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Agribot: Automatic Sapling Planting and Fertillizer Spraying Machine

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Abstract

To address the growing need for mechanization in agriculture- especially for repetitive and time-sensitive operations such as sapling planting and fertilizer application—this paper introduces AGRIBOT, a semi-autonomous robotic system tailored for efficient plantation processes. The robot incorporates a dual- Arduino setup: the first Arduino unit handles navigation, gate control for sapling release, and user alerts via a buzzer; the second Arduino oversees sapling detection through an IR sensor, activates a relay-controlled mini fertilizer pump, and operates a pair of servo motors responsible for loading saplings into the delivery pipe. Users can set the desired gap between saplings using manual switch inputs, after which the system executes the planting sequence automatically. At the end of each cycle, an audible alert provides user feedback, improving usability. Notably, the design is modular and allows coordinated functioning without requiring direct communication between the two controllers. Field simulations confirmed the prototype's accuracy in spacing, dependable mechanical response, and consistent performance. AGRIBOT presents an affordable, adaptable solution ideal for small to mid-scale farms aiming to implement precision agriculture methods.

Keywords: Agricultural robotics; Automation; Sapling plantation; Fertilizer spraying; Arduino; IR sensor; Buzzer alert system; Dual-microcontroller control; Smart farming

Introduction

Agriculture, particularly in developing countries, remains heavily dependent on manual labor for core activities such as planting and fertilizing. These operations are not only labor-intensive but also susceptible to inconsistency and inefficiency, especially when performed over large plots or for high-density crops. With the increasing cost and scarcity of farm labor, there is an urgent need for smart agricultural tools that can automate repetitive processes with minimal human supervision while maintaining consistency and precision.

AGRIBOT addresses these challenges by offering a low-cost, semi- autonomous solution capable of sapling plantation and simultaneous fertilizer application. The system is structured around a dual-Arduino architecture, which divides control logic into two functional blocks:

- Arduino 1 is responsible for driving the bot forward using BO motors via an L298N motor driver, operating a pair of servo- controlled sapling gates to drop saplings at preselected intervals, and activating a buzzer to alert the user after a predefined number of plantations. The inter-sapling spacing is selected manually using tactile switches, allowing flexible operation based on crop type.
- Arduino 2 continuously monitors sapling drop activity using an IR sensor. When a sapling is detected, it activates a relay module to switch on a DC water pump, which sprays fertilizer near the root zone. After spraying, two servo motors sequentially push the next sapling from the tray into the delivery pipe, preparing for the next plantation cycle.

This distributed logic allows each microcontroller to handle its respective functions independently while operating in loose synchronization based on physical event detection. The buzzer, controlled by Arduino 1, serves as a key user-feedback mechanism, notifying the operator after each batch of plantations and preventing unnoticed dry runs.

Literature Survey

The literature survey focuses on recent advancements in automated agricultural systems, specifically those designed for precision planting and fertilization. It explores various technologies and mechanisms used for sapling placement, soil preparation, fertilizer dispensing, and real-time monitoring, highlighting innovations aimed at increasing efficiency and accuracy in large-scale farming. The proposed solution has been derived from the findings of the following research papers which has proved helpful to achieve the proposed objectives of the project.

Mohammed Amer and et. al has presented an automated planting machine designed for precision seed placement, adaptable to different soil types, and aimed at improving planting efficiency in Palestine. Utilizing SolidWorks for design, Arduino for automation, and sensors to monitor soil conditions, the machine significantly reduces human intervention. However, challenges arise in rocky terrain, and its scalability across diverse crop types needs further exploration.[1]

Ms. Trupti A Shinde has presented an automatic sowing machine in the SSRG International Journal of Electronics and Communication Engineering. The machine, powered by a 12V battery, uses ultrasonic sensors to avoid obstacles and DC motors for controlled seed placement. Despite enhancing efficiency, its limited obstacle detection range and lack of large-scale testing restrict its wider applicability.[2]

Praveen K., Babugouda and et. al discusses a remote-controlled sprayer machine aimed at improving the precision of pesticide and fertilizer application. It incorporates DC motors and ultrasonic sensors for efficient operation and obstacle avoidance. However, the machine may face limitations in large farms and challenging terrains, and its maintenance costs could be prohibitive for small-scale farmers.[3]

Prajwal Mondhe and et. al discusses an automated bot for planting onion saplings, focusing on labor reduction and cost- effectiveness in IRJET. The machine is designed to plant uniformly across different soils but is limited to onion crops. The need for extensive field testing and high initial setup costs are highlighted as challenges.[4]

