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DESIGN AND PERFORMANCE EVALUATION OF AN IOT-BASED INTELLIGENT GREENHOUSE MONITORING AND CONTROL SYSTEM

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Abstract

The IoT-based Greenhouse Monitoring and Controlling Systems (IGMCS) are used to improve the productivity of agriculture by maximizing the use of resources and managing the environment. This paper presents a novel high-tech IGMCS that employs water sensors, LDR, DHT11, and soil moisture to monitor the water temperature and implement water control and heating by fans, LED strips, and water pumps. The system runs on the Blynk IoT environment which provides remote monitoring, data visualization and interaction. Results have shown the framework enhances the efficiency in operations, sustainable practices, and increase in crop yields. The study looks into the architecture and functional design of this system and its implications to the current greenhouse management to promote the development of smart agriculture.

Keywords: IoT, greenhouse monitoring, smart agriculture, automation, sustainability, crop yield.

1. INTRODUCTION

1.1 Background

The application of greenhouse farming has replaced the element of the modern day farming practice due to the ability to deliver out of control conditions, which have resulted to maximisation in productivity and crop-quality. Green-house construction as opposed to the outfield agriculture allows the manipulation of vital environmental conditions such as temperature, humidity, soil moisture and light strength which can be utilized. The advantage of this type of control is that crops can be cultivated all-year-long without examining the difference in the seasons or the weather patterns that will improve food security and stability in the market (Shamshiri et al., 2018, Tu et al., 2022). The greenhouses also reduce crops wastage and chemical pesticides since they restrict the exposure of crops to unfavorable weather and pests.

Despite those advantages, the traditional greenhouse operations have a high number of manual controls and manipulations. The farmers usually measure the environmental conditions either by observation or simple tools and then control the irrigation, ventilation, and shade as well. It is a resource-heavy, labour intensive, time consuming and human error laden technique of producing microclimates which may cause unstable microclimates and wastefulness of resources. In this example, excessive irrigation in the absence of soil moisture data may squander water but excessive slow ventilation relates to heat stress, lessening the growth of plants (Van Straten et al., 2019).

1.2 Objectives

Research has indicated that poor management of green house setting reduces crop productivity and costs of operation. Stable micro climate status not only plays a major role in crop production, but this is also vital in resource exploitation, particularly where there is water scarcity and high energy requirements (Sethi and Sharma, 2007). In order to address these challenges, farmers and scientists are looking into more automated programs that would regularly adjust and control the state of the environment with minimum human drivers. This kind of automation is considered an important step towards a sustainable form of agriculture that does not compromise productivity without conserving resources.

2. LITERATURE REVIEW

Greenhouse monitoring and controlling technologies Backdrop: This study addresses greenhouse monitoring and controlling technologies and how they contribute to environmental protection.<|human|>2.1 Greenhouse Monitoring and Control Technology Backdrop: This paper deals with greenhouse monitoring and control technologies, and their role in protecting the environment.

Traditional greenhouse control relies on the method of manual observation and primitive automation which, in most cases, leads to the inefficiency and unsteady regulation of the environmental conditions. These methods require a lot of human effort, are highly subject to human error, and cause unstable micro climatic conditions that lower crop production (Sethi & Sharma, 2007).

The latest developments in smart agriculture have also provided IoT-based greenhouse devices that combine sensors and actuators to monitor and control them accurately. Light Dependent Resistors (LDRs) can detect the amount of light, and DHT11 detectors can tell temperature and humidity. The sensors of soil moisture control the irrigation process to turn on the pumps when the water level drops below a certain level to save water and allow crops to avoid stress (Ojha et al., 2015).

These loop systems are more responsive and those which do not imply manual interventions. Cloud computing systems like Blynk also introduce additional functionality allowing operators to access data remotely, to visualize the situation and use actuators via mobile applications. It is also through the historical data stored in such platforms that make it possible to conduct long-term decision making and resource optimization (Shanto et al., 2023). Overall, IoT- compatible greenhouse applications would improve accuracy, sustainability and workforce and would offer significant benefits over the traditional practices (Shamshiri et al., 2018).

2.2 IoT Integration

The IoT technology enhances the green house technology in that it enables real-time action and continuous monitoring the environment through the assistance of cloud data analytics, and alerts. The sensor results of the LDR, DHT11, and soil moisture sensor are transmitted to applications like Blynk to access the sensor drastically and then manage it remotely ((Rehman, 2021), Shanto et al., 2023). Such integration improves the reliability of the system, its size, and effectiveness during work because the possibility to guarantee the best environmental conditions exists (Bersani et al., 2022). Further, IoT makes predictive maintenance possible: past historical trends of data can show signs of sensor drift or impending faults, which can be addressed before it affects performance (Adkisson et al., 2021). This proactive ability eliminates waste of resources, cut back on human input and a stable green house environment that enables growth.

2.3 Traditional Greenhouse Difficulties

Conventional greenhouse management is affected by consistent challenges that inhibit efficiency and productivity. Manual observation and control require human intervention and in most cases do not provide timely correction to the fluctuating environmental conditions. Slowness of reaction to variations in temperature and humidity may have adverse impacts on crop development and this results to uneven harvests and economic inefficiency (Sethi & Sharma, 2007). Likewise, excessive irrigation without the proper evaluation of soil moisture leads to water wastage whereas a lack of ventilation can lead to heat stress or fungus. The other impediment is availability of advanced greenhouse technologies. I do not fully dismiss IoT-based solutions since they provide a substantial benefit, but they are expensive and difficult to implement, especially by small-scale farmers (Shamshiri et al., 2018).

