GUJARAT COUNCIL ON SCIENCE AND TECHNOLOGY

Technical Report on Rover by Indian Institute of Technology, Gandhinagar

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Name of Affiliated University/Board Name:- Indian Institute of Technology Gandhinagar

Experience Of Mentor/Coach/Faculty In Years:- 6 years

Robot-Making Capability:- The mentor's research lab is fully equipped to build robots from the ground up.

Mentor Expertise: The mentor specialises in Robotics and Mechatronics and has over 15 years of experience.

Mentor Mobile Number:- 9209143733

Type of Institution:- Government

Technical Report Submitted for Robot:-Rover

Pin code: -382356

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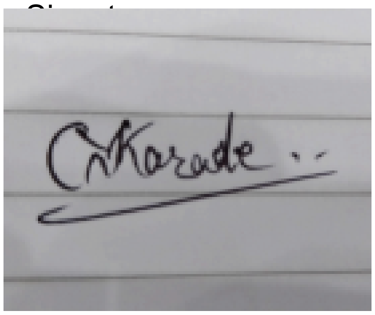

Malhar Karade Arjun Paan Srajan Dehariya

Signature of Head of Institute Signature of Mentor Dr. Madhu Vadali Rajat

Moona

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1) Description and Construction Process of Rover

Our team has designed an autonomous Rover that navigates various terrains and slope regions. It navigates with the help of GPS via coordinates from one position to another while avoiding obstacles with a powerful processor (Jetson Nano 4 GB RAM) without manual control.

Mechanical framework

a) Mechanical Design Description

1. **Frame:** The frame serves as the structural foundation for the rover, providing support for all components while ensuring stability during operation. The frame is constructed from lightweight aluminium extrusion, providing an optimal balance between strength and weight, enhancing the rover's manoeuvrability and overall performance.
   - Material used and Construction :
     i. 20*20 mm Aluminium extrusion
     ii. PLA Material used for 3-D Printing
     iii. M4 Bolts and M4 sliders fitted in extrusions are used for the frame iv.
     This extrusion is connected via a 3D-printed shaft and nuts and bolts.

2. **Rocker bogie:** Consists of two rockers linked to bogies. When one wheel encounters an obstacle, the rocker arm pivots, transferring the weight to the opposite bogie and allowing

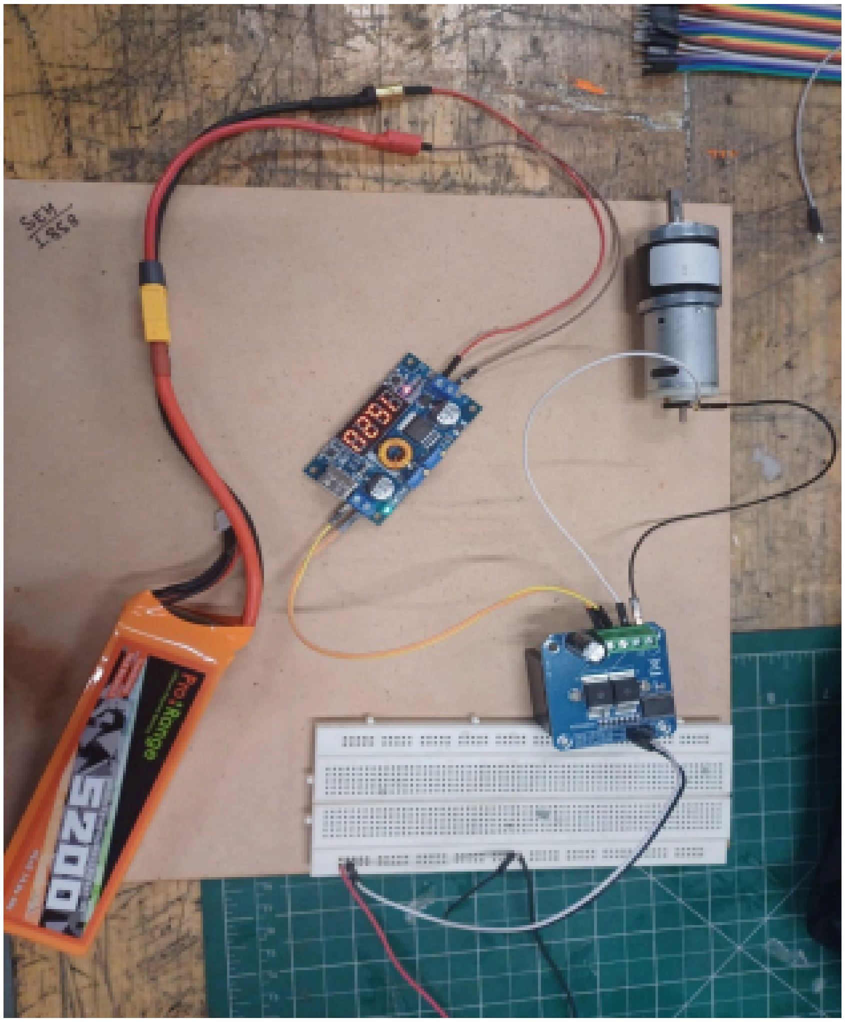
the rover to maintain contact with the ground. This mechanism provides exceptional terrain adaptability, ensuring all wheels remain in contact with the surface for optimal traction.