Akhila Gollakota presents a paper and discusses multi-purpose agricultural robot designed for tasks like ploughing and seed sowing, utilizing simple DC motors and stepper motors. This robot reduces manual labor and improves efficiency but faces challenges in uneven fields and lacks advanced features like irrigation or precision farming techniques.[5]

K Durga Sowjanya and et. al presented a multipurpose autonomous robot capable of tasks such as ploughing, watering, and monitoring crops. It integrates GPS and soil sensors for autonomous operations but may suffer from performance trade- offs due to the complexity of handling multiple functions, particularly under varying environmental conditions.[6]

Xianglei Xue presents transplanting mechanism for cotton seedlings has been presented by the author that significantly improves transplanting efficiency and seedling survival rates. While the system performs well in experimental trials, challenges such as high power consumption and complexity limit its feasibility for widespread adoption.[7]

Marius Ioan Gheres has presented an analysis of energy consumption in relation to different soil tillage tools, identifying significant variations based on tool design and soil conditions. The study emphasizes the need for efficient tool selection but highlights potential cost and environmental constraints that affect small-scale farmers.[8]

Nabayi, A. et. al has given a review of tillage practices, comparing conventional and no-tillage systems in terms of soil structure, water retention, and microbial activity. While no- tillage systems improve soil health over time, the review underscores site-specific factors and the gradual transition period needed for full benefits.[9]

Ashish Lalwani and et. al has presented a comprehensive review of autonomous agribots used for tasks such as soil testing, planting, and harvesting. Despite the potential for increased efficiency and labour reduction, challenges such as high initial costs and technological issues, like sensor calibration, limit the widespread adoption of agribots in real-world settings.[10]

System Overview

A brief overview of Agribot with the help of block diagram of each microcontroller unit along with the detailed explanation of each block is defined in Figure 1.

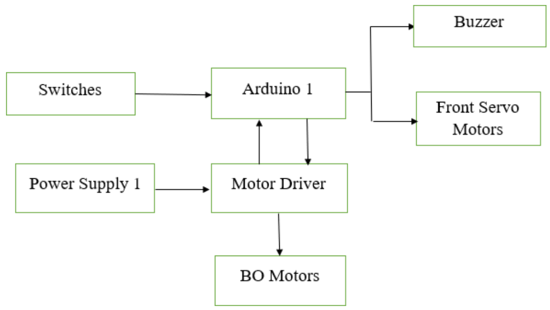

Fig 1. Block Diagram of Arduino 1

The AGRIBOT machine comprises two coordinated subsystems:

● **Arduino 1** controls movement, sapling planting via a servo-operated gate, and alerts the user using a buzzer.

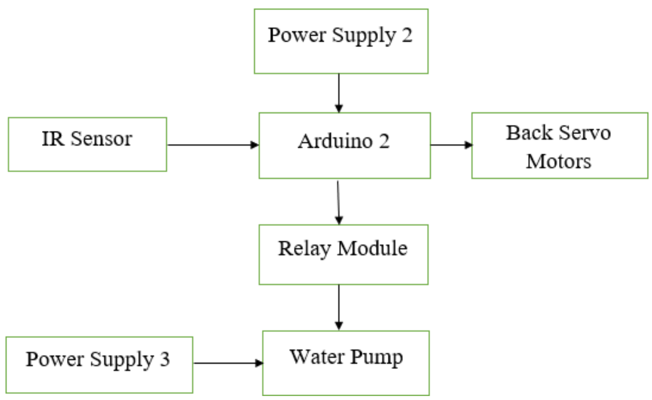

Fig 2. Block diagram of Arduino 2

● **Arduino 2** handles gate monitoring and detection using an IR sensor, activates the fertilizer spraying pump through a relay, and refills the sapling pipe via rear- mounted servo motors.

ARDUINO 1 SUBSYSTEM (Motion, Plantation & User Alert)

Power Supply 1

- Powers Arduino 1, the L298N motor driver, BO motors, front servo, and buzzer.
- Essential for ensuring uninterrupted operation of all front- end control and movement components.
- Prevents logic-level instability by keeping high-current devices on a separate regulated rail.

Switch

- Three manual switches are placed on the bot's control panel.
- The farmer uses these to set the spacing between saplings.
- Based on the selected switch, Arduino 1 delays movement before stopping to drop the next sapling.
- This allows crop-specific planting distances in real-world field applications.

BO Motor

- Drives the AGRIBOT forward in the field to reach the next planting position.
- Controlled by Arduino 1 via the motor driver based on the spacing set by the switches.
- For example, if 20 cm is selected, the motor runs just long enough to travel 20 cm, then stops.

