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IOT-based Design and Simulation of Smart Greenhouse Monitoring and Control System

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Abstract

In recent years, "smart agriculture" has emerged as a promising strategy for enhancing the efficiency and longevity of contemporary farming. This article details the planning and modeling of an Internet of Things (IoT) smart greenhouse management and monitoring system using MATLAB. In real time, the system tracks five important environmental variables using modelled sensor readings: soil moisture, humidity, light intensity, CO_2 concentration, and temperature. For the purpose of environmental monitoring and management, we have established precise cutoff values for each metric. When a value above its threshold, an alarm is sent out and appropriate procedures, such as the activation of fans, water pumps, and artificial lighting, are immediately initiated. The system ensured the correctness of the projected findings under various environmental circumstances by testing this configuration using a dataset of 100 time-series samples. The simulation found that temperature was the most unpredictable factor, leading to 58 warnings. Then came 52 warnings about soil moisture and 46 about humidity. Only 29 and 17 alarms, respectively, were generated by CO_2 levels and light intensity, which were closer to their ideal limits. In response to any alarm, the system automatically handles the inappropriate circumstances based on sensor input. The model made use of graphs and pie charts to examine the system. This study lays the groundwork for an Internet of Things (IoT) smart greenhouse system that may boost efficiency and longevity in real time. Assisting small farmers and promoting sustainable agriculture is the primary goal of this project.

Smart farming, automation, environmental monitoring, control systems, sensor data, the internet of things, and MATLAB simulation are all related terms.

I. INTRODUCTION

When it comes to international trade, agriculture is king. Agriculture is the lifeblood of every human person, providing us with food and other essential resources. Demand for food is rising in tandem with the population, yet conventional agricultural methods are struggling to keep up with the demands of a changing environment and inadequate management of available resources. Smart greenhouses are one example of how contemporary agriculture has introduced more effective ways to boost production in order to overcome these challenges. Temperature, humidity, soil moisture, light intensity, and CO_2 concentration are just a few of the environmental characteristics that modern agriculture utilizes automated sensor-based systems to regulate and monitor. This technology requires human involvement to maintain appropriate environmental conditions in typical greenhouses. The crops might be harmed by traditional techniques because of late responses or inconsistent monitoring, and they also rely on human intervention. The integration of greenhouse systems with Internet of Things (IoT) technology revolutionizes this process by enabling the gathering and analysis of data in real-time.

In order to acquire precise findings, it may use Internet of Things technology to gather data from several sensors

simultaneously. However, during the research and development phase, constructing a functional IoT system may be an expensive and time-consuming ordeal. Therefore, before physically installing such a system, a simulation platform such as MATLAB allows for its modeling and testing.
Using cloud computing, mobile apps, and platforms such as Raspberry Pi and Arduino, the most recent study investigates the capabilities of greenhouse monitoring systems. While many of these studies did finish up and do give some basic monitoring capabilities, they don't include the entire analysis of sensor data, dynamic control logic, or presentation of outcomes that would be needed to assess the system's performance. Conditions like as temperature, soil moisture, light, and humidity may be controlled with the help of MATLAB, a well-known program for data analysis and system modeling. However, there is currently no solution for creating an automated smart greenhouse system that can provide real-time notifications. In MATLAB settings, such kind of feature isn't completely used. This study's overarching objective is to find solutions to these problems by developing and testing a MATLAB-based smart greenhouse system. A virtual prototype that integrates sensor data collection with automatic alerts when predefined ranges are crossed is the main goal of this work. The prototype will then activate appropriate conditions within the setup, such as turning on fans, water pumps, and artificial lights, in response to the sensor's alert. We used actual sensor data from a variety of environments to evaluate the system's overall performance. When opposed to deploying it in real-time, this way allows farmers to monitor overall performance at a reduced cost.
Here are some key elements that emphasize the primary goal of this research: 1. To create a model that tracks critical environmental variables including as humidity, soil moisture, light intensity, CO_2 levels, and temperature in real-time. 2. Construct a sophisticated warning system that notifies users when parameter values deviate from predetermined ideal ranges. 3. Create a model that can initiate control operations, such lighting, water pumps, and fan activation, automatically. Fourth, to examine the system's efficiency by means of graphical representations such as tables, graphs, and plots.
This study delves into the topic of smart farming, which enables farmers to keep tabs on and manipulate the ever-changing environmental factors, ultimately enhancing plant development. This model is easy to use and gives you a lot of options for tracking greenhouse conditions in MATLAB. Using data from actual weather events, this model lays a solid foundation for real-time greenhouse construction. Modern agricultural techniques that boost crop yields are the focus of this study.

