

AI Based Automated Fertilizer Dispenser System

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Abstract

Efficient nutrient management is a critical determinant of crop yield and soil longevity. Conventional manual fertilizer application often results in disproportionate distribution. This leads to substantial resource wastage, ecological degradation, and escalated operational costs. Addressing the lack of accessible precision agricultural tools for farmers, this paper proposes a cost effective, Artificial Intelligence and Internet of Things enabled automated fertilizer dispenser system. By integrating microcontrollers, real time soil sensors, and intelligent actuation mechanisms, the framework calculates and dispenses precise fertilizer dosages tailored to dynamic soil conditions. Experimental outcomes demonstrate enhanced resource optimization. The system mitigates fertilizer wastage by twenty to twenty five percent while simultaneously reducing manual labor and promoting sustainable farming practices.

Keywords: artificial intelligence, Internet of Things, precision agriculture, automated dispenser, machine learning, wireless sensor networks.

1. Introduction

In contemporary agriculture, precise fertilization is paramount to ensuring optimal crop productivity, sustaining soil health, and mitigating environmental impact. Traditional agricultural practices predominantly rely on the manual broadcasting of fertilizers. This generalized approach frequently results in uneven nutrient distribution, where certain zones suffer from toxic over-application while others remain undernourished. Consequently, this imbalance fosters diminished agricultural output, severe financial loss, and long-term ecological consequences such as groundwater contamination and soil degradation. The advent of cyber-physical systems presents a robust solution to these challenges. By amalgamating Artificial Intelligence (AI) with advanced wireless sensor networks, intelligent automated systems can drastically modernize nutrient management. The proposed automated fertilizer dispenser system aims to replace intuitive manual farming with a data-driven paradigm. The field data are continuously aggregated, providing real-time microclimatic and

soil parameters such as potential hydrogen (pH), moisture content, and essential macronutrients to autonomously dictate the exact timing and volume of fertilizer required. This paper outlines the architectural design, methodology, and experimental validation of an Internet of Things (IoT) based automated dispensing prototype. By bridging the gap between sophisticated precision agriculture techniques and practical, scalable farming solutions, the system supports the global transition toward smart, sustainable agriculture.

2. Literature Review

The integration of technology into agricultural nutrient management has been a subject of extensive research, evolving from basic mechanical distribution to sophisticated, data-driven dispensing models. Early advancements primarily focused on establishing reliable wireless communication protocols within agricultural fields. Warpe [5] explored the foundational use of wireless sensor networks to distribute fertilizers, demonstrating the viability of continuous remote monitoring. However,

these early systems lacked autonomous decision-making capabilities, relying heavily on manual user triggers based on sensor readings. Subsequent research introduced physical automation to address the labor-intensive nature of manual fertilization. Mahore et al. [2] developed a microcontroller-based spot granular applicator, successfully mechanizing the physical delivery process. Similarly, Tamilarasi et al. [3] explored liquid fertilizer dispensing through existing canal systems, highlighting the efficiency of targeted liquid nutrient application. Expanding on physical automation, recent studies have increasingly incorporated robotics. Sharma et al. [7] and Singh et al. [9] developed mobile robotic frameworks capable of navigating fields to spray fertilizers and pesticides, significantly reducing human exposure to agricultural chemicals. More recently, the focus has shifted toward cognitive automation using Machine Learning (ML) and IoT. Bonifacio et al. [1] successfully implemented a Random Forest model to predict exact fertilizer dosing requirements, proving that AI can drastically improve nutrient precision. Kaur et al. [8] further emphasized the role of IoT and AI in sustainable agriculture by optimizing dispensing schedules based on multi-parameter environmental data [4]. Furthermore, automated blending systems proposed by Razak et al. [6] targeted specific chemical inefficiencies, significantly reducing nitrogen losses in the soil. Research Gap: Despite these advancements, a significant gap remains in providing a highly accessible, low-cost, and unified system that combines real-time IoT monitoring with instantaneous AI-driven actuation specifically designed for small to medium-scale farmers. Many existing robotic solutions are prohibitively expensive, while simpler micro-controller systems lack intelligent predictive logic. The proposed system in this paper bridges this gap by mounting an intelligent, sensor-driven dispensing mechanism onto a highly maneuverable, low-cost robotic chassis.

