Multi-Tasking Agri-Bot for Integrated Field and Lawn Operations: An Experimental Study

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ABSTRACT

The present systems for irrigation and lawn upkeep have inefficient water consumption, poor coverage, no automation, which contributes to resource loss and productivity decline. This specific work meets these eco-friendly agricultural innovations shortcomings through the integration of eco-seeding, eco-irrigation, eco-pesticide spraying, and eco-mowing into one system. Agri-Bot has sophisticated features that enable it to function independently by planting crops, irrigating, pesticide spraying, and mowing lawns. By default, the robot with an ultrasonic sensor is capable of steering and avoiding blockages without being led through set routes. Furthermore, its ability to capture solar energy renders it free from climatic conditions to provide reliable eco-friendly farming. Further, the unit is controlled through a custom developed native application that is multilingual, includes voice recognition, and is designed to extend user experience. This kind of multifunctional unit eases the farmers work burden and reduces human resource dependency for farming tasks. The Agri-Bot is constructed to be automated and operational in farming which increases the degree of control and farming sustainability. Its integration of various sensors and actuators provides the capability to accomplish many tasks accurately and consistently over a large tract of land.

Keywords: Multi-task agricultural robot, Solar-powered precision farming, Ultrasonic obstacle avoidance, Integrated seeding–irrigation–spraying, Bluetooth multilingual control

Introduction

Historically, farming practices in agriculture have required manual work during every step of the farming cycle, which has caused inefficiency and a lack of productivity.[1] The seeds' placement is a procedure that captures the essence of manpower and its wastefulness, for it takes a long time to do correctly and negatively affects the yield because of inconsistency and human error. Moreover, basic irrigation systems, whether automatic or manual, tend to overwater or underwater the crops, causing them not to grow optimally. The hand-held method of applying pesticides worsens the issue by endangering the crops as well as the environment and farmers. Furthermore, hand-held methods of maintaining grass for fields highlight the considerable balance of human resources and time allocated to manual work.[2] Although farming practices have historically been done in this manner, these methods are expensive, time-consuming, and challenging to perform on a larger scale. Therefore, enhanced operational efficiency, lowered labor, and a higher degree of sustainability in agricultural methods indicate a shortage of farm machinery.

An automated multi-task robot is an invention that seeks to enhance farming systems by automating essential tasks. The robot is capable of performing tasks such as seeding, irrigation, pesticide application, and lawn maintenance, requiring minimal human oversight. It is a method that enhances proper planting by accurately spraying the seeds on designated areas and adequately hydrating the plants using automated sprinklers.[3] Furthermore, it has a grass-cutting feature that makes it suitable for both lawns and fields. Thanks to the ultrasonic sensors, the robot effortlessly navigates through various dimensions in the fields, avoiding collisions even in crowded or narrow spaces. As an improvement, the farming system is user-friendly and can be utilized in multiple languages, simplifying the work for farmers regardless of their cultural or linguistic background. Additionally, the sand-settling process for the soil after planting seeds enhances its conditions for improved germination and stronger crop and also close the sand after implanting seeds with water.[4]

Robotic systems are now able to perform pest control, ecological monitoring, and other agricultural functions owing to the recent advancements in the field of robotics. Scouting and pest control have become far easier for farmers with the use of robotic bots such as climatic bots that enable real time analysis and decision making. Additionally, these robotic bots can also fetch relevant data like soil moisture and temperature to assist farmers to manage crops better and maximize yields.[5] Furthermore, the power-efficient architecture of these robots enable them to work in low power resource regions including remote and off the grid farms. This paper proposes a multi-functional robot that autonomously integrates other robot functions such as seeding, irrigation, pesticide spraying, and lawn mowing into one machine. The Agri-Bot is designed to tackle inefficiency of labor in conjunction with negative impacts on the environment, which means that it is not only practical by saving time, but also environmentally friendly, hence more efficient in sustainable agriculture in different practices.

Current Works

The research focuses on the difficulties associated with employing human-operated sprayers, which are bulky, unstable, and challenging to handle in orchards. The suggested solution is to substitute these sprayers with lighter, more advanced robots.[1,2] One of the main objectives of the study is the implementation of a Multi-Robot System (MRS) for pesticide spraying, which seeks to enhance efficiency and decrease expenses by enabling multiple robots to collaborate in a vast orchard. By implementing this approach, the need for direct robot communication is minimized, allowing

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each robot to function autonomously within its designated space. The study emphasizes the significance of task distribution and collaboration, emphasizing that the Multi-Robot Task Allocation (MRTA) process is fluid and should be adapted as the environment evolves where the task allocation is controlled through the mobile application.[3]

A new solution in precision farming illustrates its prospects by showing various robotic and multisensor technologies for agricultural purposes: sowing, seeding, harvesting, and crop maintenance.[4] The importance of precision in navigation and sensor fusion within the context of the operational task of agricultural robotics, where robots must operate in realtime in a constantly changing environment and handle various sensors. One significant issue that the study brought to light is the lack of standards for essential robotic components, which often arises due to the closed-end proprietary nature of the design process.[5,6] This fragmentation of the device selection and flexible mechanization of robotic systems is tailored to meet the specific needs of the farms. The article, The Findings of the Horizon 2020 Agriculture Interoperability and Analysis System (ATLAS) Project, asserts that it can address current challenges by implementing an open, flexible, and distributed interoperability network.[7] This network enables a wide range of sensors, machines, and analytical services to be seamlessly integrated and subsequently facilitates communication between those platforms and the sharing of information.

