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SMART FARMING USING IOT

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Abstract

To have a successful irrigation system, it is important to know the water holding capacity of the soil as well as the climate and environment. A low-cost Internet of Things (IoT) plant-monitoring system using an ESP32-CAM, a DHT11 temperature and humidity sensor and a capacitive soil-moisture sensor is described. The DHT11 will be used to monitor temperature and humidity in the environment, and the soil-moisture sensor will give a digital signal that represents the wetness or dryness of the soil. The ESP32-CAM interprets the sensor data, takes a picture of the plant and generates a local Wi-Fi hotspot and web interface which is accessible via a phone or a desktop. To program the ESP32-CAM and for serial communication a FTDI module is used during development. The system architecture, integration of the sensor hardware, the software workflow, and an algorithm for displaying sensor values and plant images is described. Future extensions for the prototype are automatic pump control and advanced plant-disease analysis.In the future, the developers intend for the prototype to include features like automated management of the water pump and advanced diagnosis of plant diseases.

Keywords : IoT, ESP32-CAM, DHT11 sensor , Capacitive soil moisture sensor, plant monitoring, smart farming, watering support, and Edge computing.

1. Introduction

Water management is crucial to ensure the healthy growth of agriculture. The traditional method of irrigation may rely on manual monitoring or predetermined watering schedules, causing overwatering or under watering. Soil and environmental conditions can be monitored to support irrigation management decisions that farmers can make on a continuous basis.

The use of IoT-based systems is a practical solution for gathering data from the environment, using sensors. The proposed system has the ESP32-CAM as the main monitoring unit. The DHT11 sensor is used to measure temperature and humidity while the capacitive soil-moisture sensor is used to indicate the moisture level of the soil. The data gathered can be useful to determine when soil water is limiting and irrigation is necessary.

The system aims to be a user friendly and compact platform for plant monitoring and irrigation decision support. The ESP32-CAM also offers camera and Wi-Fi capabilities, offering the ability to see the plant images and sensor data via a local web interface. Additional features will include automatic water pump control, remote monitoring of systems, and image-based analysis of plants.

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2. Literature Review

The use of IoT, embedded systems, sensors, and artificial intelligence is becoming more prevalent in smart agriculture. Previously irrigation systems have been operated based on periodic observation or fixed irrigation routines which may not be sufficient to deal with varying soil and environmental conditions. The recent work focuses on monitoring with sensors, automatic watering, edge computing, and AI for managing agricultural processes.

Boopathy et al. [1] described an IoT-based agricultural framework combining automated irrigation with machine-learning techniques for crop recommendation, soil classification, and disease identification. Alange et al. [2] has introduced a smart agricultural advisory solution, integrating technologies such as image recognition, soil information, meteorological data, and crop recommendations along with pest and plant disease identification. Hasib and Akib

[3] investigated an ESP32-based plant-monitoring and irrigation architecture that includes environmental and soil sensing with cloud-based visualization and alerts. Padhiary et al. [4] discussed the broader role of intelligent technologies in farm management.

ESP32-CAM-based plant-monitoring work [5] illustrates the suitability of a camera-enabled microcontroller for low-cost plant observation. TinyML-based irrigation research [6] explores local inference on resource-constrained devices, reducing dependence on continuous cloud processing. Other work has investigated edge AI and convolutional neural networks for plant-disease detection [7], smart irrigation and fertigation using sensor and cloud monitoring [8], early rice-disease detection on ESP32-class hardware [9], and resource-constrained edge-AI systems for pest and disease detection [10]. Rahman et al. [11] also explored edge-device plant-disease detection, while Verma et al. [12] discussed IoT-enabled smart fertilization and irrigation support. Adamides et al. [13] It is rumored that some works about smart farming technologies for adaptation to climate change in Cyprus state that it is very important to integrate these technologies into farming. Bayar et al.[14] presented the use of Artificial Intelligence of Things (AIoT) in precision agriculture, especially in irrigation, nutrient management, and detecting plant diseases.Their study demonstrates the potential of combining artificial intelligence with IoT technologies to improve agricultural monitoring and decision-making.

