Robot for Land and Air Deployment

Final Report submitted
for ID3802: Open Ended Lab Project

by

Kiran M V
(122101019)

&

Vaibhav Nagar
(132101031)

under the guidance of

Dr. Santhakumar Mohan

INDIAN INSTITUTE
OF TECHNOLOGY
PALAKKAD

Contents

1 Abstract

This paper presents a novel design for a robot capable of both land and air deployment by combining a quadrotor with a wheeled mobile robot. This configuration enables smooth transitions between driving on the ground and flying, overcoming obstacles that may be encountered during missions. The primary focus is on the design aspects, particularly the integration of the quadrotor with the wheeled robot and the details of the rear-wheel drive mechanisms. The paper provides a comprehensive overview of the mechanical and electronic integration, the control systems, and the coordination between the two modes of movement. Testing results show that the robot can effectively switch between land and air modes, demonstrating its potential for use in a variety of challenging environments.

The paper includes a series of experiments performed on a physical prototype. These experiments validate the effectiveness of our design and theoretical analyses, providing valuable insights. This research has the potential to serve as a significant reference in the field of flying car development.

2 Introduction

Quadcopters have the ability to navigate challenging and inaccessible terrains, find application in areas such as search operations and military surveillance. However, their limited operational duration and range, stemming from high energy consumption, pose challenges. Recognizing the energy efficiency of terrestrial locomotion, this paper explores the development of a robot capable of both terrestrial and aerial locomotion to enhance adaptability to diverse environments and extend operational capabilities

The design involves appending a quadrotor to a wheeled mobile robot, facilitated by a separate gear mechanism and specially designed wheels. This integration, achieved through a meticulously crafted gear system, allows for a seamless transition between terrestrial and aerial modes of locomotion. Our design addresses challenges posed by complex terrains and obstacles in mission environments, offering a solution that enhances adaptability and extends operational capabilities.

We also explore the rear-wheel drive mechanisms crucial for enabling dual modes of locomotion. To validate our design, we conducted a series of experiments on a physical prototype, focusing on energy analysis and transitions between aerial and terrestrial modes. The outcomes not only confirm the effectiveness of our approach but also provide valuable insights for optimization.

3 Design

This section outlines the innovative design of our land/air robot, emphasizing the integration of a quadrotor into the wheeled mobile robot structure. Key aspects of the rear-wheel drive mechanisms, essential for enabling dual modes of locomotion, are also highlighted.

3.1 Mechanisms Involved

We are using the Ackerman Mechanism for steering of the rover. The Mechanism consists of a worm gear which transmits motion to a spur gear, the spur gear is connected to a shorter spur gear as to increase the angular velocity of the motion of steering as compared to actuation, as this shorter gear is constrained to the shorter link i.e. the connecting link of the four bar double rocker mechanism.

3.2 Synthesis Methods

We have primarily used Autodesk Fusion 360 and Autodesk Autocad for the creating the 2D and 3D drawings. For the synthesis of the parts, we have used the laser cutter with Acrylic as the Material and the 3D printer with PLA as the material.

4 Hardware and Electrical Circuitry

4.1 Electronic Components

The electronic components are essential elements in driving both terrestrial and aerial locomotion. The electronic components of the robot comprises of

Table 1: List of Electronic Components

Electronic Components	Specification	Quantity
Brushless DC Motor	935KV	4
Electronic Speed Controller	30A	4
Lithium Polymer Battery	11.1V, 1800 mAh	1
Power Distribution Board	12V	1
Arduino Uno	-	1
Accelerometer MPU-6050	-	1
Bluetooth module HM10	-	1
DC Motor Driver	12 V	1
Servo SG90	5 V	1
DC Motor	12 V	2