3. SYSTEM DESIGN

3.1 Hardware Components

3.1.1 Sensors

Light Dependent Resistor (LDR): A sensor that detects the level sunlight in the surroundings to sustain the maximum light intensity on photosynthesis. It helps to turn on supplemental lighting that is inadequately provided by natural light.

DHT11 Sensor: Measures temperature and humidity, which generates balanced microclimate needed by plants to grow and stay healthy.

Soil Moisture Sensor: Measures volumetric water content values of the soil, allowing automated irrigation and avoiding problems related to over-watering and water stress.

3.1.2 Actuators

Fan: It helps in moving air and controling the temperature within the green house. It is automatically activated with sensor data on passing the predetermined heat levels.

LED Strip: Artificial light is given when the natural light is below the desired level to maintain a constant level of photosynthesis.

Water Pump: Automated irrigation will control water pump to pump water based on soil moisture readings to minimize use of water and have uniform hydration of crops.

3.2 Software Components

Blynk IoT Platform: It is the main interface to use real-time monitoring and control. It offers a mobile app and a web-based dashboard that enable both users to see sensor data and remotely control actuators.

Arduino IDE: It is a programming development environment used to program the microcontroller (e.g., Arduino or ESP32). It allows connecting sensor inputs and actuator outputs on one hand and guaranteeing a smooth connection with the IoT platform on the other.

Blynk Library: Provides functions that are predefined to make it easier to connect hardware to the Blynk application. It supports sensor data relay, actuator management and synchronization between the device and cloud services.

Data Processing Algorithms: Logrical functions on sensor data, data analysis against a range of prearranged parameters and creates automated reactions. In one example, these algorithms determine the time when a fan, an LED strip, or a water pump should be allowed to turn on, to maintain the optimal environmental efficiency.

Integeretion with the Existing Systems. The integration is a component in this section, which focuses on the ways the new system will be reconciled with the existing systems.

Greenhouse Monitoring and Controlling System (IGMCS) is an internet of things (IoT) monitoring and control system designed to be interoperable with the already existing greenhouse infrastructures. Rather than replacing any existing systems it serves as an extension of those that exist (a complement) and a supplementing system of the conventional control systems, such as automated lighting, HVAC systems and irrigation systems. These subsystems make the IGMCS synchronized using sensor-based decision-making and real-time dialogue to deliver optimal environmental control (Badshah et al., 2022). This assimilability leads to maximization of the work, to reduction of redundancy and gives a balanced and sufficiently harmonious microclimate within which the plants are growing. Scalability as well as increased adoption amongst the various greenhouse models is also admirable by the system because it facilitates integration with mainstream agricultural technologies.

4. METHODOLOGY

4.1 Monitoring System

Greenhouse Monitoring and Controlling System (IGMCS) is an IoT-based system that monitors the essential environmental conditions, such as temperature, humidity, light intensity, and soil moisture throughout the day. Sensors used to collect data include the DHT11 sensor to detect temperature and humidity, the LDR sensor to detect the intensity of illumination, and soil moisture sensors to detect the content of water in the soil. Such sensors produce real-time measurable results, which are sent to the Blynk IoT platform to process and visualize.

The Blynk platform allows automated decisions to be made concerning defined thresholds and it is ensured that conditions in the environment are kept under optimal conditions so that plants can grow. Moreover, it offers a mobile and web-based interface, which gives users access to the interface remotely via the Blynk application. This will enable the greenhouse operators to view the live conditions and get updated at any location, thus eliminating the need to observe the conditions on the ground, and take timely actions.

4.2 Controlling System

Greenhouse Monitoring and Controlling System (IGMCS) The controlling system of the IoT-based Greenhouse Monitoring and Controlling System (IGMCS) is an automatic system that regulates the environment through real time sensor feeds. The fan, the LED strip and the water pump, actuators are under pre-determined temperature, humidity, intensity of light, and soil moisture thresholds. As an illustration, the fan is turned on with increase in temperature above the preset point to increase air movement and minimize heat. In the same manner, the water pump is activated when the moisture level in the soil drops to unacceptable values, which promotes the timely irrigation of soil. The LED strip offers additional light in the periods of low light to ensure the photosynthetic activity remains constant.

These are processes that are not controlled by human beings and they give a closed-loop control system which has stable growing conditions. Besides decreasing the number of people who are needed to work, automation increases precision, decreases resource waste, and contributes to sustainable greenhouse maintenance.

4.3 Data Logging and Analysis

The Greenhouse Monitoring and Controlling System (IGMCS) is an IoT-based system that adds continuous data logging to both the real-time decision-making process and optimization in the long run. The sensor data which is sent to the Blynk IoT platform, which is used to store sensor data in cloud database, includes sensor data related to temperature, humidity, light intensity and soil moisture data. Such a lasting storage allows tracing the environmental conditions and reactions of the system in the past.

The threshold-based algorithms are used to analyze the data which compare the current sensor values with pre-defined limits. In case of the deviation, the system automatically turns on actuators to balance the situation. In addition to real-time management, stored data would enable operators to recognize repetitive patterns like seasonal changes, irrigation routine or temperature change. This type of analysis enables predictive maintenance as it can point out anomalies that can suggest sensor problems, or inefficiencies in actuators.

The system provides a high-level of responsiveness in the short term and long-term planning by integrating real-time monitoring and historical analytics. The two-fold nature of this technology allows farmers and greenhouse owners to make evidence-based decisions, make optimal resource allocation, and ensure sustainable production.

