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FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

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AgriBotix

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Dedication

This project is dedicated to the Martyrs of Gaza and the West Bank whose memories and indomitable spirit are a source of strength and endurance. This is dedicated to my family for being there and believing in me. This work serves as a small effort towards much bigger battles and is done wholeheartedly with admiration and appreciation.

Disclaimer

This report was prepared by Ahmad Saad and Mohammad Alwazni, both affiliated with the Computer Engineering Department within the Faculty of Engineering at An-Najah National University.It has not been modified or revised beyond editorial adjustments required for assessment, and it may include errors in language and content.

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Abstract

Our graduation project focuses on the development of an intelligent agricultural robot that designed to enhance and mechanize core activities in greenhouse farming. This autonomous robot addresses the challenges of maintaining consistent plant conditions in controlled environments, reducing the need for human labor, increasing crop yield, and enhancing sustainable agricultural practices.

The robot is a compact, agricultural unit that navigates through the greenhouse using advanced sensors and real-time data. It is equipped with a GPS module to track its path throughout the greenhouse. The robot relies on signals from plants via ESP channel and has moisture meters distributed all over the greenhouse to check plant water needs. Whenever any shortage of it is noted, one may find the robot moving automatically towards and it sprays water there letting it reach optimum moist conditions that facilitate the growth of these crops. Furthermore, the robot can carry insecticides which are sprayed on plants to protect plants from pests.

1 Introduction

1.1 Problem Statement

The agricultural sector plays a pivotal role in sustaining global food production, and technological advancements are crucial to meet the rising demand for efficient farming. The Problem is driven by increased demands of modern agriculture and the constraints posed by traditional methods of farming.
It highlights the critical importance of efficiency and sustainability, regarding farming, while it also acknowledges problems that farmers have in maintaining conditions for crops, especially in greenhouses environments. Focus of attention is directed towards important activities like watering, and pest control which are usually carried out by human labor with little efficiency.

1.2 Objectives

The primary objective of this project is to develop an intelligent agricultural robot, capable of autonomously navigating greenhouse environments, in an orderly context performing tasks like watering, and pest control. A one facility included in the load is designed to reduce on manual labor, improve production, and grow the green farming concept. This project aims to solve the problems of modern greenhouse farmers by utilizing advanced sensor technology, GPS navigation, and real-time data to promote the development of technology in the agricultural industry towards higher efficiency.

1.3 Significance

The main goal of this project is to develop a robot that is capable to autonomously performing essential agricultural tasks with precision and efficiency. The project contributes by saving time and effort for farmers by automating activities such as watering, and pest control. In addition to that, the Agribotix robot aims to not only enhance efficiency but also contribute to resource optimization and environmental sustainability. The integration of market demands and projections underscores the relevance of this work in addressing contemporary challenges in agriculture,

1.4 Report Organization

This report provides a comprehensive summary of the Agribotix project, covering various aspects. We begin by identifying the constraints encountered in our work, including equipment limitations, tools used, and time constraints. Following this, we review existing agricultural robotics systems to provide background on the topic and highlight the unique characteristics we have incorporated compared to those systems. The methodology adopted in our work is thoroughly explained, offering insight into the methods and strategies utilized. Subsequently, we present our findings and engage in a discussion to analyze and compare the results obtained. In conclusion, we offer a summary of the entire project and discuss our plans for future enhancements aimed at further improving our work.

2 Constraints and Earlier coursework

2.1 Limitations & Constraints

2.1.1 Limited Time

Working on the Agribotix project was challenging because we had limited time to do all necessary tasks in a very short summer semester and within restricted hours of Electronic Laboratory.

2.1.2 Limited Resources

We faced several challenges with the resources needed for the Agribotix project. First, was sourcing suitable wheels with tracks that could handle the varied terrain of a greenhouse environment, which wasn't easily available in our city. This meant we had to spend extra time searching for it, which slowed us down. Another major challenge was finding the specific type of sprinklers that we needed for the project. This put us in a position where we had to look for suboptimal solutions which affected our original design. Additionally, the availability of a modern GPS module, that could effectively track the robot in real-time as it navigated the greenhouse was also a challenge. These resource limitations not only slowed down the progress of the project but also required us to make adjustments to our design and budget, ultimately impacting the overall outcome.

2.1.3 Lake of experience & Handling with components

Working with new components like the ESP32-CAM, GPS module, MPU-6050, and moisture sensor presented significant challenges, particularly when trying to integrate them all to work together simultaneously.

Additionally, our lack of practical experience we had some hardware subjects throughout our studies, this was our first time in practical application, so we made some mistakes that cost us extra effort, money and time.

