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Design and Development of a Multifunctional Agricultural Robot Prototype for Precision Farming

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Abstract

This document represents the design and development of a multifunctional agricultural mobile robot aimed at automating several farming tasks, including soil moisture measurement, precise irrigation, seed planting, and grass cutting. The robot uses an Arduino Nano as its central controller, with capabilities to measure soil humidity across a range of 0-100%, controlled by moisture sensors. The robot's speed of operation is 0.5 m/s, and it can cover an area of approximately 100 m² per cycle. The robot is equipped with servo motors for accurate seed planting and grass cutting, and a simple smartphone application enables real-time monitoring and control of robot functions. The moisture sensors trigger the watering mechanism, while the robot precisely plants seeds at predefined intervals and utilizes a rotating fan blade for grass cutting, improving efficiency and reducing manual labor. The robot's seeding mechanism can plant seeds at intervals of 5 cm, enhancing planting precision. A mobile application developed via MIT App Inventor facilitates user interaction, enabling the activation of various functions like watering, seeding, and mowing, while providing live sensor feedback. This research highlights the potential of such systems in addressing labor shortages, resource optimization, and enhancing food security through precision agriculture.

Keywords: Agribot, Multi-controlled robot, Automation, Precise Agriculture.

1. Introduction

The agricultural field monitoring robot developed with the Arduino Nano platform at its base, this robot enables performing repetitive tasks in farming operations. It is equipped with sensors that are integrated with the Blynk IoT platform, allowing real-time monitoring of soil moisture and humidity [1]. Due to a growing global population and limited arable land, sustainable food supply systems are needed. However, traditional farming uses heavy and complicated tractor equipment. Inaccuracy causes soil compaction and resource waste. Precision farming, which adapts resource use to each plant, is emerging as population increase and climate change threaten agricultural techniques [2]. Automation technology has encompassed several domains of human activity, including industry, communication, corporate offices, home tasks, education, transportation, building, satellite operations, and combat. Currently, robots and automation technologies are widely used in the agricultural industry. The investment to include robots in agricultural industries is driven by many incentives, including reducing labor forces, saving time, and meeting increased product demand [3]. The expansion of the agricultural sector is vital for alleviating poverty in Bangladesh. With around 47.3% [4] of the country's labor force and a contribution of over 22% [5]. Agriculture is crucial to food production and global food security. However, labor shortages, resource constraints, and expanding populations present significant challenges. Automation using robots may solve these issues. Agricultural robots can plant, weed, harvest, and monitor crops. Efficiency, labor costs, and resource management improve [6]. This research comprehensively overviews the meticulous design and operational mechanisms of our agricultural robot prototype and provides insight into the potential of autonomous and precision-driven agriculture outside laboratory settings. The results of this research will contribute to the scholarly discourse around the use of robots in agriculture and, more significantly, to the development of sustainable agricultural practices in the emerging era of agriculture. The goal is to use technology and advancements in agriculture to create a future characterized by increased productivity, reduced ecological footprint, and enhanced food security to meet the needs of a rapidly expanding global population.

2. Literature Review

Several researchers have offered design and manufacturing methods regarding agricultural robots. Mobile Agricultural Robot Swarms (MARS) promotes autonomous farming using low-intelligence robot swarms. OptiVisor coordinates these robot swarms. OptiVisor plans optimizes, supervises, and mediates robot-cloud service interactions [2]. Some papers compare the economic feasibility of three hypothetical autonomous robotic systems to conventional systems and find that all three are economically viable, with the most profitable

