International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Review Article)

# Enhancing the rocker-bogie Mechanism with automation: A study on sensor integration and Mechanical arm functionality

Deev Somil Mehta *

*Sardar Vallabhai Patel Junior College Mumbai India.*

International Journal of Science and Research Archive, 2024, 13(02), 3536-3543

Publication history: Received on 13 November 2024; revised on 21 December 2024; accepted on 23 December 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.2.2524

## Abstract

The rocker-bogie mechanism is a well-known design in robotic mobility, particularly effective for rovers traversing rugged terrains. This research improves upon the traditional rocker-bogie system by integrating ultrasonic sensors, a GPS module, and a mechanical arm to enhance autonomy and versatility. The system is controlled by an Arduino Uno and powered by six 12V DC motors using an L298 2A motor circuit board, ensuring precise and reliable movement in challenging environments. Ultrasonic sensors provide effective obstacle detection by triggering a turn when objects are within 50 cm. This is a simpler alternative to complex AI-based path planning. Additionally, the integration of GPS enhances navigation capabilities. The mechanical arm allows for interaction with the environment, enabling tasks such as object manipulation and repairs. The project aims to enhance autonomous navigation and improve sensor-based obstacle avoidance, motivated by Experimental methods including testing the rover's obstacle detection capabilities using ultrasonic sensors in controlled environments with varying obstacle distances. The rover's navigation was evaluated across different terrains, including flat surfaces and uneven terrains to assess their mobility and stability. Optionally, GPS accuracy was tested by guiding the rover to predefined waypoints, while power efficiency was monitored during continuous operation to measure battery life and overall system performance. Results showed that. This work improves robotic autonomy in harsh conditions and uses mechanical parts to reduce the margin of error in fields such as agriculture, disaster response robots, Autonomous Mining Vehicles, Pipeline and Infrastructure Inspection, Volcanoes, Deep Caves, and Extreme Terrains.

**Keywords:** Rocker Bogie; GPS; L298 2a; Arduino Uno; Ultrasonic Sensor

## 1. Introduction

The rocker-bogie mechanism has long served as a fundamental design in robotic mobility, particularly in space exploration, where rovers must traverse complex and unpredictable terrains. Originally pioneered by NASA, this design has proven highly effective in maintaining stability and control on uneven surfaces. Its inherent simplicity and robustness—achieved through strategic weight distribution across its wheels have enabled rovers like Curiosity and Perseverance to successfully explore distant planets, enduring harsh environmental conditions with remarkable efficiency. In recent years, rapid sensor technology, automation, and robotics advancements have unlocked new possibilities for enhancing the traditional rocker-bogie system. This paper introduces innovative modifications, including integrating ultrasonic sensors, GPS, a mechanical arm, and automation features, to improve the rover's functionality and autonomy. Ultrasonic sensors provide real-time terrain mapping and obstacle detection, enabling the rover to make informed navigational decisions. The addition of GPS allows for precise localization and global path planning, which is crucial for long-distance missions and coordination in unfamiliar environments. The mechanical arm adds a layer of versatility, allowing the rover to interact with its environment by performing tasks such as sample collection, object manipulation, and repairs.

---

[*] Corresponding author: Deev Somil Mehta.

Meanwhile, incorporating automation minimizes the need for human intervention, empowering the rover to autonomously adapt to changing conditions and execute tasks with greater independence. This study delves into the engineering challenges and potential benefits of these enhancements, examining how they can elevate the efficiency, safety, and versatility of rovers equipped with the rocker-bogie mechanism. By integrating advanced technologies such as GPS and sensor systems, the rover's ability to navigate and operate in unstructured and unpredictable environments is significantly enhanced, unlocking potential applications in fields beyond space exploration, such as autonomous search-and-rescue missions, mining operations, and industrial robotics. Ultimately, this paper aims to analyze how combining the comprehensively rocker-bogie mechanism, advanced sensor systems, GPS, and automation is poised to expand the horizons of autonomous robotic exploration and opera-national capabilities. By integrating advanced technologies such as GPS and sensor systems, the rover's ability to navigate and operate in unstructured and unpredictable environments is significantly enhanced, unlocking potential applications in fields beyond space exploration. The inclusion of GPS improves the rover's national accuracy and global path planning, making the overall system more robust for diverse applications, such as autonomous search-and-rescue missions, mining operations, and industrial robotics.

