Group number: 22321

Title: Greenhouse Soil and Irrigation Monitoring System

Abstract

The major obstacle Egypt faces in becoming more efficient is managing and utilizing modern technologies to improve humans' life, specifically through the development of an intelligent greenhouse aimed at optimizing crop growth year-round. The project implements Multi-Sensor Integration, allowing for continuous monitoring of essential parameters such as soil moisture linked to a water pump for moisture regulation, light intensity which triggers a buzzer if light level exceeds requirements, temperature monitoring, and air quality sensors that detect CO_2 concentration variations between day and night. The system is designed to provide real-time data updates every 30 seconds to ensure optimal conditions for plants. A Bluetooth terminal interface provides a user-friendly digital platform for non-technical users, and the greenhouse stores data for up to a year through Tera Term, transferring it to Excel sheets. Alerts notify users when environmental thresholds are breached, enhancing responsiveness. Additionally, the sensors are powered by a battery designed to last a minimum of six months without replacement, supporting sustainability. The battery is supported by renewable energy sources to extend its lifetime. In conclusion, the integration of a soil moisture sensor with a water pump addresses soil dryness and excessive water consumption, contributing to efficiency.

Introduction

Egypt faces major environmental challenges, including improving its scientific and technological environment, reducing climate change effects **(Lindwall, 2022)**, and enhancing its industrial and agricultural base while recycling waste for economic and environmental purposes. This challenge focuses on developing an integrated multi-sensor system for monitoring conditions, providing real-time feedback and alerts, and addressing accessibility concerns. One such project is the "Soil Moisture Monitoring System" which uses IoT and Raspberry Pi technology to automate irrigation processes **(Tan, Gebremariam, Rahman, Salman, & Xu, 2022)** by collecting data from humidity, temperature, and sound sensors. It offers cost reduction, water efficiency, and low maintenance but faces initial setup costs, technical complexity, internet connectivity dependence, sensor limitations, and scalability concerns. Another essential prior solution is "Towards Automated Greenhouse Monitoring" which offers benefits like improved crop growth, resource efficiency, and environmental control **(Li, Guo, Zhao, Wang, & Chow, 2021)**, but also faces challenges like implementation, initial costs, and limited practical application. Overall, Egypt's environmental challenges require a comprehensive approach to address these challenges and promote sustainable development. To avoid the previous disadvantages and provide easy readings to non-technical users, a safe remote monitoring system was developed using Arduino and sensors like soil moisture, light intensity, gas, and temperature. In order to achieve the desired results, certain design requirements were chosen. The first is using Multi-Sensor Integration: soil moisture (Controlling the water pump), light intensity, air quality (specific CO_2), and temperature. The second design requirement involves making the system provide real-time data updates every 30 seconds. The third involves using a Bluetooth terminal to design a user-friendly digital interface that visualizes data for non-technical users. The fourth involves storing the data for at least one year of continuous operation using Excel and Tera Term applications. The fifth involves using an alert mechanism to notify users when thresholds are reached, activated by a buzzer. The sixth involves running the sensors on a battery-powered by a renewable source, which is a solar panel, and operating continuously for at least six months without replacement. Finally, a technical report will explain sensor integration, signal interpretation techniques, and the system's performance in a test environment. The chosen solution addresses Egypt's environmental concerns by constructing a greenhouse for monitoring the soil and plant conditions using eco-friendly materials like palm fronds, which are highly resistant to high temperatures and direct sunlight, thereby regulating temperature. The greenhouse's dome-like form helps distribute heat evenly. The solution will be implemented in Al Minya, Upper Egypt, utilizing the region's fertile soil and favorable climate to enhance crop yields. Overall, the solution will address the selected design requirements and achieve the desired results.

Methodology

The project methodology consisted of several steps, including the construction of the greenhouse, the installation of sensors, and the implementation of a feedback control system.

- The base consists of a plastic box used to hold the soil and basil.
- The design of the dome was selected to optimize the distribution of heat within the greenhouse
- Palm fronds were selected as the base of the dome due to their flexibility and strength, after which the dome was covered with plastic sheets, as them. These material selections were made based on scientific considerations of their specific advantages and properties. Overall, the methodology aimed to create optimal conditions for any plants within the greenhouse, to achieve the design requirements successfully.

Feedback control system:

First, the solar panel was connected to its charger then connected to the battery and the converter to elevate the output voltages of the solar panels to 12 volts which will feed the system.
In the feedback control system, multiple sensors were utilized, including a temperature sensor (DHT22), light intensity sensor (photoresistor sensor), soil moisture, air quality sensor (MQ-135), connected to specific pins on the Arduino UNO and breadboard. When the measured intensity reached the specified threshold, the buzzer activated to provide an alert. An H-bridge was utilized to interface with the water pump, which controls the irrigation of the soil when the
moisture increases. The whole system was linked to the smartphone through a serial Bluetooth terminal mobile application for the continuous monitoring of the recordings. To save these historical data there was a connection between the system and tera term application to represent these data in simple form via Excel Sheet.

