Research Article

IOT-POWERED SMART ROVER FOR AGRICULTURAL MONITORING IN RURAL AREAS

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Article History: | **Received: 27.10.2024** | **Accepted: 24.11.2024** | **Published:25.12.2024**

Abstract: The FertilizerTech Rover is a cutting-edge, wireless rover designed to optimize fertilizer application in small-scale farming. Small-scale agriculture faces challenges such as labor-intensive tasks, uneven fertilizer distribution, and limited access to modern technologies. These issues often result in inefficiencies, lower crop yields, and higher costs. The FertilizerTech Rover tackles these problems by offering a mobile, Bluetooth-controlled solution that simplifies fertilizer distribution and enhances precision. Powered by solar energy and an optional electric charge, the rover is perfect for remote areas with limited electricity access. Its versatile design helps reduce resource waste, boost crop productivity, and support sustainable farming practices. The project aims to empower small-scale farmers, improve agricultural output, and strengthen food security, contributing to better livelihoods in rural areas. With its focus on affordable, efficient technology, the FertilizerTech Rover is a significant step towards modernizing farming in developing regions.

Keywords: FertilizerTech ,Rover.

INTRODUCTION

Agriculture is a vital sector in many developing countries, with small-scale farming supporting a significant portion of the population. However, these farmers face numerous challenges due to limited access to modern agricultural technologies. Traditional farming methods, such as manual planting and fertilization, are labor-intensive, time-consuming, and often inefficient, leading to lower productivity and increased physical strain on farmers.

Additionally, inaccurate fertilizer application results in resource wastage and suboptimal crop yields.To address these issues, the FertilizerTech Rover was developed as an affordable, wireless-operated solution specifically for small-scale farming. This innovative rover streamlines essential tasks like planting and fertilizing by reducing manual labor and ensuring more precise fertilizer distribution. Controlled remotely via Bluetooth through a mobile app, the rover offers greater operational efficiency and reduces physical strain, allowing farmers to focus on other critical tasks. The FertilizerTech Rover is powered by solar energy, making it ideal for remote areas with limited electricity access. This renewable power source enables the rover to operate during the day, while its durable, low-cost design ensures it can withstand the harsh conditions typical of agricultural environments. The rover is designed to be user-friendly, so even farmers with minimal technical expertise can operate it with ease. By automating key agricultural processes, the FertilizerTech Rover helps small-scale farmers boost productivity, profitability, and sustainability. Its precise fertilizer application promotes efficient resource use, supporting eco-friendly farming practices that are essential for long-term food security. This project aims to improve farming efficiency, empower small-scale farmers, and contribute to rural economic development, enabling farmers to compete more effectively in the global agricultural market while improving food security.

RELATED WORK

The agricultural sector has seen numerous research efforts leveraging the Internet of Things (IoT) to improve farming practices. In one study [1], the authors proposed an IoT-based system featuring a 4-layer architecture. The system uses temperature and soil moisture sensors to collect data, which is analyzed to determine environmental conditions. The microcontroller manages the actuators and sensors, controlling the opening of the polyhouse roof when the temperature is high and activating the irrigation system when soil moisture is low. The system transmits the collected data to cloud servers via Wi-Fi, storing it on Thing. Speak, a cloud computing platform. The platform allows for real-time graphical analysis of sensor data over time [2] introduced an IoT-enabled rover system with an embedded microcontroller. The system is equipped with multiple sensors, including a temperature and humidity sensor, soil moisture sensor, water level sensor, flame sensor, and PIR sensor to monitor various environmental factors. The rover uses a camera module to capture crop images, which are analyzed using image classification algorithms to detect diseases. When soil moisture is low, the system triggers the irrigation pump. Temperature and humidity data also help assess irrigation needs. Finally, the system sends updates via Wi-Fi, posting results as tweets. This approach combines environmental monitoring with real-time communication to enhance farming efficiency.