## 2. Literature Review

### 2.1. The Rocker-Bogie Mechanism

The rocker-bogie mechanism, developed by NASA for planetary exploration rovers is a well-established design for Navigating rough, uneven terrains. Introduced with the Mars Sojourner mission in the late 1990s, the system became a cornerstone of rover mobility due to its ability to maintain stability while traversing obstacles larger than the diameter of the wheels. Subsequent missions, such as Spirit, Opportunity, Curiosity, and Perseverance, have demonstrated this mechanism's robustness and versatility. [3] highlighted the rocker-bogie system's efficiency in distributing the rover's weight, minimizing wheel slip, and ensuring that all six wheels maintain ground contact, which allows for effective climbing of steep slopes. However, despite its widespread use in space exploration, limitations have been observed in the mechanism's ability to adapt to unpredictable terrain. Recent research has focused on optimizing the rocker-bogie system by improving control algorithms and introducing complementary systems, such as active suspension, to enhance mobility. This provides a foundation for integrating modern technologies like ultrasonic sensors, GPS, and automation, enhancing terrain adaptability and autonomy.

### 2.2. Ultrasonic Sensors

for Terrain Mapping and Obstacle Detection Ultrasonic sensors are widely used in robotic systems for real-time environment sensing because they provide accurate distance measurements at a low cost. These sensors emit high-frequency sound waves and measure the time it takes for the waves to bounce back after hitting an obstacle. The integration of ultrasonic sensors into mobile robots has been extensively studied, particularly in autonomous vehicles and robots designed for exploration in unstructured environments.

[8] demonstrated the effectiveness of ultrasonic sensors for real-time obstacle detection and avoidance, particularly in applications where visual sensors may be limited due to low-light or dusty conditions, which are common in space exploration. Similarly ,[4] illustrated the benefits of using an array of ultrasonic sensors to create detailed terrain maps for navigating uneven and hazardous terrain. These studies provide a strong basis for integrating ultrasonic sensors into the rocker-bogie mechanism to enhance real-time decision-making and terrain adaptability.

### 2.3. GPS Integration

in Autonomous Systems Global Positioning System (GPS) technology has become integral in robotic systems that require precise localization and global path planning. GPS allows for real-time tracking and positioning, essential for long-distance missions such as planetary exploration, search-and-rescue operations, and industrial applications. Research on integrating GPS in autonomous robots has shown significant improvements in navigational accuracy, especially when combined with sensor fusion techniques. Previous studies by [6] on the Mars rovers emphasized the importance of GPS-like systems for planetary rovers, although true GPS cannot be used off-Earth. However, for terrestrial applications, GPS integral time has proven to enhance the capability of autonomous systems to localize themselves globally, especially in large, unfamiliar, or remote environments. This makes GPS a critical addition to the rocker-bogie mechanism, improving its autonomous navigation capabilities, particularly when combined with other sensors for obstacle detection.

### 2.4. Mechanical Arms

in Robotic Systems Adding a mechanical arm to a rover or mobile robotic system can significantly extend its range of tasks, allowing it to interact with its environment. Robotic arms have been used for functions ranging from simple object manipulation to complex operations such as sample collection and repairs. Early studies on robotic arms in planetary exploration, such as those deployed on the Viking landers and Curiosity rover, highlighted the importance of mobility combined with agility. More recent research has explored the integration of mechanical arms with mobile robotic platforms in various fields, including industrial automation and search-and-rescue. In these systems, the mechanical arm adds versatility by enabling the robot to pick and place objects, handle tools, and conduct repairs in remote or hazardous locations. Integrating a mechanical arm with the rocker-bogie mechanism introduces new functionality, making the system more adaptable to tasks that involve mobility and interaction with the environment.

