DEVELOPMENT OF A UAV - UGV CONVERTIBLE ROBOT

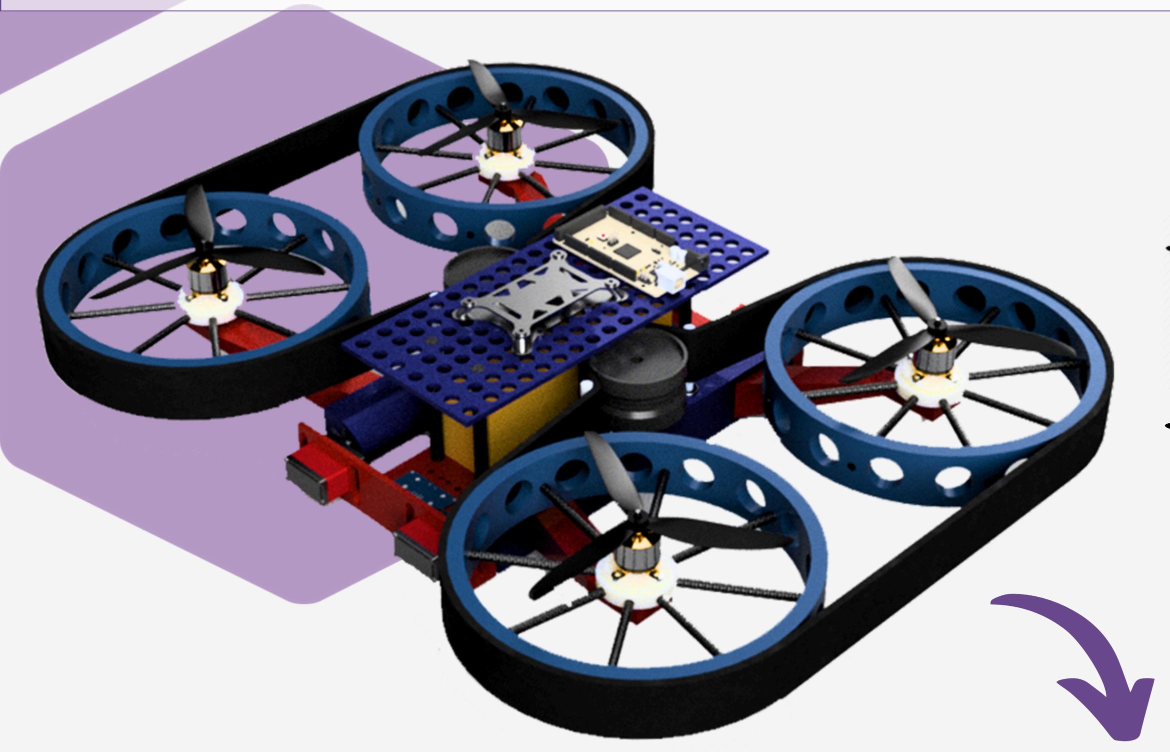
INDIAN INSTITUTE OF TECHNOLOGY PALAKKAD

Project Guide: Dr. Santhakumar Mohan | Amar Hamdan Thayyil, 132001007 | Labeeb Nassar, 132001019

Introduction

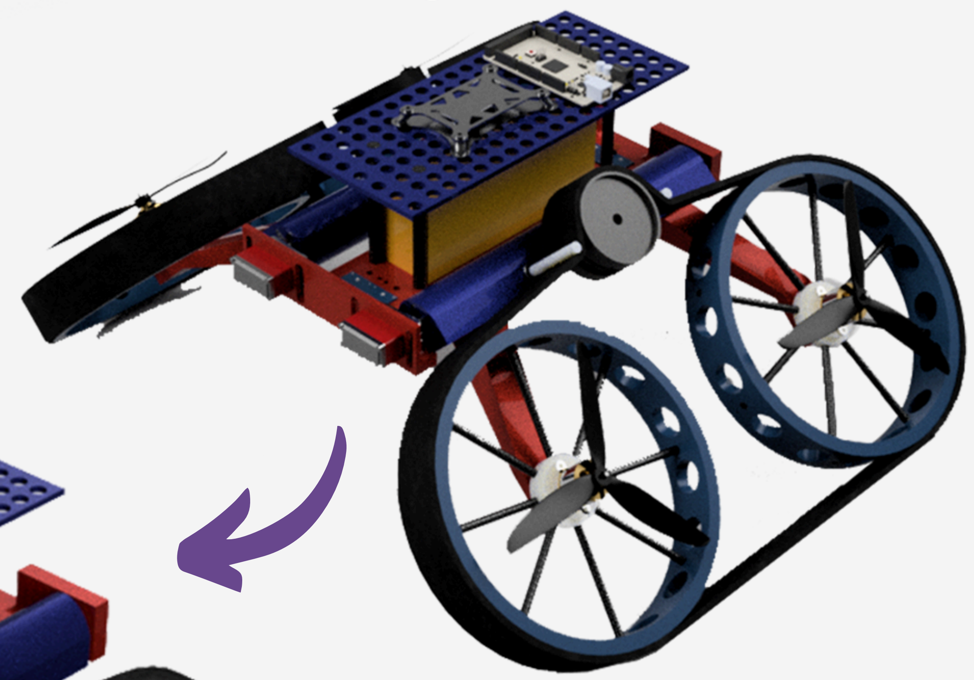
- Convertible robots arise from multi-modal robotic platforms for diverse applications, with minimal human intervention, adapting through shape or configuration changes.
- UAVs excel in surveillance & monitoring but face limitations in confined spaces & heavy payloads.
- UGVs are proficient in carrying heavy payloads and confined spaces, but have terrain limitations.
- Combining UAV and UGV capabilities in a robot allows seamless transformation for tasks requiring a mix of ground and aerial operations.

