Sardar Vallabhbhai National Institute of Technology Surat-395007, Gujarat.

Autonomous Modular Agriculture Robot

Objective:

Our objective is to create a multipurpose mobile robot that is capable of incorporating different modules that dedicate to a specific farm work

Introduction

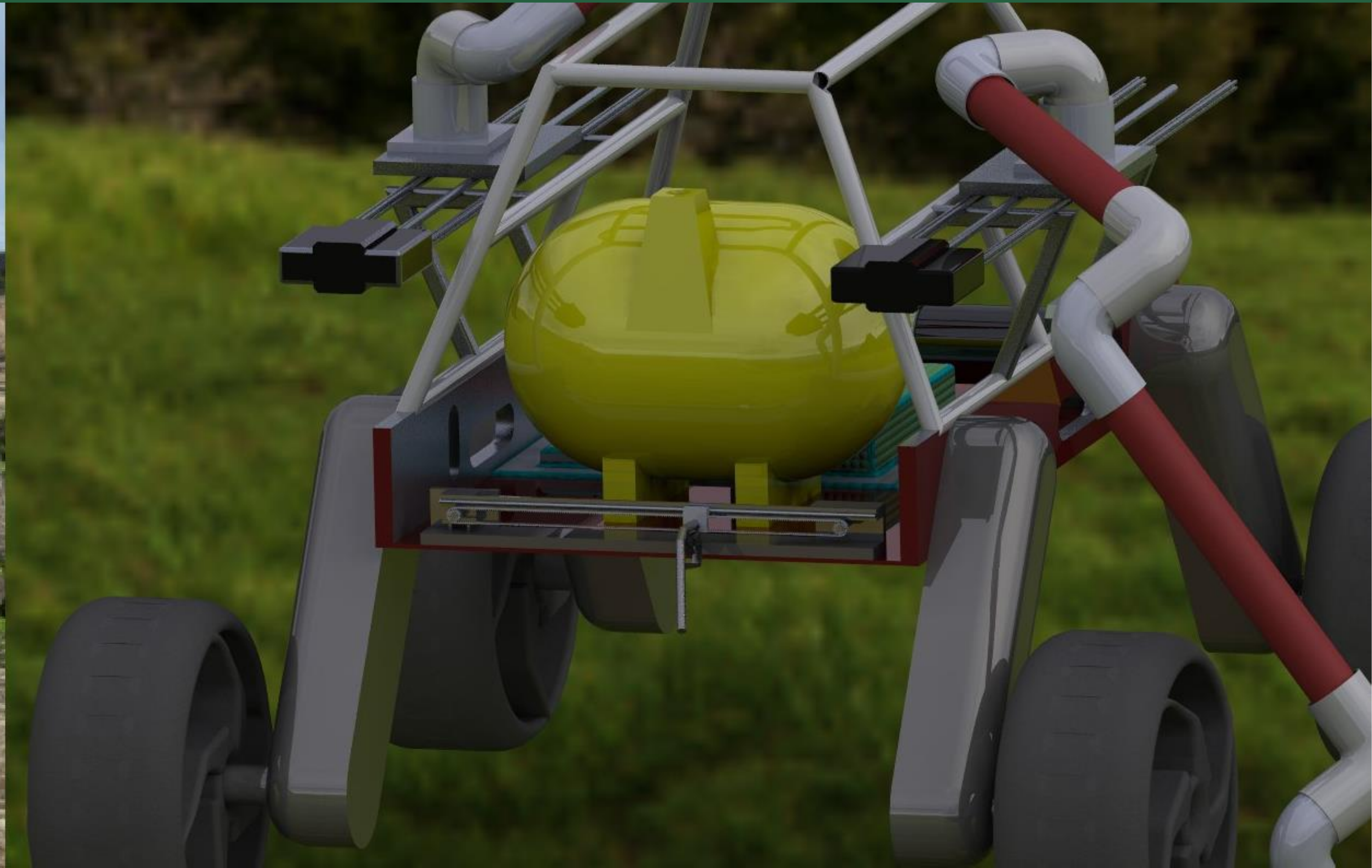
Robotics in Agriculture:

- **Autonomous Mobile robots**
- **Precision Agriculture**
- **Problem - Individual robots for individual tasks**
- **Solution - Modules for each task (Modular design)**

Modularity

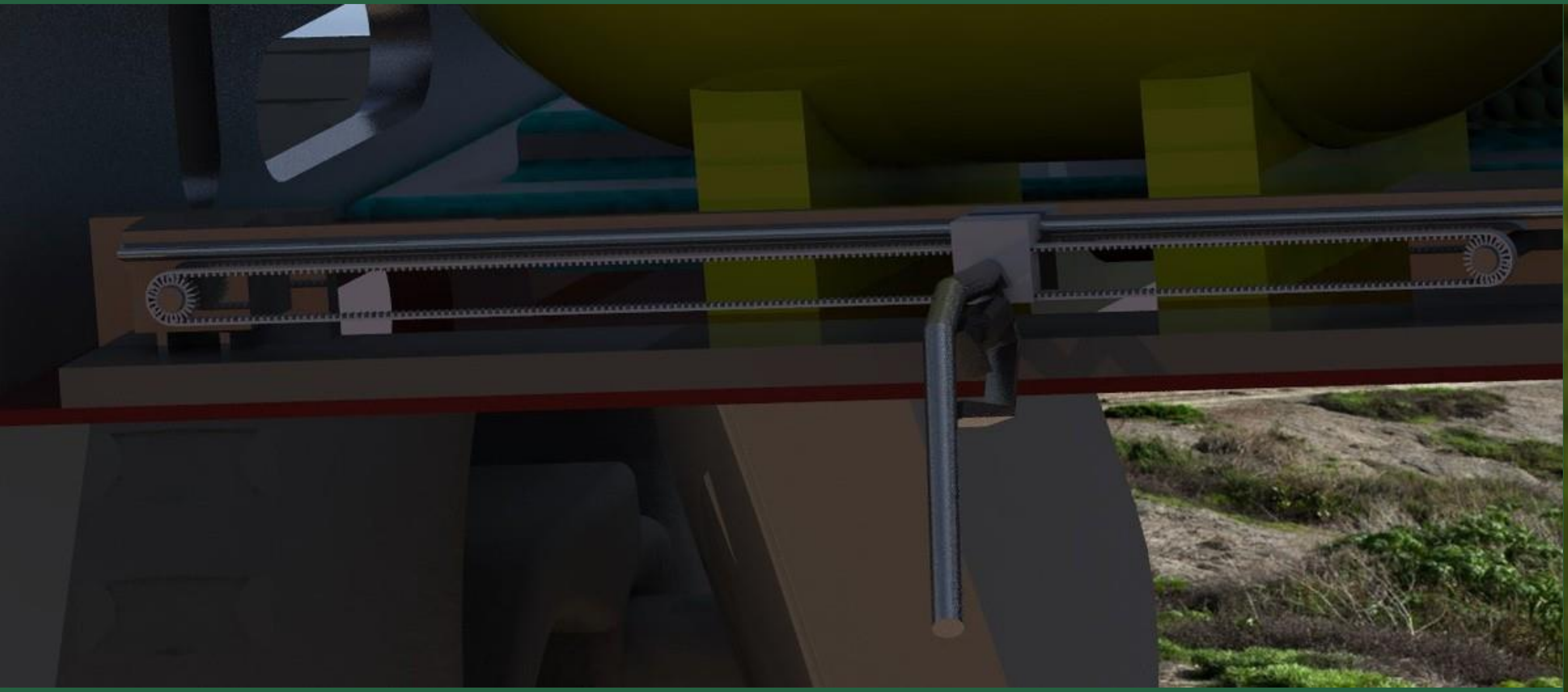
- Our robot is designed modularly, so that the manufacturing cost and assembly cost will be reduced drastically.
- We used "Design for X" principles while designing, thus number of parts needed is decreased.
- Individual modules designed to perform specific tasks can be attached seamlessly to the main base robot.

Robust Modular Design:



Spraying Module:

- The spraying module consists of a tank which holds pesticide or weedicide depends on the application. The tank is connected to the sprayer system which is actuated by a stepper motor to go to a specific position where weed is detected. Once the sprayer is in position a servo motor will trigger the sprayer nozzle thus spraying the contents onto weed.
- The entire spraying module can be detached and attached easily. The tank that is used in the design is readily available to the farmers



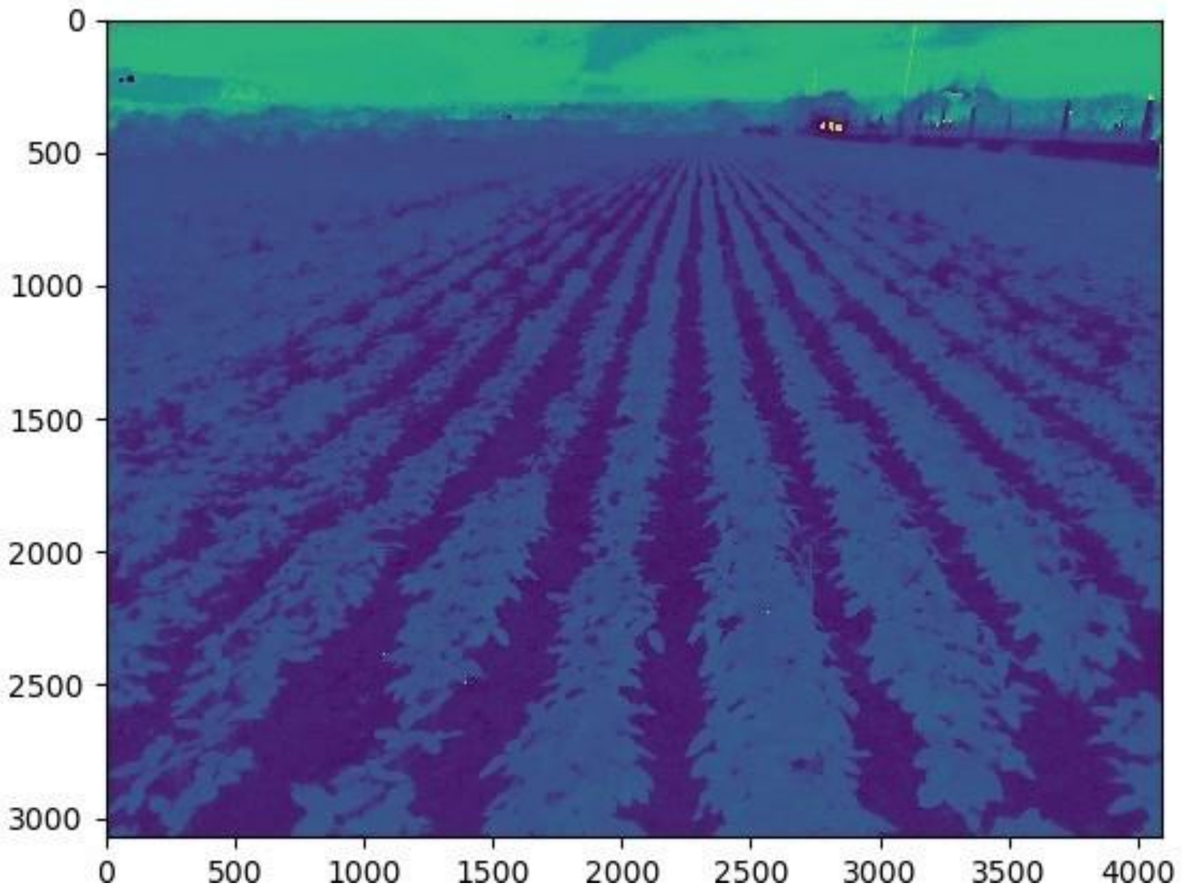
Precision crop and Vegetables Harvesting:

We have designed a lightweight robot arm that is capable of picking Vegetables and also specific cash crops like Cotton

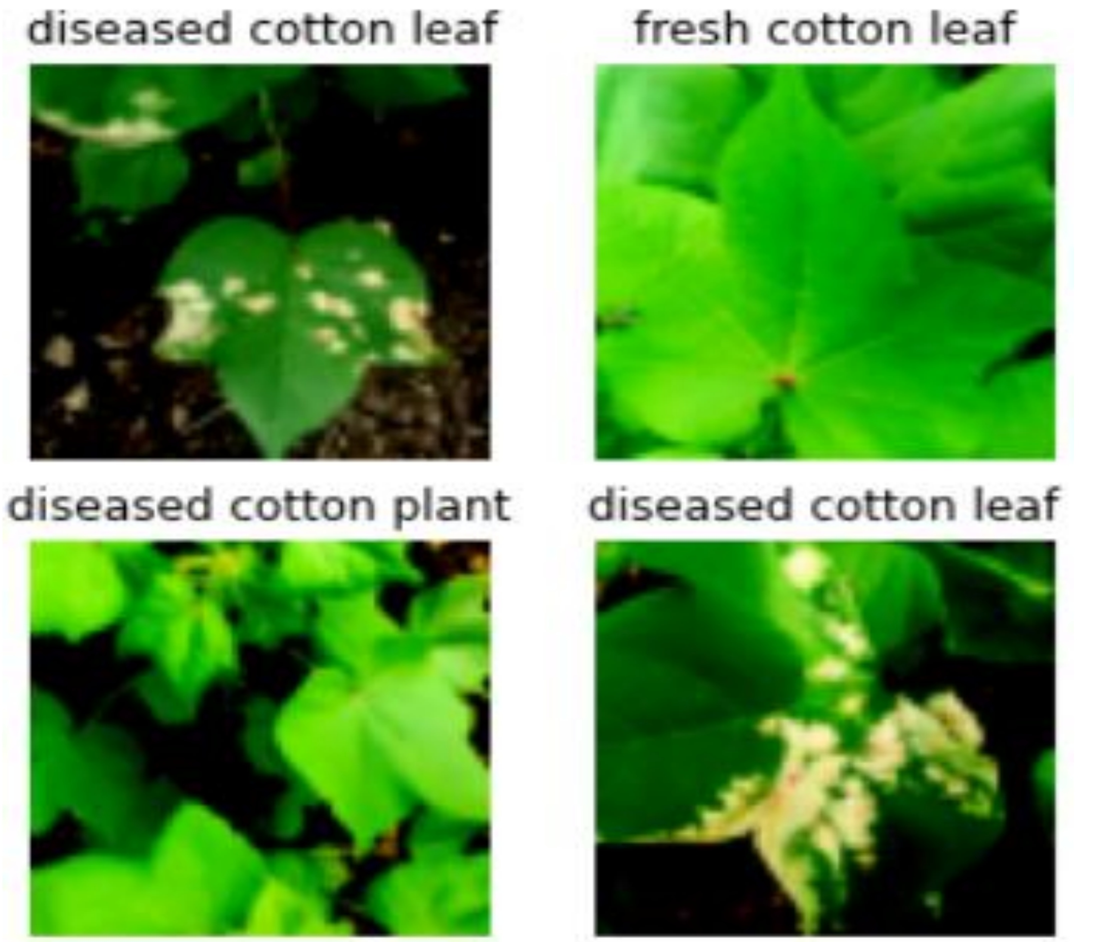
AI and Computer Vision Module:

