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An IOT Enabled Wireless Greenhouse Monitoring System

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Abstract— ***Our project's main aim is to increase food production, economic development in rural communities, environmental sustainability of food production through our proposed work. The paper proposed is a wireless greenhouse monitoring system that utilizes a Supervisory Control and Data Acquisition (SCADA) application and an Arduino UNO microcontroller board. The system aims to provide real-time monitoring of the greenhouse environment using various sensors, including temperature and humidity sensors, gas sensors, and level sensors. The data collected from these sensors is transmitted wirelessly to a central SCADA system that displays the data and allows for remote control of the greenhouse environment. The system's key features include its ability to control the greenhouse's environment remotely, increasing efficiency, and reducing manual labour. The data collected by the sensors can be used to optimize the greenhouse environment, allowing for better plant growth and increased productivity. The system also features cloud storage, allowing for easy access and analysis of the controlled and monitored data. This wireless greenhouse monitoring system provides a convenient and efficient method for monitoring and controlling the greenhouse environment, allowing for increased productivity and better management of resources. Additionally, the system is cost-effective and easy to install, making it accessible to small-scale greenhouse farmers. The proposed system can be utilized in a wide range of greenhouse applications and is an excellent tool for those seeking to optimize their greenhouse's productivity and sustainability.***

Index terms: Internet of things, Sensor, Arduino Uno, SCADA.

I. OVERVIEW

A wireless greenhouse monitoring system is a system that uses wireless technology to remotely monitor and control various environmental parameters in a greenhouse, such as temperature, humidity, water level. The system typically consists of sensors that are placed in the greenhouse to collect data, a wireless communication network that transmits the data to a central control unit, and a software application that allows the user to view and analyse the data and control the greenhouse environment. The advantages of using a wireless greenhouse monitoring system include increased accuracy and reliability of data collection, reduced labour costs associated with manual data collection, improved control over greenhouse conditions, and the ability to remotely monitor and control the greenhouse from anywhere with an internet connection. Wireless greenhouse monitoring systems can be customized to meet the specific needs of the user, and can be integrated with other automation systems, such as irrigation. They can also be used in a variety of greenhouse settings, including commercial greenhouse operations, research facilities, and hobby greenhouses. A wireless greenhouse monitoring system provides a powerful tool for growers to optimize their greenhouse environment and improve plant health and productivity.

II. INTRODUCTION

In recent years, the integration of Internet of Things (IoT) technology in various applications has been gaining popularity, including the management of public toilets in societies. IoT-enabled monitoring and controlling systems have emerged as a promising solution for addressing the challenges associated with the maintenance of public toilets in societies.

A wireless greenhouse monitoring system is an innovative and efficient way to monitor the environment within a greenhouse. The system utilizes a variety of sensors and communication technologies to gather data and transmit it to a centralized location for analysis and management. Greenhouses are used to grow a wide range of plants, and maintaining optimal environmental conditions is critical for successful growth. This includes monitoring temperature, humidity, light, and air quality, as well as water and nutrient levels.

Traditional greenhouse monitoring systems rely on manual measurements and adjustments, which can be time-consuming and prone to error. Wireless greenhouse monitoring systems, on the other hand, allow for real-time monitoring and control, providing a more accurate and efficient way to manage the greenhouse environment.

Wireless greenhouse monitoring systems typically consist of a network of sensors distributed throughout the greenhouse, which collect data and transmit it to a central controller. The controller then uses wireless communication technologies, such as Wi-Fi or Bluetooth, to transmit the data to a remote server or cloud platform for analysis and management. Wireless greenhouse monitoring systems provide an efficient and convenient way to monitor and control the environmental conditions within a greenhouse, ensuring optimal growth conditions for plants and reducing energy costs through automation.

2.1. IOT TECHNOLOGY

The Internet of Things (IoT) describes the network of physical objects “things” that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from ordinary household objects to sophisticated industrial tools. With more than 7 billion connected IoT devices today, experts are expecting this number to grow to 10 billion by 2020 and 22 billion by 2025.

IoT (Internet of Things) technology is a network of interconnected physical devices, vehicles, buildings, and other objects that have sensors, software, and connectivity that allow them to collect and exchange data. The IoT technology aims to enable intelligent communication between physical objects, which allows them to share information, make decisions, and automate tasks without human intervention.

IoT technology is made up of four basic components: sensors, connectivity, data processing, and applications. Sensors are responsible for collecting data about the environment, such as temperature, humidity, and motion, and then transmitting that data to the next component, which is connectivity. Connectivity refers to the various networks that connect devices, such as Wi-Fi, Bluetooth, or cellular networks. Data processing is the third component, where the collected data is analysed and processed using software and algorithms to make sense of the data and generate insights. Finally, applications are the user-facing interfaces that allow users to interact with the IoT technology, such as mobile apps or web dashboards.