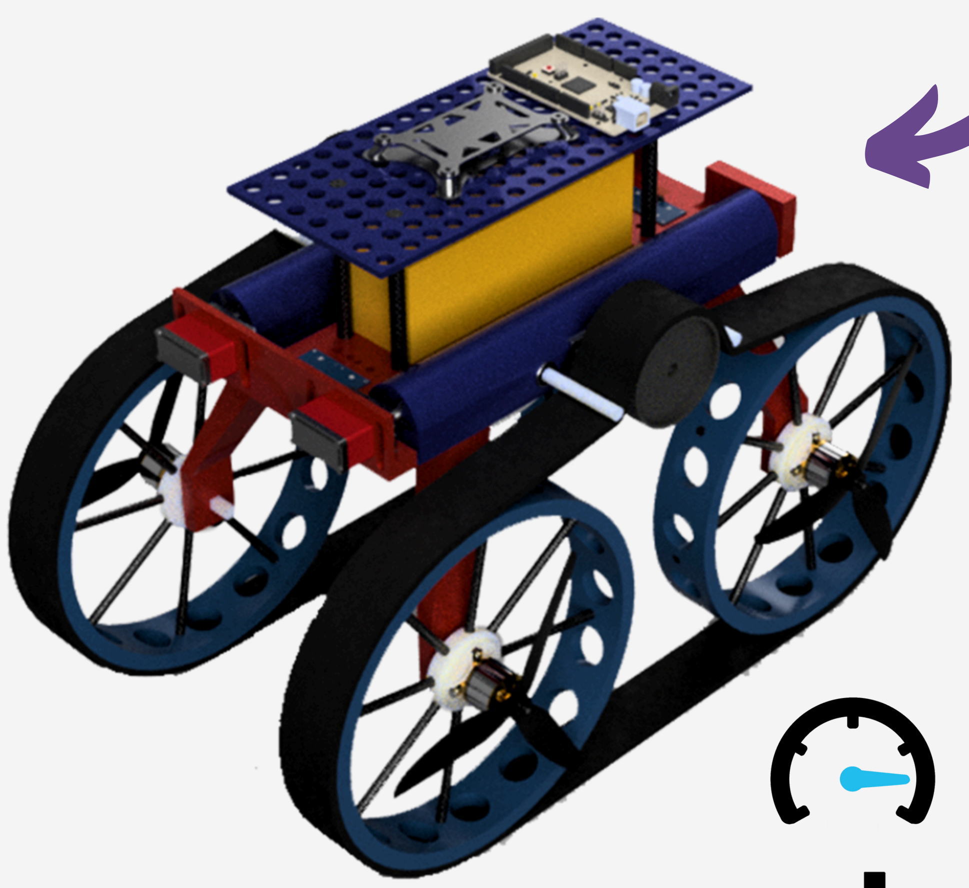
CAD Model



= 6 minutes

= 3.3 kg





Transformation Phase

= 0.25 m/s

= 4.8 kg

Methodology

Unlike conventional differential wheels on UGV's, the robot developed in this project is equipped with a track belt drive mechanism. Advantages:-

- Improved Traction
  - Reduced slippage
- Weight Distribution
  - Higher payload capacity
  - Lower ground pressure
- Others
  - Off-road Capability
  - Shock Absorption
  - Durability

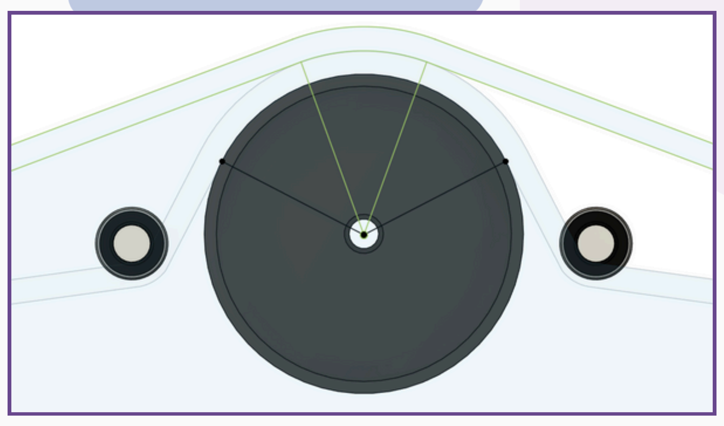
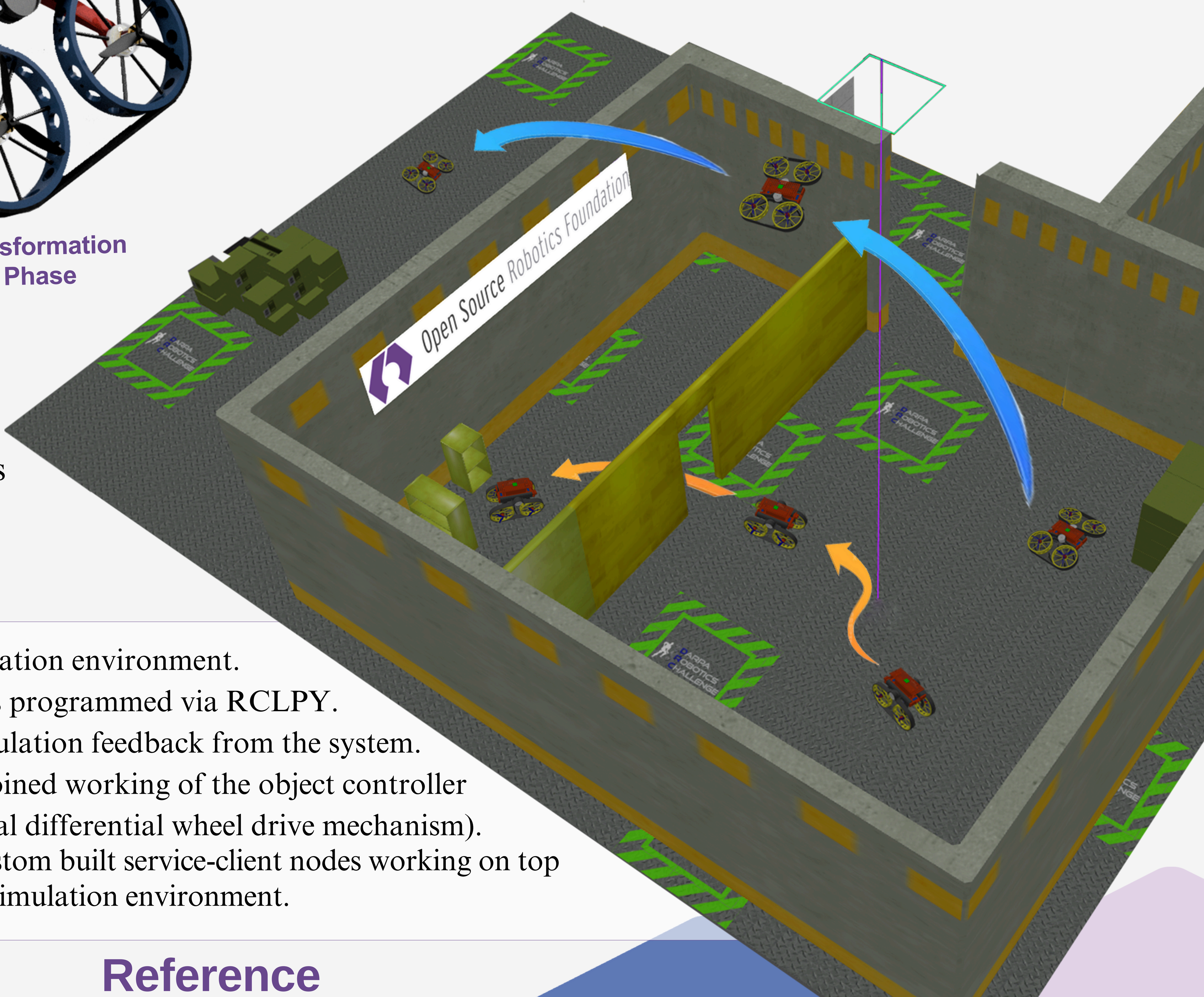