- ○ Material Used and Construction:
    - i. Combination of 2 bearings with an inner diameter of 15 mm, one bearing attached to the frame and the other to the rocker (assembled with the motors and tiers)
    - ii. PLA for making a shaft that connects both the bearing
    - iii. Another shaft is used to connect the bearing and frame with the help of M4 Bolt and M4 Sliders

Left side tilt of rocker bogie

3. **Wheels and Mobility:** The wheels are designed to provide excellent traction on uneven surfaces and absorb shocks, reducing the impact on the rover's structure.
    - ○ Material Used and Construction:
        - i. We are using six wheels for better stability
        - ii. Wheels are made of 3-D Printed PLA material, have an Outer diameter of 15 cm and are directly connected to the DC motor.
        - iii. The 1st shaft is connected to the rocker extrusion, and it has a box-like structure to hold the servo motor and bearing. The servo is used to change the rover's direction, and the bearing is used as a connector of the servo and the DC Geared motor to reduce the load of the DC Geared motor and wheel on the servo motor. The shaft is created with the help of a 3-D printer
        - iv. 2nd shaft is created to connect the servo motor to the DC Geared motor for smooth rotation

Note: The wheels are in the process of fabrication. They are supposed to be delivered by the vendor by the end of 17th Oct. Work related to wiring & control setup is done & thus, we aim to "teach" the whole "moving" model by the presentation day.



Calibration & testing of motors

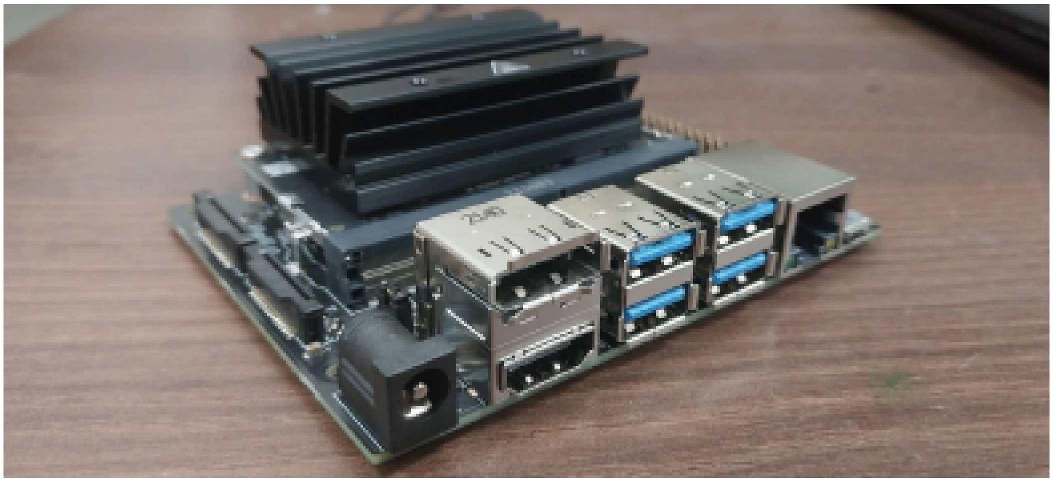
- Breadboard connections are placed in a PCB accordingly
- The wiring part from the battery is done using the XT 60 Battery connectors