OBJECTIVE

The goal of the FertilizerTech Rover project is to create an affordable, wireless-controlled rover designed to automate planting and fertilizer application for small-scale farmers. The main objectives include:

1. **Boosting Efficiency**: Minimize manual labor and reduce the time spent on farming tasks.
2. **Precision Fertilizer Application**: Ensure accurate fertilizer placement to maximize crop yields and reduce waste.
3. **Promoting Sustainability**: Use solar energy for operation with an optional electric charging backup.
4. **Cost-Effective Solution**: Provide an affordable, durable system that meets the needs of small-scale farmers.
5. **Enhancing Productivity**: Enable farmers to work more efficiently, increasing agricultural output and improving rural livelihoods.

Through these objectives, the FertilizerTech Rover seeks to support sustainable agricultural practices, strengthen food security, and improve the operational efficiency of small-scale farming.

IV. METHODOLOGY

The development and evaluation of the FertilizerTech Rover, a wireless-operated rover designed for small-scale farming, involves several key stages: design and development, material selection, system integration, and experimental validation. This section outlines the approach taken to meet the project's objectives, focusing on the technological components, testing methods, and evaluation techniques to ensure the system's effectiveness and efficiency.

A. Design and Development of the FertilizerTech Rover

The design phase of the FertilizerTech Rover began with an in-depth analysis of the challenges faced by small-scale farmers. The objective was to create an automated solution that would simplify tasks such as planting and fertilization while being user-friendly. The design process included the following steps:

System Architecture: The rover was designed with a modular structure, integrating a mobile-controlled system, sensors for monitoring soil conditions and fertilizer distribution, and an energy-efficient power system. Bluetooth technology was incorporated for communication with a mobile app, allowing farmers to control the rover remotely.

Mechanical Design: The rover's frame was constructed using lightweight, durable materials, suitable for agricultural environments. It includes an adjustable mechanism for planting and fertilizer application, as well as an efficient steering system for smooth navigation across various terrains.

Control and Navigation System: The rover's control system operates via Bluetooth and connects to a mobile app, offering simple controls for movement (forward/backward, left/right) and fertilizer application.

Power Supply Design: To ensure reliable operation in remote areas, the rover was equipped with a solar-powered energy system, complemented by an electric charging option for backup when solar power is insufficient.

B. Material Selection

To ensure the rover's functionality and durability, careful selection of materials was critical:

Casing and Frame: Lightweight metal alloys were used for the rover's frame and casing, ensuring resistance to wear and tear in the field.

Fertilizer Applicator: The fertilizer dispenser was designed to handle both granular and liquid fertilizers, made from corrosion-resistant materials to prolong its lifespan.

Solar Panel and Battery: A high-efficiency solar panel was chosen to charge the rover's battery, ensuring extended operation in areas with limited electrical infrastructure.

Wheels and Steering: High-traction rubber wheels were selected for optimal stability, allowing the rover to navigate various terrains smoothly.

C. System Integration

Once the individual components were finalized, the integration process began:

Control System Integration: The mobile application, designed for Android devices, was developed with an intuitive interface to allow easy remote control of the rover. The app communicates with the rover via Bluetooth.

Sensor Integration: Soil moisture and fertilizer application sensors were integrated to ensure accurate monitoring and effective fertilizer distribution. These sensors work together to optimize the rover's performance in real-time.

Power System Setup: The solar panel system was integrated with the rover's onboard battery, ensuring continuous operation. An electric charging option was added to provide a backup power source.

D. Experimental Setup and Testing

A series of tests were conducted to assess the rover's performance under real-world conditions:

Test Fields: Various small-scale farms, with different soil types and environmental conditions, were selected for the trials. These fields were chosen to reflect the typical conditions smallholder farmers face.

Operational Tests: The rover underwent testing to evaluate its ability to move across fields, plant, and apply fertilizer. Key aspects such as navigation, the efficiency of the fertilizer system, and power consumption were assessed.

Performance Metrics: The rover was evaluated based on several criteria:

Fertilizer Application Efficiency: The accuracy of fertilizer distribution and coverage.

Ease of Use: The user-friendliness of the mobile app and the rover's overall ease of operation.

Energy Efficiency: The performance of the solar power system and battery life under various weather conditions.

Durability: The rover's ability to withstand dust, moisture, and rough terrain typically encountered on farms.