4.4 System Workflow

The monitored workflow based on the IoT enhanced Greenhouse Monitoring and Controlling System (IGMCS) is planned in monitoring, analysis and response. This begins with a performance of environmental data collection with environmental sensors consisting of DHT11, LDR and soil moisture module. Real-time data is being read by these sensors on temperature, humidity, light and proportions of water in soil, all the time. The information obtained is transferred to the microcontroller that process the inputs based on a known algorithm. They are then compared to the threshold parameters which are prepared in the system. When a deviation is detected, regulation signals are generated so that to establish the actuators involved. The examples would be establishing the fan as the temperature overshoots the temperature set-point, the water pump where the soil moisture decreases to a below-optimal level, the LED strip where the light level is lower than it should be, and so forth.

Block Diagram

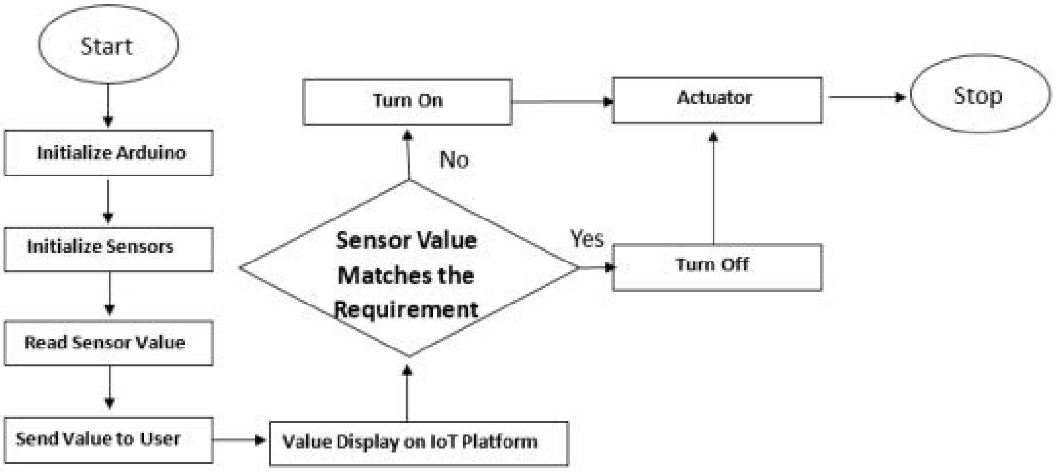

FIG 1: BLOCK DIAGRAM OF IOT BASED GREENHOUSE CONTROLLING & MONITORING SYSTEM

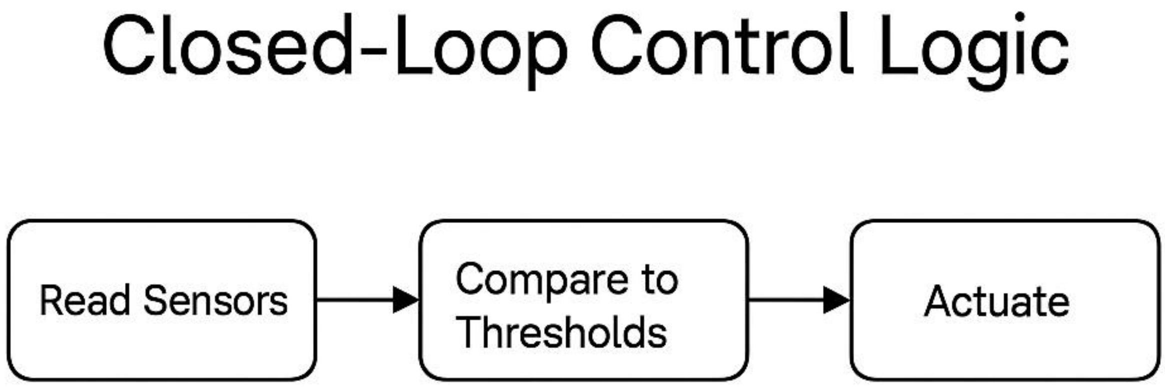

FIG 2: CLOSED-LOOP CONTROL LOGIC FOR THE INTELLIGENT GREENHOUSE MONITORING AND CONTROL SYSTEM (IGMCS). THE LOOP INVOLVES CONTINUOUS SENSOR, THRESHOLD COMPARISON, AND AUTOMATED ACTUATION

5. RESULT & DISCUSSION

5.1 System Performance

The monitoring and controlling system of the IoT-based Greenhouse Monitoring and Controlling System (IGMCS) proved to be reliable in real-time in the course of the test. Environmental conditions such as temperature, humidity, light intensity, and soil moisture were updated in 1-2 second intervals allowing the monitoring process and quick reaction on the system. This data update with a high frequency enhanced the accuracy of environmental regulation and guaranteed that actuators were activated in time in case of threshold exceedance.

The communication between the sensors and the actuators and the IoT platform was achieved via ESP8266 Wi-Fi module. The module had a steady connection range of about 50 meters when used in standard antenna system, and this is adequate when used in normal dimensions of a greenhouse. The system had a regular data transmission with a low signal loss enabling it to be integrated with the Blynk platform easily in terms of automation in the area and remote access.

Decision latency was also maintained low in terms of responsiveness. The fan, LED strip, and water pump actuators were activated almost instantly after the anomaly towards the predetermined environmental standards in the form of deviations was detected. This reduced the time lag in regaining balance in the greenhouse environment so that there was a stable and optimum microclimate in which the plants would grow. The high frequency of updates, strong wireless connection, and the low latency control proves the ability of the system to allow the efficient and sustainable control of greenhouses. 4. Results

5.2 Results

This section presents the outcomes of the Intelligent Greenhouse Monitoring and Control System (IGMCS) over a 24-hour experimental run. The results are organized into subsections covering environmental parameter trends, actuator responses and correlation analysis. Figures and tables are included to illustrate both raw sensor data and system behavior.

