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List of Abbreviations

SL.NO.		ABBREVIATIONS
1.	VAR	Versatile Autonomous Rover
2.	GSM	Global System for Mobile Communication
3.	NASA	National Aeronautics & Space Administration
4.	PVC	Polyvinyl Chloride
5.	IDE	Integrated Development Environment
6.	FIDO	Field Integrated Design & Operations
7.	SIM	Subscriber Identity Module
8.	SMS	Short Message Service
9.	LiDAR	Light Detection and Ranging
10.	QR	Quick Response

List of Figures

CHAPTER 1:
INTRODUCTION OF PROJECT

1.1 INTRODUCTION

The Versatile Autonomous Rover (VAR) is an innovative robotic system designed to incorporate cutting-edge features such as autonomous navigation, obstacle detection and avoidance, GSM-controlled access, voice assistant integration, autonomous document delivery, and step maneuverability. Inspired by the growing advancements in AI and robotics, this project seeks to align with recent trends and technologies in the field.

We focused primarily on the hardware design, drawing inspiration from NASA's rocker bogie mechanism to achieve enhanced mobility and stability. Key highlights include:

i. **Hardware Development:**

- Constructed the chassis using 10 cm wheels and half-inch PVC pipes, ensuring optimal stability and durability.
- Implemented the rocker bogie suspension system, enabling stair-climbing capabilities and rugged terrain maneuverability.

ii. **Software Development:**

- Parallel to hardware, we developed algorithm for autonomous navigation, employing direct path-based method for efficient and reliable fixed-location navigation.
- The software part is just simulated in Arduino IDE tool.

We have developed the hardware structure, ensuring a robust foundation for implementing the rover's advanced functionalities.

1.2 MOTIVATION

The primary motivation behind this project stems from the growing demand for autonomous robotic systems capable of navigating and operating in challenging and unstructured environments. With advancements in technology, robots like the ones equipped with the Rocker-Bogie mechanism have the potential to revolutionize industries such as space exploration, disaster response, and remote sensing. Inspired by the success of NASA’s Mars Rovers and their ability to traverse rugged terrains, we aimed to develop a scalable and efficient system that could address similar challenges. The project also reflects our enthusiasm for creating innovative solutions that merge theoretical concepts with practical applications, pushing the boundaries of navigation and mobility systems. Additionally, we were driven by the desire to contribute to advancements in autonomous robotics, making them more reliable, adaptive, and accessible for real-world applications.

- Real-World Challenges
- Inspiration from NASA
- Technological Advancement
- Practical Applications
- Learning and Innovation
- Protection of Sensitive Equipment
- Efficiency and Adaptability

1.3 PROBLEM STATEMENT

In the modern era of rapidly advancing technology, there is a growing demand for systems, platforms, or robots capable of seamlessly automating tasks, providing users with enhanced ease, efficiency, and comfort to keep pace with a fast-moving lifestyle. However, many robots face challenges with stability, especially when navigating uneven surfaces, climbing stairs, or carrying payloads, which can lead to imbalance and limited functionality. Furthermore, robots often struggle to navigate multi-level buildings due to difficulties in detecting and avoiding obstacles, particularly when transitioning between floors. To address these issues, optimizing battery life and ensuring efficient power distribution across all components is essential to enhance both performance and reliability.

1.4 OBJECTIVES

The objectives of development and implementation:

- **Obstacle Detection and Avoidance:** Algorithms based on sensor data enable effective collision avoidance.
- **GSM Controlled Rover Access:** A unique numbering scheme allows users to send SMS commands for rover services.
- **Voice Assistance:** Using an AI Thinker offline module through which the rover recognizes voice and reply using the pre-defined responses.
- **Autonomous Navigation:** Algorithms enable the rover to navigate different environments and perform missions autonomously in pre-defined location.
- **Renewable Energy-Powered Battery System:** A solar-powered battery system recharges the rover, eliminating the need for human intervention.
- **User-Controlled Imaging:** Cameras capture images based on user commands, enabling data collection for analysis.
- **Staircase Maneuverability:** The rocker-bogie suspension allows the rover to climb and descend steps, adapting to uneven terrain.
- **Autonomous Document Delivery:** The rover is equipped with a payload system to deliver documents or carry loads between locations.