Figure: The track belt on driving pulley with and without the idler shafts. Contact angle (green) without idler shaft = 40º, Contact angle (black) with idler shaft = 120º

The track is powered by a belt drive mechanism at the pivot, with propeller guards acting as driven pulleys supporting the UGV. Idler shafts at the driving pulley ensure belt tension and increase the contact angle from 40º to 120º.

Ultrasonic sensors equipped on the robot serves as a fail-safe method, ensuring proper ground contact before the UAV converts into the UGV. This will prevent transformation attempts during the flight. These sensors are particularly useful while landing on inclined terrains.



Simulation

- 3D CAD - model imported to Gazebo simulation environment.
- Control structure for each mode of motion is programmed via RCLPY.
- Drone motion stability achieved via imu simulation feedback from the system.
- Tracked mobile robot simulation is the conjoined working of the object controller and differential drive kinematic model (virtual differential wheel drive mechanism).
- Transformation action was achieved using custom built service-client nodes working on top of force-torque plugins available for Gazebo simulation environment.

Conclusion

The convertible robot's versatility from UAV to UGV can be utilized in several sectors such as defense, disaster response, exploration, agriculture, and environmental monitoring. Its also useful in warehouse's for transportation and inventory management. A remarkable development of this domain can be seen in the near future as the robotics technology continues to push its boundaries.

Reference

1: Gazebo Fuel Ignition Assets, Open Robotics, ROS2-Gazebo, 2020
2: TraceParts, Autodesk Fusion 360, 2023
3: Warehouse Assets, Amazon Web Services, 2021

Acknowledgement

Our sincere gratitude to Dr. Santhakumar Mohan, our project guide for his continuous support in this project. Our special thanks to the BTP coordinators and IIT Palakkad for providing the opportunity to work on this project at the UG level.

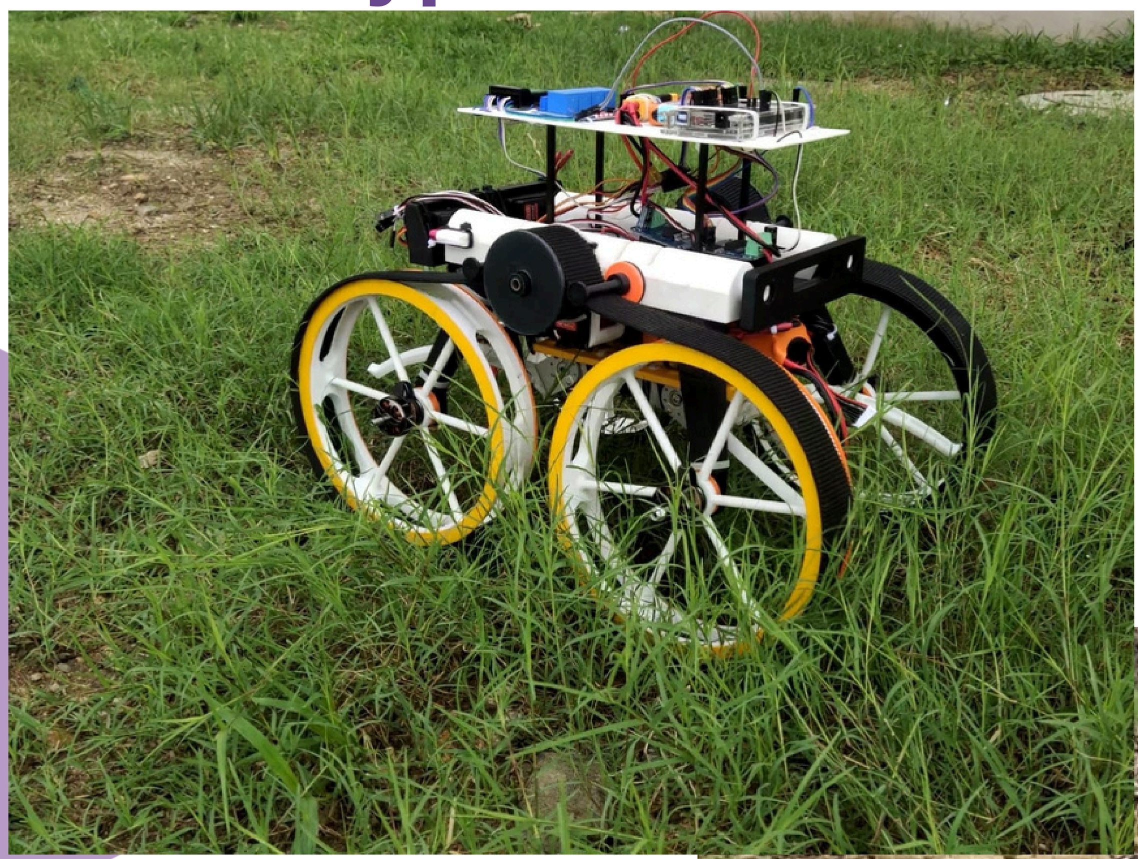
Department Of Mechanical Engineering | Reach Us: 132001007@smail.iitpkd.ac.in, 132001019@smail.iitpkd.ac.in

DEVELOPMENT OF A UAV - UGV CONVERTIBLE ROBOT

INDIAN INSTITUTE OF TECHNOLOGY PALAKKAD

Project Guide: Dr. Santhakumar Mohan | Amar Hamdan Thayyil, 132001007 | Labeeb Nassar, 132001019