IoT technology has many applications, from smart homes to smart cities, healthcare, transportation, agriculture, and industrial automation. For example, in agriculture, it can be used to monitor soil moisture, temperature, and nutrient levels to optimize crop growth and yield. IoT technology offers tremendous opportunities for businesses and consumers to improve efficiency, productivity, and quality of life by connecting devices and enabling intelligent communication between them.

III. PROBLEM STATEMENT

The management of larger farms with several greenhouses require data acquisition in each greenhouse and their transfer to a control unit which is usually located in a control room, separated from the production area.[1]

Greenhouses represent a closed environment which can be strictly monitored by humans in order to provide optimal conditions for the growth of plants.[2]

A solution based on a SCADA network application and improve the monitoring sensors for efficient operation.[3]

IV. LITERATURE REVIEW

Agriculture in the Kingdom of Saudi Arabia (KSA) faces several constraints, including extreme temperatures, water scarcity, sea water desalination costs, and non-fertile soil. To overcome this hostile environment and ensure agricultural self-sufficiency, multiple government agricultural programs were launched to ensure food security. Indeed, agricultural self-sufficiency is a sign of a country’s stability and strength. Agricultural self-sufficiency can only be achieved by introducing innovative environmentally suitable solutions and modern agricultural technologies necessary for improving productivity and decreasing production costs. Greenhouse farming is interesting in the sense that it succeeds in isolating the yield of nature, and allowing the protection of plants against the immediate impact of external climatic conditions. In the desert climate where the summer lasts over half of the year, as in Saudi Arabia. The average temperature in July is around 43 °C, and the average one in January is about 14 °C. It is impossible to enhance the production of vegetables and fruits like tomatoes, Cucumbers, Sweet peppers and strawberries, as the optimum temperature for their growth falls in the range between 11°C to 28°C.In order to overcome the very restrictive climatic conditions in the KSA, a highly scalable intelligent system that monitors the greenhouse environment, generates the reference temperature, and regulates the internal temperature was developed. The use of a PN model allows us to monitor the greenhouse environment, to generate suitable reference temperatures, and to supervise the whole system. A controlled awning that reduces the effects of the Sun rays was also introduced. The proposed system is autonomously able to: monitor the outside temperature, monitor the energy consumption rush hours, monitor the angles of the Sun rays, generate the suitable temperature, send this temperature as a reference signal for temperature regulation, guarantee that the ambient greenhouse temperature reaches this reference temperature, and finally, goes into standby state in the absence of tasks to accomplish. The main innovative point of this work is to build a smart system through associating different techniques; greenhouse monitoring and supervising through PN, temperature regulation using a closed loop system and awnings control to obtain a smart framework that reduces energy consumption and ensuring an appropriate greenhouse growing environment. This is considered very beneficial while achieving energy savings and reducing production costs, it keeps an appropriate environment for plants to grow. The effectiveness of the proposed approach is demonstrated via a number of simulations that are performed using a greenhouse temperature transfer function. Additionally, all captured information that is

related to energy consumption, internal greenhouse temperature and other agricultural attributes are structured using a proper strategy of model transformations, then stored and archived in the dynamic Neo4j graph-based database system. This is introduced and discussed as a scalable design of a supporting management information system in the second part of this work [1]

Evaluating the quality of environments within greenhouses has been an important aspect of greenhouse agriculture. However, the existing greenhouse monitoring systems are generally unable to evaluate the quality of greenhouse environments, and at present, it is evaluated manually, which leads to the failure of timely and effective evaluation. Therefore, how to evaluate the greenhouse environment quality accurately, quickly, and automatically is an urgent issue to be tackled. Inspired by the optimization algorithm, clustering algorithm, and probabilistic neural network (PNN), this article proposes the application of a novel PNN evaluation algorithm to a decentralized greenhouse monitoring system to evaluate the environment quality in real time. First, the original training samples are clustered by an improved K-means clustering algorithm (called K-means- α), and the training samples near the cluster centroids are used as new ones to establish the PNN structure. Then, the particle swarm optimization (PSO) algorithm (whereby the fitness function is defined as the PNN's classification error rate on the test samples) is used to iteratively optimize smoothing factors adopted by different classes of pattern units in the PNN. The optimized PNN is finally obtained (called α-PSO-M-PNN). The experimental results demonstrate that compared with conventional PNN-based algorithms, the optimized PNN algorithm has the advantages of a simpler network structure, higher classification accuracy, and requiring fewer training samples. In addition, it is more suitable for the microprocessor-based monitoring system because its computational and storage requirements are within the limits of the microprocessor.[2]