Weed Detection

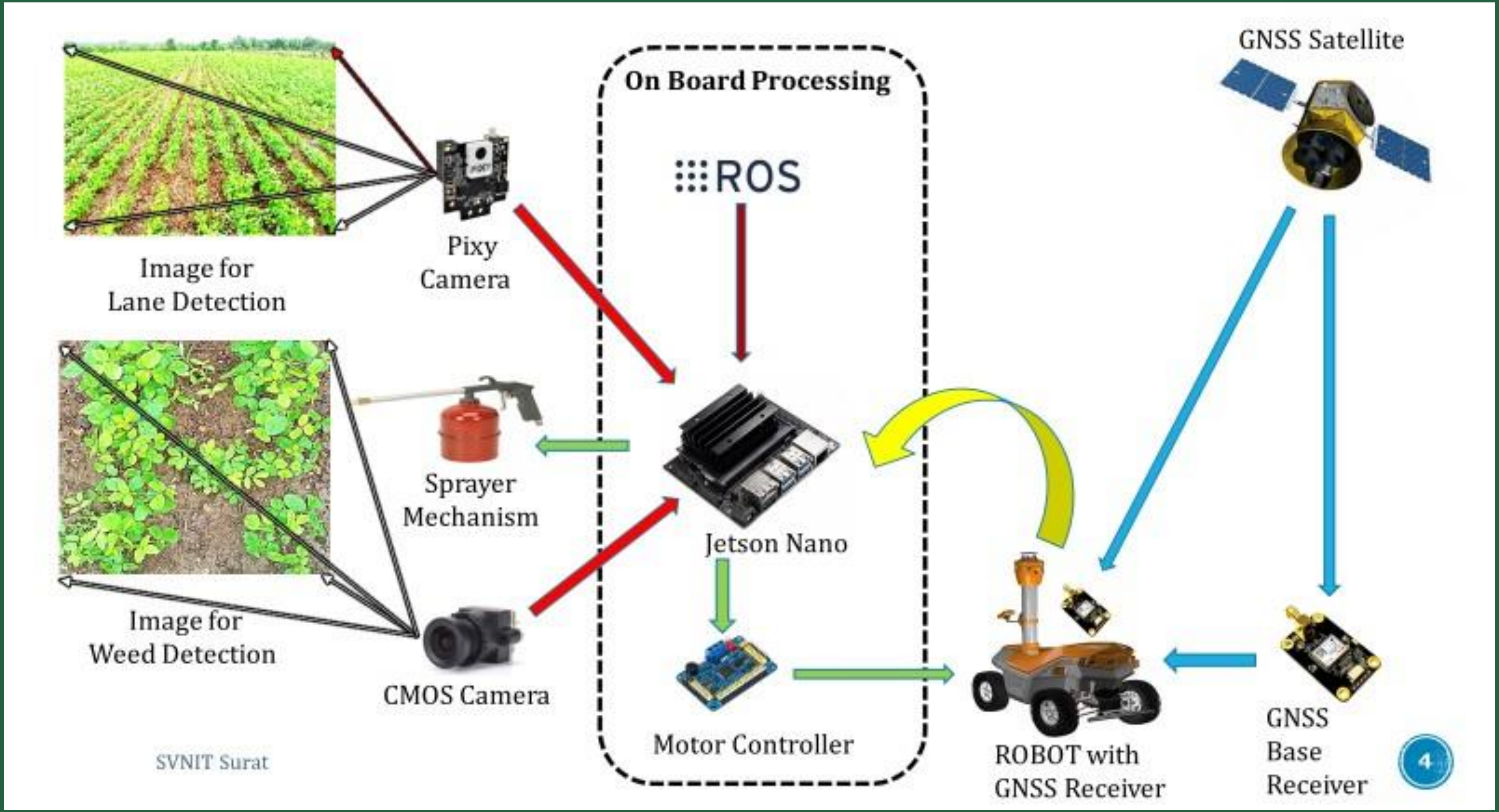
Lane Detection



Disease Classification



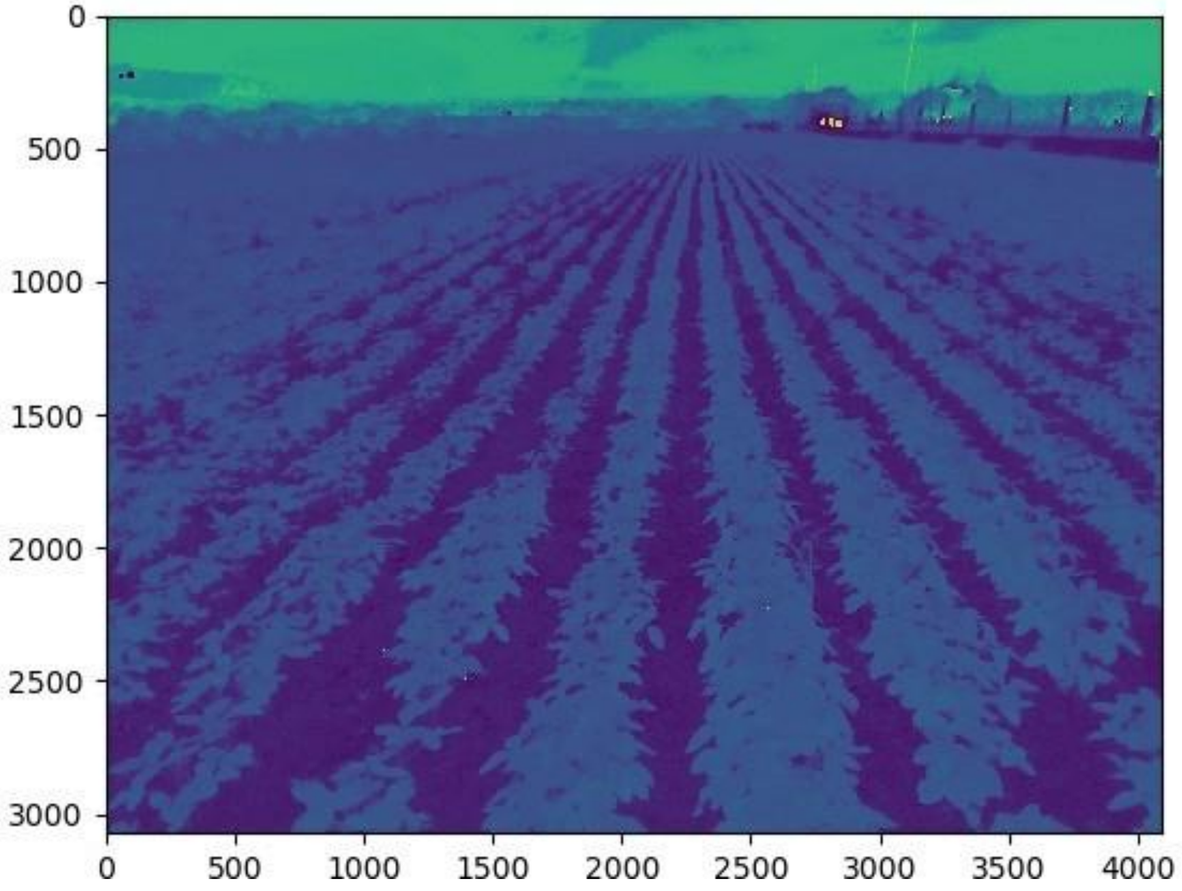
Proposed Architecture



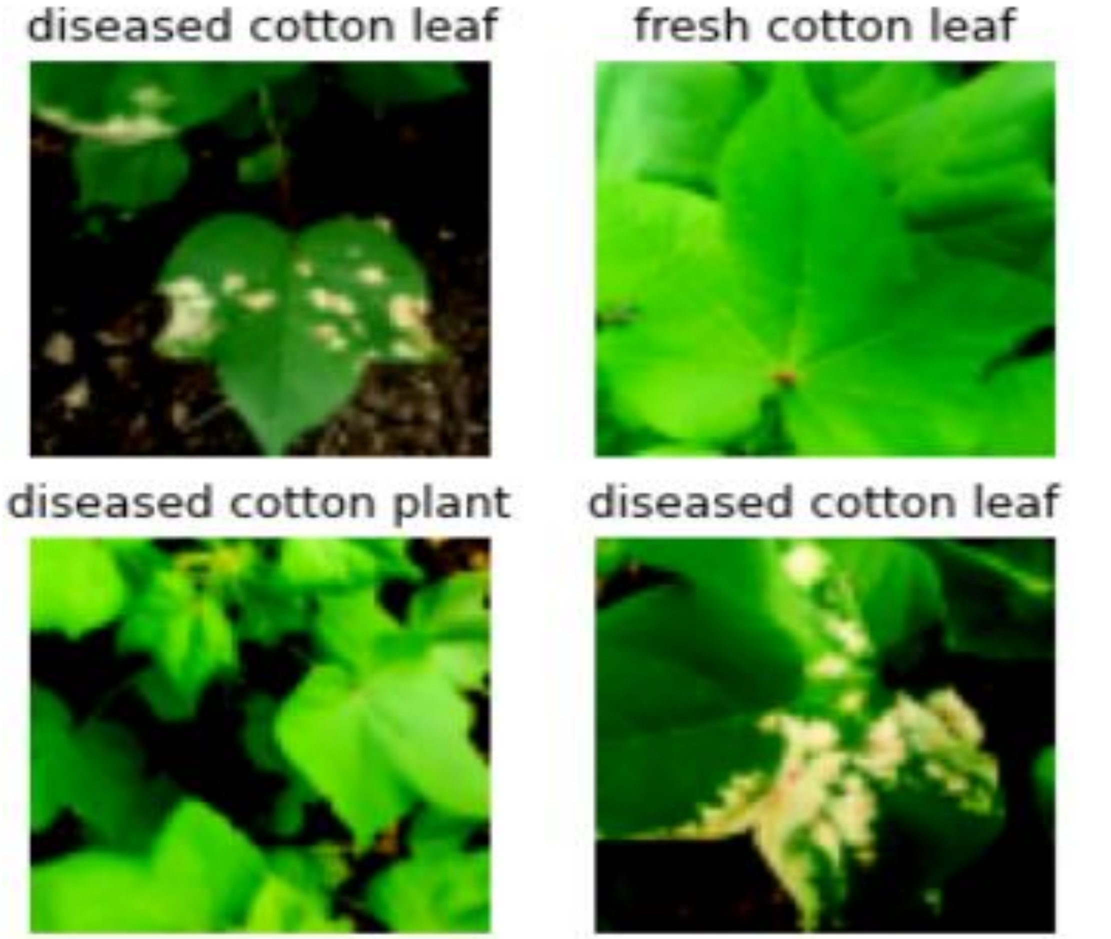
AI and Computer Vision Module:

Weed Detection

Lane Detection



Disease Classification

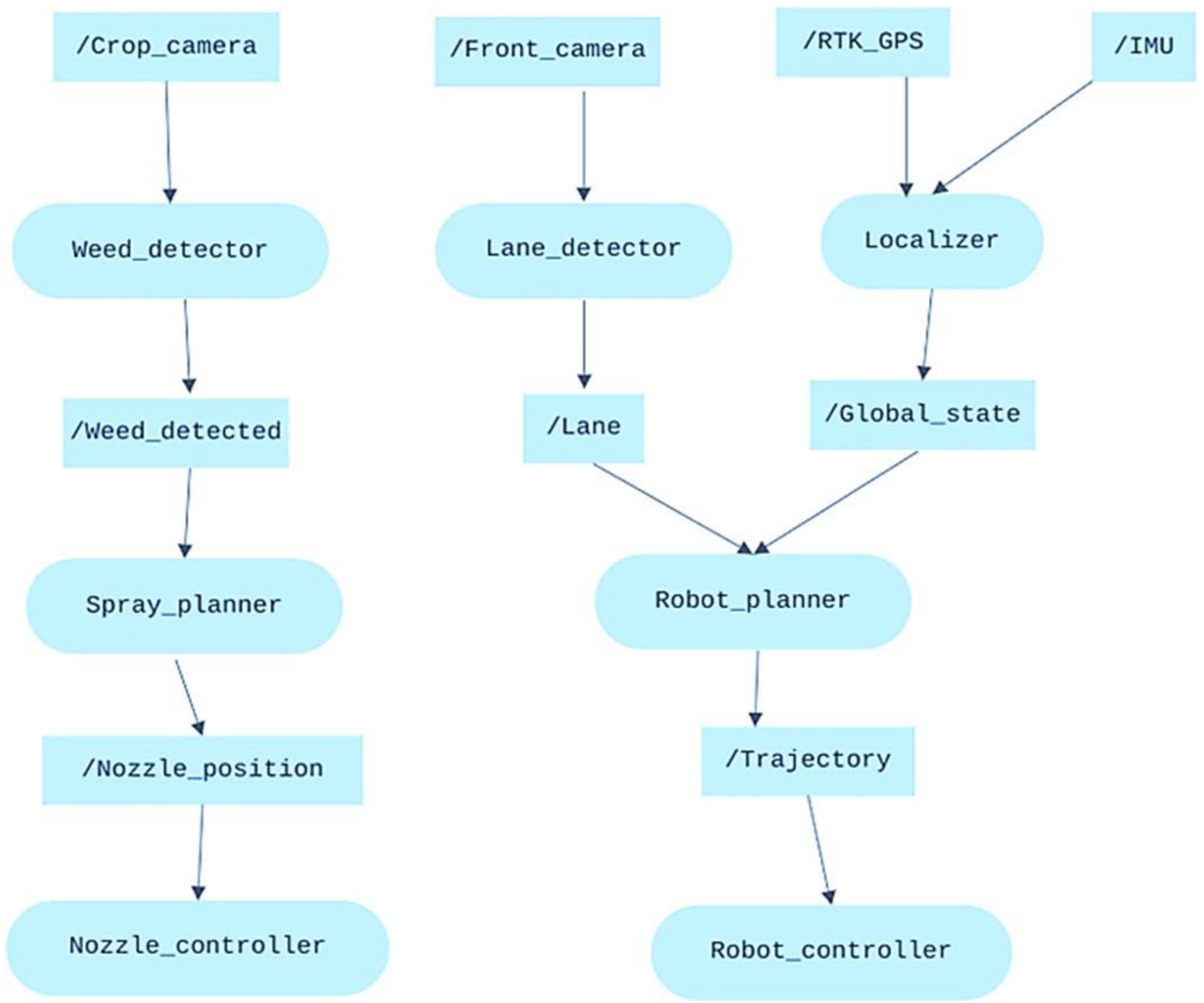


Proposed Methodolgy

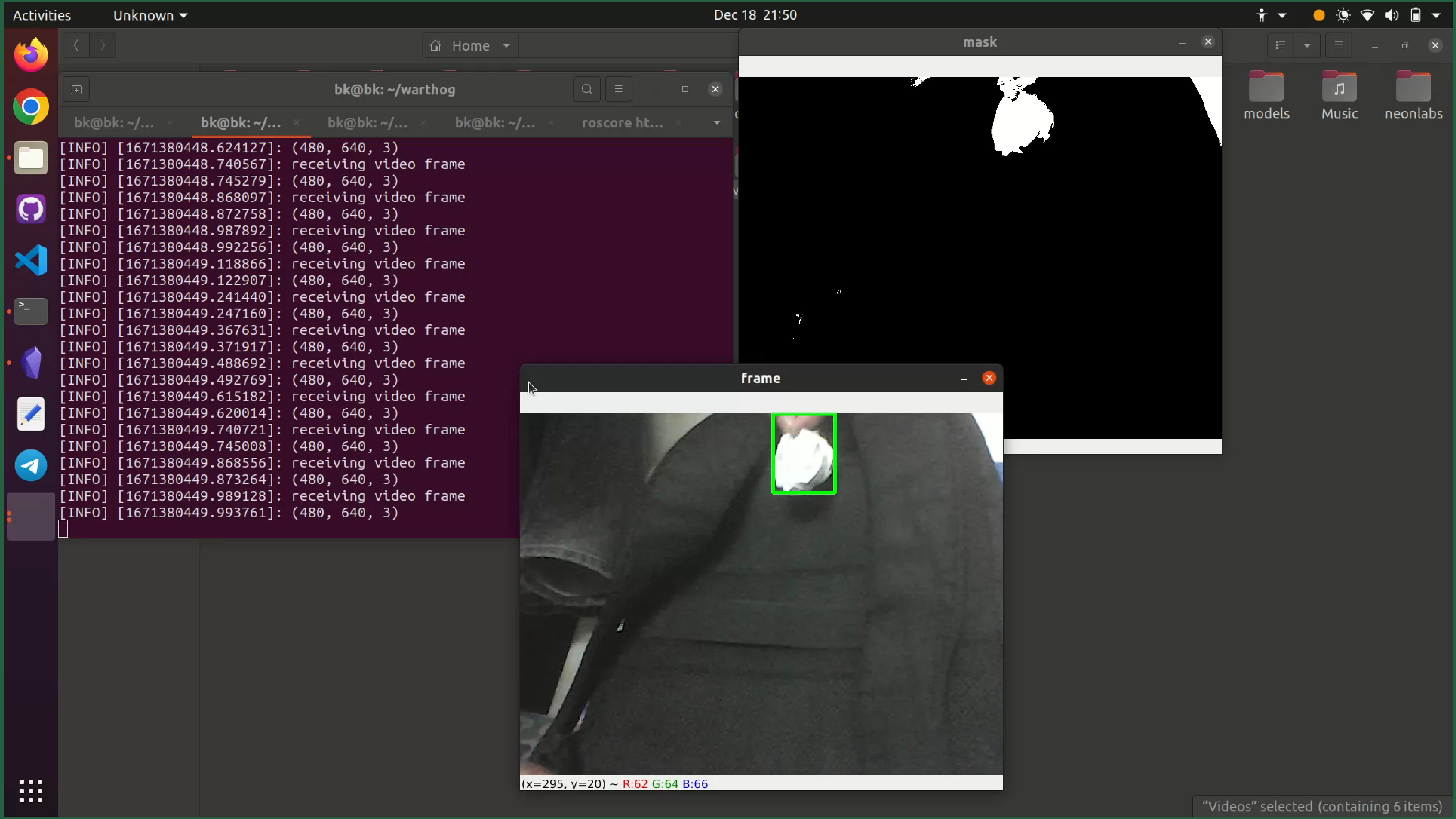
- Development of a modular ecosystem using robot operating system (ROS) for farming applications.

- Vision-based weed and crop detection, classification, localization and precisely spraying over weeds, and diseases.

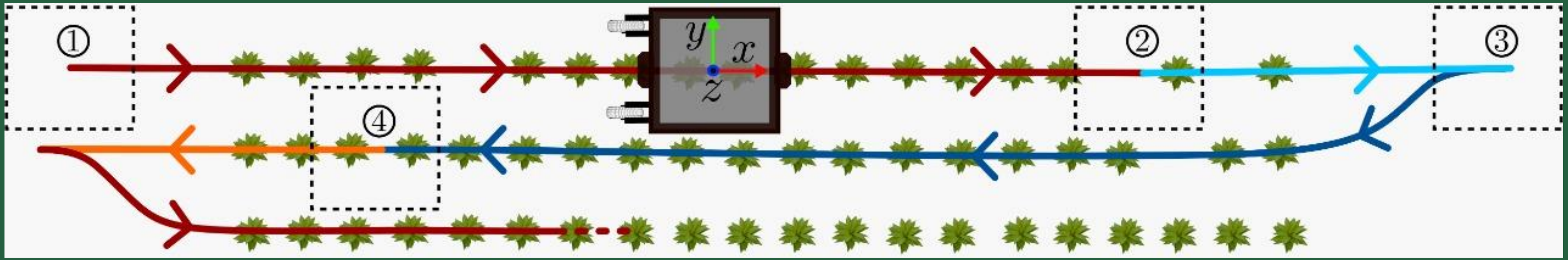
- The robot operating system will interface with micro-controllers to control vehicle trajectory, and sprayer nozzle position and get sensor data.



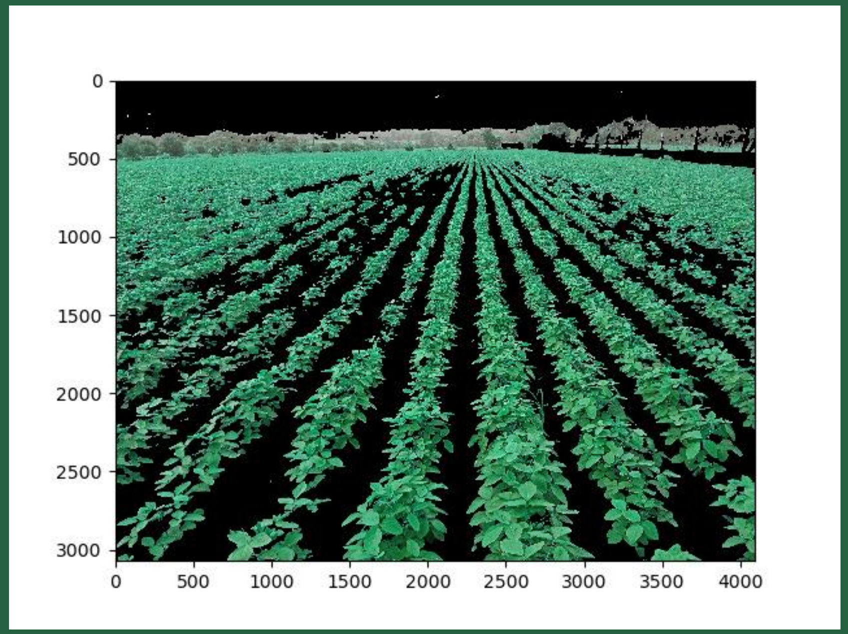
Cotton Detection



Lane Detection



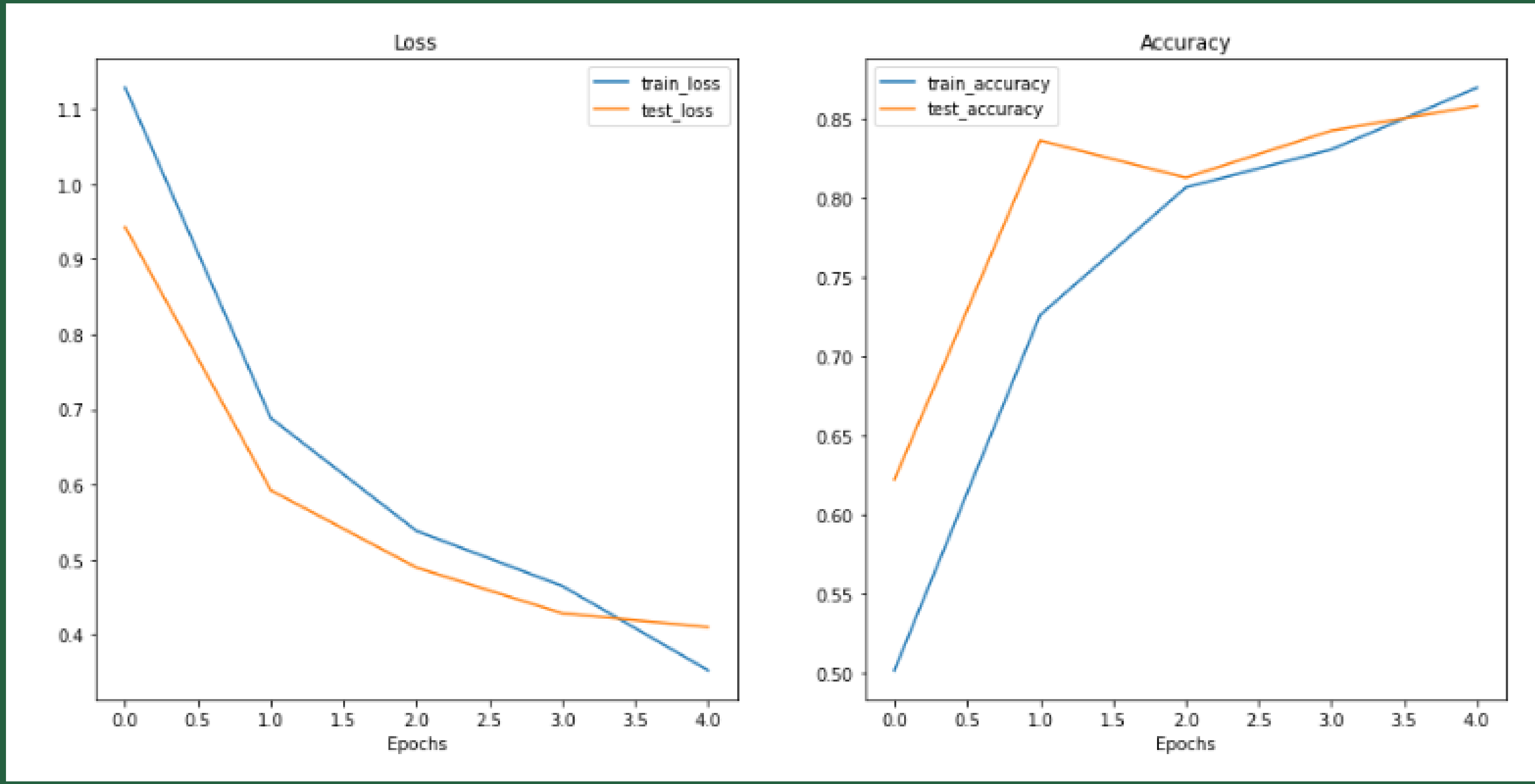
Color Masking



Hough Transform

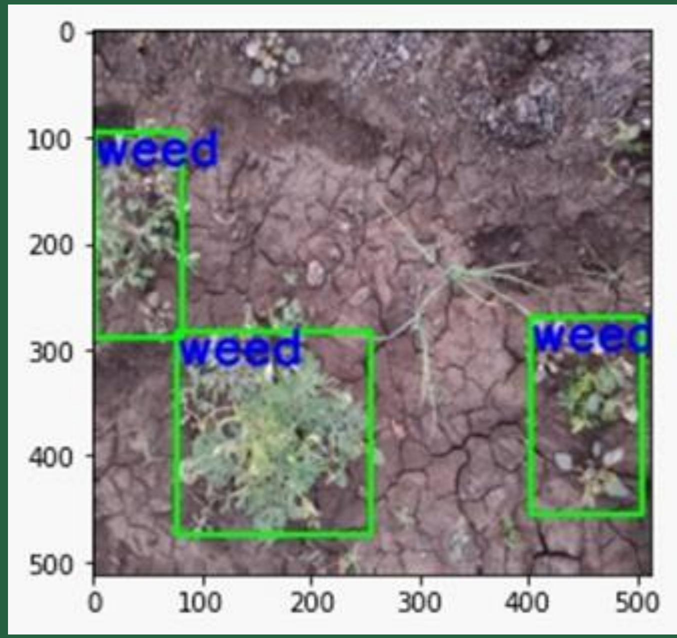
Lanes are sent in form of line vector to navigation module.