Alahmad et al. [15] reviewed the application of IoT sensors and big data in precision crop production.In their study, the researchers draw attention to the need for agricultural data collection and analysis for better crop management and agricultural resource management.Ramu et al. [16] reviewed various applications of IoT in agriculture, highlighting the role of connected sensors and monitoring systems in improving farming practices. Sadiq et al. [17] examined IoT-enabled smart irrigation systems through a bibliometric review, demonstrating the growing research interest in automated irrigation and efficient water management.

The study by the authors listed in [18] discusses AIoT architectures, technologies, and solutions for smart agriculture. Such systems can support automated monitoring, intelligent decision-making, and efficient agricultural resource management. Tzounis et al. [19] reviewed recent advances and future challenges associated with IoT applications in agriculture. Their work provides a foundation for understanding how connected sensors and communication technologies can support precision farming. Zhang et al. [20] presented a worldwide overview of precision agriculture, explaining the importance of using agricultural information and technology to improve farming efficiency.

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Based on these studies, the proposed system focuses on developing an IoT-based smart farming solution using an ESP32 development board, a DHT11 temperature and humidity sensor, a capacitive soil moisture sensor, and an ESP32-CAM module. The system aims to monitor environmental conditions, identify insufficient soil moisture at an early stage, and capture plant images for visual monitoring. By integrating real-time sensor readings and image-based observations, the proposed framework seeks to support timely irrigation decisions, improve plant monitoring, and reduce unnecessary water usage.

These studies indicate growing interest in multi-parameter sensing, remote dashboards, automated irrigation, and AI-assisted crop analysis. This paper discusses a simple system to sense things, which is basically composed of the identification of temperature and humidity and of the soil moisture while taking a photo of the plant by ESP32-CAM.

3. Research Gap

A number of smart-agriculture systems use several sensors, distributed computing infrastructure, automated control systems, or advanced machine-learning algorithms.These approaches can increase system complexity. A compact and economical plant-monitoring system is still useful where the immediate goal is to observe basic environmental conditions and identify whether soil moisture indicates a possible need for irrigation.

The working system hence aims at an actual sensing layer including ESP32-CAM, DHT11 sensor, and capacitive soil-moisture sensor. It makes no claim towards the complete crop diagnostics or automatic irrigation control. Instead, it provides a basis that can be built upon with such things as additional sensors and pump control as well as logging and image analysis in the future.

4. System Design and Architecture

4.1 System Overview

The ESP32-CAM is the main processing and monitoring unit.Temperature and humidity data are sensed by the DHT11 sensor, whereas the capacitive moisture sensor checks the soil condition.The information received can then be processed by the ESP32-CAM, which is used to take pictures of plants and produces a local web server via its Wi-Fi access point. A user may access the data via the web server using a mobile phone or computer.The FTDI module is used during development for programming and serial communication.

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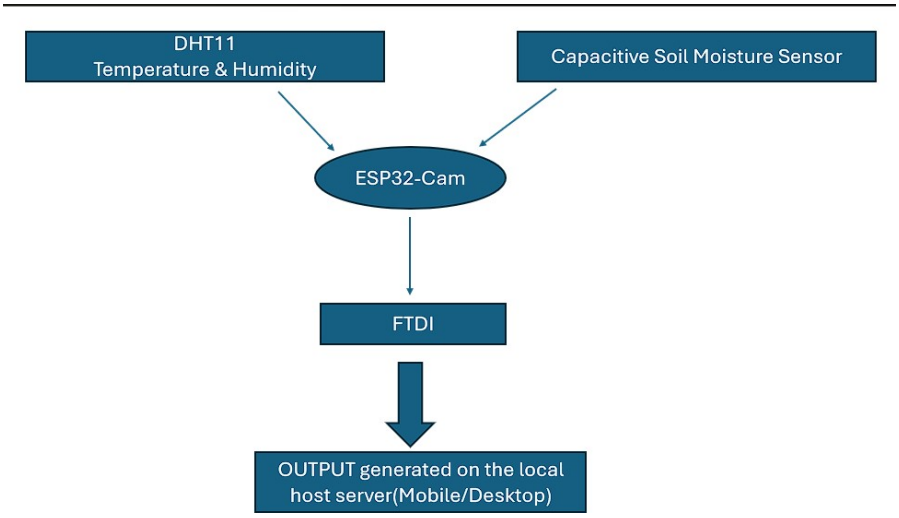


