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PlantPal Pro

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This project is not just the culmination of months of effort—it is a testament to the power of teamwork, resilience, and shared purpose. To everyone who played a role in making this vision a reality: this success belongs to all of us.

Disclaimer

This report is the dedicated work of Teama Amer and Ayat Abuomar, students of the Computer Engineering Department, Faculty of Engineering, at An-Najah National University. It is presented in its original form, with only minor editorial adjustments for clarity, and may contain occasional linguistic or content imperfections.

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This document stands as a testament to the authors' efforts, vision, and commitment, and its impact is solely in the hands of those who choose to engage with it.

Abstract

PlantPal Pro is a groundbreaking automated production line designed to address critical challenges in modern agriculture by optimizing seed germination and seedling production. This innovative system integrates cutting-edge automation technologies with precision farming techniques to streamline the cultivation process, enhance productivity, and promote sustainability. The project aims to provide a holistic solution for farmers and agricultural enthusiasts, minimizing the reliance on manual labor while ensuring consistent and superior plant growth outcomes.

The system operates with a user-friendly interface accessible via a K-Pad or a dedicated mobile application, allowing users to select their desired seed types with ease. Once the selection is made, the automation process begins with the precise allocation of soil into planting containers. Seeds are then delicately positioned in the containers, followed by the careful addition of essential nutrients and vitamins tailored to each specific seed type. These nutrients are scientifically calibrated to create the ideal conditions for healthy germination and seedling growth.

Subsequently, a secondary layer of soil is applied to secure the seeds, and a sophisticated water dispensing mechanism delivers accurately measured droplets to maintain optimal moisture levels. This meticulous approach ensures that every seed receives the appropriate care required for robust development. The system's design accommodates a wide variety of seed types, making it a versatile solution for diverse agricultural needs.

PlantPal Pro also emphasizes sustainability and responsible farming practices by reducing resource wastage and improving efficiency. By automating labor-intensive tasks, the system not only saves time and effort but also eliminates errors associated with manual processes, such as overwatering, nutrient imbalances, and inconsistent planting depths. This results in uniform seedling quality, higher success rates, and increased agricultural productivity.

This project underscores the potential of integrating technology into traditional farming methods to achieve sustainable and scalable agricultural practices. By empowering farmers with tools that simplify complex processes, PlantPal Pro offers a transformative solution that bridges the gap between technological innovation and practical agricultural application. It promotes a future where farming is not only more productive but also more efficient, sustainable, and accessible to all.

PlantPal Pro represents a significant leap forward in the field of automated agriculture, paving the way for a new era of precision farming. Through its innovative design and impactful approach, it seeks to redefine how we grow and sustain crops, ensuring a brighter, more sustainable future for agriculture.

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Chapter One: Introduction

1.1 Overview

Agriculture has always been a cornerstone of Palestinian livelihoods, yet farmers face numerous challenges that hinder productivity and sustainability. Limited access to resources, reliance on traditional manual farming techniques, and the effects of climate change and political constraints have placed significant pressure on Palestinian farmers to adopt innovative solutions to sustain their agricultural practices.

PlantPal Pro is an automated production line specifically designed to address these challenges by revolutionizing seed germination and seedling production. By automating key farming processes, such as soil preparation, seed placement, nutrient application, and precise watering, the system reduces manual labor and ensures optimal conditions for plant growth. This not only increases efficiency but also helps farmers achieve higher yields and consistency in their crops.

The system is tailored to the needs of Palestinian farmers, providing an accessible and user-friendly interface through a K-Pad and mobile application. Users can select seed types, manage nutrient levels, and monitor the entire process with ease. PlantPal Pro emphasizes sustainable practices by optimizing resource use, minimizing waste, and supporting a diverse range of crops, making it particularly valuable for Palestinian farmers operating in resource-constrained environments.

This project represents a transformative approach to agriculture in Palestine, offering a modern, efficient, and scalable solution to support farmers in overcoming the challenges they face. By bridging technology with traditional farming practices, PlantPal Pro aims to empower Palestinian farmers, enhance their productivity, and contribute to the sustainability of agriculture in the region.

1.2 Statement of the problem

Palestinian farmers play a vital role in sustaining local communities and the agricultural economy. However, they face significant challenges, including limited access to advanced technologies, labor shortages, inefficient resource use, and environmental impacts from traditional farming methods. Political and economic constraints further exacerbate these issues, making it difficult for farmers to adapt to modern agricultural demands.

Seed germination and seedling production are particularly problematic, as manual methods are labor-intensive, inconsistent, and waste valuable resources. Maintaining precise environmental conditions and nutrient requirements for healthy seedlings remains a major hurdle, affecting productivity and crop quality.

There is a critical need for a practical and cost-effective solution to automate these processes, reduce dependency on manual labor, and improve efficiency. PlantPal Pro addresses this gap, providing Palestinian farmers with an innovative tool to overcome these challenges and promote sustainable agriculture.

1.3 Objectives

- **Automate seed germination and seedling production** by developing a system to handle soil preparation, seed placement, nutrient application, and controlled watering.
- **Leverage AI technology** to select the most suitable vitamins and nutrients for each seed type using a specially designed AI model, ensuring optimal seedling growth.
- **Promote sustainability** by optimizing resource use, reducing waste, and encouraging environmentally friendly farming practices.
- **Empower Palestinian farmers** with a user-friendly platform that simplifies farming processes and reduces manual labor.
- **Increase agricultural productivity** by improving the efficiency and scalability of seedling production to meet growing demands.
- **Integrate modern technology** by providing an innovative solution with an intuitive interface accessible via a K-Pad or mobile application.

1.4 Importance of work

The significance of PlantPal Pro extends beyond automation, positioning it as a transformative tool for modernizing agriculture and empowering Palestinian farmers. Its importance can be outlined as follows:

- **Empowering Farmers**: By automating the labor-intensive processes of seed germination and seedling production, PlantPal Pro reduces physical effort, saving farmers valuable time and energy. This allows them to focus on other essential aspects of farming, such as planning, harvesting, and marketing, improving overall efficiency.
- **Promoting Sustainability**: PlantPal Pro advocates for sustainable farming practices by minimizing resource waste and optimizing the use of water, soil, and nutrients. Its precision-driven approach ensures that each seedling receives the exact resources it requires, reducing the environmental impact of agricultural practices.
- **Integrating Advanced Technology**: By incorporating a specially developed AI model, the system selects the most suitable vitamins and nutrients for each seed type, ensuring healthier seedlings and higher crop yields. This innovation bridges the gap between technology and traditional farming, making precision agriculture more accessible.
- **Addressing Local Challenges**: Palestinian farmers face unique challenges, including resource scarcity, political instability, and economic constraints. PlantPal Pro provides a practical, cost-effective solution tailored to their specific needs, equipping them with tools to overcome these barriers and sustain their livelihoods.
- **Increasing Agricultural Productivity**: By ensuring consistent and optimal growing conditions, PlantPal Pro significantly enhances the success rate of seed germination and seedling production. This translates into higher yields, better-quality crops, and the ability to meet increasing agricultural demands.
- **Boosting Economic Opportunities**: Increased productivity and efficiency result in economic growth for farmers and local communities. PlantPal Pro helps farmers achieve greater profitability and competitiveness, strengthening the agricultural economy in Palestine.
- **Encouraging Innovation in Agriculture**: PlantPal Pro serves as a model for combining automation, AI, and sustainability in farming. Its innovative approach inspires the development of similar technologies, driving progress in agriculture at both local and global levels.
- **Enhancing Food Security**: By improving the efficiency and consistency of agricultural production, PlantPal Pro contributes to ensuring a steady supply of quality crops, addressing food security concerns in Palestine and beyond.
- **Providing Educational Value**: The project serves as a learning platform for farmers, students, and researchers, showcasing the potential of advanced technology in agriculture. It highlights the benefits of adopting innovative methods to improve farming practices.
- **Reducing Dependency on External Resources**: With its automated system and precise resource management, PlantPal Pro helps reduce dependency on external inputs, such as imported fertilizers or specialized labor, making farming more self-reliant and resilient.

1.5 Organization of the report

This report provides a comprehensive examination of the PlantPal Pro project, starting with an introduction that outlines the project's scope, objectives, and significance. It explores the constraints encountered during development, solutions implemented to overcome them, and the relevant standards and codes that guided the process. The report further highlights the hardware components used, the role of earlier coursework in shaping the project, and an extensive review of existing literature to establish the context and identify gaps addressed by PlantPal Pro. The methodology section delves into the system's design and implementation, including the integration of AI, hardware, and software. Following this, the testing and evaluation processes are discussed, focusing on system performance, AI accuracy, and user feedback. The report concludes by summarizing the project's contributions to addressing agricultural challenges, along with recommendations for future improvements. Supplementary materials, including the complete system code and additional technical details, are provided in the appendix for reference.

Chapter Two: Constraints, Standards/ Codes and Earlier course work

During the development of the PlantPal Pro project, several constraints were encountered and systematically addressed. These challenges included limitations in budget and available resources, as well as the need to comply with agricultural and technological standards. The project team ensured that the design and implementation of the system adhered to relevant industry codes, safety requirements, and sustainability guidelines.

To overcome these constraints and ensure compliance, the team relied heavily on their foundational knowledge gained from earlier coursework and training in relevant engineering and technical disciplines. This background provided critical insights into hardware integration, software development, and system optimization, forming a robust framework for the successful design and deployment of PlantPal Pro. The ability to apply prior learning effectively was instrumental in navigating the challenges and achieving the project's goals.

