desired speed) to move
- **Feedback:** Motor monitors the RPM and sends the Measured RPM to the controller
- **Error Calculation:** Calculates the error by subtracting the Measured RPM from Target RPM
- **PID Correction:** Make the corrective signal to increase or decrease the motor's power by using a PID algorithm

Manual Control



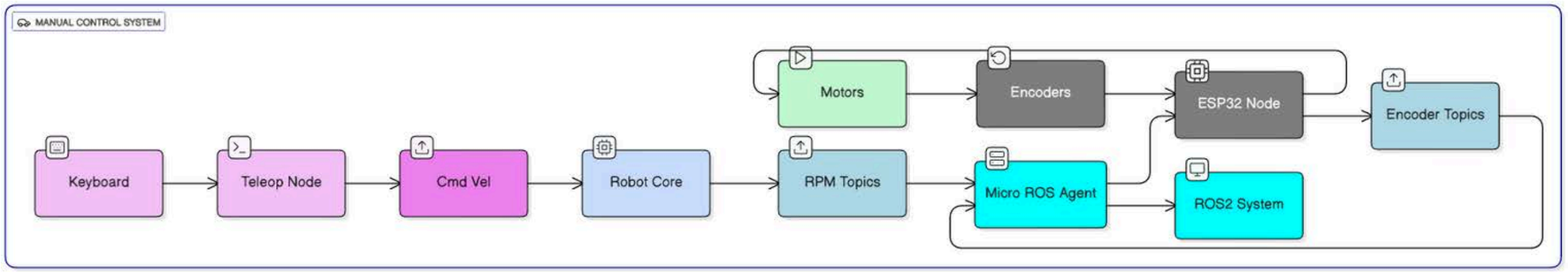
- The robot can be manually controlled by keyboard inputs using ROS2
- When a key is pressed, the **teleop twist keyboard** node reads the input and sends the velocity and direction command to **cmd vel**
- The **robot core** node converts the commands into RPM values and sends them to the motor nodes
- The micro-ROS agent sends the commands to the ESP32 via a serial UART interface

Autonomous Control



- The robot first uses LIDAR sensor data and wheel odometry (encoder data) to perform Simultaneous Localization and Mapping (SLAM) via the Cartographer node, building a 2D occupancy grid map of the surroundings.
- Once the map is complete, the Nav2 stack is launched. It determines the robot's current position, calculates a global and local path to a given goal, and generates velocity commands.

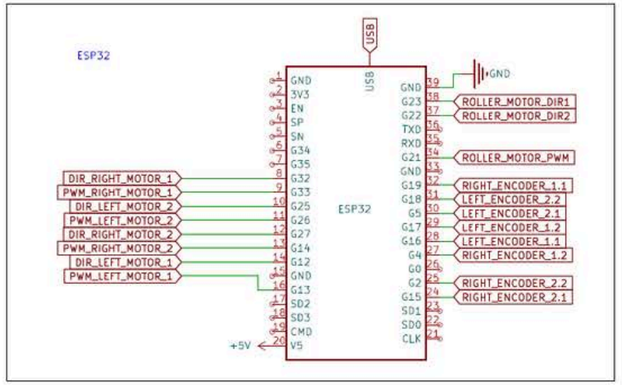
Autonomous Control

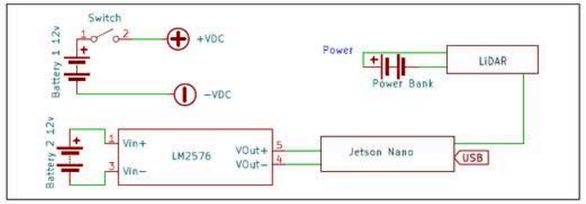


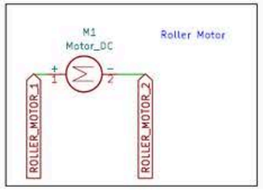
- The Robot Core node subscribes to these velocity commands, converts them into specific wheel speed targets (RPMs), and sends them to the ESP32 for motor control via the Micro-ROS Agent.
- The navigation stack constantly uses new LIDAR obstacle data to update the path dynamically, ensuring smooth tracking and obstacle avoidance toward the goal.