CHAPTER 2:
LITERATURE SURVEY

SL. NO.	AUTHORS	YEAR	DESCRIPTION	TITLE
1.	Mohit Dhawale, Rohan Bedarkar, Raj Warudkar, Shantanu Mohod, Devanshu Dhawale, Tanmay Joshi, Y.D. Bansod	2022	The initiation of rocker bogie suspension system can be traced to the development of planetary rover which are mobile robots, especially designed to move on a planet surface. Early rovers were tele-operated like the Lunakhod - I while recent ones are fully autonomous, such as FIDO, Discovery and recently developed Curiosity mars exploration rover.	Rocker Bogie
2.	Swapnil Umesh Ambre, Shruti Vasudev Sawant, Pratik Mhatre, Swapnil Ashok Ashtekar	2023	Arduino-based mobile phones have emerged as a compelling alternative to traditional devices, offering flexibility and personalization. The integration of SIM800L modules provides cellular connectivity for voice calls, SMS, and data access.	Interactive Arduino GSM Communication System
3.	Dinesh Dubal, Darshan Thakur, Shivam Pol, Pradip Gunvant	2024	In this rover model we have used various autonomous navigation algorithms which are integrated in mobile robots, including obstacle avoidance, path planning, and localization techniques. By comparing different approaches, we highlight their strengths and limitations, and propose future research directions for improving navigation capabilities in robotic systems.	Integrated Robot Used Sensing Multiple Functions
4.	S. Karthikeyan, Prasanth S	2023	The design of a wheeled stair climbing robot equipped with a 3D imaging system for obstacle detection is capable of traversing staircases with varying heights and shapes and is equipped with a sliding mechanism for smooth transition between steps. Only when the robots are being used can the effectiveness be seen.	Development Of Stair Climbing Robot for Goods Transport

CHAPTER 3:

METHODOLOGY

3.1 HARDWARE

3.1.1 ROCKER BOGIE MECHANISM

The rocker mechanism is designed to create oscillatory motion, enabling upward and downward movement that enhances surface grip, improving the rover's ability to climb inclined surfaces. This mechanism offers several advantages; as one part moves upward, the other oscillates freely along the connecting shaft, ensuring stability. The wheels on the rocker end provide additional motion support, increasing grip and aiding the bogie in pushing forward. The bogie, a key structural element, facilitates steering and supports the rover's main frame. Its connection to the rocker allows smooth rotational movement, enabling the rover to navigate uneven terrain with ease.

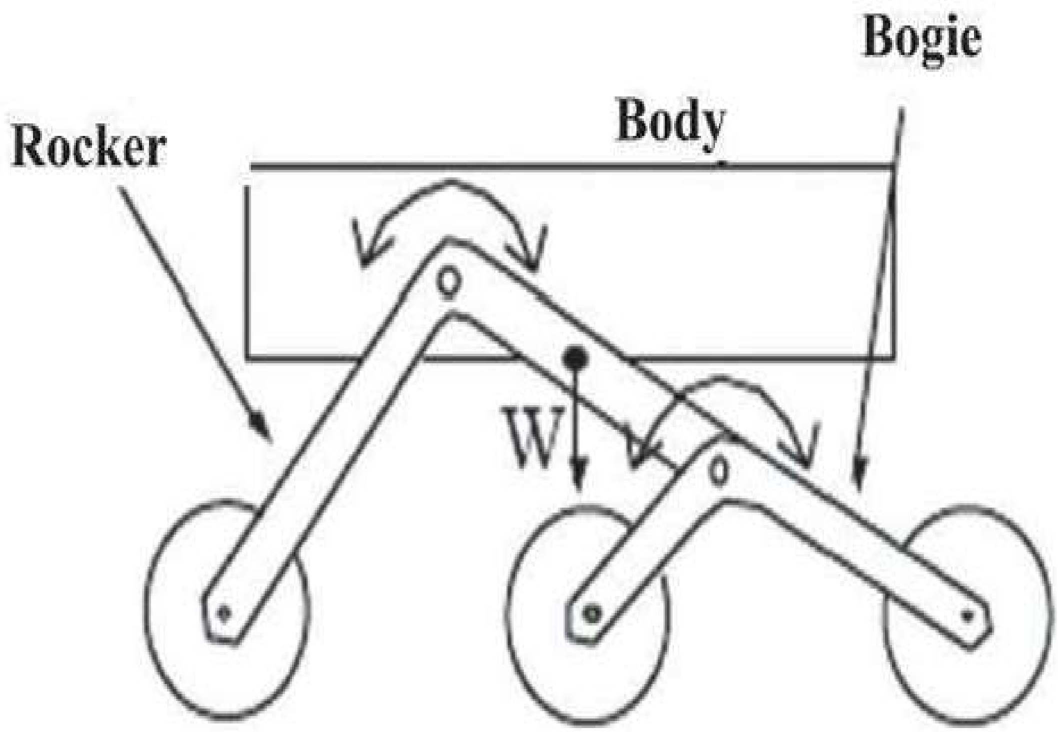


Figure 1. Referred Rocker Bogie Mechanism

The hardware used in the project includes six wheels of 10 cm diameter each, a 3-meter-long half-inch PVC pipe, four 45-degree elbows, two T-joints, and two 90-degree elbows. To secure and connect all components, we also utilized screws, and steel threads, ensuring the design is both durable and efficient.

3.1.2 HARDWARE COMPONENTS

3.1.2.1 ARDUINO UNO

- It is an open-source microcontroller board based on the **ATmega328P.**
- It features **14 digital I/O pins** (**6** can be used for **PWM**), **6 analog inputs, USB interface, power jack**, and **UART/SPI/I2C** communication.
- It operates at **5V**, with a **16 MHz clock speed** and **32 KB flash memory**.

❖ **How it Works:**

- It runs a user-programmed sketch (code) written in the **Arduino IDE** using **C/C++.**
- Continuously reads input from sensors or modules and controls output devices like motors.
- Offers a simplified hardware-software interface for rapid prototyping and embedded application.