Motor Driver (L298N)

- Used to drive the BO motors based on commands from Arduino 1.
- Converts low-current signals from Arduino into sufficient power for the motors to move AGRIBOT.
- Essential for regulating movement in small, accurate bursts between sapling placements.

Front Servo Motors

- Positioned at the bottom of the vertical PVC sapling-holding pipe.
- Controlled by Arduino 1 to release exactly one sapling at each stop.
- After the bot halts at the correct location, the front servo rotates briefly to open the gate, dropping a sapling, then closes to hold the remaining saplings.
- This ensures one-by-one, controlled plantation without jamming or double-drops.

Buzzer

- Controlled by Arduino 1 to alert the user when a predefined number of saplings i.e. 3 have been planted.
- Located visibly and audibly on the bot so the operator knows when a refill or task check is required.
- For example, during a test run, after 3 saplings are planted, the buzzer will beep continuously to prompt a refill or halt.

ARDUINO 2 SUBSYSTEM (Sapling Detection, Fertilizer Spray, and Pipe Refill)

Power Supply 2

- Supplies Arduino 2, IR sensor, relay module, rear servos, and 12V water pump.
- Dedicated to isolate the fertilizer subsystem from interfering with movement/plantation logic.
- Ensures stable relay switching and sensor reading even during pump surges.

IR Sensor

- Placed at the exit of the sapling tray pipe.
- Detects whether a sapling has moved past (i.e., the servo has dropped one) thus monitoring gate movement.
- Acts as a trigger for spraying: once a sapling is detected dropping, it signals Arduino 2 to start the fertilizer cycle.
- Also acts as a safety check: if no sapling is detected during movement, the system knows the tray is empty.

Relay Module

- Used by Arduino 2 to control the DC water pump that sprays fertilizer.
- Once IR sensor detects gate opening and sapling drop, Arduino 2 energizes the relay to turn ON the pump.
- After a fixed spray duration, Arduino 2 turns OFF the relay to stop spraying.
- This ensures fertilizer is applied directly after planting, minimizing waste and improving crop rooting.

Water Pump

- Sprays fertilizer at the planting location immediately after a sapling is dropped**.**
- Only activated when the IR sensor confirms a sapling has passed.
- Ensures the fertilizer is applied precisely to the root zone for each sapling.

Back Servo Motors

- Mounted at the rear near the main sapling tray.
- These servos refill the planting pipe by pushing the next sapling into the vertical pipe after each drop.
- Operated by Arduino 2 after each spray cycle to ensure the next sapling is ready.

Functional Overview

The distribution of tasks between the two Arduinos can be explained with the help of the flowchart given.

Arduino 1 in the AGRIBOT system is responsible for executing the core cycle of movement and sapling plantation based on user-defined spacing. It takes input through manual switches, drives the motors to move the robot forward, operates servo motors to drop saplings at precise intervals, and alerts the user once a batch of saplings is planted.

The process begins when the user selects one of three switches corresponding to different planting distances. Based on the selected input, Arduino 1 activates the BO motors to move the robot forward for a calibrated duration. After completing the forward movement, the robot halts, and a pair of servo motors operate sequentially to open and close a mechanical gate that drops a sapling into the soil.

This cycle is repeated three times, allowing the robot to plant three saplings in a batch. Once the cycle is complete,

