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Research Paper

Analyzing the efficiency of Arduino UNO microcontroller in monitoring and controlling the microclimatic parameters of greenhouse

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ABSTRACT

At present greenhouse farming has become more popular in contrast to traditional farming because of its adjustment capability of the environmental parameters such as temperature, humidity, light intensity, and soil moisture according to the requirements of the crops. Continuous monitoring and controlling facilities of the greenhouse system allow the farmers a good maintenance system with good quality and high yield of the crops. In this paper, an Arduino microcontroller was used in a greenhouse system for an automatic monitoring system for cultivation incorporating various sensors such as a temperature-humidity sensor, and soil moisture sensor to collect parameters for monitoring the environment of the greenhouse. The collected data were used to control the temperature using cooling fans which facilitated the greenhouse controlling the environment. For storage and processing the data the controller code was generated in the Arduino programming language, and finally inserted into the Arduino UNO R3 microcontroller. A solar power system with a rechargeable battery was installed as a source of energy to ensure continuous power supply to the greenhouse system. Implementation of a greenhouse with a microclimatic parameter monitoring and controlling system will result in mitigating land and labor requirement problems for small-scale farmers, and gardeners as well as supplying suitable data for agricultural researchers.

***Keywords*:** Greenhouse cultivation, Smart system, Sensors, Microclimate, Automated process, Solar energy, Microcontroller.

The agricultural industry is the main key factor for the growth of the national economy of Bangladesh. This agricultural sector is controlling the country's economy as well as land use, making up 19.29% of the country's GDP (Islam *et al.,* 2015). But the amount of total cultivable land is reducing day by day for various reasons which results in the production of sufficient food for a vast population. Concerns related to climate change, such as riverbank erosion, have a significant influence on household food security since they cause people to lose acreage, which has changed their farming status over the years (Alam *et al.,* 2020). The findings of the study showed that, in coastal Bangladesh, the percentage of agricultural land fell dramatically between 2005 and 2019 where it is largely due to the effect of salinity, which, in particular, after surge flood events, encourages farmers to use their land for aquaculture, such as shrimp farming, and it is significantly responsible for this cultivable land disaster (Adnan *et al.,* 2020; Islam *et al.,* 2015; Khan *et al.,* 2015). A feasible solution to the problem of the availability of land for cultivation would be for households to cultivate their required vegetables and crops in a greenhouse that does not require a lot of space.

A greenhouse is a specially designed homestead structure intended to provide a controlled atmosphere for an improved cultivation process with minimum land space. When compared to open-field gardening, a greenhouse will often produce more crops per square meter because the microclimatic parameters that impact crop output are continuously monitored and controlled to ensure that an optimal environment is maintained (Enokela and Othoigbe, 2015). Urban rooftop greenhouses are becoming more and more popular as a wise choice because they expand the low-lying green space in most cities and create additional agricultural spaces (Pons *et al.,*

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2015). Temperature, photoperiod, humidity, moisture content, and light intensity are examples of environmental variables that have significant effects on crop quality, yield, flowering, and maturation and that's why farmers should maintain these factors according to the crop's requirement for better production. Polyhouse may be a preferable option for crops that require warm and dry microclimatic conditions (Verma and Joshi, 2021). The atmosphere of a greenhouse, which maintains the primary microclimate parameters of solar radiation, temperature distribution, and relative humidity, would be suitable to address this issue. Researchers have identified irrigation water as an important factor for sustainable production and experimented to determine the optimum irrigation amount for drip irrigation in greenhouse conditions (Lee *et al.,* 2020). Controllable greenhouse climate variables that impact crop growth and yield include air temperature, solar radiation, and air relative humidity and also have an impact on energy costs, which can make up to 40% of the entire cost of production (Lamprinos *et al.,* 2015*)*.