❖ **How we used it in our Rover:**

- It served as the **central controller** managing communication and coordination among all components:
- Receives **SMS** via **GSM SIM900A** module through **UART.**
- Interprets voice commands from **VC-02 voice module**.
- Reads distance from the ultrasonic sensor and controls servo for scanning.
- Sends control signals to **L298N** to drive **DC motors** based on commands and sensor data.
- All decision-making logic for navigation, obstacle avoidance, mode switching **(voice/GSM/autonomous)** was implemented on Arduino.
- Enabled **real-time control** and intelligent responses, making the rover efficient and reliable.

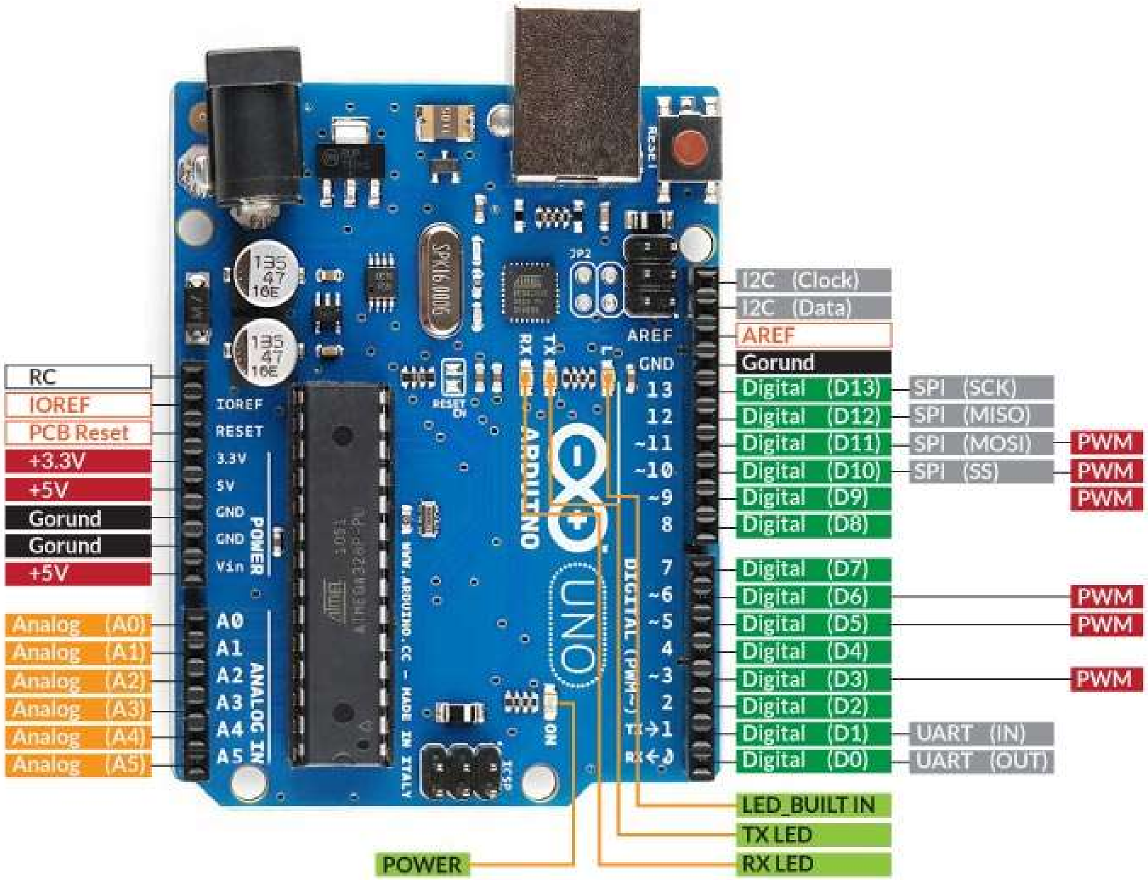


Figure 2. ARDUINO UNO

3.1.2.2 GSM SIM 900A MODULE

- It is a **GSM/GPRS** module used for wireless communication over **2G cellular networks.**
- It supports **SMS**, **voice calls**, and **internet (GPRS).**
- Controlled using **AT commands** via **UART (serial) communication**.

❖ **How it Works:**

- It operates with a standard **SIM card**, similar to mobile phones.
- It sends and receives data via **GSM cellular towers**.

❖ **How we used it in our Rover:**

- The user sends **SMS commands** from any **mobile phone**.
- Then the Arduino receives and decodes these SMS messages using serial communication due to which the Rover acts on the command to move, turn, or stop.
- This makes the rover remotely controllable from **any location**, without the need for **Wi-Fi or Bluetooth.**