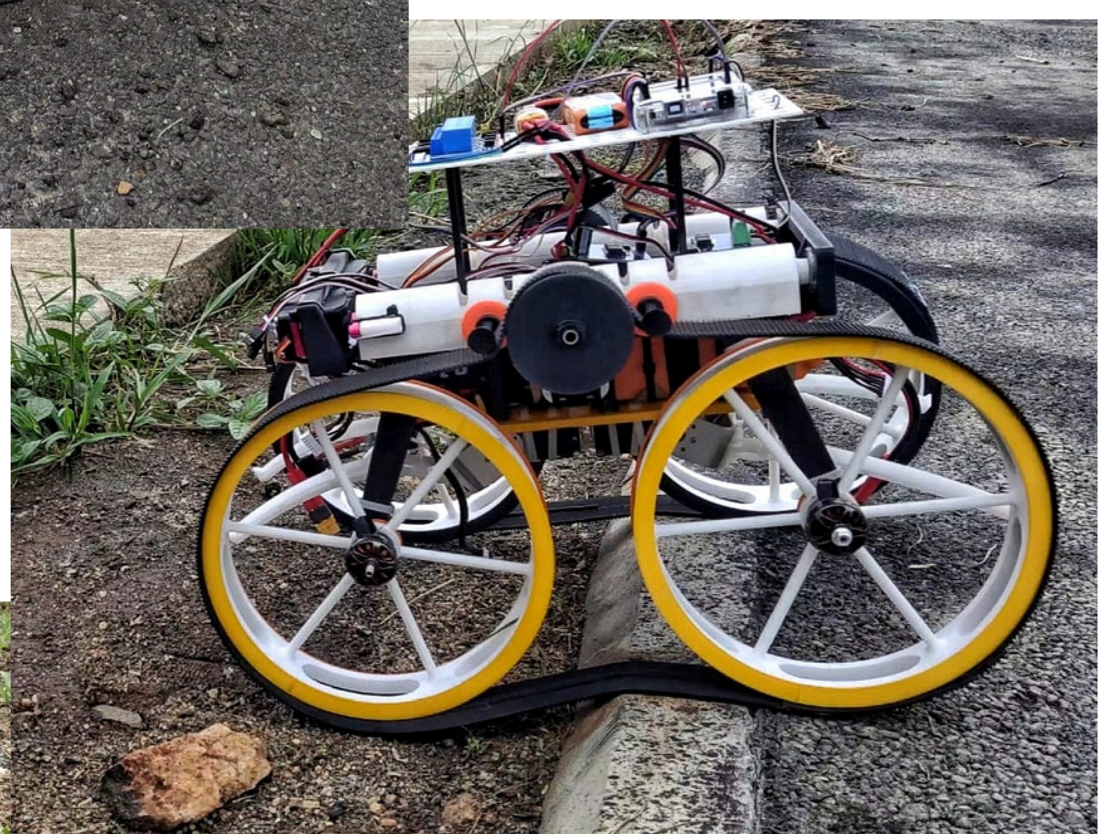
Prototype & Terrain Test



Grass & Soft Ground

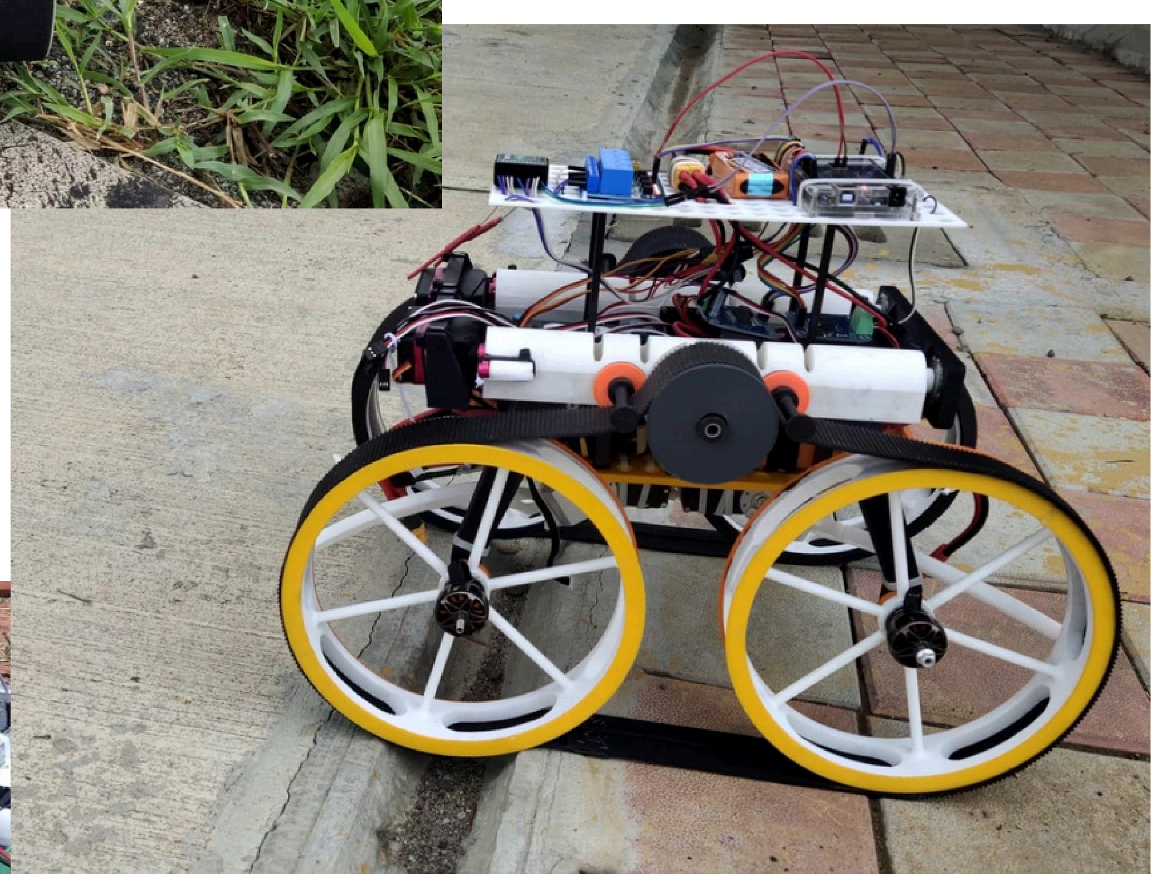
Rocks & Gravels

Asphalt



Steps

Rugged



Trench

Holes

Hardware Results

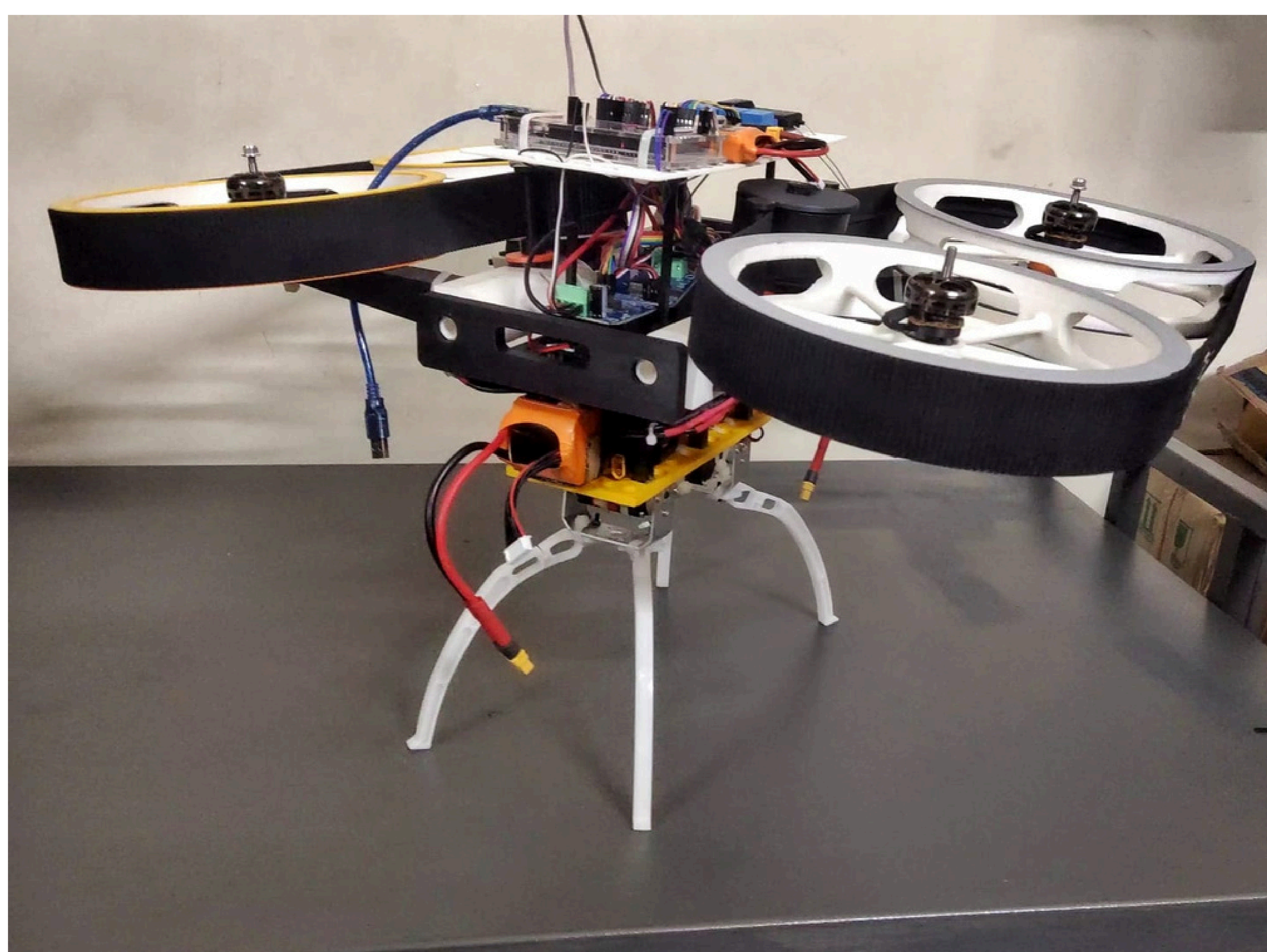
- The UGV mode the track belt mechanism allows the bot to move in the expected differential drive format, the motor driver controls the speed and direction of rotation of each motor driving the belt mechanism.
- The UAV mode of the bot which is controlled by the pixhawk 2.4.8 flight controllert. The sensors on the flight controller were calibrated to suit the bot weight distribution which helped stabilize the motion of the drone.
- For the conversion part, the landing gear mechanism helps to convert the bot while preventing the belt from slipping off the wheel. The landing legs were easily able to hold the upper weight of the bot with the help of a 60 kg cm servo motor. Although a conclusion was made from the hardware testing that the 150 kg cm servo would be a better choice in terms of providing sufficient force downwards to convert back to UAV from UGV mode.