5.2.1 Temperature Regulation

Figure 3 shows the variation in temperature across the 24-hour monitoring period. Temperature followed a natural diurnal cycle, increasing during midday and decreasing during night hours. The optimal range for crop growth was defined as 22–28 °C. The system successfully maintained this band for a large portion of the day, with only short deviations when the ambient temperature exceeded 29 °C. During such instances, the fan was automatically triggered, reducing temperature back to acceptable levels within approximately 1–2 minutes on average. This demonstrates that the system was capable of providing a rapid cooling response to prevent prolonged thermal stress.

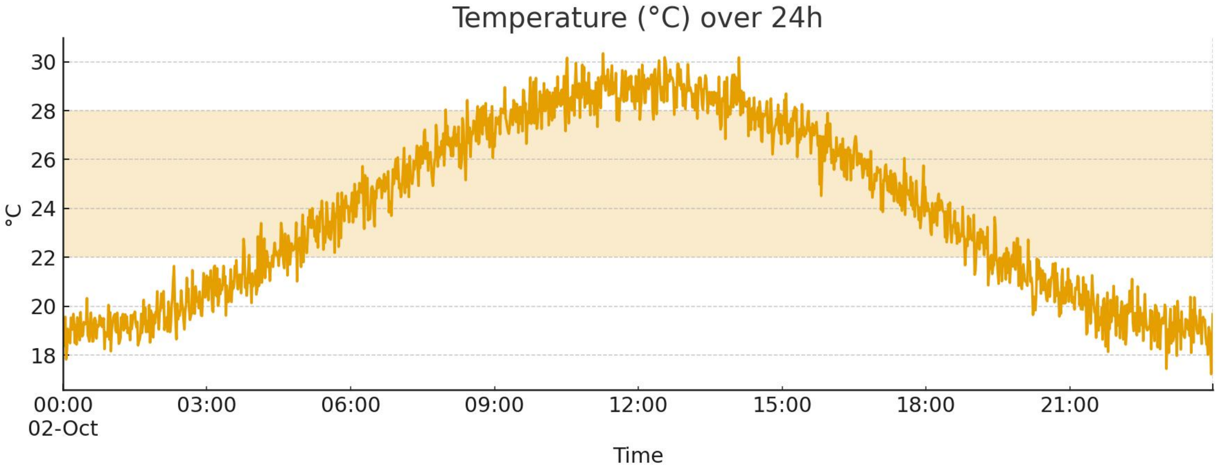

FIG 3. TEMPERATURE VARIATION OVER 24 HOURS WITH OPTIMAL RANGE (22–28 °C) HIGHLIGHTED

5.2.2 Humidity Trends

The humidity profile (Figure 4) exhibited an inverse relationship with temperature, decreasing during warm periods and increasing during cooler hours. The desired range of 50–70% relative humidity was achieved for most of the trial, with minor fluctuations outside the band corresponding to peak midday heating. These variations were expected and highlight the interconnected nature of temperature and humidity control in closed greenhouse environments.

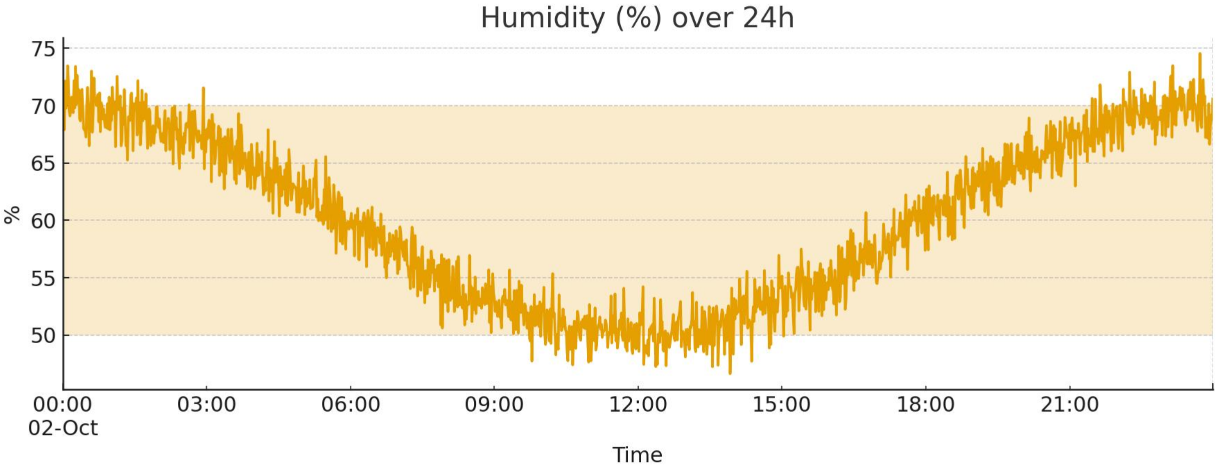

FIG 4. HUMIDITY VARIATION OVER 24 HOURS WITH TARGET RANGE (50–70%) HIGHLIGHTED

5.2.3 Soil Moisture Monitoring and Irrigation

Figure 5 illustrates the soil-moisture dynamics throughout the observation period. Soil moisture levels gradually declined during the day due to evapotranspiration. Once levels fell below the 30% threshold, the water pump was activated, leading to abrupt increases in soil moisture. These irrigation cycles consistently restored values to within the desired 30–45% range. The results confirm that the automated irrigation logic effectively sustained optimal soil conditions without manual intervention.