Data Acquisition and Processing

Egypt is currently confronting a challenging mission: leveraging advanced technologies and modern development methods to address key societal and environmental challenges. These include reducing pollution, combating climate change, strengthening the country’s economic and agricultural foundation, and improving the quality of life through science and technology. This semester, a critical project focuses on creating an autonomously intelligent building, which offers a sustainable solution to these pressing concerns.

The solution involves a greenhouse system, divided into two main components:

1. The Feedback System
2. The Building Construction Method

Greenhouse Design and Feedback System

The proposed greenhouse supports the cultivation of various annual crops with specific growth requirements. The prototype consists of:

- A plastic box base connected to a plastic sheet.
- A palm leaf dome, designed to maintain internal temperatures unaffected by external weather conditions.

The feedback system incorporates multiple sensors to meet the project's design requirements:

- Soil Moisture Sensor: Regulates soil moisture and dryness, activating a connected water pump to reduce water consumption.
- Light Intensity Sensor: Monitors light levels to ensure optimal plant growth, with an alert buzzer to indicate excessive light intensity.
- Temperature Sensor: Tracks internal temperature changes due to the light bulb.
- Air Quality Gas Sensor: Monitors carbon dioxide emissions from plants, recording concentration changes day and night.

Power System and Battery Life:

The greenhouse is powered by renewable energy, utilizing silicon solar panels to convert sunlight into electricity. This aligns with the law of conservation of energy (CH.3.01), which states that energy cannot be created or destroyed, only converted.

Key considerations for solar panel efficiency include:

- Efficiency varies throughout the day, peaking at midday and decreasing during morning and afternoon hours due to the sun's position.
- Temperature increases reduce efficiency by 0.4% to 0.5% for every degree Celsius above 25°C.

Lithium-Ion Batteries:

- A lithium-ion battery was selected for its high efficiency (95% or higher) and long life span.
- Each battery supports 6000 charge cycles before significant degradation.

For calculating the life of the battery for this system the battery will have 2 cycles per day so dividing the whole cycles over the cycle per day $\frac{\mathbf{6000}\ \boldsymbol{cycles\ for\ battery}}{\mathbf{2}\ \boldsymbol{cycles\ per\ day}} = \mathbf{3000}$ **cycles (means 3000 days)**, then to know the time it will stay before damaging or replacing $\frac{\mathbf{3000}}{\mathbf{365}\ \boldsymbol{days/year}} = \mathbf{8.21}$ **years**

To calculate the battery's performance over six months:

$\mathbf{2}\ (\boldsymbol{cycles\ per\ day}) \times (\mathbf{6}\ \boldsymbol{months}\ \times \mathbf{30}\ \boldsymbol{days\ in\ month}) = \mathbf{360}$ **cycles per 6 months**

This confirms the lithium-ion battery's suitability for the system.

Data Collection and Transmission

- Data is collected continuously for at least a year, updated every 30 seconds.
- Transmission is handled via the Tera Term application, which automatically saves data in an Excel sheet and generates user-friendly graphs for easy interpretation by non-technical users.

Results and Observations

Positive Results:

1. The hardware and software met all design requirements.
2. The water pump efficiently reduces soil moisture when necessary.
3. The light bulb provides optimal heat and light conditions for plant growth.
4. Heat retention is enhanced by the plastic sheets.
5. Data is well-organized in an Excel sheet, offering a user-friendly digital interface.

Negative Results:

1. Solar Panel Efficiency: Drops with temperature increases, reducing power output.
2. Bluetooth Module Range: Limited to 10 meters, restricting long-distance sensor readings.
3. Solar Panel Voltage: A converter was required to boost the panel's 5-volt output to recharge 4-volt lithium-ion batteries effectively.

System Testing and Precision

The system's performance was evaluated using various trials:

Average Rate of Change:

$\boldsymbol{y}4 - \boldsymbol{y1}\ / \boldsymbol{x}4 - \boldsymbol{x1}$ = 479-465 / 27.1-26.9 = 70, as $\boldsymbol{y}4$ and $\boldsymbol{y1}$ represent the final and initial value of light intensity respectively and $\boldsymbol{x}4$ and $\boldsymbol{x1}$ represent the final and initial value of temperature respectively (these values are taken after turning on the bulb).

This indicates that a 70 lux change in light intensity results in a 1°C temperature increase.

Precision Calculations:
Was used in calculating the average "mean" of a group of values using this formula: **sum of values /their number =** 479+474+471+465 / 4 = 472.25, it used also while calculating the precision.

Conclusion

After testing the prototype, we concluded that employing the soil moisture sensor in conjunction with the water pump is crucial for addressing the challenges of excessive water consumption and dry soil conditions. We also observed a direct relationship between the temperature and light intensity sensors, which is vital for optimizing plant growth. The system is designed to provide real-time data updates every 30 seconds, allowing for timely adjustments to maintain optimal growing conditions. A Bluetooth terminal creates an intuitive digital interface that visually presents data, making it accessible for non-technical users and enhancing user experience. Additionally, the system can store data for a minimum of one year of continuous operation, utilizing the Tera Term application for efficient data transfer to Excel sheets. Sustainability is further promoted by the battery, which is engineered to operate for at least six months without replacement and is supplemented by renewable energy sources to extend its lifetime.

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