Robot Specification (Test Results)

- Total Weight : 6.040 kg
- Rover Max. Speed: 0.20 m/s
- Rover Max. Distance: 390m
- Rover Battery Life: 30 mins
- Rover Charging Time: 20 mins
- Rover Payload Capacity: 2.5kg
- Rover Gradeability: 29°
- Drone Max Hover Time:
- Drone Max Flight Time:
- Drone Charging Time: 70 mins

Inference & Conclusion

- The robot functioned smoothly on the tested terrains.
- The hinge conversion mechanism and the retractable landing gear mechanism functions they are intended to be.
- The idler shafts are to be designed thicker inorder to withstand the force from the track belt.
- The build material of the T-pins has to be changed in order to withstand the temperature from the BLDC motors.
- The track belt gradually looses tension and tends to slip on the driving pulley. Changing this to a timing belt solves this issue.



Landing Gear & Transform

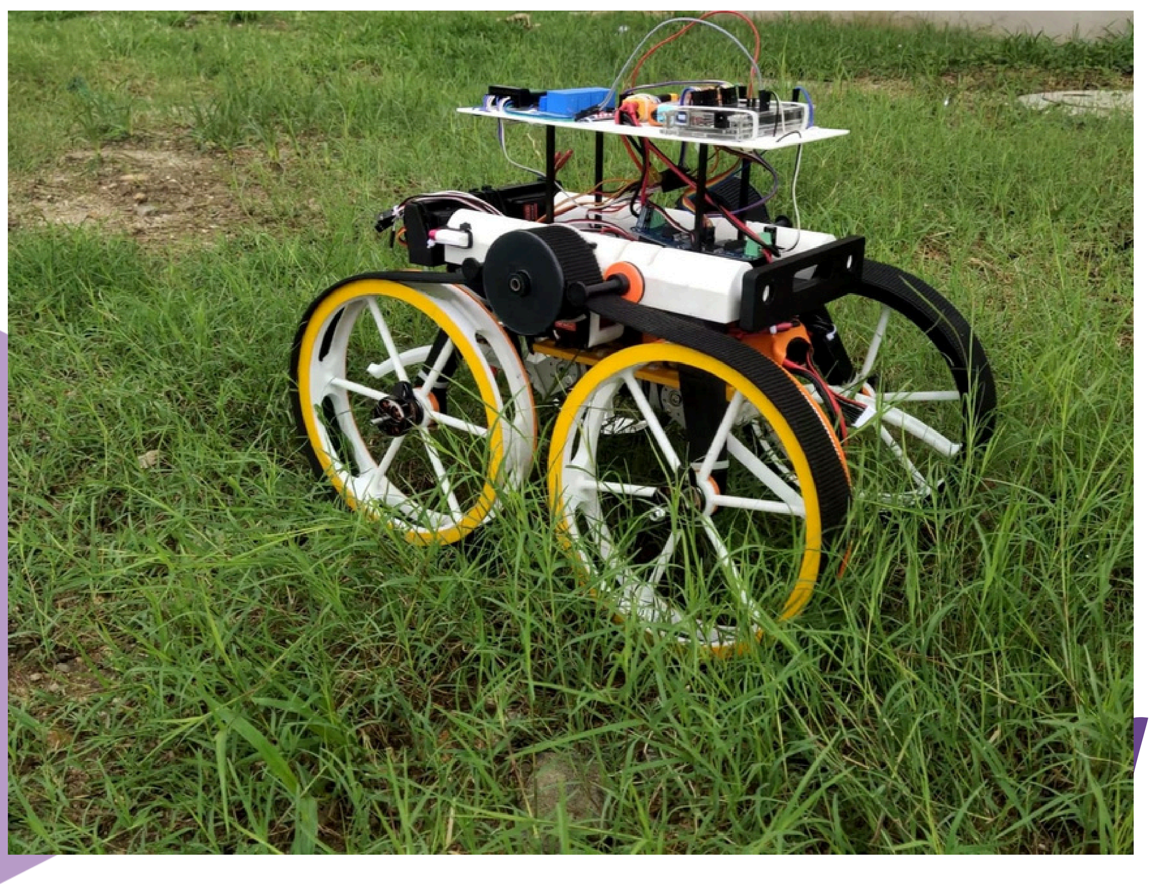
Department Of Mechanical Engineering | Reach Us: 132001007@smail.iitpkd.ac.in, 132001019@smail.iitpkd.ac.in

