Self-Sustaining Greenhouse: Automated Climate and Nutrition Control

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Abstract:

Traditional greenhouse farming methods face several challenges in maintaining optimal growing contains for tomatoes and mint plants. Manual irrigation practices often result in water wastage and inconsistent soil moisture levels, while arbitrary fertilizer application without precise NPK(Nitrogen, Phosphorus, Potassium) measurements leads to inefficient nutrient distribution and potential crop damage. Furthermore, unregulated temperature and humidity levels in conventional greenhouse can significantly impact plant growth and yield. Thes4 manual intervention-dependent systems are not only labour-intensive but also prone to human error, leading to increased operational costs and reduced crop productivity. This project implements an automated greenhouse system IoT and Machine Learning technologies through three essential modules. The irrigation module employs soil moisture sensors connected to a drip irrigation system, ensuring precise water delivery based on real-time moisture levels. The fertilizer management module utilizes NPK sensors to measure soil nutrient content, with ML algorithms processing this data to automate and optimize fertilizer dispensing schedules. The third module maintains optimal environmental conditions through automated temperature and humidity control systems. All these modules work cohesively through a central control system, eliminating the need for constant manual monitoring while ensuring efficient resource utilization. This data-driven automation approach not only reduces human intervention but also optimizes resource usage for improved crop yield.

Keywords:

Greenhouse Automation, NPK Sensor Technology, Automated climate Control, Real-Time Crop Monitoring.

1. Introduction:

Greenhouse production has provided great assist to farmers to help them produce more crop with controlled conditions. Despite the traditional greenhouse production, they experienced numerous challenges such as inefficient irrigation, inappropriate fertiliser usage, and unpredictable weather.Humam labour tends to cause excessive or ineffective fertiliser and temperature, humidity that changes excessively.[1]

These issues reduce crop yields and increase cost of operation making greenhouse farming difficult to farming.[2]By utilizing current technology like IoT and Machine Learning we could provide more innovative solution to amplify functioning of greenhouse. IoT sensors provide real-time measurements of the moisture, NPK, and the environment, eliminating the need for manual intervention.[3] Studies have shown that using sensor-based irrigation systems can conserve up to 40% of water by delivering the right quality based on actual soil needs.

[4] Likewise, ML algorithm and NPK sensors ensure proper fertilizer control, optimal nutrient plant balance and avoidance of soil destruction.[5] Climate control is also important factor to consider in greenhouse farming. Temperature and humidity changes can affect the plant growth and yield. IoT-powered automated heating, ventilation and air conditioning (HVAC) systems ensure maximum climate conditions to provide consistent plant growth[6]. Moreover, ML models are applied to forecast climate change, and you can adjust in advance. The self- sustaining greenhouse system proposed here combines IoT and ML to overcome these challenges by automating irrigation, fertilizer regime, and climate control.[7] Water levels are monitored by soil moisture sensors, which trigger a drip irrigation system. Soil nutrients are monitored by NPK sensors and ML based algorithms decide on the appropriate fertilizer regime.[8] IoT based climate control systems also adjust temperature and humidity levels automatically to

create optimal conditions with the use of such technologies the system needs less human intervention, uses resources efficiently, and performs better.

2. Literature Survey:

[1] "IoT System for Greenhouse Monitoring" by E.P. Popovici, M.A. Hannan

This paper introduces an Internet of Things (IoT)- based greenhouse monitoring system capable of enhancing the growing conditions of plants by gathering and processing data in real time. The system employs a Raspberry Pi as the central computer, which connects various sensors to read temperature, air humidity, and air pressure. It also employs a Raspberry pi camera with a near-infrared (NIR) filter to monitor the health of the plants. The gathered data are processed and analysed to maintain the environmental conditions in the greenhouse at the optimum level. This system enhances farming efficiency, minimizes the extent of manual labour, and assists with precise farming through automated monitoring and control.

[2] "An Automated Greenhouse System Using Agriculture Internet of Things for Better Crop Yield "by S.R. Nandurkar, V.R. Thool, and R.C. Thool.