4.2 Control System

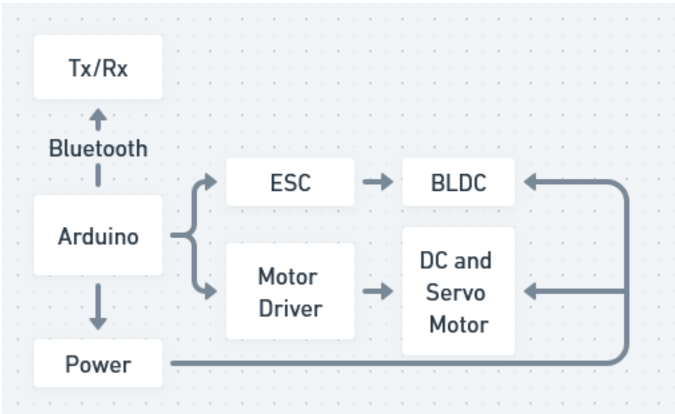

Figure 1: Control system for the robot

The control system of the electronic circuitry includes the wireless communication between an operator and the robot via Bluetooth module. The running part and mode transformation are controlled by a microcontroller (Arduino UNO), while the flying part is governed by the MPU 6050 accelerometer, which acts as an Inertial Measurement Unit (IMU). The MPU 6050 provides raw data on flight attitude and velocity, primarily serving the purposes of flight attitude control and navigation. The power supply is facilitated by a Li-PO battery.

5 Mechanical Parts Involved in the Mechanics of the Rover drone

1. Planetary Gear (116 teeth, Module 2, Pressure Angle 20deg) 2. Spur Gear (15 teeth, Module 2, Pressure Angle 20deg) 3. Spur Gear (30 teeth, Module 2,

Pressure Angle 20deg) 4. Steering Mechanism (worm Gear, spur gears, links) 5. Chassis 6. Base Plate