2.2 Earlier coursework

Our university coursework provided a solid foundation of knowledge crucial for the development of the Agribotix robot. Courses in hardware engineering, such as Digital Circuits Design I and II, Microcontroller Programming, Electronics, Microprocessor Lab, and Critical Thinking and Scientific Research, equipped us with the necessary tools and expertise. These courses enabled us to tackle the challenges of designing and integrating hardware for the Agribotix project and preparing a compelling presentation.

3 Literature Review

Here are some examples of agricultural robotics that we found while searching for some features to add to our project.

- Farmer Robot

This project introduces a revolutionary farmer robot designed to optimize and automate key tasks in agriculture. The robot is equipped to navigate through the farm autonomously, utilizing a walking mechanism for versatility across various terrains. Its primary functions include digging holes for planting agricultural seedlings, dispensing fertilizer for enhanced soil nutrition, and seamlessly communicating with the Drip Irrigation System to initiate watering.

- Farmbot Robot

The FarmBot is robot allows the farmers or anyone wants to use his backyard to farm in efficient and easy way. FarmBot will be responsible for the whole farming process starting with the seeds planting going through irrigating the crops reaching to having a good agricultural crop. FarmBot guarantees that the farming process is going efficiently by monitoring all the factors that could affect the plants such as the temperature and humidity.

- Agricultural Robot

This project will propose the first model of the smart agricultural system in Palestine, which should contain the basic elements of any agricultural system, and then develop it into a model that meets the market needs.the main output of this project will be a smart agricultural system that can be versatile and easy to apply and use in the field for which it is designed.

- Autonomous Robot For Future Sustainable Farming

This project will propose an autonomous navigation with pest prevention robot that can travel agricultural fields autonomously and guided by user predetermined waypoints set in mission planning software. The robot which is mounted with an AI camera on top of the robot that uses object detection technique which allows for targeted pesticide spraying and focusing on specific plants or areas to successfully tackle fungal and pest related problems.

4 Methodology

In this chapter, we provide a detailed account of the materials, methods, and standards applied in the development of our Agribotix robot.This methodology encompasses the design, integration, and testing of various components, each crucial for the effective execution of agricultural tasks.

4.1 Standards and specifications

Our project adheres to engineering standards, ensuring reliability and compatibility. Specifically, we use the IEEE 802.11 standard for communication protocols, emphasizing seamless connectivity and data exchange within the system. we have written 3 main pieces of code which are for the Arduino Mega, the main design ESP32, and one for the ESP32, which handles the wireless communication. The codes were implemented using the Arduino IDE in C++ language which includes several libraries such as esp_now.h, AsyncTCP.h, ESPAsyncWebServer.h, TinyGPS++.h, Wire.h, MPU6050_light.h, WiFi.h, WiFiClient.h, and many other libraries that helped to implement the required functionalities.

4.2 Hardware Components

In this section, we will discuss the hardware components we utilized and the reasons for their selection:

- **Arduino Mega**

  The Arduino Mega 2560 is a flexible and powerful microcontroller board, an extended version of the popular Arduino Uno. It features the ATmega2560 microcontroller, providing 54 digital I/O pins, 16 analog inputs, and sufficient memory. We used it for the large number of inputs/outputs we needed to complete this project.

  We useed the Arduino Mega 2560 to connect with several key components to ensure smooth operation. We connected the MPU6050 Gyroscope Sensor for motion tracking in movement, the GY-NEO6MV2 GPS Module for accurate positioning, also a dual-channel relay module to control the water pump, and the servo motor we used to manage the sprinklers.

  We started with Arduino Uno, but as our project grew, we needed faster serial communication speeds since our communication operates on a 115200 baud rate. That's why we chose the Arduino Mega 2560. Mega's faster serial communication speed compared to the Uno ensures our data transfers are quick and reliable, which is crucial for our project's performance.

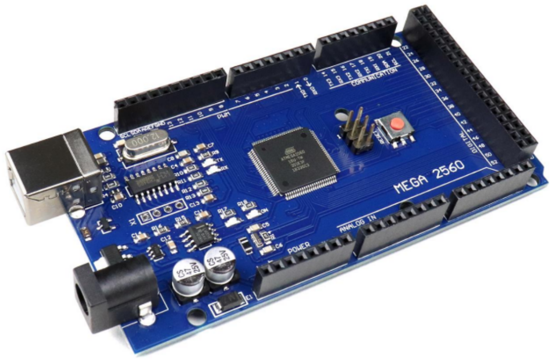

Figure 4.1: Arduino Mega 2560

- **ESP32**

  The ESP32 is a versatile microcontroller module designed for IoT projects, featuring dual-core processing, built-in Wi-Fi and Bluetooth, ample memory, GPIO pins, and communication interfaces. It is widely used for wireless connectivity, sensor integration, and IoT applications.

