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ADVANCEMENTS IN COMPUTATIONAL DATA ANALYTICS FOR AUTONOMOUS SMART FARMING SYSTEMS USING IOT

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ABSTRACT

In modern agriculture, the adoption of smart farming techniques, particularly precision-controlled greenhouses, is imperative for improved productivity. This paper explores the utilization of the Internet of Things (IoT) in agricultural monitoring and control systems. Through IoT, various aspects of farming such as environmental conditions, security, and city planning can be revolutionized. Our focus lies in the development of an IoT application tailored for smart farms, with a specific emphasis on greenhouse agriculture.

Keywords: Smart Farming, Greenhouse Management, Internet of Things (IOT), Precision Farming.

I. INTRODUCTION

The development of plant growth technologies is becoming crucial for both cash and food crops. Modern agriculture faces challenges due to limited knowledge about agricultural advancements. In the past, our ancestors used general methods for all plants, but now, with new technologies, we can grow plants under specific conditions, leading to higher yields and less need for compost. Precision agriculture in greenhouses is gaining popularity because of affordable technologies that help farmers optimize production. A greenhouse is a transparent structure that controls temperature, moisture, light, and other factors to create the best conditions for plant growth. Precision agriculture uses technology to monitor and respond to environmental changes. The Internet of Things (IoT) connects devices to the internet, allowing data from greenhouses to be collected and analyzed so farmers can make informed decisions.

1.1 Problem Statement

An Autonomous Smart Farming System for Computational Data Analytics using IoT addresses the challenges faced in traditional farming practices by leveraging IoT technologies for automated data collection and advanced analytics. This system incorporates sensors placed throughout the farm to monitor various environmental parameters such as soil moisture, temperature, humidity, and light intensity in real-time. The data collected from these sensors is transmitted to a centralized cloud platform where it undergoes sophisticated data analytics and machine learning algorithms.

These algorithms analyze the data to provide actionable insights and predictive models for optimizing farming operations. For example, they can predict crop growth patterns, detect diseases early, optimize. Irrigation schedules, and recommend appropriate fertilization strategies based on real-time conditions and historical data.

1.2 Objective

The key goal of IoT-based autonomous smart farming system for computational data analytics is to develop and deploy an innovative solution that optimizes farming operations through real-time monitoring and data-driven decision-making. Specifically, the project aims to increase crop yield by 25% and reduce operational costs by 30% compared to traditional methods within one year of deployment.

This will be achieved by integrating IoT sensors and data analytics across the farming infrastructure to monitor crucial parameters such as soil quality, crop growth stages, weather conditions, and resource usage. By leveraging machine learning algorithms and automation, the system intends to enhance farming efficiency and sustainability by providing actionable insights for timely interventions and optimized resource allocation. The project timeline includes completing development and deployment within 18 months, followed by continuous monitoring and refinement over the subsequent 24 months to ensure ongoing improvements in productivity and profitability.

These objectives are Specific (focused on optimizing farming operations through IoT and data analytics), Measurable (quantifying increase in crop yield and reduction in operational costs), Achievable (feasible within the project scope and technological capabilities), Relevant (addressing modern challenges in agriculture), and Time-bound (clear timelines for development, deployment, and long-term evaluation). They provide a structured approach for implementing and assessing the effectiveness of the autonomous smart farming system.

II. NEED OF AUTONOMOUS SMART FARMING SYSTEM

Compared to traditional farming methods, an autonomous smart farming system with computational data analytics offers numerous advantages. By analyzing real-time data on soil quality, crop growth stages, weather patterns, and resource usage, these systems can optimize farming operations effectively.

IoT-enabled sensors play a crucial role in collecting and transmitting data to the central analytics platform, allowing for precise decision-making and resource allocation in farming practices. This automation not only enhances operational efficiency but also enables timely interventions to maximize crop yield and minimize costs.

Implementing an autonomous smart farming system with computational data analytics ensures sustainable farming practices while improving profitability through informed decision-making.

