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Vidyut: Design and Development of a Cost-Optimized 6WD Landmine Detection Rover with Real-Time GPS Localization

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Abstract - Landmines continue to pose significant humanitarian and environmental threats, particularly in post-conflict regions where unexploded ordnance remains undetected for decades. Existing detection techniques are either labor-intensive or economically impractical for large-scale applications. This paper presents the design and implementation of **"Vidyut," a cost-efficient six-wheeled (6WD) robotic rover** intended for preliminary landmine detection and localization. The system integrates a metal detection module, GPS-based positioning, and wireless Bluetooth communication to enable remote operations and real-time monitoring. A hybrid mobility architecture using both BO motors and high-torque metal-gear motors ensures terrain adaptability. Upon detecting metallic anomalies, the system halts, generates an alert, and transmits geolocation data for further analyses. Experimental validation demonstrated reliable operation across uneven terrains with satisfactory detection accuracy for shallowly buried objects. The proposed system provides a scalable and low-cost foundation for semi-autonomous demining.

KeyWords: Landmine Detection, 6WD Rover, Embedded Systems, GPS Localization, Metal Detector, Bluetooth Control

1.INTRODUCTION

Landmines are concealed explosive devices designed to detonate on physical interaction. Despite global disarmament efforts, millions of active landmines remain buried worldwide, causing severe injuries, fatalities, and long-term socioeconomic disruption.

Traditional demining approaches rely heavily on manual probing or trained animals, which are inherently hazardous and inefficient. Recent advancements in robotics have introduced autonomous and semi-autonomous systems that can reduce human exposure. However, many such systems rely on complex architectures involving LiDAR, SLAM, and high-end processing units, rendering them unsuitable for low-resource deployment.

This study aims to bridge this gap by proposing a **low-cost, modular, and scalable rover system** that combines embedded systems with practical sensing techniques. The proposed rover, "Vidyut," emphasizes simplicity, affordability, and reliability, making it suitable for academic, research, and preliminary field applications

2. SYSTEM ARCHITECTURE

The system is divided into four major subsystems.

I. **Mobility Subsystem** – 6WD drive mechanism
II. **Detection Subsystem** – Inductive metal detection
III. **Localization Subsystem** – GPS-based positioning
IV. **Control & Communication Subsystem** – Arduino + Bluetooth

The architecture follows a centralized control model, wherein the microcontroller processes the sensor inputs and controls the actuation.

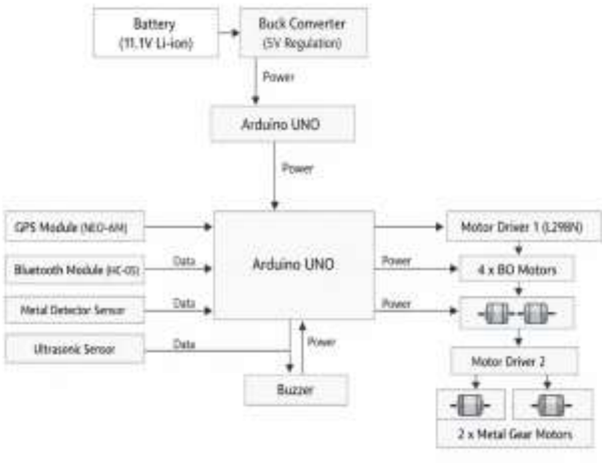

Fig .1: Block Diagram of Vidyut Landmine Detection Rover

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3. SYSTEM PARAMETERS

To evaluate the performance of the proposed rover, key design and operational parameters were defined as shown in Table 1

S. NO	*PARAMETER*	*VALUE*	*DESCRIPTION*
1	Total Mass (m)	~3.5 kg	Weight of complete rover
2	Wheel Diameter	60 mm	BO motor wheels
3	Number of Wheels	6	6WD configuration
4	Motor Type	BO + Metal Gear	Hybrid drive system
5	Motor Speed	100–200 RPM	Balanced torque-speed
6	Battery	11.1V, 4500 mAh	Li-ion battery
7	Detection Range	5–6 cm	Metal detector
8	GPS Accuracy	±3 m	NEO-6M module
9	Communication Range	10–15 m	Bluetooth HC-05
10	Controller	Arduino UNO	Central control unit