DEVELOPMENT OF A UAV - UGV CONVERTIBLE ROBOT

INDIAN INSTITUTE OF TECHNOLOGY PALAKKAD

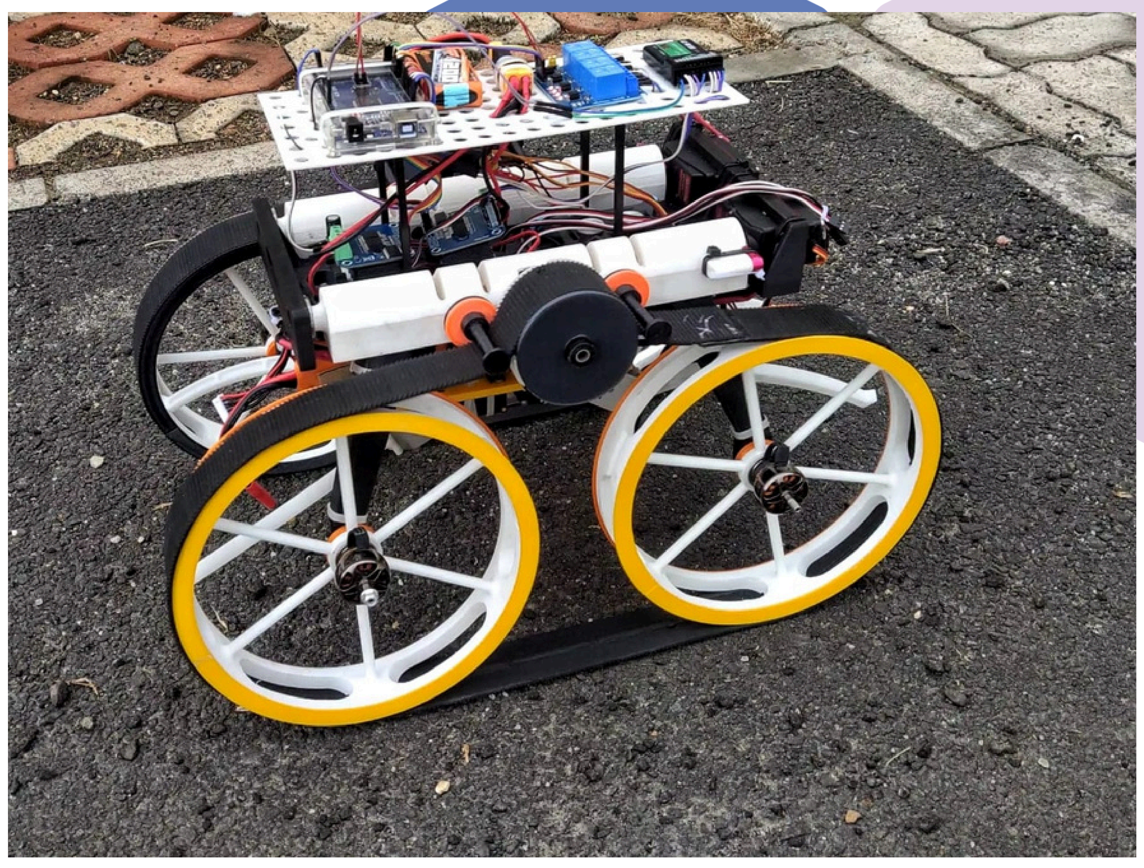
Project Guide: Dr. Santhakumar Mohan | Amar Hamdan Thayyil, 132001007 | Labeeb Nassar, 132001019