  In our project, we utilized a single ESP32 module that connects to four moisture sensors to monitor humidity levels within the greenhouse. When two of these sensors detect a drop in humidity, the ESP32 sends a signal using the ESP-NOW protocol to another ESP32. The ESP32 then relays this information to the Arduino Mega, which triggers the robot to initiate the necessary processes. This setup allows for efficient and responsive automation.

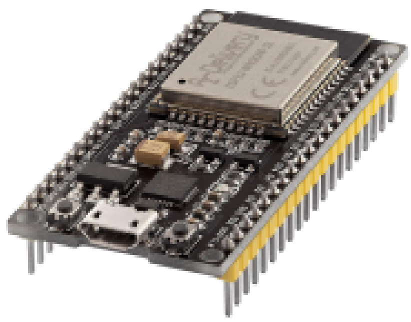

Figure 4.2: ESP 32

- **ESP32-CAM**

  The ESP32-CAM is a versatile and compact camera module that integrates an ESP32 microcontroller with a built-in camera, offering both Wi-Fi and Bluetooth connectivity. It's widely used in IoT and robotics projects for capturing images, and streaming video.

  In our Project, We incorporated an ESP32-CAM module to enhance the robot's functionality. The ESP32-CAM provides a live video stream of the bottom view of the robot, allowing for real-time monitoring of its operations. The video data captured by the ESP32-CAM is then sent into the system, ensuring seamless integration and control within the system.

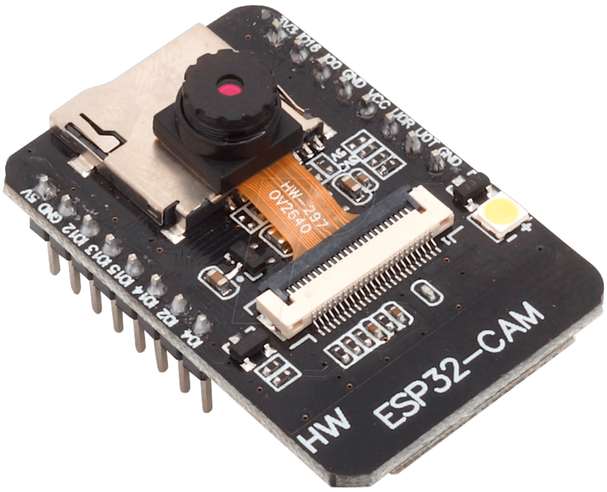

Figure 4.3: esp32 cam

- **Moisture Sensor**
  A moisture sensor is a device designed to measure the water content in the soil. It operates by detecting the resistance between two metal probes inserted into the ground, where varying moisture levels affect the resistance.

  In our Project, We utilized four moisture sensors to accurately measure soil moisture levels. These sensors work by measuring the electrical resistance between two metal probes inserted into the soil.

  By monitoring these changes, the sensors provide real-time data on soil moisture, which is crucial for determining when irrigation is needed. In our setup, if two of the sensors detect low moisture levels, a signal is sent to the ESP32, triggering the irrigation process. This automated response ensures that crops receive the right amount of water, optimizing growth and conserving resources.

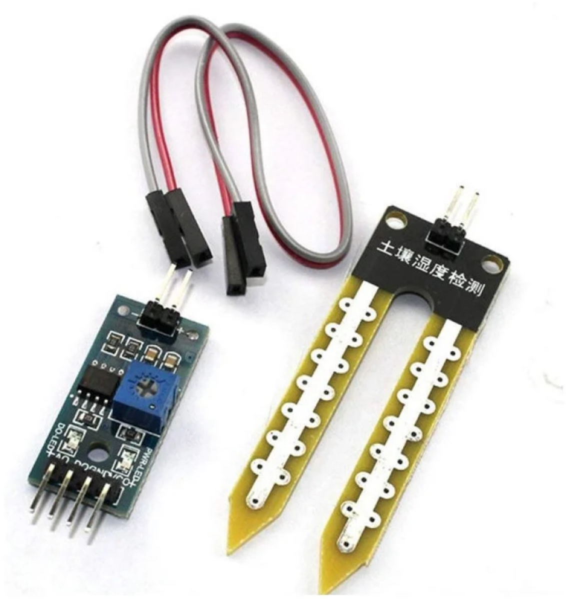

Figure 4.4: Moisture Sensor

- **MPU-6050 Gyroscope Sensor and Accelerometer**

  The MPU-6050 is a sensor chip that combines a gyroscope and an accelerometer. It tracks rotation and acceleration in three dimensions each, providing 6 degrees of freedom (6DoF) data, it communicates digitally with microcontrollers and often includes a built-in processor for handling motion calculations.

  In our project, the MPU-6050 was used to calculate the orientation and movement of the robot. It provided real-time data on the robot's tilt and angular velocity, which was crucial for maintaining stability and accurate navigation. By processing this data, we were able to ensure that the robot's movements remained smooth and controlled.