Previous research revealed that, when compared to the traditional greenhouse spraying system, the Smart Microclimate Control System for Greenhouses could save 66.8% of the water and energy (electricity) used for early spraying throughout the cultivation period. This finding demonstrates how the SMCS will strengthen agricultural resilience to hydro-climate uncertainty and encourage the conservation of resources (Chen *et al.,* 2022). Using a Supervisory Control and Data Acquisition (SCADA) system and a Programmable Logic Controller (PLC), a monitoring system was created to precisely control and predict the conditions of a greenhouse (Ding *et al.,* 2018). This system would enable intelligent control and real-time monitoring of the artificial environment's soil temperature, air humidity, soil moisture, carbon dioxide concentration, and light intensity. By increasing the relative humidity inside the greenhouse using a cooling fan, the temperature can be reduced during high-temperature conditions (Kale *et al.,* 2006). Mostakim *et al.,* (2020) implemented fuzzy logic in the proposed framework to control GHS variables, including temperature, humidity, light, soil moisture, and the watering system of the plant, and in their research, the temperature-controlling controller employed a temperature sensor to obtain the current temperature as input. Another study was conducted to put into practice the characteristics of a ZigBee wireless sensor network-based greenhouse monitoring system (Lamprinos *et al.,* 2015*)*. This network is made up of several sensor nodes that gather data on environmental conditions and send it to a remote database.

This study was intended to investigate the use of Arduino UNO microcontroller in a greenhouse agriculture system that uses a sensor device with continuous current data capabilities to monitor the crop environment in a greenhouse at a minimal cost of resources. The study was performed with the following objective: (1) To monitor and control the parameters of the greenhouse environment using a sensor device for improving agriculture production management. (2) To collect and store data on the environmental parameters of the greenhouse that could be used by the researchers for research purposes. (3) To reduce the amount of cultivable land by introducing smart greenhouse farming.

MATERIALS AND METHODS

Study location

A location with adequate sunlight and ventilation was chosen to build the prototype of the proposed greenhouse. A well-built rooftop was chosen for this purpose as it could be the best option for this type of greenhouse. It is situated at the temporary campus of Khulna Agricultural University, Khulna, Bangladesh.

Greenhouse, devices and sensors

A Quonset greenhouse was installed vertically on the roof of the building with a plastic pipe structure (Fig. 1(a)). The dimension of the greenhouse was around 7.5ft×5 ft×4ft (length, width, height). Polythene was used as a covering material. Monitoring parameters were temperature, humidity, and soil moisture would be monitored with the help of different sensors and controlled by installing the cooling fan, and water pump. The water tank was used for irrigation purposes and two cooling fans were used for temperature control.

Arduino UNO: Arduino microcontroller board model no UNO R3 (Fig. 1(b)) is an open-source microcontroller that allows for easy programming, deleting, and reprogramming at any time. An Arduino Uno board includes 14 digital input/output pins (6 of which can be used as PWM outputs), six inputs for analog signals, a 16 MHz quartz crystal, a USB port, a power jack, an ICSP header, and a reset button (Galadima, 2014). These modules support the microcontroller and link to a computer via a USB cable and they can be powered by the external power supply (AC-to-DC adapter or battery). The board can operate on an external supply from 6 to 20 volts.

DHT11 sensor: The DHT11 (Fig. 1(c)) is a temperature and humidity sensor that can measure temperature with an accuracy of ±2°C between 0 and 50°C and relative humidity with an accuracy of ±5% RH between 20 and 90% RH within a temperature range of 0-50°C (Gay and Gay 2018). In this instance, four DHT11 sensors were used to simultaneously measure the temperature and humidity.

Soil moisture sensor: To optimize water management through precise irrigation scheduling, the soil moisture content is an essential parameter to identify the water requirement of soil. Since soil moisture sensors can provide continuous, nondestructive data at various depths, they have been extensively utilized for many years to measure soil moisture levels (Dong *et al.,* 2020). This sensor has two probes that were inserted into the soil at 15 cm depth from the surface (Fig 1(d)).

Power source: In this study, the main power source was solar energy. We used a 20W solar panel (Fig. 1(e)) and a 12V battery allowing for continuous monitoring and management of the greenhouse system. The solar panel produces electricity that is used to charge the battery which ensures continuous power delivery to the system.

(a) **(b)** **(c)** **(d)** **(e)**

Fig. 1: Different materials used in greenhouse **(a)** Prototype of the proposed greenhouse, **(b)** Arduino UNO (Microcontroller chip), **(c)** DHT11 sensor, **(d)** Soil moisture sensor, **(e)** Solar panel of the greenhouse

Liquid crystal display: A flat panel display or other electronically modified optical device that takes advantage of liquid crystals' ability to modulate light is known as a liquid crystal display (LCD). We used two LCDs one was a 20*4 character capacity with an operating voltage of 5V and the other was a 16*2 LCD with an operating voltage of 4.2 V to 5.3 V. A Buck converter circuit was used to keep the voltage constant.