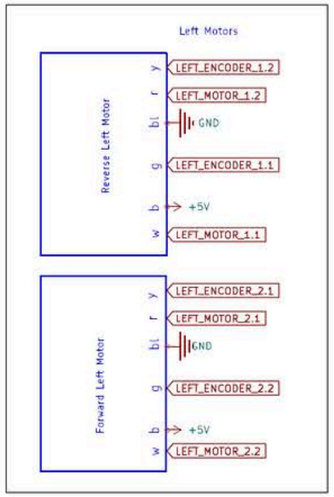
Circuit Design

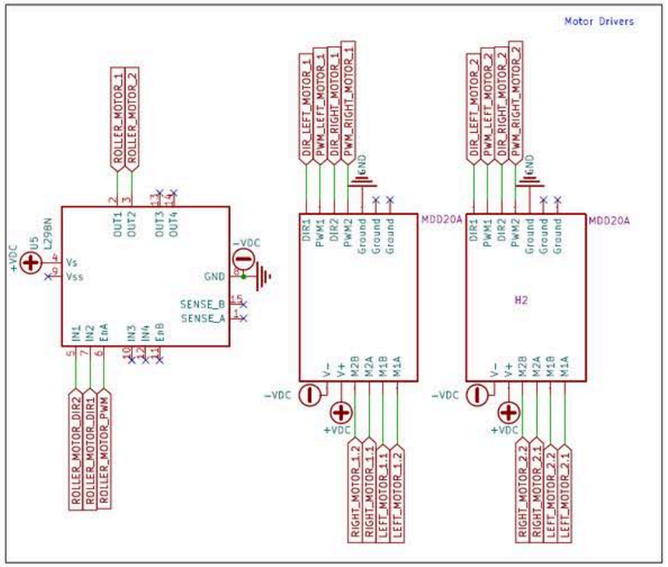
Circuit Schematic

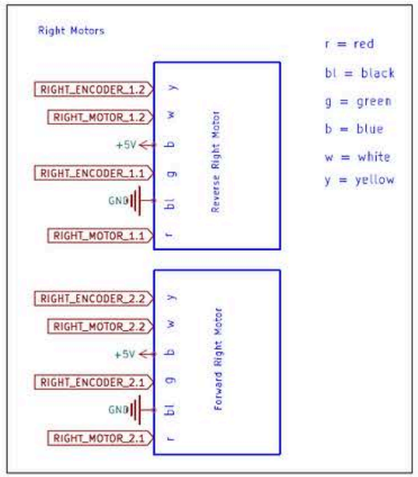




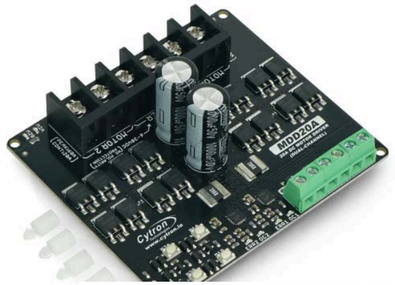




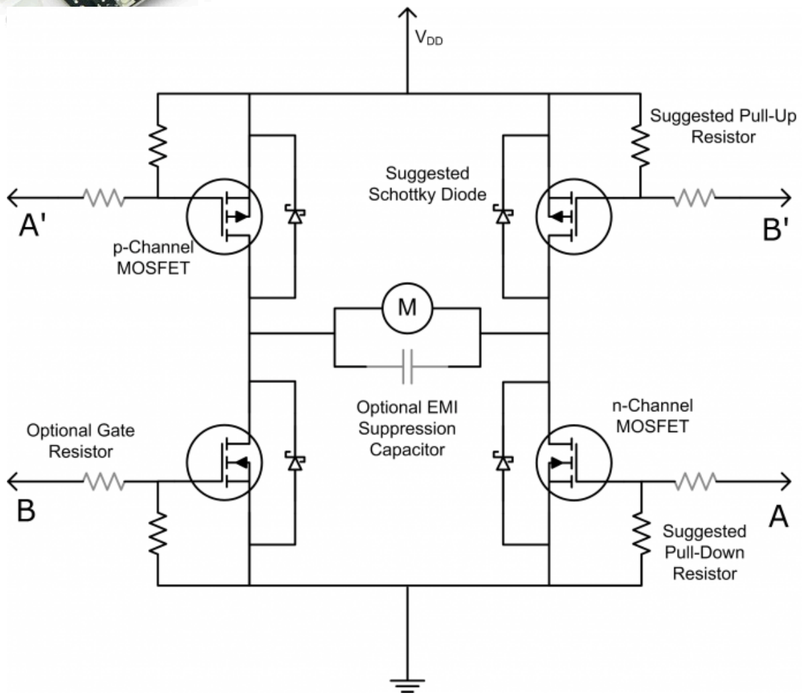




Circuit Design



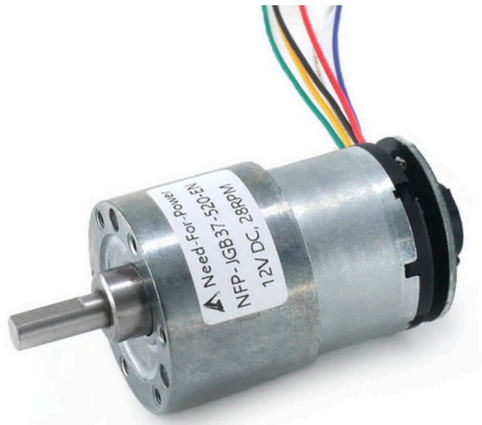
MDD20A- Encoder Motor Driver



- Dual H-Bridge design with NMOS MOSFETS
- Uses 16 MOSFETS, 8 for each H-Bridge
- Each switch in the H-Bridge uses 2 parallel MOSFETS for reduced heat and less load
- Allows to reverse the direction of the motor and change speed using PWM signals
- Schottky diodes used to provide a path for the inductive current to flow

Circuit Design

JGB37-520 12V Encoder motor



- Uses 12 Volts, with 37 RPM
- Generates 30 Kg.cm torque per each motor
- Why 37 RPM, and not something faster?
- Lower RPM within the same category of voltage gives more torque