Figure 1: Overall system architecture showing sensor inputs, ESP32-CAM processing, FTDI

4.2 Hardware Components

- **ESP32-CAM:** The main processing and monitoring module is the ESP32-CAM module which collects the readings, takes images of the plants, and is also capable of providing Wi-Fi connections.
- **DHT11 sensor:** easures the temperature and humidity around it and its data line is connected to GPIO13 in this configuration.
- **Capacitive soil-moisture sensor:** senses the condition of the soil moisture.It is connected to GPIO12.
- **FTDI module:** Provides serial communication and programming between the computer and ESP32-CAM via the TX and RX connections.

The operation of the ESP32-CAM includes reading the data given by the sensors connected to it. The ESP32-CAM can also capture plant images for visual monitoring.The paper provides data on the cloud-monitoring model in which sensor readings from the sensors are sent to ThingSpeak for visualization purposes.



Figure 2: Shows the interconnection of the ESP32-CAM, FTDI circuit, capacitive soil moisture sensor, and DHT11 sensors.

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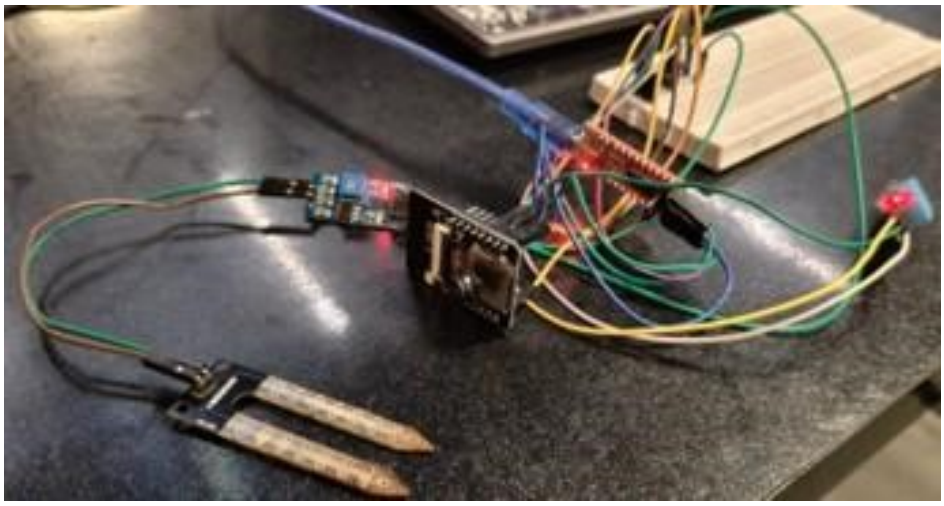


Figure 3: Photograph of the assembled plant-monitoring prototype and connected sensors.

Components	Quantity	Price	Total
1.ESP32-CAM OV3660	1	$6-9	$6
2.FTDI 23-2	1	$1.5-3.5	$1.5
3.USB-Cable	1	$1-2	$1
4.DHT11	1	$1-2	$1
5.Capacitive Soil Moisture Sensor Module(1)	1	$1-2 +$0.5-1.5	$1+$0.5
6.Breadboard	1	$1.5-3	$1.5
7.Jumperwires	1 Set	$1.5-2.5	$1.5
ESTIMATED COST	9	$13-23	TOTAL COST-$14

Figure 4: Estimated component-wise cost of the prototype as provided in the project material.

4.3 Software Architecture

The programming in this project is done in the Arduino IDE on the ESP32 Arduino framework; here, the camera and the sensors are initialized, temperature and humidity values are read, measuring values are received from the soil moisture sensor, and the monitoring screen is updated. The Serial Monitor is used to observe readings and system status during development.