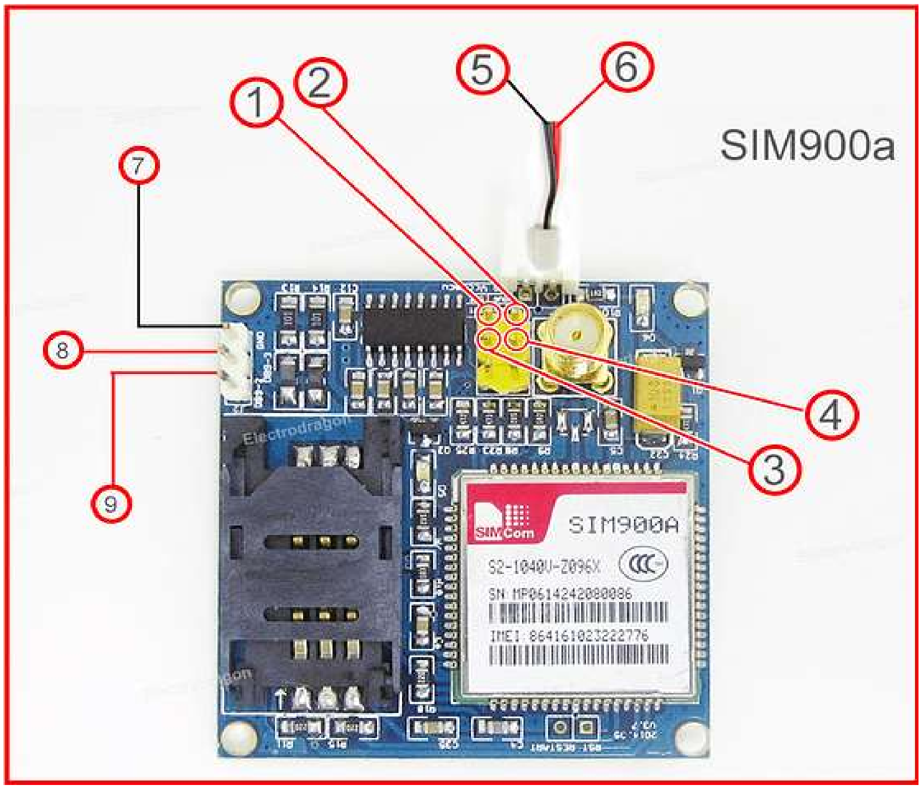


Figure 3. GSM SIM 900A MODULE

3.1.2.3 ULTRASONIC SENSOR AND SERVO MOTOR

- The **HC-SR04 ultrasonic sensor** is a non-contact distance measurement device that uses **40 kHz sound waves** to detect obstacles.
- It calculates distance using the **Time-of-Flight** formula:

  Distance = (Time × Speed of Sound) / 2 (where speed of sound ≈ 343 m/s).
- The **servo motor** is a rotary actuator that positions the sensor at specific angles (0°–180°) using **PWM signals** for precise movement.
- Together, they form an intelligent scanning system for the rover to perceive and react to its surroundings.

❖ **How it Works:**

- The **ultrasonic sensor** emits a sound pulse and waits for the echo; the time taken is used to compute distance.
- The **servo motor** rotates the sensor in different directions (left, center, right), enabling multi-angle scanning.
- This pairing allows the rover to "look around" and assess the safest direction to move.
- Controlled via **Arduino**, which processes the data in real time and makes decisions accordingly.

❖ **How we used it in our Rover:**

- The **servo motor was mounted with the ultrasonic sensor** to scan the environment dynamically.
- The Arduino triggered the servo to rotate in **multiple directions**, taking distance measurements at each angle.
- If an obstacle was detected within **20–30 cm**, the rover executed an **avoidance maneuver**.
- This setup enhanced **autonomous navigation** by helping the rover detect, decide, and navigate **around obstacles smartly and safely**.

Figure 4. Ultrasonic Sensor Mounted on Servo Motor

3.1.2.4 L298N MOTOR DRIVER AND DC GEARED MOTORS

- The **L298N** is a dual-channel H-Bridge motor driver used to **control the direction and speed** of DC motors through logic-level signals from the Arduino.

- It supports **bidirectional control** and **PWM-based speed modulation**, which is essential for smooth and precise robotic motion.
- **DC geared motors (30 RPM, 3 kg-cm torque)** are low-speed, high-torque motors commonly used for robotic applications requiring **stable movement** and **payload capacity**.
- Together, they form the core actuation mechanism that propels the rover and handles navigation maneuvers.

❖ **How it Works:**

- The Arduino sends control signals **(IN1, IN2, ENA)** to the **L298N**, determining **motor direction** and **speed** via **PWM.**
- The motor driver manages **power delivery** to the motors, acting as a bridge between low-power logic and high-power motors.
- The geared motors use a **reduction gearbox** to provide high torque and maintain stable, slow-speed movement.
- Each motor’s direction and speed are individually controlled to achieve desired motion.

❖ **How we used it in our Rover:**

- We have used **two L298N modules** to control **six DC motors — 3 per driver** — for **differential drive**.
- Enabled **forward, reverse, and turning** by varying motor direction and speed on each side.
- **30 RPM motors** ensured steady and safe movement across indoor surfaces.
- **3 kg-cm torque** gave the rover enough power to **carry documents** and **climb over small obstacles**.
- The setup allowed the rover to **respond intelligently** to commands from voice, SMS, and sensors by executing **precise driving actions**.