- Encoder allows precise movement of the motor, great for wheels

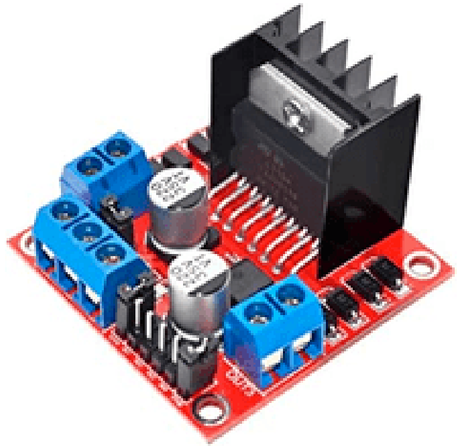
Circuit Design

BJT vs MOSFETS for H-Bridge Circuits

BJT	MOSFET
Requires constant current	Only requires Volatge (can be driven with almost 0 current)
High Voltage Drop (0.2-1V)	Very Low Voltage Drop (0.02-0.1V)
High Heat Dissipation requiring external heat sinks	Lower heat dissipation
Slow Switching Speeds	Faster Switching speeds
Does not support high frequency PWM	Supports high frequency PWM
Supports low currents and inefficient at higher currents	Low Rds minimizing current loss and supporting high currents

Circuit Design

L298N - Roller Motor Driver





- Despite the benefits of MOSFET based H-Bridge drivers, why use l298n?
- Roller only needs to be turned on or off
- No PWM signal needed
- L298N is easily available and easy to use
- Roller motor draws very little current (0.06A)