Proposed Methodology

An automated multi-task robot designed for seeding, irrigation, pest control, and lawn care, with the goal of enhancing agricultural productivity.

Our farmer's assistant robot integrates all the essential components of the agricultural system into a single device, as it sows seeds, regulates irrigation, safeguards against harmful animals, and maintains a tidy and well-kept lawn. The precise placement of seeds at the optimal depth and distance from each other ensures optimal germination. The smart watering system also delivers water according to the needs of the plants, thus conserving it. By focusing the application of pesticide in specific areas where only certain plants need to be eliminated, the amount of pesticide pollution is reduced. Additionally, the robotic device can also mow and trim the grass, making it a versatile tool for managing the user's lawn as shown in Figure 1. Additionally, the specific multilingual application enables seamless interaction as the robot responds to text commands in multiple languages, making it more user-friendly.[8]

A. Automated Irrigation and Lawn Care Systems

- Automated irrigation and lawn care systems have transformed agriculture by ensuring consistent and accurate moisture levels for crops, minimizing labor expenses, and saving time.
- These systems guarantee that plants receive the appropriate amount of water at the right time, avoiding both overwatering and drought stress.
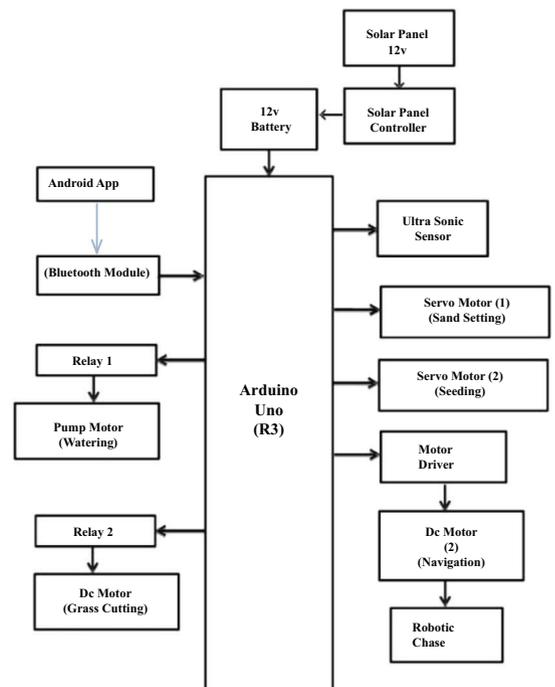

Fig 1 | Work flow diagram of multi-task Agri-bot

- In addition to irrigation, automated lawn care systems ensure a well-maintained landscape by trimming the grass when it reaches a predetermined height, reducing the need for manual lawn care.

B. Seeding and Sand Settling Systems

- With aided technology, the seeding and spreading of sand system guarantees all seeds and soil nutrients are uniformly placed.
- This process enhances the soil quality and subsequently brings about the perfect environment for crops to flourish.
- Having the automation systems integrated makes the agricultural activities easier while effectively guaranteeing healthy crops, beautiful lawns, and consistent outcomes without much human activity.[9]

The integration of Bluetooth technology into the system enables users to access and utilize power through tablets, computers, and mobile devices. This guarantees effective management of extensive operations because the users can remotely monitor irrigation, lawn care, and soil systems from a desired distance. Bluetooth technology simplifies the process of making adjustments, resulting in increased efficiency in the cordless operation of the system. Furthermore, incorporating ultrasonic sensors and machine learning algorithms into the navigation strategies of robotic systems ensures that they can navigate autonomously in fields without human intervention as shown in Figure 2. These sensors aid the robots in navigating through challenging terrains and obstacles such as boulders, trees, and uneven surfaces, expanding their applicability in diverse settings. These modifications to the system greatly enhance its abilities while reducing

the physical effort required during operation, resulting in an automated farming process.[10]

It is an Arduino Uno R3 ATmega328P which is responsible for the control and regulation of all activities of the Automated Multi-Task Robot while also responding to environmental stimuli that is the brain of the robot. The robot measures distance to such obstacles with the help of ultrasonic sensors as shown in (see Fig. 2) which in turn enables it to move around without colliding into any objects.