This paper suggests an IoT-Based automated greenhouse system design and implementation to increase crop yield through smart monitoring and control. The system employs a range of sensors to capture real-time environmental parameters, which are transmitted to a cloud server for processing and decision-making. Through the help of automation, the system optimizers irrigation, fertilizer application, and climate control in a way that conserves resource efficiently and improves farm productivity. The proposed method minimizes human intervention while optimal growing conditions re ensured, hence improving crop yield and sustainability.

[3] "IOT Based Greenhouse Monitoring and Controlled System" by S.S. Patil and S.R. Kale. This paper illustrates and intelligent greenhouse system through IoT to monitor and control plant growing conditions. It utilizes the ESP8266 Node MCU module to continuously monitor essential environmental parameters like temperature, humidity, and soil moisture. Automatic systems control these parameters immediately to keep the optimal conditions, which decreases the need for human intervention and maximizes the utilization of resources. This solution is an efficient and low-cost approach to automating greenhouse, which increases farming efficiency and sustainability.

[4] "Intelligent Agriculture Greenhouse Control System Based on Internet of Things and Machine Learning" by Cangqing Wang

This paper presents an IoT-driven machine learning-managed smart greenhouse for agriculture for optimal crop growing conditions. The system continuously monitors the most significant environmental parameters and uses machine learning algorithms to analyse data to allow automated temperature, humidity, and soil water content adjustments. The system, leveraging predictive analytics, maximizes crop output, saves resources, and reduces human interference. The approach is a sustainable and effective precision agriculture method for guaranteeing better productivity and preservation of the environment.

[5] "IoT Based Automated Greenhouse Monitoring system" by S. Rajalakshmi and S. Devi Mahalakshmi

This article demonstrates the development of an automated greenhouse monitoring system based on IoT to enhance temperature and humidity regulation. The conventional manual methods require frequent checks and adjustments, causing issues and inconsistent growing conditions. Sensors and real-time monitoring are employed in the new system to regulate climate automatically, enabling plants to grow in favourable conditions. Reducing the requirement for human intervention and smoothing out the environment, the system improves the yield of crop and enables sustainable agriculture.

Table 1: Comparison Table

S. No	Author Name	Hardware Components	Communication Technology	Merits	Limitations
1	E.P. Popovici, M.A. Hannan	Raspberry Pi, Sensors (Temperature, Humidity, Air Pressure), Raspberry Pi Camera (NIR filter)	IoT-based communication	Enhances farming efficiency, minimizes manual labor, enables precise farming	Limited details on automation and cloud-based processing
2	S.R. Nandurkar, V.R. Thool, R.C. Thool	**Multiple IoT Sensors** (Temperature, Humidity, Soil Moisture, Light Intensity), **Microcontroller**, Actuators.	Cloud-based IoT communication	Optimizes irrigation, fertilizer application, and climate control, minimizes human interventio n	Dependence on cloud connectivity for real-time decision making
3	S.S. Patil, S.R. Kale	ESP8266 Node MCU, Sensors (Temperature, Humidity, Soil Moisture)	Wi-Fi-based IoT communication	Low-cost solution, reduces human interventio n, - maximizes resource utilization.	Limited scalability and processing power compared to advanced ML-based solutions

4	Cangqing Wang	**IoT Sensors** (Temperature, Humidity, Soil Moisture, Light Intensity), **Machine Learning-based Analysis System**, Actuators	IoT with Machine Learning for predictive analytics	Maximizes crop output, saves the resources, reduces human interferenc e, enables precision farming	Requires advanced computational capabilities and ML model training
5	S. Rajalakshmi, S. Devi Mahalakshmi	**IoT Sensors** (Temperatur e, Humidity), **Microcontro ller**, Actuators	IoT-based real-time monitoring	Automates climate regulation, enhances yield, ensures sustainable agriculture	No mention of advanced control mechanisms or AI-based predictions

3. Proposed Methodology:

3.1 Components

3.1.1 NPK Sensors

NPK sensors are employed to track the level of track the level of Nitrogen (N), Phosphorus (P0, and Potassium(K) present in the soil. All three of these nutrients are highly essential for plant growth and production. The sensor provides real-time information that makes farmers or greenhouse systems aware of the nutrient composition in the soil. Depending on the readings, the appropriate fertilizers can be added to maintain the health of the soil and enable plants to produce. Overuse of fertilizers can destroy the soil and contaminate water, and underuse and lead to a lack of nutrients in plants. The sensors detect the changes in electrical conductivity in the soil, which is like changing levels of nutrients is frequently integrated with IoT system for remote control and automation.