4. **Mechanical Body Assembly:** In the assembly, the frame, Rocker bogie, wheels and shafts are connected, and one additional MDF sheet of 3 mm is attached to the frame (which is used to set up all the electronic components)

b) Electronics Design Description

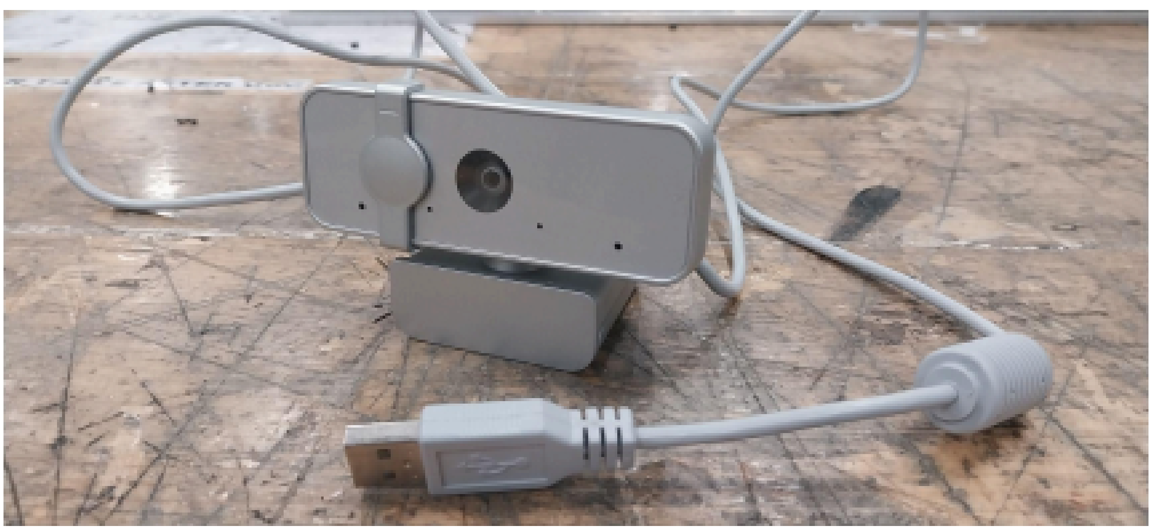
1. **Processor :** The central processing unit of the rover, responsible for executing algorithms for navigation, obstacle detection, Avoidance, and communication.
   - We use the Jetson Nano 1.4-GHz quad-core ARM A57 CPU, 128-core Nvidia Maxwell GPU and 4 GB of RAM.
   - It offers significant computational power for real-time image processing, making

it suitable for complex tasks such as autonomous navigation based on depth detection.



Nvidia™ Jetson Nano™

2. **Webcam**: Webcam used for object avoidance
    - ○ We used a Lenovo 300 FHD Webcam powered by a Full HD 1080P 2.1 Megapixel CMOS camera.
    - ○ It's an easy plug-and-play setup using an USB 2.0 cable directly connected to the jetson.



Webcam

3. **Motor:** Motors are essential for enabling movement, control, efficiency ○ We use a 12 V Planetary Geared Motor, Rated at 200 RPM,
    - ○ They can handle continuous loads up to 15 kg·cm, with a stall torque of 60 kg·cm.