The provided support of strong control coupled with rapid movement is enabled by the operation of the DC motors through the motor driver. This holistic construct is what allows the robot to carry out a number of different functions like seeding, pest control, etc. with no possibility of collision. Thus, this robot is able to boost productivity in agriculture while at the same time, streamline processes.

Elements such as energy efficiency play a crucial role in improving the robot's efficiency and effectiveness. Because the robots utilize sophisticated battery systems, they can effectively manage their energy usage, prolonging the duration the robots are operational while also preventing unnecessary recharging. By minimizing operational downtime and preventing unnecessary energy wastage, the processes become more environmentally friendly. The scalability of this architecture enhances its flexibility, allowing it to operate in expansive agricultural regions and coordinate the work of multiple robots simultaneously. This feature guarantees that extensive tasks can be accomplished with exceptional efficiency while minimizing human involvement as shown in Figure 2. Additionally, the system is built to support multiple languages, enhancing its usability for users from various regions of the world.[11] This feature enhances user comfort by removing language barriers, enabling effective communication and comprehension. In summary, these modifications enable the development of highly advanced, efficient, and user-friendly automated systems that can be utilized in any agricultural region, regardless of its size.

The workflow commences with the sensors continuously monitoring the surroundings, gathering information like distance, temperature, or fluid levels. The Arduino Uno R3 ATmega328P analyses the collected data, and using predetermined logic, it regulates the actuators, such as the DC motor, DC servo motor,

or water pump. For instance, if the ultrasonic sensor detects an object within its range, the system may halt the motor or execute a specific action as shown in Figure 3. The Bluetooth module enables users to control the system remotely through the Android app, granting them the ability to modify settings or access real-time data from any location within the Bluetooth range.

The suggested system not only motivates farmers to adopt modern agricultural methods but also greatly increases the productivity of farming. Traditional methods of farming are greatly reduced due to the controlled raising of temperature, light, humidity, and atmospheric pressure, which creates an optimal growing environment. This allows for more efficient sustainable agriculture with lower carbon footprints that aid the economy.[12]

Moreover, increased mechanization of farming processes enhances general productivity due to reduced man power and removed human error. This coupled with the system's ability to enforce proper maintenance of crops distinctly improves productivity. Also, the features of the platform ensure that crops are not overwatered or neglected by adjusting operating procedures in real-time, therefore crops always get the care they need. The combination of technology and automation helps achieve a sustainable, effective, and highly efficient agricultural methodology that propounds the future of precision farming.

Experimental Setup

Like an Android smartphone, the HC-05 Bluetooth Module makes it possible to establish wireless links to external devices enabling communication with the Arduino Uno R3 ATmega328P. Users can command the Arduino from the mobile app and get information like sensor and status of the system in return, allowing control over the system to be done remotely. This automated communication enables the user to control the motor, sensor and pumps at the desired time and place.

A DC motor drives a water pump that handles liquids by circulating or as with irrigation-automatically shifting water in or out of an area around a set point. For instance, the pump can be set to supply water to the plants, which will happen once the dirt has moisture lower than a set point value. Many applications require the transfer of fluids such as irrigation, cooling or other processes where liquid is moved (Figure 4). The pump serves this purpose and is thus very functional which
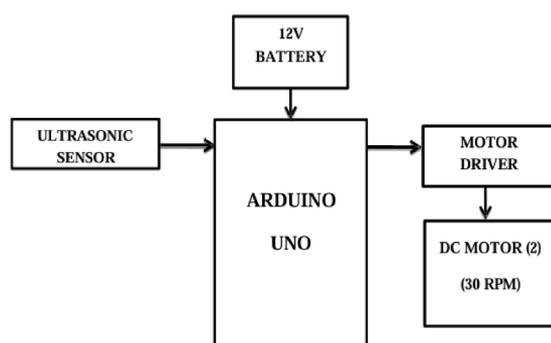
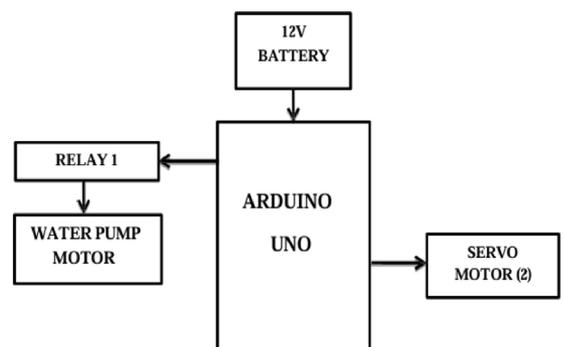Fig 2 | Autonomous navigation and obstacle avoidance