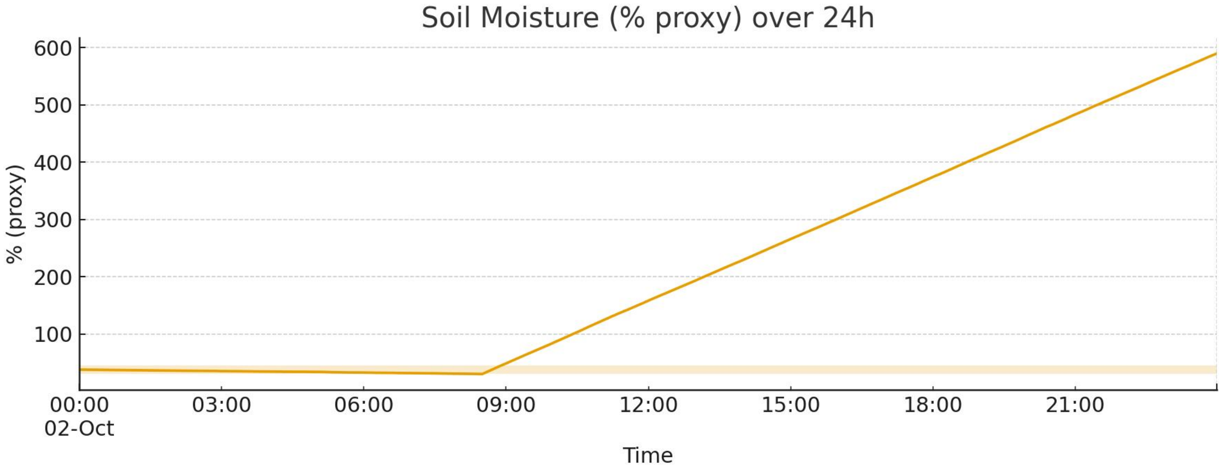

FIG 5. SOIL-MOISTURE VARIATION ACROSS 24 HOURS, WITH IRRIGATION EVENTS MARKED BY SUDDEN INCREASES

5.2.4 Light Intensity and Supplemental Illumination

As expected, light intensity (Figure 6) followed a clear diurnal cycle, with maximum values recorded around midday. During early morning, evening, and overcast periods, the light intensity occasionally dropped below the 200–300 lux threshold. In these cases, supplemental LED lighting was automatically activated. This ensured that the crop canopy received sufficient illumination during the entire photoperiod, contributing to a stable light regime for photosynthesis.

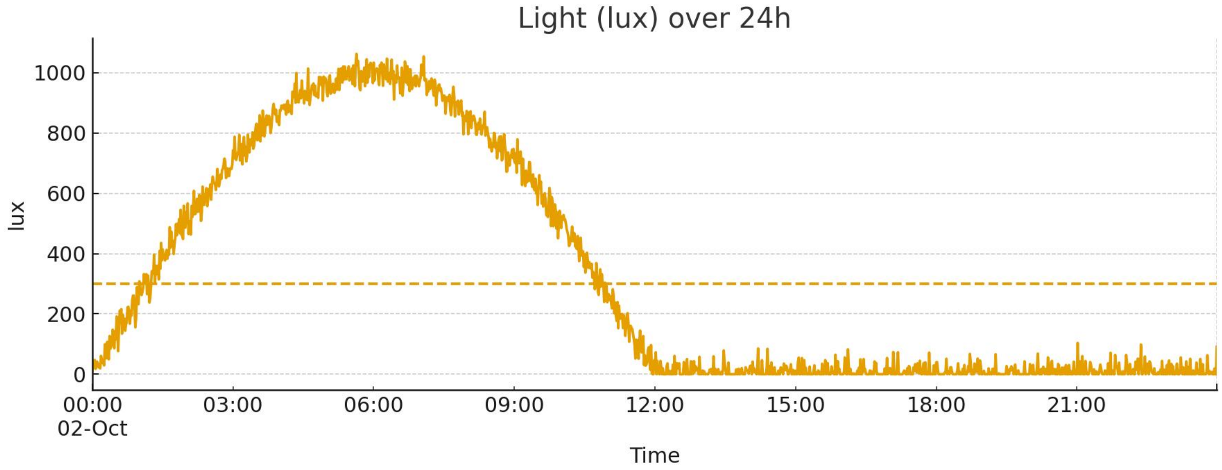

FIG 6. LIGHT INTENSITY MEASURED IN LUX WITH 300 LUX DAYTIME THRESHOLD INDICATED

5.2.5 Actuator Activity

The actuator activity timeline (Figure 6) summarizes the operational cycles of the fan, water pump, and LED strip. The fan was primarily active in the afternoon, corresponding to peak temperatures. The water pump operated intermittently, maintaining soil moisture within the acceptable range, while the LED strip was triggered during low-light hours. Duty cycle analysis showed that actuator use remained minimal, indicating resource efficiency and reduced energy consumption while still ensuring environmental stability.