2.1 Constraints

The development of the PlantPal Pro system faced several challenges that required creative problem-solving and resource management. The team encountered technical limitations, particularly in integrating diverse components such as AI, servo motors, stepper motors, and H-bridges, which required extensive research and learning. Budget constraints made sourcing high-quality components like NEMA 17 motors and drivers difficult, while limited time added pressure to balance academic commitments with project demands. Hardware integration posed significant challenges, including synchronizing the DC motor, wooden mechanism, and multiple servos for precise operations. Developing the AI model for tailored vitamin selection and ensuring system accuracy across soil dispensing, seed placement, and watering required meticulous calibration and multiple iterations. Additionally, testing the system in real-world agricultural settings was restricted by access to suitable environments. Despite these constraints, the team leveraged prior knowledge, efficient planning, and iterative testing to deliver a practical and impactful solution tailored to Palestinian farmers..

2.2 Problems and solutions

To enhance the usability of the PlantPal Pro system, we have developed a mobile application that allows users to interact with the production line. Through the app, users can select the type of seeds they wish to plant and monitor the progress of the planting process in real-time. For this to be achieved, a reliable communication mechanism was required to bridge the mobile application with the system hardware.

In this project, we utilized an **ESP8266 Wi-Fi module** to establish wireless communication between the mobile application and the Arduino Mega. Initially, integrating the ESP8266 with the Mega posed challenges due to compatibility issues and the need for precise configuration. After extensive testing, we successfully configured the ESP8266 to communicate seamlessly with the Arduino Mega via serial communication.

The solution involved connecting the **ESP8266** module to the Arduino Mega using appropriate TX (Transmit) and RX (Receive) pins. The ESP8266 operates as a bridge, relaying user commands from the mobile app to the Mega, which then executes the appropriate actions within the production line. Power supply considerations were also addressed to ensure stable operation of the ESP8266.

Below is the general schematic used for this setup:

- The **ESP8266** module communicates with the Mega through TX and RX pins.
- The **TX pin of the ESP8266** is connected to the RX1 pin of the Mega (Pin 19), and the **RX pin of the ESP8266** is connected to the TX1 pin of the Mega (Pin 18).
- A common ground wire is used to establish a reference between the two components.

This configuration ensures reliable and real-time communication between the mobile app and the hardware, enabling precise seed selection and monitoring during the planting process. The integration of the ESP8266 module not only simplifies user interaction but also enhances the overall functionality of the PlantPal Pro system.

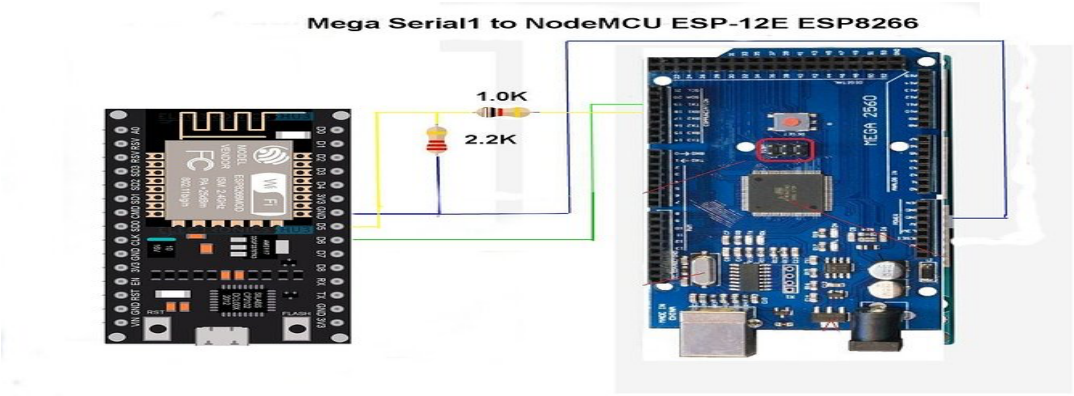

Figure 1: Serial connection between mega and ESP8266

The ESP8266 module connects the mobile app to the **Arduino Mega 2569**, relaying user commands for seed selection and process control. The Mega executes these commands to automate soil, seed, nutrient, and water dispensing.

2.2.3 Configuration for Arduino Mega 2569

The **Arduino Mega 2560** is the central controller for the PlantPal Pro system, chosen for its robust capabilities and versatility. With 54 digital I/O pins, 16 analog inputs, and ample memory, it efficiently handles multiple components and tasks. To configure the Mega 2560, it's first powered via USB for development or a reliable 7-12V power source for standalone operation. Pin assignments are then established, such as digital pins for the ultrasonic sensor (e.g., Trig on Pin 7, Echo on Pin 6) and PWM pins for the RGB LED (e.g., Pins 9, 10, 11). The program is written and uploaded using the Arduino IDE, ensuring the correct board and port are selected. The Serial Monitor is invaluable for debugging, allowing real-time data verification, such as distance readings from the sensor. This setup not only ensures precise operations but also offers scalability, with the Mega's abundant I/O pins and processing power enabling future expansions.

2.2.4 Choosing the appropriate driver for the stepper motor

The selection of motor drivers was crucial for ensuring the reliable and precise operation of the PlantPal Pro system. The project uses a combination of motors, including a larger motor for driving the production line and stepper motors for soil dispensing and layering. To meet these requirements, the **HY-DIV268N-5A microstep driver** was chosen for its advanced features and compatibility with the system.

1. **HY-DIV268N-5A Microstep Driver for the Production Line Motor**:
   The HY-DIV268N-5A driver was selected to power the larger motor driving the production line. With its **5A current capacity**, it can handle the high current demands of the motor while maintaining smooth and reliable operation. Its microstepping capabilities enable finer control over the motor's movements, ensuring precise positioning along the production line.

Drivers for Stepper Motors:
A motor driver module that allows control of the speed and direction of two DC motors or one stepper motor by providing bidirectional current flow. We used the L298N H bridge to control the stepper motor that is responsible for passing empty containers to start a new production process.

Figure 2: L298N driver

2.2.5 Choosing the appropriate motor

The motors for PlantPal Pro were selected based on their specific roles and performance requirements. A high-power DC motor was chosen for driving the production line due to its ability to handle heavy loads and provide consistent torque. For precise tasks like soil dispensing, seed placement, and watering, stepper motors were used for their accuracy and incremental control. These motors were carefully paired with the HY-DIV268N-5A driver and a dual power supply system to ensure reliable and efficient operation across all planting processes.

2.3 Standards and Codes

The development of the PlantPal Pro system adhered to various standards and codes to ensure safety, reliability, and compatibility. Electrical safety standards were followed to prevent hazards during operation, especially when using high-power motors and relays. Serial communication between the ESP8266 and Arduino Mega was implemented based on UART protocols for accurate data exchange. The HY-DIV268N-5A driver and stepper motors were integrated following motor control standards to achieve precise microstepping and torque management. The ESP8266 module was configured in compliance with Wi-Fi standards (IEEE 802.11 b/g/n) to facilitate seamless wireless communication with the mobile app. Mechanical components, including the production line and wooden mechanisms, were designed to meet precision and alignment standards. Additionally, coding best practices were followed to ensure software readability, modularity, and maintainability. These standards and codes collectively contributed to the system's safety, efficiency, and effectiveness, meeting the demands of automated agricultural processes.

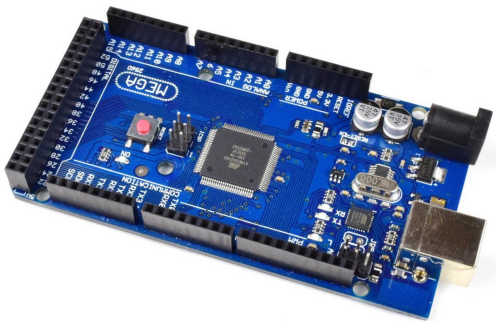

Figure 3: Arduino mega

2.4 The hardware components

2.4.1 HY-DIV268N-5A

The **HY-DIV268N-5A** microstep driver is a key component in the PlantPal Pro system, responsible for controlling the stepper motors used in soil dispensing, seed placement, and other precision tasks. This driver supports a maximum current of **5A**, making it suitable for handling both high-torque and precise operations. Its microstepping capability allows the motors to perform incremental movements with high accuracy, which is essential for the automated planting process.

The HY-DIV268N-5A also features built-in protection mechanisms, such as overcurrent and overheating safeguards, ensuring stable and reliable operation even under continuous use. Its compatibility with various stepper motors and ease of integration with the Arduino Mega simplifies the hardware setup. This driver plays a crucial role in enabling precise, smooth, and efficient motion control throughout the PlantPal Pro production line.

Figure 4: HY-DIV268N-5A driver

The **HY-DIV268N-5A** microstep driver is a versatile and high-performance component used in the PlantPal Pro system to control stepper motors responsible for tasks like soil dispensing, seed placement, and nutrient delivery. The driver supports a wide input voltage range from **12V to 48V** and can handle a current of up to **5A per phase**, making it compatible with a variety of stepper motors. Its advanced features include **over-current, over-voltage, and over-temperature protection**, ensuring the safe and reliable operation of motors even under continuous use.

The driver also allows precise control with its **internal potentiometer**, enabling adjustments to the motor's current from **0.2A to 5A**. In this project, the motor was configured to operate at **3.3A** with a microstepping resolution of **1/8 steps per revolution**, providing smooth and precise motion control critical for the automated planting process.

The HY-DIV268N-5A's robust design and adaptability made it the ideal choice for handling the stepper motors in PlantPal Pro, ensuring efficient and accurate operations throughout the production line.

2.4.2 LDR Module

The **LDR Module** (Light Dependent Resistor) is an essential component in the PlantPal Pro system, enabling precise position detection along the production line. Its resistance changes with light intensity, making it effective for detecting interruptions in a laser beam. Integrated with laser diodes, the LDR Modules are placed at six key checkpoints. When a planting cup blocks the laser beam, the LDR detects the change, signaling the system to stop and perform specific actions like soil dispensing, seed placement, or watering. Compact, reliable, and energy-efficient, the LDR Module ensures accurate detection and precise automation,.