independent grass-cutting system. They emphasize the theme of autonomous automated systems improving agricultural efficiency and profitability [7]. Agriculture is in trouble due to an aging population and fewer farmers. A Wearable Agri-Robot was created to help farmers with hard labor and specific postures. Analyzing the wearer's myoelectric potential confirmed the robot's efficiency in relieving farmers' workload [8]. Due to food security issues, agricultural robots are popular. To be practical, farm robots need affordable and dependable assistance [9]. Theoretical advances and cutting-edge technology are accelerating agricultural robot development. However, the diverse agricultural environment restricts their use. Future agricultural robot research should emphasize agronomics, sensors, and automation [10]. Recent autonomous agricultural robots concentrate on greenhouse, fruit-harvesting, and navigation systems. It imagines a robot that selectively picks fragile crops and explores agricultural robotics developments. Using this idea, a melon-harvesting robot prototype collects 85% of the fruit [11]. Tech improvements in informatics, sensing, and navigation are revolutionizing agriculture. Agricultural robots may automate labor-intensive field procedures that require delicate plant/product contact or are repetitive. The article discusses agricultural robotics research and the requirement for processing algorithms, communication, and sensor systems [12]. Agricultural robots in field activities demonstrate their strengths and weaknesses. The primary idea is that robots must adapt to the unstructured agricultural environment while being cost-effective, safe, and trustworthy [13]. The increasing prevalence and advancement of soft robotics and actuators make developing a soft-bodied robot feasible. This evolution could enhance monitoring and operational capabilities, particularly in delicate environments or circumstances requiring a more delicate approach. Soft robotics has the potential to revolutionize the way robots interact with plants by allowing them to imitate biological responses based on natural processes [14].

3. System Design and Components

The prototype was designed by integrating essential hardware and software components, with the Arduino Nano microcontroller as the system's brain. Moisture sensors are placed strategically to monitor soil humidity, triggering the robot to take action when moisture levels fall below a threshold. Servo motors (MG996R and SG90) control the seed-planting and grass-cutting mechanisms, while brushed DC motors powered by L298N motor drivers enable movement across agricultural terrain. The plastic fan blade is used for efficient grass-cutting**.** The entire system is powered by a 12V LiPo battery with voltage regulation provided by a buck converter**.** Fig. 1 depicts the simulation in Proteus, which was conducted to verify the system's behavior before hardware implementation. The water pump is synchronized with moisture sensor data to apply water where needed, while the seeding mechanism ensures accurate planting at pre-determined intervals.

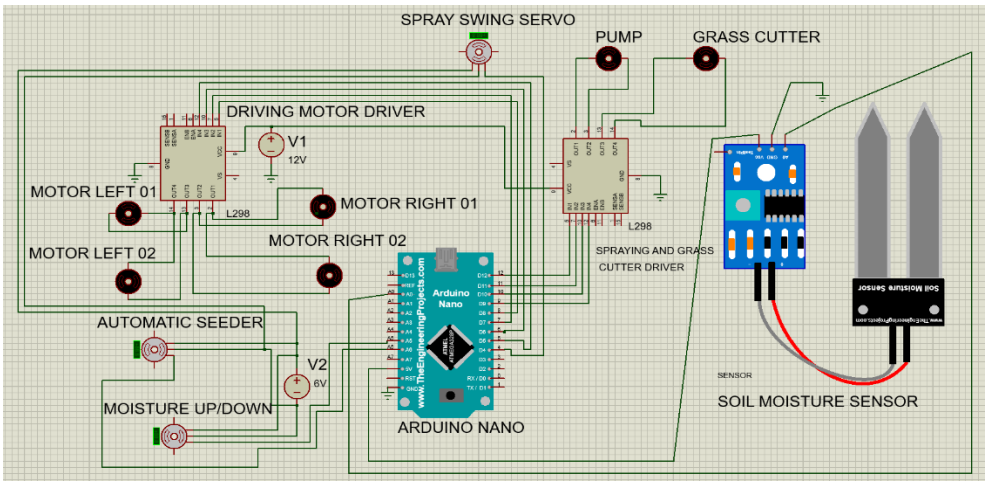


Fig. 1. Simulation of system behavior in Proteus

5. Methodology

The methodology focuses on the integration of physical components and software to create an efficient agricultural robot prototype. Key parameters considered in the design include soil moisture levels, task precision (seeding, watering, grass cutting), and mobility across diverse terrains. The system uses soil moisture sensors to gather real-time data, which is processed by the Arduino Nano to evaluate soil moisture and trigger appropriate actions like watering when necessary. Challenges in designing the robot included achieving precise moisture measurement and accurate resource allocation for irrigation. Moisture data from sensors is used to control a water pump, delivering water only to areas with low moisture, addressing the challenge of efficient water usage in agriculture. The use of servo motors ensures precise seed placement and grass cutting, while DC motors enable the robot to