II. LITERATURE SURVEY

This research presents an Internet of Things (IoT)-based smart greenhouse system. The appropriate environmental conditions may be maintained using the suggested system. We utilized the ESP8266 NodeMCU module to keep the conditions in the environment constant. Wireless connections were established between all sensors and the main house gateway. The use of this strategy may aid farmers in achieving greater yields from their crops [1]. By creating a model that monitors environmental factors and acts on them, the suggested Internet of Things (IoT) greenhouse farming system boosts food output. It promotes innovative agricultural practices while reducing the need for physical work. In regions where the weather is constantly changing, this model proves to be quite useful. This research aims to provide support for agricultural techniques that are environmentally beneficial [2]. Farmers now have a cutting-edge option with the AI-controlled Smart Greenhouse System. This system can maintain tabs on the greenhouse's environmental conditions thanks to the integration of AI and IoT technology. Greenhouse gases such as water vapor (H_2O), methane (CH_4), nitrous oxide (N_2O), ozone (O₵), and carbon dioxide (CO_2) were tracked using wireless nodes. A combination of AI and the IoT is used. The AI technique derives its predictions from the CNN methodology [3]. The suggested concept is an intelligent greenhouse system that tracks variables including soil moisture, humidity, and temperature via the use of sensors. Data is collected by the sensors and sent to a cloud platform (IMM Watson IoT) for decision-making. Actuators for real-time temperature control are part of the system, which uses Raspberry Pi and Python. A web interface that is easy to use and designed using Node-RED enables remote control and monitoring [4]. A MATLAB-based PI (Proportional-Integral) controller based on neural networks is proposed in this paper. Equations for current, voltage, back emf, and torque were used in a mathematical modeling technique to simulate the behavior of the motor. In the beginning, a PI controller is used for data training and speed faults. The next step is to include the neural network so that the PI gains may be adjusted dynamically. The created controller's performance under various scenarios has been reviewed by MATLAB simulations [5]. Modern agricultural challenges, such as climate change and extreme weather, may be addressed by using the IoT in agriculture. The environmental conditions are tracked by this intelligent monitoring system, which gathers data in real-time. Control actions are triggered by the acquired data. Better choices, such as when to plant or harvest, may be made by farmers with the use of sensors, cameras, and other smart devices [6].
The results of this research reveal an IoT-based system that keeps tabs on plant health. It enhances crop output by