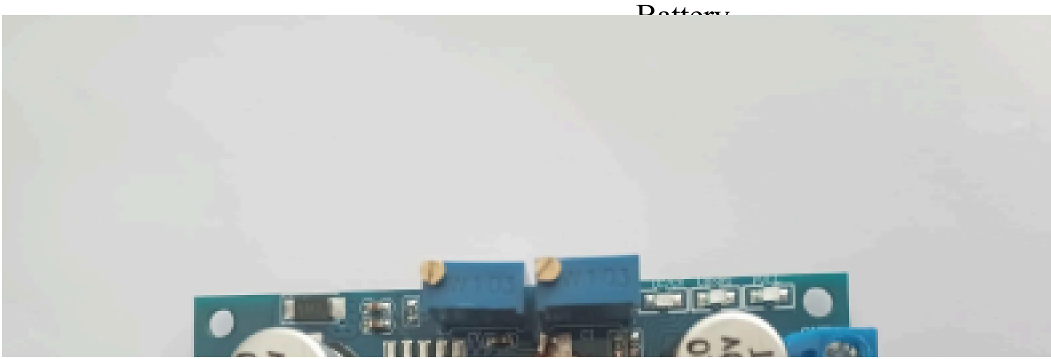
Planetary Motor

4. **Power Supply**: The power supply is as per the motor specification and the operating of the rover
    - The Rover is powered by the 14.8 V, 5200mAh 40c lithium polymer battery with XT60 connectors.
    - The rover's power supply is calculated using six motors requiring 12V and 0.8A-7A each.
    - The Jetson Nano, powered by a 5V supply 3A-4A current, also contributes to the power consumption.

   Calculations :
    - For a 30-minute runtime, we calculated the required amp-hours (Ah) to sustain the system.
    - For six motors and jetson, the approx required Ah is 6, so we are using a 5.2 Ah power supply (we may increase or decrease the operating time by varying the power supply).

Battery

5. **Buck Converter:**



A Buck converter is used to step down the battery voltage (14.8V) to the required 12V for the motors.

- ○ DC-DC XL4015 adjustable step-down Module converts a 5-38V DC input to an adjustable 1.25-36V DC output with 96 %efficiency

Buck Converter

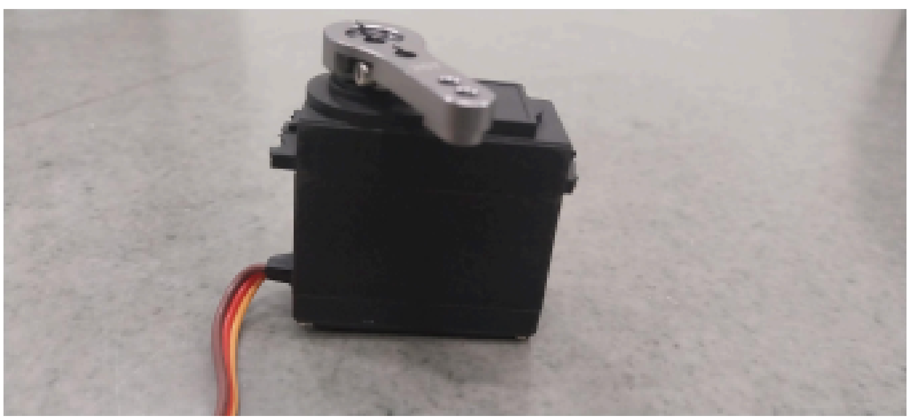
6. **Motor Driver:** The motor driver regulates the current from the battery to the motor, ensuring proper power management and control of the motor operation. ○ BTS7960 High Power Motor Driver can handle up to 43A of current with a supply voltage range of 5.5V to 27V.

○

Considering the fact that we may need heavy torque for steeper slopes, more current may be required, a motor driver of higher current rating was used.