III. LITERATURE SURVEY

The development of an autonomous smart farming system for computational data analytics using IoT has emerged as a focal point in agricultural innovation. Numerous studies advocate for sophisticated yet cost-effective solutions aimed at optimizing data utilization, enabling precise decision-making, and ultimately enhancing agricultural productivity.

These advancements underscore the transformative potential of IoT-driven data analytics systems in agriculture, offering capabilities such as real-time data processing, predictive analytics, and remote operational management. The integration of such systems represents a pivotal step forward, fostering resource efficiency and promoting sustainable farming practices crucial for addressing contemporary agricultural challenges.

The evolution towards an autonomous smart farming system leveraging IoT for computational data analytics has captured considerable interest within the agricultural sector. Recent literature emphasizes the implementation of advanced, cost-effective solutions designed to maximize data insights, facilitate informed decision-making, and ultimately boost agricultural efficiency and productivity. These innovations underscore the profound impact of IoT-driven data analytics systems, offering capabilities such as real-time monitoring, predictive modeling, and remote management.

Studies highlight the scalability of IoT solutions in agriculture, accommodating farms of various sizes and geographic locations. This scalability enables broader adoption across diverse agricultural landscapes, from small-scale family farms to large commercial operations, thereby democratizing access to cutting-edge technology and its benefits.

Moreover, the integration of IoT in smart farming systems not only enhances operational efficiency but also supports sustainable practices by optimizing resource utilization. By continuously monitoring environmental conditions and crop health, these systems contribute to reduced water consumption, minimized chemical usage, and improved soil health, aligning with global initiatives for sustainable agriculture and food security.

IV. PROPOSED SYSTEM

To test the proposed smart greenhouse system, a prototype experimental model was created using an embedded system device that includes several sensors and a microprocessor. The proposed model is designed to track several greenhouse characteristics for two crops, Gerbera and Broccoli, in different climates. A microcontroller Node MCU ESP 32 is connected to all of the needed sensors for obtaining the green house parameters. A personal computer is used to collect data serially with timestamp values for data logging of various parameters. Temperature and Humidity, Light Intensity, CO2 and Soil Moisture are all continually monitored for 10 days on the Adafruit IO cloud Platform utilizing the MQTT protocol under day and night conditions within specific time intervals. Operational workflow of proposed system that how the system operates.

