



**Faculty of Engineering and Information Technology
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RootRise

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Acknowledgment

We begin by remembering our brothers and sisters in Gaza and all across Palestine who continue to face hardship every day under occupation. This work is dedicated to their strength, resilience, and unbroken spirit.

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Disclaimer Statement

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Abstract

Tending to multiple plants can be annoying and time-consuming. Not everyone has the time or knowledge to water, sow, or fertilize each planter correctly. **RootRise** is a device that automates plant care with precision and efficiency.

RootRise is built on a CNC system that moves along the X, Y, and Z axes to tend six pots arranged in a 2x3 grid. The system performs watering, sowing, and fertilizing using three magnetic, removable heads mounted on the Z-axis. These heads are detached as needed, perform the required tasks, and return to their original positions. It also automatically sows seeds using a suction device that picks up and places each seed into its respective pot.

The system irrigates plants automatically based on soil moisture levels using sensors mounted on the Z-axis, which move precisely via a servo motor. A light sensor (LDR-based) monitors light levels and activates the pot lights when needed. Water level sensors measure the available water for irrigation and fertilization. Users can control the system via a keypad and view real-time readings on an LCD. Additionally, a dedicated app allows remote monitoring and management, providing feedback on watering, light, and soil conditions.

RootRise simplifies plant care, making it more efficient and reliable. It eliminates the time and stress of tending to multiple plants, ensures each plant receives the care it needs, and allows users to focus on other activities while the system works automatically.

Chapter 1: Introduction

1.1 Statement of the problem

Plant owners, whether at home or on small-scale farms, often find it challenging to give their plants the proper care, as the process requires continuous effort throughout the year. Tasks such as watering, sowing, and fertilizing are usually carried out manually, making them exhausting, time-consuming, and prone to human error. Many people also lack the technical knowledge to determine the correct amount of water, which may lead to overwatering or underwatering and negatively affect plant health and growth. In addition, monitoring soil moisture without technical assistance is difficult, resulting in inconsistent plant care.

Furthermore, the traditional equipment available for plant care is often limited in scope, requiring separate tools for watering, sowing, and fertilizing. These tools are not integrated into a unified system, forcing users to perform each task manually and repeatedly. Remote monitoring and management of plant conditions are also major challenges, as most existing solutions lack real-time data and smart control. This absence of automation and integration reduces efficiency, especially for individuals with limited time or a large number of plants to manage.

RootRise provides a solution by offering an automated, precise, and reliable system that integrates watering, sowing, fertilizing, and monitoring into a single platform, ensuring consistent plant care with minimal user intervention.

1.2 Objectives

The main goal of the RootRise project is to develop a fully automated, precise, and efficient plant care system. To achieve this, the project focuses on the following objectives:

1. Design and implement a CNC-based moving platform capable of navigating multiple pots arranged in a grid.

2. Develop interchangeable tool heads for watering, seed planting, and fertilization, using magnetic attachments to enable automatic switching between tasks.
3. Integrate a soil moisture sensor and automated irrigation system for precise and optimal watering.
4. Implement a vacuum-based seed planting mechanism that ensures accurate placement for different seed types.
5. Incorporate an LDR sensor to monitor ambient light and control artificial lighting when needed.
6. Monitor water and fertilizer levels through dedicated sensors to ensure uninterrupted operation.
7. Provide a local user interface with a keypad and LCD for manual control and real-time feedback.
8. Enable remote monitoring and control via a web application for seamless smart plant management.

1.3 Project Scope

This project can be used by anyone who takes care of plants, whether at home or on a small farm. It makes tasks like watering, planting seeds, and checking soil moisture easier, so even people with little experience can use it without problems.

1.4 Significance of the work

Taking care of plants is important for home gardens and small farms because proper watering, planting, and fertilizing directly affect the health and productivity of plants. The RootRise system helps plant owners take care of their plants automatically and accurately, reducing mistakes like overwatering or underwatering. With RootRise, users save time and effort, as it handles daily plant care tasks. Its sensors and automation monitor soil moisture, control watering, and plant seeds precisely, ensuring plants grow well and reducing the stress of daily maintenance. RootRise also allows users to monitor and control the system remotely through a web app, providing real-time updates and control from anywhere. This makes plant care more convenient and flexible. By

combining automated movement and sensors, RootRise makes plant care precise, reliable, and connected, letting users focus on other tasks while keeping their plants healthy.