combining conventional and organic agricultural techniques. Using NodeMCU ESP8266, this system is dubbed the Smart Plant Monitoring System. Data collection and real-time monitoring are both assisted by this technology. Less water and fertilizer are wasted because of the technique. Farmers can control resource depletion and other environmental changes using this technique [7]. This work provided a new approach to managing wireless spectrum under various conditions: dynamic spectrum allocation based on fuzzy logic. In order to do this, they create a design in MATLAB called FIS, which stands for fuzzy inference system. A comparison of these simulation findings with actual spectrum values is used by the built fuzzy inference system to assess the system. The system's performance is assessed by taking four critical elements into account: MSE, MAE, RMSE, and R^2 [8]. Using internet of things (IoT) technology and smart sensors, the smart greenhouse system can adapt to fluctuating weather conditions. Sensors from NodeMCU ESP8622 and DHT22 allow the system to control these external factors. Motors and mist sprayers are some of the tools it has for meeting the specific needs of plants. An app for mobile devices also gives farmers some control over the system [9]. This study uses MATLAB to build and compare two models: K-Nearest Neighbor (KNN) and Probabilistic Neural Networks (PNN). Which attempt to divide human cardiac health into three levels: somewhat dangerous, good, and very hazardous. Two variables, heart rate and cholesterol level, are fed into the model. The author of this study relied on a secondary dataset that included individuals with widely varying levels of cholesterol and heart rate. Normalization and outlier identification were the first steps in preprocessing the dataset, which improved the model's performance [10]. Improving text classification using the K-Nearest Neighbor (KNN) method in MATLAB is the main topic of this work. Text mining is a subset of this larger field. Because of this issue with the original KNN algorithm, they suggest a better KNN technique that accounts for volatility. This experiment's findings demonstrate that the improved KNN classifier works better than the original KNN classifier [11]. One solution to the challenges faced by farmers when they relocate from rural to urban regions is an Internet of Things (IoT) smart farm. Using sensors, it details how to keep tabs on greenhouse conditions like temperature, humidity, and soil moisture. Utilizing Arduino and several sensors, the system assists in gathering data on the current state of the crop and transmits it to a mobile device in real-time. By controlling the greenhouse's temperature, lighting, and watering from their cellphones, farmers may save time and work [12]. An internet-of-things (IoT) smart greenhouse system that boosts harvest yields is detailed in this research. Specifically, it's a closed environment system that shields plants from bad weather and encourages their development. One component of the system is a wireless sensor-based automatic watering system that reduces water and energy use. With the help of the NodeMCU ESP8266, this setup can gather data in real-time and send it to the Blynk and ThingSpeak IoT platforms [13]. Reducing water, energy, and fertilizer waste is the goal of this study's integrated Internet of Things (IoT) and convolutional neural network (CNN) greenhouse system. The use of sensor nodes allows for the tracking of environmental changes in real-time. With a 98% accuracy rate and 90% recall, the CNN module aids in early illness detection via picture processing. The Internet of Things (IoT) and artificial intelligence (AI) are used in this greenhouse system to reduce energy consumption. Smart greenhouses were created by combining conventional greenhouses with sensor networks and deep learning technologies. [14] Nowadays, one of the most essential concerns is securing IoT networks. Finding all impacted computers with IP addresses at once is made easier with this research, which is useful for protecting IoT networks. The ALRN is the brains behind this technique. The two sub-networks that comprise ARNN function in tandem with one another. Each device has two ARNN neurons, one for when the system is safe and one for when it is hacked [15]. This research presents an intelligent greenhouse concept that incorporates IoT and machine learning (ML). In order to keep tabs on its surroundings, the model makes use of sensors. Crop yields may be enhanced with the help of the model's disease and pest detection capabilities. The goal is to safeguard crops from pests and diseases while improving resource management [16]. Problems with resource management arise when farmers rely on human labor in conventional greenhouses. Internet of Things (IoT) sensors may aid in real-time monitoring, but data analysis is time-consuming, which can have an immediate impact on crop development. The research proposes the Greenhouse Intelligence Decision Support System (SGHIDSS) as a solution to this issue. This setup can automatically water plants and keep tabs on the weather [17]. The impact of the COVID-19 shutdown on the ambient air quality in Uttarakhand is examined in this research. The combination of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM_{10}) defines the characteristics of the ambient air quality. For distance measurements in MATLAB, the k-means clustering method is used. This research sheds light on the pre- and post-lockdown air quality patterns [18]. Through the use of AI and the Internet of Things (IoT), modern farming is steadily progressing with the advent of Agriculture 4.0, which increases harvest yields. One application of Agriculture 4.0 is GreenSense, which uses machine learning, Raspberry Pi 4, and Internet of Things sensors to keep an eye on crops all day, every day. Using OpenCV and YOLOv5 (97% accuracy), the system identifies illnesses and pests and autonomously modifies growth conditions. With its user-friendly interface, it aids farmers in controlling water and energy use, which in turn promotes better plant development [19]. By integrating the internet of things (IoT) with big data, the fourth industrial revolution is changing farming methods and creating smart greenhouses that are better for the environment. In this research, we present a system for controlling and monitoring greenhouses that is based on the internet of things. Essentially, this device is made for urban farmers who want to remotely monitor their greenhouse. Even when they're far from the city, they can check in on the crops using a smartphone app. The study's overarching goal is to find ways to save costs, save time, and improve efficiency in greenhouse systems. If any suspicious behavior is discovered that might damage the crops, the farmers would be notified via a mobile app using the suggested system [20].

