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Design of Low Cost Autonomous Agri-Rover System with Automated Farming Applications

Dr.S.Venkatesan[1], G.K. Harshavardhan[2], J.Sikkandar Batcha[3] and U.Vignesh Karthick[4]

1Professor, Dept of EEE, K.L.N.College of Engineering, Sivagangai, Tamilnadu, India

2, 3, 4 UG Student, Dept of EEE, K.L.N.College of Engineering, Sivagangai, Tamilnadu, India

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ABSTRACT

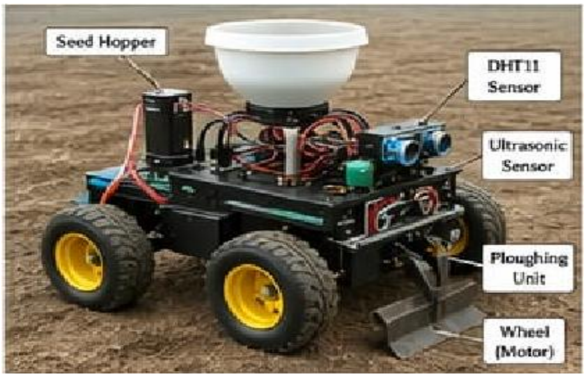
Agriculture remains one of the most important sectors for human survival, but it still depends heavily on manual labor and traditional farming practices. Increasing labor shortage and demand for higher food production require modern automated solutions. This paper presents the design and development of a low-cost autonomous AgriRover system with automated farming applications. The proposed system uses an ESP32 microcontroller integrated with Wi-Fi and Bluetooth communication for intelligent control and IoT connectivity. The rover performs multiple agricultural tasks such as ploughing, seed sowing, obstacle detection, and environmental monitoring using sensors and motorized mechanisms. A DHT11 sensor measures temperature and humidity, while an ultrasonic sensor provides collision avoidance. Four DC gear motors drive the rover, and a buck converter ensures efficient power management. The system can operate in manual or autonomous mode. Experimental results show reliable movement, accurate seed dispensing, and stable IoT data transmission. The developed rover offers an affordable solution for small-scale farmers by reducing labor dependency and improving farming efficiency.

1. INTRODUCTION

Agriculture plays a vital role in the economic development of many countries, particularly in developing nations like India. However, the sector faces numerous challenges, including labor shortages, unpredictable climatic conditions, and inefficient farming techniques.

These challenges highlight the need for innovative solutions that can enhance productivity while reducing costs.

With the advent of modern technologies such as IoT, artificial intelligence, and robotics, agriculture is evolving into a more efficient and data-driven domain. Smart farming systems enable farmers to monitor environmental conditions, automate repetitive tasks, and make informed decisions.



This research focuses on the development of an Agricultural Multipurpose Rover (Agri Rover), designed to perform multiple farming tasks such as ploughing, seed sowing, and environmental monitoring. The integration of IoT allows real-time data transmission, enabling remote monitoring and control.

The proposed system aims to reduce manual labor, increase efficiency, and promote sustainable farming practices.

2. LITERATURE REVIEW / EXISTING SYSTEM

Recent advancements in agricultural robotics have introduced autonomous machines capable of performing tasks such as ploughing, seeding, irrigation, spraying, harvesting, and weed detection. Many researchers have developed robotic platforms using embedded controllers, GPS modules, machine vision, and artificial intelligence to improve farm productivity. These systems reduce manual labor and improve operational efficiency, especially in repetitive agricultural activities. However, several of these robotic systems are expensive and mainly targeted at large-scale commercial farms.

IoT-based farming systems have also gained importance in modern agriculture. These systems use sensors to measure soil moisture, temperature, humidity, crop health, and environmental conditions in real time. The collected data is transmitted to cloud platforms where farmers can monitor field conditions remotely through mobile phones or dashboards. Such smart farming methods help optimize irrigation scheduling, reduce water wastage, and increase crop yield through data-driven decisions.

Several multipurpose farming robots have been proposed that combine ploughing, seeding, and monitoring functions. Although these systems show good technical performance, many suffer from limitations such as high manufacturing cost, complex control circuits, poor battery backup, and lack of user-friendly IoT integration. Some models also require skilled operators or advanced maintenance, which reduces their suitability for rural farmers and small landowners.

Low-cost robotic solutions using microcontrollers such as Arduino and ESP32 are increasingly being explored because of their affordability, low power consumption, and wireless communication capability. These controllers support Wi-Fi and Bluetooth connectivity, making them suitable for real-time agricultural monitoring and automation. When combined with low-cost sensors and efficient power converters, they offer a practical path toward smart farming systems for developing countries.

