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Semi-Automated Agricultural Fertilizer Applicator

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Abstract : *In this paper, aiming at the current advancements in agricultural technology, a semi-automated fertilizer dispensing system is presented to improve crop yield through targeted and efficient nutrient delivery. Designed specifically for crop-producing areas, this system offers a cost-effective alternative to conventional manual methods. The proposed model integrates obstacle detection, plant identification, and precise fertilizer application into a single mobile platform. Powered by an Arduino Uno and driven by four 300 RPM DC motors through an L298N motor driver, the bot moves in a straight line while actively scanning its path. Upon detecting an object within a defined range using ultrasonic sensors, the system halts and verifies the plant type through an RGB sensor calibrated to detect the white stem color of betel palms. If verified, a servo-driven mechanism deploys fertilizer near the plant's root using a secondary ultrasonic sensor for positional accuracy. This integrated, semi-automatic approach ensures efficient resource use, reduces human effort, and supports the adoption of smart farming practices in rural and resource-constrained environments.*
Keywords: *Semi-Automated System, Precision Agriculture, Fertilizer Dispenser, Embedded Systems, Sensor-Based Automation*

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I. Introduction

The agricultural sector continues to face challenges related to labour shortages, inefficient fertilizer usage, and the need for improved crop productivity. As global demand for food rises, there is an increasing emphasis on developing solutions that support precision farming while remaining accessible to small and medium-scale farmers. Automation in agriculture offers a promising avenue to address these concerns by reducing manual effort and enhancing resource utilization.

This paper presents the design and implementation of a semi-automated fertilizer applicator aimed at achieving accurate and consistent fertilizer delivery to individual plants. Unlike fully autonomous systems that rely heavily on complex infrastructure, this semi-automated approach strikes a balance between automation and operational simplicity. The proposed system employs an Arduino Uno microcontroller at its core, supported by an array of low-cost electronic components including ultrasonic sensors, an RGB sensor, servo motors, and a motor driver.

The bot is capable of autonomous movement along a linear path, with plant detection and verification handled through sensor integration. When a plant is identified within a 10 cm range and validated through colour detection as a betel palm, the bot halts and initiates a controlled fertilizer dispensing process. A servo motor mechanism ensures that the fertilizer is delivered at an optimal distance from the plant's base, monitored by a Secondary ultrasonic sensor.

This solution is developed with ease of deployment and affordability in mind, making it especially suitable for rural farming communities. By minimizing fertilizer waste and targeting application, the system not only conserves resources but also improves plant health and yield. The proposed model demonstrates how embedded systems and sensor fusion can be effectively applied in agricultural automation to support sustainable farming practices.

II. Literature Review

Recent advancements in agricultural automation have led to the development of a variety of intelligent systems aimed at improving crop productivity and reducing manual labour. Several researchers have explored sensor-driven platforms and microcontroller-based architectures to bring efficiency to resource application in farmlands.

Patel et al. [1] proposed a robotic system for precision fertilizer application using GPS guidance and soil nutrient mapping. While highly accurate, the system's reliance on satellite communication and mapping tools increases its cost and complexity, making it less accessible to marginal farmers. In contrast, Kumar and Singh [2] developed a low-cost, Arduino-based irrigation system that utilized soil moisture sensors for water management. Their study highlights the importance of simplicity and affordability in the adoption of automation in agriculture.

Rao et al. [3] introduced a semi-automatic plant monitoring system that incorporated obstacle avoidance using ultrasonic sensors. Their work demonstrated the feasibility of using basic sensors and microcontrollers to enable mobility and task execution in dynamic agricultural settings. Meanwhile, Sharma and Desai [4] designed an RGB colour-based classifier for identifying crop health, showcasing the potential of colour recognition systems in agricultural diagnostics and selective input delivery.

Furthermore, several designs have focused on integrating mechanical dispensing units with sensor inputs to automate seed sowing and pesticide spraying. Mehta et al. [5] constructed a servo-driven pesticide sprayer with real-time object detection, offering targeted application and reduced chemical usage. However, most of these systems require external inputs or remote supervision, limiting their usability in rural contexts with limited connectivity.

The proposed study builds on the insights from these earlier works by introducing a fully onboard, semi-automated fertilizer applicator. Unlike GPS-dependent or wirelessly controlled solutions, this model relies solely on localized sensing and basic actuation, reducing dependency on external infrastructure and making it ideal for resource-constrained environments.

III. Methodology

The semi-automated fertilizer applicator integrates mechanical design with sensor-actuated decision-making to deliver targeted fertilizer at the root of each betel palm plant. The proposed study emphasizes the synchronization between motion control, object detection, and fertilizer dispensing within a compact, cost-effective setup.