Figure 4.5: MPU6050

- **NEO6MV2 GPS module with antenna**

  The NEO6MV2 GPS module is a compact and highly sensitive GPS receiver that is used to track precise location data by providing longitude and latitude coordinates. In our project, this module was essential for tracking the movement of the robot around the greenhouse.

  We utilized the GPS to record the robot's path as it moved through the greenhouse. This recorded path, based on longitude and latitude data, was then used to automate the robot's future movements. By following the saved coordinates, the robot could navigate the greenhouse autonomously.

Figure 4.6: NEO6MV2 GPS module with antenna

- **Stepper Motor Nema 23**

  The Nema23 stepper motor is a high-torque electromechanical device that converts electrical pulses into discrete mechanical movements. Unlike traditional motors, which rotate continuously, stepper motors move in precise steps, allowing for accurate control of position and speed. In our project, We used 4 stepper motors to control the wheels of the robot, allowing for accurate and smooth movement within the greenhouse.

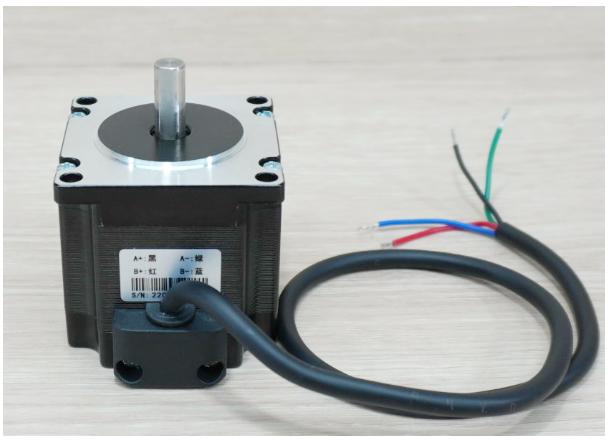

Figure 4.7: Stepper Motor Nema 23

- **TB6600 Stepper Motor Driver**

  The TB6600 Stepper Motor Driver is a robust and reliable device designed to control stepper motors in high-performance applications that require high precision and torque. The driver is Known for its ability to handle up to 4A of current and operate within a voltage range of 9V to 42V. In our project, we utilized four TB6600 drivers to manage the stepper motors that control the movement of robot, ensuring accurate and reliable operation.

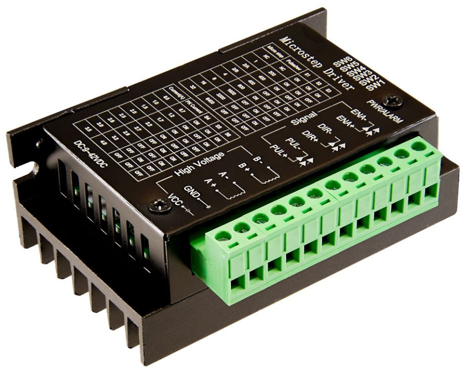

Figure 4.8: TB6600 Stepper Motor Driver

- **Diaphragm Pump**

  The Diaphragm Pump is a versatile and efficient device, operating within a voltage range of 6 to 12 volts. It is designed to move fluids with consistent pressure and flow.

  In our project, we utilized four diaphragm pumps: two for the water tank and two for the pesticide tank. Each pump is connected to its respective sprinkler system, ensuring efficient and precise distribution of water and pesticides across the greenhouse.

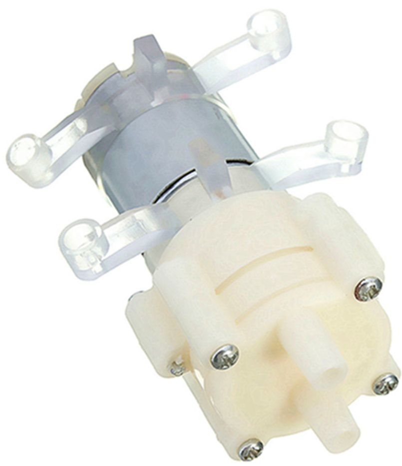

Figure 4.9: Diaphragm Pump

- **The S3003 Servo Motor**

  The S3003 Servo Motor is a compact and reliable component designed to provide precise control of angular movement within a 180-degree range. Known for its robustness and accuracy.

  In our project, We used the S3003 Standard Servo Motor to manage the operation of the sprinklers. Its ability to accurately control angles ensures that water is evenly distributed across the designated areas.

Figure 4.10: The S3003 Servo Motor

- **sprinkler**

  Sprinklers are designed to deliver water or liquid substances evenly over a specified area.The sprinkler system in our project plays a crucial role in the efficient distribution of water and pesticides.

