Intelligent Greenhouse Monitoring and Control System Based Arduino UNO Microcontroller

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***Abstract*—Nowadays, there is a significant diminution in agricultural production due to the unpredictable control of crop climate conditions. Thus, to alleviate the crops exposure from excess cold or heat and unwanted pests, an intelligent environment monitoring and control system based Arduino UNO board consisting of ATmega 328P microcontroller has been developed for a small-scale agriculture namely greenhouse. The system user can monitor and control the greenhouse climate conditions remotely via web interface/mobile applications and GSM in a real-time manner. To deliver the environmental conditions in a timely manner, low-cost wireless sensor network (WSN) is used to monitor the temperature, humidity, soil moisture and light of the greenhouse. The sensor network constitutes a multi-hop network structure for large coverage. The developed system is implemented and tested in laboratory conditions using Proteus toolkit. Arduino Integrated Development Environment (IDE) tool is used to develop necessary software. The results show that the proposed system can closely monitor and evaluate greenhouse farming field conditions accurately. Finally, the user can send control decisions instantly to boost the yield growth conditions and thus, increase the crop production considerably.**

***Index Terms*—Intelligent Greenhouse; WSN; Multi-Hop; Large Coverage; Monitoring and Control System; Arduino Uno; Microcontroller; Proteus Toolkit.**

I. INTRODUCTION

Currently, the global demand for food is greatly increasing due to the rapid growth of population. On the other hand, the production of sufficient food becomes a huge challenge because of climatic unpredictability [1]. Even thus, numerous studies did prove that most of crops produce well into a greenhouse, it is important to highlight that the control of environmental factors is one of the most significant and tough parameters to ensure the efficiency of greenhouse [2]. Thus, the agricultural environmental monitoring and control play a vital role in the production of abundant and sustainable food as the crop growth conditions will be closely scrutinized and the risk of disease will be identified [3].

The advent of wireless sensor network (WSN) technology provides a suitable platform for developing remote monitoring and control system of greenhouse conditions [4]. Hence, authors in [5], [6] and [7] did propose greenhouse monitoring and control systems based on WSN technique. However, their systems are not well-suited with the modern devices as an old 8-bit 8051 microcontroller is implemented. On the other hand, authors in [8], [9] and [10] did initiate a greenhouse monitoring and control system using a programmable Interface Controller (PIC) microcontroller. Nevertheless, the unintended PIC reset caused by errata in its library/documentation makes these systems unstable for real-time applications. Furthermore, the complexity and high price of the S3C2440 microprocessor makes the system developed in [11] too expensive for rural people and small-scale agriculture [12]. Moreover, despite using Arduino UNO as microcontroller, the system developed in [13] is limited because it can only monitor the greenhouse conditions. Finally, even thus, the author in [14] did develop a greenhouse monitoring and control system based on WSN, the GUI creation in LabVIEW is more complex and difficult to implement. Hence, in this research, a low-cost and real-time system based Arduino UNO Atmega 328 microcontroller was developed to intelligently monitor and control the crop growth conditions in a small-scale agriculture using Proteus toolkit. Thus, based on the sensed environmental conditions, the system will automatically act on the actuators either to open/close the fan to regulate the temperature or to open/close water pump for water irrigation, etc.

II. SYSTEM BLOCK DIAGRAM

As shown in Figure 1, the proposed intelligent greenhouse monitoring and control system is composed of three main functional bloc systems. First, Monitoring Bloc System (MBS) configured by a multi-hop wireless sensor network (WSN) to cover a large area while sensing several environmental parameters such as temperature, humidity, soil moisture, light, etc. Second, Control Bloc System (CBS) that comprises of Arduino UNO with various interfaces to provide connection with global system for mobile communication (GSM) module along with Internet Server to operate the Arduino UNO microcontroller, a Liquid Crystal Display (LCD) to show the instant field environment conditions and various motors/actuators to react on Arduino instructions. A User Block System (UBS) is located at last position. Through the web interface/mobile application, the cultivator/system user can monitor and act on various actuators/motors based on collected/sensed field data to enhance the crop growth conditions.