The Greenhouse Gas Monitoring Instrument (GMI) is a short-wavelength infrared (SWIR) hyperspectral-resolution spectrometer onboard the Chinese satellite GaoFen-5 that uses a spatial heterodyne spectroscopy (SHS) interferometer to acquire interferograms. The GMI was designed to measure and study the source and sink processes of carbon dioxide and methane in the troposphere where the greenhouse effect occurs. In this study, the processing and geometric correction algorithms of the GMI Level 1 product (radiance spectrum) are introduced. The spectral quality and greenhouse gas (GHG) inversion ability of the Level 1 products are analyzed, and the results illustrate that the specifications meet the mission's requirements. An initial evaluation of the resolution, signal-to-noise ratio (SNR), and stability of the radiance spectrum reveals that the overall function and performance are within the design objectives. A comparison between our Level 1 products and the theoretical spectrum shows that the root mean square (rms) of the residual is approximately 0.8%, and the Level 1 products of the GMI captured within five months after observations have good spectral stability characteristics (less than 0.005 cm^{-1} for Band 1, 0.003 cm^{-1} for Band 2, 0.002 cm^{-1} for Band 3, and 0.004 cm^{-1} for Band 4). These results demonstrate that the GMI payload and the processing algorithm all work well and reliably. Furthermore, based on the Level 1 products, a GHG retrieval experiment is carried out, and the results are compared with data from Total Column Carbon Observing Network (TCCON) stations. The initial comparison of the XCO_2 results yields a value of 0.869 for R^2 (goodness of fit), 0.51 ppm for bias (mean of absolute error), and 0.53 ppm for σ (standard deviation of error). Similarly, the XCH_4 comparison yields values of 0.841 for R^2, 4.64 ppb for bias, and 4.66 ppb for σ. [3]

V. HARDWARE DESCRIPTION

5.1. ARDUINO UNO

Arduino Uno as in figure 5.1.1 is used which is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset

button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your Uno without worrying too much about doing something wrong, worst-case scenario you can replace the chip for a few dollars and start over again.

Figure 5.1.1

5.2. LCD

LCD as in figure 5.2.1 is used as a type of display technology used in various electronic devices, including digital watches, calculators, televisions, computer monitors, and microcontroller-based projects like Arduino. An LCD consists of a layer of liquid crystal material sandwiched between two polarizing filters. When an electric current is applied to the liquid crystal layer, the crystals align themselves in a way that allows light to pass through the second polarizing filter, creating visible characters or images. LCDs are commonly used in microcontroller-based projects to display information such as sensor readings, menu options, and other output. They are available in various sizes and resolutions, and some also come with built-in controllers that simplify their interfacing with microcontrollers like Arduino. To use an LCD with Arduino, you will typically need to connect its pins to the appropriate pins on the Arduino board, and then use an LCD library to control the display. There are several libraries available for this purpose, including the LiquidCrystal library that comes with the Arduino IDE. The library provides functions to display characters, clear the screen, set the cursor position, and other basic operations

Figure 5.2.1

5.3. LM35

LM35 as in figure 5.3.1 is used as a precision temperature sensor that is commonly used in electronic projects. It is an analog sensor that can measure temperature in the range of -55°C to 150°C with an accuracy of ±0.5°C. The LM35 sensor works by outputting a voltage that is proportional to the temperature it measures. Specifically, the output voltage of the LM35 increases by 10 millivolts per degree Celsius increase in temperature. For example, if the temperature is 20°C, the output voltage of the sensor will be 200 millivolts. To use the LM35 sensor with an Arduino board, you would typically need to connect the sensor's output pin to one of the analog input pins on the Arduino board, and then use the analogRead() function to read the sensor's output voltage. Where sensorPin is the analog input pin connected to the LM35 sensor, and 5.0/1023.0 is a scaling factor that converts the sensor's output voltage to a value between 0 and 5 volts. LM35 is a widely used temperature sensor due to its simplicity, accuracy, and ease of use with microcontrollers like Arduino. It is commonly used in temperature monitoring and control applications, such as thermostats, incubators, and HVAC systems.