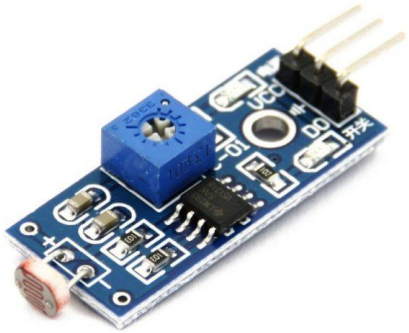

Figure 5: IR-sensor

In this project, **six LDR Modules** are strategically placed along the production line to detect the position of planting cups and control the system's operations. Each LDR is paired with a laser diode to create a light beam that the system uses to monitor the cups' movement. When a planting cup interrupts the laser beam directed at the LDR, the module detects the change in light intensity and sends a signal to the Arduino Mega, which then stops the line and triggers a specific action.

The **first LDR** detects the arrival of a planting cup at the starting position. When the beam is interrupted, the line stops, and the cup is lowered into position using a DC motor controlled by an H-bridge. The **second LDR** stops the line again to dispense the first layer of soil into the cup using a stepper motor. Once this step is completed, the line moves to the **third LDR**, where the system selects the appropriate seed based on user input from the mobile app or keypad. A servo motor corresponding to the selected seed opens, allowing seeds to drop into the cup.

At the **fourth LDR**, the AI-determined vitamin is dispensed using another servo motor, ensuring precise nutrient delivery for optimal plant growth. The **fifth LDR** pauses the line to dispense a second layer of soil, covering the seeds and nutrients, using another stepper motor. Finally, the **sixth LDR** stops the line for watering. A water pump controlled by a relay dispenses a specific amount of water to hydrate the seeds before the line resumes movement.

This precise coordination of the LDR Modules ensures that every planting action is carried out at the correct location, enabling seamless automation and consistent performance in the PlantPal Pro system

2.4.3 Stepper Motor for the Production Lin

The **stepper motor** is a precise and reliable electromechanical device used in the PlantPal Pro system for tasks requiring controlled and incremental motion, such as soil dispensing and production line movement. Unlike traditional DC motors, stepper motors divide their rotation into fixed steps, allowing for precise positioning without the need for feedback sensors. This makes them ideal for applications demanding high accuracy. The motors offer excellent torque at low speeds, enabling them to handle the weight of planting cups or soil dispensers with ease. Paired with microstepping drivers, the stepper motors can achieve smoother motion and greater precision by dividing each step into smaller increments. Their reliability and repeatability ensure consistent performance, making them a critical component for the

Figure 6: stepper mottor

A large stepper motor, paired with a 5A HY-DIV268N driver, powers the production line in the PlantPal Pro system. This motor ensures the smooth and consistent movement of planting cups along the line, stopping at specific checkpoints for soil, seed, nutrient, and water dispensing. The stepper motor's high torque and precision are critical for handling the weight of the cups and their contents. It operates using a 24V 6A power supply, which provides sufficient voltage and current for stable and efficient performance during continuous operation.

2.4.4 DC Motor

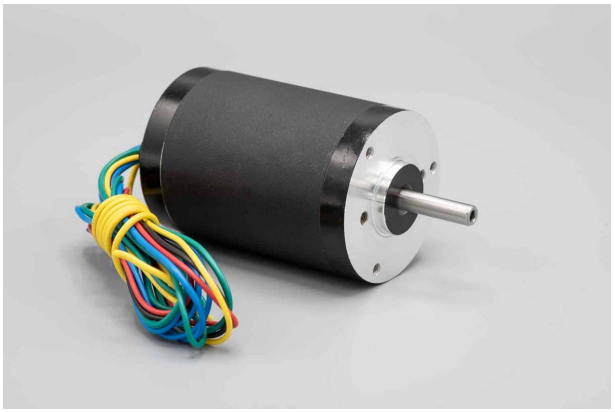

Figure 7: DC motor

In the PlantPal Pro system, the DC motor drives a wooden mechanism, known as the "tractor," which is connected to a rod attached to the motor. This mechanism performs a rotational motion, pulling the tractor forward and then returning it to its original position. This motion precisely lowers the planting cups to their designated positions along the production line. Controlled by an L298N H-Bridge driver, the motor operates in both forward and reverse directions, ensuring smooth and reliable performance. This mechanism efficiently facilitates the lowering of cups for planting, ensuring accurate alignment for processes such as soil addition, seed placement, and watering.

2.4.5 L298N H-Bridge Driver

The **L298N H-Bridge driver** is a versatile motor driver used in the PlantPal Pro system to control the DC motor that operates the wooden mechanism for positioning planting cups. The H-Bridge allows bidirectional control of the motor by reversing the polarity of the current, enabling the motor to move forward and backward as needed. This capability is essential for tasks that require precise movement, such as pulling planting cups into position for soil dispensing, seed placement, and watering, and returning them to their original position. The L298N operates within a voltage range of **5V to 35V** and can supply up to **2A per channel**, making it suitable for driving the system's DC motor. Its built-in heat sinks ensure stable operation by dissipating heat during extended use, while its straightforward design allows for easy integration with the Arduino Mega, enabling precise control of motor speed and direction.

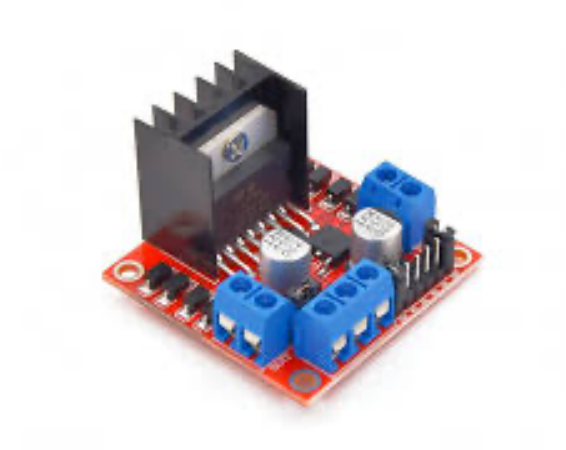

Figure 8: L298N H-Bridge Driver

2.4.6 Keypad

Matrix Keypad is a type of input device that is used to interface with microcontroller boards such as Arduino. It is designed to provide a simple and easy way to input numerical data and it consists of 16 buttons arranged in a 4x4 matrix configuration. Each button is assigned a unique code, and when a button is pressed, the keypad sends a signal to the microcontroller board, which can then be used to trigger a specific action or event. The REES52 4x4 Matrix Keypad is commonly used in applications such as access control systems, digital lockers, and home automation projects. The keypad is simple to connect and use, it doesn't require many pins of the microcontroller and it can be powered by 5V DC. The REES52 4x4 Matrix Keypad is a cost-effective, easy-to-use, and versatile solution for inputting numerical data in various projects.

We use the Keypad to enter the number of your car slot , if the driver wants to take your car out .

Figure 9: Keypad

2.4.7 SG90 Servo Motor

The **SG90 Servo Motor** is a compact and lightweight motor used in the PlantPal Pro system for tasks that require precise angular control. This motor is ideal for applications like dispensing seeds or vitamins, where specific and controlled movements are necessary. The SG90 operates using Pulse Width Modulation (PWM) signals, which allow the Arduino Mega to position the servo arm accurately at desired angles, typically between **0° and 180°**.

The SG90's small size and low power requirements make it suitable for integration into the system without placing significant demands on the power supply. Despite its compact design, the motor is capable of delivering sufficient torque to reliably open and close seed and vitamin dispensing mechanisms. Its durability and ease of control make it a vital component in ensuring the precision and efficiency of the automated planting process.

Figure 10: SG90 Servo Motor

2.4.8 Microstep Driver

The **Microstep Driver**, specifically the HY-DIV268N-5A, is an essential component in the PlantPal Pro system, used to control the stepper motors responsible for precise tasks like soil dispensing and seed placement. This driver supports a wide input voltage range of **12V to 48V** and can handle currents up to **3A per phase**, making it ideal for medium-power stepper motors. Its microstepping capability allows the motors to perform smoother and more precise movements by dividing each step into smaller increments, which is crucial for achieving the accuracy required in the planting process.

The HY-DIV268N-5A also includes built-in protection features such as overcurrent, overvoltage, and overtemperature safeguards, ensuring reliable and safe operation. The driver's internal potentiometer allows for current adjustments to match the exact needs of the motors, ensuring efficiency and preventing overheating. In the PlantPal Pro system, the microstep driver ensures accurate control of motor movements, enabling smooth soil layering, seed dispensing, and nutrient application, contributing significantly to the system's automation and precision.

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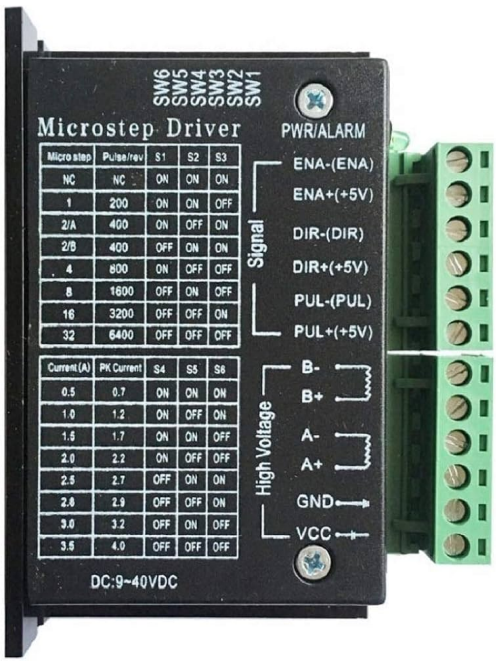

Figure 11: Microstep Driver

2.4.9 2-Channel Relay Module

An Arduino buzzer is a type of passive electronic component that can generate a sound when an electrical current is applied to it. It can be connected to an Arduino microcontroller board and controlled by sending digital signals through one of the board's digital output pins. The Arduino board can be programmed to control the frequency and duration of the sound emitted by the buzzer, allowing for the creation of various types of sounds and patterns. Arduino buzzers are widely used in various applications, such as alarms, timers, and musical

instruments. They are small, inexpensive and easy to use, and can be connected to the Arduino board in a variety of ways, such as directly connecting it to a digital output pin or using a transistor or an optocoupler to control the current flowing through the buzzer.
In our project, we use the Buzzer to let the driver know that the entrance has been paid.