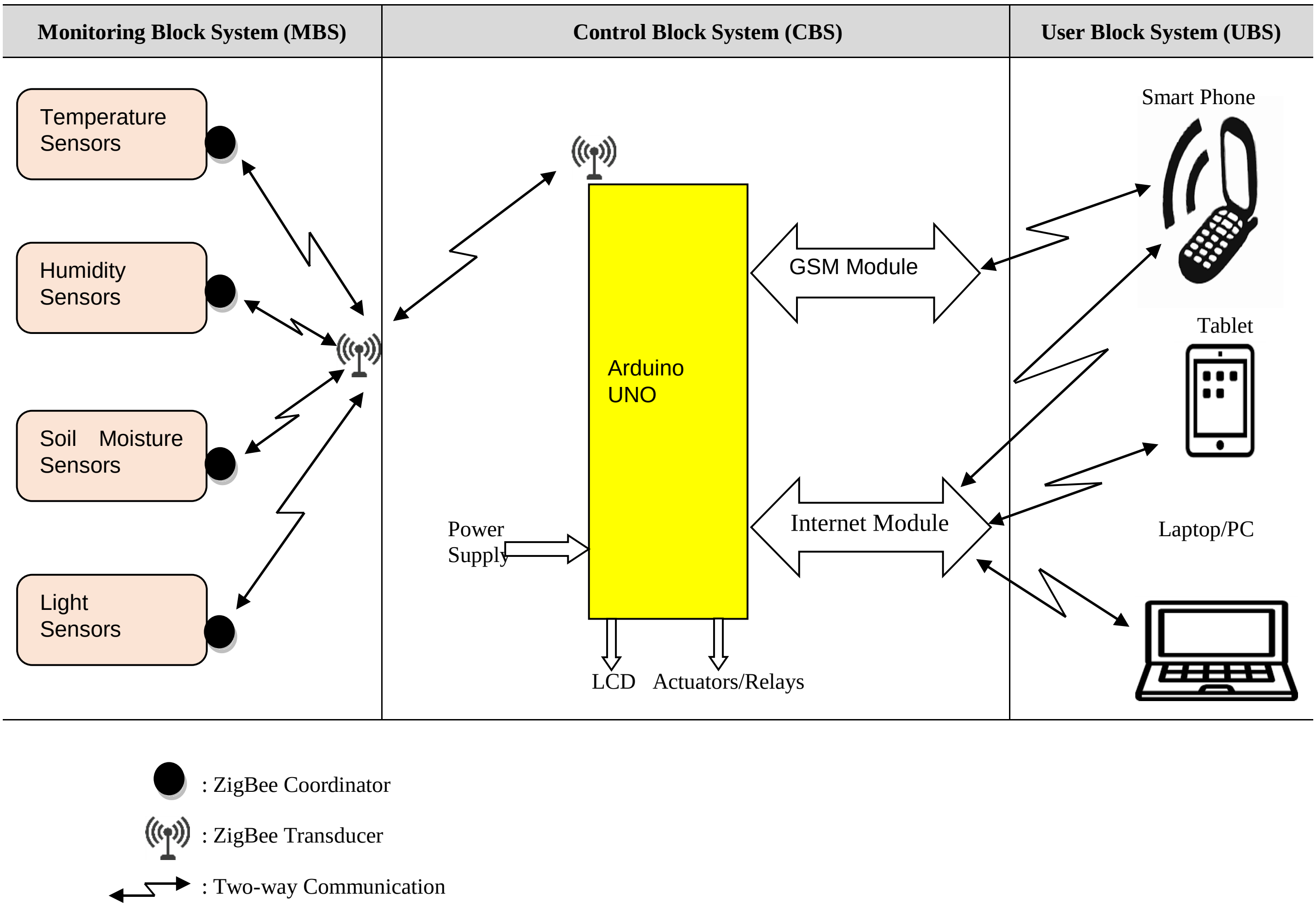

Figure 1: Functional Block Systems

A. Monitoring Block System

A cost-effective WSN is implanted in the greenhouse for instant climate monitoring. Therefore, temperature sensors, humidity sensors, soil moisture sensors and light sensors are deployed in the greenhouse area where a resilient multi-hop network is implemented for large coverage monitoring. To create a robust, self-healing and long-life monitoring network system, a low power ZigBee/IEEE802.15.4 module operating at 2.4GHz license-free Industrial, Scientific and Medical (ISM) spectrum (15) is used. The subsequent section discusses the various monitoring sensors used in this project.

a. Temperature Sensor: The LM35 sensor is implanted for temperature monitoring. This is an analog, linear temperature sensor whose output voltage varies linearly with the change in temperature. The LM35 temperature sensor is a three-terminal linear temperature sensor from National Semiconductors. It has higher precision and a wider range of linear working. It can measure temperature from -55 degrees Celsius to +150 degrees Celsius. At ordinary temperatures, it can provide ±1/4°C common precision of room temperature without the need of additional calibration or fine-tune [16].
b. Humidity Sensor: The SHT7 sensor is a single chip relative humidity and temperature sensor module but in this project, it is, only, used for monitoring greenhouse humidity conditions [17].
c. Soil Moisture Sensor: ML3 ThetaProbe Soil moisture sensor is used to monitor greenhouse soil moisture. This sensor provides reliable and accurate measurement with ±1% of soil moisture accuracy [18].
d. Light Sensor: Light dependent resistor (LDR) is a light-controlled variable resistor that is used as a greenhouse light sensor detection. The resistance of a photoresistor decreases with the rise of the light intensity. In this project, the LDR will act as the greenhouse curtain control to allow the amount of sunlight in the greenhouse. Hence, depending on the incident light intensity, the motor opens/closes the curtain and therefore control the light intensity of the greenhouse [19].