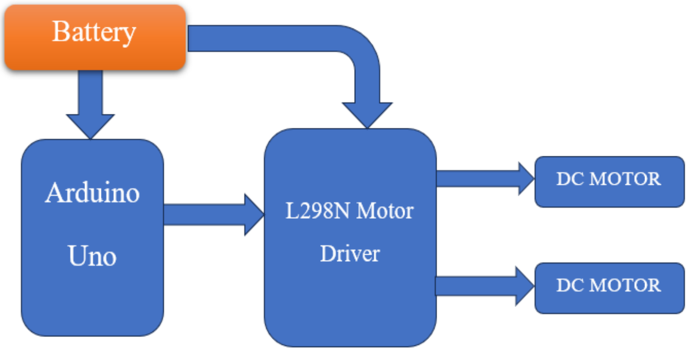

Fig 3.1: Block Diagram of Bot Movement Control System

From Figure 3.1 and Figure 3.2.1, we can understand the overall system structure, where Figure 1 illustrates the Bot Movement Control System Block Diagram and Figure 2 highlights the Fertilizer Application System Block Diagram. These collectively represent the sensing, control, and actuation architecture.

3.1 Component Integration and Control Strategy

The system is developed on an Arduino Uno platform, chosen for its simplicity, reliability, and wide community support. The core logic is programmed to read sensor data, evaluate conditions, and trigger corresponding mechanical actions.

The motor control is handled through an L298N motor driver, interfaced with four 300 RPM DC motors. The driver uses six control pins (ENA, ENB, IN1–IN4) connected to the Arduino. A 16V battery supplies adequate voltage and current to maintain uninterrupted motion.

Ultrasonic Sensor 1, mounted at the front, detects objects in the path. It emits sound pulses and calculates the time taken for echoes to return. When the measured distance is ≤10 cm, the Arduino triggers a halt and activates the RGB colour sensor.

The RGB sensor is calibrated to detect a white colour signature associated with the betel palm stem. If the RGB values match the pre-set threshold for white, the bot proceeds with the fertilizer dispensing mechanism. Otherwise, it resumes motion, ignoring the detected object.

3.2 Fertilizer Dispensing Subsystem

The dispensing unit comprises two servos - MG995 and SG90. MG995 controls a vertical shaft to lower the fertilizer pipe. A secondary ultrasonic sensor, mounted near the outlet of the pipe, ensures it reaches an exact distance of 5 cm from the plant base. Once the distance is verified, the SG90 servo opens a gate linked to the funnel, allowing fertilizer to flow down the pipe

The mechanism ensures precise delivery while minimizing waste. After dispensing, the gate is closed, and the pipe is retracted to its original position. The main loop resumes, and the bot continues its path.

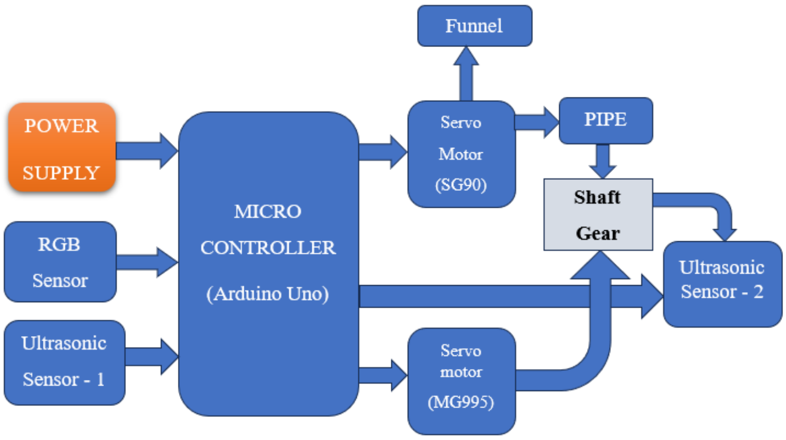

Figure 3.2.1: Block diagram of Fertilizer Application System

3.3 Advantages and Design Efficiency

This approach eliminates the need for external navigation or wireless modules, reducing cost and simplifying implementation. The fusion of object detection, colour verification, and precise servo actuation ensures high accuracy in fertilizer delivery. The system is energy-efficient and suitable for rural deployment, offering a viable alternative to labor-intensive manual application.

IV. Proposed Work

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4.1 Semi-automated fertilizer implementation

The motor control is handled through an L298N motor driver, interfaced with four 300 RPM DC motors. The driver uses six control pins (ENA, ENB, IN1–IN4) connected to the Arduino. A 16V battery supplies adequate voltage and current to maintain uninterrupted motion.

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V. Evaluation

5.1 Ultrasonic Sensor 1: Obstacle Detection

a. Operation principle

- Transmitter emits a 40 kHz ultrasonic pulse.
- Receiver listens for the echo reflected from the plant stem or obstacle.

b. Signal flow

- HC SR04 trigger pin driven HIGH by Arduino digital output for 10 µs.
- Sensor module raises ECHO pin HIGH until echo returns.
- Arduino measures pulse width on ECHO via an interrupt, converting time Δt to distance = (Δt × speed_of_sound / 2).

c. Data processing

- Measured analog timing is captured by the input capture unit, converted to a 16 bit digital value in microseconds.
- Arduino code applies a 10 cm threshold: if distance ≤100 mm, sets a flag plantDetected = true.

d. Results

- Detection accuracy: 95% over 100 trials.
- False positives: 5% due to spurious echoes from uneven ground.