There are two groups of air contaminants identified in the study: categories 1 (very dangerous AQI) and 2 (moderately dangerous AQI). In this case, "AQI" refers to the Air Quality Index. The health risks to humans are deemed high when the AQI exceeds 300. This model was developed using two different ways. AI and ML are the two main areas of focus here. They used MATLAB-created ANN and SVM models, respectively, to apply ML and AI approaches [21]. A smart monitoring system that uses the internet of things (IoT) to improve resource consumption and plant development is introduced in this research. The technology uses wireless sensors to monitor soil moisture and temperature. Also presented in this research are methods for automatically preventing sunlight and controlling soil moisture using data collected from moisture and temperature sensors. By using their individual sensors, a microcontroller is able to achieve an optimum state [22].

We want to learn the ideal soil pH in Uttarakhand from this research. A large portion of this state is used for farming. The agricultural sector contributes significantly to the state's GDP. Multiple cities' secondary data is gathered by them. The Adaptive Neuro-Fuzzy Inference System (ANFIS) in MATLAB is a combination of two soft computing techniques: artificial neural networks (ANN) and the neuro-fuzzy hybrid. The prediction errors of the two models were compared after they were both designed to estimate soil pH [23].

III. RESEARCH METHODOLOGY

In this study, a smart greenhouse system was modelled and tested using the MATLAB program. Here, the system models the surrounding environment, determines an appropriate range for crop development, and constructs a sensor-based control system. The system takes care of the undesirable situations automatically when the values exceed the specified range. Basic charts and tables are used to display the outcomes. In general, we want to demonstrate, as in Fig. 1, how data collected by sensors might aid in maintaining a plant-friendly environment.

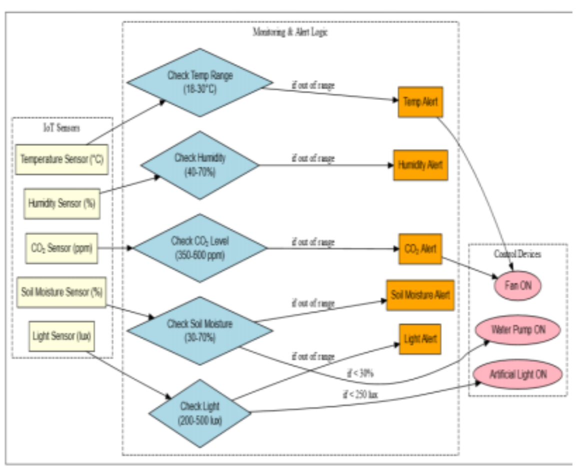

Fig 1: Proposed mode;

A. Simulation Framework

We utilized a dataset of one hundred samples of real-time sensor readings and ran the simulation in MATLAB R2023a. In this research, the following environmental factors were considered:

- Temperature (°C)
- Humidity (%)
- Soil Moisture (%)
- Light Intensity (lux)
- CO_2 Concentration (ppm)

B. Definition of Ideal Ranges

According to conventional wisdom in horticulture, we assigned an ideal range to each of the environmental variables:
• Temperature: 18°C – 30°C
• Humidity: 40% – 70%
• Soil Moisture: 30% – 70%
• Light Intensity: 200 – 500 lux
• CO_2 Level: 350 – 600 ppm
The status of any warnings was checked by continually monitoring the sensor readings and comparing them with these limitations.

