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Design, Fabrication and Monitoring of Automated Polyhouse

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The agriculture sector faces the challenge of feeding a growing population while dealing with the effects of climate change. With the limited expansion of cropland, agriculture automation has become necessary. Internet of Things (IoT) and Artificial Intelligence (AI) have made significant strides in various industries, including agriculture. These digital technologies offer smart systems that can monitor, control, and visualize farm operations in realtime, approaching human expertise. The potential applications of IoT and AI in agriculture include smart machinery, irrigation systems, pest control, crop monitoring, and more. Automated polyhouses equipped with IoT and AI

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components can optimize crop conditions, enhancing yield and quality while minimizing climate impacts. Over the past decade, research in this field has matured, transitioning from conceptual stages to implementation. The integration of AI and IoT into agriculture practices poses technical challenges, but understanding these technologies will facilitate their adoption and the development of IoT and AI-based solutions in farming.

Keywords: Polyhouse; agriculture; automation; internet of things; artificial intelligence.

1. INTRODUCTION

Polyhouse is a type of greenhouse that utilizes contrsolled climatic conditions to enhance plant growth and yield. It is made up of a galvanized iron structure covered with UV-stabilized poly film sheets. Polyhouses are cost-effective compared to other greenhouse structures like polycarbonate and glass. They provide a low-cost solution for greenhouse farming, particularly in areas with harsh climates [1].

There are two types of polyhouses: manually operated and automatically operated using IoT. Manual polyhouses require human intervention for temperature, humidity, and ventilation control. However, they have several disadvantages [2]. Manual polyhouses require a lot of labour, are less accurate, offer limited control, can be costly to operate, are prone to errors, have limited flexibility, and offer limited monitoring capabilities. They are also highly dependent on weather conditions, which can affect plant growth and yields [3,4].

To overcome these limitations, automation using IoT technology is introduced in polyhouse farming. IoT-based smart greenhouse farming utilizes sensors to monitor environmental conditions like light, humidity, temperature, and soil moisture [5]. It automates the irrigation system and allows farmers to monitor the field conditions remotely. Automation in polyhouses improves efficiency, reduces labour costs, offers greater control, enhances monitoring capabilities, improves energy efficiency, increases flexibility, improves productivity, ensures better quality produce, reduces the risk of disease, and improves food safety [6]. Monitoring is crucial inside polyhouses to maintain optimal growing conditions. Regular monitoring of temperature, humidity, soil moisture, and equipment performance helps identify and address issues early on, minimizing crop loss. Web-based and mobile-based applications provide real-time monitoring, data collection, and analysis. They enable remote access, alert and notification systems, and improved efficiency. These applications integrate with various sensors and equipment, have user-friendly interfaces, and provide visualizations of data for easy interpretation.

Mostly the polyhouse is constructed in east to west direction to allow proper entry of sunlight in polyhouse farming; we can protect our crops from any adverse environment such as high humidity or high temperature. There is a facility in the polyhouse to control temperature or humidity. Polyhouses offer controlled environments for plant growth, and automation using IoT technology enhances their efficiency and productivity. Regular monitoring and the use of web-based and mobile-based applications simplify the management and optimization of polyhouse environments, leading to higher yields, improved crop quality, and reduced operating costs [7].

2. MATERIALS AND METHODS

The present study was conducted at the Vaugh Institute of Agricultural Technology & Sciences, SHUATS, Prayagraj.

2.1 Materials

a. Node-MCU: Node-MCU is an open-source development board based on the ESP8266 Wi-Fi module. It is used as a microcontroller in this project, providing Wi-Fi connectivity and compatibility with the Arduino development environment. The small-sized board can be easily programmed using Lua scripting language and has input/output pins for connecting sensors and other components. It is ideal for IoT applications like home automation and remote monitoring.

b. DHT11 Sensor: The DHT11 is a digital temperature and humidity sensor module. It measures relative humidity from 20% to 90% with an accuracy of ±5% and temperature from 0°C to 50°C with an accuracy of ±2°C. It provides a digital output and operates on a 3.3V to 5V power supply. The DHT11 is commonly used in projects requiring basic temperature and humidity measurements [8].

c. Soil Moisture Sensor: Soil moisture sensors measure water content in the soil. They use different sensing principles such as resistance or capacitance to estimate moisture levels. These sensors typically consist of probes inserted into the soil and provide analogue or digital output signals. Proper installation and calibration are necessary for accurate readings. Soil moisture sensors are valuable for optimizing irrigation and plant health.

d. Exhaust Fan: Exhaust fans are used to remove unwanted odours, moisture, and pollutants from an enclosed space. They improve indoor air quality by promoting air circulation and removing contaminants. They are essential for maintaining a healthy and comfortable environment, especially in areas with high humidity.

e. Water Pump: Water pumps create flow and pressure to move water from a source to a desired location. In this project, the water pump is used to provide moisture to the plants based on readings from the soil moisture sensor. A submersible pump requiring a 3 to 6V power supply is used for irrigation purposes.

f. Relay: A relay is an electrical switch controlled by an electromagnetic coil. When energized, the contacts close, allowing electricity to flow through the circuit. When de-energized, the contacts open, breaking the circuit. A 5V relay is used in this project to operate the exhaust fan based on temperature readings from the DHT11 sensor.