Chapter 2: Literature Review

Recent studies show that using automation and sensors can make plant care much easier and more efficient. For example, smart garden systems for home use rely on soil moisture sensors to monitor the soil's moisture level and automatically water the plants when needed. These systems often use microcontrollers like Arduino to control watering and can be monitored remotely through a web or mobile app, reducing the chance of overwatering or underwatering[1].

In larger farms or orchards, automated irrigation systems use more advanced sensors, such as capacitance-type soil moisture sensors, combined with algorithms based on methods like the FAO water balance. These systems adjust water delivery according to the soil's real-time moisture and plant needs. Studies have shown that such systems can match or even improve the accuracy of manual irrigation done by experienced farmers, while saving water and labor[2].

These studies demonstrate that combining sensors, automation, and smart control can make watering precise, reliable, and convenient. RootRise applies these ideas to provide an automated system that monitors soil moisture and waters plants accurately, helping users take care of their gardens and small farms with minimal effort.

Chapter 3: Methodology

3.1 Overview of the System

The system is designed to automate plant care by performing watering, seed planting, and fertilizing with accuracy. It operates on six pots arranged in a 2x3 grid. The images below show the final look of the design.



Figure 1 : Side view of the RootRise system.



Figure 2 : Front view of the RootRise system.

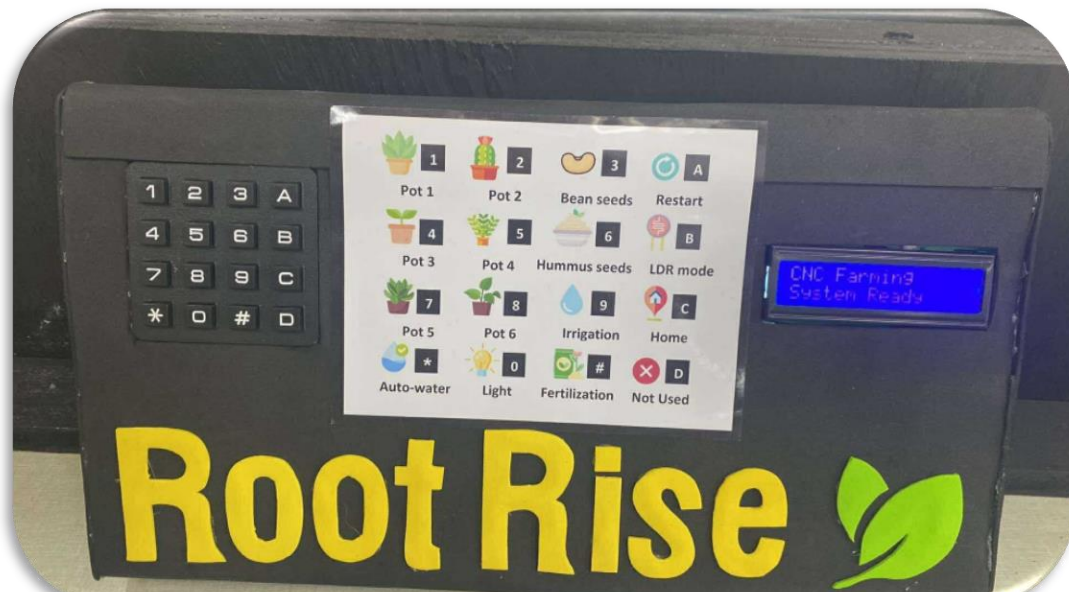


Figure 3 : Control board with LCD display and keypad interface for user input.

3.2 Features and Hardware Components

3.2.1 Moving Part

The motion system is designed to provide precise and stable movement along the three axes (X, Y, and Z).

Used Components

For the **X-axis**, **two NEMA 23 stepper motors** were selected. These motors provide higher torque compared to smaller models, which is important because the X-axis carries most of the system's weight and requires strong and stable movement. The motors are mounted on metal rods that serve as linear guides, ensuring smooth horizontal travel.



Figure 4 : Metal rods used as linear guides for smooth movement.



Figure 5 : NEMA 23 stepper motor used for driving the X-axis.

