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ROCKER-BOGIE MECHANISM FOR DEFENCE APPLICATIONS

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Abstract:

This project presents a multi-functional defence robot developed using a rocker-bogie suspension mechanism to ensure smooth movement over rough and uneven terrains commonly found in border and warzone environments. The rocker-bogie structure, inspired by systems used in NASA rovers, provides excellent stability and strong obstacle-climbing capability, making it deal for remote military operations. The robot is powered by a NodeMCU based on ESP8266 microcontroller, which enables wireless communication. A metal detector module is integrated into chassis to detect landmines and buried metallic threats, thereby enhancing soldier safety through unmanned mine detection. For shortrange obstacle avoidance, IR sensors are mounted on the front of the robot to automatically identify objects, trenches, or barriers. A buzzer alarm system provides immediate audible alerts whenever a mine or obstacle is detected. To strengthen surveillance capabilities, the robot is equipped with a 360-degree night-vision camera that streams live video footage to a remote operator. This feature makes the system suitable for nighttime and low-visibility operations. Additionally, a laser pointer module is incorporated to simulate target marking similar to firearm aiming systems, assisting defence personnel in precise threat identification. The integrated design ensures semi-autonomous operation with multiple sensing and monitoring features. Overall, this low-cost defence robot effectively combines terrain navigation, mine detection, obstacle monitoring, and real-time surveillance. It offers a promising technological solution to reduce soldier risk and enhance operational efficiency in hazardous defence environments.

Keywords:

Rocker-Bogie Mechanism, Unmanned Ground Vehicle (UGV), Landmine Detection, NodeMCU (ESP8266), Obstacle Avoidance, Night-Vision Surveillance, Wireless Control, Laser Module.

1.INTRODUCTION

Technological advancements in robotics and embedded systems have significantly transformed the way dangerous and repetitive tasks are performed. Environments such as battlefields, disaster zones, and contaminated areas pose serious threats to human life. One of the most critical problems in such environments is the presence of landmines, which continue to cause casualties long after conflicts have ended. Traditional manual detection methods are slow, risky, and expensive.

Mobile robots provide an effective alternative by allowing remote operation and autonomous sensing. However, many conventional wheeled robots struggle to move efficiently on uneven or rocky surfaces. To overcome this limitation, specialized suspension mechanisms are required. The rocker-bogie mechanism, originally developed for planetary rovers, enables stable movement over rough terrain without using complex active suspension systems.

At the same time, the integration of Internet of Things (IoT) technology has enabled robots to communicate with cloud platforms, allowing users to monitor and control systems remotely. By combining a rocker-bogie based rover with IoT connectivity and multiple sensors, a powerful and versatile robotic platform can be developed.

This paper proposes an IoT enabled multi-function rover based on a rocker-bogie mechanism capable of landmine detection, obstacle avoidance, and real-time surveillance. The system is designed to be low-cost, modular, and suitable for real-world deployment.

2.LITERATURE SURVEY

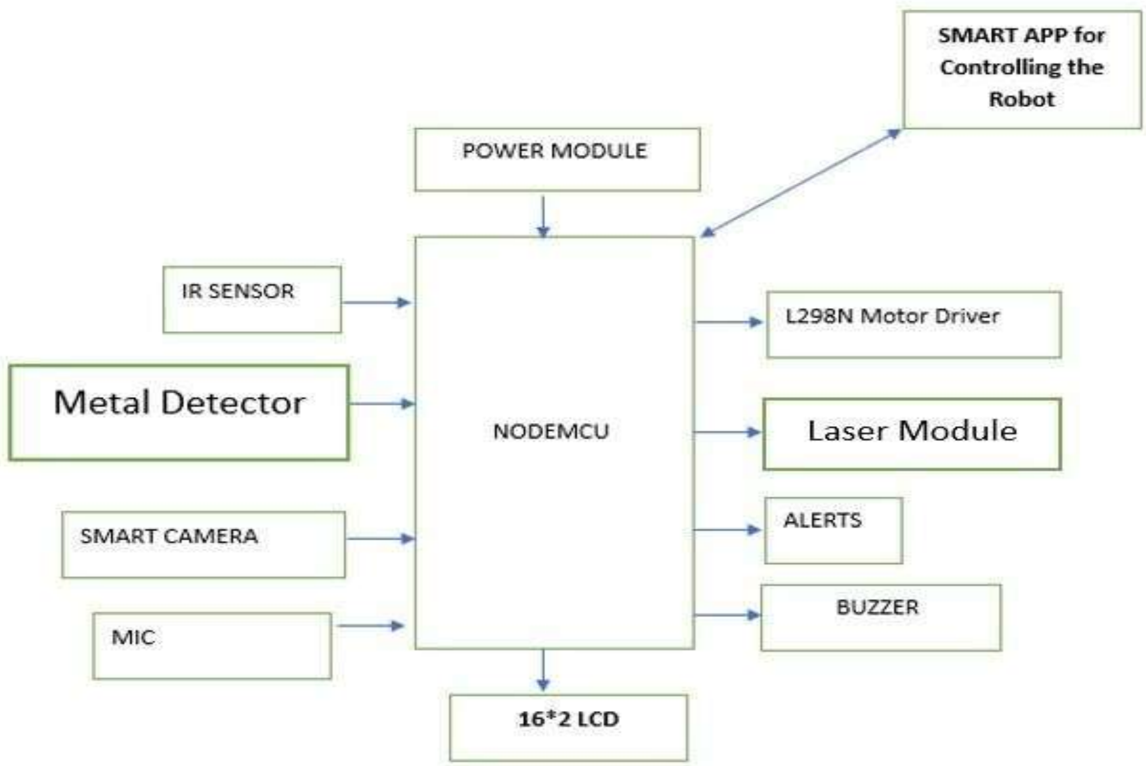
Several researchers have investigated the use of rocker-bogie mechanisms for robotic mobility in uneven terrain. Studies show that this mechanism allows robots to climb obstacles up to the radius of the wheel while maintaining stability. Planetary rovers developed by space agencies demonstrate the effectiveness of this design.