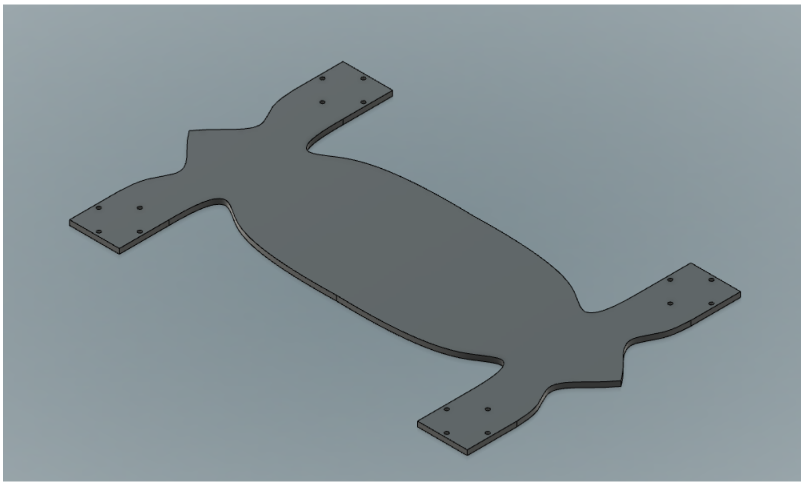

Figure 2: Baseplate

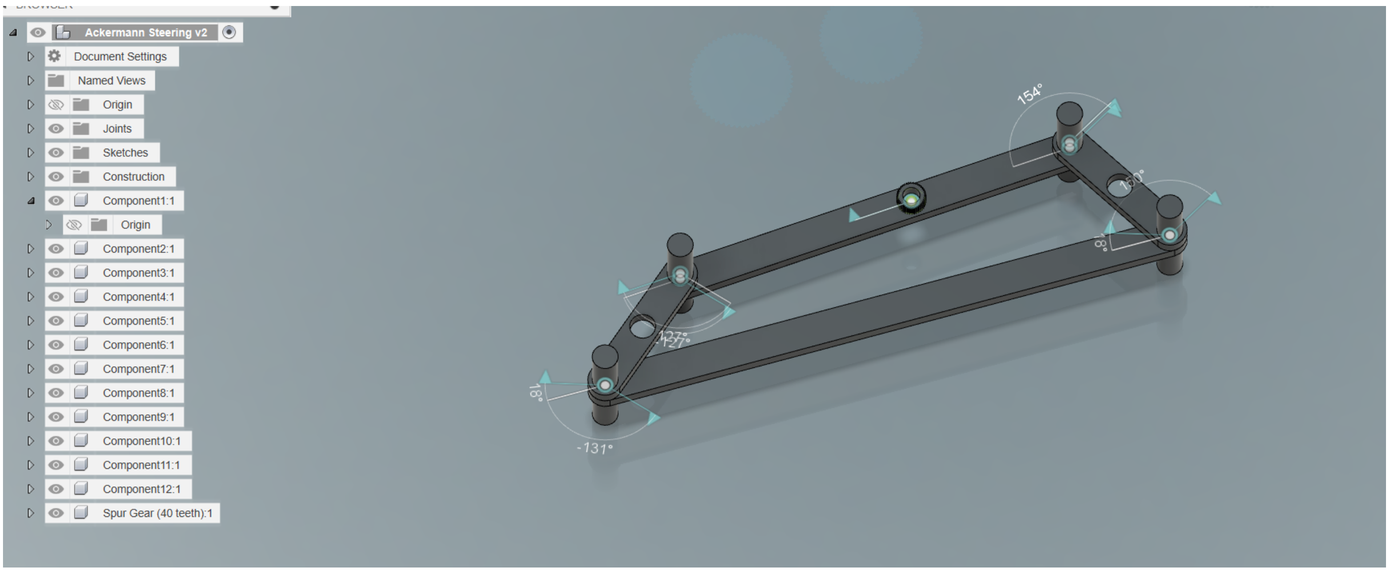

Figure 3: Steering Mechanism

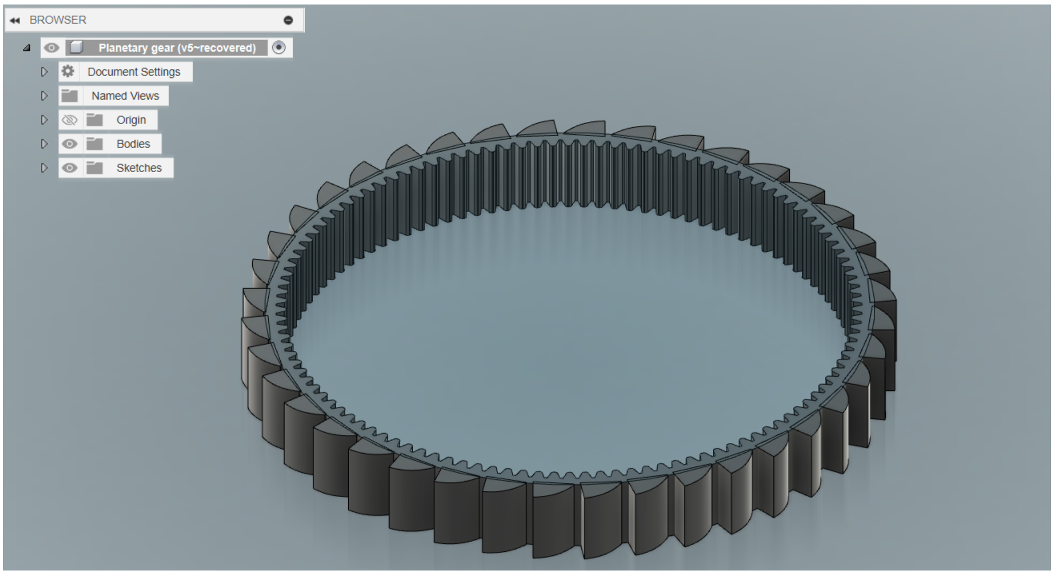

Figure 4: Wheel

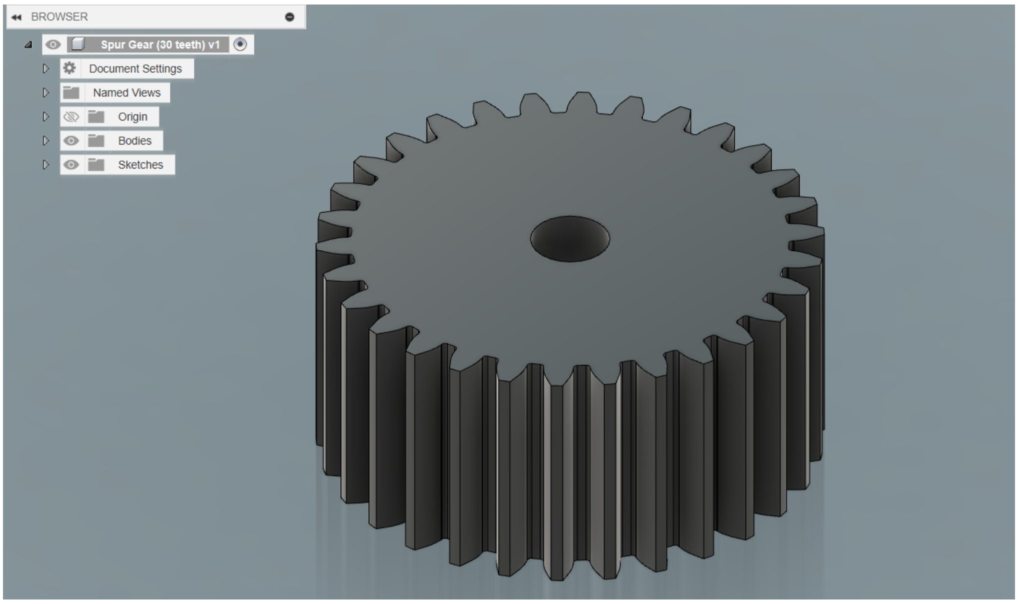

Figure 5: Spur Gear 1

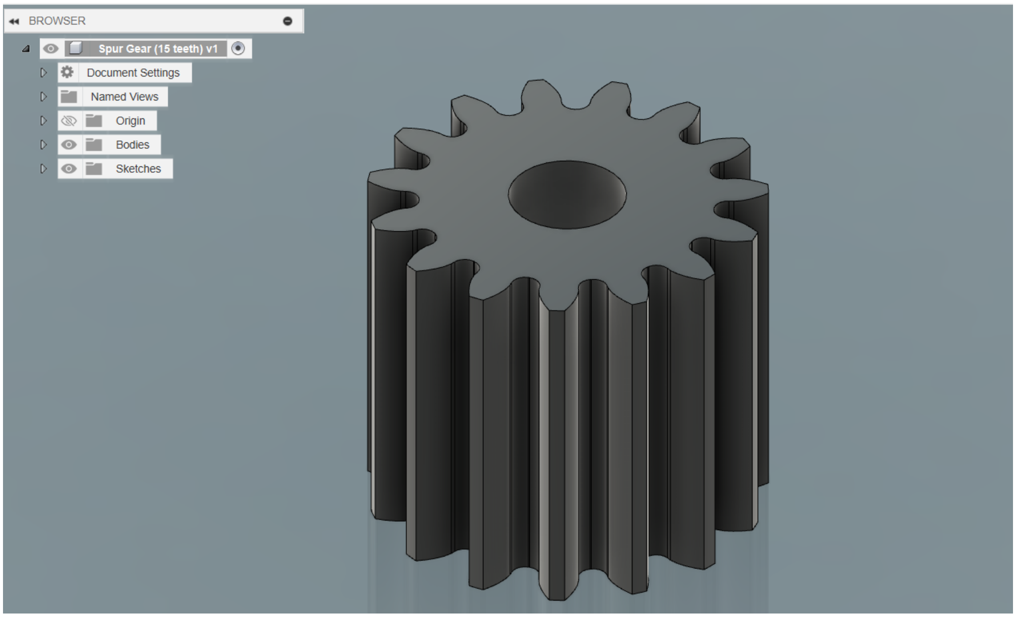

Figure 6: Spur Gear 2

6 Experiment Setup and Discussion

Figure 7: Final Setup

The experimental setup aimed to assess the performance and functionality of the transformable land/air robot prototype.

Figure 8: Top View

Control systems involved the Arduino UNO microcontroller for terrestrial operations. The MPU 6050 accelerometer acting as an IMU for flight control and Bluetooth module HM-10 is used for communication .