The **Y-axis** is driven by a **NEMA 17 stepper motor**, which is smaller but sufficient since the Y-axis carries less load compared to the X-axis. Ball bearing rollers are used to ensure smooth and stable motion along this axis. However, to prevent imbalance caused by the additional Z-axis assembly, a counterweight was added. This counterweight helps distribute the load evenly, reduces stress on the motor, and allows smoother vertical movement.

The Z-axis itself is controlled by another **NEMA 17 stepper motor**, as the vertical motion requires precision but not high torque. This axis is responsible for moving the tool heads up and down, ensuring accurate positioning during operations such as watering, seeding, or fertilizing.



Figure 6 : NEMA 17 stepper motor used for the Y-axis and Z-axis movement.



Figure 7 : Ball bearing rollers.



Figure 8 : Counterweight.

Arduino Mega

The Arduino Mega is used as the main controller of the system. It connects to all the motors, sensors, and drivers, and sends the right commands to control movement and operations. The Mega was chosen because it has more pins and memory compared to other Arduino boards, which makes it suitable for handling several components at the same time.



Figure 9 : Arduino Mega controlling the RootRise system.

Stepper Driver

The system uses a 3.5 A stepper driver to run the stepper motors. The driver works like a middle part between the controller and the motors. It gives the motors the right power so they can move smoothly and with good accuracy. The driver also makes sure the motors don't take more current than they need, so they don't get too hot. With this driver, the motors (NEMA 23 and NEMA 17) can move the system on the X, Y, and Z axes in a stable way.



Figure 10 : 3.5 A stepper driver controlling the NEMA 17 and NEMA 23 motors.

Power Supply and Wiring



Figure 11 : Wires used in the RootRise system.



Figure 12 : Power supply used to provide stable voltage.

Limit Switches

The system uses **four limit switches**, installed at the start and end of both the X and Y axes. These switches help prevent the motors from moving beyond the allowed range, protecting the system from collisions and ensuring safe and accurate operation.



Figure 13 : Limit switches to protect X-Y axis movement.



Figure 14 : Counterweight on Y-axis for balanced vertical movement.

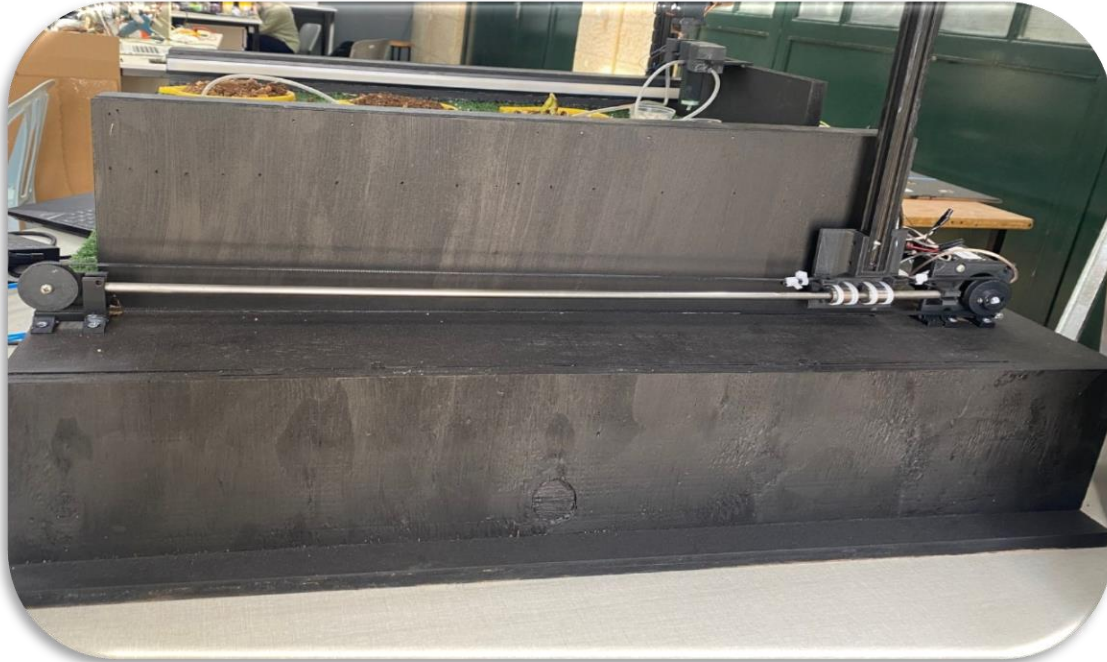


Figure 15 : NEMA 23 stepper motor driving the X-axis of the RootRise system.