Table .1: Parameters of the Vidyut Landmine Detection Rover

4.MECHANICAL DESIGN OF CHASSIS

The mechanical structure of the rover is designed using a lightweight yet rigid PVC pipe-based frame, as shown in the developed prototype model. The chassis follows a 6-wheel drive (6WD) configuration, which significantly enhances traction and stability on uneven terrains such as sand, soil, and gravel.

The design incorporates:

- Front and middle wheels powered by BO motors for mobility
- Rear wheels powered by high-torque metal gear motors for load handling
- A rectangular frame structure to support electronic components
- Elevated mounting for electronics to avoid ground contact

The metal detector module is positioned at the front, close to the ground surface (~2–3 cm), ensuring maximum detection sensitivity.

This design ensures:

- Uniform weight distribution
- Improved terrain adaptability
- Reduced slippage in loose soil

Compared to conventional 4WD systems, the 6WD configuration provides better **load balancing and obstacle traversal capability**, which is essential for real-world deployment.

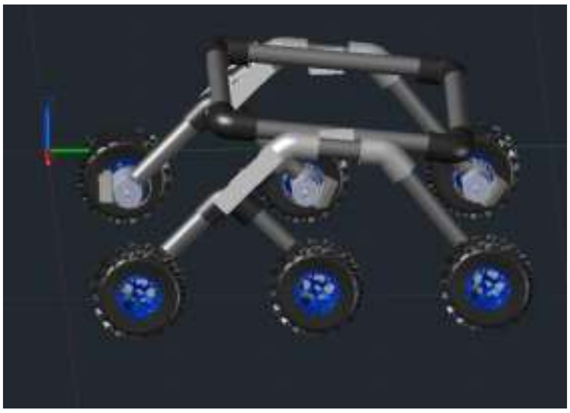

Fig .2:3D Model of 6WD Rover Chassis Structure

5. ELECTRICAL AND CIRCUIT DESIGN

The electronic architecture is centered around the Arduino UNO, which acts as the main processing unit. The system integrates multiple modules including motor drivers, sensors, and communication units.

5.1 Circuit Description

The circuit consists of:

- **Two L298N motor drivers** to control six DC motors

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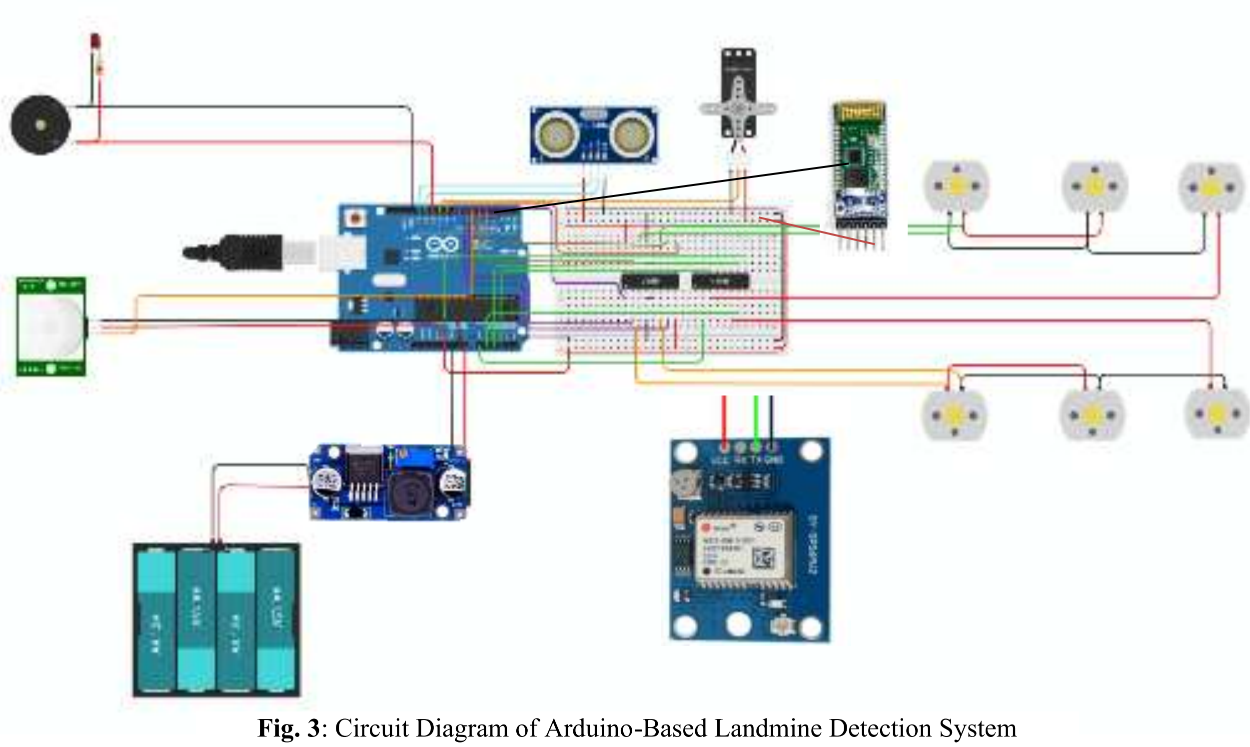

Fig. 3: Circuit Diagram of Arduino-Based Landmine Detection System

I. **HC-05 Bluetooth module** for wireless control
II. **NEO-6M GPS module** for location tracking
III. **Metal detector module** for sensing metallic objects
IV. **Buck converter** for voltage regulation

The power system is divided into:

- **High-power line (11.1V)** → motors
- **Regulated 5V line** → Arduino and sensors

A **common ground connection** is maintained across all components to ensure stable operation.

Voltage dividers are used to protect RX pins of communication modules from over-voltage.

6. WORKING METHODOLOGY

The operational workflow of this system is as follows:

I. The rover is controlled remotely using a Bluetooth interface.
II. The metal detector continuously scanned the ground surface.
III. When a metallic object is detected,
   - The rover immediately halts its movement.
   - A buzzer alert is triggered.
   - GPS coordinates were acquired.
IV. Location data were transmitted to the user device.

This event-driven architecture ensures a rapid response and minimizes the risk of accidental triggering
The working process is illustrated in **Fig. 4**