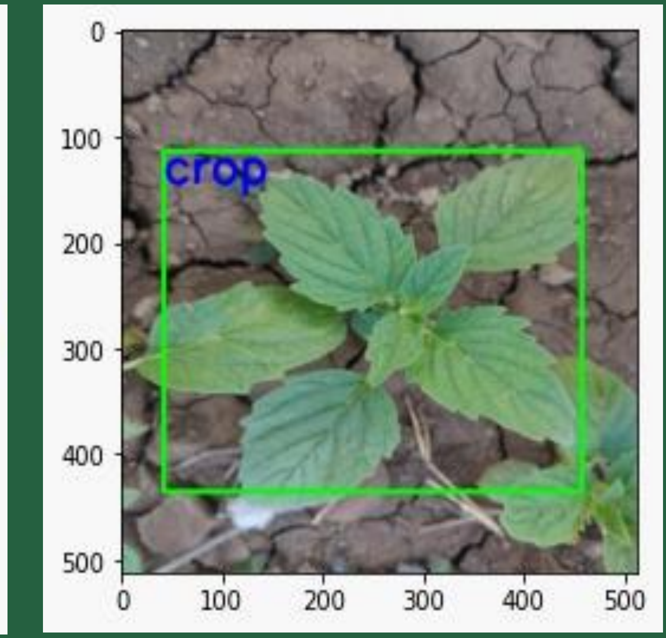
Cotton Disease Classification & weed detection

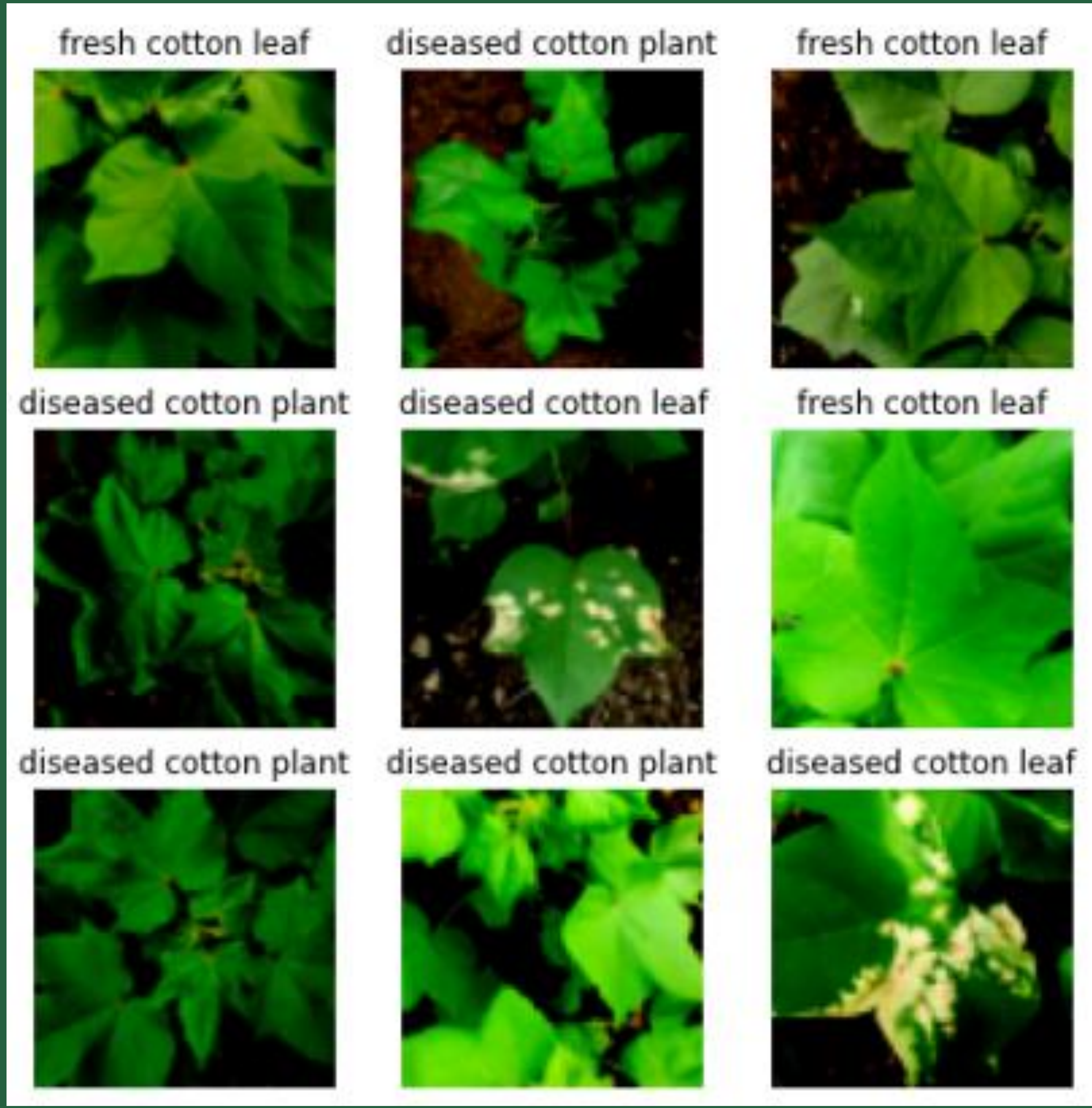


Results

- Test Accuracy = 86% (lr=0.002,epochs=5)
- Deep Learning model : TinyVGG (Convolutional Neural Network)