3.2.2 Interchangeable Tool Heads

The system uses magnet-based interchangeable tool heads that allow it to perform multiple tasks, including watering, fertilizing, and seed planting. The magnetic mechanism makes attaching and detaching tool heads simple, quick, and reliable. Each tool head can be automatically positioned and swapped as needed, enabling the system to handle different plant care operations without manual intervention while maintaining flexibility and efficiency.



Figure 16 : Magnet-based tool heads allow automatic swapping for watering, fertilizing, and seed planting.

Used Components

Water Pumps

The system uses **two water pumps**—one for watering and one for fertilization. These pumps deliver the right amount of water or fertilizer to each pot, controlled automatically by the system based on sensor readings.



Figure 17 : Water pumps for automatic watering and fertilization.

Water Level Sensors

Water level sensors are used to monitor the amount of water available in the tanks. They ensure that the pumps have enough water to operate and prevent the system from running dry, helping maintain reliable watering and fertilization.



Figure 18 : Sensors to monitor water levels in tanks.

Seed Suction Mechanism

For the seed suction mechanism, several vacuum pumps were tested, but they did not have enough power to pick up the seeds. To solve this, a **vacuum cleaner motor** was used, providing sufficient suction to handle the seeds reliably.



Figure 19 : Vacuum motor used for reliable seed suction.

Relay Modules for Pumps

A **2-channel relay module** controls the two water pumps, allowing the system to turn watering and fertilization pumps on or off independently. This ensures safe and precise operation without overloading the control board.

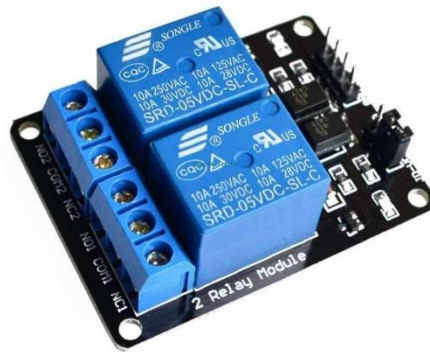


Figure 20 : Relays for safe and automated device control.

3.2.3 Soil Moisture Monitoring

The system uses a soil moisture sensor mounted on the Z-axis to measure the moisture level of the soil. The sensor helps the system decide when to water, ensuring plants receive the right amount of water and preventing overwatering or underwatering.

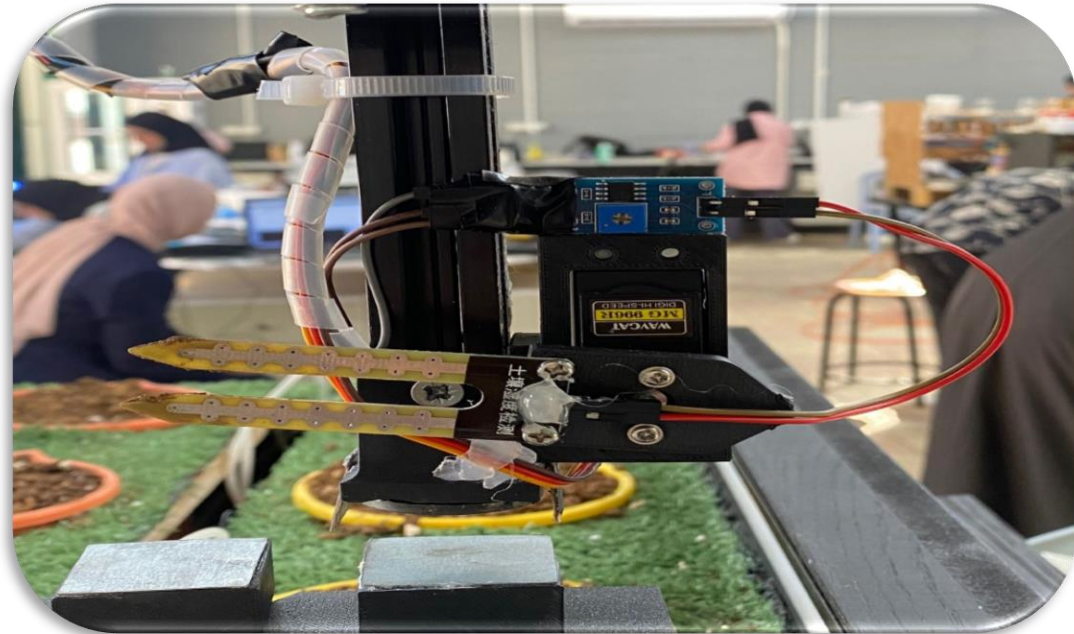


Figure 21 : Soil moisture sensor used to monitor soil wetness and control watering automatically.

