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Intelligent Farming System Using IoT with Automated Robot for Ploughing Seeding and Sprinkling Tasks

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Abstract

The increasing demand for agricultural productivity and labor efficiency has driven the adoption of smart farming technologies, with global precision agriculture expected to grow at over 13% annually and labor shortages affecting nearly 40% of farming operations in developing regions. Additionally, inefficient traditional practices contribute to reduced yield and increased resource wastage, emphasizing the need for automation in agriculture. These environments demand intelligent, multi-functional machines capable of performing continuous field operations with accuracy and consistency. Traditional farming methods rely heavily on manual labor and separate machinery for each task, leading to increased time consumption, higher costs, inconsistent seed placement, and inefficient water usage. Furthermore, conventional systems lack real-time monitoring and remote-control capabilities, reducing overall productivity and adaptability to changing conditions. To address these challenges, the proposed IoT Agricultural Robot for Automatic Ploughing, Seeding, and Sprinkling utilizes the ATmega328 microcontroller integrated with an IoT module to develop a smart and automated farming solution. The robot is equipped with DC geared motors for soil ploughing, a seed dispensing mechanism for uniform seed placement, and an automated sprinkler system for irrigation. The IoT module enables remote control and real-time monitoring of the robot's operations, allowing farmers to manage field activities efficiently. The system operates on a regulated power supply and is programmed using embedded C through the Arduino IDE, ensuring reliable performance. This integrated approach enhances agricultural efficiency, reduces labor dependency, optimizes resource utilization, and supports the development of sustainable and smart farming practices.

Keywords: Agricultural Automation, Arduino IDE, DC Geared Motors, Internet of Things, Precision Farming, Seed Dispensing System, Smart Irrigation, Soil Ploughing, Wireless Control

1. Introduction

The increasing demand for higher agricultural productivity and improved labor efficiency has accelerated the adoption of smart farming technologies worldwide [1]. Global precision agriculture is expected to grow at over 13% annually, driven by the need to optimize crop yield and resource utilization. At the same time, labor shortages are impacting nearly 40% of farming operations in developing regions, creating significant challenges for timely and efficient agricultural activities [2]. Additionally, inefficient traditional practices often lead to reduced productivity and increased wastage of resources such as water and seeds. These trends highlight the growing importance of intelligent, automated solutions capable of performing multiple farming operations with accuracy and consistency [3].

In modern agricultural environments, there is a strong need for systems that support automation, real-time monitoring, and efficient field management.

Traditional farming methods rely heavily on manual labor and the use of separate machinery for different operations such as ploughing, seeding, and irrigation [4]. This approach is time-consuming, labor-intensive, and often results in inconsistent outcomes due to human error. Farmers must invest in multiple machines, increasing operational costs and complexity [5]. Additionally, conventional methods do not ensure uniform seed placement or efficient water distribution, which can negatively impact crop growth and yield [6]. The lack of integration and automation further limits the ability to adapt quickly to changing environmental conditions, reducing overall farming efficiency.

In real-time scenarios, these limitations lead to several critical challenges affecting productivity and sustainability. Manual operations can cause uneven ploughing, irregular seed distribution, and inefficient irrigation, resulting in poor crop development. Labor shortages further delay farming activities, impacting seasonal cycles and overall yield [7]. The absence of real-time monitoring and remote control prevents farmers from managing operations efficiently, especially in large or remote fields. Additionally, excessive use of water and seeds increases resource wastage and operational costs. These challenges highlight the need for an intelligent, IoT-based agricultural system capable of automating multiple farming processes, ensuring precision, reducing labor dependency, and enhancing overall efficiency in modern agriculture.

2. Literature Survey

Kassir et al. [8] proposed a real-time monitoring and control system for autonomous agricultural robot trajectories using an edge-fog computing architecture. MacEachren et al. [9] proposed a geovisualization framework for knowledge construction and decision support that integrated spatial data visualization with analytical tools.

Endsley et al. [10] proposed a theoretical framework for situation awareness that defined perception, comprehension, and projection stages in dynamic environments. Parent et al. [11] proposed the MurMur project for modeling and querying multi-representation spatio-temporal databases that supported complex spatial and temporal data management.

Golab et al. [12] proposed data stream management techniques for handling continuous and high-velocity data in real-time systems. Kumar et al. [13] proposed a review on the impact of wireless sensor networks in precision agriculture, focusing on data acquisition, monitoring, and automation. Dincă et al. [14] proposed a comparative analysis between in-memory and on-disk databases, focusing on architectural design, performance, and use cases.