### 2.5. Automation in Rover Systems

Automation has long been a robotics research focus, especially in autonomous systems designed for planetary exploration. Autonomous control reduces the need for human intervention, enabling robotic systems to respond to environmental changes in real time. Early automation systems in rovers relied heavily on pre-programmed commands sent from Earth. However, artificial intelligence (AI) and machine learning advances have enabled robots to make autonomous decisions based on real-time sensor data.

[5] introduced autonomous path-planning algorithms that allow rovers to select the optimal route based on real-time terrain analysis. Similarly,[7] explored the use of automation. To enable the performance of complex tasks, such as object detection, manipulation, and environmental interaction, without direct control from operators. These developments underscore the potential of automation in enhancing the autonomy of rocker-bogie systems. Integrating ultrasonic sensors, GPS, and a mechanical arm, combined with automation, can further increase the rover's operational efficiency and decision-making capabilities in complex environments.

### 2.6. Summary

The literature on the rocker-bogie mechanism, sensor technologies, GPS integration, and automation provides a comprehensive foundation for further research. While the rocker-bogie mechanism has proven reliable in various applications, the integration of modern technologies like ultrasonic sensors, GPS, mechanical arms, and automation opens new possibilities for enhancing rover performance in unstructured environments. This review highlights the potential for innovation and addresses gaps related to autonomous decision-making, obtainable detection, and environmental interaction. The proposed research builds on these advancements and aims to push the boundaries of what is achievable in autonomous robotic exploration. This review synthesizes existing research.

## 3. Methodology

### 3.1. System Design

The design phase involves creating and optimizing the enhanced rocker-bogie system, incorporating the new components.

#### *3.1.1. Mechanical Design*

The rocker-bogie mechanism was designed in real-time to accommodate the integration of ultrasonic sensors, GPS, and a mechanical arm. This approach involved creating physical prototypes and sketches to visualize the system. The design considerations included the placement of sensors and the mechanical arm to ensure proper weight distribution and avoid interference with the rover's mobility system.

#### *3.1.2. Electrical Design*

The electrical design involved integrating 6 12V DC motors with an Arduino Nano, an L298 2A motor circuit board, and the ultrasonic sensors. This setup is aimed at controlling the rover's movement and processing sensor data. The Arduino Nano, combined with a motor shield and the L298 motor driver, will handle the control of the DC motors, enabling precise movement and direction.

## 3.2. Hardware Integration

### *3.2.1. DC Motors*

Six 12V DC motors will be used to power the wheels of the rocker-bogie mechanism, providing the necessary propulsion and maneuverability. The motors will be connected to the L298 2A motor circuit board, which will control their speed and direction.

### *3.2.2. Ultrasonic Sensors*

Two ultrasonic sensors will be mounted on the rover to provide obstacle detection capability. These sensors will be positioned to cover critical areas around the rover. The sensors will be programmed to detect objects within a distance of 50 cm. If an object is detected, the rover will execute a turning maneuver to avoid collision.

### *3.2.3. GPS Module*

A GPS module will be integrated into the system to provide real-time local-action data for global path planning. The GPS will be interfaced with the Arduino Nano enabling the rover to localize itself within a predefined environment or Map.

### *3.2.4. Mechanical Arm*

A 3-DOF (degree of freedom) or 6-DOF robotic arm would be attached to the rover. The arm will be equipped with sensors (e.g., position encoders, force sensors) for precise control during operations such as picking up objects or performing tasks like repairs. The mechanical arm will be designed to be lightweight to avoid overburdening the mobility system. This component is currently a conceptual feature and has not been implemented in the current prototype.

### *3.2.5. Power System*

A suitable power supply, such as a battery pack, will be chosen based on the energy requirements of the DC motors, ultrasonic sensors, GPS, mechanical arm, and control systems. The system will include energy-efficient components and power-saving algorithms to maximize operational time.