Figure 5.3.1

5.4. DHT11

DHT11 as in figure 5.4.1 is used as a temperature and humidity sensor that is commonly used in electronic projects. It is a digital sensor that can measure temperature in the range of 0°C to 50°C with an accuracy of ±2°C, and relative humidity in the range of 20% to 80% with an accuracy of ±5%.The DHT11 sensor works by outputting a digital signal that represents the temperature and humidity it measures. Specifically, the sensor outputs a 40-bit data stream that includes the temperature and humidity values in binary format. To use the DHT11 sensor with an Arduino board, you would typically need to connect the sensor's data pin to one of the digital input/output pins on the Arduino board, and then use a library such as the DHT library to read the sensor's output data. The library provides functions to read the temperature and humidity values from the sensor, and also includes error checking and retries to ensure reliable data transmission. DHT11 is a widely used temperature and humidity sensor due to its low cost, simplicity, and ease of use with microcontrollers like Arduino. It is commonly used in environmental monitoring and control applications, such as weather stations, greenhouses, and indoor air quality monitors.

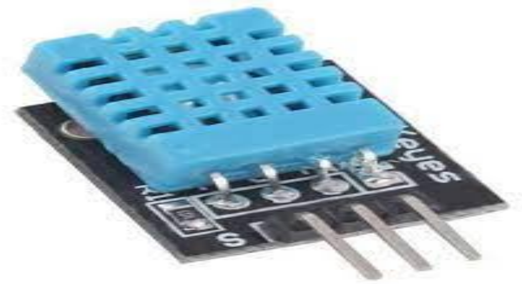

Figure 5.4.1

5.5. MQ2

MQ2 as in figure 5.5.1 is used as a gas sensor that is commonly used in electronic projects. It is a semiconductor sensor that can detect the presence of various gases in the air, including LPG, propane, methane, hydrogen, and alcohol. The MQ2 sensor works by measuring the resistance of its sensing element when it is exposed to the target gas. Specifically, the sensor's resistance decreases when it is exposed to the target gas, which can be measured and used to determine the gas concentration. To use the MQ2 sensor with an Arduino board, you would typically need to connect the sensor's pins to the appropriate pins on the Arduino board, and then use an analog input pin to read the sensor's output voltage. You can then convert the sensor's output voltage to gas concentration using a calibration curve that maps the sensor's output voltage to gas concentration for the target gas. MQ2 is a widely used gas sensor due to its low cost, versatility, and ease of use with microcontrollers like Arduino. It is commonly used in gas leakage detection and monitoring applications, such as gas detectors, alarm systems, and industrial safety systems.

Figure 5.5.1

5.6. ESP8266

ESP8266 as in figure 5.6.1 is used s a low-cost, Wi-Fi enabled microcontroller that is commonly used in Internet of Things (IoT) projects. It is a highly integrated chip that includes a full TCP/IP protocol stack and a built-in Wi-Fi module, which makes it easy to connect to Wi-Fi networks and communicate with other devices over the Internet. The ESP8266 can be programmed using the Arduino IDE or other programming environments, and supports a variety of programming languages and frameworks, including C++, MicroPython, and Lua. It has a powerful processor with up to 160 MHz clock speed, and comes in several variants with different amounts of memory and features. To use the ESP8266 with an Arduino board, you would typically need to connect the ESP8266's serial interface to the Arduino's serial interface, and then use the Arduino IDE to upload code to the ESP8266. The ESP8266 can also be used standalone, without an Arduino board, by connecting it to a power source and programming it using a USB-to-serial converter. ESP8266 is a powerful and versatile microcontroller that is widely used in IoT projects, home automation, and industrial automation applications. It is well-supported by the open source community, and has a large ecosystem of libraries and frameworks that make it easy to develop complex applications with the ESP8266.