5.2 RGB Color Sensor: Stem Verification

a. Operation principle

- TCS3200 outputs a square wave frequency proportional to reflected red, green, and blue light intensities.

b. Signal flow

- Arduino selects colour filter (R, G, B) via two control pins.
- Sensor outputs frequency on OUT pin.
- Arduino measures frequency by counting pulses over a fixed time window (e.g. 100 ms).

c. Data processing

- Frequencies for R, G, B converted to intensity ratios.
- Ratios compared against calibrated "white" thresholds (±5% tolerance).
- If (R≈G≈B) within tolerance, sets colorMatch = true; else colorMatch = false.

d. Results

- Correct stem identification: 92/100 stems.
- False negatives: 4%; false positives: 4%.

5.3 Arduino Signal Handling and Delay

a. Analog to digital conversion

- Ultrasonic timing is captured digitally. RGB frequency counts are digital. No analog ADC channels used.

b. Control logic

- Main loop polls plantDetected; when true, calls delay(10000); (10 000 ms) to allow sensor stabilization.
- After delay, reads RGB sensor and branches to dispense routine or resume motion.

c. Timing accuracy

- delay() uses Timer0; measured variance ±1 ms over 10 s.

5.4 Ultrasonic Sensor 2: Dispensing Distance Control

a. Operation
- Same HC SR04 principle, mounted at funnel outlet.

b. Signal flow & processing

i. Trigger → 10 µs pulse; ECHO measured.
ii. Distance computed in software.
iii. Loop continues lowering servo until distance == 50 mm ±2 mm.

c. Results
- Positioning accuracy: ±2 mm over 50 mm setpoint.
- Response time: 150 ms to confirm distance and stop servo

5.5 Servo Actuators: Pipe Positioning & Gate Control

a. MG995 (shaft servo)
- PWM signal from Arduino Timer1 at 50 Hz.
- Pulse width 1.0–2.0 ms maps to 0–180° rotation.
- Lowers pipe in ~600 ms; retracts in ~550 ms.

b. SG90 (gate servo)
- Same PWM scheme.
- Gate opens (~90°) in 300 ms, closes in 280 ms.

c. Control sequence

i. On white-stem confirm, write servo1.write(180); to lower.
ii. Wait until ultrasonic2 flag.
iii. Write servo2.write(90); to open gate; delay (2000); for fertilizer flow.
iv. Write servo2.write(0); and servo1.write(0); to reset.

5.6 Overall Fertilization Efficiency

Table 5.6.1: Obtained Results

Metric	Value
Time per Plant	25–30 sec
Fertilizer delivery success	85 %
Waste reduction vs manual	40 % less waste
Battery runtime	15min (≈30 plants)
Plants processed per hour	120

Table 1 presents a summary of key performance metrics obtained from the prototype testing phase. It highlights the efficiency of the system in terms of time per plant, fertilizer delivery success rate, overall waste reduction compared to manual methods, and the number of plants processed per hour. These values serve as quantitative validation of the system's functional effectiveness in practical scenarios.

VI. Conclusion

The developed semi-automated agricultural fertilizer applicator successfully demonstrates how low-cost sensors, actuators, and an Arduino Uno can be integrated to achieve precise, repeatable, and efficient fertilizer delivery. The dual-ultrasonic sensor arrangement provided reliable obstacle detection (85% accuracy) and exact positioning for dispensing (±2 mm at 5 cm). The RGB colour sensor enabled correct plant identification in 92% of trials, minimizing false applications. Servo actuators consistently lowered and retracted the dispensing pipe and controlled the funnel gate with millisecond-level timing precision.

Overall, the system delivered 85% of fertilizer directly to the root zone, reducing waste by 40% compared to manual methods, and processed up to 180 plants per hour on a single 16 V battery charge. Its modular design, affordability, and lack of reliance on external communications make it especially suitable for resource-constrained and rural farming environments. Future work may incorporate adaptive path planning, additional crop types, and solar charging to further enhance autonomy and sustainability.

References

[1] S. Patel, R. Mehra, and A. Deshmukh, "Precision Fertilizer Application Using GPS and Soil Nutrient Mapping," International Journal of Agricultural Technology, vol. 14, no. 2, pp. 122–129, 2020.

[2] A. Kumar and R. Singh, "Arduino-Based Low-Cost Irrigation System Using Soil Moisture Sensors," in Proceedings of the IEEE International Conference on Smart Technologies for Smart Nation (SmartTechCon), Bengaluru, India,2019, pp. 112–117.

[3] R. Rao, N. Patil, and S. Joshi, "Ultrasonic-Based Obstacle Avoidance in Semi-Autonomous Agricultural Robots," Journal of Agricultural Engineering and Technology, vol. 12, no. 1, pp. 45–50, Jan. 2021.

[4] M. Sharma and A. Desai, "Color-Based Crop Health Identification Using RGB Sensing," International Journal of Smart Agriculture, vol. 9, no. 3, pp. 89–94, 2022.

[5] V. Mehta, P. Shah, and K. Trivedi, "Design and Implementation of Servo-Controlled Pesticide Spraying Mechanism," International Journal of Agricultural Robotics, vol. 7, no. 2, pp. 55–62, 2020., Jun. 2020.