move effectively across varied agricultural terrain, overcoming issues of terrain variability and movement control. Another challenge was providing remote control and monitoring capabilities. This is solved through the integration of a mobile application that communicates with the robot via Bluetooth. The app allows for real-time monitoring of sensor data and control of robot functions, improving user accessibility and system flexibility. The software architecture dynamically adjusts the robot's tasks based on sensor input, enabling it to operate autonomously in changing environments. This combined hardware and software approach allows for optimized task performance (watering, seeding, mowing) and real-time responsiveness to agricultural conditions, overcoming common challenges in agricultural automation. This link enables the robotic system to independently evaluate the humidity levels of the agricultural area and detect watering requirements [15]. Fig. 2 shows the full functioning flowchart of the system. It represents the logic applied and the decisions microcontrollers make based on that logic.

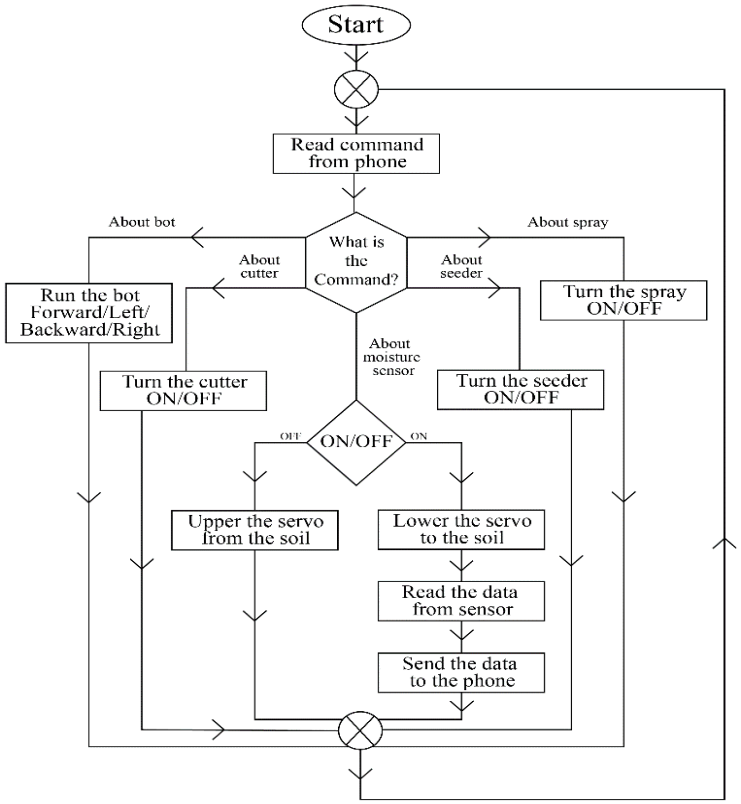


Fig. 2. Flowchart of the Agricultural robot

The components work together in synchronization to precisely and effectively react to dynamic moisture conditions indicated by the sensor. Brushed gear DC motors enable the robot to navigate agricultural terrain quickly and flexibly [16]. The incorporation of a mobile application enhances the usefulness of the system.