Various landmine detection robots have been developed using metal detectors, ground penetrating radar, and chemical sensors. While these systems provide good accuracy, they are often expensive and complex.

IoT-based surveillance robots using Wi-Fi enabled microcontrollers such as ESP8266 and ESP32 have also been widely reported. These robots typically integrate cameras and ultrasonic sensors for monitoring and obstacle detection. However, most existing systems focus on a single application such as surveillance or obstacle avoidance.

The proposed work differs from previous studies by integrating landmine detection, surveillance, and rough-terrain mobility into a single IoT-enabled rover, making it more practical and economical.

3.SYSTEM ARCHITECTURE



The overall system architecture consists of four major modules:

1. Mechanical Module
2. Control Module
3. Sensor Module
4. Communication and Cloud Module

3.1 Mechanical Module

The rover uses a six-wheel rocker-bogie mechanism. Each side of the rover contains a rocker arm and a bogie link connected through a pivot joint. This arrangement ensures that all wheels remain in contact with the ground, improving traction and stability.

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3.2 Control Module

NodeMCU (ESP8266) acts as the central controller. It processes sensor inputs, controls motor drivers, and manages communication with the Blynk IoT cloud.

3.3 Sensor Module

The rover is equipped with:

- Metal detector for landmine detection
- Ultrasonic sensor for obstacle detection
- Smart camera with night vision
- Servo motors for camera rotation

3.4 Communication and Cloud Module

Wi-Fi connectivity is used to connect the rover to the Blynk cloud platform, enabling remote monitoring and control through a smartphone.

Table I summarizes the main hardware modules and their roles within the system.

Table I: Hardware Components and Functions

Component	**Functionality**	**Interface Type**
NodeMCU (ESP8266)	NodeMCU is a Wi-Fi enabled microcontroller board widely used in IoT applications. It provides sufficient processing capability	Digital/Analog
Metal Detector	The metal detector works by generating an electromagnetic field and sensing changes caused by nearby metallic objects	Digital GPIO
Ultrasonic Sensor	The ultrasonic sensor measures distance by sending ultrasonic pulses and calculating echo time	Digital GPIO
Smart Camera with Night Vision	The camera provides live video streaming and includes infrared LEDs for low-light operation.	Digital

Motor Driver	Motor driver modules amplify control signals to drive DC motors	PWM(pulse width modulation)
IR sensor	An IR sensor (Infrared sensor) is an electronic sensor that detects objects or obstacles by using infrared light	Digital/Analog
Buzzer	A buzzer is an electronic audio signalling device that converts electrical energy into sound. It produces a beep or buzzing sound when voltage is applied	Digital
Laser	A laser is a device that produces a highly focused, coherent, and monochromatic beam of light using the process of stimulated emission	Digital
MIC	A microphone (MIC) is an input device that converts sound waves (acoustic energy) into an electrical signal	Digital/Analog
16*2 LCD	It is widely used with microcontrollers such as Arduino Uno, NodeMCU (ESP8266), and other embedded boards to show text like sensor values, system status, or messages	Parallel interface

4.METHODOLOGY

The implementation of the Rocker-Bogie robot centers on a four-wheeled suspension mechanism designed to maintain stability and traction across highly irregular terrains, including agricultural land, stairs, and inclined surfaces. Mechanically, the system utilizes two rockers and two bogie links to distribute weight evenly, allowing the vehicle to surmount obstacles up to 1.5 times the diameter of its wheels without the need for complex spring systems. The hardware architecture is driven by an ESP32 or NodeMCU microcontroller, which coordinates a suite of specialized components: an L298N motor driver for two DC gear motors, an ultrasonic sensor for obstacle avoidance, a metal detector for landmine identification, and an infrared (IR) camera for night vision surveillance. Electrical control is managed through Pulse Width Modulation (PWM) for speed regulation, while integrated sensors provide real-time feedback; for instance, the system is programmed to halt and trigger a buzzer alert if metal is detected or if an obstacle is sensed within 20 cm.