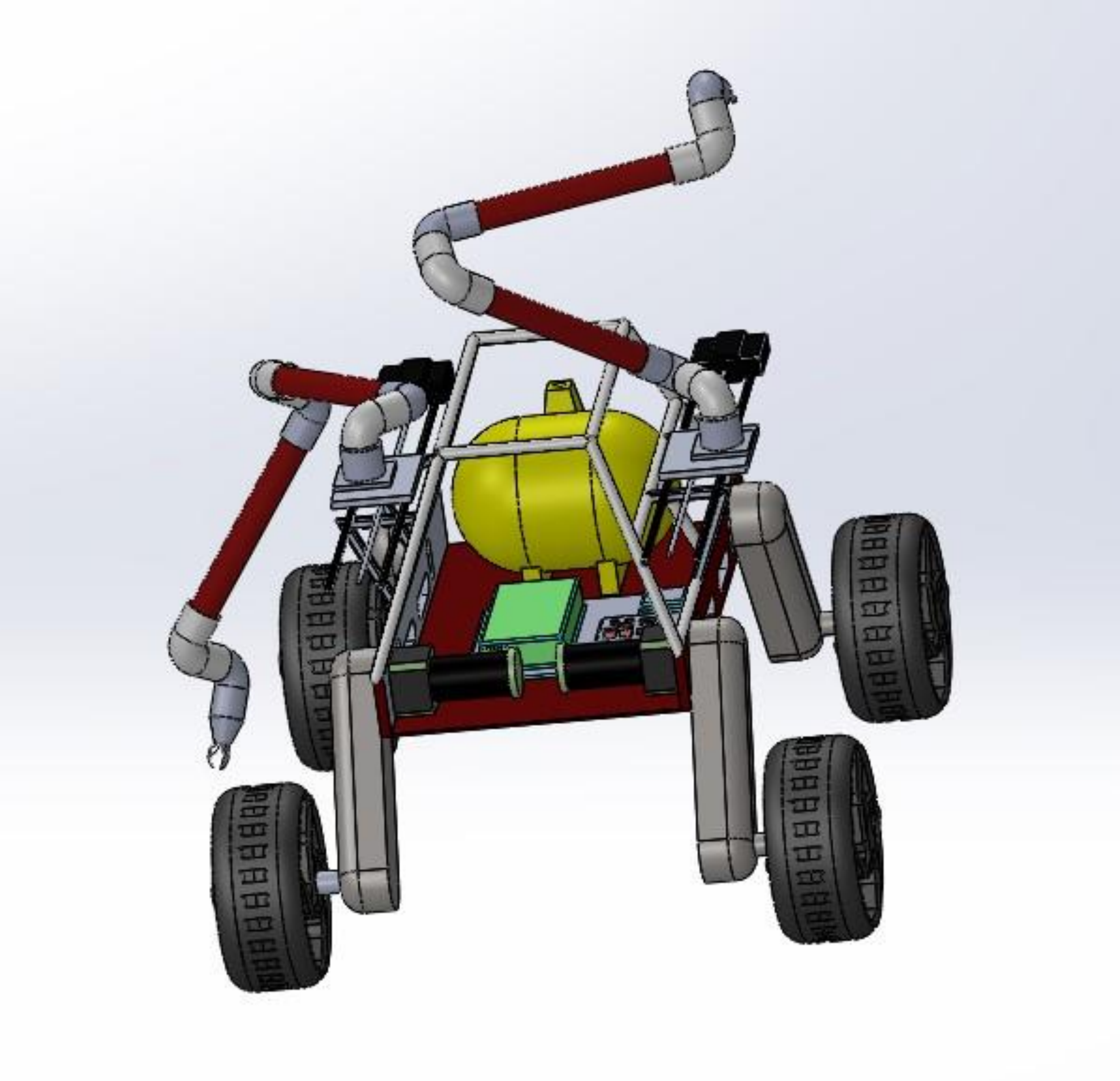


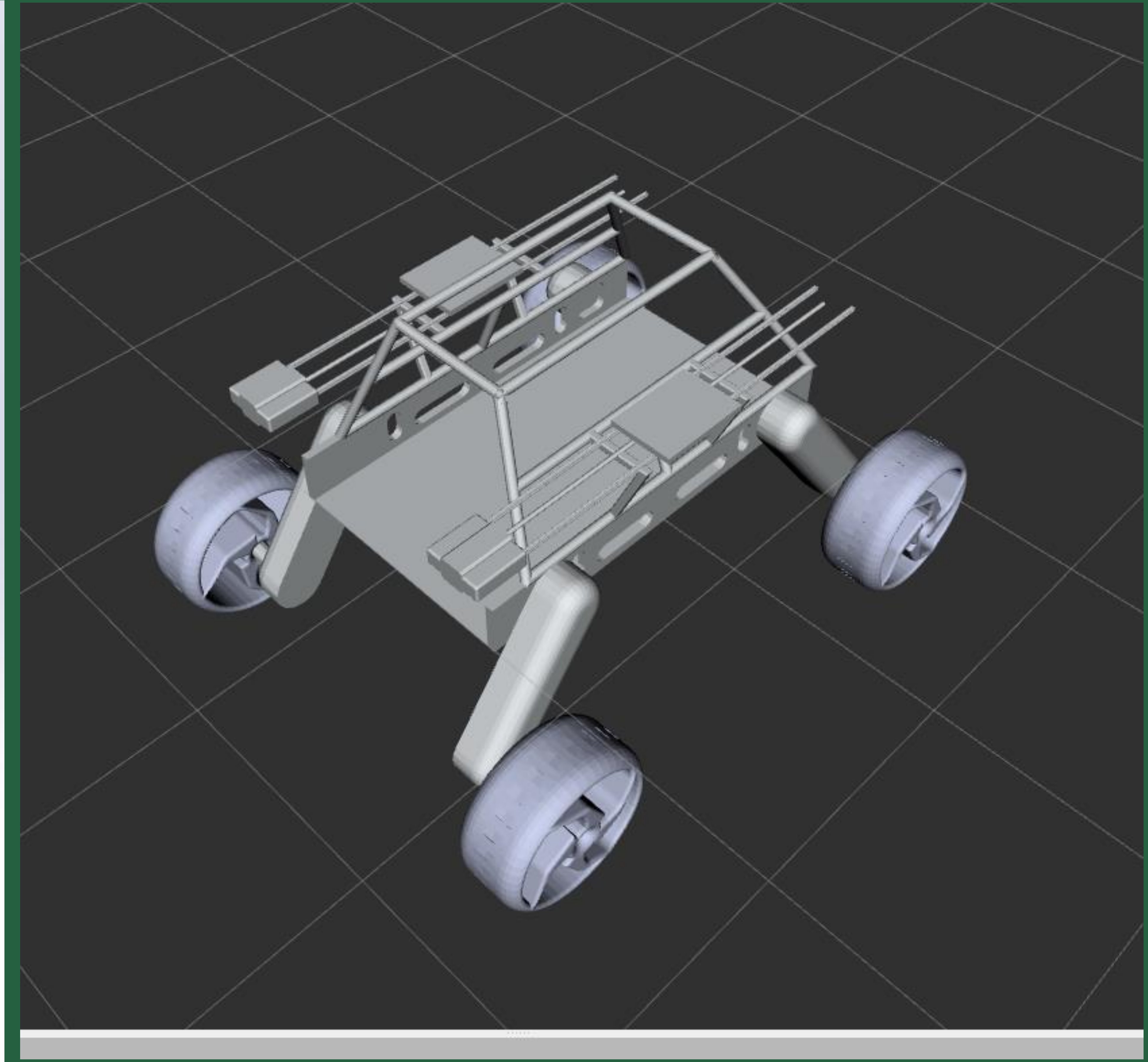


Robot Modelling & Simulation

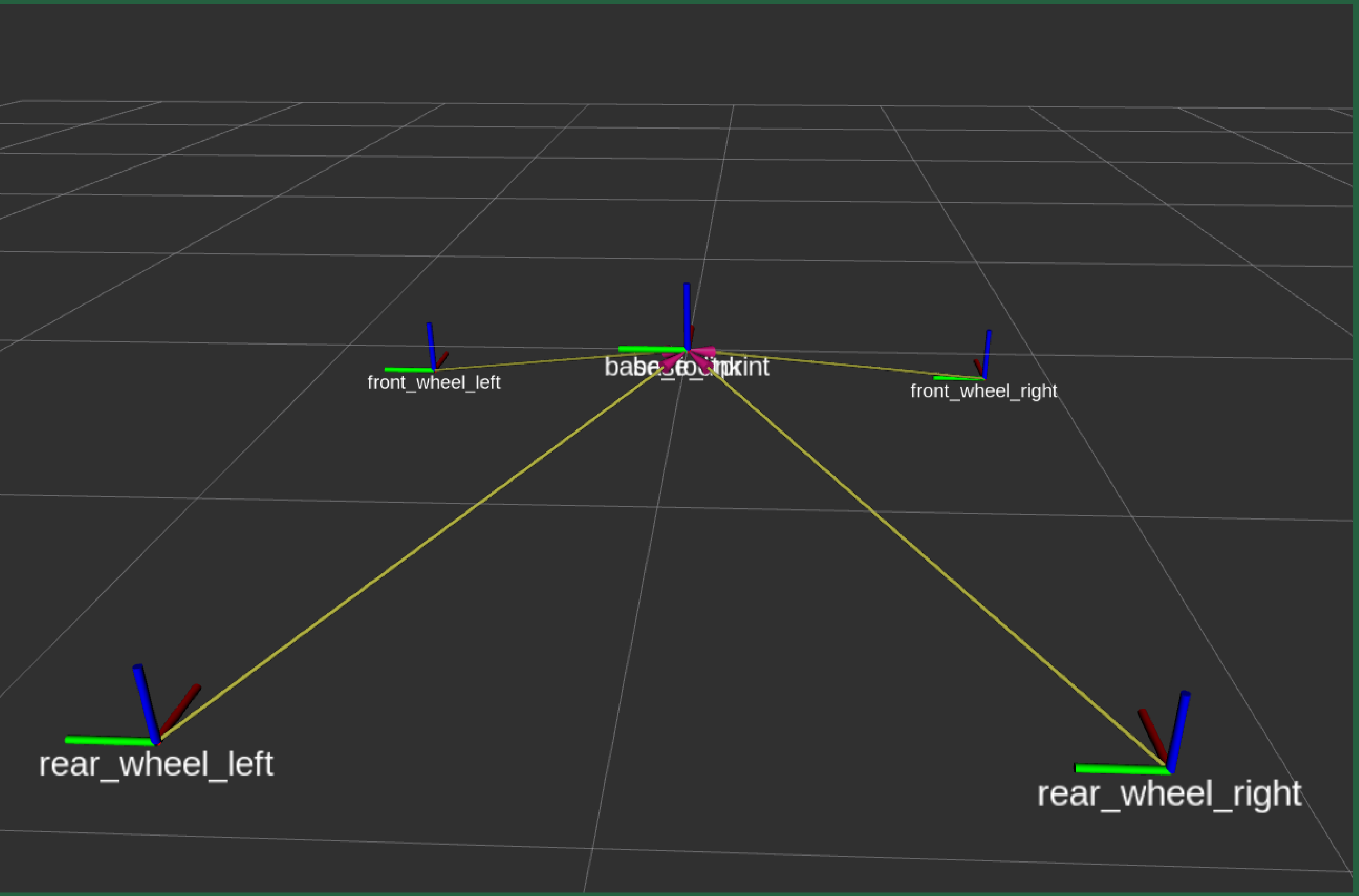
- 3D Model design using Solidworks
- URDF (Universal robot description format) used for ROS
- Transformation tree & Kinematic chain
- Kinematics of drive (Differential drive)
- Gazebo plugin & World
- Sensors Integration in Gazebo
  - IMU, Camera, GPS
  - Rviz, RQT
  - Final Rviz & gazebo
  - Control Video & Live demo If possible

3D Model



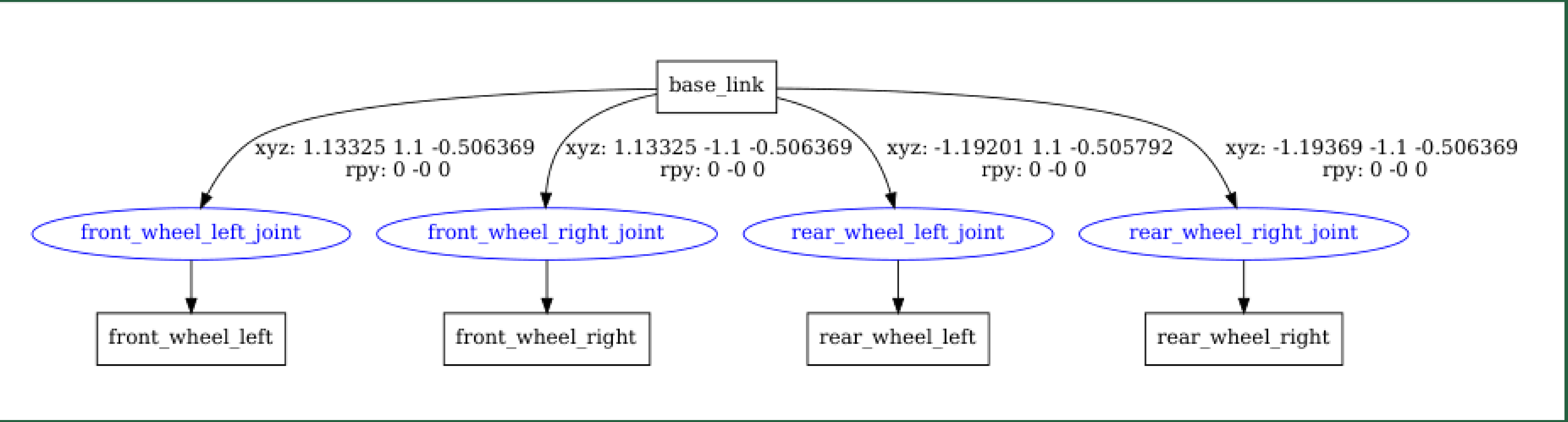


URDF

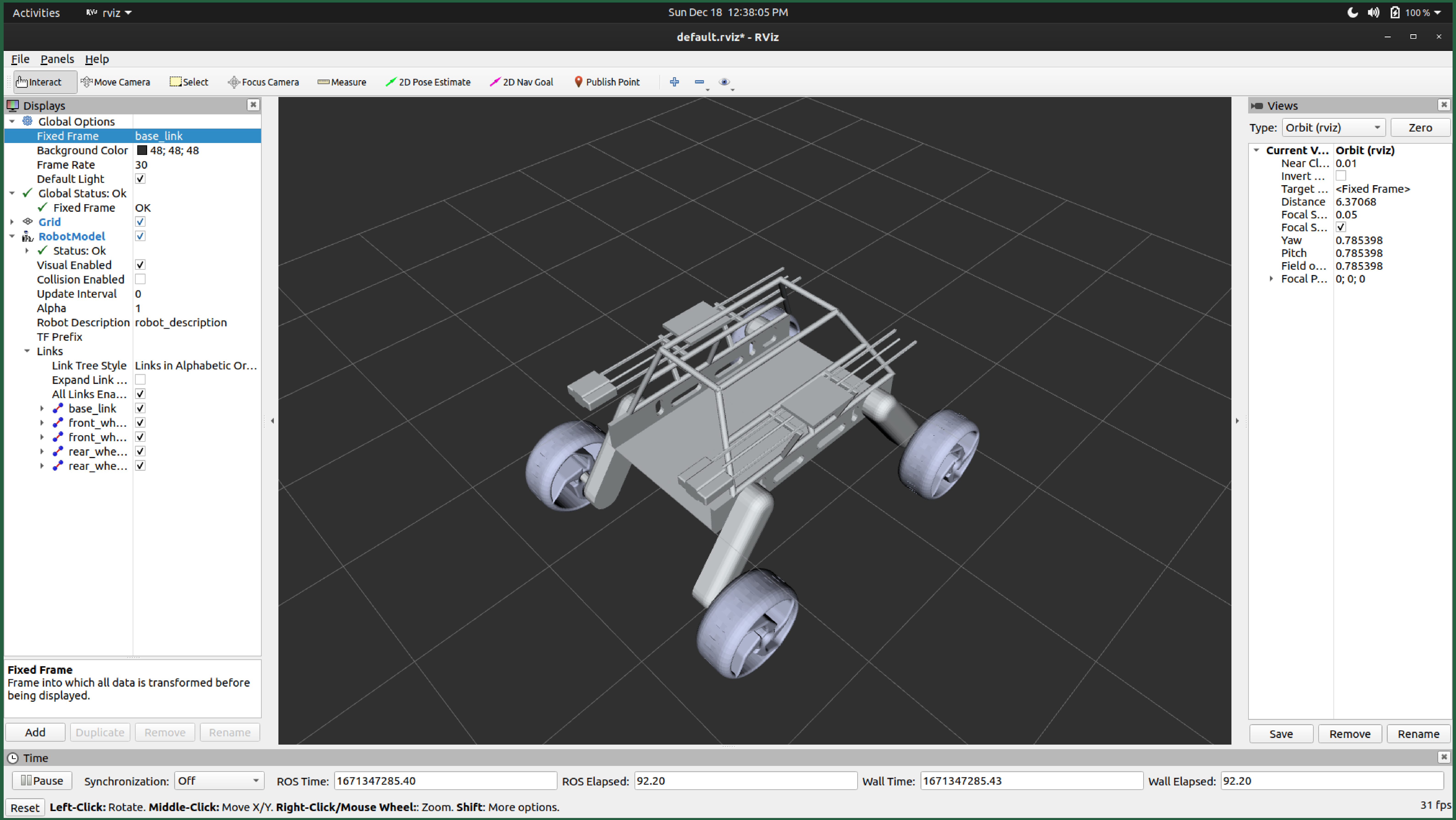


- XML file format used in ROS to describe all elements of a robot
- specify the kinematic and dynamic properties of a single robot
- Joints, Links, Properties (Visual, collision, Inertial)
- Poses, Transformation matrix
- Limitations : Can't describe Parallel linkages

Transformation Tree

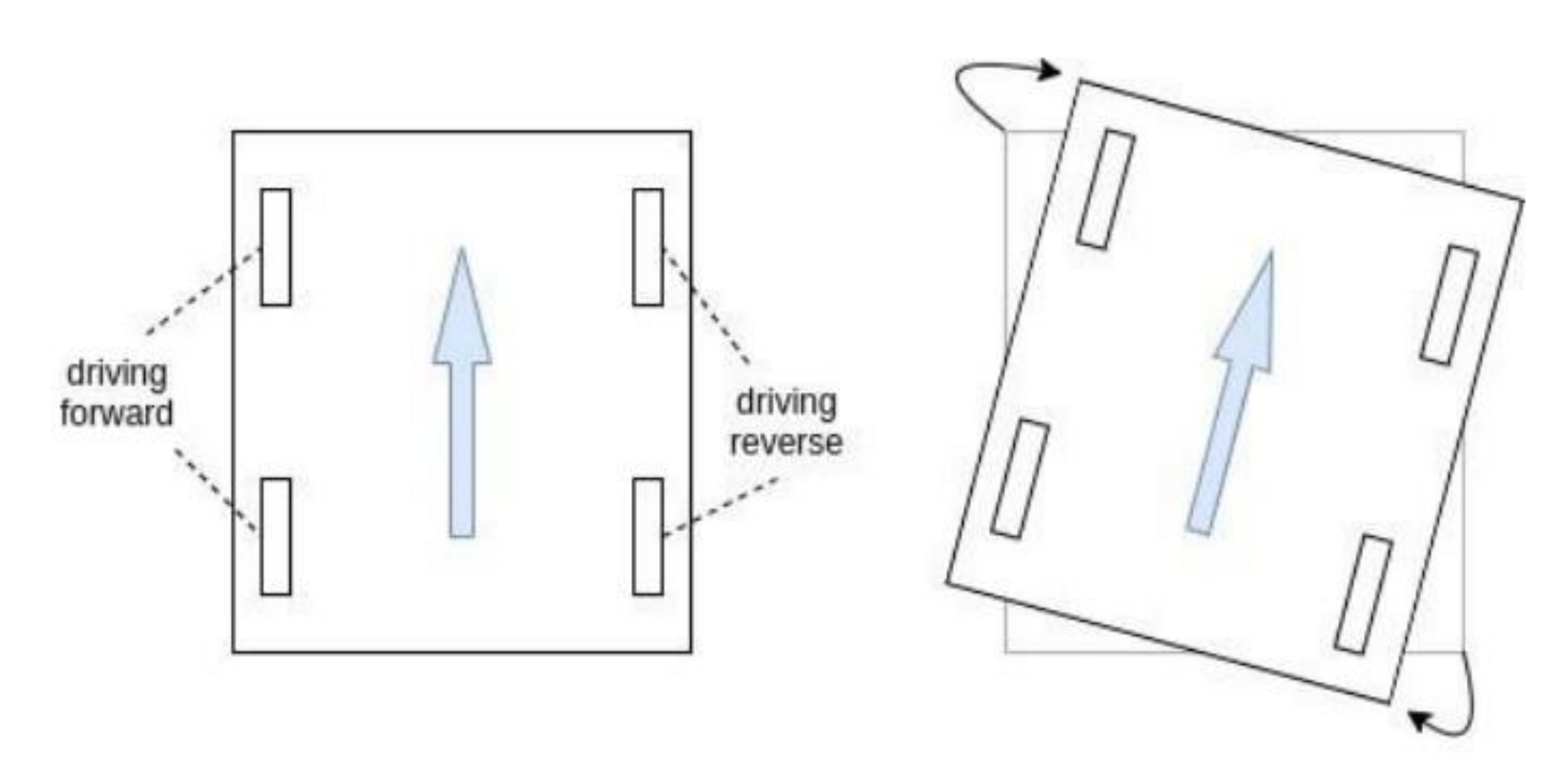


RViz


Activities
rviz
Sun Dec 18 12:38:05 PM
100 %
default.rviz* - RViz
File
Panels
Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Nav Goal
Publish Point
Displays
Global Options
Fixed Frame
base_link
Background Color
48; 48; 48
Frame Rate
30
Default Light
Global Status: Ok
Fixed Frame
OK
Grid
RobotModel
Status: Ok
Visual Enabled
Collision Enabled
Update Interval
0
Alpha
1
Robot Description
robot_description
TF Prefix
Links
Link Tree Style
Links in Alphabetic Or...
Expand Link ...
All Links Ena...
base_link
front_wh...
front_wh...
rear_whe...
rear_whe...
Fixed Frame
Frame into which all data is transformed before being displayed.
Add
Duplicate
Remove
Rename
Views
Type:
Orbit (rviz)
Zero
Current V...
Orbit (rviz)
Near Cl...
0.01
Invert ...
Target ...
<Fixed Frame>
Distance
6.37068
Focal S...
0.05
Focal S...
Yaw
0.785398
Pitch
0.785398
Field o...
0.785398
Focal P...
0; 0; 0
Save
Remove
Rename
Time
Pause
Synchronization:
Off
ROS Time:
1671347285.40
ROS Elapsed:
92.20
Wall Time:
1671347285.43
Wall Elapsed:
92.20
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
31 fps