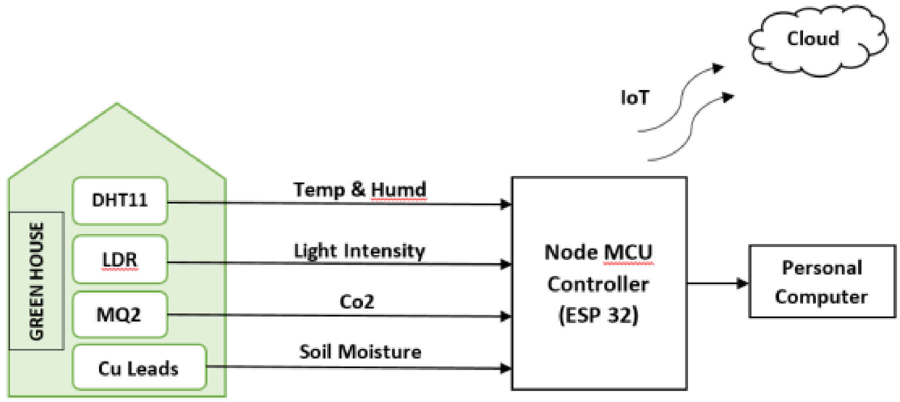

Fig 4.1: Proposed Experimental Model

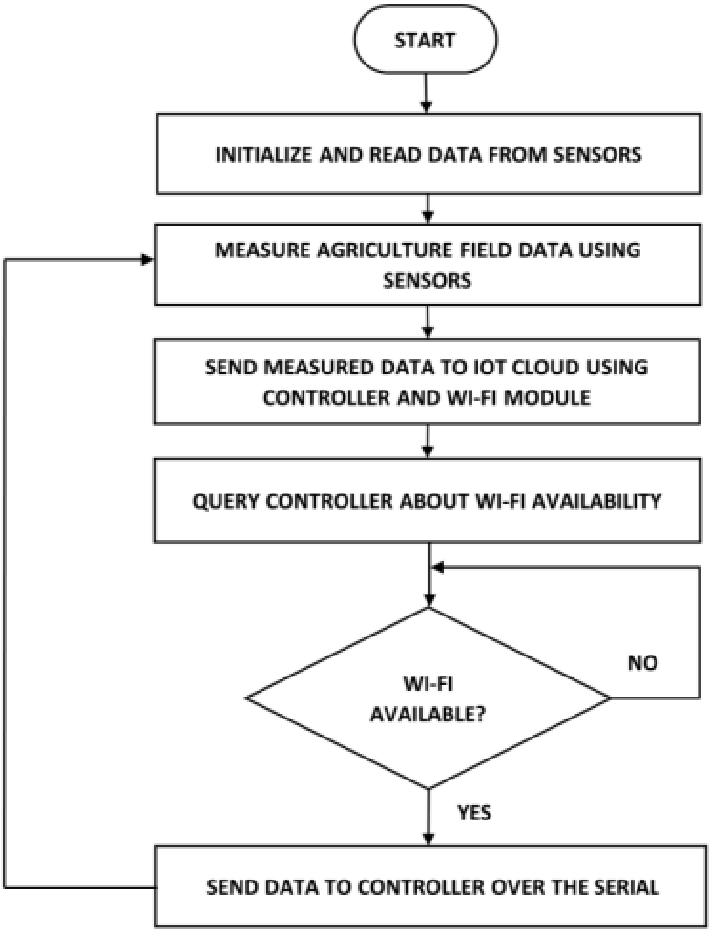

Fig 4.2: Workflow of experimental model

Adafruit IO is a platform for visualizing, responding to, and interacting with sensor data. With the support of MQTT, the data is also kept private and safe. MQTT (Message Queue Telemetry Transport) is a TCP/IP-based lightweight publish-subscribe protocol. MQTT employs a message broker to route messages between senders who send them and receivers who are interested in receiving them. Messages can be published and subscribed to using the same client. Each message is associated with a specific subject. The message routing information is the topic, and it is essentially a string with slash separated hierarchical levels. Clients subscribe to these topics, and the broker sends them all messages with topics that match their subscriptions. Wildcards can also be used to easily subscribe to several topics. For example, how temperature sensor data from a greenhouse system is sent.

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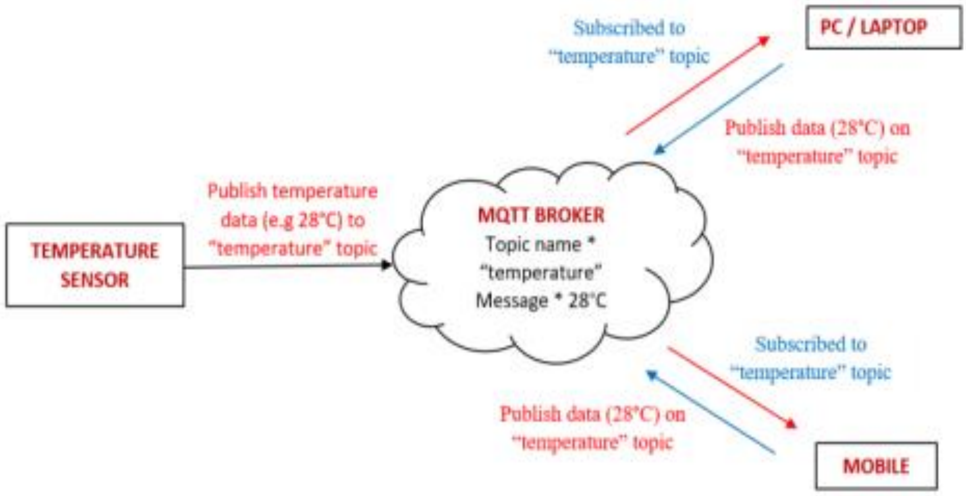