3.1.2 Exhaust Fans

Exhaust fan are crucial components of greenhouse automation. They regulate the indoor climate. The fans function by removing excess heat and moisture, which prevents overheating and excessive moisture. This is crucial in the control of fungal growth, as fungi grow in moist and stagnant conditions. Proper air circulation by exhaust fans makes the temperature uniform in the greenhouse. It also introduces fresh air, which is crucial in carbon dioxide exchange for photosynthesis. The fans can be operated manually or by an automated system that adjust their operation in terms of temperature and humidity levels. Energy-saving fans are preferable to consume less electricity but are efficient.

3.1.3 Soil Moisture Sensors

Soil moisture sensors are employed to determine the quantity of water in soil. They assist in determining the optimal times to water plants, preventing overwatering or underwatering. The sensors can measure the quantity of water in the soil or the electrical conductivity of the soil. Depending on Real-time data, irrigation systems can automatically provide water only when necessary, conserving water. Excess water can cause roots to rot and nutrients to leach away, and dry soil can dry out plants and cause them to grow smaller.

3.1.4 DHT Sensors

The DHT sensor is a digital sensor of low cost which is used to measure the temperature and humidity in most of the IOT projects. It has a thermistor for the temperature measure and capacitive sensors to detect the moisture level. This sensor also provides an accurate value and sends values via the single wire communication system. This makes the

process easy to integrate with the different devices like Arduino, Raspberry Pi. We have different types of DHT sensors which have the differences in the accuracy of the outputs shown.

3.1.5 Arduino UNO & Nano

The Arduino UNO is a microcontroller which is widely used in the embedded systems. It is developed on the ATMega328P microcontroller and works on the 5V with the clock speed with 16MHz. This board has a 14 digital I/O pins and 6 analog pins which acts input pins. It also supports the Multiple communication protocols like the UART, SPI and the I2C and can be easily configured using the USB connection for its ease of use. It has a strong community support and a high reliability.

3.1.6 MAX485

This is a low power transceiver which is used for the long distance and the more reliable serial communication in the industrial and the embedded applications. It operates with 5V power supply, and it allows the half-duplex communication, which can be transmitted and received but not at the same time. It also efficiently helps to convert the Transistor-Transistor Logic signals to RS-485 Signals.The transceiver also supports the data transmission rates of 2.5 Mbps and have a fail-safe property. Because of its long-range communication capabilities.

3.1.7 Node MCU

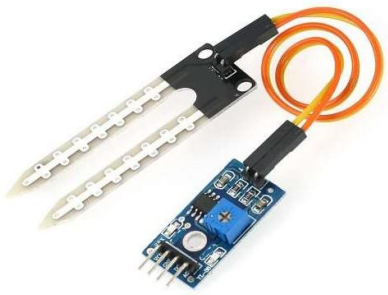
Node MCU is a IoT related microcontroller based on the ESP8266 and designed for the WIFI based system where it also supports programming in C++ offering the easy development process for developers. It is in a small size and low power consuming which will make it suitable for the portable system and, it can work on the embedded projects where it comes with the 11 general input/output pins and different pins like I2C, SPI etc.

3.1.8 Arduino IDE

The Arduino IDE is the open-source software which will be used for different functions like writing, compiling and uploading code to the Arduino Microcontroller boards. It provides a good user-friendly interface which is built with support for the C and C++ programming,

making it easy for beginners and experts to develop embedded projects. This IDE includes an Editor, a compiler and an uploader. Arduino Ide support various microcontrollers, including Arduino UNO, Nano, Mega and ESP32 and includes integration with external plugins and libraries. It also has a Serial Monitor, which enables real-time communication and debugging.