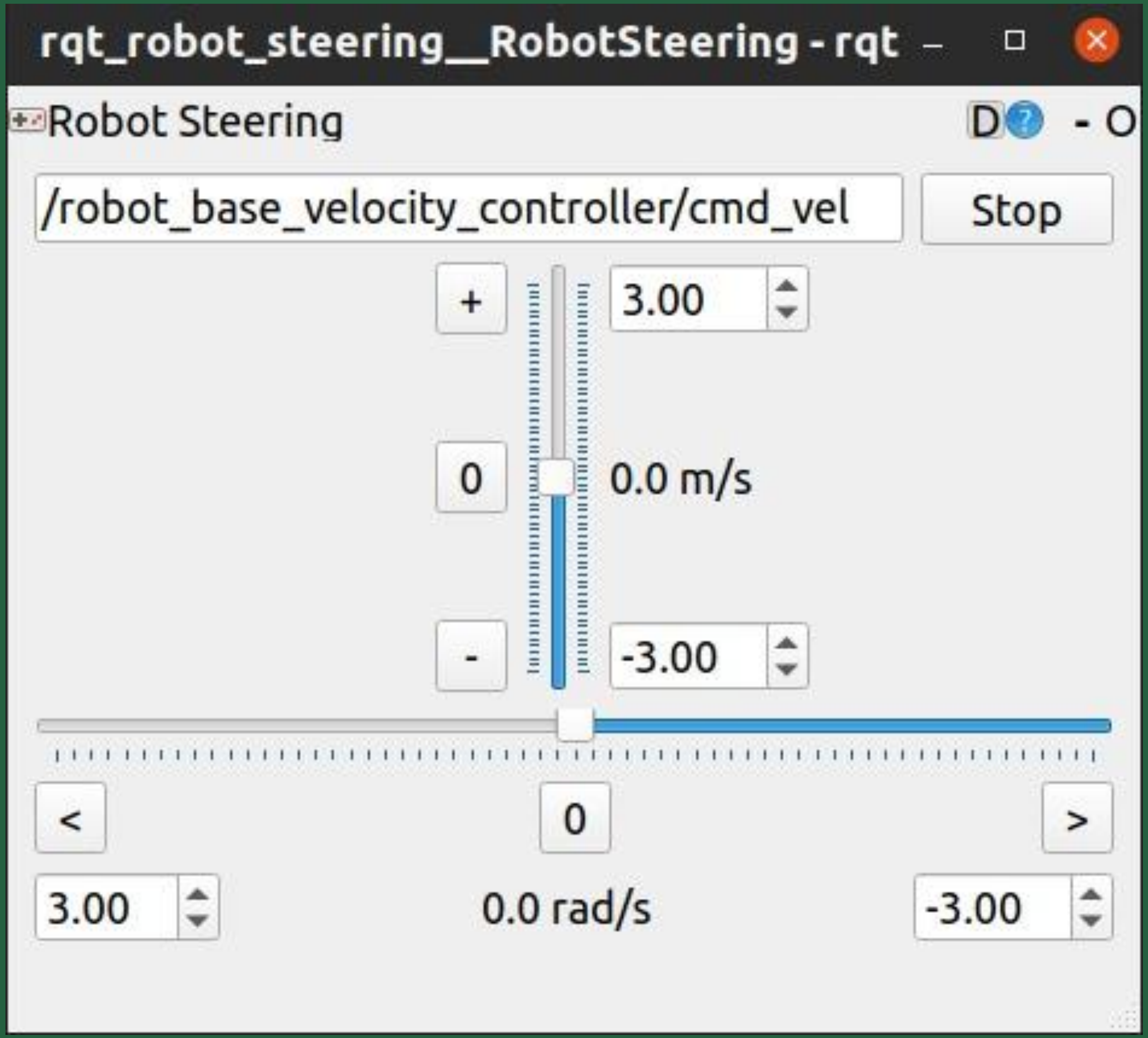
Gazebo Plugins

- Differential drive
- Controller
- Sensors (IMU, GPS, Camera, Lidar)



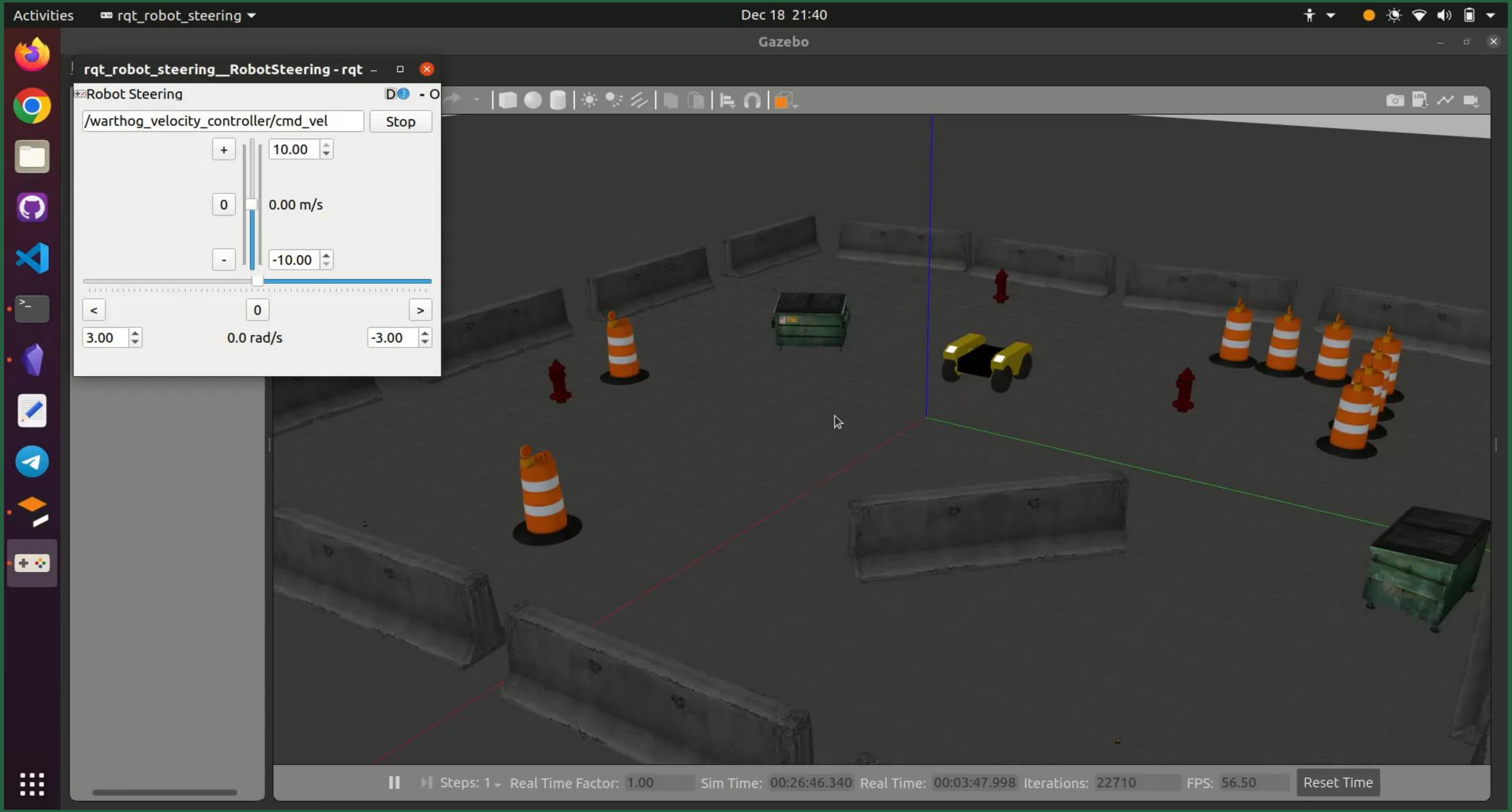
RQT

Gazebo: Image View
Topic:
~/agribot/dummy_link/camera/image
Hz:
30.03
Bandwidth:
15.07 MB/s



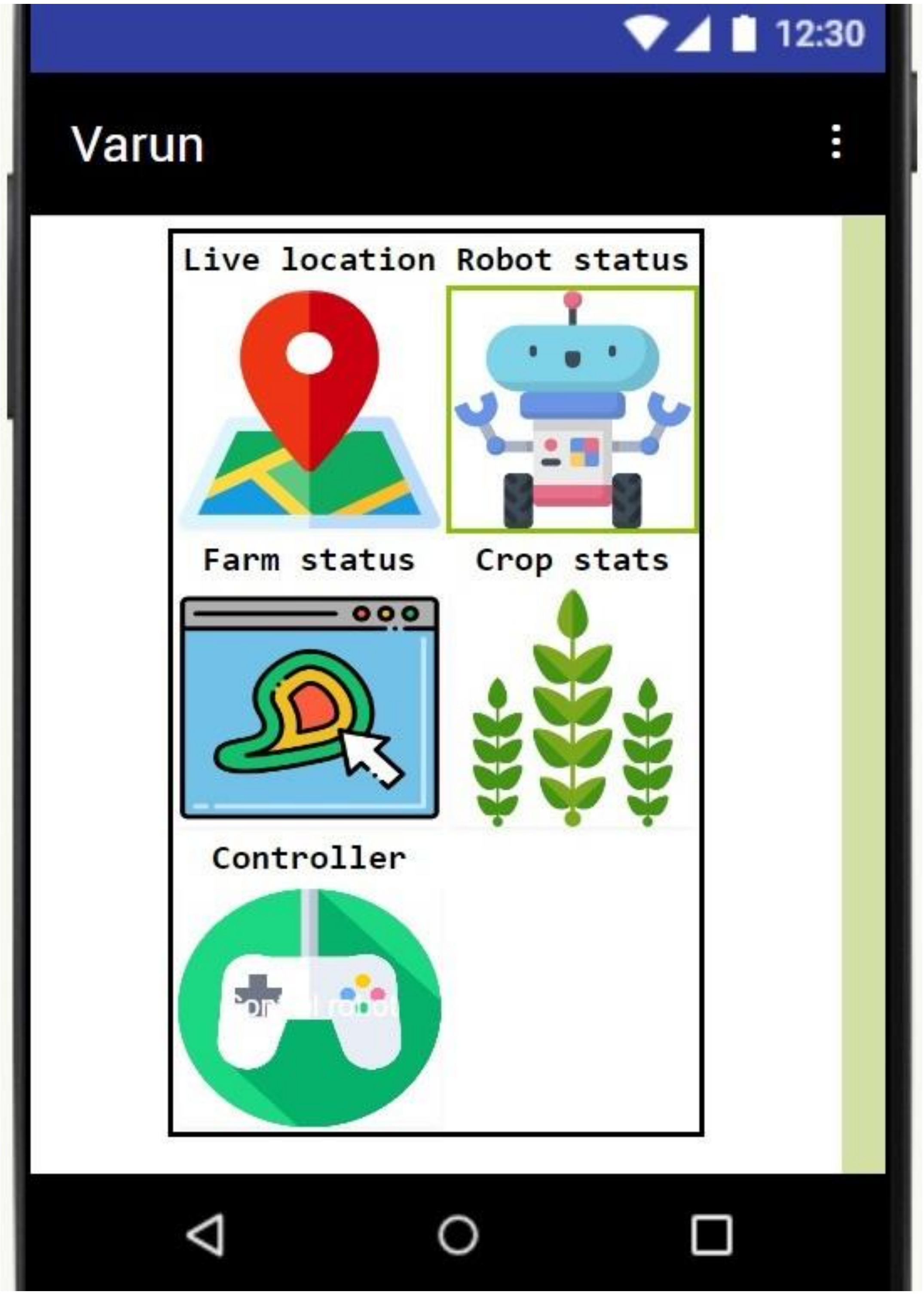
rqt_robot_steering__RobotSteering - rqt
Robot Steering
/robot_base_velocity_controller/cmd_vel
Stop
+
3.00
0
0.0 m/s
-
-3.00
<
0
>
3.00
0.0 rad/s
-3.00