Fig. 1. LCD screen with I2C

g. LCD Screen with I2C: An LCD screen with I2C has a built-in interface chip that allows it to be controlled using the I2C protocol. This simplifies wiring and reduces the number of pins required for communication. It can display text, graphics, and other information and is useful for visual feedback and user interaction.

h. Breadboard: A breadboard is used for prototyping electronic circuits. It has a grid of interconnected holes where components and wires can be inserted to create temporary connections. Breadboards allow for easy experimentation and testing of circuit designs without soldering.

Fogger: A fogger is a device that produces a dense vapour or fog-like substance for creating atmospheric effects. It can temporarily increase humidity in the immediate area, useful for controlled environments like terrariums or indoor gardens.

2.2 Methods

All sensors (DHT11 and Soil Moisture Sensor), actuators (exhaust fan, water pump, and fogger), and LCD screen were connected to Node-MCU using jumper wires, breadboard, and relays. Coding was done in Arduino IDE and uploaded to Node-MCU. Sensors and LCD screens were powered by an external power circuit. The plant was placed in a polyhouse and the power was turned on. Data was gathered and displayed using the CAYENNE cloud. The Node-MCU sent sensor values to the cloud, allowing users to remotely access data on their mobile phones or laptops via the cloud.

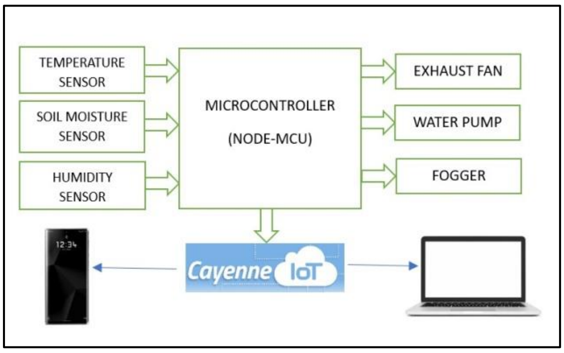


Fig. 2. Block diagram of the concept of the developed system

Design Consideration of Polyhouse: Important considerations for designing a polyhouse include orientation for sunlight exposure, strong structure and materials, proper ventilation, heating and cooling systems, reliable irrigation, automation and control systems, accessibility and maintenance, data acquisition and analysis, and efficient time and resource management. These considerations can be tailored based on specific needs, crop types, and local regulations. Expert consultation is valuable for optimal design [9].

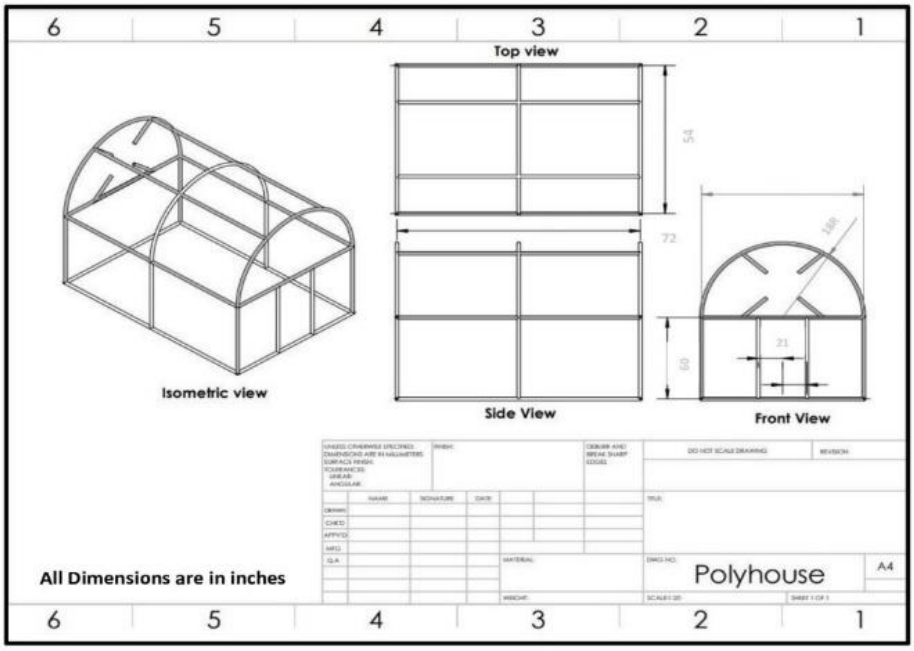
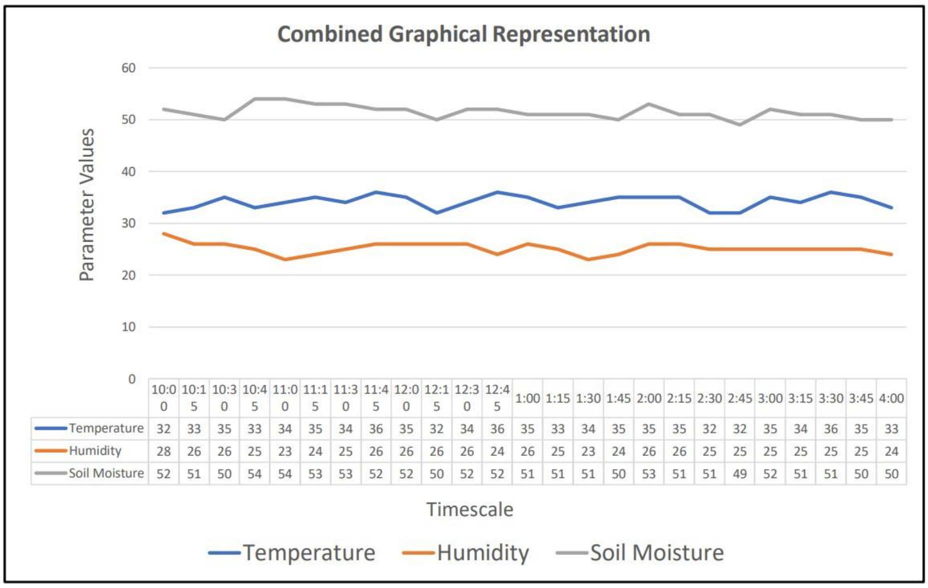