Prototype & Terrain Test

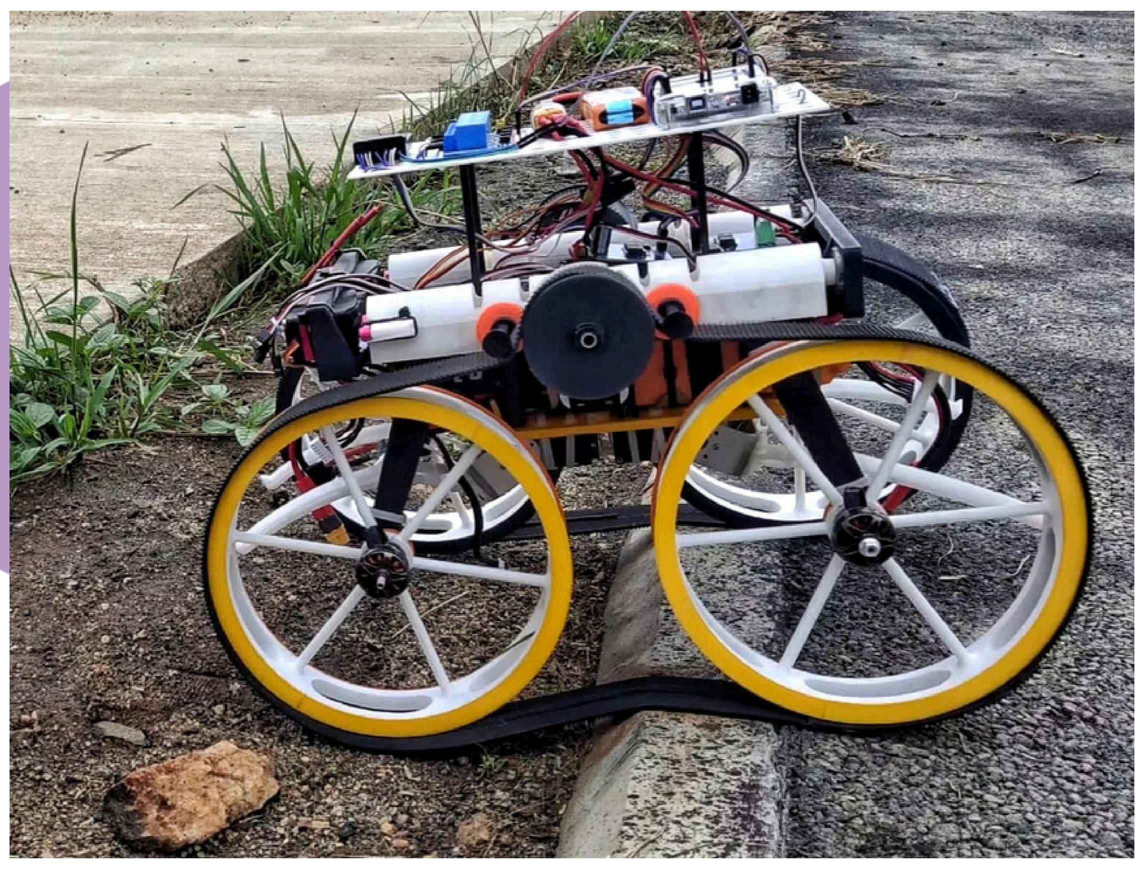


Grass & Soft Ground

Rocks & Gravels

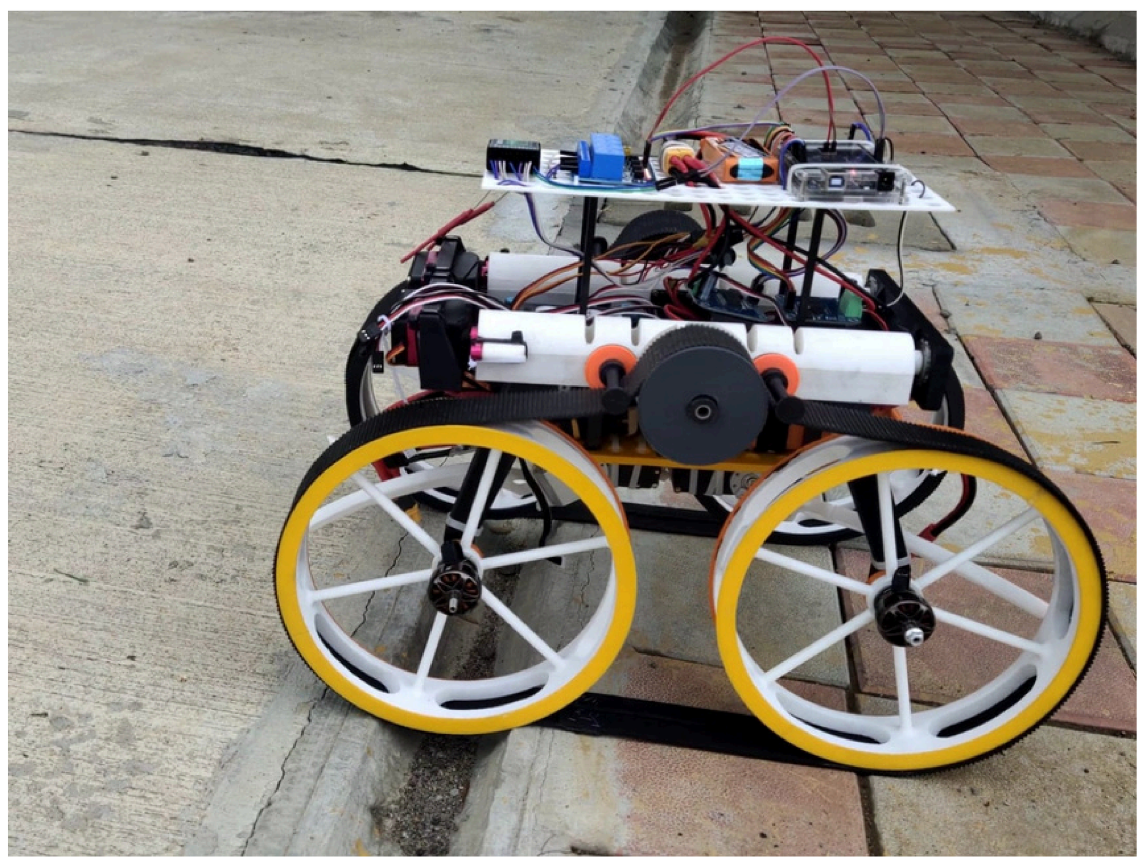


Asphalt

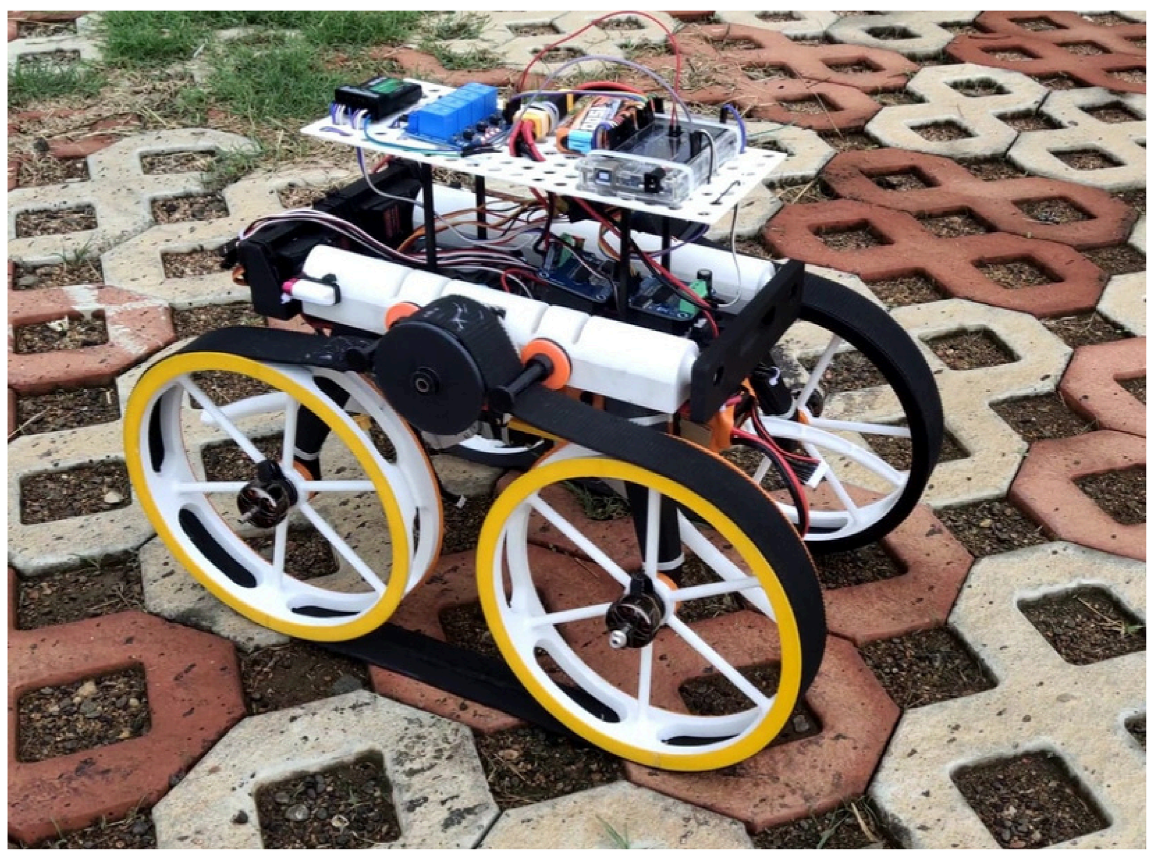


Steps

Rugged



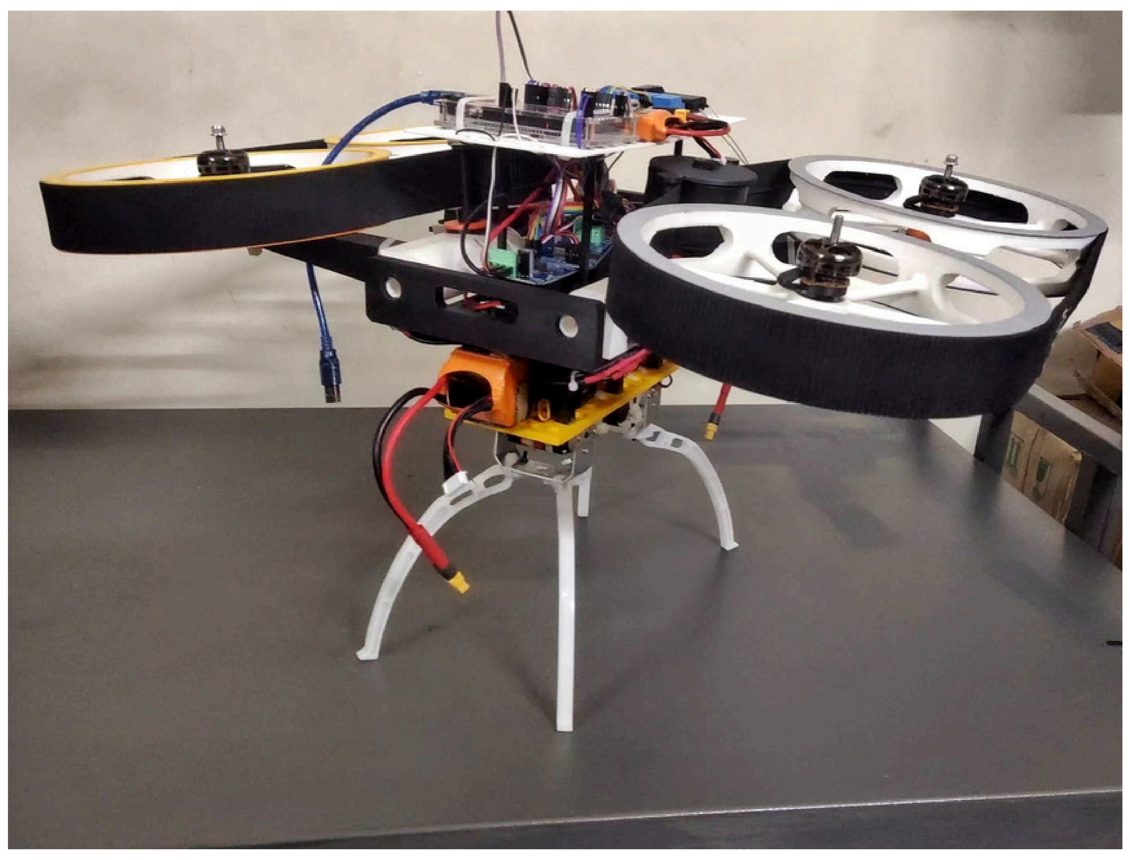
Trench



Holes

Robot Specification - Test Results -

- Total Weight : 6.040 kg
- Rover Max. Speed: 0.20 m/s
- Rover Max. Distance: 390 m
- Rover Battery Life: 30 mins
- Rover Charging Time: 20 mins
- Rover Payload Capacity: 2.5 kg
- Rover Gradeability: 29°
- Drone Max Hover Time*: 6 min
- Drone Max Flight Time*: 4 min
- Drone Charging Time: 70 mins



Landing Gear & Transformation

Hardware Results

- The UGV mode the track belt mechanism allows the bot to move in the expected differential drive format, the motor driver controls the speed and direction of rotation of each motor driving the belt mechanism.
- The UAV mode which is controlled by the pixhawk 2.4.8 flight controller. The sensors on the flight controller were calibrated to suit the bot weight distribution which helped stabilize the motion of the drone.
- For the conversion part, the landing gear mechanism helps to convert the bot while preventing the belt from slipping off the wheel. The landing legs were easily able to hold the upper weight of the bot with the help of a 60 kg-cm servo motor. Although a conclusion was made from the hardware testing that a 150 kg-cm servo would be a better choice in terms of providing sufficient force to convert back to UAV from UGV mode.

Inference & Conclusion

- The robot functioned smoothly on the tested terrains.
- The hinge conversion mechanism and the retractable landing gear mechanism functions they are intended to be.
- The idler shafts are to be designed thicker in order to withstand the force from the track belt.
- The build material of the T-pins has to be changed in order to withstand the temperature from the BLDC motors.
- The track belt gradually loses tension and tends to slip on the driving pulley. Changing this to a timing belt solves this slipping issue.

Department Of Mechanical Engineering | Reach Us: 132001007@smail.iitpkd.ac.in, 132001019@smail.iitpkd.ac.in