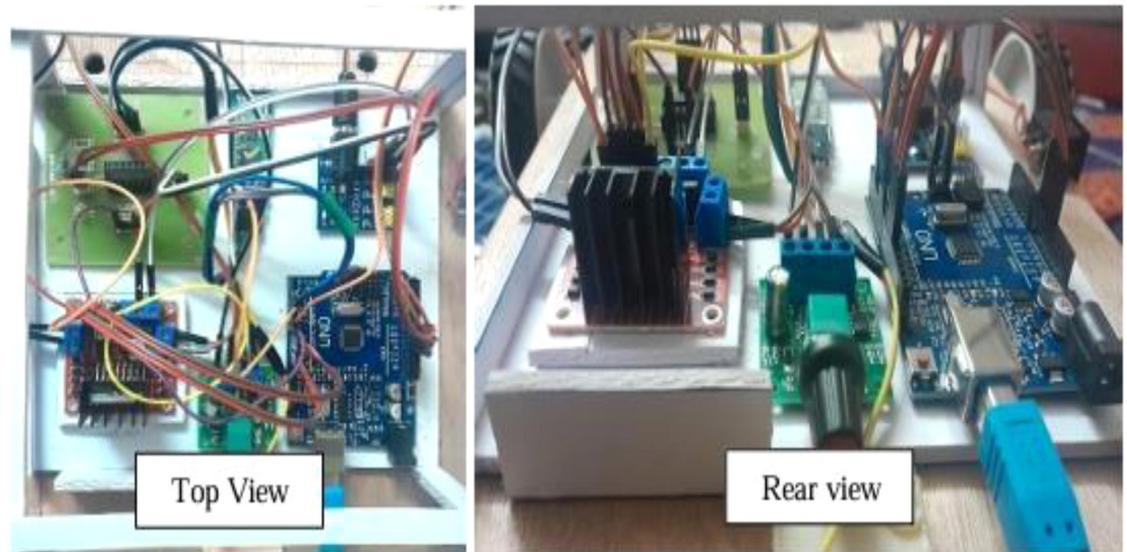Fig 3 | Automated seeding and irrigation system
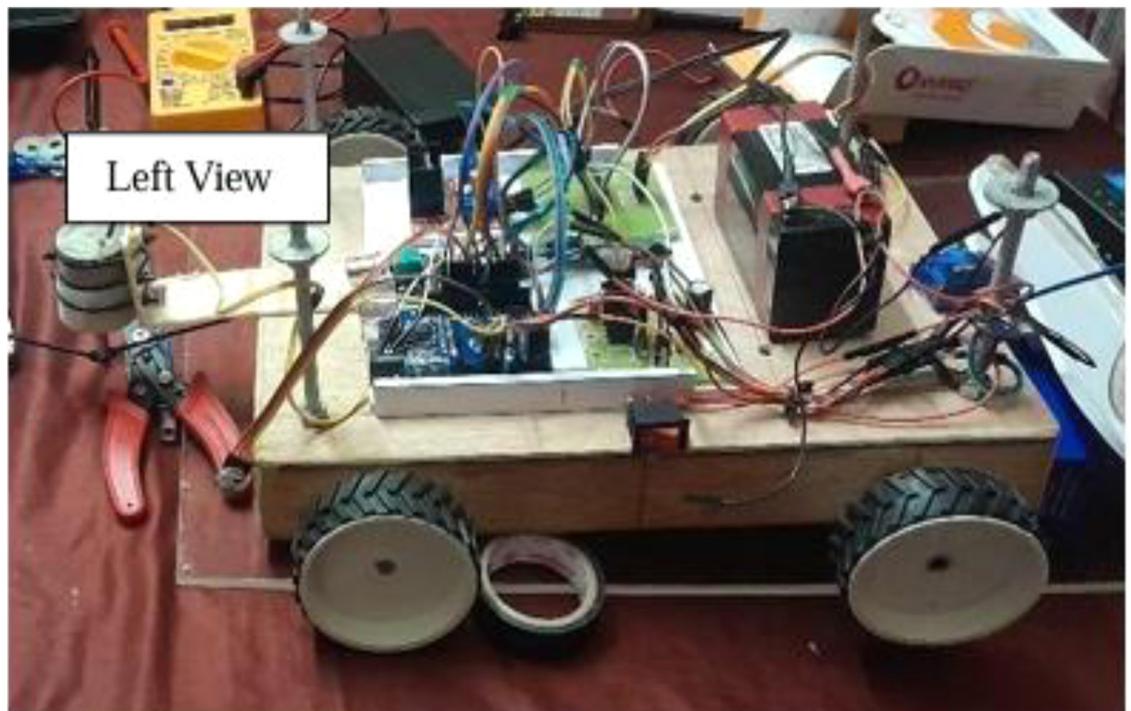
Fig 4 | Wiring setup

Fig 5 | Assembly setup

makes the system workflow begins with the sensors constantly monitoring the environment, collecting data such as distance, temperature, or fluid levels.[13] The Arduino Uno R3 ATmega328P processes this data, and based on predefined logic, it controls the actuators such as the DC Motor, DC Servo Motor, or Water Pump (Figure 5).