Benos et al. [15] proposed a systematic review on human–robot interaction in agriculture, analyzing interaction techniques, usability, and system design challenges. Huuskonen et al. [16] proposed an augmented reality-based system for supervising multi-robot operations in agricultural fields. Adamides et al. [17] proposed a heuristic evaluation of user interfaces for semi-autonomous agricultural robot sprayers, focusing on usability and human interaction.

Mallas et al. [18] proposed a comparative analysis of performance between experts and farmers when operating agricultural robots. Capallera et al. [19] proposed a systematic review of human-vehicle interaction systems to support driver situation awareness in automated vehicles. Boehm et al. [20] proposed a real-time geospatial visualization system to enhance situation awareness through dynamic data representation.

Fuchs et al. [21] proposed adaptive consoles for supervisory control of multiple unmanned aerial vehicles that adjusted interface elements based on operational context. T Friedrich et al. [22] proposed urgency-based color-coding

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techniques to support visual search in supervisory control displays for unmanned aircraft systems. Hoang et al. [23] proposed MobilityDuck, a mobility data management system using DuckDB for efficient storage and querying of mobility datasets.

3. Proposed System

Figure 1 illustrates the architecture of an agricultural robot designed for automatic ploughing, seed dispensing, and watering operations. The system is divided into two main sections: transmitter and receiver. The transmitter section encodes user commands using an RF-based communication system, while the receiver section decodes these commands and executes them through an Arduino UNO, which acts as the brain of the system. The robot integrates motor drivers, DC motors, servomotors, and relay-controlled mechanisms to perform farming tasks. Additionally, IoT capability is achieved using the ESP8266, allowing control via an Android smartphone. This system reduces manual labor and enables efficient and automated agricultural operations.

Step 1: Transmitter Section Operation: The transmitter section consists of an RF transmitter, HT-12E encoder IC, and a 5V power supply. User commands such as forward, backward, left, right, and stop are encoded into serial data using the encoder and transmitted wirelessly via RF signals to the receiver section.

Step 2: Receiver Section Processing: The receiver section includes an RF receiver and HT-12D decoder IC. The received serial data is converted back into parallel data and sent to the Arduino UNO for processing. The Arduino interprets these commands and controls the robot accordingly.

Step 3: Ploughing Mechanism: The ploughing tool is interfaced with the Arduino and operates in ON/OFF modes. Based on user commands, the Arduino activates or deactivates the ploughing mechanism to prepare the soil.

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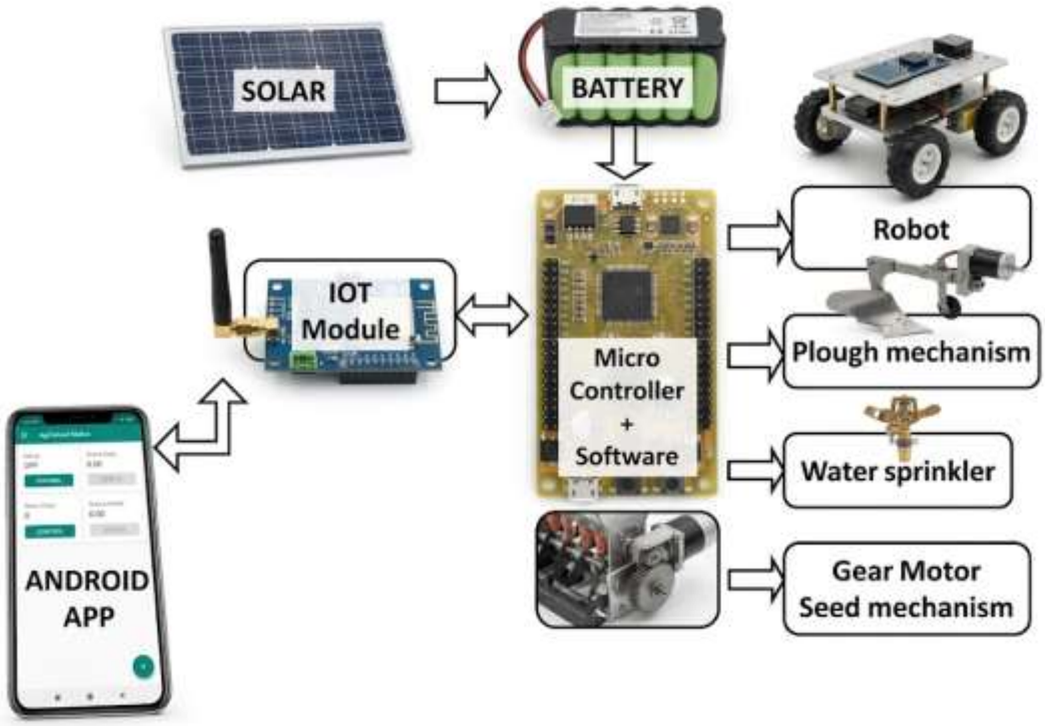

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Figure 1: Block Diagram of Agricultural Robotic System.