The web server includes a dashboard page and an endpoint for capturing images. The local dashboard contains the readings of temperature in Celsius, humidity in percentage, moisture level of soil and the picture of the plant.The original design describes refreshing the monitoring webpage every five seconds.

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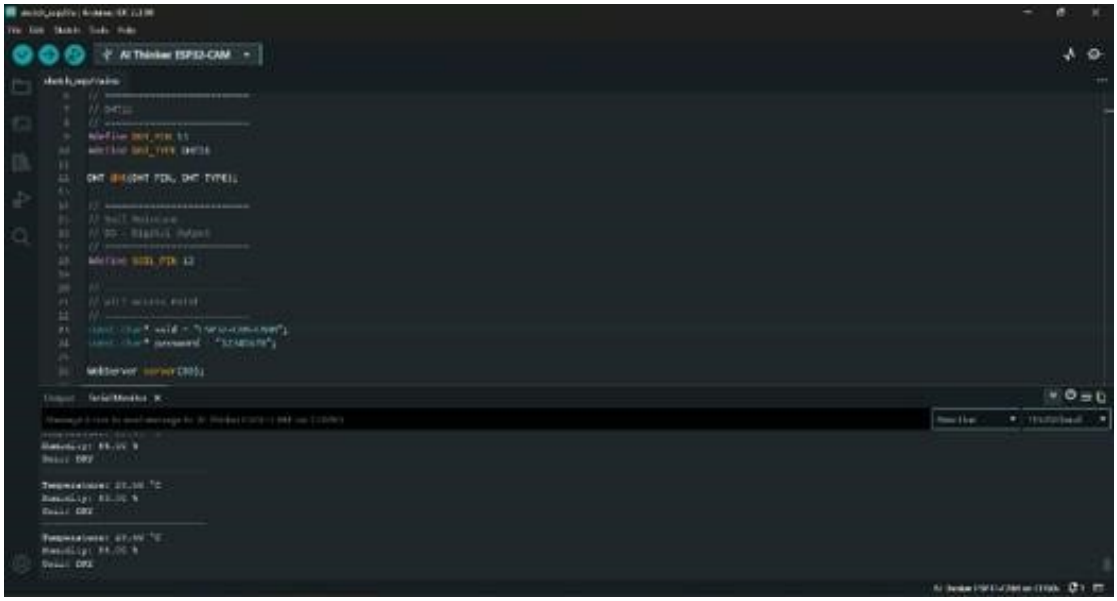


Figure 5: ESP32-CAM program being displayed on Arduino IDE with serial output.