Fig. 3. Design Layout of Polyhouse

3. RESULTS AND DISCUSSION

The polyhouse framing material was chosen as Cast Iron due to its high tensile strength, durability, and cost-effectiveness. Polyethylene was selected as the covering material for its widespread use and durability. The chosen plant for the study is Dumb-Canes, an ornamental and medicinal plant known for its antidote properties against snakebites and treatments for various ailments. It thrives in shade but benefits from intense light during winter. Sensors such as a soil moisture sensor and DHT-11 (temperature and humidity sensor) are used to monitor moisture content, temperature, and humidity. Actuators, including a water pump and exhaust fan, are controlled by the microcontroller (Node-MCU) based on sensor signals. Data is displayed on an LCD screen and uploaded to the Cayenne cloud for convenient monitoring and control.



	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00
Temperature	32	33	35	33	34	35	34	36	35	32	34	36	35	33	34	35	35	35	32	32	35	34	36	35	33
Humidity	28	26	26	25	23	24	25	26	26	26	26	24	26	25	23	24	26	26	25	25	25	25	25	25	24
Soil Moisture	52	51	50	54	54	53	53	52	52	50	52	52	51	51	51	50	53	51	51	49	52	51	51	50	50

Fig. 4. graphical representation of temperature, humidity & soil moisture with time inside polyhouse

Table 1. Observation table of Temperature in different time spans

Date	Timestamp	Channel	Sensor Name	Data Type	Unit	Value	Actuator	Status (1-ON, 0-OFF)
23/05/2023	10:00:00 AM	1	Temperature	temp	Celcius	32	Exhaust Fan	0
23/05/2023	10:15:00 AM	1	Temperature	temp	Celcius	33	Exhaust Fan	0
23/05/2023	10:30:00 AM	1	Temperature	temp	Celcius	35	Exhaust Fan	1
23/05/2023	10:45:00 AM	1	Temperature	temp	Celcius	33	Exhaust Fan	0
23/05/2023	11:00:00 AM	1	Temperature	temp	Celcius	34	Exhaust Fan	0
23/05/2023	11:15:00 AM	1	Temperature	temp	Celcius	35	Exhaust Fan	1
23/05/2023	11:30:00 AM	1	Temperature	temp	Celcius	34	Exhaust Fan	0
23/05/2023	11:45:00 AM	1	Temperature	temp	Celcius	36	Exhaust Fan	1
23/05/2023	12:00:00 PM	1	Temperature	temp	Celcius	35	Exhaust Fan	1

4. CONCLUSION

A Dome-shaped polyhouse has been designed and fabricated with IoT and AI technologies to create a smart and automated system for plant growth. By integrating sensors and actuators, the polyhouse can monitor and control environmental factors such as temperature, humidity, and irrigation. This automation reduces manual intervention and ensures optimal growing conditions. The collected data from sensors, including humidity, temperature, and soil moisture, is transmitted to a cloud platform for analysis. This integration improves crop productivity, reduces labour requirements, and enables informed decision-making based on real-time data. Moreover, the polyhouse promotes sustainable agriculture practices by optimizing resources, conserving water, and reducing the use of pesticides and fertilizers. This technology-driven approach revolutionizes modern agriculture by enhancing crop management, disease prevention, and environmental conservation. The polyhouse with IoT and AI represents a significant advancement in agriculture, offering benefits to farmers and supporting the future of food production.

APPLICATION OF RESEARCH

Design, Fabrication and Monitoring of Automated polyhouse and to measure Temperature, Soil moisture and Humidity.

RESEARCH CATEGORY

Automation and Experimental Research in Polyhouse.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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