6. Results and Discussions

The agricultural robot prototype was tested for its performance in soil moisture measurement, seed planting, and grass cutting. When the mobile app is opened, it initially shows a "Not Connected" status, indicating no active connection between the app and the robot. To establish a connection, the user presses the "Connect" button in the app. The app then scans for nearby Bluetooth devices. Once the scan is complete, the app displays a list of available Bluetooth devices. The user selects the robot from this list. After a successful connection, the "Not Connected" label changes to "Connected" and turns green, indicating that the app is now linked to the robot. Fig. 3 shows the mobile app interface, allowing for easy control and monitoring, with features for monitoring moisture levels, activating irrigation, deploying the moisture sensor, and controlling seed planting and grass cutting. Fig. 4 presents the hardware representation of the prototype. Robots successfully detected soil moisture using sensors that convert analog readings to digital values. Moisture levels were displayed on the mobile app and used to trigger irrigation when necessary. The system showed accurate moisture readings, optimizing water usage based on real-time data. The robot's seeding mechanism, controlled by a servo motor, dispensed seeds at precise intervals. The system was effective in automating seed planting, improving planting efficiency and crop yield. The robot used a rotating fan blade for grass cutting. The combination of the Arduino Nano, servo motors, and moisture sensors allowed the robot to perform tasks with precision.

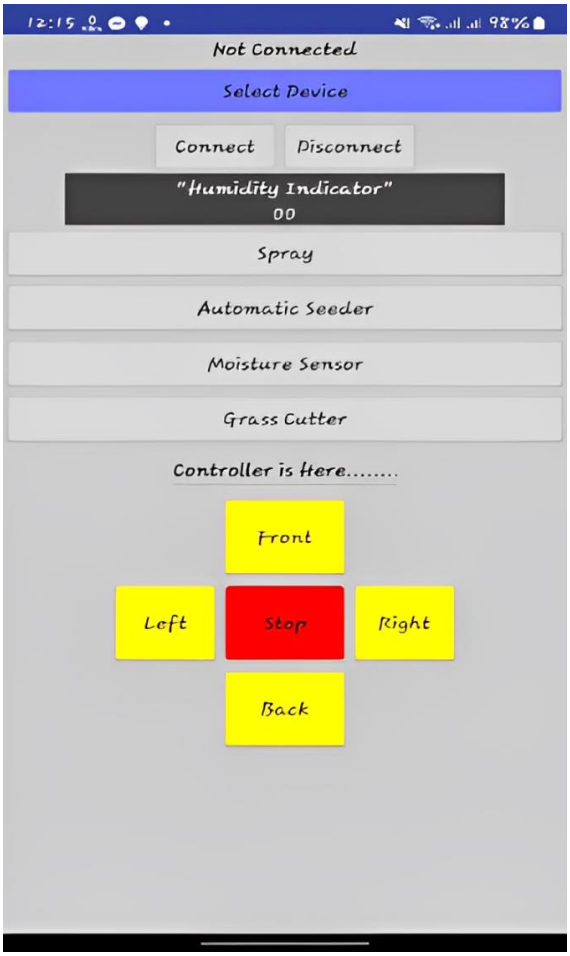


Fig. 3. Mobile app to control the robot

The analog output of the soil moisture sensor is converted into digital form using an Analog-to-Digital Converter (ADC). The soil moisture sensor produces varying readings within the ADC value range of 0 to 1023.

Moisture (in %) = 100 – (Analog output * 100) ---------- [17]

The highest value of the 10-bit ADC, which corresponds to zero moisture, is 1023. The moisture value is sent and shown in the "Humidity Indicator" to the mobile app.