Figure 12: 2-Channel Relay Module

2.4.10 Computer Power Supply

The **computer power supply** is a key component in the PlantPal Pro system, providing reliable and stable power to various low-voltage components. This power supply is repurposed from a standard computer system and delivers multiple voltage outputs, including **5V, 12V**, and **3.3V**, making it ideal for powering components such as the Arduino Mega, ESP8266, servo motors, relay modules, and sensors.

The computer power supply's high efficiency and capacity to handle multiple outputs ensure that all electronic components in the system operate consistently without power interruptions. Its built-in safety features, including overcurrent and thermal protection, contribute to the overall reliability of the system. In PlantPal Pro, the computer power supply is crucial for maintaining the seamless operation of the system's control and communication elements while keeping the power distribution efficient and organized.

Figure 13: Computer Power Supply

2.4.11 Laser Diode

The **laser diode** is a critical component in the PlantPal Pro system, used in conjunction with the LDR modules for position detection along the production line. The laser diode emits a focused beam of light that acts as a checkpoint marker. When a planting cup interrupts this beam, the corresponding LDR module detects the change in light intensity, signaling the system to perform specific actions such as soil dispensing, seed placement, or watering.

The laser diode is compact, energy-efficient, and capable of generating a highly focused beam, ensuring accurate and reliable detection even in environments with varying lighting conditions. Its integration with the LDR modules enhances the precision of the system, enabling smooth automation and coordination of the planting process. The laser diode's low power requirements make it ideal for continuous use in PlantPal Pro without adding significant energy demands to the system.

Figure 14: laser Diode

2.4.12 HC-SR04 Ultrasonic Sensor

The **HC-SR04 Ultrasonic Sensor** is a crucial component of the PlantPal Pro system, playing a dual role in distance measurement and ensuring precise operational control along the production line. The sensor operates by emitting ultrasonic sound waves and measuring the time it takes for the waves to reflect back after hitting an object. This measured time is converted into distance using the speed of sound, enabling the detection of the presence and position of planting cups or other components.

In **PlantPal Pro**, the HC-SR04 ensures that planting cups are properly aligned before performing tasks such as soil dispensing, seed placement, or watering. Its high accuracy (up to 3mm) and reliable range (2cm to 400cm) make it an ideal choice for automated systems requiring precision.

Additionally, the HC-SR04 is used to monitor the jars containing seeds or vitamins in the system. If a jar is detected to be empty, the ultrasonic sensor triggers a halt in the production line, preventing further processing. In such scenarios, the integrated RGB light system is programmed to emit a **red light**, alerting operators to the issue.

The sensor's seamless integration with the **Arduino Mega** allows real-time data processing and the activation of corresponding actions at each stage of the planting process. Its role in monitoring and error detection contributes significantly to the overall reliability and efficiency of the PlantPal Pro system.

Figure 15 : HC-SR04 Ultrasonic Sensor

2.4.13 Power Supply 24v 6A

A power supply unit that provides a stable 24V DC output with a current capacity of 6A, suitable for powering motors, controllers, and other devices requiring 24V. We used this power supply to provide power for the stepper motor that is controlling the main iron rail**,**

Figure 16: Power Supply 24v 6A

2.4.14 DC 12V Micro Electric Solenoid Valve

The **DC 12V Micro Electric Solenoid Valve** is a critical component in the PlantPal Pro system, used to control the flow of water to the planting cups during the watering stage. This **normally open (N/O)** valve allows water to flow by default and closes when powered, enabling precise control of water delivery. The valve is connected to a **relay module**, which is managed by the Arduino Mega. The relay controls the power supplied to the valve, allowing the system to open or close the valve as required.

The solenoid valve operates at **12V DC**, making it compatible with the system's power supply and ensuring efficient performance. Its compact design allows it to be seamlessly integrated into the production line, while its reliable operation ensures that the correct amount of water is dispensed at the right time. This precise control is essential for the automated planting process, contributing to the accuracy and efficiency of the PlantPal Pro system.

Figure 17: DC 12V Micro Electric Solenoid Valve.

2.4.15 RBG AND MOS

In our production line, **two lights (red and green)**, implemented using an RGB LED system, are used to clearly communicate the operational status of the system. At the start of the line, the red light is activated, indicating that the system is initializing and the line is not yet running. Once the production line is fully operational and progressing as expected, the green light switches on, signaling efficient performance. The green light remains active throughout the operation until the end of the production process. When the line finishes its cycle or encounters an issue, the light returns to red, indicating that the line has stopped.

In addition to signaling the end of the process, the red light is also triggered if the **ultrasonic sensor detects a lack of vitamins or seeds**. This ensures that critical issues are immediately visible, prompting quick resolution to avoid downtime. The RGB LED system, while currently utilizing only red and green, provides the flexibility for future enhancements by allowing other colors (such as blue or yellow) to represent additional states or warnings. This clear visual communication, with red indicating the line is stopped and green signaling smooth operation, simplifies monitoring for workers and supervisors, reduces response times, and ensures streamlined workflows.

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Figure 18 : RGB

2.5 Earlier Course work

- **Microcontroller**

- Taking the Microcontroller course played a significant role in the successful implementation of our project. This course provided a strong foundation in programming and interfacing microcontrollers, which was essential for effectively utilizing the Arduino Mega as the central component of the PlantPal Pro system. The hands-on experience gained through programming exercises and projects enabled us to confidently program and interface various components, such as sensors, motors, and actuators, within the system. Additionally, the theoretical concepts covered in the course, such as digital and analog inputs/outputs, PWM control, and serial communication, were directly applicable to the design and functionality of the system. The skills and knowledge acquired from this course were instrumental in ensuring the precise control and coordination of all components in our automated planting process.

- **Electronic circuits**

- The **Electronic Circuits** course was fundamental to the successful implementation of our project. This course provided a comprehensive understanding of circuit design and analysis, which was essential in creating and integrating the electronic components of the PlantPal Pro system. Topics such as circuit components, power supplies, and sensor interfacing were directly applied in designing and testing circuits for power management, motor drivers, and sensor signal processing. The practical, hands-on experience emphasized in the course equipped us with the skills to troubleshoot, refine, and optimize our circuit designs effectively. The knowledge and techniques gained from this course were instrumental in ensuring the reliability and efficiency of the system's electronic infrastructure, contributing significantly to the project's success.

- **Wireless:**

- The **Wireless** course provided a comprehensive understanding of wireless communication technologies and their applications, which was crucial for designing and implementing the wireless communication component of the PlantPal Pro system. The knowledge gained in topics such as wireless protocols, network design, and wireless security was directly applied to establish seamless communication between the control unit (Arduino Mega) and the users' devices via the ESP8266 module.

Additionally, the course deepened our understanding of the challenges and trade-offs in wireless communication, enabling us to make informed decisions about selecting and configuring the most suitable wireless technology for our system. The skills and insights gained from this course played a vital role in ensuring reliable and efficient wireless communication, contributing significantly to the successful implementation of the project.

- **Arduino Course**

- The **Arduino** course provided a solid foundation in using the Arduino microcontroller platform, which was crucial for implementing the PlantPal Pro system. This course covered programming and interfacing techniques specific to Arduino, enabling us to effectively utilize the Arduino Mega as the core component of our project. Through the use of Arduino's built-in libraries and functions, we were able to quickly prototype and test various system functionalities, including sensor input, motor control, and communication with external devices. The course's focus on practical, hands-on projects also helped us develop problem-solving skills, allowing us to overcome technical challenges during the project's implementation. The knowledge and skills gained from this course were instrumental in ensuring the success of the PlantPal Pro system.

- **App Inventor Course**

The **App Inventor** course was instrumental in the implementation of our project, equipping us with the skills and knowledge needed to develop a user-friendly and visually appealing mobile application. Through the course, we learned to utilize the App Inventor platform to design and build Android applications. The drag-and-drop interface allowed us to create the layout and user interface of the app effortlessly, while the blocks editor enabled us to program its behavior and functionality.

Using the knowledge gained, we developed a mobile application that allows users to interact with the system seamlessly. This includes selecting planting options and monitoring the planting process. The mobile application played a vital role in the project, enhancing user accessibility and convenience while ensuring a smooth and intuitive experience.

Chapter Three: Literature review

This chapter explores the existing research, technologies, and systems that informed the development of the PlantPal Pro system. The review highlights advancements in automated agricultural systems, IoT-enabled smart farming, and AI-driven solutions for precision planting. These studies and technologies provided valuable insights and benchmarks for designing an efficient and innovative system tailored to the needs of Palestinian farmers.

3.1 Automated Agricultural Systems

Automated agricultural systems have gained significant attention in recent years as a means to improve productivity and sustainability in farming. Research has focused on using robotics and automated mechanisms for tasks such as planting, harvesting, and irrigation. For example, studies on automated planting machines have shown how precision mechanisms, such as stepper motors and microcontrollers, can ensure accurate seed placement and soil layering. These concepts were directly applicable to PlantPal Pro's production line, which uses stepper motors and sensors for precise automation.