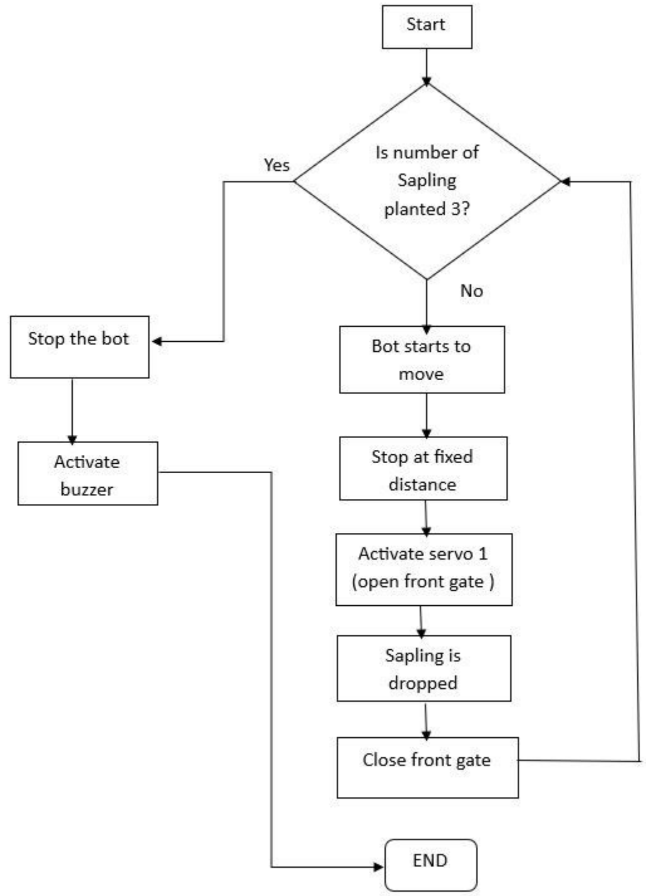

Fig 3. Flowchart of Arduino 1

Arduino 1 activates a buzzer to alert the user that the current batch has been planted. This alert also serves as a prompt for the user to refill the sapling tray if necessary or reposition the robot for the next planting row.

The design of this subsystem ensures consistent spacing between saplings, precise mechanical control of planting, and minimal user intervention. The logic operates independently and coordinates seamlessly with Arduino 2, which handles fertilizer spraying and sapling refilling based on the plantation cycle initiated by Arduino 1.

Arduino 2 automates the fertilizer application process and manages sapling pipe refilling. It operates in response to sapling drops detected by an IR sensor, which is positioned below the vertical planting pipe.

When the IR sensor detects the presence of a sapling (interpreted as a planting event from Arduino 1), Arduino 2 activates a relay that controls a 12V DC water pump. The pump sprays fertilizer at the planting site for a fixed duration, ensuring immediate and localized nutrient delivery.

Following the spray cycle, Arduino 2 initiates a dual-step sapling refill process using two rear-mounted servo motors. Servo 1 begins by pushing the next sapling forward into the planting pipe, followed by a delay and activation of Servo 2, which finalizes the positioning of the sapling. This staged refill mechanism reduces the likelihood of jamming and ensures the planting system is prepared for the next cycle.

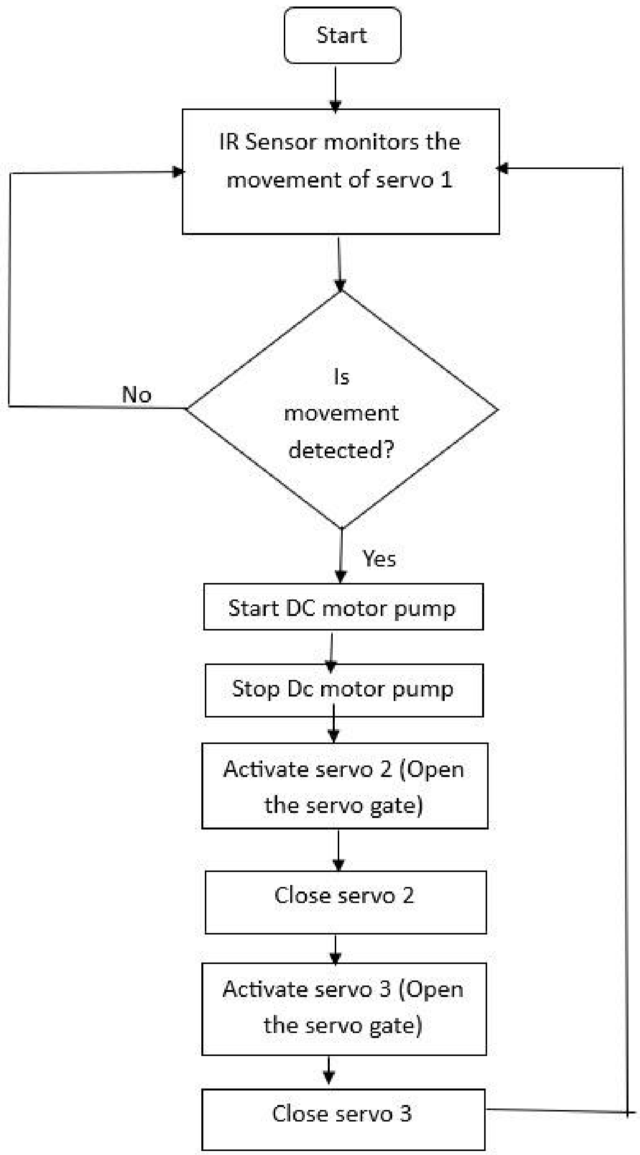

Fig 4. Flowchart of Arduino 2

Arduino 2 functions without requiring direct communication from Arduino 1. Instead, it relies on physical event detection through the IR sensor, maintaining loose synchronization with the plantation process and enabling smooth operation of the fertilizer and refill subsystems.