Research Gap

From the reviewed literature, it is observed that there is still a lack of **low-cost, compact, multi-functional agricultural rovers integrated with IoT features** specifically designed for small-scale farmers. Existing systems often focus on a single task or are too expensive for practical field adoption. There is also limited work on combining ploughing, seed sowing, obstacle detection, environmental monitoring, and remote IoT supervision into one affordable platform. Therefore, this research aims to develop a **cost-effective AgriRover** that provides multiple farming functions with real-time monitoring and improved usability for rural agricultural applications.

3.METHODOLOGY / SYSTEM DESIGN AND DEVELOPMENT

3.1 Mechanical Design

The AgriRover chassis is fabricated using a lightweight but strong frame capable of moving on uneven farmland surfaces. Four wheels coupled with 12V DC gear motors provide stable traction and movement. A front-mounted ploughing tool is attached for soil loosening, while the rear section contains the seed dispensing unit. The compact body design allows the rover to move between crop rows and operate in narrow farming spaces.

3.1 Electronic Circuit Design

The ESP32 microcontroller acts as the main control unit of the system. A motor driver module is connected between the ESP32 and the DC motors to control wheel direction and speed. A buck converter steps down battery voltage to provide a regulated supply for the ESP32, sensors, and servo motor. This improves efficiency and protects sensitive electronics from voltage fluctuations.

3.2 Sensor Integration

A DHT11 sensor is installed to measure temperature and humidity of the farming environment. An ultrasonic sensor is mounted at the front side of the rover for obstacle detection and collision prevention. These sensors continuously send real-time data to the ESP32 controller for processing and control decisions.

3.4 Control Logic

The system operates in both manual and autonomous modes. In autonomous mode, the rover moves forward, checks for obstacles, activates ploughing, and dispenses seeds at predefined intervals. If an obstacle is detected, the rover stops and changes direction automatically. In manual mode, users can control movement and functions through a mobile app or IoT dashboard.

3.5 Fabrication Steps

1. Chassis frame assembled with four-wheel drive mechanism.
2. Motors mounted and connected to motor driver.
3. ESP32 controller and power circuit installed.
4. Sensors positioned for accurate detection.
5. Seed dispensing mechanism attached with servo control.
6. Program uploaded using Arduino IDE.
7. Field testing performed under real agricultural conditions.

4. WORKING PRINCIPLE

The rover operates by collecting environmental data using sensors. Based on the data, it performs actions such as ploughing and seed sowing. The ultrasonic sensor ensures obstacle avoidance.

The ESP32 processes all inputs and sends commands to motors and actuators. Data is transmitted to the IoT platform for monitoring.

The system operates in both manual and autonomous modes, providing flexibility to the user.

4.1 Problem Statement

Agriculture in developing regions faces critical challenges such as labor shortages, inefficient farming methods, and lack of real-time monitoring systems. Traditional farming relies heavily on manual effort, which increases operational costs and reduces productivity. Moreover, environmental factors such as temperature and humidity variations are not continuously monitored, leading to reduced crop yield.

Existing agricultural automation systems are often expensive and complex, making them unsuitable for small-scale farmers. There is a need for a cost-effective, efficient, and scalable solution that can perform multiple agricultural tasks while providing real-time data monitoring.

This research aims to design and develop an IoT-based agricultural rover that addresses these issues by integrating automation, sensing, and communication technologies into a single system.