3.2 IoT-Enabled Smart Farming

The integration of IoT (Internet of Things) in agriculture has transformed traditional farming practices. IoT-enabled systems allow real-time monitoring and control of farming activities through mobile applications and wireless communication. Research in this field demonstrates how sensors and wireless modules, such as ESP8266, can be used for remote monitoring and system control. This informed the development of the mobile application for PlantPal Pro, enabling farmers to interact with the system and monitor planting operations from their smartphones.

3.3 AI-Driven Precision Planting

Artificial intelligence (AI) has emerged as a powerful tool for enhancing precision and efficiency in agriculture. Studies have highlighted the use of AI algorithms to determine optimal nutrient and water requirements for different crops. In PlantPal Pro, an AI model was implemented to select the most suitable vitamins and nutrients for each seed type, ensuring optimal growth conditions. This approach aligns with recent advancements in precision agriculture, where AI is used to reduce resource wastage and maximize crop yield.

3.4 Existing Planting Mechanisms

Existing literature on planting mechanisms provided valuable insights into the hardware and mechanical designs used in automated planting systems. Research on stepper motor-driven soil dispensers, servo-controlled seed dispensers, and water delivery systems informed the design of PlantPal Pro's production line. Additionally, studies on the use of LDR modules and laser diodes for position detection helped refine the system's checkpoint-based workflow.

3.5 Summary

The literature reviewed in this chapter provided a strong foundation for the design and implementation of PlantPal Pro. By leveraging advancements in automated systems, IoT, AI, and planting mechanisms, the system was designed to address the specific needs of farmers while ensuring precision, efficiency, and sustainability. The insights gained from existing research guided the integration of advanced technologies and innovative solutions into the project, making it a cutting-edge tool for modern agriculture.

Chapter Four: Methodology

The methodology for this project will involve the following steps:

4.1 System Design

- Conceptualized the overall system architecture, dividing it into hardware, software, and communication components.
- Mapped each component to specific tasks like seed dispensing, soil layering, and water delivery.

4.2 Hardware Integration

- Selected and connected required components:
    - **Motors and Drivers**:
        - Large stepper motor with a 5A microstep driver for the production line.
        - Smaller stepper motors for soil dispensing.
        - DC motor with an H-bridge for the wooden mechanism.
    - **Sensors**:
        - LDR modules with laser diodes at six checkpoints for cup detection.
        - HC-SR04 ultrasonic sensor for distance accuracy.
    - **Actuators**:
        - SG90 servo motors for precise seed and vitamin dispensing.
    - **Power Supplies**:
        - 24V 6A power supply for the production line motor.
        - Computer power supply for low-power components.
- Integrated components with the Arduino Mega as the central controller.

4.3 Software Development

- **Arduino Programming**:
    - Developed code to handle motor control, sensor data processing, and relay activation.
    - Coordinated system operations through inputs and outputs.
- **Mobile Application**:
    - Created a user-friendly app using the App Inventor platform.

- Enabled seed selection, process monitoring, and wireless communication with the system via ESP8266.

4.4 AI Integration

- Designed and trained an AI model to recommend vitamins for seeds based on predefined nutrient requirements.
- Integrated AI outputs with the Arduino program to automate vitamin dispensing.

4.5 Testing and Iteration

- Conducted individual and integrated testing for components:
  - Hardware: Ensured accuracy and compatibility of motors, sensors, and actuators.
  - Software: Debugged and optimized Arduino code and mobile app.
- Simulated real-world planting conditions to verify system performance.
- Made iterative improvements to optimize motor speeds, sensor placements, and app functionality.

4.6 Final Implementation

- Assembled and deployed the final system.
- Demonstrated successful performance of soil layering, seed placement, and water and vitamin delivery.
- Ensured seamless user interaction through the mobile app, meeting the project's objectives of precision and automation.

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Chapter Five: Designing and Testing of the Project

5.1 System Design

- Created a detailed system architecture, dividing the project into hardware and software components.
- Designed the hardware layout, including the positioning of motors, sensors, and power supplies.
- Developed a mobile application to enable user interaction with the system.

5.2 Hardware Testing

- Conducted individual testing for each hardware component:
  - **Motors**: Tested stepper and DC motors for precision, torque, and reliability.
  - **Sensors**: Verified accuracy and responsiveness of LDR modules, laser diodes, and ultrasonic sensors.
  - **Power Supplies**: Ensured stable power delivery from the 24V 6A and computer power supply.
- Integrated hardware components and tested their compatibility and synchronization.

5.3 Software Testing

- Programmed the Arduino Mega to coordinate motor control, sensor data, and system outputs.
- Debugged and optimized the mobile application to ensure smooth communication with the ESP8266 module.
- Simulated user inputs through the app to test system responsiveness and reliability.

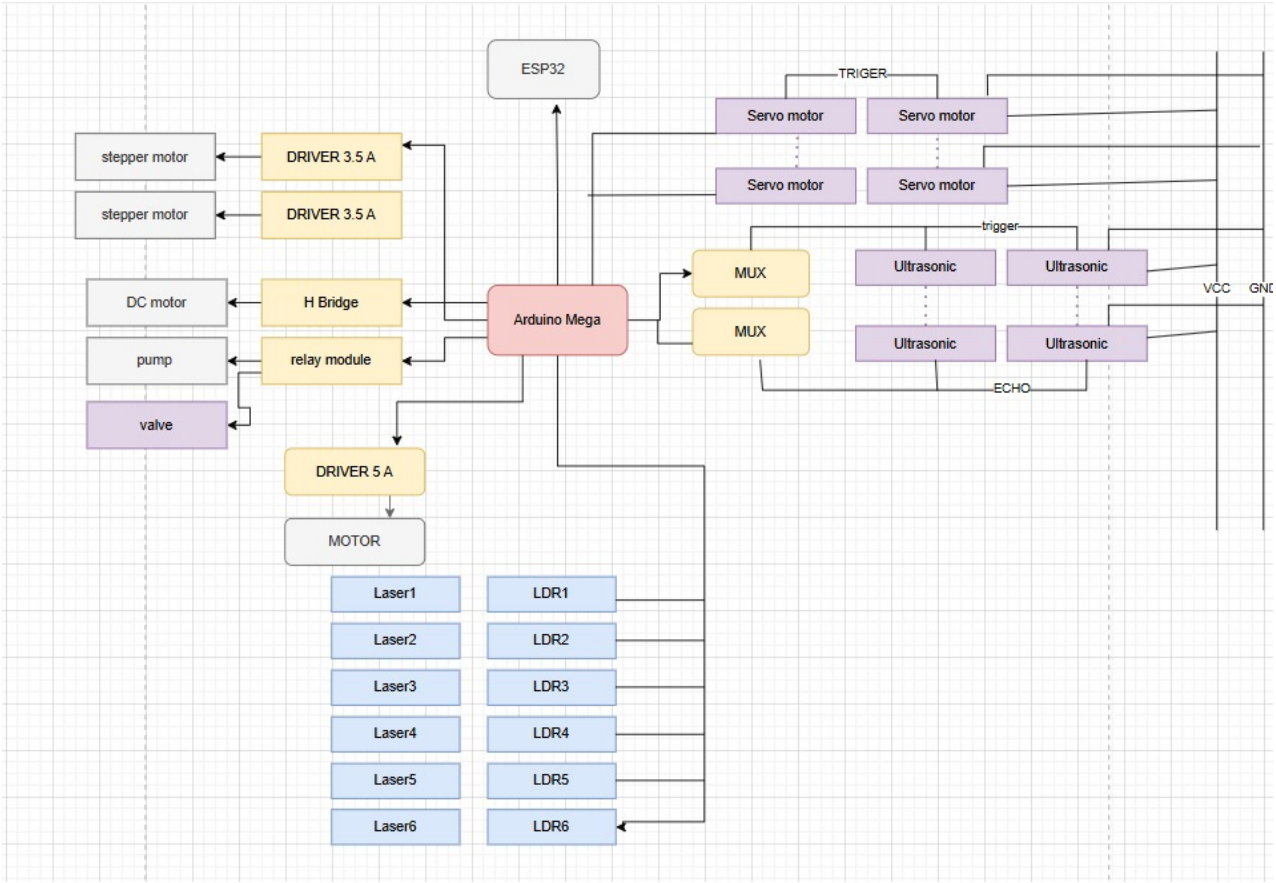

Figure 19:Project Diagram

- **App Inventor**

Creating the mobile application for the PlantPal Pro system was a crucial step in ensuring the system's user-friendliness and accessibility. To develop the application, we used the **App Inventor** platform, a drag-and-drop visual development environment that simplifies the design and creation of mobile applications for Android devices. This platform enabled us to efficiently design the layout and user interface of the application, ensuring it was intuitive and visually appealing for users.

The mobile application communicates with the PlantPal Pro system through the **ESP8266 Wi-Fi module**, allowing for seamless wireless interaction. This integration enables users to monitor and control the system remotely, making it convenient and highly functional. The app allows users to select the desired seeds, monitor planting progress, and receive updates on the system's status.

To test the application, we utilized the **Simula Android Emulator**, which allowed us to run the mobile application on a virtual device. This testing environment enabled us to evaluate the application's performance, compatibility, and functionality without requiring a physical Android device. It provided a reliable way to identify and resolve any issues during the development process.

The development process began with designing the layout and user interface, including various screens and interactive buttons for user interaction. We then programmed the application's behavior and functionality using App Inventor's block-based coding system. Key functionalities implemented included establishing a Wi-Fi connection with the ESP8266, displaying real-time system updates, and enabling users to make precise selections for planting options. This wireless integration enhanced the system’s accessibility and usability, ensuring a seamless experience for users.