3. System Architecture and Components

To achieve a self-regulating and spatially aware distribution network, the system architecture is modularly categorized into four interdependent functional units: the locomotion chassis, the input data unit, the central processing unit, and the output

actuation module. The complete hardware interconnections are illustrated in Figure 1.

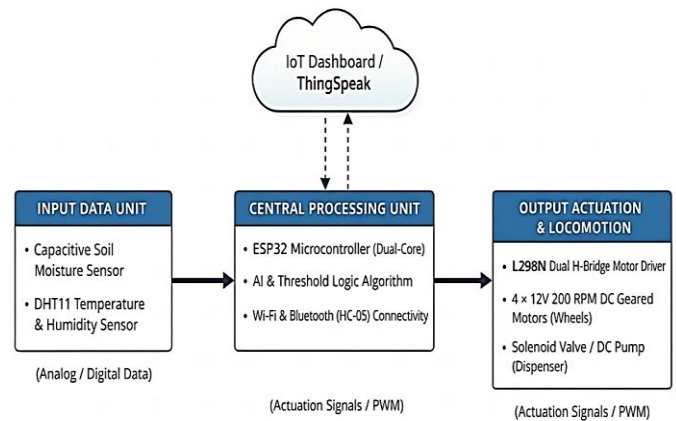


Figure 1 Block Diagram Illustrating The Mobile Robotic System Architecture And Hardware Integration

3.1. Mobile Chassis and Locomotion

Unlike stationary fertigation nodes, the proposed framework utilizes a four-wheel acrylic and metal chassis to navigate the agricultural terrain. Locomotion is driven by four 12-volt, 200 revolutions per minute (RPM) direct current (dc) geared motors. These motors are controlled by an L298N dual H-bridge motor driver module, which allows the central processor to manipulate the speed and directional vectors of the robot dynamically.

3.2. Input Data Unit

Accurate decision-making is contingent upon reliable environmental data acquisition. The mobile platform is equipped with capacitive soil moisture sensors to continuously monitor the localized water content. Furthermore, a DHT11 temperature and humidity sensor captures the ambient microclimate. These empirical data are fundamentally required by the algorithm to calculate exact dispensing metrics and timing.

3.3. Processing and Communication Unit

The central computational node is engineered around a 32-bit microcontroller, selected for its robust processing capabilities and integrated Wi-Fi and Bluetooth communication protocols. Data captured by the input layer are fed into this unit, where embedded AI algorithms interpret the telemetry. Peripheral hardware supporting this unit includes a

Bluetooth module for localized serial diagnostics and a 16x2 alphanumeric liquid crystal display (LCD) for real-time, on-site status visualization. A dual H-Bridge motor driver interfaces the microcontroller with the mechanical output systems.

3.4. Output Actuation Unit

The physical distribution of nutrients is executed by a custom-fabricated fertilizer hopper mounted at the

rear of the chassis. The hopper features an outlet connected to a localized dc motor-driven gate or peristaltic pump. The entire hardware framework is powered by a resilient 12-volt rechargeable battery pack, coupled with a 5-volt regulated supply for the logic circuits.