  In our project, We used four sprinklers: two are connected to the water pump and the other two to the pesticide pump. Each sprinkler is mounted on a stand that is precisely controlled by a servo motor. This arrangement allows us to adjust the positioning and direction of the sprinklers, providing flexibility in targeting specific areas and ensuring effective irrigation and pest control throughout the greenhouse.

Figure 4.11: sprinkler

- **Ultrasonic Sensor Module HC-SR04**

  In our project, we utilized two ultrasonic sensors to monitor the levels of water and pesticides in their respective tanks. One ultrasonic sensor is installed in the water tank, and the other in the pesticide tank. By continuously monitoring these levels, we ensure that the tanks are adequately filled and can trigger alerts when the liquid levels fall below the desired threshold, maintaining the efficiency and functionality of the irrigation and pesticide systems.

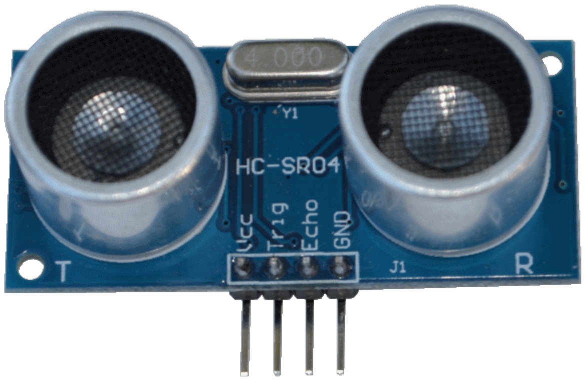

Figure 4.12: Ultrasonic Sensor Module HC-SR04

- **Lead Acid Battery**

  The Lead Acid Battery is a robust and reliable power source, This battery provides a stable 12 volts of power and has a capacity of 7.2 ampere-hours, In our project, this battery is crucial for powering the entire system, including the motors, sensors, and control units. Its capacity allows it to deliver consistent power to all components, ensuring reliable performance throughout the operation of the robot.

Figure 4.13: Lead Acid Battery

- **battery indicator**

  The Battery Indicator is a device used to monitor the charge level and overall health of a lead-acid battery. This indicator provides real-time feedback on the battery's voltage and charge status.

Figure 4.14: battery indicator

- **Jumper wires**

  Jumper wires are flexible wires with connectors on each end used for making temporary electrical connections. They are commonly used in prototyping and circuit building to establish connections between various electronic components. In this project, we utilized jumper wires to establish the necessary connections between different components. We connected the pins of the microcontroller, sensors, modules, and other electronic components by simply plugging the connectors of the jumper wires into the appropriate slots.

Figure 4.15: Jumper wires

- **Dual channel relay module**

  The dual-channel relay module serves as the interface between the Arduino Mega 2560 and the water and pesticide pumps.This module allows the Arduino to control high-voltage and high-current devices, such as our pumps, using its low-power digital outputs.