Results and Discussion

The performance of the AGRIBOT prototype was evaluated in a controlled, field-simulated environment to validate its functionality in sapling plantation and fertilizer application. As seen in Figures 5 and 6 various components, including the movement subsystem, plantation mechanism, fertilizer delivery, and sapling detection, were tested for reliability, accuracy, and synchronization.

Fig 5. Agribot prototype with enclosure

A. Sapling Plantation Accuracy

The sapling plantation mechanism was observed to perform consistently across multiple test runs. As seen in Figure 7, the operational images, three vertical PVC pipes were mounted at the front of the robot to serve as sapling reservoirs. Each pipe is equipped with a gate controlled by a micro servo motor. When the bot reached the programmed planting distance selected using one of the three onboard switches, Arduino 1 halted forward movement and triggered the corresponding servo to open the gate momentarily. This action allowed one sapling to drop precisely into the furrow created beneath the bot using mechanical splitters. Yellow-colored saplings, as seen in Figure 6 marked in the visual documentation, were correctly spaced and uniformly planted.

B. Fertilizer Spraying Synchronization

Immediately following the release of a sapling, the IR sensor positioned near the sapling drop point detected the event. This signal was fed to Arduino 2, which activated the relay module to power the DC water pump. The pump sprayed a controlled volume of fertilizer at the root zone. The timing of the spray was short and precise, ensuring that the fluid was applied directly after plantation and not during movement. The coordination between sapling detection and fertilizer application proved to be effective, with no missed sprays or redundant activations observed during trials.

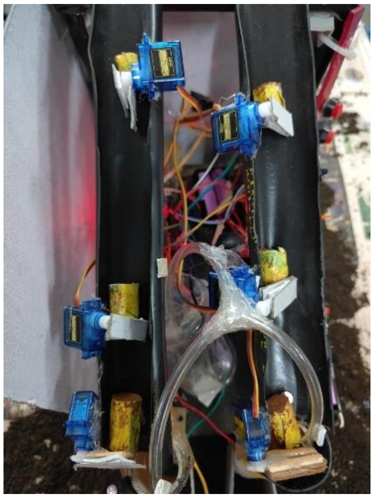

Fig 6. Top view of Agribot

Fig 7. Front view of Agribot

C. Refill Mechanism and Continuity

The refill subsystem, managed by Arduino 2, involved a pair of rear servo motors that pushed the next sapling into the delivery pipe after each planting cycle. As shown in side-view and post- plantation images, this mechanism ensured that the sapling pipe was always preloaded for the next cycle. The servos functioned without mechanical jamming or overlap between saplings. The smoothness of this operation contributed significantly to the bot's ability to maintain a continuous planting rhythm.

Fig 8. Furrow creation by T-splitters

D. Furrow Creation and Placement Precision

During testing, the mounted splitters at the front successfully created narrow furrows as seen in Figure 8 into which the saplings were placed. In post-operation images, clear furrow lines with planted saplings can be seen, confirming proper alignment between the bot's mechanical design and the expected agronomic layout. The depth and width of the furrows were consistent and suitable for most types of seedlings.

E. User Interaction and Feedback

The inclusion of a buzzer, activated after every three saplings each row were planted, served as a real-time alert system for the user. This feature ensured that the operator was aware of when to refill the sapling reservoir or halt the bot for inspection. The use of tactile switches for spacing selection allowed the system to be reconfigured quickly in the field .

F. Programmed distance vs actual distance between each sapling

Programmed distance	Actual distance
10 cm	9.7 cm
10 cm	9.8 cm
10 cm	10.3 cm
15 cm	15.1 cm
15 cm	15.3 cm
15 cm	14.8 cm

Conclusion

In conclusion, the automatic sapling planter and fertilizer sprayer project represents a significant advancement in agricultural technology, offering an efficient and automated solution for planting and fertilization. The system operates using a microcontroller, which processes user inputs from a simple interface where operators can specify the number of saplings and their spacing. The microcontroller calculates the planting sequence through guided feedback from motor encoders. Gate mechanism controls the release of saplings at fixed distance specified by the user and sprays fertilizer, the amount of fertilizer sprayed can be controlled as per the requirements of the sapling. A feature is included which ensures that the operator is alerted via a buzzer if fertilizer levels are low or if the sapling tray is empty and the process is completed. This project is particularly beneficial for nurseries, where it automates the propagation of young plants, and in agriculture, where it enhances crop planting by reducing labor costs and increasing productivity. Overall, the automatic sapling planter and fertilizer sprayer simplifies the planting process while promoting sustainable practices through optimized resource usage, making it a valuable tool for modern nurseries and agricultural operations.

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