BTS-7960

7. **Servo Motor**: It is used to change the direction of the rover
    - We are using an MG996R High-torque servo motor for rotation of 0 to 135 degree free rotation



MG996R

c) Materials used in Making the Rover

Name of Material Specification
Jetson Nano 4 GB ram
Planetary Gear DC Motor 12 V, 200 RPM GEAR RATIO 1.19.8, 0.8-7 A
Battery 5200 mAh 40 c 4s lipo battery

Buck converter Input voltage 5-36 and output voltage
Motor driver Load current 43 A
Sd card 64 GB micro SD card
Flange Bearing Inner dia=15 mm and outer dia=37 mm Slider square fitted nut M4 sliders for 20*20 extrusion Battery connector XT 60 Battery connectors

Nuts M4 Nuts

Bolts M4 *8mm rounded Bolts

Jumper wire Male-female, Male-Male, Female-Female jumper wires

Aluminium Extrusion 20*20 mm aluminium extrusions
Servo Motor with servo horn MG996R high torque servo motor 135-degree rotation
GPS Module
Camera Lenovo 300 FHD 1080P 2.1 Megapixel CMOS Camera
L-shape outer connection plate Metal L-shaped sheet used for tightening of nuts and sliders
Cables needed for connection Micro USB to USB data cable, HDMI cable, Barrel Jack cable
3-D Printed roll PLA 3-D print roll MDF 3 mm thickness MDF sheet Acrylic 3 mm thickness acrylic sheet

2) Working Model, Complexity, and Innovation of Prototype

a) Software and Algorithms:

[Github Repository Link]

- The repository will be updated as the project progresses.

i) Software

1. The Nvidia™ Jetson Nano™ is used to run the Dense Prediction Transformer (DPT). 2. Nvidia™ Jetson Nano™ uses Ubuntu 18.04 as its operating system. Nvidia also provides multiple essential Python libraries that allow users to access the GPUs available in Jetson Nano.
3. DPT is a pre-trained model for image segmentation and relative depth prediction from single images. This allows us to detect the obstacles without the need to identify them, giving us an advantage over regular YOLO or object detection algorithms as they often cannot identify the objects in the way they are not trained for.

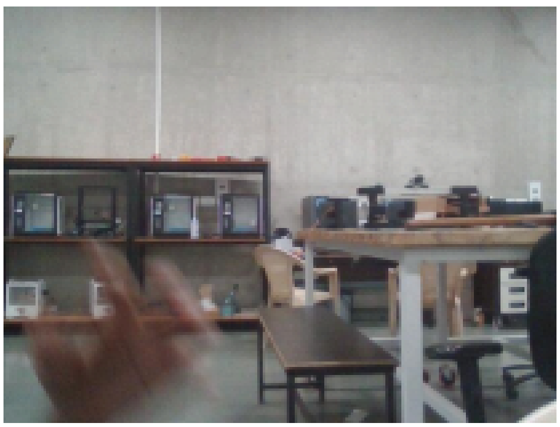
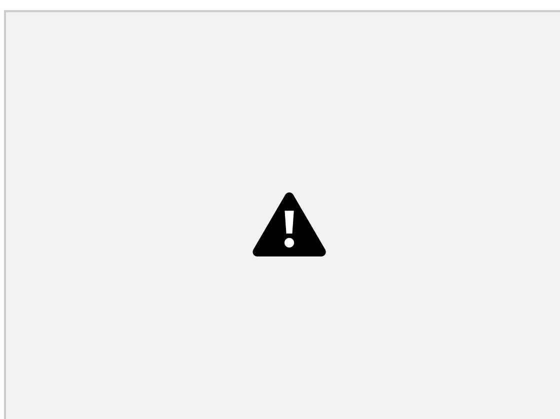


Image taken in Lab for testing DPT Monocolor depth image



Segmented image

4. DPT allows us to find objects' relative depth (distance from the camera) and then segment the image into different parts corresponding to different objects. This allows us to see the depth and inherent classification of each pixel in the image. This can calculate the average or minimum distance between the obstacle in the path and the host system

(Rover).

5. With the ability to measure the distance of different obstacles, the host system can decide the path to minimise the chances of close contact with any of the detected obstacles in the path.

ii) Navigation

1. The NEO-6M GPS module is crucial for precise navigation by providing real-time positioning data, allowing the rover to travel through challenging environments effectively. In conjunction with an object detection system, the rover can follow a predefined path and navigate around obstacles.