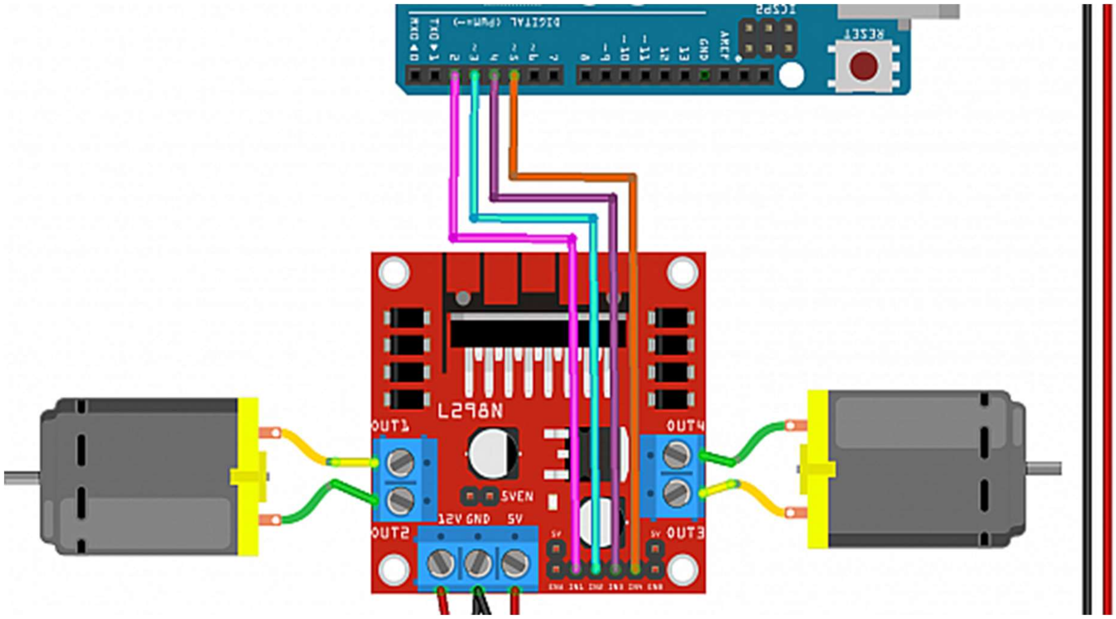


Figure 5. L298N Motor Driver and DC Geared Motors

3.1.2.5 BUCK CONVERETR

- It is a **DC-DC** step-down voltage regulator that efficiently converts higher voltage (e.g., 12V from the battery) to a stable lower voltage (e.g., 5V or 9V) required by various electronic components.
- It ensures that sensitive modules like the Arduino, sensors, GSM, and voice module receive appropriate voltage, preventing overvoltage damage.
- Known for its high efficiency and low heat generation, the buck converter is ideal for battery-operated robotic systems where power conservation is crucial.
- It plays a vital supporting role by stabilizing power supply lines and extending operational time.

❖ **How it Works:**

- The Buck Converter uses a switching regulator with a transistor, diode, and inductor to step down voltage from the input source.
- It rapidly switches the transistor on/off, storing energy in the inductor and releasing it at a lower average voltage.
- Output voltage is controlled using a feedback loop to maintain consistent voltage regardless of load changes.
- Adjustable potentiometer on the converter allows setting precise output voltage as needed by the connected module.

❖ **How we used it in our Rover:**

- Powered the Arduino Uno, GSM SIM900A, VC-02 voice module, and sensors with a consistent 5V derived from a 12V Li-ion battery pack.
- Prevented voltage spikes and ensured safe, stable operation of all electronics.
- Enhanced energy efficiency by minimizing heat loss compared to linear regulators.
- Enabled simultaneous powering of high-current and low-current modules without straining the battery.
- Played a key role in the power management system, supporting uninterrupted and reliable rover operation in both manual and autonomous modes.

Figure 6. LM2596 DC to DC Buck Converter

3.1.3 KEY FEATURES

➢ **Stability on Uneven Terrain**: The system ensures all wheels maintain contact with the ground, providing optimal stability and balance on rough or uneven surfaces.

➢ **Independent Wheel Movement**: Each wheel can independently move and adapt to the terrain, allowing the rover to navigate obstacles without losing traction.

➢ **Improved Mobility**: The rocker-bogie design allows the rover to climb obstacles, such as stairs and rocks, by utilizing the upward and downward motion of the rocker arms.

- **Weight Distribution**: The suspension mechanism effectively distributes the rover's weight, reducing the risk of tipping over and enhancing mobility on challenging surfaces.
- **Efficient Traction**: The differential drive system ensures that all wheels work together to propel the rover forward, even in challenging conditions.
- **Minimal Mechanical Complexity**: The mechanism has a simple design with few moving parts, making it reliable and easy to maintain.