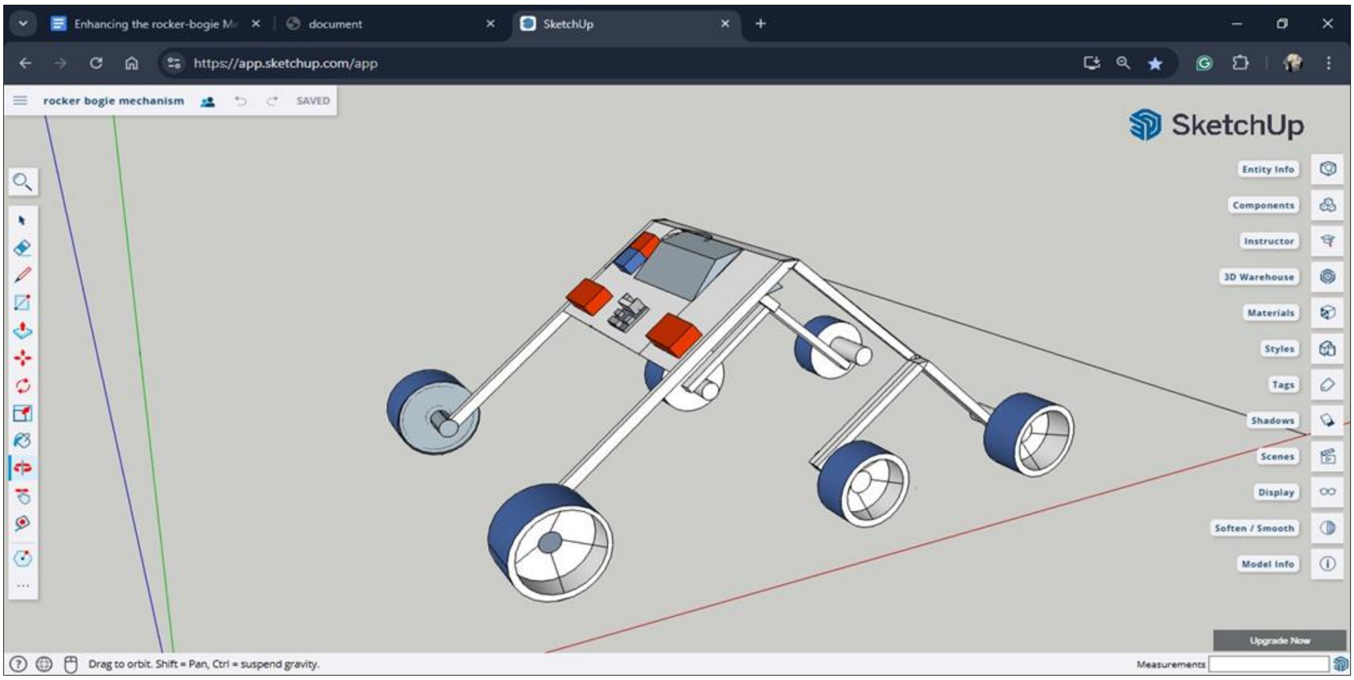

**Figure 1** Diagonal view of rocker bogie mechanism

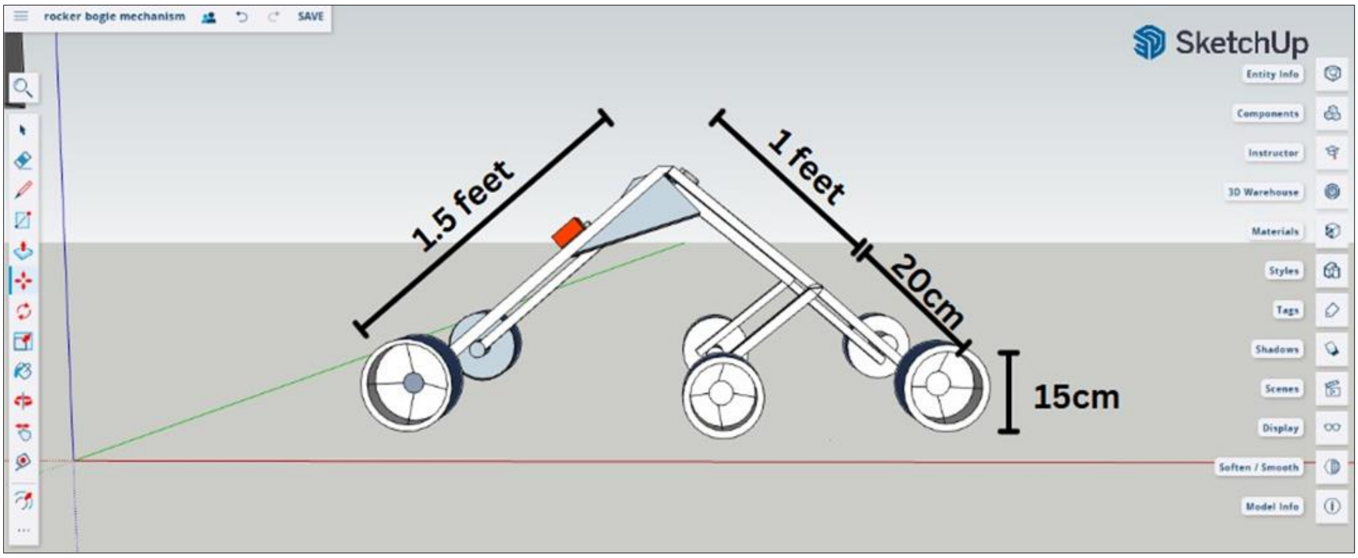

**Figure 2** Side view of measurements of rocker bogie mechanism

### 3.3. Software Development

*3.3.1. Obstacle Detection and Navigation*

The software will be developed to process data from the ultrasonic sensors. When an object is detected within the 50 cm threshold, the rover's control system will be programmed to execute a predefined turning maneuver to avoid the obstacle. The software will include basic navigation logic to ensure the rover can continue its path after avoiding obstacles, using simple rules-based decision-making.

*3.3.2. GPS Data Integration*

The GPS module will provide real-time location data to support basic path planning and navigation. The software will utilize this data to help the rover understand its position within a predefined map or environment.

*3.3.3. Mechanical Arm Control*

Although a conceptual feature, the Control algorithms will be implemented to operate the mechanical arm. An inverse kinematics algorithm would be used to control the arm's movements precisely, allowing it to perform tasks such as picking up objects or conducting repairs.

*3.3.4. Real-time Communication*

A communication framework will be developed to allow the Arduino Uno to receive and process inputs from mural timers simultaneously, sending commands to the actuators in real time. A feedback control system will be implemented to enable continuous monitoring of the rover's status and environment.