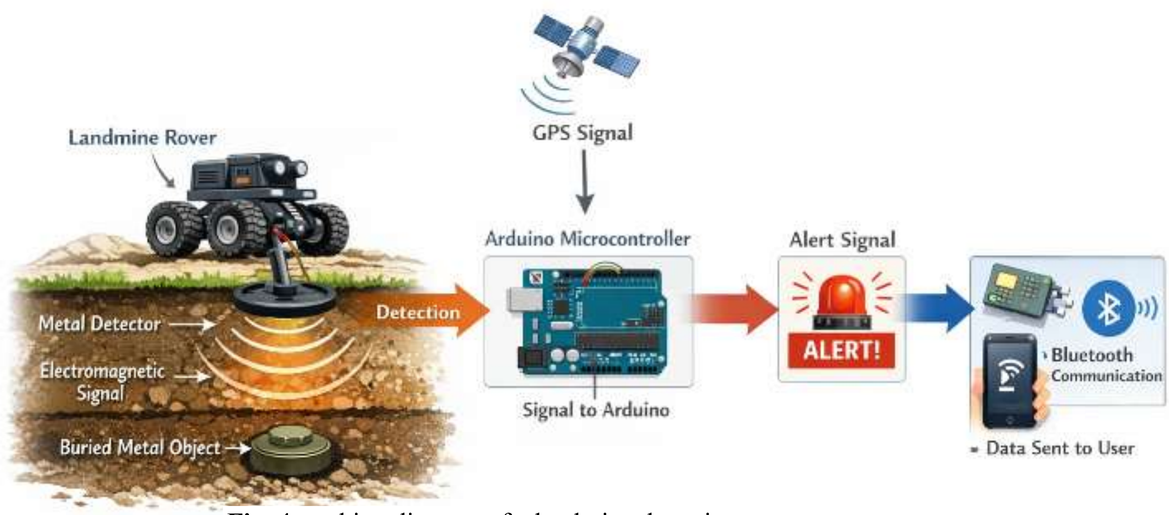

Fig. 4 working diagram of a landmine detection rover system.

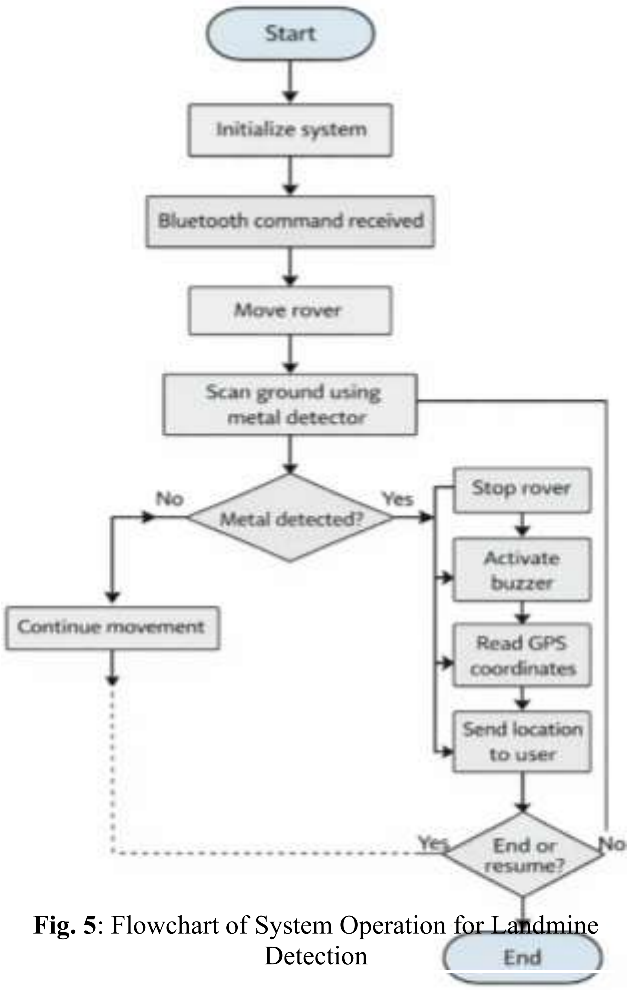

Fig. 5: Flowchart of System Operation for Landmine Detection

7. ANALYSIS AND DESIGN CALCULATIONS

To ensure proper motor selection and system performance, basic force and torque analysis were conducted.

Assumptions:

- Total mass of rover (m) ≈ 3.5 kg
- Wheel radius (r) ≈ 0.03 m
- Rolling resistance coefficient (Crr) ≈ 0.2

Rolling Resistance Force:

$$F = mg.C_{rr}$$

$$F = 3.5 \times 9.81 \times 0.2 \approx 6.87N$$

Required Torque:

$$T = F.r = 6.87 \times 0.03 \approx 0.206Nm$$

Thus, motors with torque greater than **0.25 Nm** are suitable for a reliable operation.

This simplified analysis aligns with the dynamic modeling approaches discussed in prior research.