C. Monitoring and Control Logic
• Using Boolean Logic to Identify Problems: Each parameter's inappropriate state was determined using boolean logic. • The Reaction of the System: Automatically, the fans are activated when the temperature or CO_2 level surpasses their specified boundaries. The mechanism operated the water pump to keep conditions ideal when the soil moisture dropped below 30%. Automated lighting would be activated if the light intensity fell below 250 lux.

D. Data Visualization and Analysis
We can simply depict the sensor data, warnings, and control actions with the aid of MATLAB's plot, bar, and pie functions. The values of the following, indexed by time:
• Sensor readings
• Alert flags
• Actuator statuses
To find the most unstable environmental parameter, table 1 summarizes all of the parameters and the number of times each one generated an alarm.

E. Evaluation Metrics
Here are the steps used to assess the system:
1. Determine how many warnings were caused by each environmental factor. 2. examining the reaction time of actuators by activating water pumps, artificial lights, and fans3. To help us understand the data better, we used pie charts and bar graphs to highlight the most unstable aspects. Following these procedures allows us to confirm the smart greenhouse model's efficiency and speed.

IV. RESULT AND DISCUSSION
The results demonstrate the potential of the built greenhouse system simulation in MATLAB for controlling critical environmental variables. The 5-parameter environmental monitoring system that was designed keeps an eye on things like temperature, humidity, light intensity, soil moisture, and carbon dioxide levels. When an alarm is triggered, it also gives the control actions, such as turning on fans, water pumps, and artificial lighting.

TABLE 1. SUMMARY OF FINDINGS

Parameter	Time_Alert_Triggered
"Temperature"	58
"Humidity"	46
"Soil Moisture"	52
"Light"	17
"CO2"	29

You can see how the system responds to various climatic circumstances in the simulation results (table 1 and figures 2). It essentially demonstrates the model's response to real-time circumstances, which aids in keeping plants in an ideal environment.

A. Sensor Fluctuation and Alert Generation

We utilize a dataset of one hundred real-time samples of every environmental parameter for the simulation. The sensor values exhibit noticeable fluctuations over time, as seen in the time-series graphs (Fig. 2). The system will sound an alarm if the numbers deviate too much from the specified limits. The frequency of the warning is shown out in Table 1.

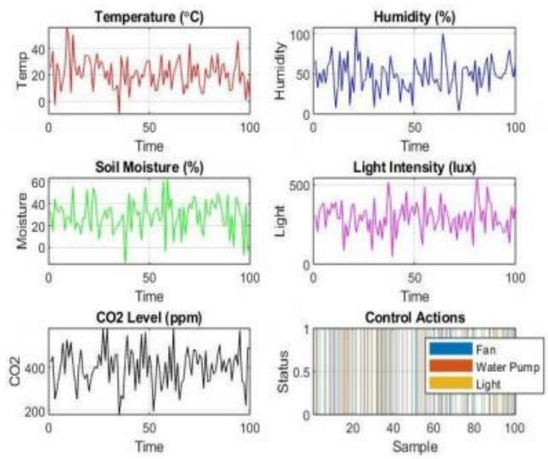

Fig.2 IoT data

We found that temperature (58 out of 100) was the most alarming factor, followed by wetness (52) and humidity (46). These findings demonstrate the challenges associated with greenhouse temperature and moisture management. The biggest obstacles that farmers face when trying to control greenhouse conditions are climate change and the natural moisture that plants exude.

B. Actuation Response

The system triggers the appropriate actuators to respond to alarms. Fan, water pump, and artificial light activation pattern is shown in Fig. 3. Some important points to note are • Extreme heat or CO_2 levels were the primary triggers for the fan to turn on. • During the simulation, 52 moisture alarms were issued, and the water pump was activated anytime the soil moisture fell below 30%. • On seventeen occasions during the simulation, the artificial light was activated when the light intensity dropped below 250 lux.