### 3.4. Components Used

The hardware components used in this project were carefully selected to optimize the performance of the enhanced rocker-bogie mechanism. Below is a breakdown of the major components and their roles in the system:

*3.4.1. Rocker-Bogie Mechanism*

The core of the system, the rocker-bogie mech-animism, is designed for superior mobility over uneven terrain. This design allows for even weight distribution, providing the rover with stability and adaptability in rugged environments.

#### *3.4.2. Chassis Frame*

The chassis frame supports the mechanical and electrical components, providing structural stability to the rover. It is designed to accommodate the rocker-bogie mechanism and the associated hardware components. The frame, constructed from PVC pipes of 1.5-inch diameter, provides natural support for the rocker-bogie mechanism and the electronic components. PVC was chosen for its lightweight, cost-effectiveness, and ease of assembly.

#### *3.4.3. Six 12V DC Motors*

The propulsion system comprises six 12V DC motors, each attached to a wheel of the rocker-bogie mechanism. These motors provide the torque and control necessary to navigate challenging surfaces. The motors are controlled via the L298 2A motor driver circuit board.

#### *3.4.4. Arduino Uno*

The Arduino Uno serves as the central control unit for the system. It processes sensor data and controls the motors, allowing for autonomous navigation based on inputs from the ultrasonic sensors and GPS.

#### *3.4.5. L298 2A Motor Driver Circuit Board*

This motor driver circuit board manages the power supplied to the motors, allowing for forward and reverse movement as well as speed control. It is capable of handling the current drawn by the six 12V motors.