Schematic system diagram

The Fig. 2 depicts the proposed greenhouse monitoring and control system's operation. The programming code for monitoring and controlling parameters has been installed into a microcontroller, which is linked to all sensors, displays, pumps, and power sources. The moisture sensor's A0 pin was linked to the Arduino board's A0 pin, while the relay module's UCC and GND pins were connected to the positive and negative ends of the power source, and the IN pin was attached to the Arduino board's digital 2 pins. The water pump's negative end was connected to the battery's negative end, the positive end was attached to the relay's NO port, and the positive side of the battery was connected to the relay's COM port. When soil moisture is low, the water pump would be turned on; when soil moisture is medium or high, the water pump would be turned off. This irrigation method involves drip irrigation. The DHT11 sensor measures temperature and humidity; the optimum temperature can be set in the programming for controlling temperature. In this study, when the temperature in the greenhouse exceeds 29°C, the cooling fan turns on, and when the temperature falls below 29°C degrees Celsius, the cooling fan turns off automatically. Relays are used to switch the cooling and irrigation unit when a certain condition is met.

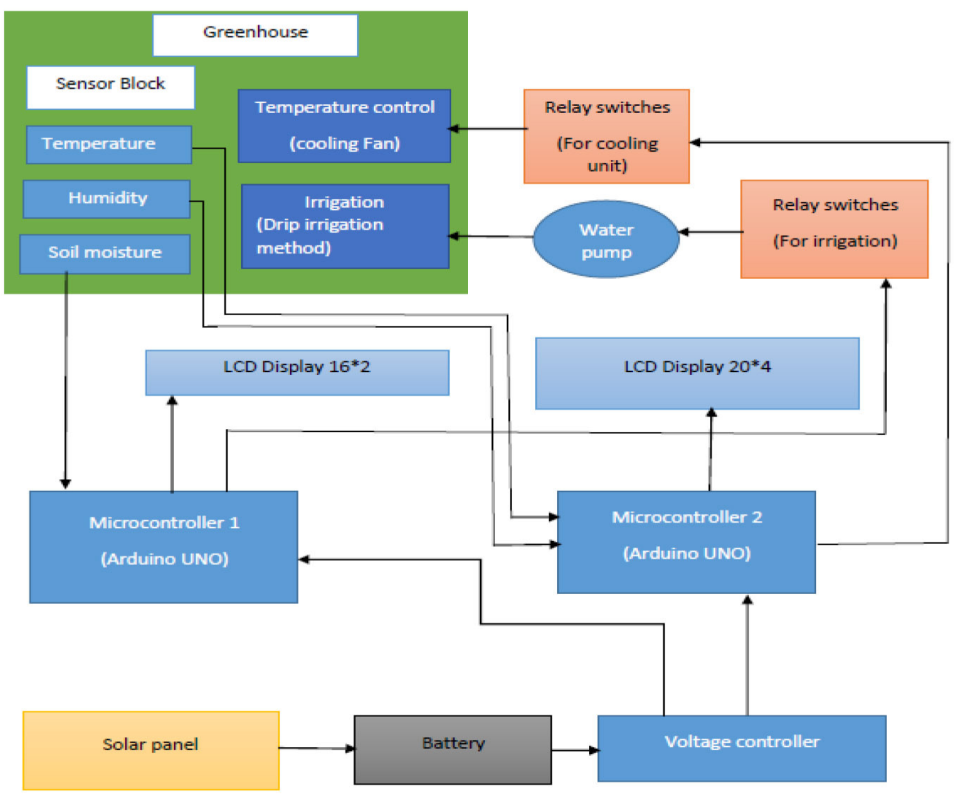

Fig. 2: Schematic block diagram of the greenhouse system

Fig. 3: Sample of the recording of the humidity and temperature on an LCD monitor

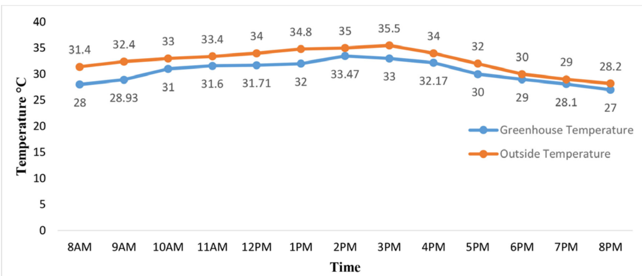

Fig. 4: Variation of the greenhouse and outside temperature at different times of the day