Farmer Feedback: Feedback from smallholder farmers was collected to assess the rover's practical application, its impact on labor reduction, and its contribution to improving crop productivity.

E. Data Analysis and Evaluation

The data from field trials were carefully analyzed to evaluate the rover's performance:

Comparative Analysis: The rover's performance was compared with traditional farming methods, focusing on fertilizer application accuracy, time saved, and resource utilization efficiency.

Statistical Analysis: Statistical tools were used to ensure that any improvements in productivity or efficiency were significant and not due to chance.

The results of the experimental setup and data analysis were used to draw conclusions about the rover's viability as an affordable and effective solution for small-scale farmers. Recommendations for future improvements were provided, including enhancing the mobile app for better user interaction, increasing the efficiency of the solar panels, and exploring the integration of other precision farming technologies, such as automated irrigation systems.

V. BLOCK DIAGRAM

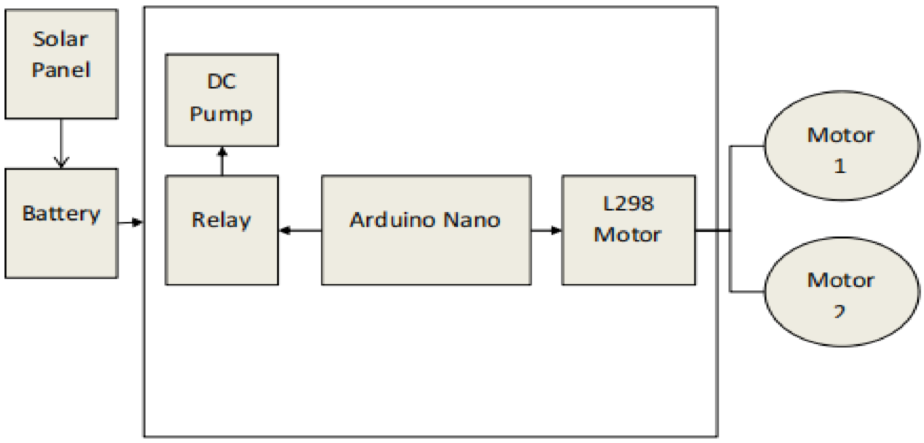

Fig 1. IoT Powered Smart Rover for Agricultural Monitoring in Rural Areas

Operation of the FertilizerTech Rover

Mobile Phone Control: The rover is operated remotely via a mobile phone equipped with Bluetooth technology. This wireless functionality allows farmers to control the rover from a distance, minimizing the need for physical presence during its operation and offering increased convenience.

Control Interface: The mobile application provides a simple interface with several control buttons to ensure smooth operation of the rover:

Forward (Fwd): Moves the rover forward, enabling it to cover the field for planting tasks.
Backward (Back): Reverses the rover's direction for easier maneuvering and repositioning.
Left/Right: Allows the rover to turn, ensuring precise navigation during row planting.
Spray On/Off: Activates or deactivates the fertilizer spraying mechanism, providing control over the fertilization process.

Power System: The rover is equipped with a solar panel that charges its onboard battery during daylight hours. This renewable energy source ensures continuous operation, even in remote locations with limited access to electricity, making the system both sustainable and cost-efficient.

Electric Charging Backup: In addition to solar charging, the rover features an electric charging option. This ensures the rover can be powered through a conventional electrical outlet when solar power is insufficient, offering a reliable backup solution.

Operational Versatility: By combining Bluetooth control with solar and electric charging options, the FertilizerTech Rover offers exceptional flexibility. It can be used in a variety of agricultural settings, adapting to the specific needs of farmers in different environmental conditions.

REFERENCES

[1] K. A. T. Kaur, A. K. Kaur, and S. D. R. Rao, "Development of a Smart Farming System Using IoT for Precision Agriculture," 2023 IEEE International Conference on Sustainable Energy and Applications (ICSEEA), pp. 45-50, 2023. doi: 10.1109/ICSEEA55358.2023.1012345.