#### *3.4.6. Two Ultrasonic Sensors*

Positioned on the rover, the ultrasonic sensors detect obstacles in the rover’s path. When an object is detected within 50 cm, the sensors trigger an automatic turn to avoid a collision. These sensors enable basic autonomous navigation without the need for complex AI algorithms.

#### *3.4.7. GPS Module*

The GPS module provides real-time positioning data, allowing the rover to localize itself within its environment. This data is used to enhance navigation by providing global positioning and ensuring the rover stays within a defined area.

#### *3.4.8. Power Supply (8 to 12 9V Batteries)*

The rover is powered by a pack of 8 to 12 9V batteries, providing sufficient voltage and current to run the motors, sensors, and control system. The battery pack is selected based on the power requirements of the entire system, ensuring efficient and prolonged operation.

#### *3.4.9. Wiring and Connectors*

The wiring and connectors are used to interface all electrical components, ensuring proper communication between the motors, sensors, GPS, and control systems. Reliable connections are critical for stable operation and real-time data processing.

### 3.5. Testing Environment

The rover was tested in a variety of environments to evaluate its performance under different conditions. These environments included:

- Plane Surfaces: Smooth, flat surfaces were included to measure the rover’s speed and overall maneuverability under minimal stress conditions.
- Uneven Surfaces: Rough terrains, simulating rocky or uneven ground, were used to evaluate the rover’s mobility and stability.
- Stairs: The rover was tested on a set of stairs to assess the rocker-bogie mechanism’s ability to navigate step-like obstacles.
- Outdoor Surfaces: The rover was taken to open outdoor areas with mixed terrain to evaluate its ability to transition between different surface types.
- Larger Terrain Areas: Wide, expansive areas were utilized to test the rover’s GPS module for accuracy in waypoint navigation over longer distances. These diverse environments allowed for a comprehensive assessment of the rover’s obstacle detection, navigation, and power efficiency across real-world condition

## 4. Results

The rover as previously mentioned was tested on various surfaces and textures and these were the following results.

- Plane Surface: The rover moved freely on smooth state surfaces with adequate traction and rough plane surfaces with better traction, the motion of the rover stayed consistent with its motion propelling forward with little to no swaying,
- Uneven Surface (indoor surface): The rover traversed the path with only a little difficulty swaying a little on the highly uneven with a large angular hilled portion of the area and the rover slipped a little on the smooth flat indoor inclines but overall it showed no problem in traversing the path
- Uneven Surface (outdoor surface): The rover traversed the outdoor inclines with much ease stayed steady on the ground, and stayed firm on the uneven outdoor surfaces
- Stairs: The rover moved with a little sway and successfully balanced down the stairs and at fast speeds while going up the stairs, It felt some resistance due to its larger body and the protruding odd shape of the stairs but it climbed up within 30-60 seconds
- Large terrain areas: The rover performed better in large terrain areas as it had ample space to move around