The methodology for developing this system follows a structured six-stage approach: mechanical design, hardware integration, sensor calibration, IoT communication setup, software programming, and rigorous field testing. During the mechanical phase, the chassis is balanced by placing the battery and controller at the center of gravity to prevent tilting during climbs. The software environment utilizes the Arduino IDE and Embedded C++ to manage the control logic, which handles simultaneous tasks such as Wi Fi-based live video streaming, sensor data transmission to a web dashboard, and two-way voice communication via an integrated microphone and speaker. The IoT implementation facilitates remote operation through platforms like Blynk or custom web servers, allowing for safe defense operations such as border surveillance and disaster rescue without human exposure. Finally, the system's efficacy is validated through experimental testing across diverse environments to evaluate performance parameters such as climbing capability, detection accuracy, and communication latency.

5.RESULTS AND DISCUSSION

Experimental testing showed that the rocker-bogie mechanism provides high stability and mobility on uneven terrain. The robot was able to move smoothly over rough surfaces such as small rocks, slopes, and irregular ground without losing balance. And the six-wheel configuration distributes the weight effectively, improving traction and enabling the robot to climb small obstacles with minimal difficulty.

The integrated metal detector module successfully identified buried metallic objects during testing. When a metallic object was detected, the buzzer alert was triggered immediately, providing a warning signal to the operator. This capability is useful for identifying landmines or metallic threats in hazardous zones without direct human involvement.

The IR sensors installed at the front of the robot demonstrated reliable short-range obstacle detection. The sensors detected objects within their operating range and allowed the system to alert the operator to avoid collisions. This feature improves the safety of the robot during navigation in cluttered environments.

The 360-degree night-vision camera provided continuous real-time video streaming to the remote operator. The camera maintained visibility in low-light conditions, allowing effective surveillance and monitoring during night operations. In addition, the laser pointer module enabled target marking, which can assist defence personnel in identifying suspicious locations during reconnaissance missions.

Although the system performed effectively during testing, some limitations were observed. The IR sensors have a limited detection range, which restricts obstacle identification at longer distances. The metal detector can detect only metallic objects and may not identify non-metallic explosive materials. Furthermore, the system relies on wireless communication, which may experience signal interruptions in remote or obstructed environments.

Overall, the results demonstrate that the proposed system is capable of performing terrain navigation, obstacle detection, landmine detection, and remote surveillance. The prototype shows potential as a low-cost unmanned ground vehicle capable of supporting defence operations and reducing the risk faced by soldiers in dangerous environments.

6.APPLICATIONS

6.1 Landmine Detection

The robot can be used to detect buried metallic landmines in war zones and border areas using the integrated metal detector. This allows defence personnel to identify dangerous explosive devices without directly entering hazardous regions, reducing the risk to soldiers.

6.2 Military Surveillance

The system supports remote monitoring through a 360-degree night-vision camera, enabling real-time observation of suspicious activities in restricted or sensitive locations. It can be deployed for border patrol, reconnaissance missions, and monitoring enemy movement in low-visibility conditions.

6.3 Disaster Monitoring

The robot can operate in disaster-affected areas such as collapsed buildings, earthquake zones, or hazardous environments where human access is difficult or unsafe. It can transmit live video to rescue teams, helping them assess the situation and plan rescue operations.

6.4 Search and Rescue Operations

The robot can assist rescue teams in locating trapped victims in dangerous environments such as mines, tunnels, or debris after natural disasters. Its ability to move over uneven terrain and send real-time video helps rescuers identify survivors and reach them more safely and efficiently.

7.CONCLUSION

This work shows how rocker bogie system works on different surfaces. As per the different weight acting on link determines torque applied on it. By assuming accurate stair dimensions, accurately dimensioned rocker bogie can climb the stair with great stability. The design and manufactured model can climb the angle up to 45̊. Also we tested for the Web cam with AV recording mounted on rocker bogie system and found satisfactorily performance obtains during this test camera has rotated around 360̊. During stair climbing test for length less than 375 mm (15 inch) system cannot climb the stair. It can be possible to develop new models of rocker bogie which can climb the stairs having low lengths.

8. AUTHORS AND CONTRIBUTIONS

Y. Balaji provided overall guidance, supervision, and provided technical suggestions, assisted in troubleshooting technical issues and refined the project documentation and presentation. T. Suneetha responsible for overall project planning, system architecture design, implementation and document preparation. B.Manjunatha Achari handled circuit design, sensor connections and NodeMCU(ESP8266) interfacing. S. Kousar Yasmeen developed the code and ensured real time monitoring. V. Madhuri and T. Sathvika managed the Wi-Fi configuration, contributed to literature review.

CONFLICTS OF INTEREST

The authors declare that they have no known financial or personal relationships that could have appeared to influence the work reported in this paper.

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