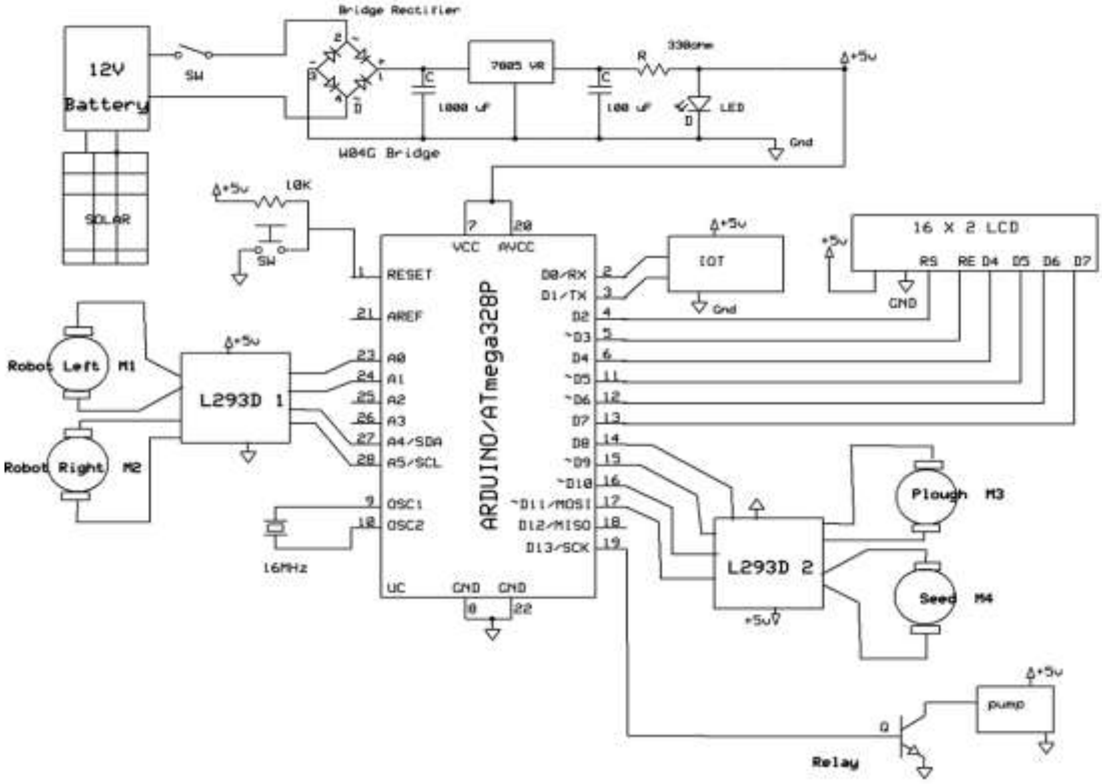

Figure 2: Circuit Diagram of Agricultural Robot for Automatic Ploughing, Seeding and Sprinkling