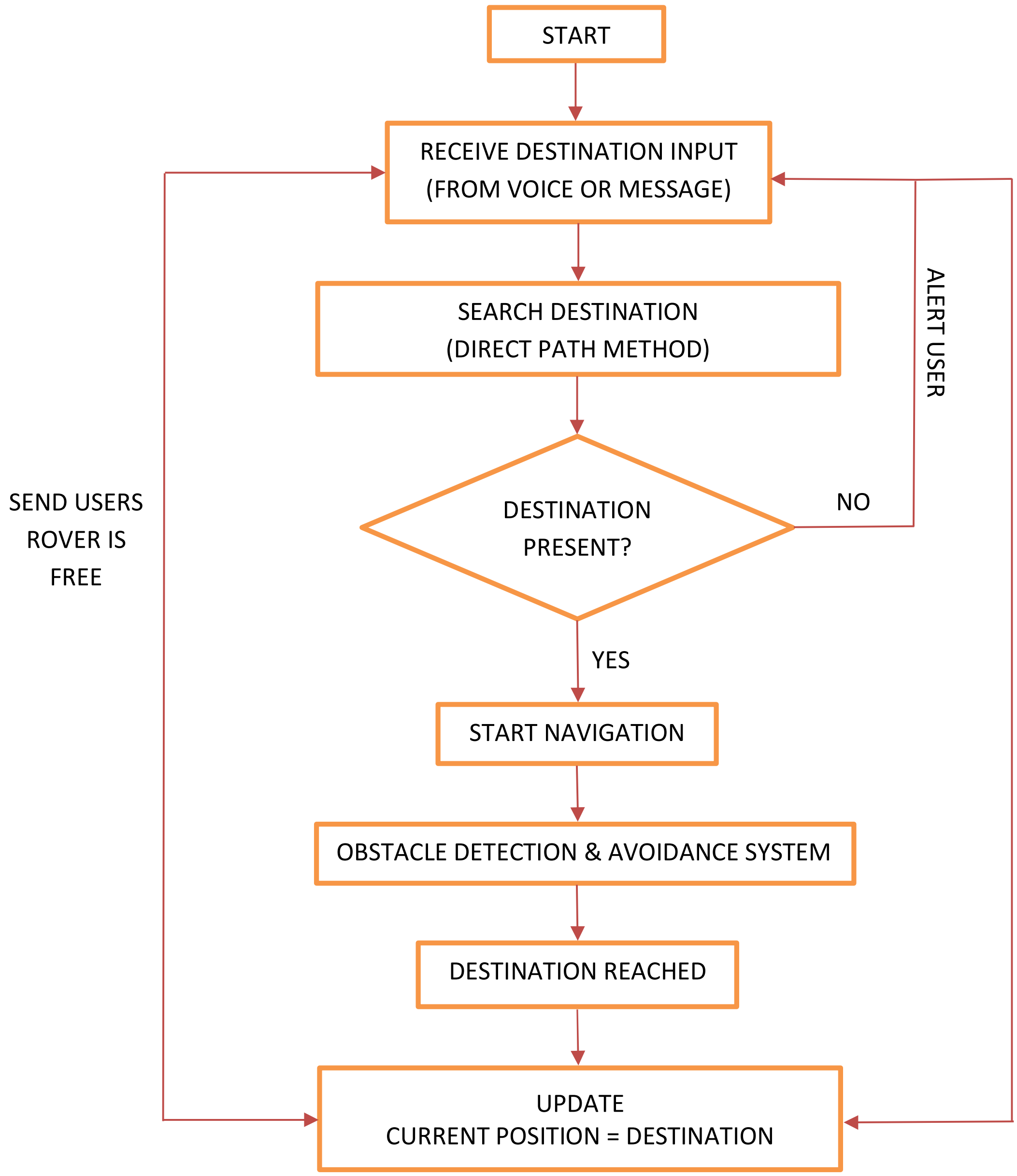
3.2 SOFTWARE

3.2.1 ROVER NAVIGATION SYSTEM

In this project, we have used the Direct Path-based navigation method. The Direct Path-based method uses separate functions for each room or destination, which is simple for a few rooms but becomes complex and increases storage requirements as the number of rooms increase.

Flow Chart:

The flowchart begins with destination input via message through GSM or voice commands through Voice module, validates it against a predefined matrix, navigates if valid, updates its position upon arrival, and prompts for re-entry if invalid.



3.2.1.1 DIRECT PATH BASED NAVIGATION METHOD

In the direct path-based method, each room is assigned a unique name. The system compares the given destination with these predefined names. Once a match is found, a set of predefined navigation instructions, such as moving forward for a specific duration, turning right, or turning left, is executed. Each room has a dedicated function containing the exact steps required to navigate to that location, ensuring precise and organized movement based on the destination.