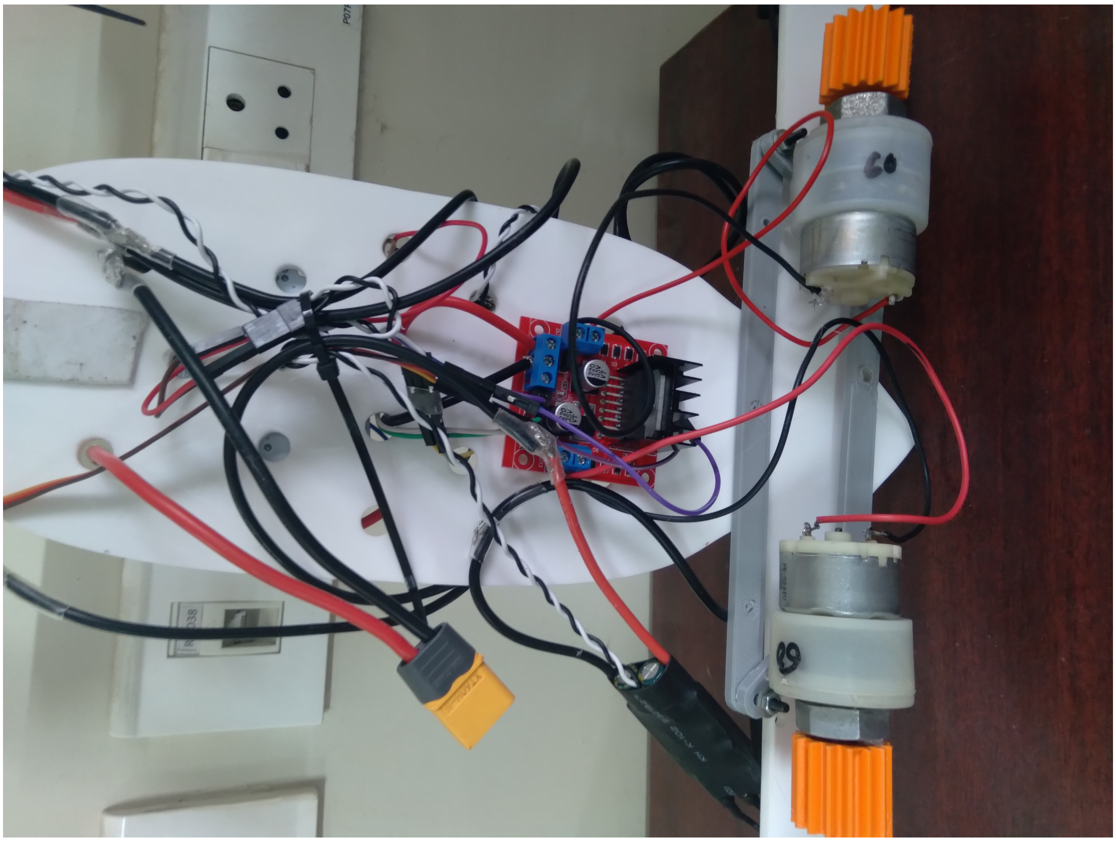

Figure 9: Bottom View

A Li-PO battery adapter is used for plugging in Li-PO battery for powering robot. DC Motor Driver is also visible in the figure

We have used an Android app for joystick.

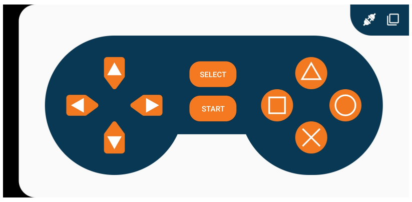

Figure 10: Bottom View

7 Conclusions

In conclusion, the development and experimentation with the transformable land/air robot have yielded valuable insights and identified areas for future enhancement. The successful integration of terrestrial and aerial locomotion marks a significant milestone in robotic versatility. The utilization of DC motors for terrestrial driving and BLDC motors for quadcopter configuration for aerial movement demonstrated effective maneuverability in both domains.

The incorporation of an advanced control system, such as a Proportional-Integral-Derivative (PID) controller, is envisaged to refine and optimize the robot's response and stability, both on the ground and in the air

We are also looking for additional measures that has to be taken to improve the gear mechanism. This involves refining the existing gear assembly to enhance its reliability and overall performance during transitions between terrestrial and aerial locomotion modes.

In summary, the envisioned future work spans a spectrum of improvements, ranging from scaling up the prototype and developing a dedicated Bluetooth app to refining control systems, optimizing stability, and innovating mechanical designs. These endeavors collectively aim to elevate the project's capabilities and contribute to its seamless integration into diverse operational environments.

Drive link of demonstration : https://drive.google.com/drive/folders/1FbftRSHkWimeQ_DyDWUomZoosLteANv2

References

[1] He Wang, Jiadong Shi, Jianzhong Wang, Hongfeng Wang, Yiming Feng, Yu You, "Design and Modeling of a Novel Transformable Land/Air Robot", International Journal of Aerospace Engineering, vol. 2019, Article ID 2064131, 10 pages, 2019. https://doi.org/10.1155/2019/2064131

[2] A. Kalantari and M. Spenko, "Modeling and Performance Assessment of the HyTAQ, a Hybrid Terrestrial/Aerial Quadrotor," in IEEE Transactions on Robotics, vol. 30, no. 5, pp. 1278-1285, Oct. 2014, doi: 10.1109/TRO.2014.2337555. https://doi.org/10.1109/TRO.2014.2337555

[3] 'B' the flying car. https://www.kickstarter.com/projects/2017062404/b-go-beyond

[4] 'B' the flying car. https://github.com/STEMpedia/Dabble/blob/a914cc62ce65202b446042c07078f8ff39cdafce/examples/02.%20Uno%20Nano%20Mega/05.Motor%20Control/MotorControl/MotorControl.ino