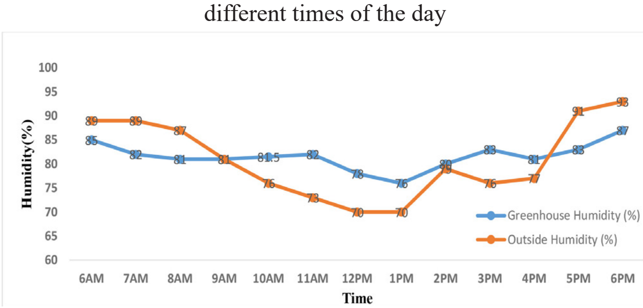

Fig. 5: Variation of greenhouse humidity and outside humidity at different times of the day

RESULT AND DISCUSSIONS

To achieve the aim of this project, an efficient monitoring and temperature-controlling system for greenhouses has been developed utilizing sensors and solar electricity. The system has successfully undergone testing in a simulated environment, demonstrating its ability to monitor air humidity, interior and outside temperature, and soil moisture level. Temperature, humidity, and soil moisture values are accurately measured, and the measured data are shown on an LCD that is attached to the system.

Temperature and humidity

The temperature and relative humidity of the greenhouse were recorded at different times of the day using DHT11 sensors. Fig. 3 shows a sample display of the recording of the humidity was 79% during the temperature of 27.10° C shown to the LCD monitor that was recorded using the sensors.

Fig. 4 represents the graphical representation of temperature at different times of the day using the recorded data from the database to show the variation of greenhouse temperature and outside temperature. Temperature was recorded for analysis with an interval of 60 minutes during June, 2023. When the temperature of the greenhouse exceeds the predefined or critical level (29° C), the mechanism activates the cooling fan. In contrast, when the temperature remains below the typical range or falls below the defined level, the fan immediately turns off.

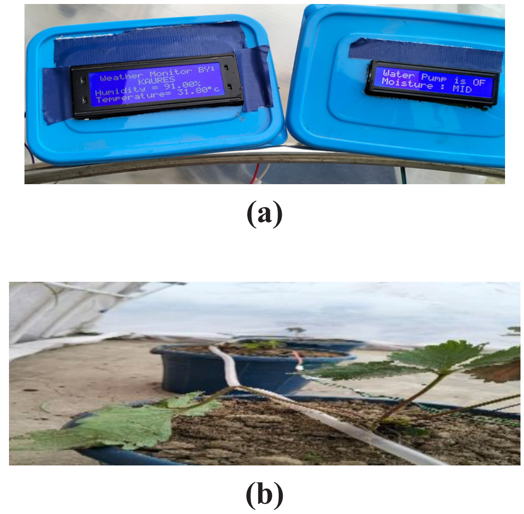

Fig. 6 (a): Sample of display of the soil moisture recordings **(b)** Installed drip irrigation system in the greenhouse

The relative humidity of the greenhouse and the outside environment at different times of the day is shown in Fig. 5. It was observed that when the ambient temperature is high during the day, then the relative humidity becomes low. Inside the greenhouse, the cooling fan system reduced the temperature by increasing the humidity. The air can contain more water vapor when the temperature increases during the day, which results in a decrease in relative humidity. For a high temperature of the atmospheric air more evaporation was taken place as a result it increased the relative humidity as well as decreased the internal temperature. Again, the relative humidity increases with decreasing air temperatures with the amount of dew present (Byrne and O'gorman, 2016).

Soil moisture

The soil's moisture content is influenced by its water content. Therefore, in this study, we prefer a soil moisture sensor to detect whether the soil is dry, humid, or wet. When the soil is dry, a servo is automatically activated to turn on the water supply to plant root zone by drip irrigation method, and irrigation depth above 2.5 to 3 cm is shown in Fig. 6 (b). The water supply will automatically be shut off when the soil becomes damp. Then, the measured values were shown to the LCD monitor. Fig. 6 (a) shows a sample of a display of the soil moisture that has been shown to the LCD monitor that is attached to the system.

CONCLUSION

The use of Arduino UNO in the greenhouse system enables the farmers to monitor and control the temperature, humidity, and soil moisture of a greenhouse. The system will also archive the data to be utilized now or in the future when needed. According to all findings and the observation tests of all sensor nodes, our project will suggest using a microcontroller for automating the greenhouse by controlling temperature and an irrigation system for proper cultivation. However, there is some future work that needs to be done such as controlling temperature using light sources, determination of fertilizer and insecticides, etc.

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