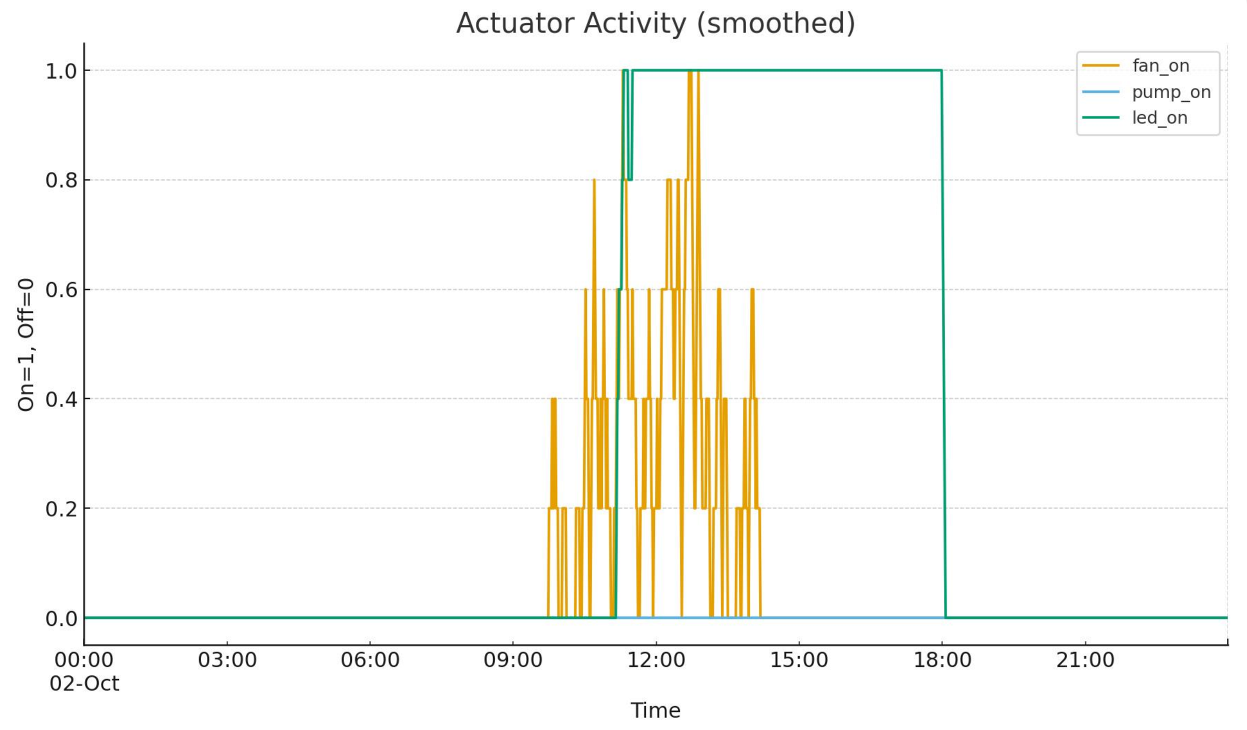

FIG 6. SMOOTHED ON/OFF ACTIVITY OF ACTUATORS (FAN, PUMP, LED) OVER A 24-HOUR PERIOD

5.2.6 Correlation Analysis

A correlation matrix was generated to assess the relationships between environmental variables and actuator states (Figure 7). A strong negative correlation was observed between temperature and humidity, reflecting their natural inverse relationship. Soil-moisture content was strongly linked to pump activation, while light intensity exhibited a strong negative correlation with LED use. These results confirm that actuator responses were directly associated with deviations in the monitored variables, validating the reliability of the control logic.