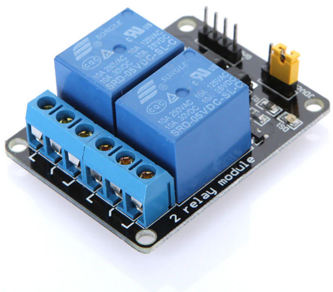

Figure 4.16: dual channel relay module

- **Final Design**

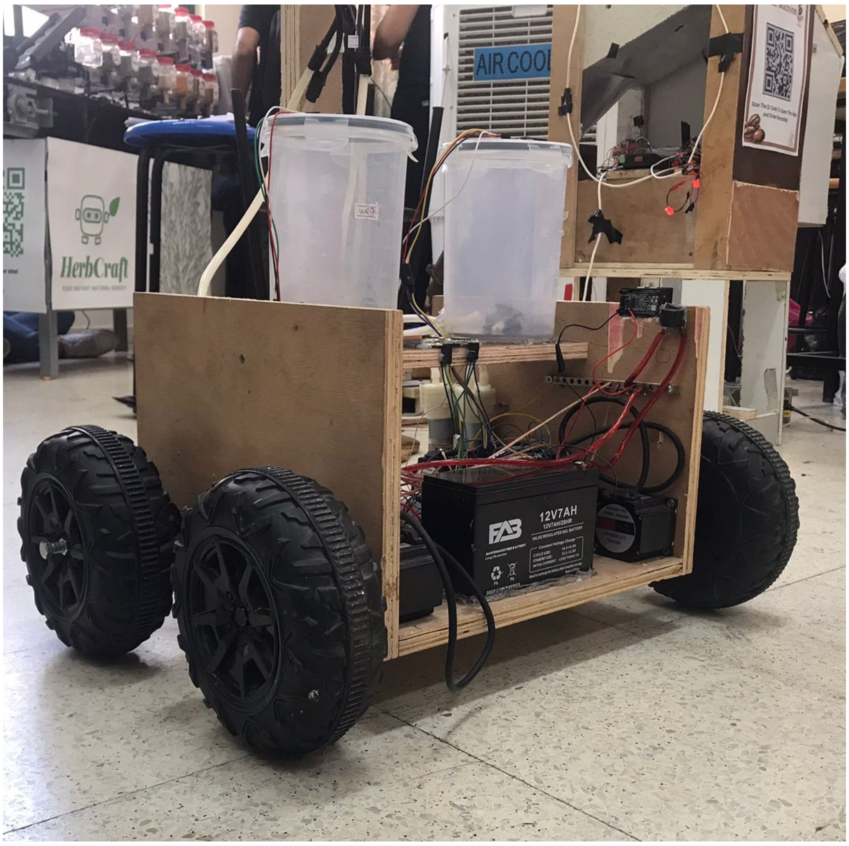

Figure 4.17: Final Design

5 Implementation

5.1 Overview of the system

The Agribotix system is designed to automate essential agricultural tasks, providing a seamless user experience from power-up to operation. Upon activation, the system initializes all connected components, including sensors, motors, and communication modules, ensuring they are ready for immediate use.

The primary control interface for Agribotix is managed through an HTML page hosted on the ESP32 module. This interface allows users to control the robot directly, sending commands to perform various tasks such as watering, and pesticide application. Users can monitor the system's status and view a live stream from the ESP32-CAM, which provides a bottom view of the robot's activities. Once the system is powered, the Arduino Mega communicates with the connected ESP32 modules, moisture sensors, and other components.

The full code of the project can be accessed at: https://github.com/malhaq/AgriBot

5.2 Wep & Mobile Page

The page of the Agribotix system is designed to be a user-friendly control interface, allowing seamless management of the robot's functions. Each button on the page is thoughtfully positioned and clearly labeled, providing intuitive access to the robot's various operations. Here's a detailed overview of the available controls: .

- Forward Movement Button ('↑'): This button moves the Agribotix robot forward.

- Left Turn Button ('←'): This button instructs the robot to turn left.

- Right Turn Button('→'): This button makes the robot turn right.

- Backward Movement Button('↓'): This button moves the robot backward..

- Water On Button('Water on'): This button activates the robot's water pumps, enabling it to start irrigating crops. .

- Water Off Button('Water off'): This button stops the water pumps, halting the irrigation process to prevent over-watering..

- Insecticide Mode Button('Insecticide mode'): This button puts the robot into insecticide application mode.

- Set Right Turn Button('Set right turn'): This button configures the robot's right-turn settings..

- Set Left Turn Button('Set left turn'): Similar to the right turn..

- Set Fluid On Button('Set fluid on'): This button activates the fluid application system, enabling the distribution of fertilizers across the farm..

-Set Fluid Off Button('Set fluid off'): This button deactivates the fluid system..

- Insecticide On Button('Insecticide on'): This button starts the insecticide spraying process, applying pesticides to targeted areas..

- Insecticide Off Button('Insecticide OFF'): This button stops the insecticide spraying..

- Set BASE Button('Set BASE'): This button sets the robot's in reference point(base position)..

- Manual Mode Button('Manual'): This button switches the robot into manual mode, giving the user direct control over all operations..

Each button on the mobile page is designed for efficient interaction, making it easy for users to control the Agribotix robot's activities.

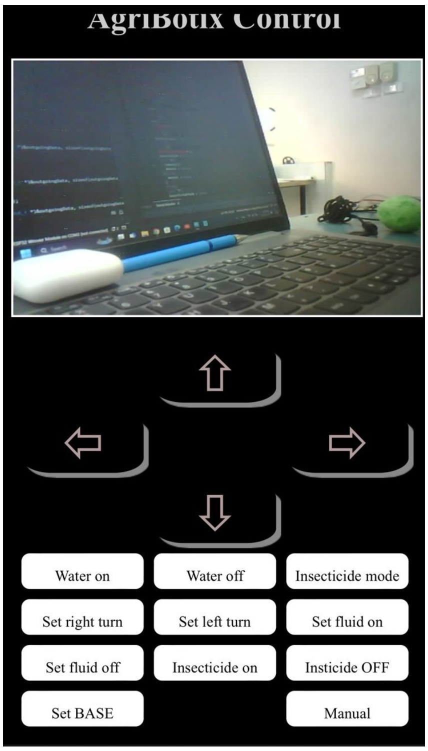

Figure 5.1: Control Page

5.3 Block Diagram

In the Agribotix system, the block diagram illustrates the interconnections between various components to facilitate seamless operation. The sensors, including moisture sensors and ultrasonic sensors, The moisture sensors are connected to the ESP32 module, Which processes input data from the sensors. The ESP32-CAM is employed to stream live video, providing real-time visual feedback within the IoT framework.