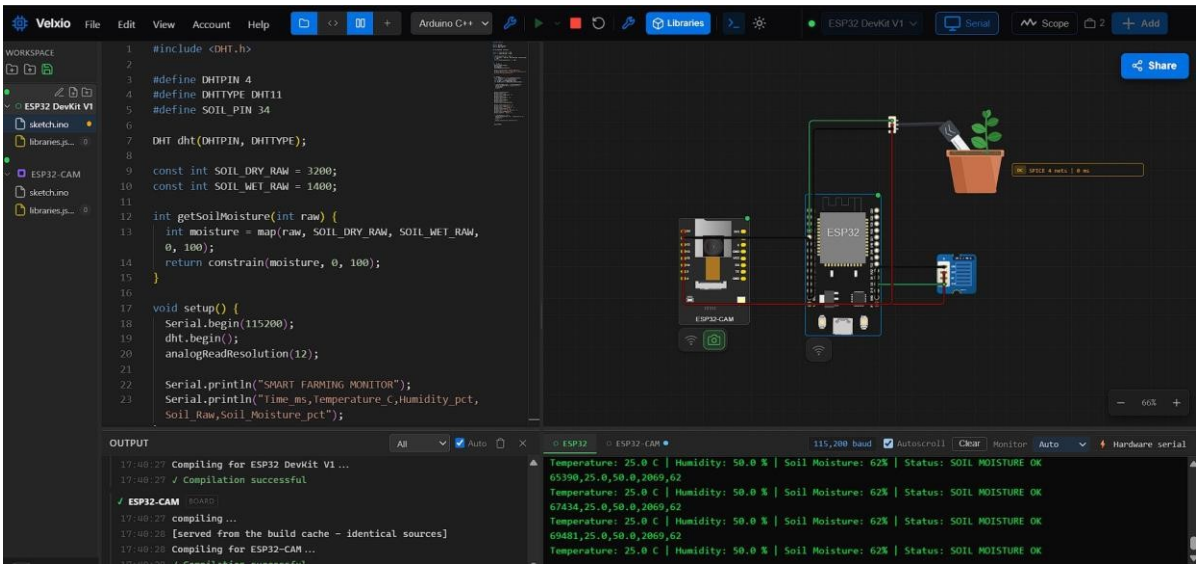


Figure 6: Design simulation workspace of ESP32-CAM setup containing the serial output readings.

4.4 Web Dashboard and Prototype

The dashboard, identified in the source paper as the Krushidhara Smart Farm interface, is intended to provide a simple monitoring view.This image portrays the ESP32-CAM plant image together with temperature and humidity data from DHT11, and wet or dry soil indicator. The system is accessible by either a mobile device or desktop that is connected to the local ESP32-CAM Wi-Fi network.

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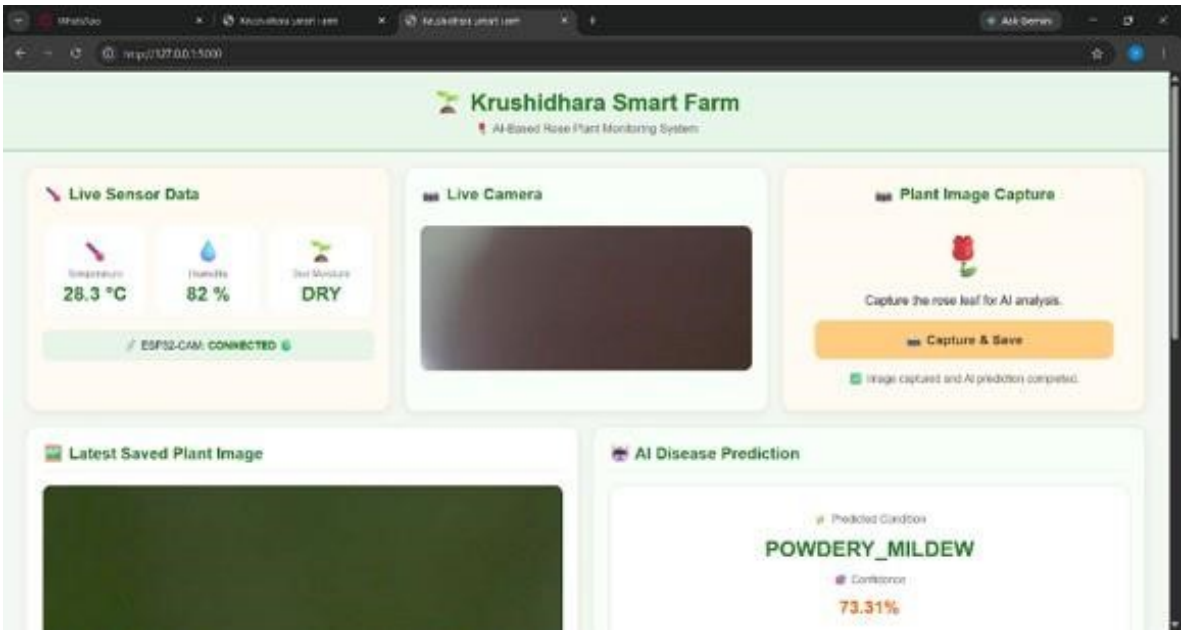


Figure 7: Desktop view of Krushidhara Smart Farm web dashboard .



Figure 8: Mobile view of plant dashboard

The physical prototype consists of the ESP32-CAM, DHT11, soil moisture sensor and FTDI module. The goal of the system is to show real-time monitoring of plants and give help with irrigation decisions. The source paper does not provide quantitative accuracy measurements or a comparative performance evaluation; accordingly, no numerical performance claim is made here.