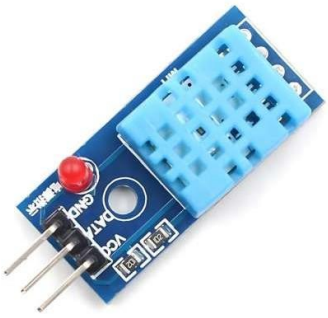
Node MCU



Soil Moisture Sensor

MAX 485

Arduino UNO



DHT Sensor

NPK Sensor

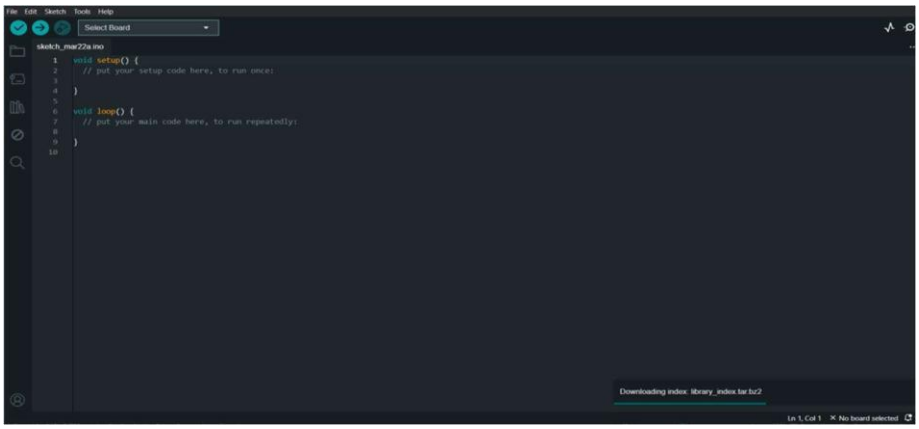


Figure : Arduino IDE

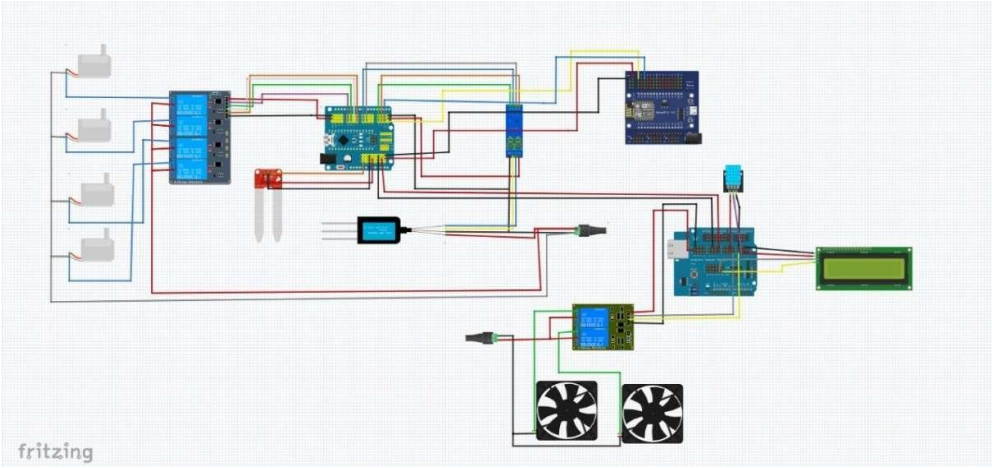


Figure: System Architecture

3.2.1 Data Collection

The data collection in this process will be going in continuous manner where it involves gathering real-time environmental and the soil parameters using various sensors. Soil moisture sensors will monitor the hydration levels. These sensors continuously will send the data to the centralized control unit where it is processed and will be analyzed. The collected data is displayed on the LCD screen and then transmitted to the IOT platform allowing remote monitoring and automated decision-making for efficient working of greenhouse management.

3.2.2 Data Processing

The data processing plays a crucial role where will collect data from the real-time sensor so that we can optimize the farming conditions. The centralized control unit collects data from the soil moisture sensor, NPK and DHT sensors for the measure of the different entities. Then the raw data is processed by using machine learning algorithms and predefined threshold values to make the accurate and best decisions. Processed data is then displayed on the LCD screen and sent to an IOT platform or mobile application which enables us for remote monitoring and automation. This processing ensures resource efficiency, sustainability and improved crop yield.