Circuit Design

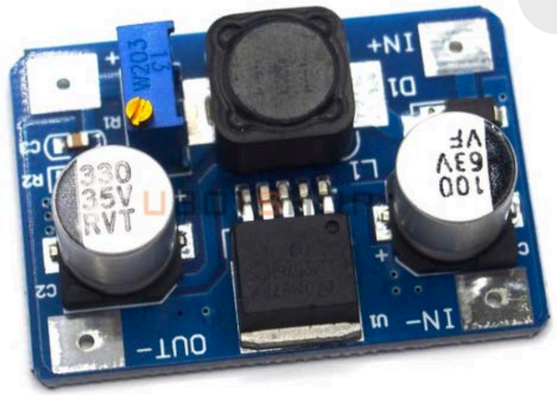
25GA-370 12V DC motor

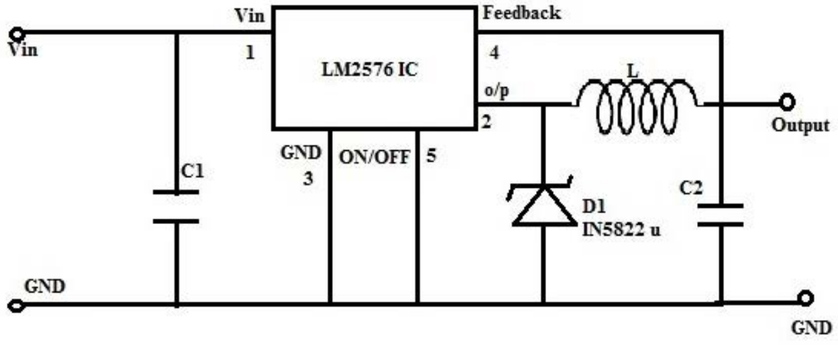


- Uses 12 Volts, with 100 RPM
- Generates 5 Kg.cm torque per each motor
- Moderate RPM make brush rotate at a reasonable rate.
- Too slow and roller will not be efficient for leaf collecting
- Too fast and the roller will not allow leaf to fall in the leaf box
- Uses DC because roller does not need precision.

Circuit Design

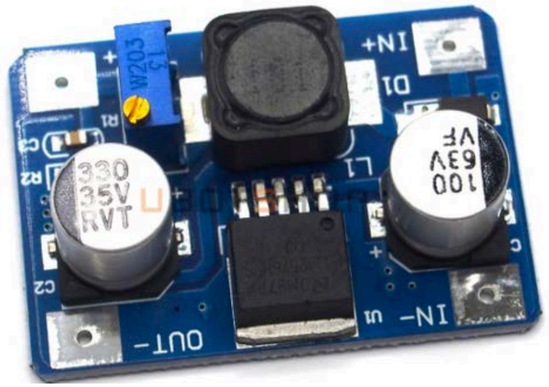
LM2576 - Step Down



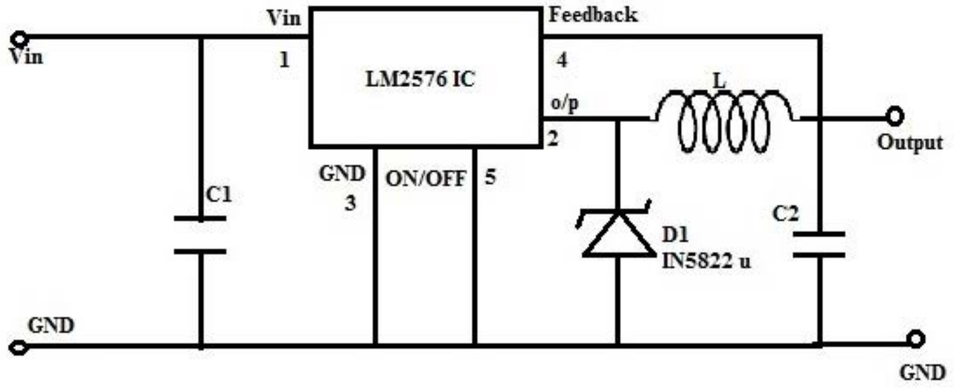


- DC Step Down for the Jetson Nano (5V)
- Capacitors- for smoothing the input voltage
- LM2576 - Rapidly turns on/off the internal MOSFET
- Inductor - Stores and releases energy
- Schottky Diode - Provides a path for current to flow when LM2576 is off
- Feedback Divider - Sets Output Voltage using Vout = 1.23 x (1 + R2/R1)

Circuit Design



LM2576 - Step Down



- The LM2576 switch on/off rapidly regulating the voltage (52kHz):
- During the ON cycle, current follows this path: input → MOSFET → Inductor → Load
- During the OFF cycle, inductor still has current, so it goes through the diode to the load
- The output voltage is fed back into the feedback pin which determines the duty cycle of the transistor

Battery Calculations

Battery No.1:

Power Drawn from Components:

ESP32 = 3.3V × 150mA = 0.495W

Encoder Motors = 4 × 12V × 1A = 48.0W

DC Motor = 12V × 185mA = 2.22W

Total = 50.715W

Power Drawn From Battery:

P_{in} = P_{out} / Effeciency*

= 50.715W / 0.95 = 53.38**W**

Battery Current Draw:

I_{draw} = P_{in} / Battery's Voltage

= 54.963W/11.1V = **4.80A**

Battery Run Time Calculation:

Run Time = Battery's Current / I_{draw}

= 2.2Ah / 4.80A = **27.5 Minutes**

Battery No.2:

Power Drawn from Components:

Jetson Nano = 10W

Total = 10W

Power Drawn From Battery:

P_{in} = P_{out} / Effeciency*

= 10W / 0.95 = 10.52**W**

Battery Current Draw:

I_{draw} = P_{in} / Battery's Voltage

= 10.52W/11.1V = 0.947**A**

Battery Run Time Calculation:

Run Time = Battery's Current / I_{draw}

= 2.2Ah / 0.947A = **2.32 Hours**

* Efficiency value from datasheet

Battery Calculations

Battery No.1:

Power Drawn from Components:

Encoder Motors Driver = 2 × 5W =10 W

Encoder Motors = 4 × 12V × 1A = 48.0W

DC Motor Driver = 1W

DC Motor = 12V × 185mA = 2.22W

Total = 61.22W

Power Drawn From Battery:

$P_{in} = P_{out}$ / Effeciency*

= 61.22W / 0.95 = 64.44**W**

Battery Current Draw:

$I_{draw} = P_{in}$ / Battery's Voltage

= 64.44W/11.1V = 5.805**A**

Battery Run Time Calculation:

Run Time = Battery's Current / I_{draw}

= 2.2Ah / 5.805A = **22.74 Minutes**

Battery No.2:

Power Drawn from Components:

Jetson Nano = 10W

ESP32 = 3.3V × 150mA = 0.495W

Total = 10.495W

Power Drawn From Battery:

$_{in}P = P_{out}$ / Effeciency*

= 10.495W / 0.95 = 11.047**W**

Battery Current Draw:

$I_{draw} = P_{in}$ / Battery's Voltage

= 11.047W/11.1V = 0.995**A**

Battery Run Time Calculation:

Run Time = Battery's Current / I_{draw}

= 2.2Ah / 0.995A = **132.66 Minutes**

* Efficiency value from datasheet

Limitations

1. Limited to operating on flat or slightly sloped terrain.

2. Range and accuracy is limited to the LiDAR scanner.

3. Jetson nano is laggy and unstable

4. Leaves falling out of the container

Results

The robot achieved its main objectives, demonstrating potential for practical leaf collection.