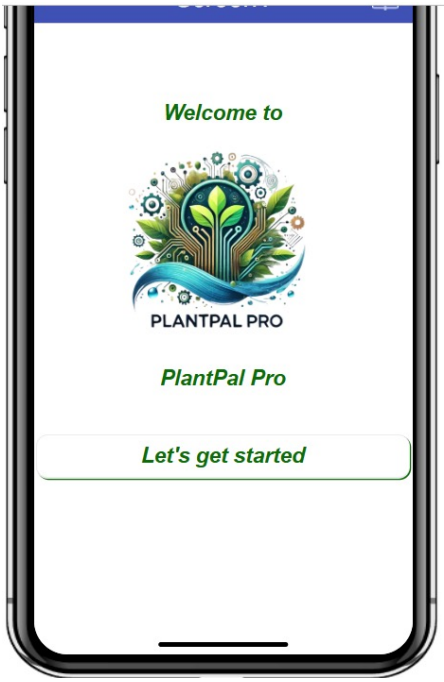

Figure 20 :App inventor design for application

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We tested the application by simulating various scenarios, such as displaying real-time system status and user interaction workflows. This process allowed us to identify and resolve bugs or issues, ensuring the application was both user-friendly and easy to navigate. Through rigorous testing and iteration, we successfully developed a mobile application that became a vital component of the PlantPal Pro system. It enabled users to seamlessly access and control the system, enhancing convenience and usability.

Using the **App Inventor** platform and the **Simula emulator** was instrumental in the development process. These tools provided an efficient way to design, test, and refine the application, allowing us to identify and address issues before advancing to the next stage of development. This ensured that the application was robust, reliable, and fully integrated with the PlantPal Pro system.

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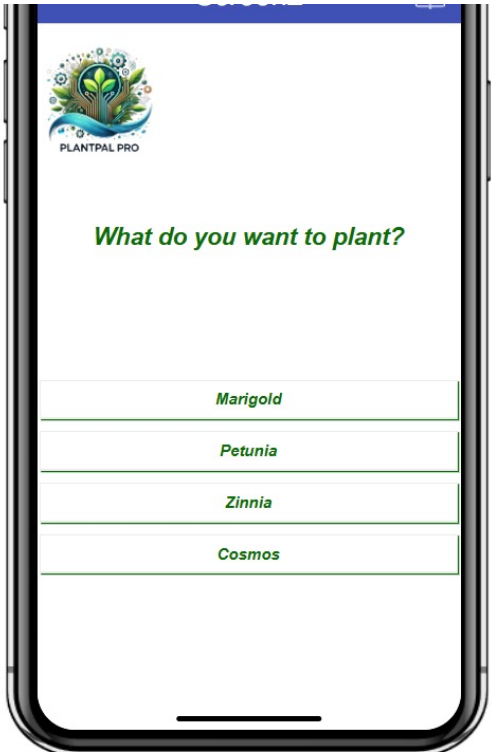

Figure 21:Main Menu

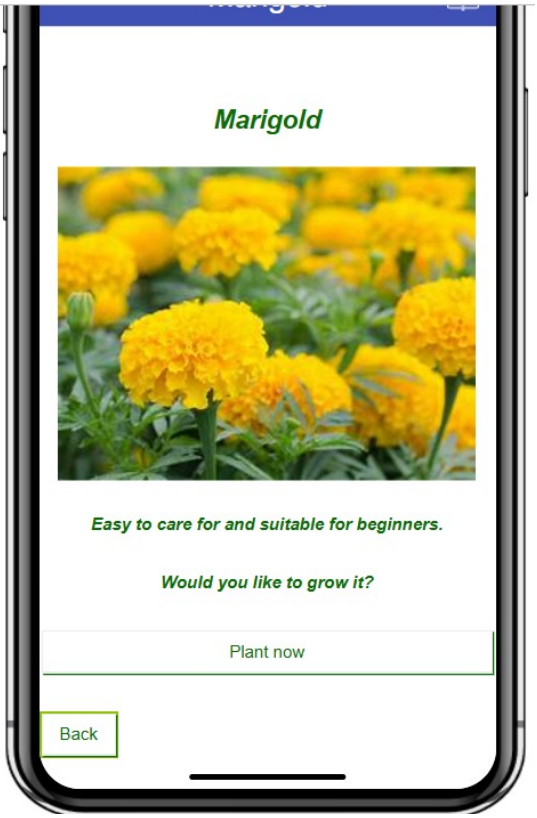

Figure 22: Marigold

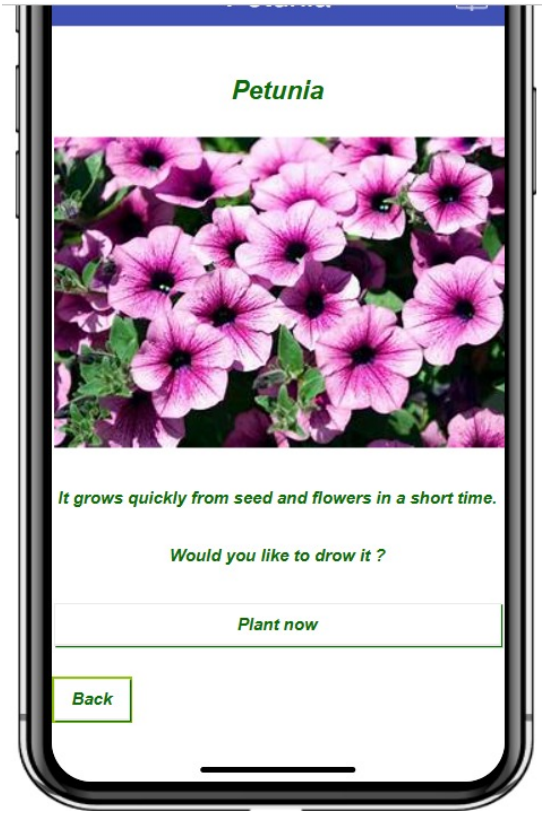

Figure 23: Petunia

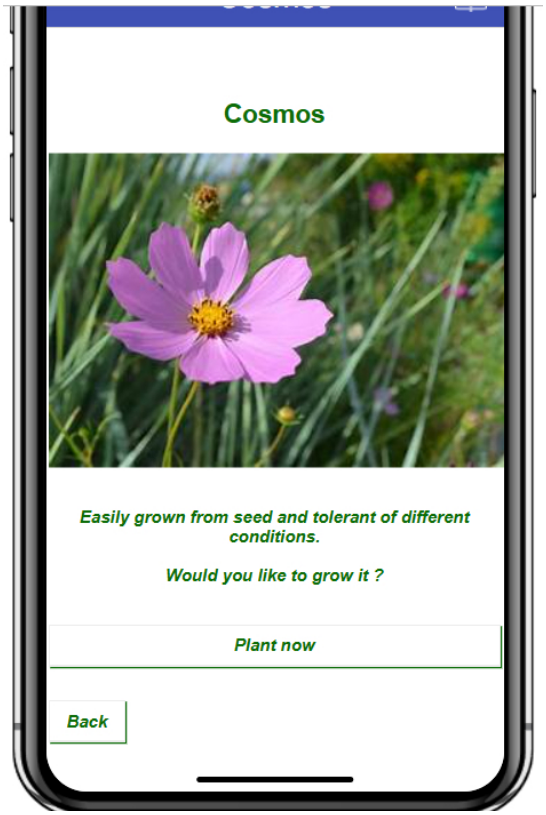

Figure 24: Cosmos

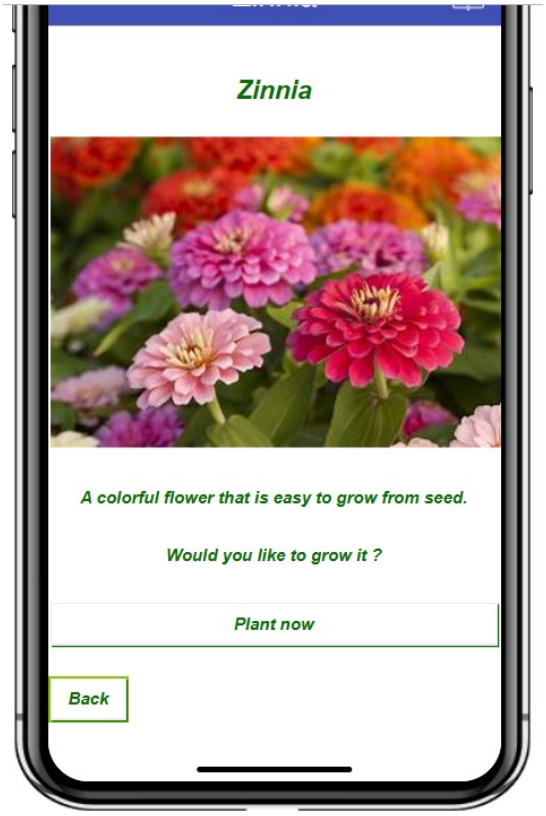

Figure 25 : Zinnia

5.4 Building the prototype

The prototype of the PlantPal Pro system was built to test the functionality, integration, and feasibility of the design. The development process included assembling the hardware, integrating the software, and ensuring smooth coordination between all components.

The hardware assembly began with constructing the production line, which included mounting the large stepper motor and its 5A driver to control the movement of planting cups. The wooden mechanism powered by the DC motor was carefully positioned to lower and adjust the cups at various stages of the process. Sensors, including LDR modules with laser diodes and the HC-SR04 ultrasonic sensor, were placed at strategic checkpoints to detect the cups' positions and provide precise feedback to the system.

The actuators, such as SG90 servo motors, were installed to handle seed and vitamin dispensing, while the solenoid valve and water pump were connected for controlled water delivery. The entire setup was powered by two separate power supplies: a 24V 6A supply for the production line motor and a computer power supply for the Arduino Mega and other low-voltage components.

Software integration involved programming the Arduino Mega to coordinate the motors, sensors, and actuators. The ESP8266 module was configured for wireless communication, enabling seamless interaction with the mobile application. The app was integrated into the system to allow users to select seeds, monitor progress, and interact with the planting process in real time.