Manual Control of Robot in Gazebo

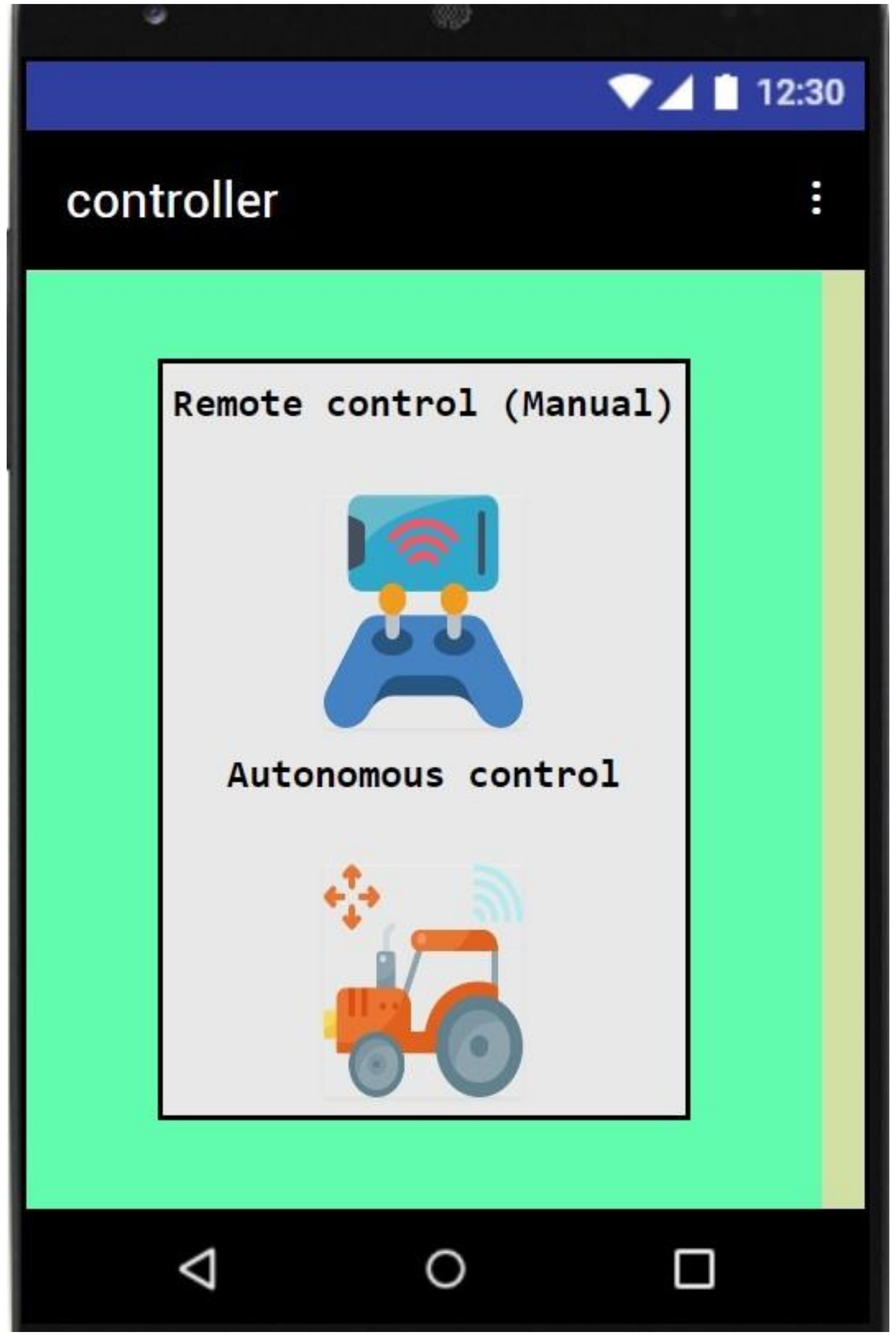


Android App

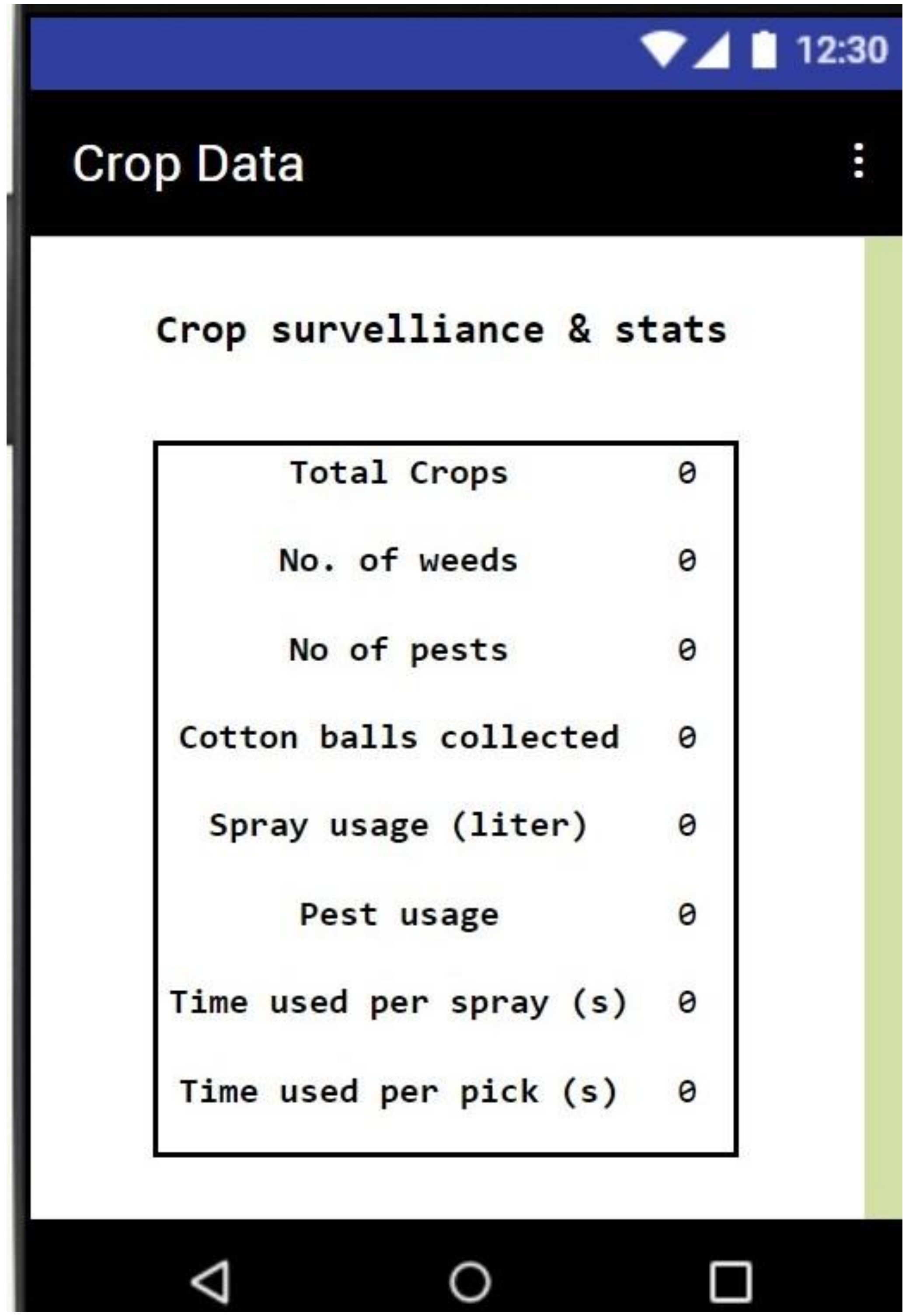
Main screen



Remote-controlled & autonomous operation

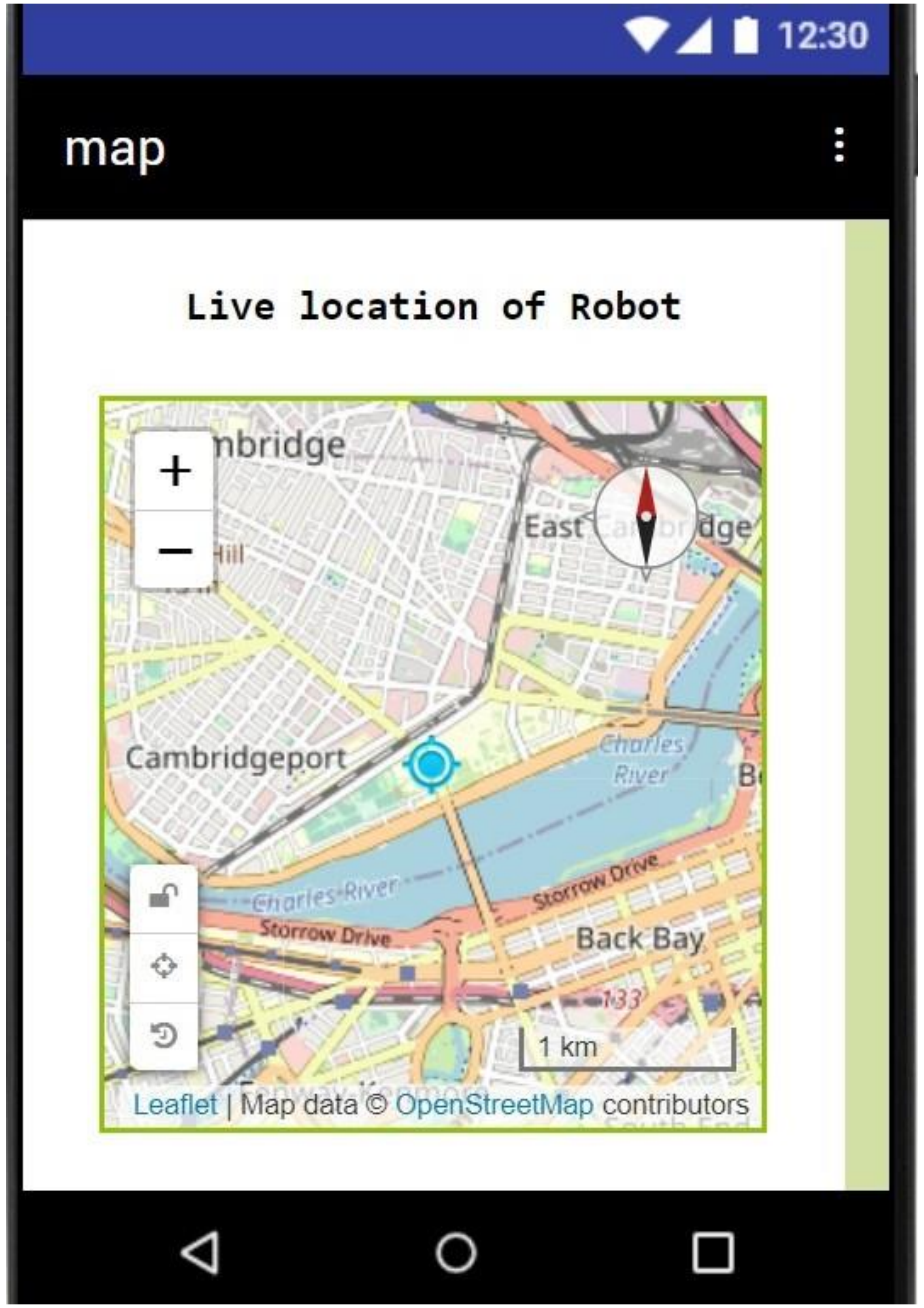


Crop data

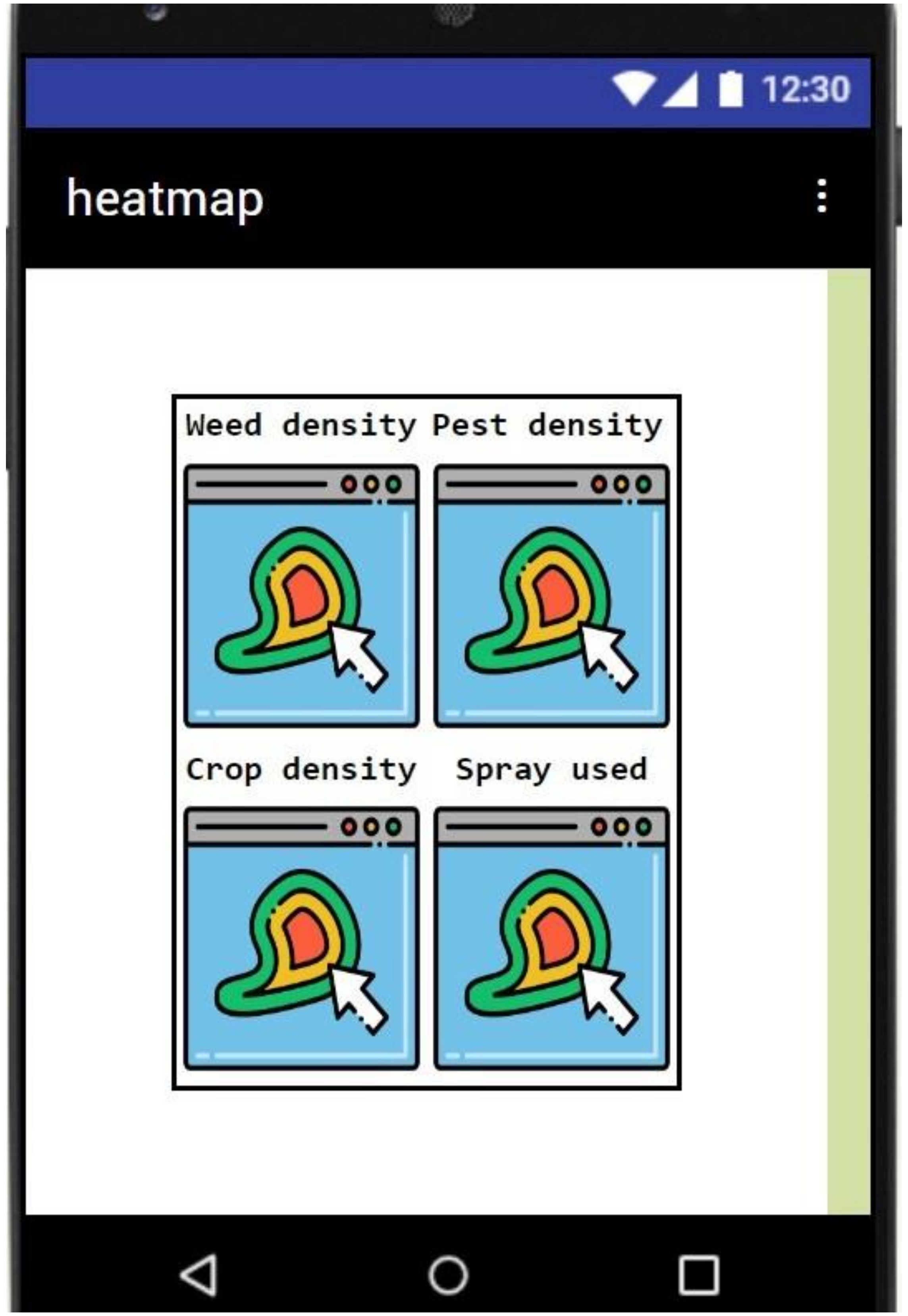


IOT: Android app

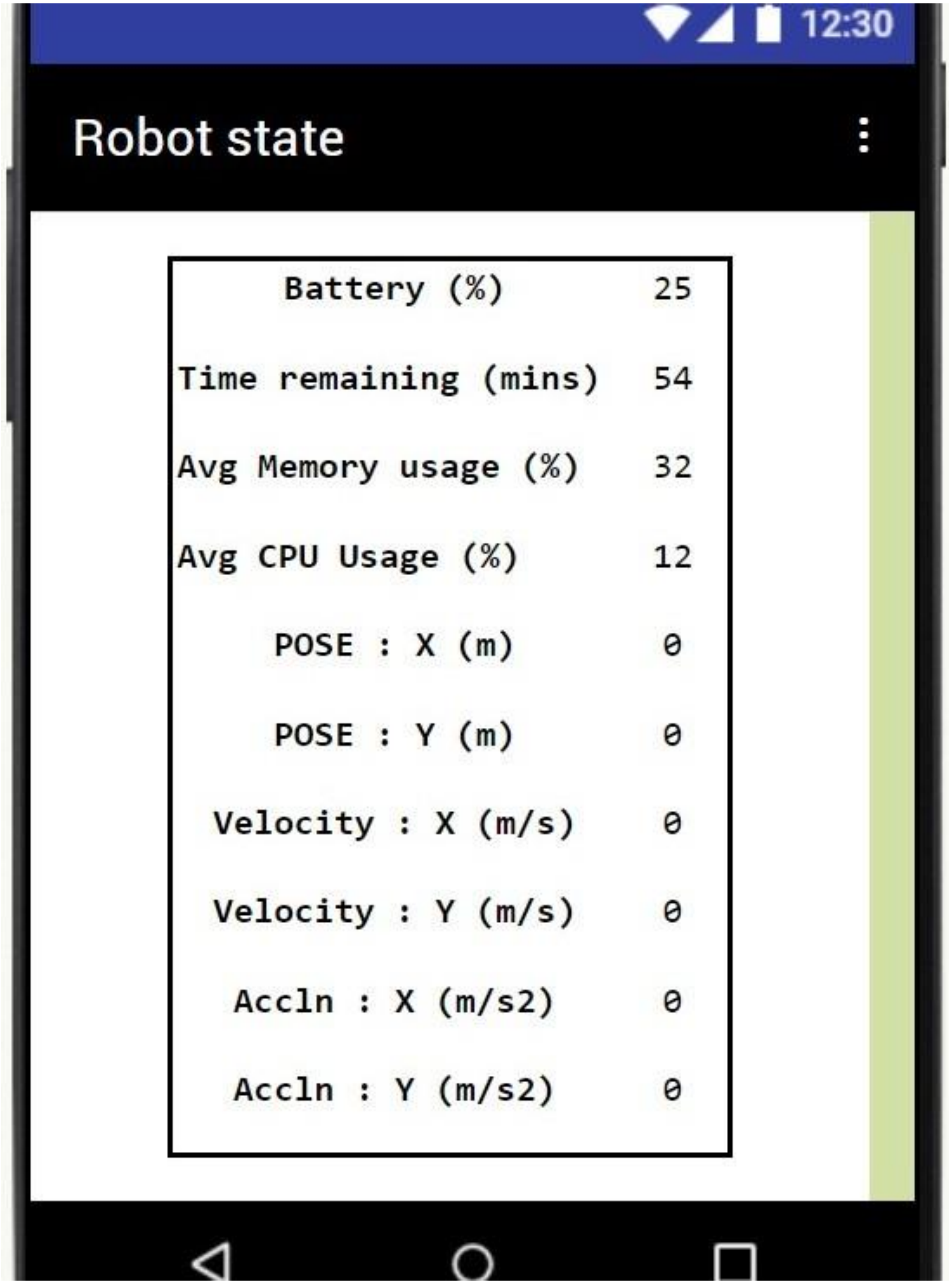
Live Location



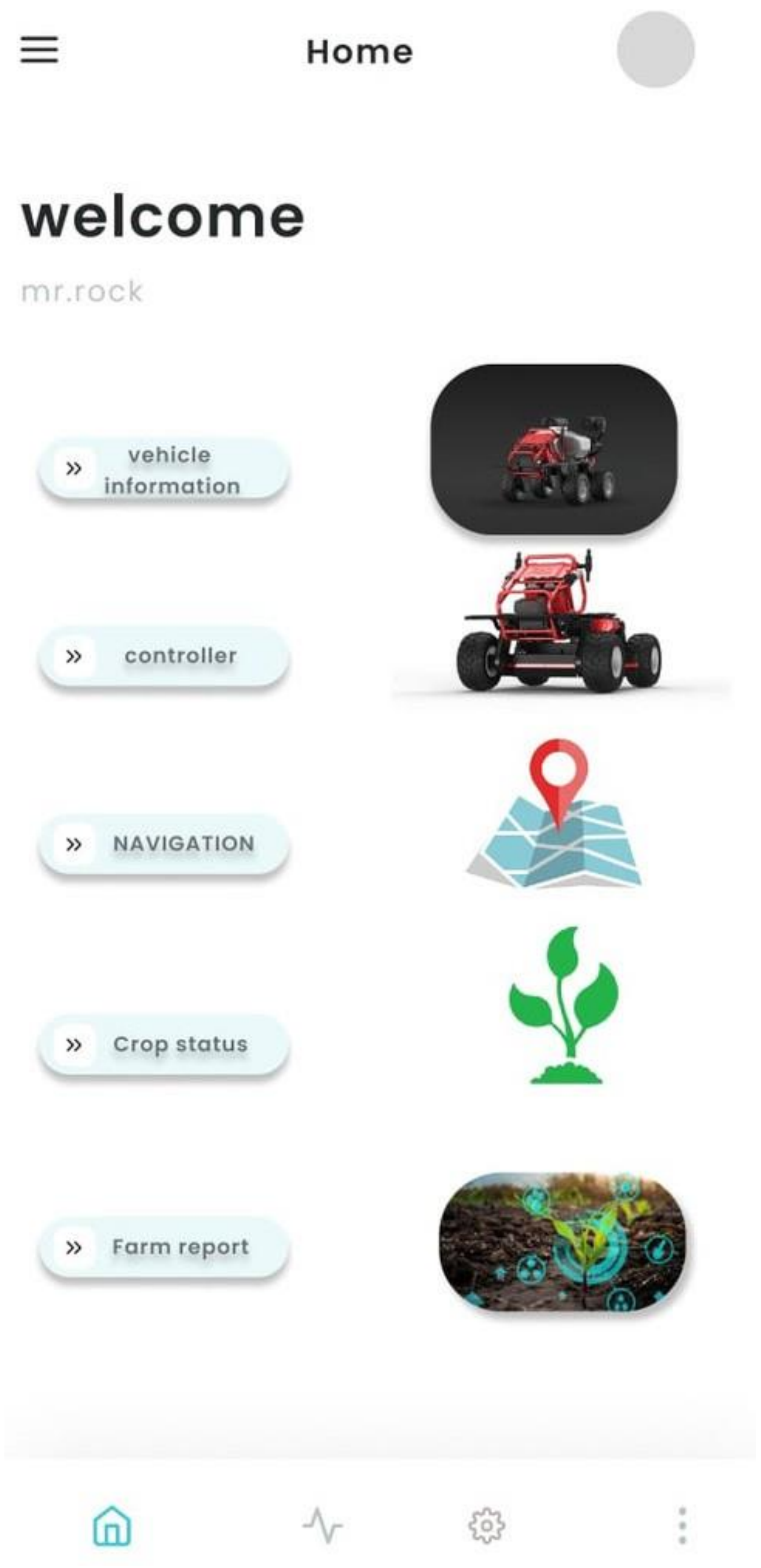
heatmap

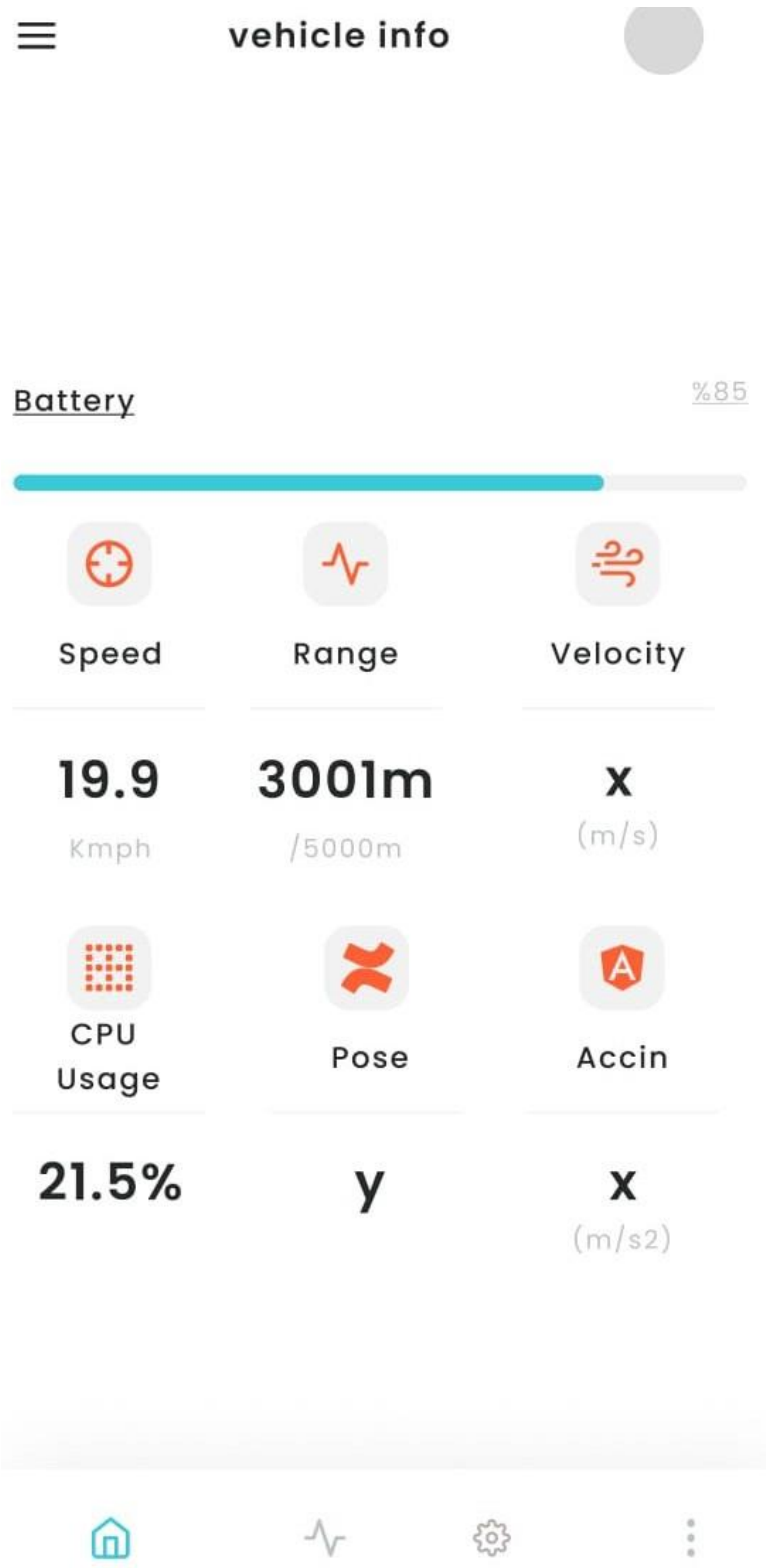


Robot live state



Android app : Next Update on UI





How is our solution Innovative and more cost-effective?

- **Cost-effective: Modularity and Manufacturing**
- **Advancement: AI, Computer vision, and IoT technologies**
- **Multiple control Modes: Autonomous, Manual**
- **Multifunctionality: Autonomous mobile robotic Platform**
- **Effective User Interface**
- **Remotely Controlled with mobile phone**
- **Data monitoring with Android App**

SPECIFICATIONS

Robot arm workspace	13.23 m3
Payload Capacity	200gm
Tank Capacity	20 Liters
Sprayer range	314.16 ~ 320 cm2
Motor Torque	9 Nm
Battery Capacity	5kW
Speed of Robot	0.5 m/s
Weight of Entire Robot	120 kg
Wheel Diameter	781.96 mm
Range of Control (android RC)	55-78 m
Total space of robot	2.3 x 2.3 x 1.46 (lbh)

Properties	Steel	Aluminum	Titanium
Strength to weight ratio	Low	High	High
Cost	Low	Moderate	High
Availability	Easily Available	Easily available	Not easily Available
Machinability	Easy	Easy	Difficult

Cost Estimation

Hardware	Price
GNSS and RTK based motion	**12,000**
GNSS Receiver Module (x2)	6,000 * 2 =12,000
Weed Detection System	**33,000**
Jetson Nano 4GB RAM	25,000
Image Sensor (Pixy 2.1 camera)	8,000
Spraying Mechanism	**7,000**
GT2 Timing Belt and Pulley(x2)	500*2 = 1000
Hollow-cone Nozzle (60 deg & 90 deg)	500*2 = 1000
Garden Sprayer with Tank (16L)	4000
NEMA17 1.6 kg-cm Stepper Motor	1,000
Vehicle Motion	**45,000**
High power High torque 24V brushed planetary gear motor. Model: 60PG60S	20,000*2=40,000
Photoelectric Speed Sensor Encoder (2)	1000*2 = 2000
DC Motor controller 250W	1,500*2=3,000
Others	**20,000**
Battery	