Empirical Results

The Flutter application is a Bluetooth controller that enables users to connect with Bluetooth devices and execute various commands for different functions. When the application starts, it requests the necessary permissions for Bluetooth usage and checks if Bluetooth is currently enabled on the device where the application is made of flutter framework using the android studio with the (Java Development kit) JDK Integrated.

Nearby devices can be connected and displayed in a list. Once the connections are established, a control panel appears with buttons that allow you to send commands for up, down, left, right, stop movements, and switches that enable the operation of pumps and the dispensing of seeds as shown in (see Fig. 6), among other functions. The application is also designed to

accommodate and support other languages such as Tamil, Telugu, Hindi, Kannada, and Malayalam with an option of choosing from a pull-down menu located in the app bar.

This application has also a comprehensive user feedback section where, sitting remotely, users can receive status updates from devices that have already been connected, allowing for control. Furthermore, to improve control ease, there is a panel with settings that allows alteration of the layout and modification of the control command intervals to the relevant devices.

The safety of the data is guaranteed by the application through the controlled and authenticated connections with the Bluetooth equipment. Users are provided with an option to easily log out of the devices at their own convenience, while the application is capable of scanning for the other devices that are within range upon reactivation of the Bluetooth system. With its intuitive design, this Bluetooth controller app is accessible and relevant across multiple regions and languages, offering support for numerous languages.[14]

The Multi-Task AgriBot is powered by the 10 W 12 V Polycrystalline Solar Panel as shown in (see Fig. 7), which provides good energy conversion efficiency. Its compact size guarantees performance in different environments. Depending on the sunlight intensity, the charging times differ: roughly 3.5 hours during the morning, 2 hours at noon, and around 5.4 hours in the evening. This flexibility allows the AgriBot to sustain its power for farming activities throughout the entire day.

The Multi-Task AgriBot is powered by a 12 V, 1.3 Ah Sealed Lead-Acid Battery as shown in (see Fig. 8), which delivers consistent energy and has an enduring performance at diverse temperatures due to its rugged ABS shell. Depending on the load the battery is discharging, it takes 6.5 hours at 0.2 A, 2.6 hours at 0.5 A, and 1.3 hours at 1.0 A. With such dependable power, the AgriBot is capable of completing operations like irrigation, seeding, and navigation without interruption.

An Automated multi-task robot that shows great functionality in executing diverse agricultural tasks, meaning more efficiency and autonomy in fieldwork, with a focus on seeding and irrigation systems, sand settling, and a grass cutting mechanism, all of which function reliably as intended at the desired tasks. The purpose of seeding is to strategically place seeds in specific locations to guarantee optimal planting coverage and uniform crop growth. The irrigation system is designed to regulate water distribution, ensuring that plants receive sufficient water without any unnecessary wastage. Additionally, regular grass-cutting will alleviate the workload of individuals involved in maintaining lawns and fields.[15]