Once the prototype was fully assembled, rigorous testing was conducted to identify any issues with hardware alignment, software bugs, or system inefficiencies. Adjustments were made to optimize motor speeds, sensor placements, and system synchronization. The prototype served as a tangible representation of the PlantPal Pro system, allowing the team to validate the design and functionality before final implementation.

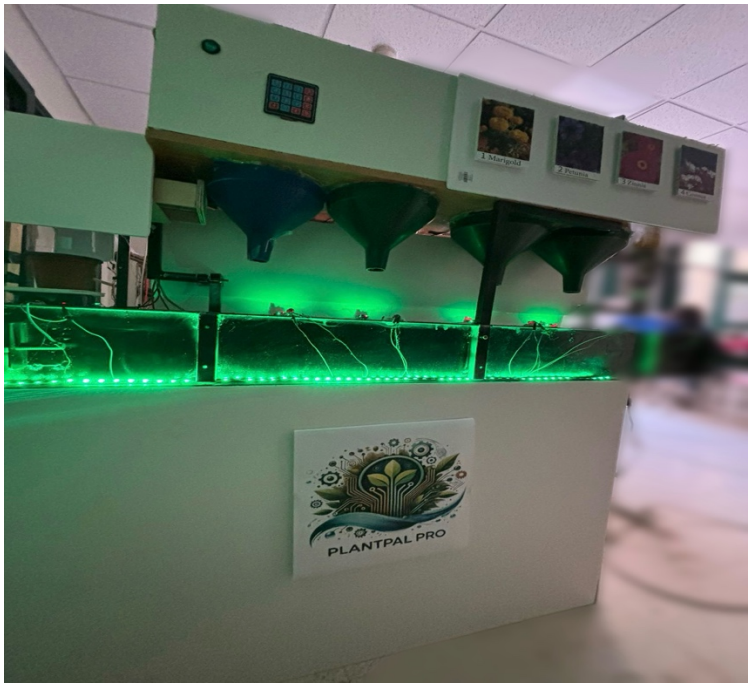

Figure 26: Mian line

Figure 27: Wooden Mechanism

Figure 28: Watering Plant

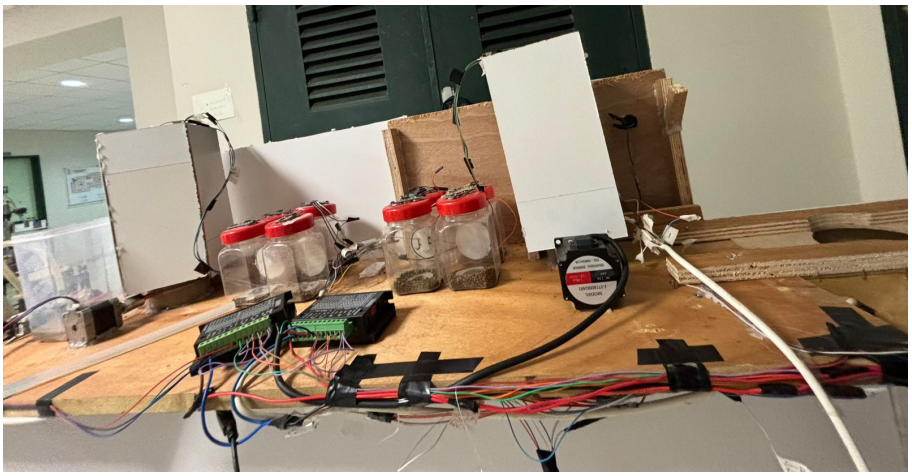

Figure 29: Behind The Scene

Figure 30: All The Project

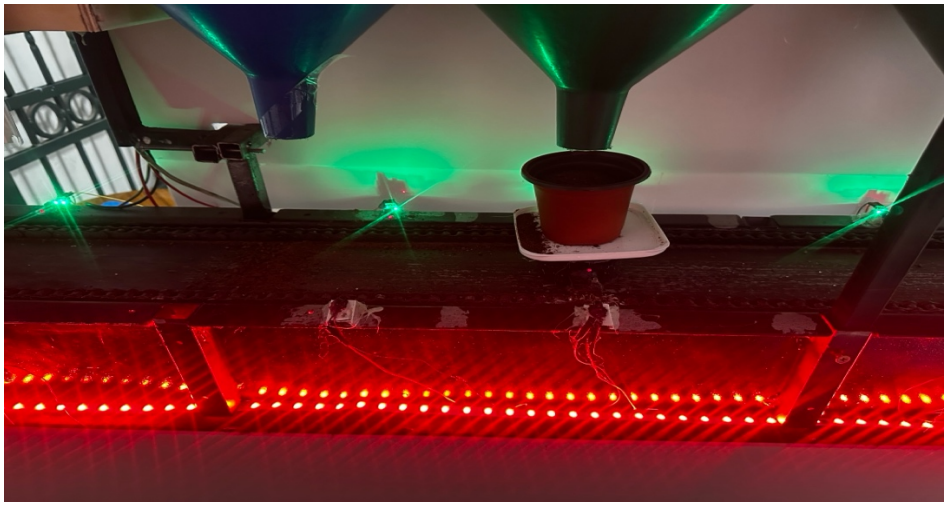

Figure 31: Test Case—Ultrasonic detrmind lack of seeds.

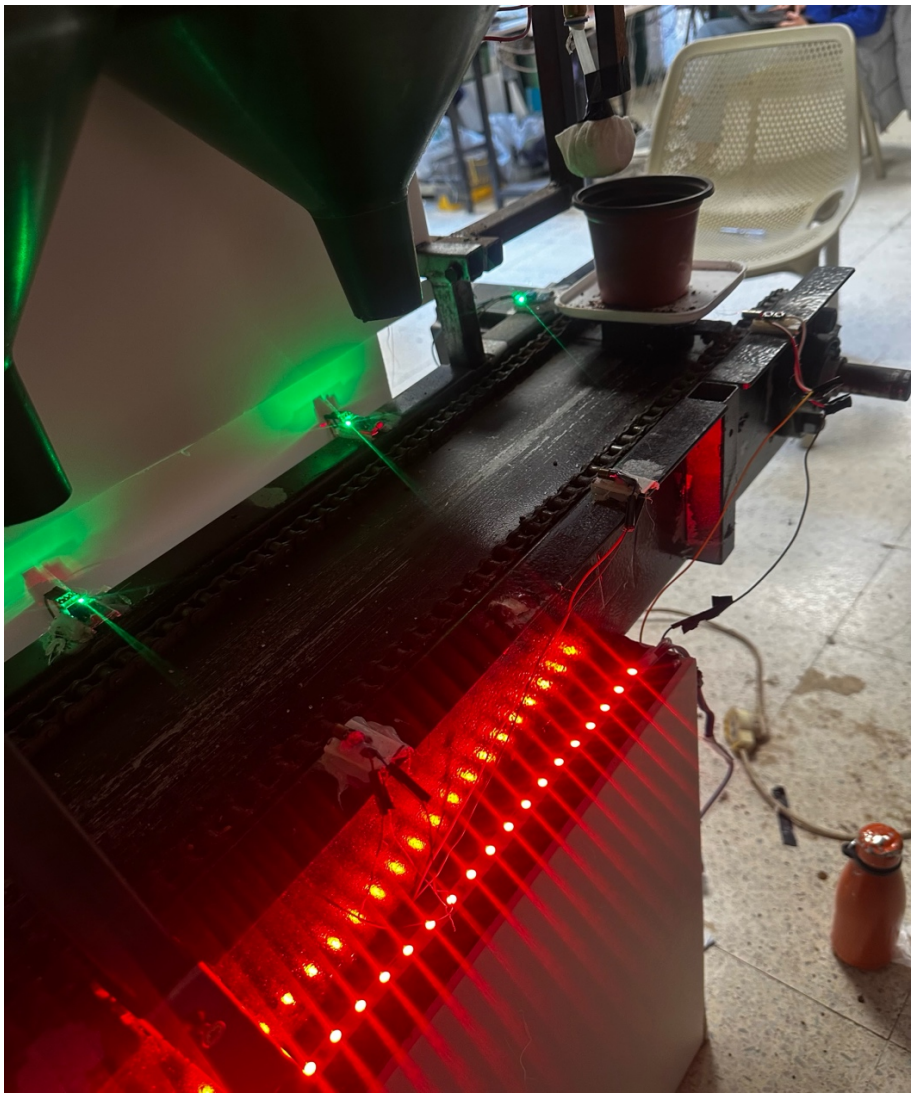

Figure 32: Test Case – Lights are red when finishing.