The Arduino Mega 2560 serves as the main microcontroller, interfacing with the ESP32 and managing the system's outputs. These outputs include the stepper motors, which control the robot's movement, the water and pesticide pumps, which are controlled through a dual-channel relay module, and the servo motor, which adjusts the sprinklers. The system is also equipped with a GPS module for positioning and an MPU6050 for motion tracking, enhancing the robot's navigation and operational efficiency.

In this setup, the ESP32 uses peer-to-peer communication via the ESP-NOW protocol to exchange data with other modules, ensuring efficient and reliable operation. The live video stream from the ESP32-CAM is accessible through an IP address, enabling remote monitoring of the robot's activities.

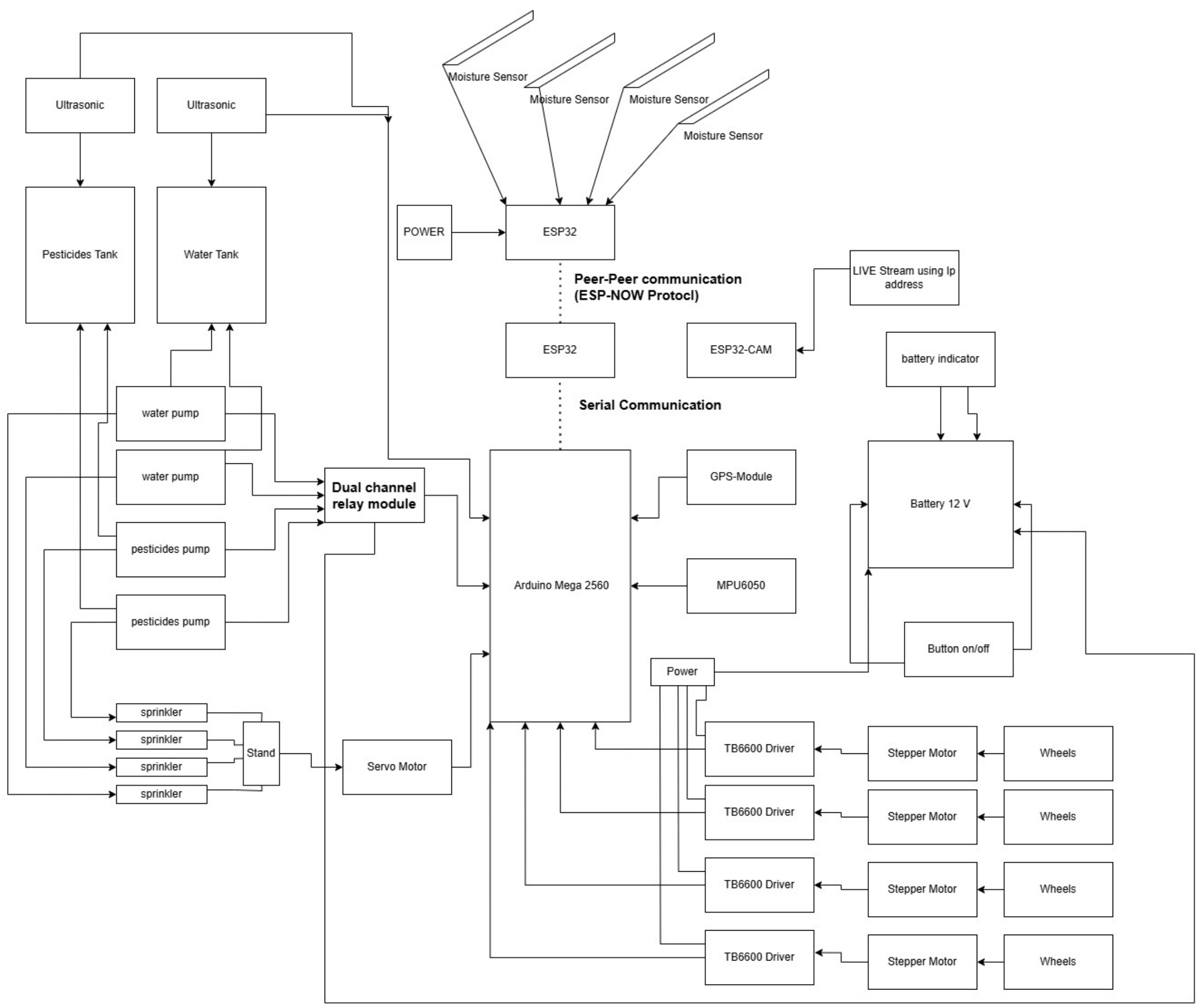

Figure 5.2: Block Diagram

6 Results and Analysis

In this section, we present a detailed summary of the data collected during the experimental trials of the Agribotix system. The results are analyzed, and statistical treatment is applied to derive meaningful insights into the performance and efficiency of the system. link

6.1 Moisture Detection Accuracy

The ESP32 module successfully detected moisture levels with an accuracy of 92% This high accuracy was achieved through careful calibration of the moisture sensors and efficient signal processing. The system reliably triggered irrigation when moisture levels fell below the predefined thresholds, ensuring optimal conditions for plant growth.