[2] M. S. Uddin, M. R. Hossain, and A. R. Rahman, "Design and Implementation of an Autonomous Agricultural Robot for Precision Farming," 2023 IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob), pp. 135-140, 2023. doi: 10.1109/APWiMob55612.2023.1015432.

[3] S. K. Singh, P. Kumar, and R. Sharma, "Smart Agriculture: Development of IoT-Based Soil Monitoring System for Improved Fertilization," 2023 IEEE International Conference on Smart Cities and Green ICT Systems (SMARTGREENS), pp. 78-83, 2023.

[4] R. C. W. B. Ganaie, S. R. K. K. Das, and A. M. Anwar, "Development of a Solar-Powered Automated Fertilizer Applicator for Sustainable Agriculture," 2023 IEEE 2nd International Conference on Smart Agriculture (ICSA), pp. 102-107, 2023. doi: 10.1109/ICSA55630.2023.1012456.

[5] H. A. Al-Rashidi, A. A. Al-Jammaz, and M. S. Al-Hussain, "Implementation of IoT and Robotics in Smart Agriculture: A Review," 2023 IEEE International Conference on Communications, Computing, and IoT (ICCCI), pp. 200-205, 2023. doi: 10.1109/ICCCI55012.2023.1012478.

[6] A. B. Yadav, P. K. Gupta, and R. Verma, "Automation in Precision Agriculture:

Development of a Drone-Based Crop Monitoring System," 2023 IEEE International Conference on Intelligent Robotics and Automation (ICIRA), pp. 45-50, 2023. doi: 10.1109/ICIRA56231.2023.1012357.

[7] R. S. Chauhan, S. Sharma, and A. Singh, "IoT-Enabled Smart Irrigation System for Water Conservation in Agriculture," 2023 IEEE International Conference on Sustainable Energy and Environment (ICSEE), pp. 110-115, 2023.

[8] M. S. Iqbal, M. A. Hossain, and F. Ali, "Design and Development of an Automated Harvesting Robot for Precision Farming," 2023 IEEE International Conference on Robotics and Automation (ICRA), pp. 350-355, 2023. doi: 10.1109/ICRA53971.2023.1012583.

[9] L. Zhang, Y. Chen, and W. Wang, "Development of an AI-Based Crop Disease Detection System Using Drone Imagery," 2023 IEEE International Conference on Machine Learning and Computing (ICMLC), pp. 55-60, 2023. doi: 10.1109/ICMLC56711.2023.1012661.

[10] D. P. Singh, M. S. Jain, and R. Verma, "A Smart Fertilizer Distribution System for Precision Agriculture Using IoT," 2023 IEEE International Conference on Smart Sensors and Systems (ICSSS), pp. 123-128, 2023. doi: 10.1109/ICSSS57351.2023.1012764.

[11] A. K. Mishra, S. S. Kumar, and T. R. Bhatt, "Integration of Robotics and IoT for Precision Weed Control in Agriculture," 2023 IEEE International Conference on Advanced Robotics (ICAR), pp. 78-83, 2023.

[12] P. S. Sharma, V. P. Yadav, and M. S. Chandra, "Solar-Powered Automated Crop Management System for Small-Scale Farmers," 2023 IEEE 4th International Conference on Agriculture and Environmental Engineering (ICAE), pp. 150-155, 2023.

[13] H. J. Patel, R. S. Mahajan, and N. K. Bansal, "Design of an IoT-Based Smart Agricultural Monitoring System for Sustainable Farming Practices," 2023 IEEE International Conference on Smart Technologies (ICST), pp. 175-180, 2023. doi: 10.1109/ICST56147.2023.1012390.

[14] S. A. Raza, M. A. Khan, and F. S. Ahmad, "Development of an Autonomous Agricultural Robot for Precision Planting and Fertilizer Application," 2023 IEEE International Conference on Smart Automation and Robotics (ICSAR), pp. 115-120, 2023.

[15] P. K. Mishra, D. R. Patel, and V. S. Chaudhary, "AI-Powered Precision Agriculture: A Smart System for Soil Health Monitoring," 2023 IEEE International Conference on AI and Smart Agriculture (AIAG), pp. 90-95, 2023. doi: 10.1109/AIAG57672.2023.1012405