Figure 5.5.1

VI. SYSTEM DESIGN

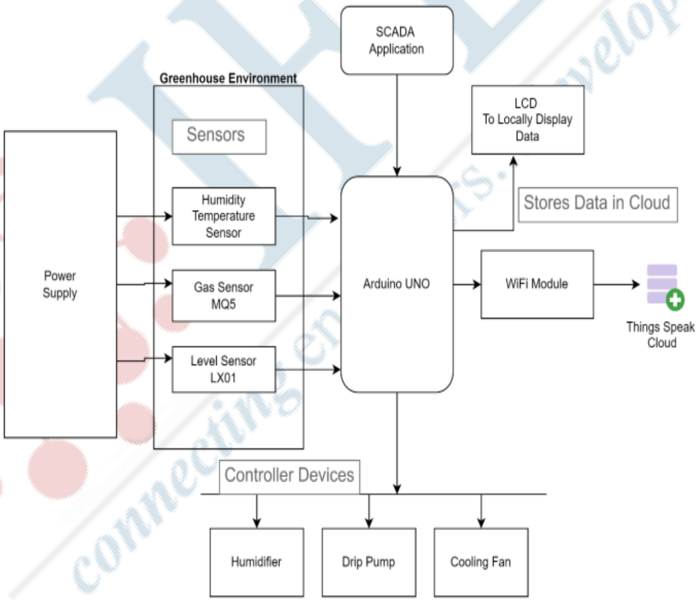

Figure 6.1

VII. SOCIAL IMPACT

1. Increased food production: Wireless greenhouse monitoring systems can help growers optimize growing conditions, leading to increased yields and more efficient use of resources such as water and fertilizer. This can help address food shortages in areas with limited access to fresh produce and help reduce food waste.
2. Economic development: Wireless greenhouse monitoring systems can create new business opportunities for growers, as they can produce high-value crops that can be sold locally or exported to other markets. This can help create jobs and stimulate economic growth in rural communities.
3. Environmental sustainability: Wireless greenhouse monitoring systems can help reduce the environmental impact of agriculture by minimizing the use of chemicals and water, and reducing greenhouse gas emissions associated with transportation of crops. This can help promote sustainable agriculture practices and reduce the carbon footprint of food production.

4. Education and research: Wireless greenhouse monitoring systems can be used in educational and research settings to study plant growth and optimize growing conditions. This can help advance our understanding of plant biology and inform the development of new agricultural technologies.

VIII. RESULT AND DISCUSSION

The wireless greenhouse monitoring system is an effective and efficient way to monitor and control the environment within a greenhouse. The system was implemented using Arduino Uno, DHT11, MQ2, and ESP8266 sensors and communication technologies. The DHT11 sensor was used to measure temperature and humidity, while the MQ2 sensor was used to detect the presence of gases such as carbon monoxide and methane. The data collected from these sensors was transmitted to the central controller using the ESP8266 module, which enabled wireless communication through Wi-Fi.

The collected data was analyzed and used to control the greenhouse environment through automated systems such as fans, heaters, and irrigation systems. Real-time monitoring of the greenhouse environment was also possible from anywhere in the world through the internet.

The results of the wireless greenhouse monitoring system showed that it was effective in maintaining optimal environmental conditions for plant growth. The system provided accurate and real-time monitoring of temperature, humidity, and gas levels, allowing for timely adjustments to be made to the greenhouse environment. Additionally, the system helped reduce energy costs through automation of systems such as fans and heaters, which were only activated when necessary. The wireless greenhouse monitoring system also helped reduce water usage by automating the irrigation system, which was only activated when the soil moisture level dropped below a certain threshold.

The wireless greenhouse monitoring system is an effective and efficient way to monitor and control the environment within a greenhouse. The system provides real-time monitoring, automated control, and remote access, which helps reduce costs and improve productivity

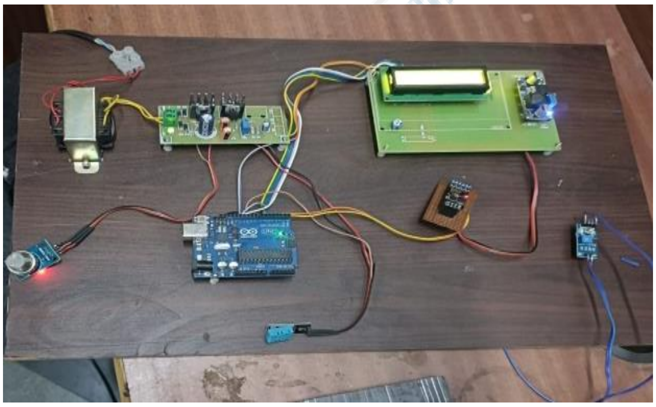

Figure 8.1

IX. CONCLUSION

In conclusion, the wireless greenhouse monitoring system is a highly effective and efficient way to monitor and control the environment within a greenhouse. By utilizing sensors and communication technologies such as Arduino Uno, DHT11, MQ2, and ESP8266, the system collects and transmits data in real-time, allowing for timely adjustments to be made to the greenhouse environment. The wireless greenhouse monitoring system helps maintain optimal environmental conditions for plant growth by monitoring temperature, humidity, and gas levels. It also automates systems such as fans, heaters, and irrigation systems, reducing energy costs and water usage. The remote access feature of the system enables monitoring and control of the greenhouse environment from anywhere in the world.

The wireless greenhouse monitoring system is an innovative and efficient solution that offers many benefits for greenhouse operators and plant growers. It helps improve productivity, reduce costs, and ensure that the environment within the greenhouse is optimal for plant growth. As the technology advances, it has the potential to revolutionize the way we grow plants and improve the sustainability of agriculture.

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