Bluetooth communication in the Multi-Task AgriBot enables control commands to be transmitted between the mobile app and the robot. The transmission time
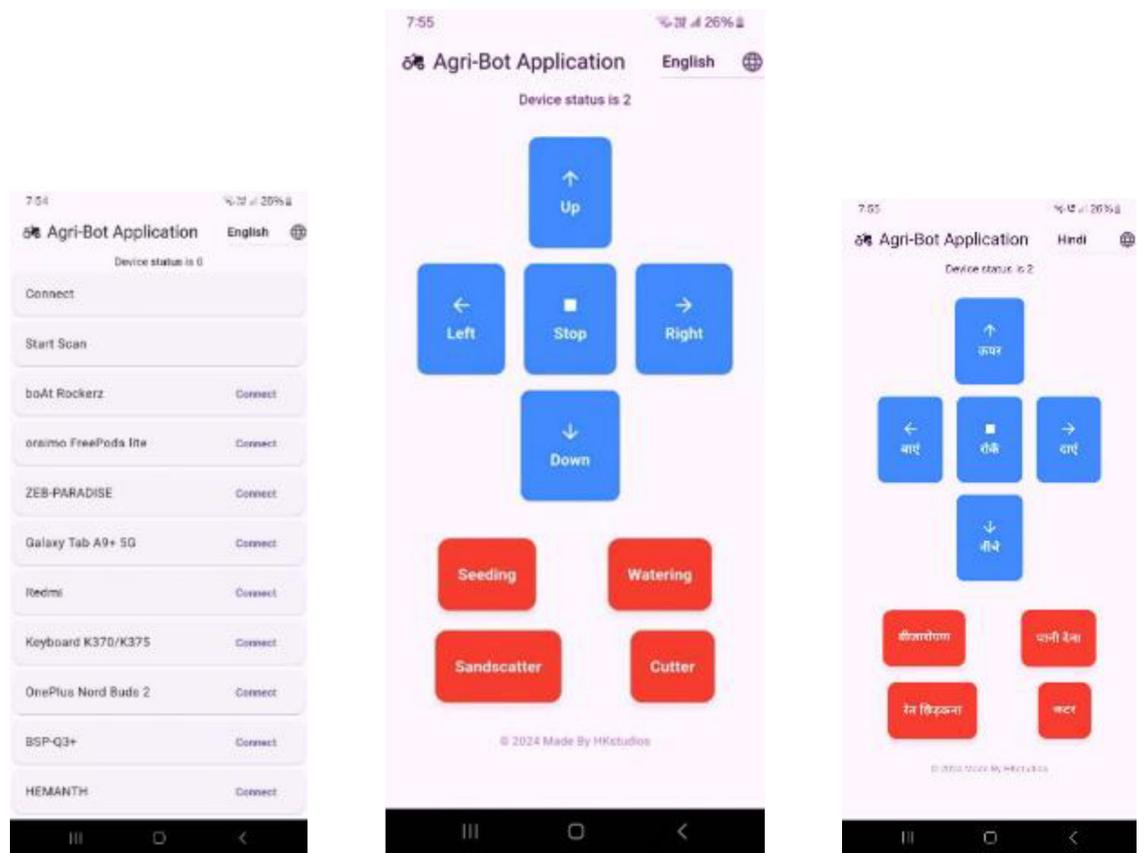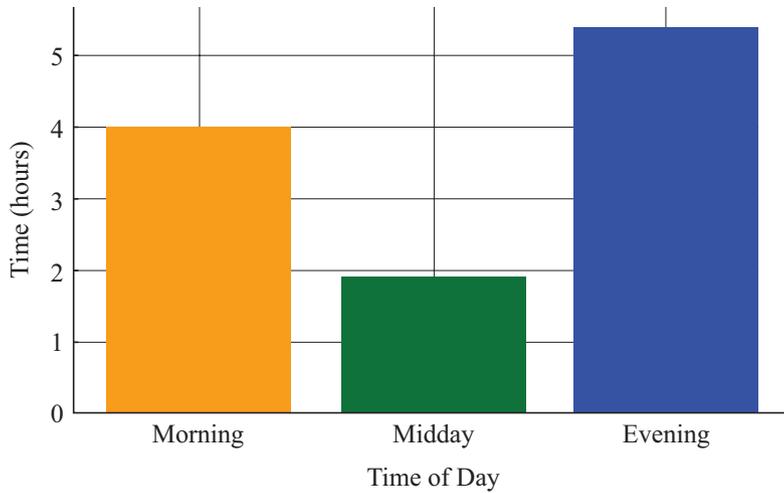

Fig 6 | Android application

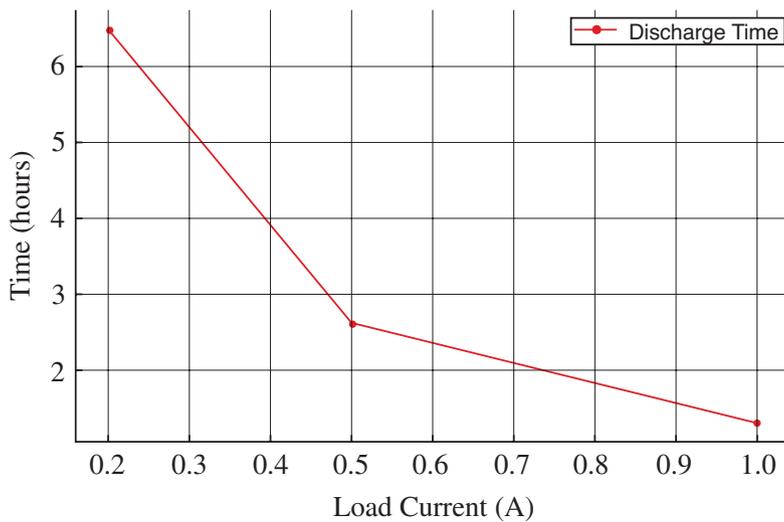Fig 7 | Charging time at different times of day

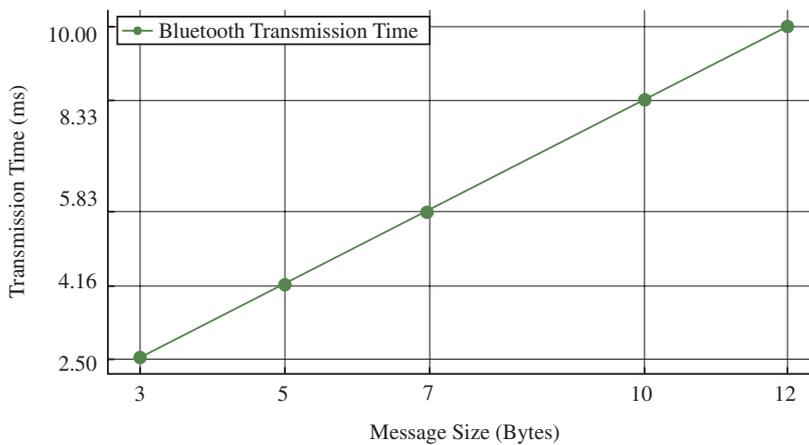Fig 8 | Battery discharge time vs load current

Fig 9 | Bluetooth transmission time vs message size

depends on message size, as shown in (see Fig. 9), which low latency

For example, a short command like "SON" (3 bytes) takes about 2.5 ms, while a longer command like "seeding ON" (10 bytes) takes around 8.33 ms.