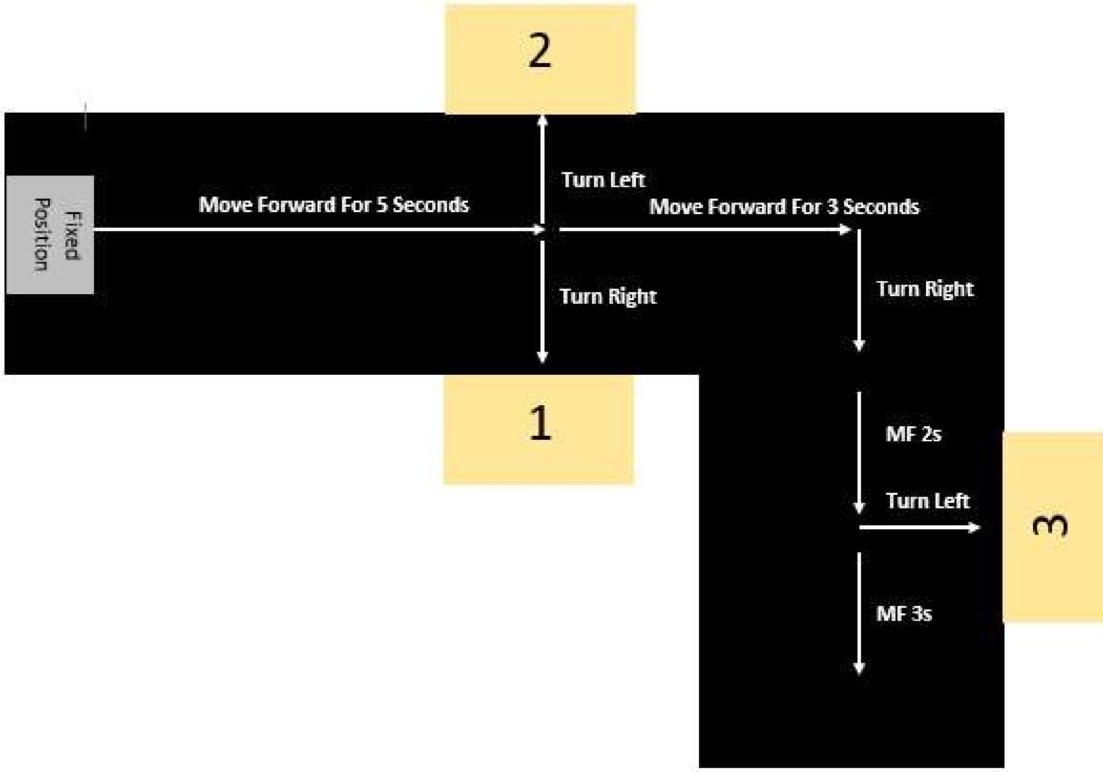


Figure 7. Direct Path based Navigation Example

CHAPTER 4:
RESULTS OF THE PROJECT

4.1 HARDWARE RESULTS

In the hardware portion of the project, we have successfully implemented the rocker-bogie suspension system and assembled all other components to securely hold the wheels attached to DC gear motors. The results are shown below.

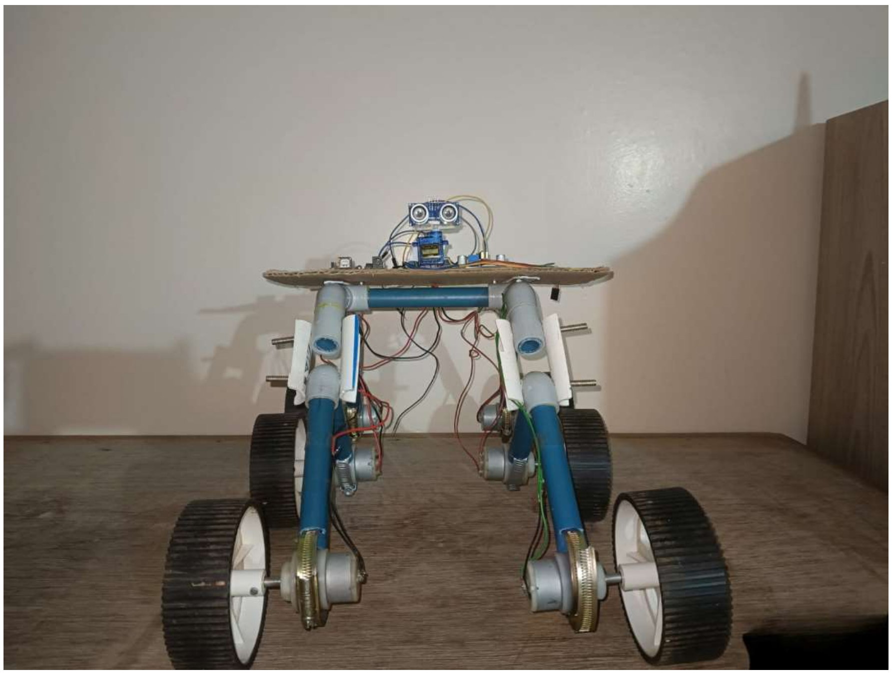


Figure 8. Rocker Bogie

4.2 SIMULATION RESULTS

As earlier stated, our primary focus was to work on the simulation aspect of our project. We focused on developing and testing the code by running it in a simulated environment. The output was observed and analysed using the Serial Monitor in the Arduino IDE tool. This approach enabled us to verify the logic, identify potential issues, and refine the code without relying on physical hardware, providing a more efficient and iterative development process. It allowed us to focus on understanding and optimizing the software functionalities before moving to real-world implementation.

1. **Direct path based method:**

In the direct path-based method, the simulation output observed in the Serial Monitor reflects the robot's movements in a sequential manner. The robot performs actions such as moving forward for 10 seconds, turning left, and turning right, with each step executed based on the pre-programmed logic. This process continues sequentially, allowing the robot to navigate toward its destination while demonstrating its path in a clear and systematic manner.