2. The GPS module continuously sends its location data to the Jetson Nano, while the object detection system identifies obstacles in the rover's path using computer vision algorithms. 3. The GPS module provides geographic coordinates (latitude and longitude) that the system translates into a local coordinate system (x and y axes) for navigation. This mapping is essential for directing the rover's movement based on its real-time position and detected obstacles.

4. The object detection system processes incoming frames from the camera, identifying and locating obstacles relative to the rover's position. This information is transformed into coordinates in the same local frame of reference used by the GPS data.

iii) Object Avoidance Navigation

1. As the rover moves, the object detection system continually scans for obstacles. Once an obstacle is detected, its coordinates are recorded, and the rover calculates the best response based on its current trajectory.
2. The rover determines its current GPS coordinates and translates them to the local coordinate system.
3. The object detection system provides the coordinates of the detected obstacle relative to the rover's local position.
4. The rover's control system employs algorithms to generate a new path around the obstacle. This involves determining new waypoints that circumvent the detected obstacle and maintaining a safe distance.
5. If necessary, the new waypoints are converted back to GPS coordinates, allowing for re-routing based on real-world locations.
6. After calculating the new path, the rover adjusts its motor's speed and direction to follow the newly defined trajectory, moving around the obstacle while continuously updating its position with the GPS module.

iv) Complexity

1. The system must continuously process GPS data, camera frames, and obstacle

coordinates, requiring efficient algorithms and optimised coding on the Jetson Nano to ensure no delays occur during movement.

2. The rover must quickly adapt its trajectory in response to new obstacles, which requires a fast computation of new paths and real-time updates to motor commands. 3. Merging GPS data with visual data from the object detection system demands sophisticated algorithms to account for potential discrepancies in positioning and timing, as the GPS can provide coordinates at different intervals than the camera captures frames. 4. The coordination between the GPS module, object detection system, and motor controllers must be seamless, ensuring that updates to position and trajectory are executed in sync.

v) Features

1. The rover can detect obstacles and adjust its route in real-time, enhancing safety and effectiveness in navigation.
2. The NEO-6M provides frequent updates on the rover's location, allowing for dynamic navigation adjustments based on its current position and detected obstacles. 3. Integrating GPS and object detection systems allows for comprehensive environmental understanding, providing a rich context for navigation decisions.
4. The ability to quickly recalibrate paths around obstacles ensures that the rover remains on course even in dynamic environments.
5. Using sophisticated algorithms that combine GPS navigation and object detection allows for adaptive pathfinding that enhances the rover's efficiency and safety.
6. The continuous feedback from the GPS and object detection systems creates a responsive navigation system capable of adapting to new obstacles and terrain features, making the rover more versatile in unpredictable environments.

b) Electronics

i) Components

Power Distribution

1. The power distribution system is essential for efficiently and safely managing and distributing electrical energy to all rover components.
2. Specification of battery 14.8V 5200mAh 40C LiPo Battery This battery can deliver up to 200A burst current, which is crucial for providing enough power for all components, particularly during high-demand scenarios like sudden acceleration or navigating obstacles
3. The battery should be centrally mounted to maintain the rover's balance and stability during operation.
4. The PDB distributes power from the battery to all components, minimising wiring complexity and potential points of failure.

5. Connect the buck converters to the PDB to create a clean and organised wiring layout, facilitating easier troubleshooting and maintenance.

Buck converter

1. Buck converters are used to step down the 14.8V output from the battery to various voltages required by different components.
2. For Jetson Nano: The converter steps down to 5V (minimum 2A), which is necessary for the Jetson Nano's operation.
3. For Motor Drivers: Typically set to provide 12V, sufficient for powering most DC motors in the setup.
4. One buck converter should be used for each unique voltage requirement to ensure efficient power delivery. Each converter must be rated to handle the maximum current draw of the components it supplies.
5. Adequate heat sinks or fans should be employed to dissipate any heat generated during operation, ensuring the longevity and reliability of the converters.