Optimizing message sizes ensures faster, more responsive communication, improving control precision and task execution in real-time operations.[16]

One aspect which needs special attention is the formation of sandy soil following sowing, which is important in the advancement of soil structure and results in better crop germination. As illustrated in (see Fig. 10), the advanced multi-tasking functionalities of an Agri-bot includes soil moisture detection, irrigation, and planting using the remnants of water from other cultivations. Along with other features he has so far mastered basic robotics with the new mobile application, designed for speakers of different languages which gives everyone the chance to control the robot without worrying about the language. The built-in accessible voice control with multi-language interface of the application provides the possibility for users to control the operations and functions of the robot with any language which increases the scope of people who can use this system.[17]

One exceptional feature of the robot is its automation of soil preparation, especially sand spreading to improve the soil texture. This results in better water retention and air circulation, which is ideal for seed germination. The robot enhances soil quality by ensuring uniform conditions which leads to better crop yield. In addition, the robot has a built-in ultrasonic sensor obstacle avoidance system that allows for unobstructed movement throughout the field (see Fig. 10). This eliminates workflow interruptions, ensuring that work progress is constant. The system is made accessible from different cultural backgrounds by a multilingual mobile application to control the robot with ease.[18]

With an advanced level of functionality, an autonomous multi-tasking robotic system brings together farming as well as other secondary activities and integrates autonomous systems, which helps in greatly lowering soperational risks while ensuring optimum sustainability for existing agricultural practices.

By incorporating a specialized multi-language application, user participation is enhanced as operators from diverse language backgrounds can effortlessly operate and personalize the robot's various functions. This inclusive approach to design expands the robot's potential in multilingual communities, allowing a larger number of farmers to benefit from the automation of essential farming tasks. The robot combines various
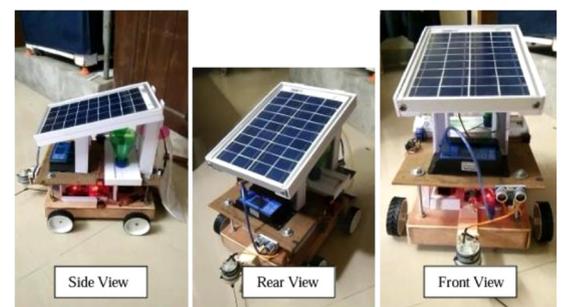

Fig 10 | Final model of multi-tasking Agri-bot

features into a single platform, providing a comprehensive and organized view of agriculture. This integration enhances productivity, reduces physical input, and promotes sustainability and efficiency in farming practices.

Conclusion

Irrigation-oriented robots promisingly reinvent precision farming as they are capable of tracking crucial factors such as soil moisture, temperature, and nutrient balance, because of which real-time mapping of the crops can be done by the farmers in order to formulate and implement better and more productive farming strategies. By utilizing sensors, the robot is capable of providing comprehensive care for the crops, resulting in increased efficiency and minimized waste. As a result of these advancements, farming will become more sustainable by enhancing the health and productivity of crops while minimizing pollution generated by the agricultural industry. This feature assists a farmer in addressing any pest or infection- related problems before they escalate into serious issues. Additionally, the automated feature of the irrigation control system guarantees that the appropriate crops receive the necessary water at the appropriate time.

When the sensor detects the need for irrigation, it is promptly carried out. This practice conserves water and prevents unnecessary expenses while also promoting the optimal growth of the plants. As a result, these advancements significantly improve agricultural practices, increase productivity, and are beneficial for the environment. The adoption of modern technology such as automated lawn care and irrigation systems is augmenting the farming industry, facilitating even greater hikes in crop production. For example, sensors installed on crops and soil can gauge the real-time weather conditions, taking into account factors like temperature, moisture level, and nutrient levels, which allow these systems to distribute an adequate amount of water to the plants so that there is maximum efficiency and little wastage.

Robotics and automation work wonders around controlling plant conditions, ensuring no waterlogging or drought occurs, as both can be highly detrimental to crop yield. Such systems and sensors are capable of monitoring soil health and moisture levels, which then allows greater insight to farmers, placing them in a better position to make adequate data- driven decisions that ensure optimal plant health and growth. Such high-quality data greatly facilitates farmers to accurately assess the correct amount of fertilizer to apply, reducing the chance of both nutrient overload and nutrient deficiency. All of this combined ultimately ensures that water and nutrient usage is sustainable and the quality of the crops is enhanced while simultaneously ensuring negative effects on the environment are minimized.