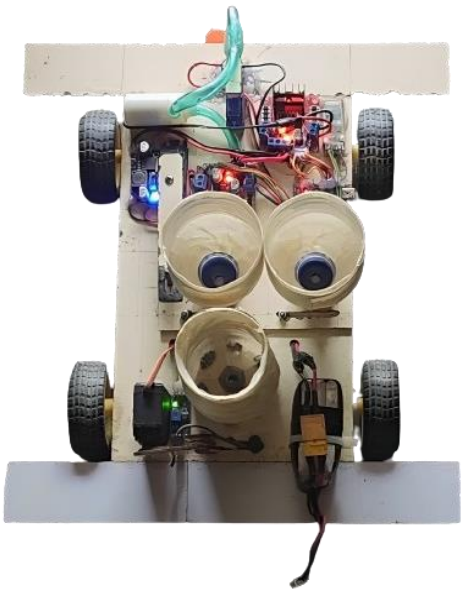


Fig. 4. Hardware representation of the prototype robot

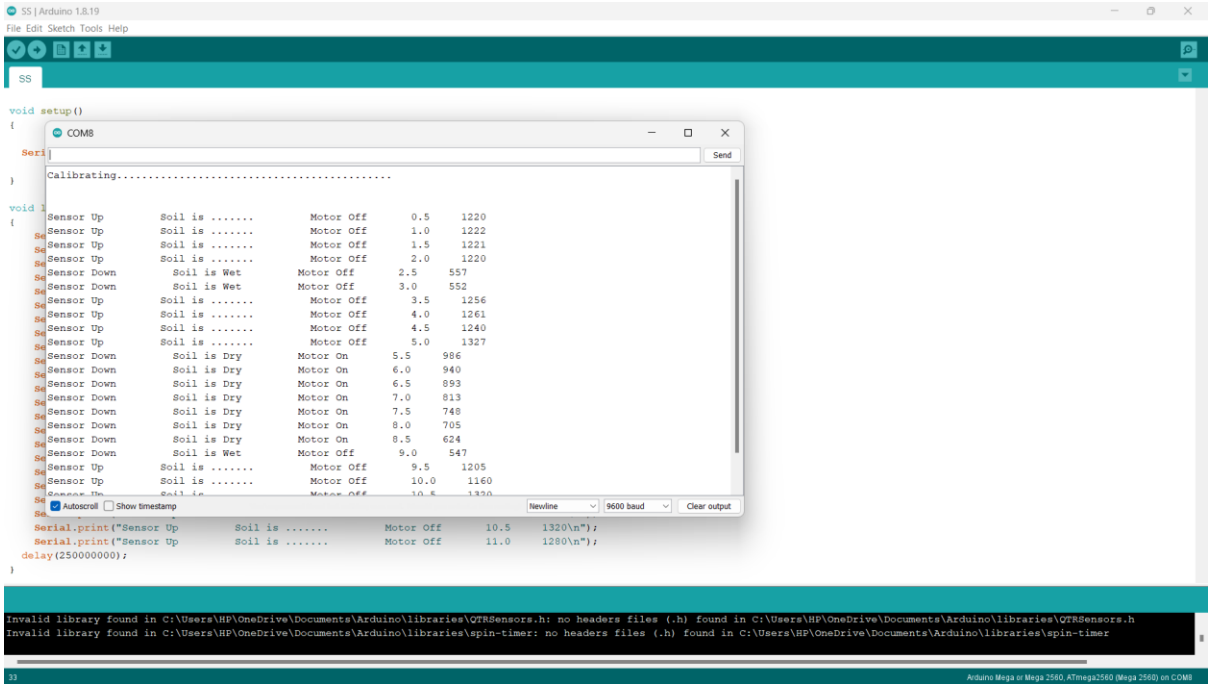


Fig. 5. Moisture Sensor data in Serial Monitor

Fig. 5 illustrates the moisture sensor data, acquired through an Arduino IDE interface and displayed on the Serial Monitor, offering real-time insights for the optimization of irrigation and water management in agricultural practices. Fig. 6 presents a Time vs. Moisture graph that tracks soil moisture variations throughout the system's operation, aiding in efficient irrigation management. Sensor readings exceeding 1000 signify no soil contact, values ranging from 600 to 1000 indicate dry soil, values between 370 and 600 correspond to wet soil, and readings below 370 suggest the sensor is immersed in water.