Jetson Nano

1. This powerful single-board computer serves as the central processing unit for tasks such as object detection, GPS navigation, and control logic for the motors.
2. It requires a stable 5V input provided by the buck converter.
3. The electronics setup is connected to GPIO pins
4. For connecting external devices such as cameras, a USB pin is used
5. For connection of the Output of jetson, HDMI cable is used initially, then a data cable USB to USB is used
6. For the connection of GPS, we use the UART port of Jetson nano

Webcam

1. Cameras are essential for capturing real-time video feeds, enabling object detection algorithms to identify obstacles and navigate effectively.
2. Lenovo 300FHD and Logitech C920 Webcams connect via USB to the Jetson Nano, allowing easy integration and data transfer.
3. It is used for real-time object detection and a mid-range

Motor Driver

1. Motor drivers control the speed and direction of each motor based on PWM (Pulse Width Modulation) signals generated by the Jetson Nano.
2. Power terminals should connect to the buck converter set to 12V.
3. DC Motor is connected to the Motor driver output. So that the motor gets the 12 v output and desired current of 5A

4. The motor driver has the PWM pins, which are used to control the speed of the motor, and the motor driver's R_PWM AND L_PWM pins are connected to the jetson to control the speed.
5. The motor driver has the R_EN and L_EN, which are used to determine the direction of the motors, enabling smooth navigation. And they are connected to the jetson.

DC Motor

1. The rover utilises Orange Planetary Gear DC Motors (12V, 96RPM, 121.7 N-cm) to provide the necessary propulsion.
2. Each motor connects to a motor driver, which receives control signals from the Jetson Nano to adjust the motor speed.
3. Has a sufficient 15kg-cm of torque to climb on the slope region
4. We are using six motors,6 Buck converters and six motor drivers to connect them in parallel to the power supply and jetson, so we are using the breadboard for connection and ground.

GPS

1. Typically operates on 3.3V to 5V; ensuring compatibility with the chosen buck converters is vital.
2. The GPS module is connected to the Jetson Nano via UART (TX/RX) to facilitate data exchange and receive accurate positioning information.

Wiring and signal flow

1. Power Flow
    - Battery → Buck Converters → Power Distribution Board → Components:
2. Signal Flow
    - Jetson Nano → Motor Drivers: The Jetson Nano sends control signals (PWM) to the motor drivers for speed and direction adjustments.
    - Jetson Nano <→ GPS Module: A bi-directional data exchange occurs for accurate navigation and location tracking.
    - Jetson Nano <→ Cameras: Real-time video feeds are sent to the Jetson Nano for object detection processing and response.

ii) Challenges faced

1. Each buck converter is appropriately rated to handle the maximum current draw of the connected components without overheating, ensuring safety and reliability 2. As multiple motors, drivers, and buck converters operate, they can generate significant heat. Utilising heat sinks or fans is necessary to maintain optimal operating temperatures. 3. Proper power and signal wiring routing is critical to minimise interference, especially in motor control and sensor signals. Shielded cables or twisted pairs may be beneficial in noisy environments.

4. Implementing cable management solutions, such as cable ties and wire looms, will help maintain an organised layout, preventing tangling and potential damage to wires during operation.

iii) Innovation:

1. Leveraging the Jetson Nano's GPU capabilities for real-time object detection and navigation allows for advanced autonomous features, enabling the rover to make quick decisions based on its environment.
2. Including a power distribution board simplifies the integration process and troubleshooting, making future upgrades or modifications easier.
3. Utilising buck converters for efficient voltage regulation and power management enhances reliability and performance by providing stable power to each component.