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The supplied plots illustrate example sensor trends over a 30-second observation interval. They are included as visual records of the readings rather than as a statistical validation of sensor accuracy.

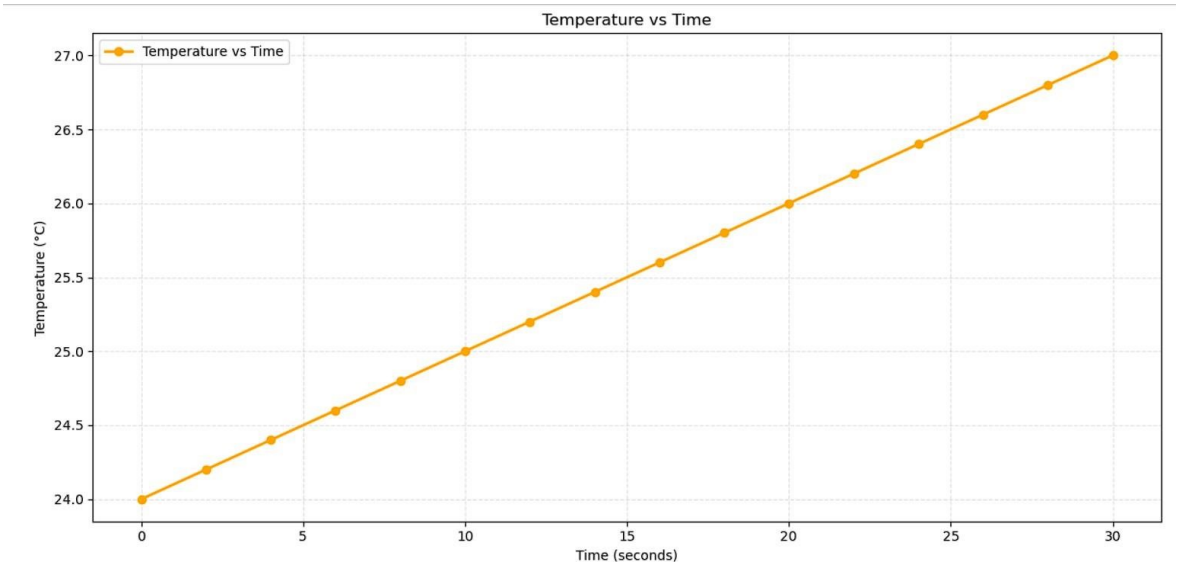


Figure 9: The temperature readings have been plotted against time.