Fig 4.3: workflow of MQTT for sensor data

V. SYSTEM IMPLEMENTATION

The Hardware and Software utilized in this project are explained as follows:

5.1.1 Hardware Equipment

5.1.1.1 NodeMCU (Microcontroller)

5.1.1.2 Temperature and Humidity sensor (DTH 11)

5.1.1.3 LDR Sensor

5.1.1.4 MQ2 Sensor

5.1.1.1 NodeMCU

Fig 5.1: NodeMCU (Microcontroller)

NodeMCU is a digital microcontroller based upon system on chip (SoC) technology to develop IoT applications (NodeMcu, 2019). It contains an onboard WIFI system for communication of data and other supporting libraries. MCU refers to the Micro Controller Unit. It provides the facility of analyzing, controlling, and monitoring of digital systems. Here are a few prominent features of NodeMCU.

In the realm of smart gardening, the NodeMCU microcontroller stands out as a versatile and efficient tool for monitoring environmental conditions such as temperature and humidity. Leveraging its capabilities can transform a conventional garden into an intelligent ecosystem, optimizing plant care and enhancing growth conditions. microcontroller offers a powerful solution for smart garden monitoring by combining data collection, real-time monitoring, Wi-Fi connectivity, and automation. By leveraging these capabilities, users can maintain an optimal environment for their plants, ensuring healthy growth and efficient garden management. The NodeMCU supports automation through programmable triggers and actions, such as activating irrigation systems when soil moisture drops below a certain threshold or adjusting lighting based on ambient light levels.

Its compatibility with platforms like Arduino IDE and various IoT frameworks makes it accessible for both hobbyists and professional developers, encouraging innovation and customization in smart gardening projects. Overall, the NodeMCU microcontroller's combination of connectivity, flexibility, and ease of use makes it an indispensable component in the development of intelligent gardening solutions.

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5.1.1.2 Temperature/Humidity Sensor

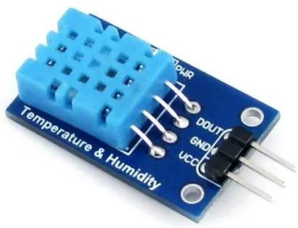

Fig 5.2. (DHT11) Temperature/Humidity Sensor

DHT11 sensor is a popular device used to measure temperature and humidity with high accuracy and stability. It is often found in home automation systems to monitor and regulate indoor climate, in weather stations for environmental data collection, and in greenhouses to maintain optimal growing conditions. Additionally, it is utilized in HVAC systems for efficient climate control and in IoT projects for real-time data logging and monitoring, providing crucial information for various applications that require precise environmental measurements. Moreover, the DHT11 is integral to various IoT projects, where real-time data logging and monitoring are crucial. It enables the development of smart applications that can analyze environmental conditions and make automated decisions. This capability is valuable in applications ranging from smart farming, where it helps in precision agriculture, to industrial processes that require constant monitoring of environmental conditions to ensure product quality and safety. The DHT11 is a commonly used Temperature and humidity sensor. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. The sensor is also factory calibrated and hence easy to interface with other microcontrollers.

The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%. So if you are looking to measure in this range then this sensor might be the right choice for you.

5.1.1.3 LDR Sensor

Fig 5.3: LDR Sensor

LDR sensors, also known as photo resistors or photocells, are passive electronic components that exhibit a change in resistance based on the intensity of light incident upon them. They belong to the category of resistors whose resistance decreases with increasing incident light intensity. This unique property makes them invaluable in various applications where light detection or measurement is required.