4. Proposed Methodology and Implementation

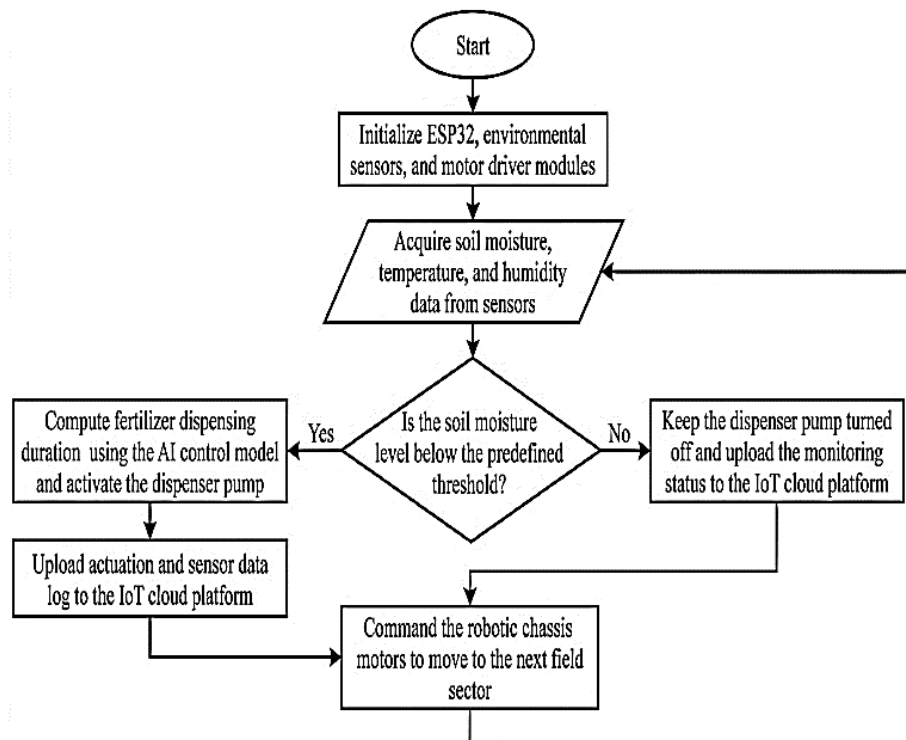


Figure 2 Flowchart illustrating the autonomous decision-making and robotic dispensing algorithm

The development and deployment of the automated dispensing robot follow a structured methodology designed to ensure precise locomotion and calibration accuracy. The logical flow of the control software is depicted in Figure 2.

4.1.1. Initial Assessment and Calibration

The deployment is preceded by a comprehensive site survey to establish baseline soil characteristics. Calibration ensures that the capacitive sensor readings are consistent with actual field conditions. The threshold limits are programmable; for example, a soil moisture threshold of 30 to 40 percent is established to dictate whether the robot should dispense nutrients or traverse to the next sector

without actuation.

4.1.2. Algorithmic Control and Synchronization

The core firmware, developed via the Arduino Integrated Development Environment (IDE), controls the synchronization between the robot locomotion and the fertilizer flow. When the robot halts at a designated coordinate, it reads the edaphic parameters. If the data indicate sub-optimal conditions (e.g., moisture falls below the baseline), the logic computes the exact duty cycle required for the dispenser motor (e.g., 25%, 50%, or 75% actuation) based on time and travel distance.

4.1.3. Telemetry and Data Processing

To facilitate remote farm management, continuous

data streams regarding soil health, robot location, and dispensing logs are securely transmitted to an IoT cloud server (such as ThingSpeak or Blynk). The processed data are visualized on a dedicated dashboard, which also issues alert notifications if a fertilizer refill is required or if sensor anomalies occur.

5. Result and Performance Analysis

Following hardware assembly and firmware optimization, the robotic dispenser was subjected to rigorous testing within controlled agricultural environments, including no-load movement tests and dispensing rate evaluations. The comparative performance metrics are summarized in Table 1. The experimental phase yielded highly favorable outcomes. The robotic platform demonstrated rapid responsiveness, possessing a sensor-to-actuation response time of less than 3 seconds. The actuation mechanisms effectively dispensed the precise quantum of nutrients uniformly across the coverage area [10-147]. One of the most significant empirical findings was a verified reduction in total fertilizer consumption by approximately 20 to 25 percent compared to conventional manual broadcasting. This optimization is directly attributed to the intelligent, threshold-based dispensing logic which strictly prevents over-application in already nutrient-dense or overly moist zones. System efficiency under test conditions reached 92 percent operational accuracy.