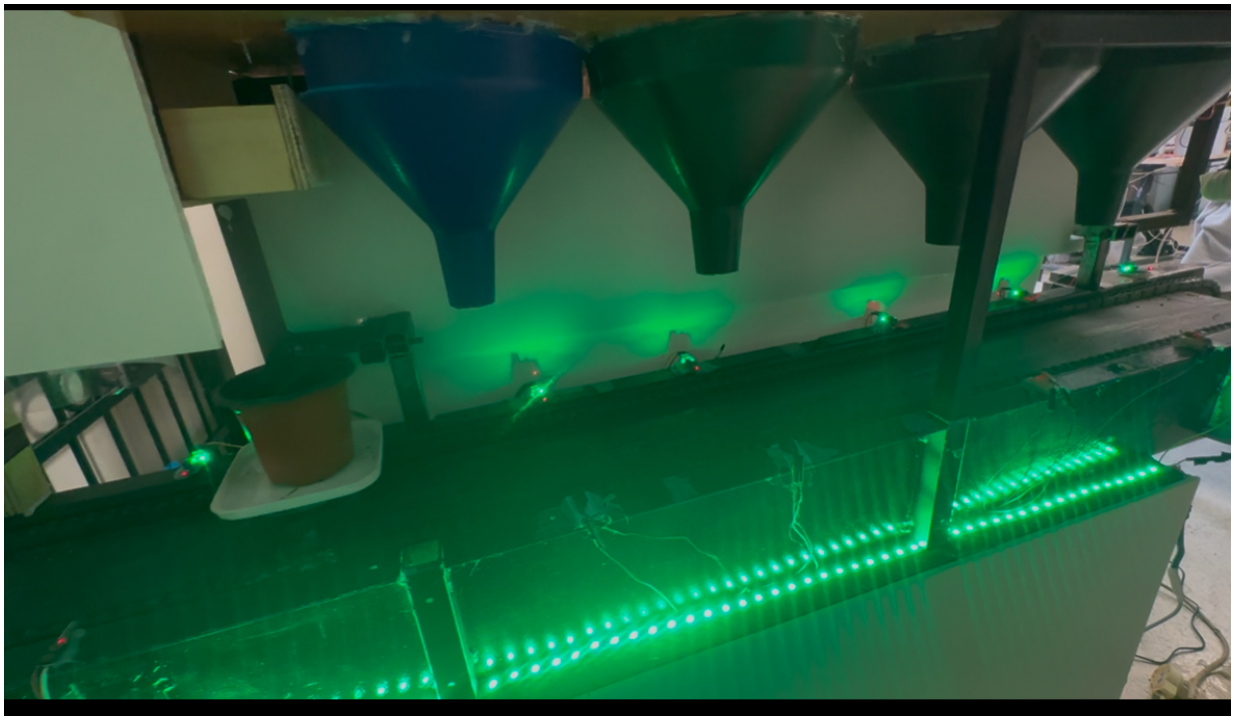

Figure 33: Test Case—Lights are green when the line starts.

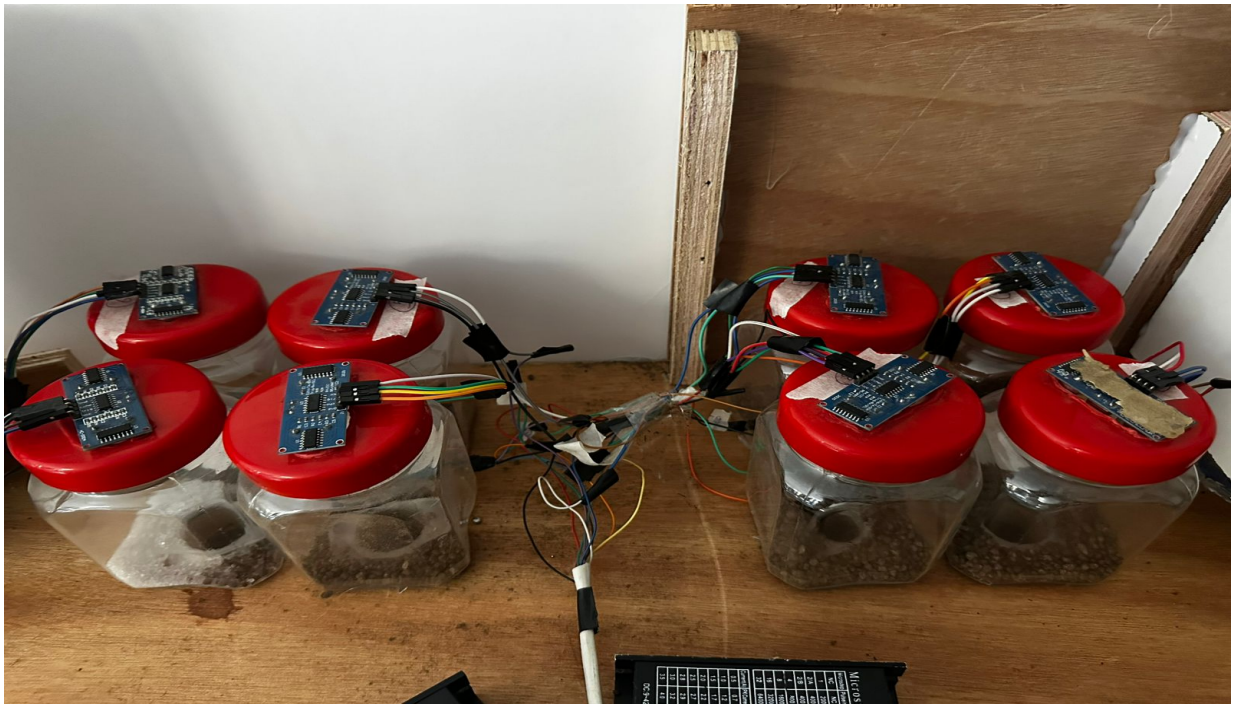

Figure 34: Ultrasonics for seeds and vitamins.

5.5 Evaluation and Analysis

The evaluation and analysis phase of the PlantPal Pro project involved assessing the performance, precision, and usability of the automated planting system based on data collected during testing. The primary goal of this phase was to ensure that the system met its objectives of efficient planting, precise nutrient delivery, and user-friendly operation.

The analysis of data from sensors, motors, and actuators demonstrated the system's effectiveness in coordinating planting tasks. The stepper motors accurately controlled soil layering and seed placement, while the servo motors dispensed vitamins and seeds as required. The use of LDR modules for position detection ensured precise movement and stopping of the planting cups along the production line. Additionally, the AI model successfully recommended the appropriate vitamins for each seed type, enhancing the planting process.

During testing, areas for improvement were identified, such as optimizing motor speeds for smoother operation and improving sensor placements for enhanced accuracy. The mobile application was evaluated for usability, and feedback suggested minor improvements in the interface to make it more intuitive for users. These insights informed further refinements to the system.

Overall, the evaluation confirmed that the PlantPal Pro system was effective in achieving its goals of precision planting and automation. The system demonstrated high reliability and efficiency, with user feedback indicating satisfaction with its functionality. The analysis provided valuable insights that will guide future iterations of the project to enhance its performance and usability further.

5.6 Reporting and Documentation

The reporting and documentation phase was an essential part of the PlantPal Pro project, ensuring that all aspects of the system's design, development, and implementation were thoroughly recorded. This phase involved creating a comprehensive project report detailing the objectives, methodology, hardware and software components, and results of the system. The documentation served as a blueprint for understanding the system’s functionality, technical specifications, and integration process.

The report included detailed descriptions of each hardware component, such as stepper motors, LDR modules, and power supplies, along with the software architecture, including Arduino code and the mobile application. Diagrams, schematics, and flowcharts were incorporated to visually explain the system’s workflow and operation. Testing results were also documented, highlighting system performance, precision, and areas for improvement.

Additionally, the documentation ensured that future developers or researchers could replicate or expand upon the project. Clear instructions were provided for hardware assembly, software installation, and system calibration. This phase emphasized the importance of clarity and accessibility in technical documentation, ensuring the project’s longevity and potential for further development.

Chapter Six : Future Work :

Future Work

In the future, the **PlantPal Pro** system aims to expand its capabilities to further enhance agricultural efficiency, adaptability, and plant care. Several key areas of development are planned, including:

1. **Plastic Houses for Flowers**:
   Introducing plastic houses (greenhouses) for flowers will ensure complete care and optimal growing conditions after planting. These greenhouses will allow for precise control of temperature, humidity, light exposure, and pest management, providing a shielded environment for delicate plants. This feature will make PlantPal Pro an ideal solution for floriculture, improving the quality and lifespan of flowers.
2. **Increased Seed Type Variety and Production**:
   Enhancing the system to handle a broader variety of seed types will enable farmers to diversify their crops and meet different agricultural needs. The system will include configurable settings for planting, watering, and fertilization tailored to the requirements of each seed type. By supporting more crops, farmers can scale production, explore new markets, and optimize resource usage.
3. **Automated Nutrient and Watering Systems**:
   A future upgrade will include an advanced nutrient delivery system that combines precise measurements of vitamins, minerals, and water for each plant. This automated system will further improve plant health and ensure consistent growth, particularly for crops with unique nutrient needs.
4. **AI-Based Growth Monitoring**:
   Integrating AI-powered growth monitoring will allow PlantPal Pro to track the health and development of plants in real-time. By analyzing data from sensors and cameras, the system can predict potential issues, recommend interventions, and even provide reports on growth progress, giving farmers actionable insights.
5. **Modular Design for Scalability**:
   Future iterations of PlantPal Pro will adopt a modular design, allowing for easy scaling of the system to larger farms or production lines. Farmers will be able to add more planting stations, greenhouses, or nutrient systems as needed, ensuring flexibility for various farm sizes and operations

Chapter Seven: Conclusion

The PlantPal Pro system represents a significant step forward in the field of automated agriculture, providing an efficient and user-friendly solution for modern planting processes. This project was developed to address the challenges faced by Palestinian farmers, such as labor-intensive manual planting and the need for precise nutrient and water delivery. By integrating advanced hardware, AI-driven decision-making, and IoT technology, the system successfully automates critical planting tasks, improving productivity and sustainability.

The system's design and implementation involved a structured approach, starting from conceptualization and hardware integration to software development and rigorous testing. Key features, such as the stepper motor-driven production line, precise soil and seed dispensing mechanisms, and AI-recommended nutrient delivery, ensured that the project met its goals of accuracy, efficiency, and user accessibility. The inclusion of a mobile application further enhanced the system by allowing users to monitor and control operations remotely, making it both practical and scalable for real-world applications.

While the PlantPal Pro system achieved its intended objectives, it also opens avenues for future enhancements. Potential improvements include expanding the AI model to support a wider variety of crops, integrating real-time environmental monitoring for adaptive nutrient delivery, and scaling the system for larger agricultural operations.

In conclusion, the PlantPal Pro project successfully demonstrated the potential of automation and AI in agriculture. It provides a foundation for further innovation in smart farming technologies, offering a practical solution to support farmers and contribute to more sustainable agricultural practices.

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