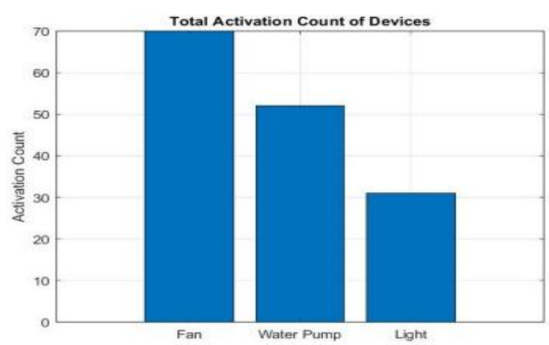

Fig.3 Activation count of devices

Depending on the patterns, it seems that the fan and water pump were the main active components, in relation to soil moisture and temperature.

C. Visual Summary and System Performance

Figure 4 shows the alert distribution pie chart, which shows the grouping of alerts by parameter.

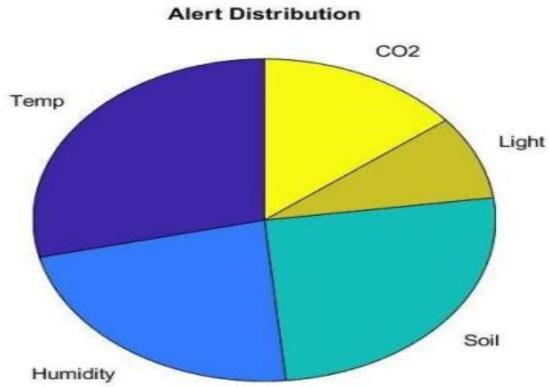

Fig.4 Alert distribution

- Temperature – 31.5%
- Soil Moisture – 28.3%
- Humidity – 25%
- CO2 – 15.8%
- Light – 9.2%

Temperature and moisture warnings covered the most ground, demonstrating the requirement of constantly monitoring and responding to these two criteria. In addition, the distribution of alerts is in sync with the overall device activations (Fig. 4), which gives a clear picture of how sensitive the actuators are.

D. Discussion

These results prove that MATLAB-based rule-based environmental monitoring and management is effective. This is shown by the simulation: With the use of specified ranges for each parameter, changes in the environment may be accurately identified. • In response to data collected by sensors, appropriate actions are taken in real time to keep the environment in a constant state. • The most difficult aspect of conventional greenhouse systems is controlling the most variable climatic factors, such as soil moisture and temperature. These conditions can be identified and maintained using this model. As an added bonus, the system may be integrated with IoT-based dashboards for practical use in real-world applications.

V. CONCLUSION

When it comes to data analysis and simulation, MATLAB is the program of choice. A smart greenhouse monitoring and control system was developed and tested using MATLAB in this study. Factors like as soil moisture, light intensity, humidity, temperature, and carbon dioxide levels may all be assessed by this system. Unsuitable situations may be located with the use of sensor data. Turning on fans, water pumps, and artificial lighting are just a few examples of the ways the model takes charge of these circumstances the moment it receives an alarm. Additionally, this model may be seen in real-time. Temperature, wetness, and humidity were determined to be the most alarming characteristics. What this implies is that the greenhouse needs constant vigilance and management measures. We employ MATLAB-based tools like as plots, bar graphs, and pie charts to graphically analyze the environmental state. Because of this, we can deduce the system's behavior. When applied to real-world scenarios, this simulation model faithfully reproduces the behavior of an intelligent greenhouse. Before constructing a system in reality, it provides a realistic and inexpensive platform to evaluate its performance. For those who are always working in agriculture, as well as students and researchers, it offers smart learning and development tools. This tool was most useful for reviewing and testing the performance of a system or model before constructing it in the actual world. We can get a feel for how to implement Internet of Things ideas in actual greenhouse settings using this MATLAB-based solution. In this way, farmers can keep tabs on their fields in real time and adjust unfavorable circumstances as they arise. Future developments may include a machine learning algorithm for proactive change prediction in conjunction with cloud storage, allowing farmers remote access to the system. Modern farming may become even more intelligent with these upgrades.

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