Used Components

Z-Axis Servo Motor (MG995)

A **MG995 servo motor** is installed on the Z-axis to rotate the soil moisture sensor. This allows the sensor to move to each pot and take accurate measurements of the soil moisture.



Figure 22 : Z-axis servo for soil moisture sensor movement.

Soil Moisture Sensor

A **soil moisture sensor** is used to check how wet the soil is, helping the system decide when to water the plants.

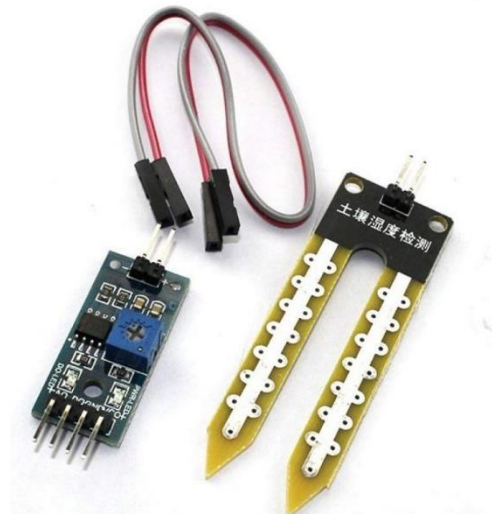


Figure 23 : Soil moisture sensor for watering control.

3.2.4 Lighting Control

The system's 4K linear lights can be controlled in two modes. In manual mode, the lights can be turned on or off using the 4x4 matrix keypad. In automatic mode, the LDR sensor automatically turns the lights on or off.



Figure 24 : Control the 4K linear lights manually or automatically via the LDR sensor.

Used Components

Linear Light (4K)

A **4K linear light** is used to provide consistent illumination for the plants. This ensures that the light levels can be controlled and monitored, supporting proper plant growth.



Figure 25 : 4K linear light for consistent plant illumination.

Power Supply for Light

An **H-100-24 switching power supply** is used to provide stable power to the 4K linear light. It converts AC voltage (175–250V, 50/60Hz) to DC 24V with a maximum current of 4.16A, ensuring the light operates safely and reliably.



Figure 26 : Power supply for 4K linear light

LDR Module for Light

An **LDR (Light Dependent Resistor) module** is used to measure ambient light levels. It helps the system decide when to turn the 4K linear light on or off, ensuring plants receive the right amount of light for proper growth.

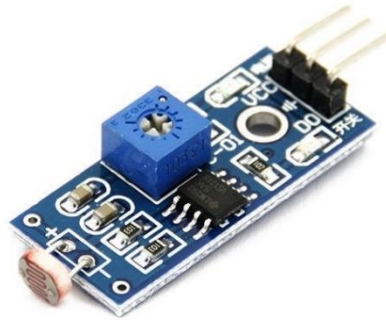


Figure 27 : LDR module for light control.

Relay Module for Light and Seed Suction

The second 2-channel relay module controls the **4K linear light** and the **vacuum pump for the seed suction mechanism**, enabling safe and automated operation of these high-power components.

Relays act as electrically operated switches, enabling the low-power signals from the Arduino Mega to control devices that require higher voltage and current. This setup ensures that all components operate safely and efficiently without overloading the control board, while providing precise automation for plant care.



Figure 28 : Relays for safe and automated device control (2).

3.2.5 User Interface (Local)

LCD Display (I2C)

An **LCD display with I2C interface** is used to show real-time information about the system, such as soil moisture, water levels, and the status of pumps and lights. Using I2C reduces the number of wires needed, making connections simpler and the setup cleaner.



Figure 29 : I2C LCD display for real-time system status.