3.2.3 Data Storage and Analysis

The data storage and analysis process in this project makes sure that the efficient management of the sensor data that is collected and improves decision-making. Sensor readings from different sensors are continuously stored in the cloud databases, local Storage or IOT platforms for real-time analysis. Once stored, the data will be analyzed using machine learning algorithms or statistical methods to detect the trends and predict the future conditions and optimize resource utilization. The stored data is accessible via web pages or mobile applications allowing farmers to monitor the greenhouse conditions. This approach improves precision farming and helps in reducing of resource wastage.

3.2.4 About Data Sets

The dataset used in this project is essential for monitoring and optimizing soil health, irrigation schedule, and nutrient distribution within the automated greenhouse system. The dataset consists of soil parameter readings collected using IoT-based sensors, Processed in real time, and stored in a database for futher analysis.

About Nitrogen - The inquiry frame for getting Soil Nitrogen Value is:

Address Code-0*01 , Function Code-0*03 , Register Strat Address-0*00 0*1e , Register Length-0*00 0*01 , CRC_L-0*E4 , CRC_H-0*0C

You will get the following as a response:

Address Code-0*01 , Function Code-0*03 , Effective Number of bytes-0*02 , Nitrogen value- 0*00 0*20 , CRC_L-0*b9 , CRC_H-0*CC

About Phosphorous - The inquiry frame for getting Soil Phosphorous Value is:

Address Code-0*01 , Function Code-0*03 , Register Strat Address-0*00 0*1f , Register Length-0*00 0*01 , CRC_L-0*b5 , CRC_H-0*CC

You will get the following as a response:

Address Code-0*01 , Function Code-0*03 , Effective Number of bytes-0*02 , Phosphorous Content-0*00 0*25 , CRC_L-0*79 , CRC_H-0*9F

About Potassium - The inquiry frame for getting Soil Potassium Value is:

Address Code-0*01 , Function Code-0*03 , Register Strat Address-0*00 0*20 , Register Length-0*00 0*01 , CRC_L-0*85 , CRC_H-0*C0

You will get the following as a response:

Address Code-0*01 , Function Code-0*03 , Effective Number of bytes-0*02 , Potassium Content-0*00 0*30 , CRC_L-0*B8 , CRC_H-0*50ss

4. Working

This system is IOT-Based automated greenhouse management system which helps in the optimizing the greenhouse farming by integrating the real-time monitoring and the automation and the machine learning. It focuses on the three primary areas like automated irrigation, intelligent fertilizer management, and the climate control with all managed through a centralized control unit. This also make sure the efficient utilization of the resources and then helps in the minimization of the manual labour and enhances the crop productivity.

This automated system plays a crucial role in maintaining optimal soil moisture levels. Soil moisture levels in the Soil. These sensors continuously monitor the real time condition of the soil. When the moisture level drops through predefined threshold, this system automatically activates a drip mechanism by ensuring precise water distribution. This also prevents the over irrigation which can damage the plant roots.

In addition to the irrigation, the system involves an intelligent fertilizer managing module to maintain balanced soil nutrition. The NPK sensors measure the Nitrogen, Phosphorus, Potassium levels in the soil. The collected data will be analysed using the machine learning mechanisms. This prevents overuse or underuse of the fertilizers.

5. Result and Discussion:

Fig:Output

Represents the output of the green house automation where the inputs are taken from the sensors and output is shown accurately . Through real time monintoring it is successfully optimized.

Fig:display output

This app explains the levels of the different plants with the different concentration and also makes sure that the motor is turned on or off for the different values and entities.

6. Conclusion

Greenhouse farming is crucial for ensuring the efficient crop growth in the controlled environments. The traditional greenhouse systems rely heavily on the manual labour, which will lead to inefficient irrigation and fertilization. The integration of IOT automation in this system has changed the modern agriculture by introducing real time monitoring and the automated decision making. The proposed system states these challenges by including sensors, microcontrollers and cloud-based system to enhance resource efficiency and the productivity. The system has three main modules which are of automated irrigation, intelligent fertilizer management and climate control. These modules work under a centralized control unit, to make sure that the real-time adjustments for maintaining a good growing condition for the crops. By automating the system we can reduce the human intervention, conserves resource and enhances the crop yield. A huge advantage of this system is its mechanism of the smart irrigation which uses soil moisture sensor to continuously monitor the water levels. As agricultural demands grow, such intelligent farming systems play a vital role in ensuring the food security, and resource conservation with environmental sustainability.

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