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Development and Fabrication of a 3D-Printed Autonomous Rover for Terrain Navigation

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***Abstract*—The presented work includes the design, development of a 21.2-centimeter-class educational autonomous rover, constructed using 3D printing and low-voltage mechatronic components. Designed for first-year B.Tech AI & Robotics students, the rover introduces the fundamentals of robotic mobility and navigation through a safe, modular, and easily repairable platform.**

The rover incorporates a PLA chassis, 6-wheel drive, Arduino Mega controller, and a sensor suite including ultrasonic and temperature and humidity sensors.

Test results demonstrate reliable movement across uneven terrain, stable sensor fusion, and robust teleoperation/autonomy in controlled environments. The rover serves as a practical educational platform aligned with NEP 2020's vision of multidisciplinary, hands-on learning.

***Index Terms*— Educational robotics, Rover, sensor fusion, terrain navigation, 3D printing.**

I. INTRODUCTION

Planetary rovers such as Sojourner, Spirit & Opportunity, Curiosity, and Perseverance have defined the state of the art in terrestrial and extra-terrestrial robotic exploration. Their locomotion systems, suspension architectures, perception units, and intelligent autonomy have shaped robotics.

However, full-scale rover development is costly and to undergraduate students. To combat this, we developed a scaled, safe, 3D-printed rover platform that captures the mechanical principles of real rovers while remaining affordable and beginner-friendly.

The rover emphasizes:

- Mechanical mobility
- Sensor perception
- Embedded control
- Additive manufacturing

This aligns with NEP 2020, which emphasizes flexible, multidisciplinary, early-stage engineering education.

II. RESEARCH OBJECTIVES

1. Build a 21 cm rover platform using 3D printing.
2. Implement a 6-wheel rover architecture.
3. Integrate terrain-adaptive suspension (rocker-bogie or independent).
4. Provide modular electronics housing.
5. Maintain safe voltage (< 12 V) for student labs.

III. SYSTEM OVERVIEW

Table 1. Parameters and components

Parameter	Value
Length	21.2 cm
Width	13 cm
Height	9 cm
Chassis	PLA (3D Printed)
Wheels	7x3 cm
Drive Motors	6 x 12V DC 500 RPM
Controller	Arduino Mega
Sensors	Ultrasonic, DHT11
Battery	12V 5200mAh
Suspension	Modified Rocker Bogie
Max Speed	5 km/h
Ground Clearance	3 cm
Payload	1.3 kg

The block diagram of the overall rover design is shown in Figure 1.

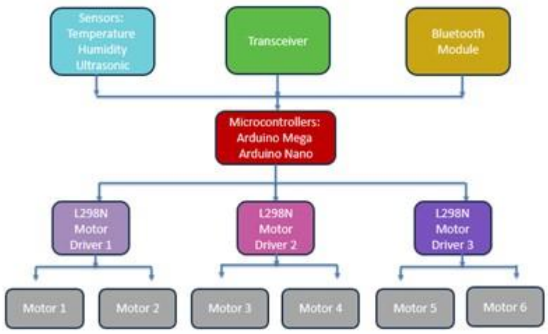

Fig. 1. Block Diagram of Rover Prototype

IV. MECHANICAL DESIGN

A. Chassis Architechture

The rover follows a rocker-bogie inspired design. The bogie arms support middle and rear wheels. The centre chassis module houses electronics and battery.

B. Structural Strengthening:

The load-bearing beams are strengthened with PLA reinforcement.

C. 3D Printed Parts

Table 2. Printed part specifications

Component	Material	Infill	Notes
Rocker-Bogie Joints	PLA	20%	High-strength
Chassis Plate	PLA	30%	High-strength

V. DRIVE SYSTEM

A. Wheel and Motor System

Each of the 6 wheels is driven by a 500 RPM BLDC motor on independent motor driver channels. The wheels have a diameter of 7 cm and a width of 3 cm.

B. Suspension Mechanics

The rocker-bogie system maintains stability across uneven terrain. The system en-sures constant ground contact, passive mechanical conformity and low power con-sumption on uneven terrain.

C. Controller

The microcontroller used is an Arduino Mega. It handles motor control, sensor fusion and obstacle avoidance by using data from the ultrasonic sensor.

D. Sensors

Table 3. Sensor specifications

Sensor	Purpose
DHT11	Measuring temperature and humidity, providing live readings
Ultrasonic	Obstacle detection

E. Power

The power source is a 12V 5200mAh LiPo battery

VI. CONTROL ARCHITECHTURE

A. Software Stack

At low-level, the Arduino Mega controls the motors through PWM. At high-level, the microcontroller uses data from the ultrasonic sensor to detect obstacles and correspondingly control the motors to avoid them.

B. Motor Control

Wheel velocities are control controlled using:

$$PWM = K_p(v_{ref} - v_{actual})$$

C. Sensor Fusion

Complementary filter for roll/pitch/yaw:

$$\theta = 0.98(\theta + gyro \cdot dt) + 0.02(acc)$$

VII. EDUCATIONAL IMPACT

This rover provides a hands-on-platform for learning CAD modelling and 3D printing. It also provided a deeper understanding of mechanical assembly, embedded elec-tronics, motor control and sensor fusion. Aligned with NEP 2020, it supports early exposure to multidisciplinary robotics. The complete assembled protype of the rover is shown in Figure 2.

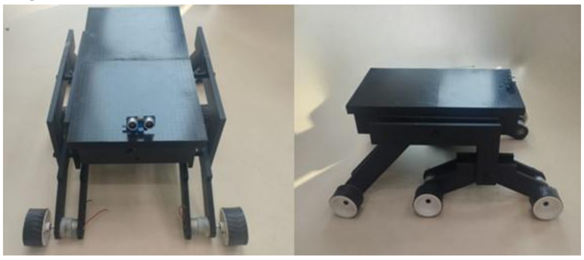

Fig. 2. Rover Prototype

IX. DISCUSSION

A. Strengths

This rover is completely 3D-printed, which allows for greater control over dimensions. The design is also modular, enabling any repairs required and future enhancements if required. It is also low-cost (< ₹20,000) and has a safe operating voltage (<12V). This makes it suitable for multi-semester learning.

B. Limitations

The body, made of PLA, will soften above 45°C. The motor torques also limit pay-load.

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