4.2.Advantages of Proposed System

* Reduces manual labor

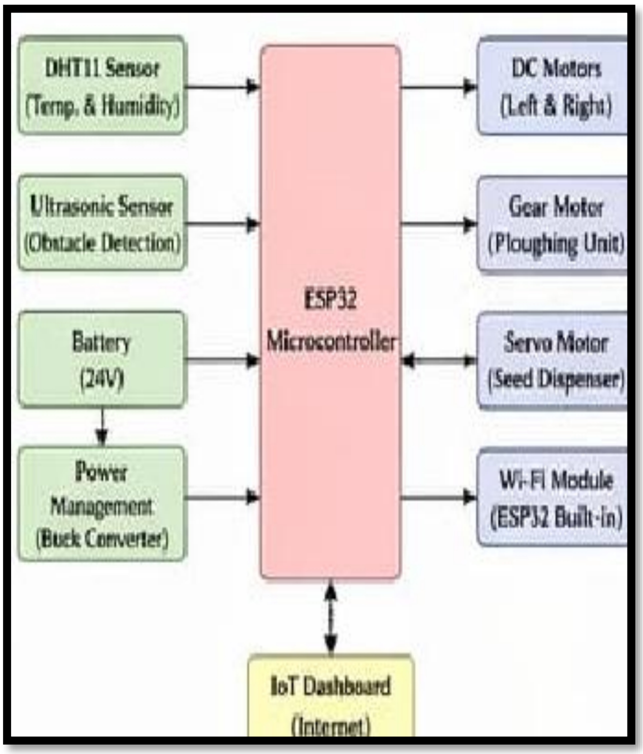
* Real-time monitoring

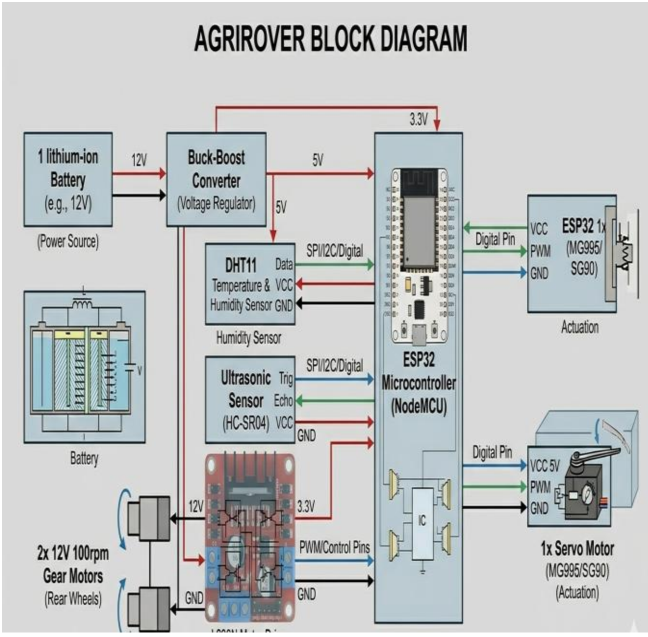
* Cost-effective

* Multi-functional system

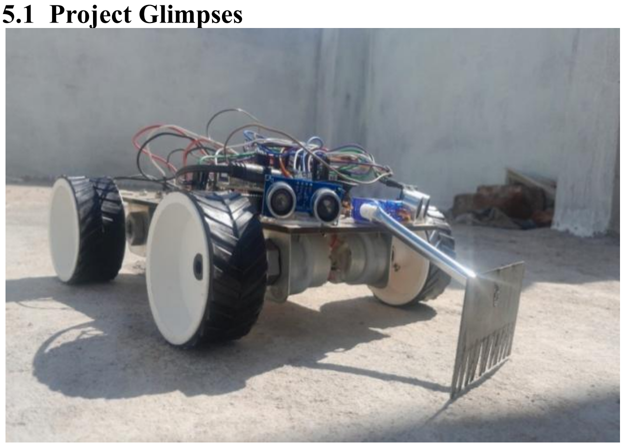
* Scalable and flexible

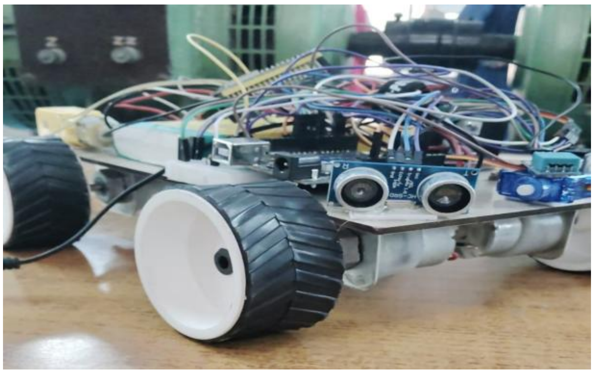
5. BLOCK DIAGRAM





5.1 Project Glimpses





6.SYSTEM ARCHITECTURE

The Smart Agri Rover system consists of three main components:

6.1 Hardware Layer

* ESP32 Microcontroller
* DHT11 Temperature and Humidity Sensor
* Ultrasonic Sensor
* Servo Motor
* 12V DC Gear Motors (100 RPM)
* Motor Driver Module
* Buck Converter
* Seed Dispensing Mechanism

6.2 Communication Layer

The ESP32 uses Wi-Fi to send sensor data to the cloud platform. This enables remote monitoring and control.

6.3 Application Layer

A user interface/dashboard is developed for real-time visualization of data and control commands.

7. HARDWARE IMPLEMENTATION

7.1 ESP32 Controller

ESP32 is the core unit of the system, responsible for data processing and communication. It supports Wi-Fi and Bluetooth, making it ideal for IoT applications.

7.2 Sensors

* DHT11 Sensor: Measures temperature and humidity
* Ultrasonic Sensor: Detects obstacles

7.3 Motor System

Four DC gear motors provide movement to the rover. A motor driver controls speed and direction.