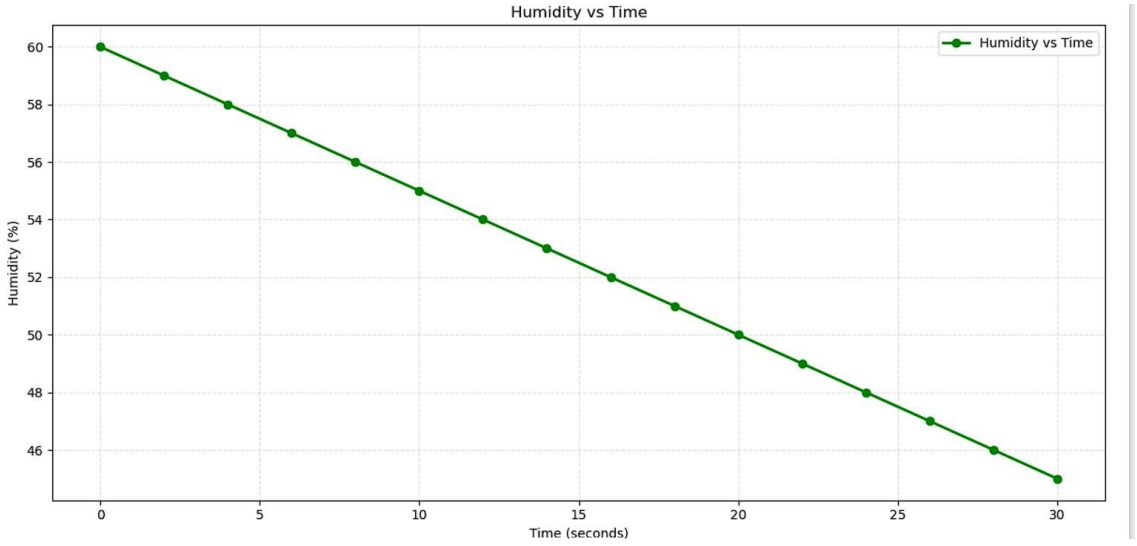


Figure 10: The relative-humidity readings have been plotted against time.

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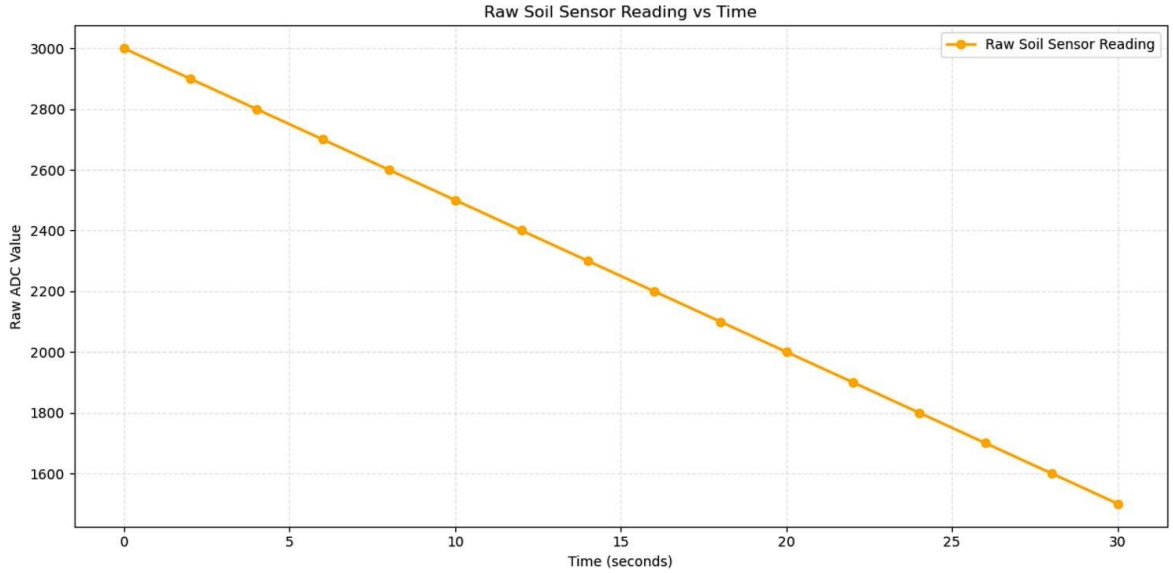


Figure 11: The raw soil-sensor ADC readings have been plotted against time.