6.2 Communication Efficiency and Reliability

we evaluate the communication performance of the Agribotix system, focusing on peer-to-peer communication between the ESP32 modules, as well as serial communication between the ESP32 and the Arduino Mega.

6.2.1 Peer-to-Peer Communication Between ESP32 Modules

The two ESP32 demonstrated effective peer-to-peer communication using the ESP-NOW protocol. This setup enabled direct and efficient data exchange between the modules, with a data transfer rate consistently above 95%. The reliability of this communication ensured that moisture detection signals were promptly transmitted between the Esp, facilitating timely irrigation and other actions based on sensor data.

6.2.2 Serial Communication Between ESP32 and Arduino Mega

The serial communication between the ESP32 and the Arduino Mega was successful, with data transmission remaining stable and consistent. The baud rate of 115200 allowed for rapid and reliable exchange of data, including camera feed and sensor readings. This reliable serial connection supported real-time decision-making and control, crucial for the robot's operations within the greenhouse.

6.2.3 Serial Communication Between GPS Module and Arduino Mega

The serial communication between the GY-NEO6MV2 GPS module and the Arduino Mega was highly effective, utilizing a baud rate of 9600. This setup enabled stable and reliable transmission of GPS data, with the baud rate supporting consistent and accurate data exchange.

6.3 Navigation and Path Tracking Precision

The integration of the NEO6MV2 GPS module and MPU6050 sensor allowed for precise navigation of the robot within the greenhouse. The Agribotix system consistently maintained its designated path with tracking accuracy. The level of precision ensures that the robot navigates the greenhouse efficiently, covering all areas that require attention without deviation.

6.4 Step Control and Movement Accuracy

The Nema23 stepper motors, controlled by the TB6600 drivers, exhibited high precision in movement. Allowing the robot to navigate smoothly and accurately across different sections of the greenhouse. This precision is crucial for avoiding obstacles and ensuring efficient coverage of the greenhouse area.

6.5 Water and Pesticide Distribution Accuracy

The dual-channel relay module controlling the water and pesticide pumps exhibited reliable performance during the trials. The system maintained a consistent flow rate, ensuring uniform distribution across the crops.

6.6 Sprinkler Control and Coverage Uniformity

The servo motor used for controlling the sprinklers performed with high precision, achieving uniform coverage over the crops. The variance in coverage ensures that all plants receive equal treatment. This level of control is critical for maintaining crop health and maximizing yield.

6.7 Enhanced Farm Monitoring

The ESP32-CAM provides live video streaming, allowing users to remotely monitor the robot's activities. This feature offers real-time insights into farm conditions and the robot's performance, empowering users to make informed decisions.

7 Conclusion and Future Work

7.1 Conclusion

Agribotix is a great advancement in agricultural automation, especially for greenhouse farms, offering an effective integration of hardware and software to enhance agricultural efficiency. The project demonstrates how technology can improve farming practices by automating irrigation, monitoring soil moisture, and navigating through the greenhouse with precision.

The successful deployment of moisture sensors, GPS navigation, and real-time camera monitoring ensures that plants receive the right amount of water at the right time, which contributes to healthier crop growth. The precise control of the robot's movement and reliable communication between components allow for efficient and accurate operation, reducing manual labor and minimizing errors.

Agribotix's ability to automate essential tasks and provide real-time data makes it a user-friendly and effective solution for farmers looking to optimize their operations. Overall, Agribotix stands out as a thoughtful integration of advanced technologies, and how it can lead to significant improvements in agricultural productivity and sustainability.

7.2 Future Work

For future enhancements, Agribotix can benefit from several improvements.

1. Implement Image Processing: Adding image processing to detect the path in the greenhouse can make navigation more accurate.

2. Upgrade Sprinklers: Using modern sprinklers can improve water distribution, ensuring plants get the right amount of water more efficiently.

3. Expand to All Farms: Extend the robot's capabilities to work not just in greenhouses but in all types of farms.

4. Increase Multitasking: Enhance the robot to handle more tasks, such as planting seeds, applying fertilizers, and monitoring plant health.

5. Switch to Track-Based Wheels: Changing the wheels to track-based ones can provide better traction and stability, especially on uneven surfaces.

6. Enhance Environmental Sensing: Add more sensors to monitor additional environmental factors providing more data to optimize farming conditions.

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