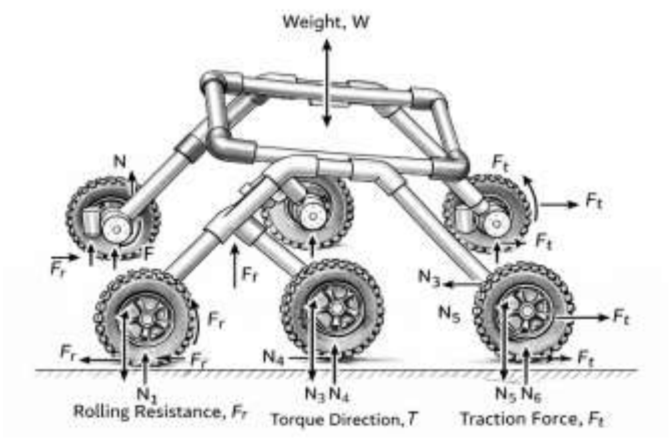

Fig.6: Mechanical force diagram of a six-wheeled rover

7.1 POWER CONSUMPTION AND RUNTIME

Component	*Current*
BO Motors	~800 mA
Metal Motors	~1.5 A
Electronics	~300 mA
Total	~2.6 A

Estimated runtime:

$$Runtime \approx 1.5 - 2\ hoursRuntime$$

7.2 Effectiveness of Metal Detection

- Detection depth: 5–6 cm
- Reliable for metallic objects
- Performance affected by soil conditions

7.3 GPS and Communication Performance

- GPS accuracy: ±3 m
- Bluetooth range: 10–15 m
- Stable real-time communication

8. RESULTS AND DISCUSSION

The developed prototype was tested under controlled conditions, including soil, sand, and rough surfaces.

The performance comparison is shown in Chart 1

Observations:

- The rover maintained stable motion across uneven terrain due to 6WD configuration
- Metal detection was effective within a range of approximately **5–6 cm**
- GPS module provided location accuracy within **±3 meters**
- Bluetooth communication remained stable within **10–15 meters**

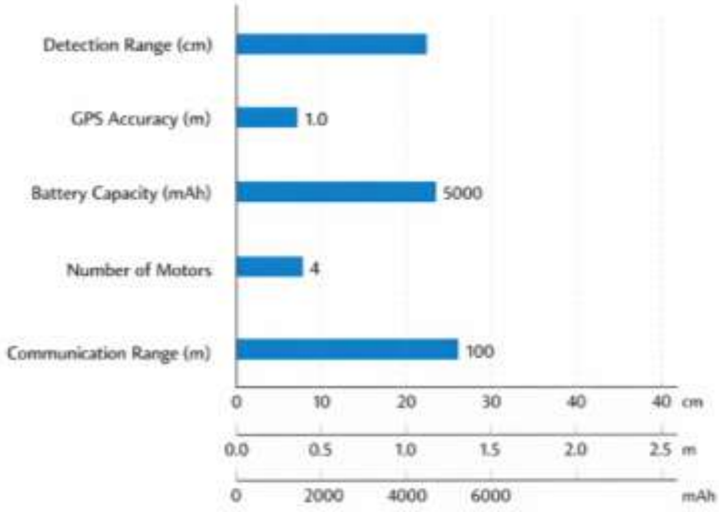

Chart.1: Landmine Detection Rover System Performance Comparison

Discussion:

The results indicate that the rover performs effectively in detecting shallow metallic objects and navigating uneven terrain. The 6WD configuration significantly improves mobility and stability.

However, detection depth limitations and GPS inaccuracies highlight the need for further improvements.

9. CONCLUSIONS

This paper presented the design and implementation of "Vidyut," a cost-effective landmine detection rover. The system successfully integrates detection, localization, and communication functionalities. The prototype demonstrates the feasibility of using embedded systems for safe and efficient landmine detection.

10. FUTURE SCOPE

Future improvements include:

- Autonomous navigation using SLAM
- AI-based detection systems
- Advanced sensors (GPR, thermal imaging)
- Cloud-based monitoring

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