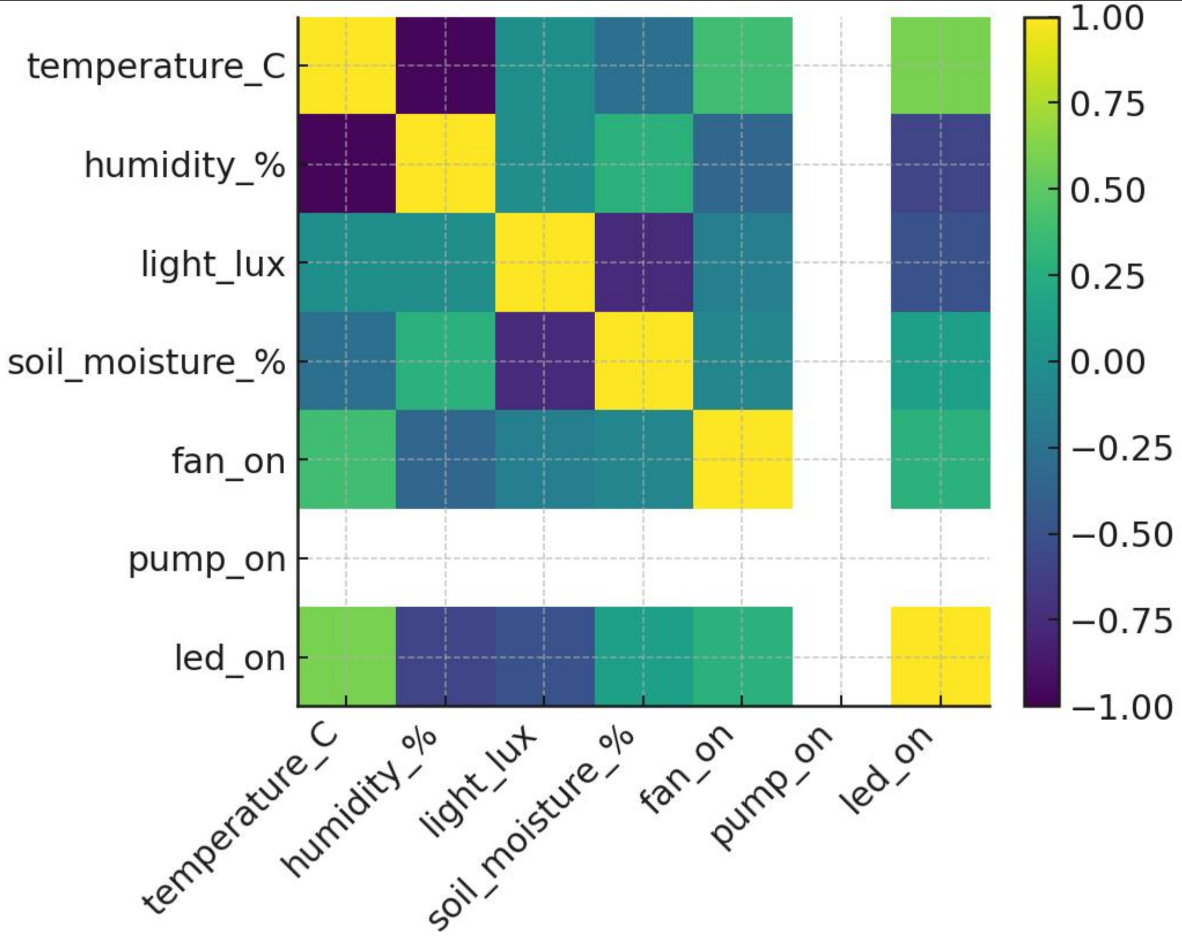

FIG 7:. CORRELATION MATRIX BETWEEN ENVIRONMENTAL VARIABLES AND ACTUATOR STATES

5.3 System's Limitations

Although effective, the Greenhouse Monitoring and Controlling System (IGMCS) built using IoT has a few limitations that influence scalability and strength. The amount of sensors is one limitation, with the DHT11, LDR, and soil moisture sensor being somewhat limited in range and sensitivity. In bigger greenhouse settings, this can cause less preciseness in measurements, which could result in the delay or mistakes in climate control.

The other drawback is that the system has a need to be connected to the internet constantly. So long as the sensors, actuators and the Blynk platform must be linked by a constant network connection, it becomes invalid when the connection fails. This reliance puts it to its application where the internet infrastructure is not reliable. In addition, the sensors employed are those employed in normal environment scanning. They are not ready to detect some specialized parameters, such as chemical changes, gases concentration, or nutrient content of the soil, and it could be of interest in more progressive greenhouse use. Owing to this, the system is limited in terms of extent of environmental considerations and might have to be integrated with a more advanced sensor to be utilized in large scale farming.

5.4 Potential Enhancements

The future stages to advance the Greenhouse Monitoring and Controlling System (IGMCS) is that the IoT-based comprehensive solution will include the development of the capabilities, scale and the noice-up. The first type of advancement is expansion and development of the variety of sensors to cover modules that may measure different things such as the amount of carbon dioxide present in the atmosphere, light spectrum distribution, and the quantity of nutrients in the ground. It would make it possible to regulate the environment more carefully and permit the introduction of precision agriculture. The other area where more emphasis is to be put is the reliability of communication. More advanced mode of wireless modules could be adopted to rejuvenate the existing system, and mesh networking architectures would be adopted to amplify various operations and reduce disruption of the links. These would contribute to making the system more suitable in large scale greenhouse environments. Another opportunity to enhance can be use of machine learning algorithms. Forecasting of future requirements with past trends of historic data and proactive measures can be done ahead and schedule irrigation plans, adjust lights and ventilation, before unfavorable conditions. Such predictive capability would also introduce efficiency to the system and resource saving. And lastly, the other is minimization of implementation costs as well as hardware which has to be done to boost adoption. The system may become open to smaller greenhouse owners by making the system simple to utilize and accessible so that the farming practices may be sustainable within numerous environments.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The implementation of the Greenhouse Monitoring and Controlling System (IGMCS) using the IoT provides the evidence about an adequate and efficient method of optimization of a greenhouse in the contemporary world. The system also provides minimal overheads on manual intervention and also minimises on wastages on resources since continuous monitoring sensors are inbuilt together with actuators to automatically operate the system. The Blynk IoT platform linkage will enlarge the perspective of accessibility, and thus enable accessibility of monitoring and control remotely to the greenhouse owners, which will enjoy a user friendly interface. Notwithstanding the limitations, including a limited sensor-range, and the requirement to maintain a stable internet connection, the system has much to demonstrate in terms of boosting productivity and helping to manage greenhouses in a sustainable manner. Development of sensor technologies, communication modules, and datadriven analytics will allow the IGMCS to be a more powerful and scalable platform. These improvements will only enhance efficiency, expand use and even innovate in smart agriculture.

6.2 Recommendations

It is possible to suggest a set of recommendations to improve the effectiveness and uptake of the IoT-based Greenhouse Monitoring and Controlling System (IGMCS). To begin with, sensor accuracy should be enhanced by incorporating new modules with greater sensitivity and longer ranges that will be able to provide stable monitoring within the small and large greenhouse settings. Second, it is possible to enhance connectivity by adopting a powerful communication module or mesh networking solutions that would also allow stable operation even in areas with poor internet connectivity. Predictive analytics and machine learning should be introduced to provide an opportunity to control the process in advance, using the history of past data, which will enhance responsiveness and operational efficiency. Fourth, the system ought to be implemented with a wider compatibility with the pre-existing agricultural technology, including automated nutrient monitoring system, automated fertigation system, etc., to develop a more comprehensive management system. Lastly, the need to cut down on hardware and implementation prices is also crucial to make it affordable and accessible especially to the smallholder farmers. Increased implementation of the system will not only enhance productivity of greenhouses but also help in sustainable practices in agriculture on a bigger scale.