References

1   N. Xu, Z. Li, J. Kang, Q. Meng, M. Niu, "Agricultural Vehicle Automatic Navigation Positioning and Obstacle Avoidance Technology Based on ICP," May 2024. https://doi.org/10.1109/ACCESS.2024.3402743

2   K. Lochan, A. Khan, I. Elsayed, B. Sutharet, L. Seneviratne, I. Hussain, "Advancements in Precision Spraying of Agricultural Robots: A Comprehensive Review," July 2024. https://doi.org/10.1109/ACCESS.2024.3450904

3   A. Milella, A. Petitti, S. Rilling, A. Rana, R. Galati, M. Hoffman, J. Livin Stanly, G. Reina, "Robot-as-a-Service as a New Paradigm in Precision Farming," Dec. 2024. https://doi.org/10.1109/ACCESS.2024.3381511

4   S. Dhananjay Vyas, V. KumuthaSubash, M. Mepani, S. Venkatesh, A. Sinha, A. Guha, S. Dey, "Energy- and Safety-Aware Operation of Battery-Powered Autonomous Robots in Agriculture," Mar. 2024.

5   S. Adebola, M. Presten, R. Parikh, S. Aeron, S. Mukherjee, S. Sharma, M. Theis, W. Teitelbaum, E. Solowjow, K. Goldberg, "Automated Pruning and Irrigation of Polyculture Plants," May 2024. https://doi.org/10.1109/TASE.2024.3388576

6   M. Car, B. Arbanas Ferreira, J. Vuletic, M. Orsag, "Structured Ecological Cultivation with Autonomous Robots in Agriculture," Jan. 2023.

7   B. Wang, Y. Yan, Y. Lan, M. Wang, Z. Bian, "Accurate Detection and Precision Spraying of Corn and Weeds Using the Improved YOLOv5 Model," Feb. 2023. https://doi.org/10.1109/ACCESS.2023.3258439

8   M. Govindaraju, D. Fontanelli, S. Selva Kumar, A. S. Pillai, "Optimized Offline-Coverage Path Planning Algorithm for Multi-Robot for Weeding in Paddy Fields," Mar. 2023. https://doi.org/10.1109/ACCESS.2023.3322230

9   L. Song, J. Huang, Q. Liang, L. Nie, X. Liang, J. Zhu, "Trajectory Tracking Strategy for Sliding Mode Control with Double Closed-Loop for Lawn Mowing Robot Based on ESO," Sep. 2023. https://doi.org/10.1109/ACCESS.2022.3166816

10 Y. Avigal, M. Presten, M. Theis, "Simulating Polyculture Farming to Learn Automation Policies for Plant Diversity and Precision Irrigation," July 2022. https://doi.org/10.1109/TASE.2021.3138995

11 J. Pak, H. Son, J. Kim, Y. Park, "Field Evaluation of Path-Planning Algorithms for Autonomous Mobile Robot in Smart Farms," May 2022. https://doi.org/10.1109/ACCESS.2022.3181131

12 R. Firoozi, S. Sattarzadeh, S. Dey, "Cylindrical Battery Fault Detection Under Extreme Fast Charging: A Physics-Based Learning Approach," Jun. 2022. https://doi.org/10.1109/TEC.2021.3112950

13 W. Chi, Z. Ding, J. Wang, G. Chen, L. Sun, "A Generalized Voronoi Diagram-Based Efficient Heuristic Path Planning Method for RRTs in Mobile Robots," May 2022. https://doi.org/10.1109/TIE.2021.3078390

14 F. Rovira-Más, V. Saiz-Rubio, A. Cuenca-Cuenca, "Augmented Perception for Agricultural Robots Navigation," May 15, 2021. https://doi.org/10.1109/JSEN.2020.3016081

15 Q. Yao, Y. Tian, Q. Wang, S. Wang, "Control Strategies on Path Tracking for Autonomous Vehicle: State of the Art and Future Challenges," Jul. 2020. https://doi.org/10.1109/ACCESS.2020.3020075

16 J. Kim, H. Son, "A Voronoi Diagram-Based Workspace Partition for Weak Cooperation of Multi-Robot System in Orchard," Jan. 2020. https://doi.org/10.1109/ACCESS.2020.2969449

17 T. Chen, F. Meng, "Development and Performance Test of a Height-Adaptive Pesticide Spraying System," Jun. 2018. https://doi.org/10.1109/ACCESS.2018.2813667

18 R. Berenstein, Y. Edan, "Automatic Adjustable Spraying Device for Site-Specific Agricultural Application," May 2018. https://doi.org/10.1109/TASE.2017.2656143