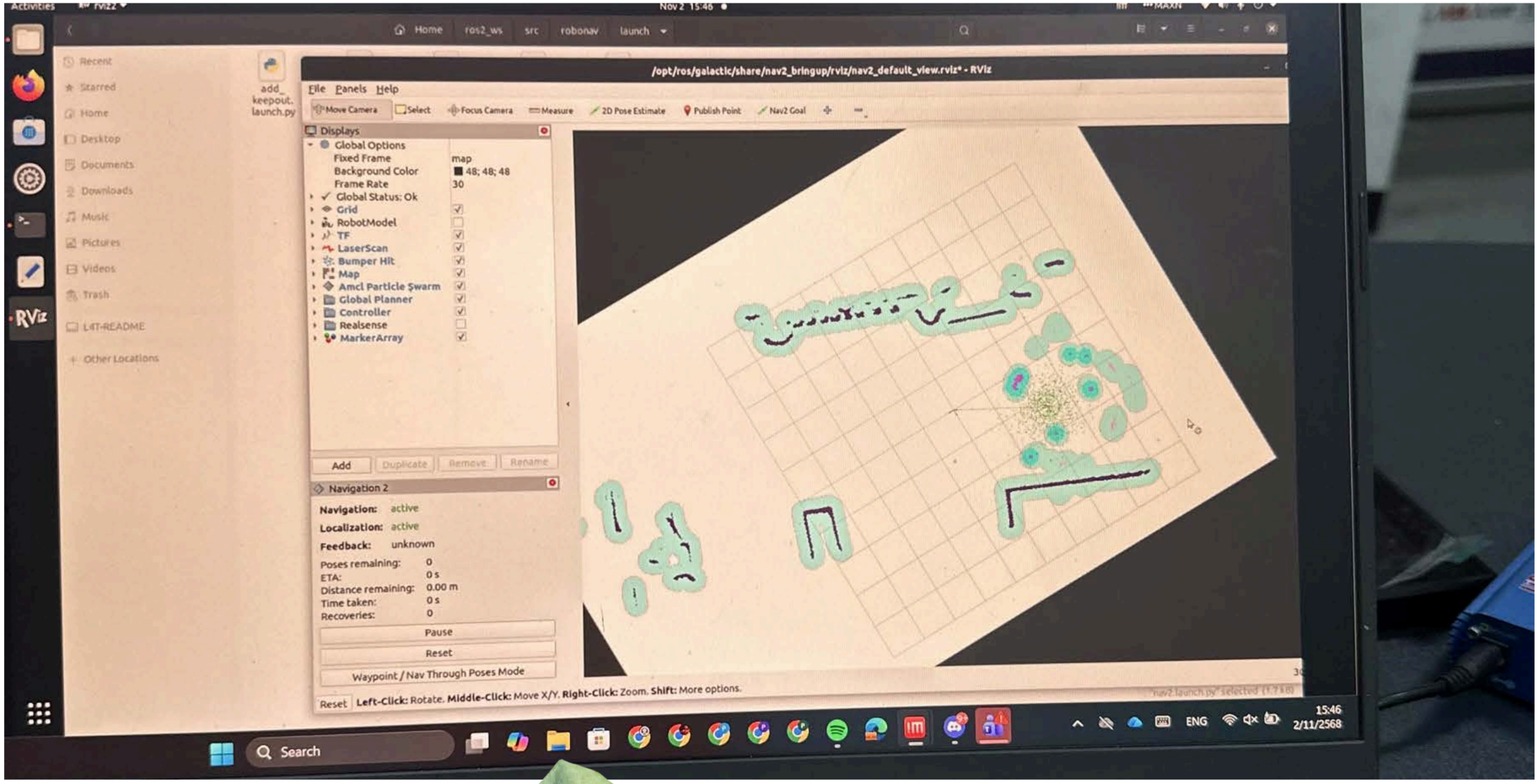
The robot could map and navigate a designated area.

Worked well in controlled indoor settings, but showed inconsistencies outdoors due to uneven surfaces.

The manual mode was successful, providing consistent and responsive, minimal-delay control

The integration of the ESP32, Jetson Nano, sensors, and ROS2 framework was efficient, and reliable

Lidar Map


/opt/ros/galactic/share/nav2_bringup/rviz/nav2_default_view.rviz* - RViz
File Panels Help
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
Publish Point
Nav2 Goal
Displays
Global Options
Fixed Frame map
Background Color 48; 48; 48
Frame Rate 30
Global Status: Ok
Grid
RobotModel
TF
LaserScan
Bumper Hit
Map
Amcl Particle Swarm
Global Planner
Controller
Realsense
MarkerArray
Add
Duplicate
Remove
Rename
Navigation 2
Navigation: active
Localization: active
Feedback: unknown
Poses remaining: 0
ETA: 0 s
Distance remaining: 0.00 m
Time taken: 0 s
Recoveries: 0
Pause
Reset
Waypoint / Nav Through Poses Mode
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click: Zoom. Shift: More options.
Search
ENG
15:46
2/11/2568

Future Works

1. A more robust LiDAR system could be developed with longer detection ranges and higher resolutions.

2. AI assisted navigation could be implemented to assist the robot's decisions making capabilities, allowing for dynamic path planning in a more complex environment

3. A redesigned roller to adapt to uneven surfaces and achieve better contact with leaves

4. A self-charging docking station or the use of higher-capacity lithium-ion batteries to extend operational uptime

5. To ensure safety during navigation, height and tilt sensors can be added to avoid curbs, potholes or steep slopes

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Cost

Component	Part Number	Quantity	Unit Price	Total Price (฿)
Jetson Nano		1	3306	3306
Roller Motor Driver	L298N	1	60	60
Encoder Motor Driver	MDD20A	2	1180	2360
Encoder Motors	JGB37-520	4	485	1940
Roller Motor	25GA-370	1	86	86
ESP32		1	240	240
ESP32 Extender		1	56	56
Voltage Step Down	LM2576	1	95	95
Lidar	RPLidar A1	1	2500	2500
Switch		3	12	36
12V LiPo Battery		2	536	1072
Aluminum Base		1	952	952
Wheels		4	556	2225
Total				14928

Thank You