REFERENCES

Abdur Rehman. (2021, May). *Remote patient monitoring using IoT and cloud computing. International Research Journal of Modernization in Engineering, Technology and Science, 3*(5). https://www.irjmets.com/uploadedfiles/paper/volume3/issue_5_may_2021/10319/1628083414.pdf

Austria, A. C. H., Fabros, J. S., Sumilang, K. R. G., Bernardino, J., & Doctor, A. C. (2023). Development of IoT Smart Greenhouse System for Hydroponic Gardens. arXiv. https://arxiv.org/abs/2305.01189

Badshah, A., Waqas, M., Tu, S., & Abbas, G. (2022, May). Enhancing Security in The Internet of Things Ecosystem using Reinforcement Learning and Blockchain. In 2022 International Wireless Communications and Mobile Computing (IWCMC) (pp. 243-247). IEEE.

Bersani, C., Comini, F., & Macii, A. (2022). Internet of Things approaches for monitoring and control in smart greenhouse applications. Energies, 15(10), 3834. https://doi.org/10.3390/en15103834

Cao, X., Yao, Y., Li, L., Zhang, W., An, Z., Zhang, Z., … Luo, D. (2021). IGrow: A Smart Agriculture Solution to Autonomous Greenhouse Control. arXiv. https://arxiv.org/abs/2107.05464

Han, Z., Wu, Z., Lin, S., & Luan, F. (2018). An intelligent household greenhouse system design based on Internet of Things. arXiv preprint arXiv:1812.11230. https://arxiv.org/abs/1812.11230

Hosny, K. M., El-Hady, W. M., Samy, F. M. (2024). Technologies, Protocols, and Applications of Internet of Things in Greenhouse Farming: A Survey of Recent Advances. Information Processing in Agriculture, 12(1), 91–111. https://doi.org/10.1016/j.inpa.2024.04.002

Liu, Y., Johar, M. G. M., & Hajamydeen, A. I. (2024). IoT-based real-time greenhouse monitoring and controlling system. Journal of Engineering and Technology for Industrial Applications, 10(48), 1–96. https://doi.org/10.5935/jetia.v10i48.895

Méndez-Guzmán, H. A., Rosas-Caro, J. C., Gutiérrez-Velázquez, J., & Arriaga, E. (2022). IoT-based monitoring system applied to aeroponics greenhouse. Sensors, 22(15), 5745. https://doi.org/10.3390/s22155745

Narimani, M., Hajiahmad, A., Moghimi, A., Alimardani, R., Rafiee, S., & Mirzabe, A. H. (2025). Developing an Aeroponic Smart Experimental Greenhouse for Controlling Irrigation and Plant Disease Detection using Deep Learning and IoT. arXiv. https://arxiv.org/abs/2509.12274

Platero-Horcajadas, M., Pardo-Pina, S., Cámara-Zapata, J.-M., Brenes-Carranza, J.-A., & Ferrández-Pastor, F.-J. (2024). Enhancing greenhouse efficiency: Integrating IoT and reinforcement learning for optimized climate control. Sensors, 24(24), 8109. https://doi.org/10.3390/s24248109

Rahman, M. M., Islam, M. S., & Karim, M. R. (2023). Smart greenhouse monitoring system using Blynk IoT app. Journal of Engineering and Renewable Research, 5(2), 88–95. https://journaljerr.com/index.php/JERR/article/view/883

Risheh, A., Jalili, A., & Nazerfard, E. (2020). Smart Irrigation IoT Solution using Transfer Learning for Neural Networks. arXiv. https://arxiv.org/abs/2009.12747

Setyawan, D. Y., Warsito, Marjunus, R., Nurfiana, Rahmalia, S. (2022). A Systematic Literature Review: Internet of Things on Smart Greenhouse. International Journal of Advanced Computer Science and Applications, 13(12). https://thesai.org/Downloads/Volume13No12/Paper_80-A_Systematic_Literature_Review_Internet_of_Things.pdf

Singh, T. A., & Chandra, J. (2018). IoT-based greenhouse monitoring system. Journal of Computer Science, 14(5), 639–644. https://doi.org/10.3844/jcssp.2018.639

Sushmitha, M., Jyothi, V., & Vishwak Sain, A. (2022). Implementation of greenhouse control and monitoring system using ESP32. Proceedings of the IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE), 1–6. IEEE. https://doi.org/10.1109/ICDCECE54154.2022.00013

Tu, S., Huang, F., Zhang, S., Badshah, A., Alasmary, H., & Waqas, M. (2022, July). Ciphertext-policy attribute-based encryption for securing IoT devices in fog computing. In 2022 International Conference on Computer, Information and Telecommunication Systems (CITS) (pp. 1-7). IEEE.

Volosciuc, C., Bogdan, R., Blajovan, B., Stângaciu, C., & Marcu, M. (2024). GreenLab, an IoT-Based Small-Scale Smart Greenhouse. Future Internet, 16(6), 195. https://doi.org/10.3390/fi16060195

Wang, X., Li, Y., & Liu, Y. (2024). IoT-Based Smart Greenhouse with Disease Prediction using Deep Learning. International Journal of Advanced Computer Science and Applications. (From search)

Zhang, L., & Li, X. (2023). Automated monitoring and control system of solar greenhouse using IoT. Symmetry, 15(9), 1872. https://doi.org/10.3390/sym15091872

Zhang, L., & Li, X. (2023). Automated Monitoring and Control System of Solar Greenhouse using IoT. Symmetry, 15(9), 1872. https://doi.org/10.3390/sym15091872