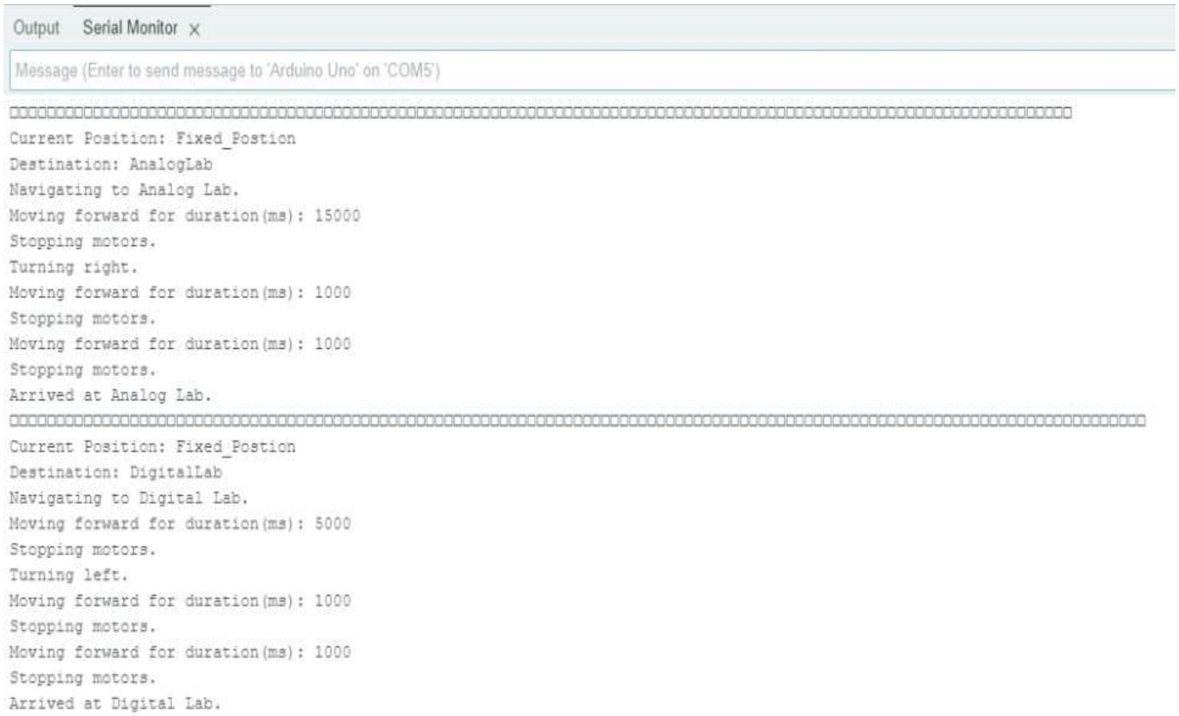


Figure . Simulation Result of Direct Path based Navigation

4.3 FUTURE SCOPE

The future scope of our rover project is vast, with immense potential for enhancement and diversification across multiple domains. One significant area for development is the integration of advanced artificial intelligence (AI) and machine learning (ML) algorithms to improve the rover's decision-making capabilities. By incorporating real-time data processing and predictive analytics, the rover can evolve into a more intelligent and autonomous system capable of handling complex tasks with minimal human intervention. For instance, the inclusion of advanced path-planning algorithms could allow the rover to navigate dynamically changing environments, such as disaster zones or crowded urban areas, more efficiently. Additionally, incorporating 5G communication modules can enhance the rover's connectivity, enabling seamless remote operation and faster data transmission, which is crucial for applications requiring high-speed interaction, such as telemedicine or remote monitoring. Expanding its operational scope, the rover can be equipped with additional tools like robotic arms for precision handling of objects, LiDAR sensors for enhanced spatial awareness, and thermal imaging cameras for applications in search and rescue missions or industrial inspections.

CHAPTER 5:

CONCLUSION

The successful completion of our rover project signifies a major milestone in our journey toward advancing autonomous robotics technology. This rover, designed to perform a multitude of tasks, showcases a perfect blend of innovation, precision engineering, and practical problem-solving. Equipped with features such as object avoidance, staircase maneuverability, pre-loaded map-based indoor navigation, GSM module-based communication, interactive voice assistant capabilities, QR code scanning, gesture and face recognition, video streaming, and object detection, the rover demonstrates exceptional versatility and adaptability. Its solar-powered energy unit ensures sustainable operation, while its ability to transport documents adds a layer of practical utility. Each subsystem was meticulously developed and integrated, overcoming challenges such as ensuring seamless coordination, optimizing power efficiency, and maintaining system reliability under various operating conditions. By achieving its objectives, the project not only validates the feasibility of combining advanced sensors, AI algorithms, and mechanical systems in a compact platform but also lays the groundwork for future enhancements and applications in fields ranging from disaster response and healthcare delivery to industrial automation and smart surveillance. This rover is a testament to the potential of interdisciplinary collaboration and a stepping stone toward building more sophisticated, intelligent robotic systems that can transform the way we interact with technology and our environment.

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