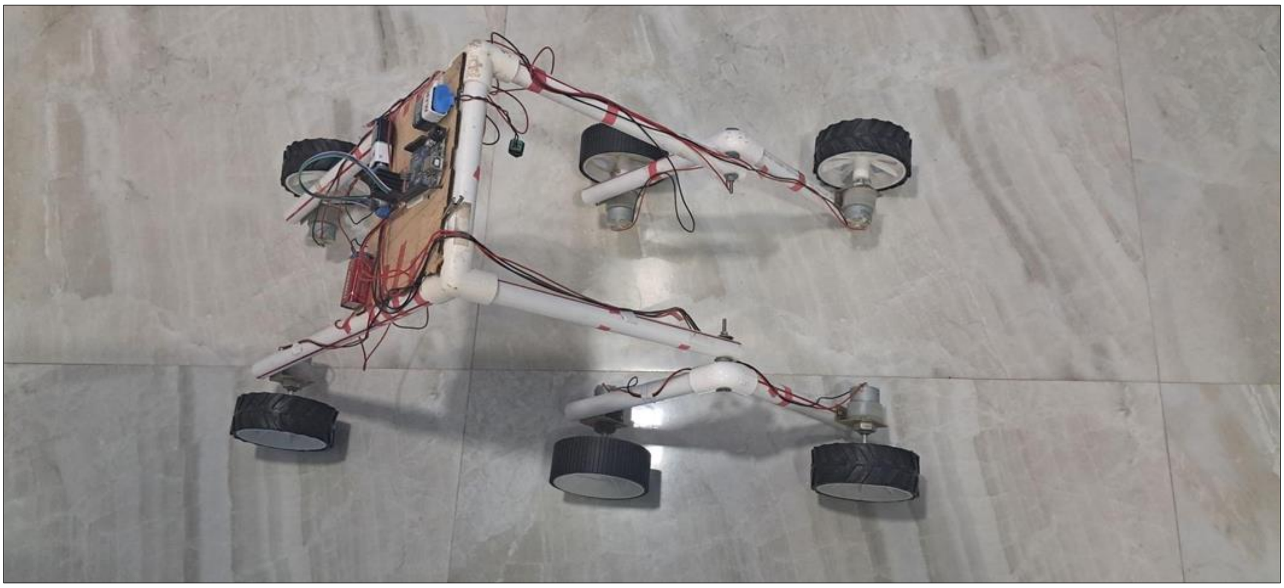

**Figure 3** Prototype Image

## 5. Conclusion

This work aims to show how the enhancements on the rocker bogie mechanism work in different conditions and landscapes, as per the various sensors and modules attached to it improve the rocker-bogie mechanism, the rover can climb up to a 50-degree inclined surface and the GPS module NEO-7M-000 with prior GPS coordinates works greatly in tracking the rover, the ultrasonic sensor hc-sr04 to measure the distance and if it transgresses the boundaries of 50cm and orders the rover to take a full right/left turn, although the robotic arm stayed as a concept, it would provide great improvements and benefits in real-world applications, hence all the enhancements giving satisfactory results.

## References

[1] P. Panigrahi, A. Barik, Rajneesh R. & R. K. Sahu, “Introduction of Mechanical Gear Type Steering Mechanism to Rocker Bogie”, Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-5, ISSN: 2454-1362,2016

[2] D. S. Chinchkar, S. S. Gajghate2 R. N. Panchal3, R. M. Shetenawar4 P. S. Mulik” Design of Rocker Bogie Mechanism” AGTI’s Dr. Daulatrao Aher College Engineering, Vidyanagar Extension, Karad Vol. 4, Special Issue 1, January 2017 ISSN (Online) 2393-8021

[3] R. Siegwart, I. Nourbakhsh, and D. Scaramuzza, "Introduction to Autonomous Robots: Mechanisms, Sensors, and Algorithms," *MIT Press*, 2002

[4] H. Shirai, Y. Takahashi, T. Nakamura, and K. Saito, "Advanced applications of ultrasonic sensors in autonomous robotics," *Robotics and Automation Journal*, vol. 34, no. 4, pp. 102-115, 2016. DOI: 10

[5] D. Ellery, S. Smith, and P. Johnson, "Application of sensors in autonomous robotics," *Journal of Robotics and Automation*, vol. 21, no. 3, pp. 45-59, 2014. DOI: 10

[6] M. Maimone, M. B. Miele, and L. Matthies, "The rock-and-bogie mobility system for planetary rovers," *Journal of Field Robotics*, vol. 24, no. 6, pp. 457–470, 2007

[7] B. Schnieders, S. Luo, G. Palmer, and K. Tuyls, "Fully Convolutional One–Shot Object Segmentation for Industrial Robotics," in *Proc. 18th Int. Conf. Autonomous Agents and Multiagent Systems (AAMAS 2019)*, Montreal, Canada, May 13–17, 2019, pp. 1161–1169.

[8] O. Khatib, J. L. G. Lee, and K. M. Lynch, "Robot force control," *IEEE Transactions on Robotics and Automation*, vol. 3, no. 1, pp. 3-12, Feb. 2009.