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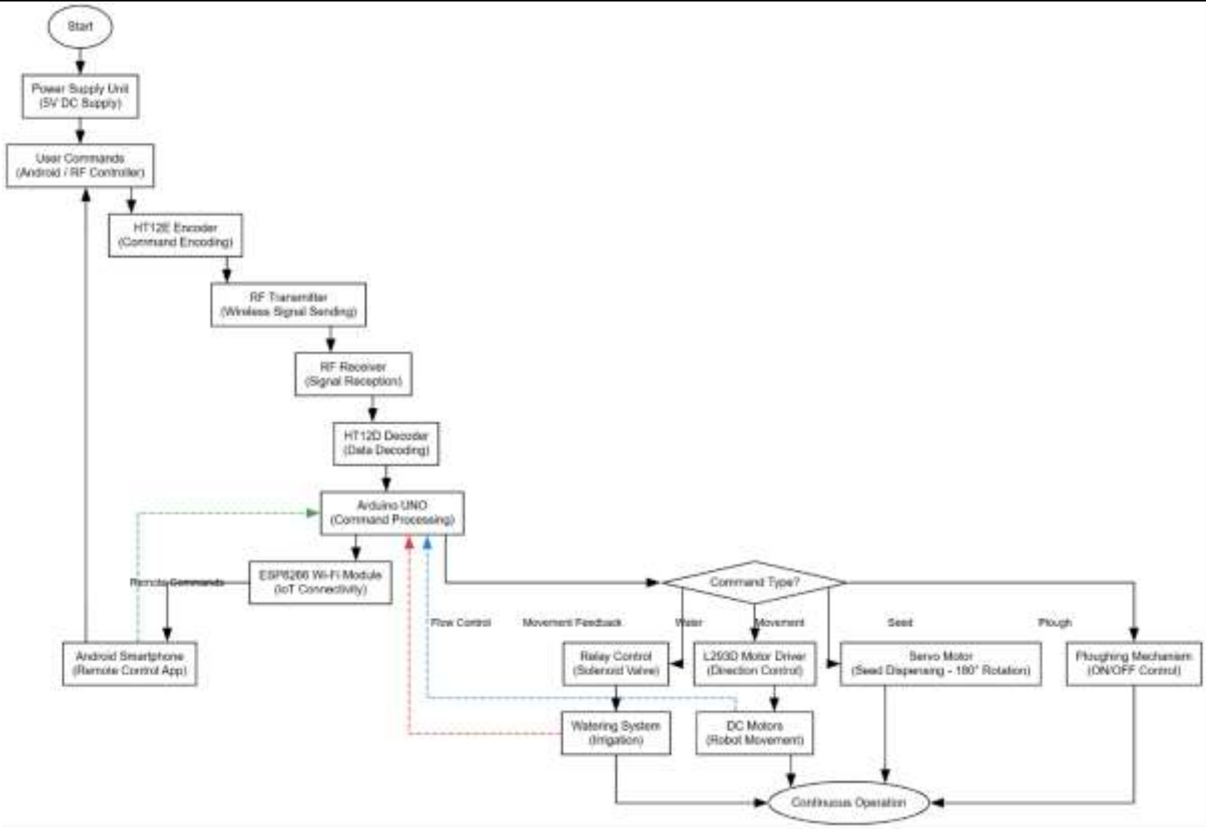

Figure 3: Working Procedure of Proposed System.

Step 4: Seed Dispensation System: Seeds are stored in a container controlled by a servomotor. When the servomotor rotates to 180°, it opens the container flap, allowing seeds to be dispensed evenly across the field.

Step 5: Watering Mechanism: The watering system uses a relay and solenoid valve. The relay controls the valve to start or stop water flow, ensuring proper irrigation after seed dispensing.

Step 6: Motor Driver (L293D) Control: The L293D Motor Driver IC is used to control the direction and movement of DC motors. It enables bidirectional control, allowing the robot to move forward, backward, left, and right.

Step 7: Robot Movement using DC Motors: DC motors connected to the wheels drive the robot. These motors receive signals from the motor driver, enabling controlled navigation across the field.

Step 8: Power Supply Unit: A 5V DC power supply is used to power the Arduino and other electronic components, ensuring stable operation of the entire system.

Step 9: IoT Integration using Wi-Fi Module: The ESP8266 enables IoT functionality by connecting the robot to a wireless network. This allows remote control and monitoring through an Android application.

Step 10: Android Smartphone Control An Android smartphone with a Telnet-based application is used to send commands to the robot via the Wi-Fi module, enabling user-friendly and remote operation.

Figure 2 illustrates the circuit diagram of an automated agricultural robot designed for ploughing, seeding, and water sprinkling operations using an Arduino ATmega328P microcontroller. The system is powered by a hybrid energy source consisting of a 12V battery and a solar panel, with a regulated

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power supply section including a bridge rectifier, filter capacitors, and a 7805-voltage regulator to provide a stable +5V output. The microcontroller serves as the central control unit, interfacing with two L293D motor driver modules that control multiple motors: left and right motors for robot movement, a plough motor for soil cultivation, and a seed motor for automated seed dispensing. A relay-controlled pump is integrated for irrigation purposes. Additionally, an IoT module enables remote monitoring and control, while a 16×2 LCD displays system status and operational parameters. This integrated design allows the robot to perform essential farming tasks autonomously, improving efficiency, reducing manual labor, and supporting smart agriculture practices.