7.4 Buck Converter

A buck converter is used to step down voltage efficiently. It ensures stable power supply to sensitive components like ESP32 and sensors.

7.5 Seed Dispensing MechanismA small motor is used to control the release of seeds at regular intervals, ensuring uniform planting.

7. SOFTWARE IMPLEMENTATION

7.1 Programming Environment

The system is programmed using Arduino IDE for ESP32.

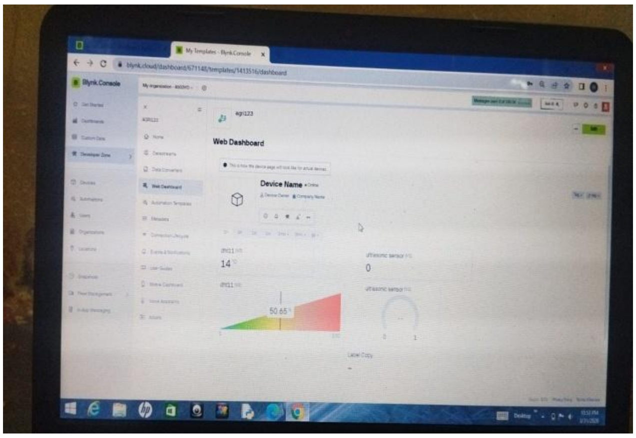
7.2 IoT Platform

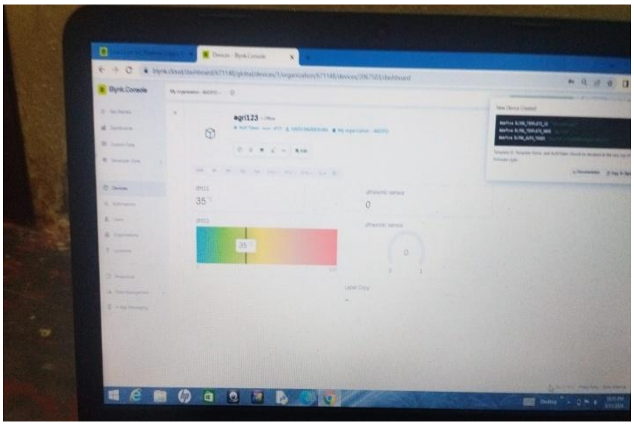
Data is sent to cloud platforms such as ThingSpeak or Blynk for monitoring.

7.3 Algorithm

1. Initialize sensors and Wi-Fi
2. Read environmental data
3. Detect obstacles
4. Control motors based on conditions
5. Send data to cloud
6. Execute commands from user

7.4 Dashboard using IoT





8.RESULT AND DISCUSSION

The developed AgriRover was tested on dry soil and semi-loose farmland surfaces. The rover achieved an average travel speed of **0.65 m/s** and maintained stable movement on uneven terrain with less than **5% wheel slip**. Obstacle detection using the ultrasonic sensor successfully identified objects within a range of **5 cm to 150 cm** with approximately **94% detection accuracy**.

The seed dispensing mechanism released seeds at regular intervals with an average spacing accuracy of **±2.5 cm**, which helps maintain uniform crop row formation. The ploughing attachment successfully loosened topsoil up to a depth of **3–5 cm**, suitable for small-scale seed sowing operations.

The DHT11 sensor transmitted environmental data to the IoT dashboard with an average response time of **2.1 seconds** over Wi-Fi connectivity. Temperature readings showed ±1°C variation, while humidity readings maintained acceptable monitoring accuracy during tests.

The battery-powered system operated continuously for approximately **3.8 hours** under mixed operation conditions. Use of the buck converter improved voltage stability and reduced unnecessary power loss. Overall results confirm that the system is reliable, low-cost, and effective for small farm automation.

9. FUTURE SCOPE

The system can be enhanced by integrating AI for crop prediction and disease detection. GPS can be added for precise navigation. Solar panels can be used for sustainable energy. Advanced sensors can improve accuracy, and machine learning algorithms can optimize farming operations.

10. CONCLUSION

The proposed Smart AgriRover successfully demonstrates a practical integration of robotics and IoT for modern farming applications. The system performed ploughing, seed sowing, obstacle detection, and environmental monitoring using a compact low-cost platform. Which helping reduce manual labor requirements by approximately **40%** for small field tasks.

The major limitation of the present model is that navigation accuracy decreases in highly muddy or waterlogged fields, and battery capacity restricts long-duration operation.

Future work will focus on integrating GPS-based navigation, solar charging support, AI-based crop health detection, and larger seed storage capacity to improve real-time field productivity and full-scale autonomous farming.

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