4x4 Matrix Keypad

A **4x4 matrix keypad** is used to allow the user to select the pot number and the desired operation, such as watering, fertilizing, seeding, controlling the light, or enabling automatic watering based on the soil moisture sensor. This provides a simple and interactive way to control and customize the system's actions.



Figure 30 : 4x4 keypad for selecting pots and controlling system actions.

3.2.6 RootRise Web Application

The RootRise web application provides a remote interface for users to monitor and control the system. It replicates the functionality of the 4x4 matrix keypad, allowing users to:

- Select the pot number.
- Perform operations such as watering, fertilizing, and seeding.
- Remotely turn the lights on or off.
- Enable automatic watering based on soil moisture levels.

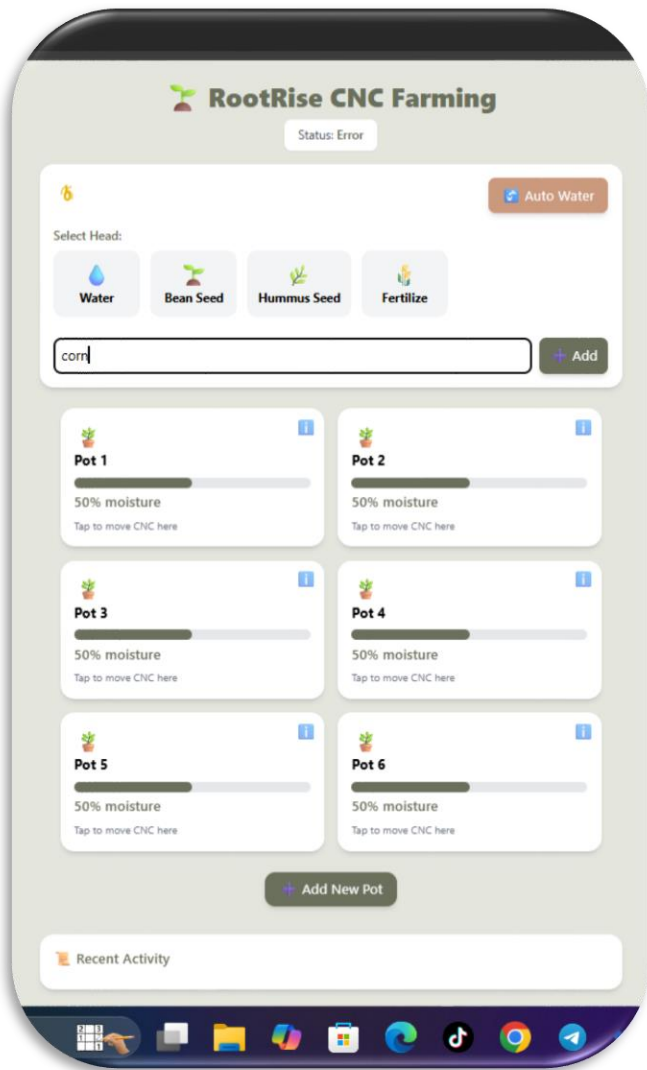


Figure 31 : Add a new seed to the system through the app.