Battery Management System(BMS)	3,000
Transmission system(to be decided)	
Total	**117,000**

Sr. no.	Equipment	Justification
1.	GNSS receiver Modules	One receiver module is used for navigating robot and other is used as fixed base station (Since the cost of a base station is in range of 1.5to 2 Lacs, we'll be using another GNSS module as a base station.)
2.	NVIDIA Jetson Nano	For on-board processing of image data, this development board also has GPU which can process moderate-level deep learning models for lane detection and weed detection
3.	Pixy 2.1 camera	Smart Vision Sensor-Object Tracking Camera. This sensor works in a very simple way: it only detects the images we need and can send the corresponding data to your processor via 6 different channels: UART, SPI, I2C, USB, digital or analog!
4.	Hollow-cone Nozzle	Nozzles are needed for spraying mechanism.
5.	Garden Sprayer with Tank	This is already being used in farms for spraying purpose. Since we're proposing a modular farming robot, this can be used changeable module with variable capacity tank.
6.	NEMA17 Stepper Motor	this stepper motor is required to precisely run the time-belt connected to nozzle spraying mechanism with an step angle 1.8 °.
7.	High power High torque 24V brushed planetary gear motor	This is the main driving motor. One is connected to the left two wheels and another is connected to the right two wheels. The two wheels at the left are connected together. This facilitates differential drive. The differential drive is necessary for easy maneuvering and to make sure the robot turns at the end of the U-turn in a small radius.
8.	Photoelectric Speed Sensor Encoder	This is used as positional sensor switch (limit switch) to find the position of the wheel (rpm).
9	Battery Management System(BMS)	This is required because we'd be arranging various cells in parallel and series order to get the required 24 V output voltage. This BMS monitors and manages a battery pack in order to protect it from damage, prolong its life, and keep the battery operating within its safety limits.


THANK YOU!!!