The fundamental principle behind LDR sensors is the photoconductivity effect. When photons (light particles) strike the surface of the LDR, they excite electrons within the semiconductor material of the sensor. This excitation allows more charge carriers (electrons and holes) to conduct electricity, thereby reducing the resistance of the LDR. Conversely, when light intensity decreases, fewer charge carriers are generated, resulting in higher resistance.

5.1.1.4: MQ2 Sensor

Fig.5.1.1.4: MQ2 Sensor

The MQ2 sensor is a type of gas sensor that detects a variety of gases such as methane, butane, propane, alcohol, smoke, and carbon monoxide (CO).

It is widely used for gas leakage detection in homes and industries, as well as for air quality monitoring in various environments. Moreover, the MQ2 sensor plays a vital role in monitoring air quality, particularly in urban environments where pollution levels can significantly impact public health. Its capability to detect carbon monoxide and smoke makes it indispensable in fire detection systems, contributing to early warning and prevention measures. Furthermore, its integration into consumer electronics and smart home devices enhances safety and convenience, offering real-time monitoring capabilities.

Continued advancements in sensor technology are enhancing the sensitivity, accuracy, and response times of MQ2 sensors, further expanding their utility across industries. As environmental and safety regulations tighten, the MQ2 sensor's reliability and versatility position it as a critical tool in safeguarding human health and well-being while optimizing operational efficiency in diverse applications.

5.1.2 Application of project

- Utilizes historical and real-time data to predict crop yields, disease outbreaks, and optimal planting times, enhancing decision-making for farmers.
- Optimizes water and fertilizer usage based on soil moisture, nutrient levels, and weather forecasts, reducing wastage and improving efficiency.
- Allows farmers to remotely monitor and control irrigation systems, greenhouse conditions, and livestock health via smartphones or computers, ensuring proactive management and timely interventions.
- Integrates AI algorithms to analyze data patterns, detect anomalies, and suggest actionable insights for improved farming practices.
- Promotes sustainable farming practices by minimizing environmental impact through precise resource management and reduced chemical usage.
- Scales from small-scale farms to large agricultural enterprises, accommodating diverse needs and optimizing operations across different crop types and geographical locations.

VI. FUTURE SCOPE

The system could integrate real-time data analytics capabilities, leveraging IoT sensors to automate farming processes such as nutrient delivery and pest management. This advanced analytics system can optimize agricultural practices by providing timely insights, enhancing crop yield and sustainability efforts. Incorporating machine learning algorithms, the system can analyze sensor data in real-time to optimize crop growth conditions, enabling precision agriculture practices that enhance yield efficiency and resource utilization. The implementation of edge computing technology in the system enables rapid processing of sensor data locally, facilitating real-time decision-making for optimal crop management and resource allocation in smart farming scenarios.

VII. CONCLUSION

A smart greenhouse system is a hybrid of IoT and agriculture that is driven by market demand and optimized according to a set of rules. Automation and high efficiency are required for monitoring and regulating the greenhouse environment. Because the precise information was discovered, they could be completely included in the gap analysis based on their constraints and the likelihood of a job extension. In traditional greenhouses, growers can control environmental parameters using a proportional control system that involves manual intervention, which typically leads in output loss, energy waste, and greater labor expenses. An automated greenhouse monitoring system based on the IoT comes to the rescue to handle these difficulties. The IoT is a widely used technology for linking things and collecting data. On Adafruit IO, the device is designed to remotely monitor greenhouse elements including as CO2, soil moisture, temperature, and light. Farmers may collect this data using an Adafruit IO cloud account and an internet connection. Thus, the system will employ IoT to help farmers eliminate physical visits to the field while simultaneously enhancing yield by maintaining accurate greenhouse factors such as CO2, soil moisture, temperature, and light. The findings for greenhouse elements such as CO2, soil moisture, temperature, and light for broccoli and gerbera plants are investigated with the help of graphical representation based on the practical data collected by the suggested model. Furthermore, utilizing artificial intelligence, work on more particular agriculture crops with precision agriculture can be done.

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