Complexity:

1. The system must ensure that each motor receives the correct voltage and current, with proper power regulation to prevent component damage.
2. The setup's various components can generate heat, necessitating careful consideration of thermal management strategies.

c) Mechanical Frame and Rocker-Bogie

i) Components

1. The rocker-bogie mechanism enables the rover to traverse rugged terrain while maintaining stability. The two rocker arms pivot, allowing each rover's side to adapt to uneven surfaces. When one wheel encounters an obstacle, the rocker pivots to raise the opposite wheel, distributing the load and maintaining traction on all wheels.
2. We have made a Rocker bogie in such a way that if one wheel is climbing from the rock, then the other wheel with the same connection has to be in contact with the ground, and we have executed the design with the help of a bearing joint (stress point)
3. Double-bearing joints in the rocker-bogie enhance the motion's durability and smoothness, ensuring less wear and tear over time. It allows for seamless operation without the need for active suspension control.

4. The connection between bearings is made with the help of the 3-D Printed Material. 5. The load of the motor, which is attached to the rocker-bogie, is controlled by the two different 3-D Printed Shafts in which a casing is created to connect the arm of the rocker-bogie with the motor. One shaft connects the arm, and the other is fixed with the DC motor and connected with the servo motor to change the rover's direction. 6. We have attached the bearing between the servo and the DC motor to reduce the load on the servo motor.

7. The frame provides a rigid foundation for the rover. It houses the rockers, bogies, motors, electronics, and other components. The frame is created with the extrusion, and the M4

sliders and M4 bolts connect some The remaining extrusion is connected by a 3-face, 3-D printed shaft.

ii) Complexity

1. The complexity comes from the need to balance the movement of the rocker-bogie arms without actuators. The pivot points must be precisely aligned, and the bearing system must handle the weight distribution while ensuring unrestricted movement. Additionally, the suspension must work without causing too much oscillation.
2. Bearings add complexity because they must be installed at precise angles and tolerances to ensure minimal friction and efficient movement. Any misalignment could lead to performance issues.
3. The frame's modular design allows for easier assembly but requires precise cuts and fittings. Fasteners like M4 sliders and bolts must be correctly installed to secure each frame section.

iii) Feature

1. The rocker-bogie system provides superior performance on uneven ground. All wheels remain in contact with the surface, ensuring excellent traction and stability, which is critical for autonomous navigation in rough environments.

2. The bearings used at each joint allow smooth rotation of the rocker's arms, ensuring the system adapts to obstacles without jerky movements or significant mechanical resistance. 3. The aluminium extrusion frame offers flexibility in design. It allows easy adjustments and modifications, enabling the team to add or remove components without compromising the rover's integrity.

iv) Innovation

1. The rocker-bogie is commonly used in the Rover but only for the backside wheels. In our Prototype, we have integrated a Rocker bogie Mechanism in the front wheel 2. Hybrid design approach—using both lightweight aluminium and custom 3D-printed components—provides a high degree of flexibility in assembly and future upgrades. 3. Double-bearing joints in the rocker-bogie enhance the motion's durability and smoothness, ensuring less wear and tear over time. It allows for seamless operation without the need for active suspension control.

v) Features of Rover

1. Integrates advanced GPS technology for precise location tracking and navigation, enabling the rover to operate independently in various environments.
2. Utilises high-definition webcam and image processing algorithms to identify and avoid obstacles dynamically, enhancing operational safety and efficiency.

3. The rover’s construction allows easy upgrades and modifications, facilitating customisation based on specific research or operational requirements. 4. Features a lithium polymer battery and an adjustable buck converter, optimising power usage and extending operational time while maintaining high performance. 5. Equipped with a rocker-bogie suspension system, the rover can traverse uneven terrains effectively, ensuring stability and traction on slopes and rugged surfaces. 6. Implements reliable communication protocols for seamless data transmission between components, ensuring effective coordination of control signals.

7. Utilises powerful planetary gear motors that provide a high torque-to-weight ratio, enabling the rover to carry substantial loads while maintaining speed and agility. 8. Capable of logging data during operation, allowing for post-mission analysis and performance assessment, crucial for research and development purposes. 9. Incorporates sophisticated navigation and obstacle avoidance algorithms, improving the rover's real-time decision-making capabilities