Figure 3 shows the flowchart of proposed system. It operates by transmitting user commands wirelessly through the RF module, which are decoded and processed by the Arduino UNO. Based on these commands, the robot performs ploughing, seed dispensing, watering, and movement operations. The integration of IoT allows remote control, making the system efficient, automated, and suitable for modern smart agriculture.

4. Results and Discussion

Figure 4 illustrates the central control circuitry consisting of the Arduino/ATmega microcontroller, power supply unit, and IoT communication module. The LCD display shows the system status indicating the operation of the agricultural robot.

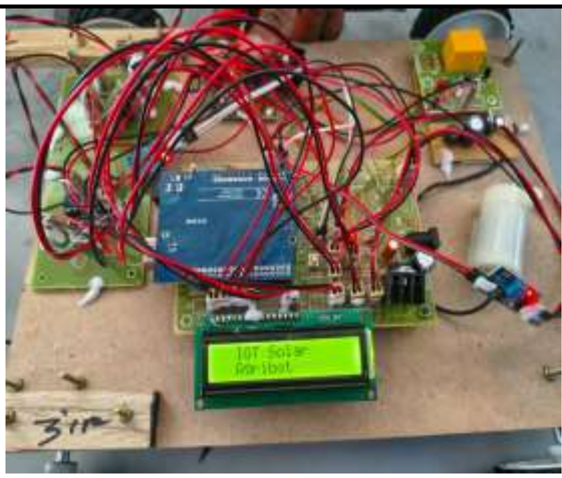

Figure 4. Control Unit and IoT Monitoring Interface.

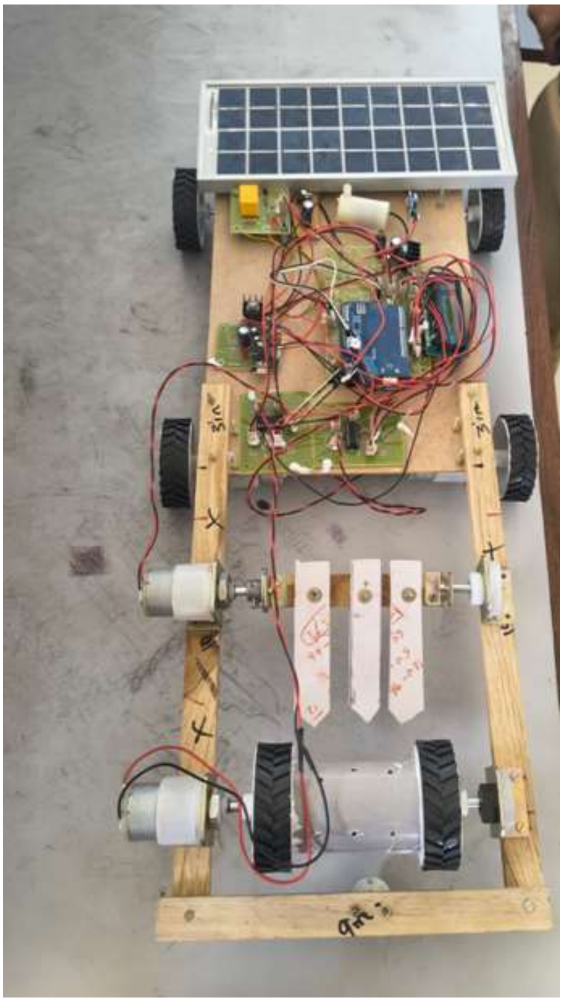

Figure 5. Hardware Prototype of IoT Agricultural Robot

Figure 5 shows the complete hardware prototype of the IoT-based agricultural robot.

The robot is built on a mobile chassis integrated with DC motors, ploughing mechanism, seed dispenser, and water spraying unit powered by a solar panel and controlled using a microcontroller

5. Conclusion

The proposed IoT Agricultural Robot for Automatic Ploughing, Seeding, and Sprinkling presents an efficient and intelligent solution to modern agricultural challenges by integrating automation, multi-functional operation, and remote monitoring capabilities. By utilizing the ATmega328 microcontroller along with IoT connectivity, the system enables precise and continuous execution of essential farming activities such as soil ploughing, uniform seed dispensing, and controlled irrigation. This reduces dependency on manual labor, minimizes operational time and cost, and ensures consistent performance across farming processes. The ability to remotely monitor and control the robot enhances flexibility and allows farmers to respond effectively to changing field conditions. Furthermore, the optimized use of resources such as water and seeds contributes to improved crop yield and sustainability. Finally, this system supports the advancement of smart agriculture by increasing productivity, enhancing efficiency, and promoting cost-effective and environmentally friendly farming practices.

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