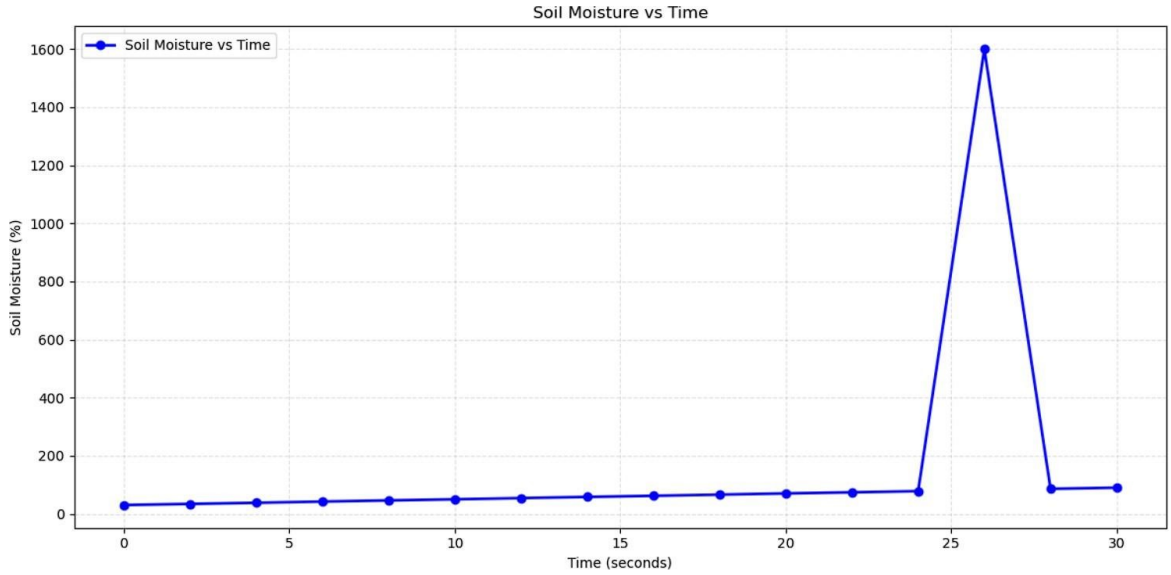


Figure 12: Supplied soil-moisture plot. The spike seems to be out of line with the other readings; thus, it will be treated as an anomaly until proven otherwise.

5. Algorithm

Algorithm 1: System for plants monitoring and irrigation detection based on ESP32-CAM.

1. The ESP32-CAM must be initialized and the camera pins configured.
2. The camera resolution must be set to VGA with the maximum image quality being JPEG.
3. The DHT11 sensor must be initialized and assigned to GPIO 13.

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4. The soil moisture sensor must be connected to GPIO 12 and configured for digital input.
5. . The Wi-Fi access point must be created with SSIDESP32-CAM-FARM and its IP address must be retrieved.
6. While the system is powered on:
    a. The web server must be initialized and the root path must be configured for dashboard display and /capture for capturing and displaying images from the plant.
    b. After the system is powered:
    c. The temperature and humidity will be read from DHT11.
    d. The soil moisture sensor will be checked for its digital output.
    e. If a capture state of the soil will be defined based on the sensor output – LOW will indicate that it is wet and HIGH that it is dry.
    f. Display the plant image, temperature, humidity, and soil condition on the monitoring webpage.
    g. Refresh the monitoring webpage every five seconds.
7. Repeat until the system is shut down.

6. Discussion and Limitations

This project illustrates that an ESP32-CAM is more than a simple ESP32-CAM; it serves as a compact processing and monitoring device for plant care. With the help of the registered parameters, it is possible to find out the plant's growth changes and make more decisions than just following a standard irrigation schedule.

The moisture readings depend on the type of sensor, type of soil, temperature, salinity, orientation of the sensor, and adjustment of sensor. Therefore, the interpretation of wet or dry should be tested in advance against the actual setup. The DHT11 gives basic data on temperature and humidity while the current solution does not cover various parameters like the light, rain, soil, etc., which impact the water requirements.

The system primarily monitors conditions and supports irrigation decisions; it does not provide a complete plant-health assessment or automatically operate a water pump in the described implementation.The detection and description of diseases, rare nutrition, and pests require the application of special algorithms and suitable data.

6.1 Future Work

The extensions may involve adding more environmental sensors and several measuring soil moisture sensors, establishment of moisture criteria for individual crops, storage of the recorded data, and analysis of irrigation patterns. There may also be a combination of ESP32-CAM and image-processing algorithms used for monitoring plants. Automatic pump control and remote data access may be considered in future designs.

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7. Conclusion

The proposed monitoring system has been designed and developed at lower cost using IoT technology. It uses ESP32-CAM for processing the readings of DHT11 temperature-humidity sensor and capacitive soil-moisture sensor. It performs all the functions required to get different readings of tree health, take necessary images, and create a local Wi-Fi dashboard. The information collected can indicate the dry state of the soil so that proper decision regarding irrigation can be made using the information gotten.

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