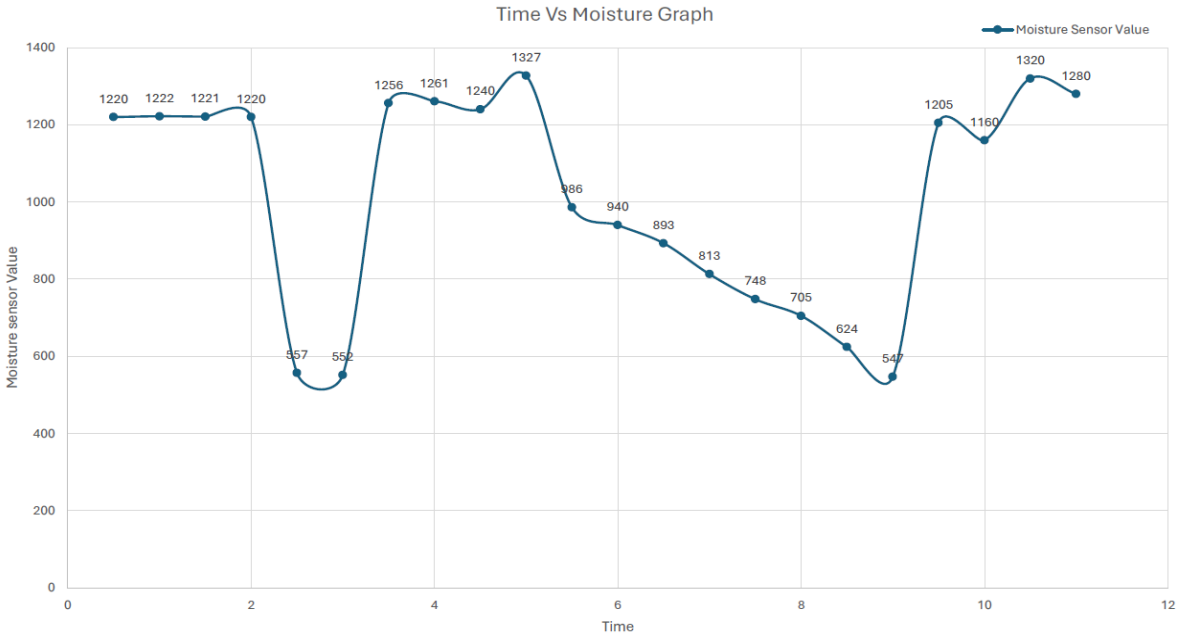


Fig. 6. Time vs Moisture graph during real-time application

7. Future Scopes

The potential advancements of this prototype offer significant promise for transforming the agricultural industry. Integrating real-time monitoring via IoT-enabled cameras could enhance system functionality, enabling

continuous surveillance, data sharing, and remote control. The addition of advanced sensors to assess soil health—measuring variables such as nutrient levels and composition—would improve precision agriculture, optimizing resource use and boosting crop yield. Incorporating image recognition technology for plant health monitoring can facilitate early detection of pests, diseases, and growth patterns, further enhancing decision-making capabilities. Integration of machine learning, artificial intelligence, and automation would enable the robot to adapt to dynamic agricultural conditions. Collaboration with agronomists and farmers is key to refining the system. Ultimately, this prototype, once fully developed, has the potential to serve as an autonomous farm supervisor, providing real-time insights and recommendations for optimal farm management.

8. Conclusion

This study introduces a mobile agricultural robot prototype that successfully performs precision farming tasks in real-time, delivering highly accurate results. The robot effectively integrates soil moisture measurement, irrigation, seed planting, and grass cutting, demonstrating its capacity to optimize resource use, reduce labor dependency, and enhance crop productivity. Utilizing widely accessible components such as the Arduino Nano, servo motors, and moisture sensors, coupled with a user-friendly mobile application for real-time monitoring and control, the prototype showcases both practicality and scalability. The system performed as expected, automating essential agricultural tasks with precision—ranging from accurate seed planting to optimized irrigation based on real-time moisture data. The results were highly satisfactory, confirming the robot's capability to operate autonomously and efficiently in a variety of agricultural scenarios. This research highlights the potential of agricultural robotics to transform farming practices, providing a solid foundation for future innovations in precision agriculture and automation.

9. References

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