Precision	dispensing cycle
Battery Endurance	4.5 Hours (Continuous operation on 12V 7Ah)
System Efficiency	92% operational accuracy in field conditions

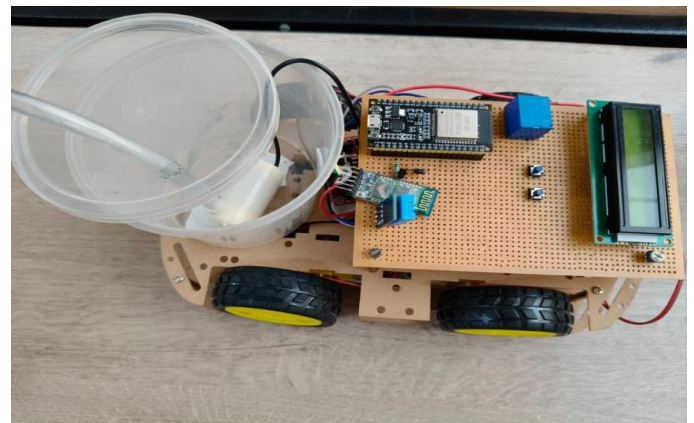


Figure 3 Fabricated Prototype Of The Autonomous Fertilizer Dispensing Robot

Table 1 System Performance and Operational Metrics

PARAMETER	OBSERVED PERFORMANCE/ VALUE
Sensor Accuracy	$\pm 2\%$ (Soil Moisture), $\pm 0.5^\circ\text{C}$ (Temperature)
Control Response Time	<3 seconds (Sensor detection to pump actuation)
IoT Telemetry Latency	<5 seconds (Data upload to ThingSpeak cloud)
Fertilizer Utilization	20-25% reduction compared to manual methods
Dispensing	5% volumetric accuracy per

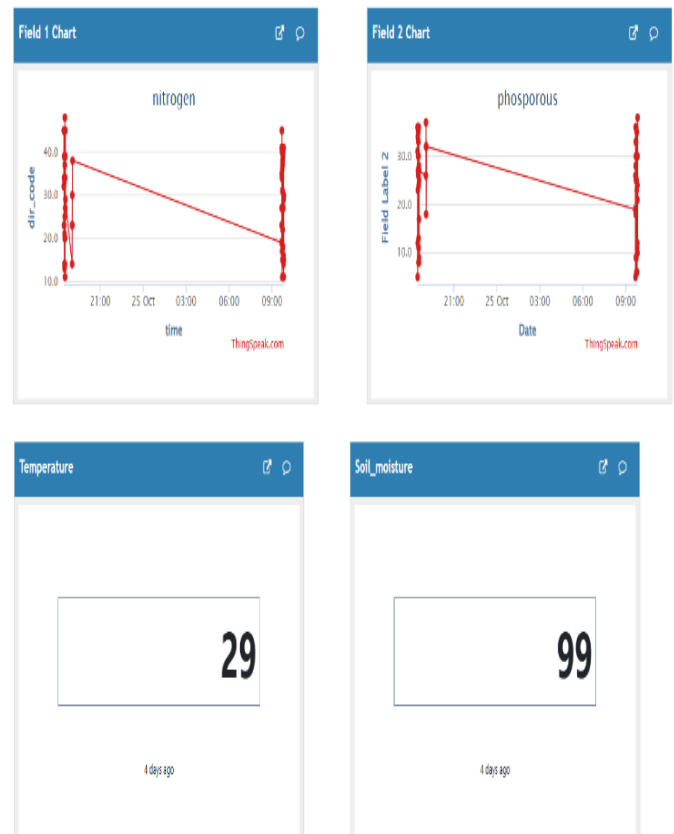




Figure 4 Thing speak IoT Dashboard Visualization Showing Real-Time Sensor Telemetry For Soil Moisture And Nitrogen Levels

Conclusion And Future Scope

This research successfully conceptualizes and validates a smart, mobile automated fertilizer dispensing robot powered by AI and IoT connectivity. By transitioning from labor-intensive manual broadcasting to a highly calibrated, sensor-driven autonomous robotic approach, the prototype achieves remarkable improvements in operational efficiency. The system precisely tailors nutrient delivery to real-time, site-specific soil demands, substantially curbing fertilizer wastage, protecting aquatic ecosystems from agricultural runoff, and promoting robust crop yields. Future iterations of this research will focus on integrating Global Positioning System (GPS) modules and machine vision for fully autonomous path planning and navigation. Furthermore, scalability for multi-unit operations could be achieved by coordinating a fleet of these robots to rapidly cover large agricultural topologies. Integrating advanced machine learning models for predictive yield analysis and outfitting the chassis

with solar panels for extended battery endurance will further refine the system readiness for mass-market adoption shown in Figure 3 and 4.

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