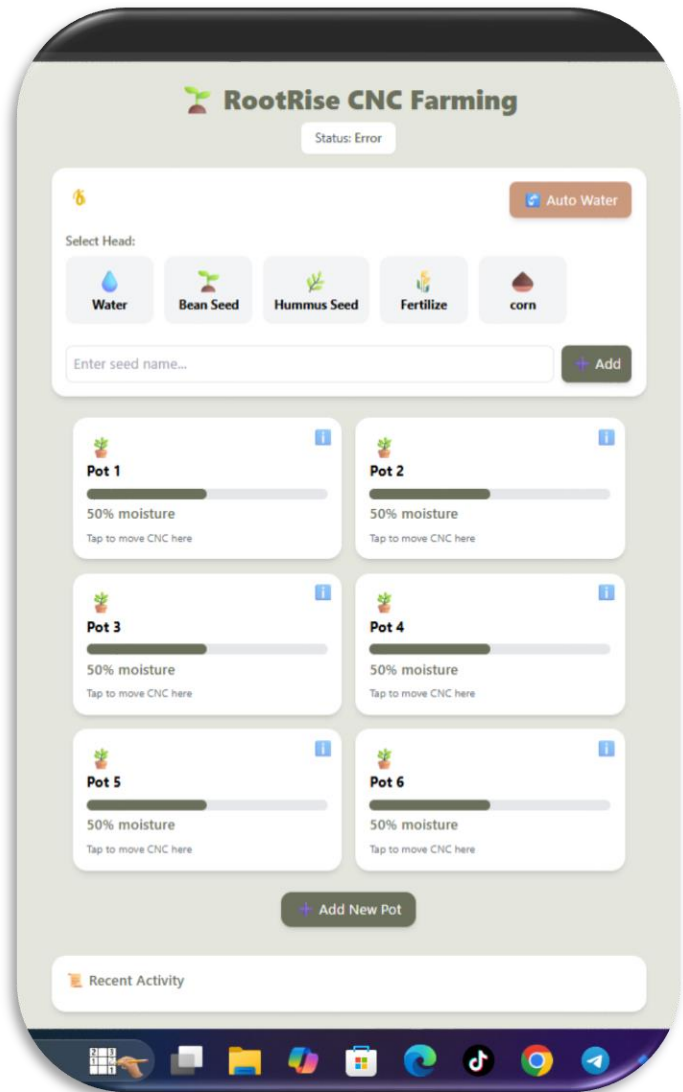


Figure 32 : Add a new seed to the system through the app (2).

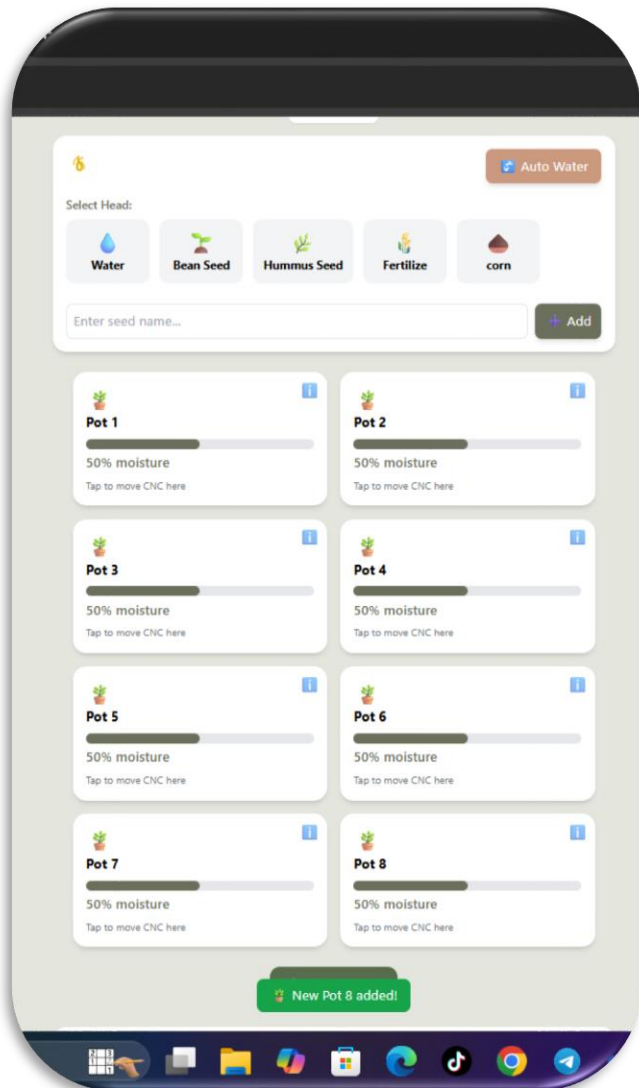


Figure 33 : Add a new pot to the system through the app.

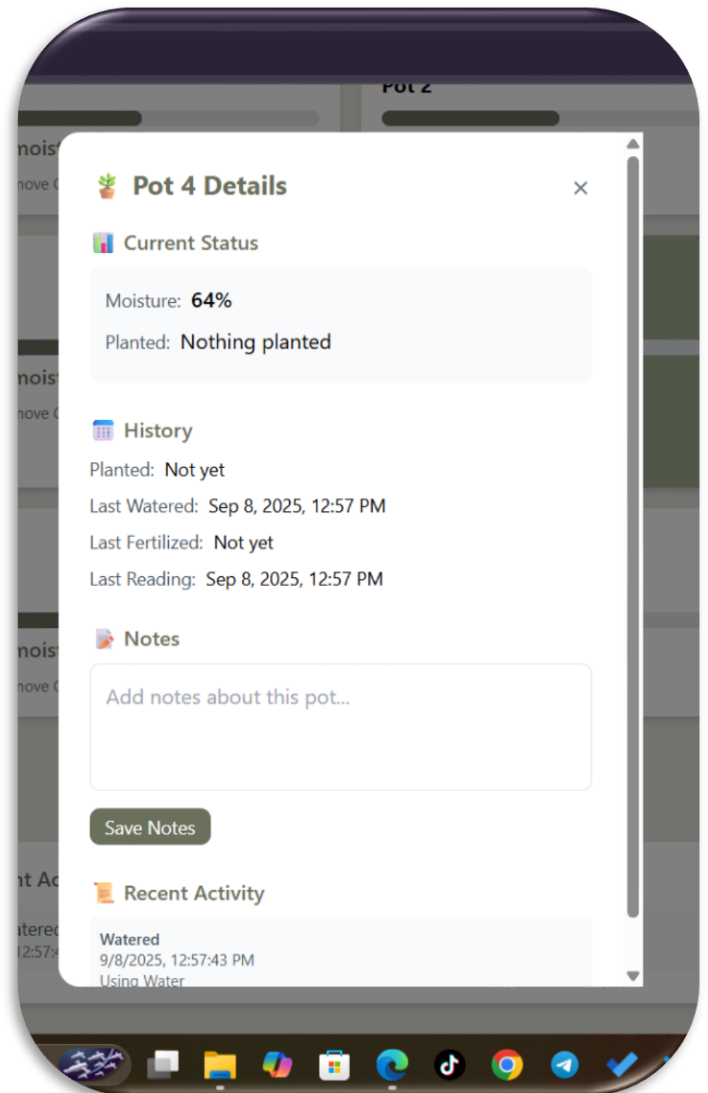


Figure 34 : View and track detailed information for any pot through the app.

Chapter 4: Problems and Challenges

The problems encountered were as follows:

- The seed suction mechanism initially failed because the vacuum pumps tested did not have enough power to pick up the seeds.
- Dealing with new components that had never been studied in courses was challenging.
- Completing the project within a short period of time added pressure and difficulty.
- Determining the correct location for each tool head so it could return accurately after use was a challenge.
- Arranging the irrigation, fertilization, and suction hoses for planting was difficult.
- The X-axis required high torque to carry the system weight, which needed careful motor selection.
- Balancing the system with the Z-axis movement was challenging, requiring counterweights.
- Wiring and power management for multiple motors, sensors, pumps, and lights was complex.
- Integrating all components (motors, sensors, pumps, light, keypad, LCD) to work together reliably was difficult.
- Dealing with 220V in some cases was very risky.

Chapter 5: Results and Discussion

The RootRise system made important plant care tasks automatic, including watering, fertilizing, planting seeds, and controlling light. Soil moisture sensor gave accurate information, so the system could water plants just the right amount and avoid overwatering or underwatering. The vacuum seed system worked well after using a stronger motor, making sure seeds were placed correctly in each pot.

Stepper motors moved the tool heads smoothly and accurately along the X, Y, and Z axes, and counterweights kept the system balanced. Relay modules and the ESP8266 allowed the pumps, lights, and seed system to be controlled automatically or remotely through a web app.

Overall, the system showed that using automation and sensors can save time, reduce manual work, and provide consistent care for plants. Small issues, like arranging hoses and placing the tool heads correctly, were solved with careful testing, proving the system is reliable and effective.

Chapter 6: Conclusion and Future Work

Conclusion

The RootRise system shows that plant care can be automated in a simple and reliable way. With soil moisture sensor, stepper motors, a vacuum seed system, pumps for watering and fertilizing, and light control, the system reduces manual work and provides consistent care for small gardens or home plants. Automation makes plant care easier, faster, and more accurate.

Future Work

Some ways to improve the system in the future include:

- Controlling more pots and larger garden areas.
- Adding sensors for temperature and humidity to monitor plants better.
- Using smart algorithms to water, fertilize, or plant seeds automatically based on weather and plant growth.
- Making the seed system faster and more accurate.
- Improving the app for easier control, alerts, and data analysis.
- Using renewable energy to make the system more eco-friendly and energy-efficient.

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