B. Control Bloc System

In this project, Arduino UNO microcontroller is used to control various actuators/relays based on sensed climate conditions of the greenhouse. There are three pumps respectively for drip irrigation, cooling and fogging system and four aero exhaust fans to control the temperature and humidity of the greenhouse. Hence, whenever an irregularity is detected in the sensed data, the corresponding actuators will be instantly switched ON/OFF to regulate the greenhouse climate conditions. The subsequent section discusses the main components of the Control System.

a. Arduino UNO: The Arduino Uno board in Figure 2 is a controller board based on ATmega328P microcontroller. It is an open source and platform independent. It is an easy-to-use hardware and software. It provides 14 digital input/output pins, 6 analog inputs, 16 MHz ceramic resonators, a USB connection, a power jack, an ICSP header and a reset button. The ATmega328P has 32KB of Self-Programmable flash program memory, 1KB of EEPROM, 2KB of SRAM and 23 programmable I/O lines. The operating voltage should be between 1.8V to 5.5V [20].

Figure 2: Arduino UNO board [20]

b. LCD display: A Liquid Crystal Display (LCD) in Figure 3 will be used to display in real-time the data from various sensors and other abnormal conditions.

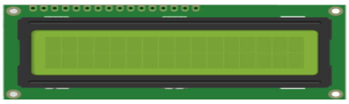

Figure 3: Arduino UNO board [21]

c. GSM Module: The GSM SIM900A module in Figure 4 will be used to send the sensed information to the cultivator/owner mobile in the form of SMS using AT commands so that appropriate actions can be triggered accordingly.

Figure 4: Simcom GSM SIM900A [21]

d. Internet Module: This module includes routers, modems among other devices used to send the collected information to the cultivator/owner smartphone, tablet or laptop/PC in the form of SMS using AT commands so that appropriate actions can be triggered accordingly.

C. User Block System

This bloc is, mainly made of mobile/smartphones, tablets and laptop/PC as human interface machine (HIM) platform. Hence, via this HIM platform, cultivator/owner of the greenhouse can trigger necessary actions based on remotely sensed data.

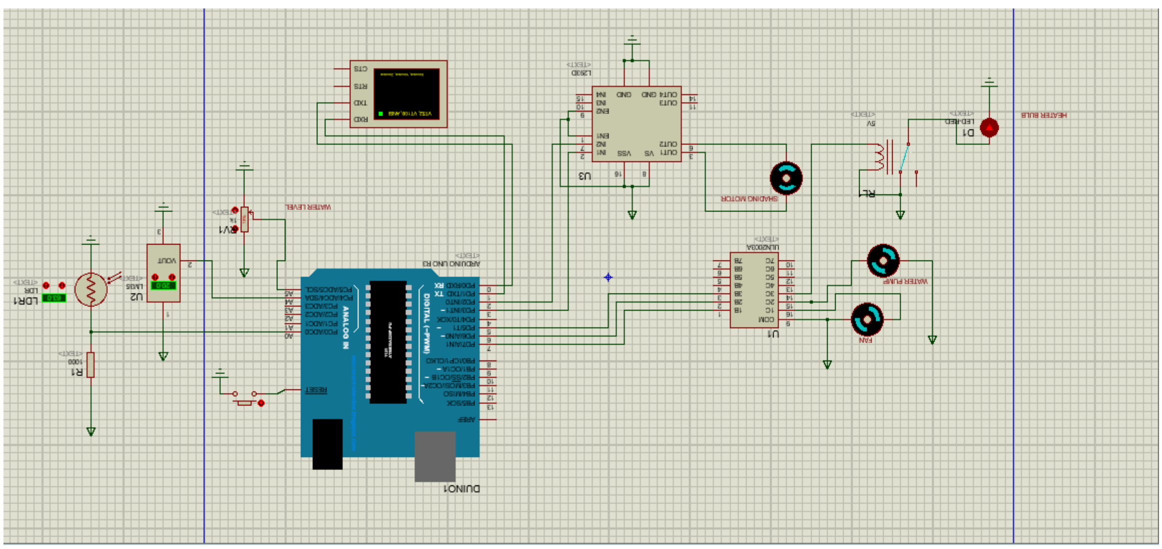

Figure 5: Block Schematic Diagram

III. Schematic Diagram

Proteus is a simulation software commonly used for digital system simulation, schematic capture, and printed circuit board design. This software is used to draw the schematic diagram of the proposed system in this project. The block schematic diagram of monitoring and control of greenhouse environment conditions is shown in Figure 5.

IV. Simulation Results And Discussion

For the system simulation, the Arduino file consisting of C++ coding is converted into (. hex) file to allow its calibration in the Proteus software.

a. Temperature Sensor Simulation and Analysis*:* To monitor the temperature, the LM 35 sensor is connected to pin PC4/ADC4/SDA of Arduino Uno (Atmega328p). For the simulation purpose, the threshold temperature is set to 20°C as in Figure 6. It is observed that when the sensed temperature is less than the fixed threshold value, the virtual terminal displays a "fan off" message and the heater are ON as in Figure 7(a). On the other hand, when the sensed temperature is greater than the fixed threshold value, the virtual terminal displays a "fan on" message and the heater is OFF as shown in Figure 7(b).

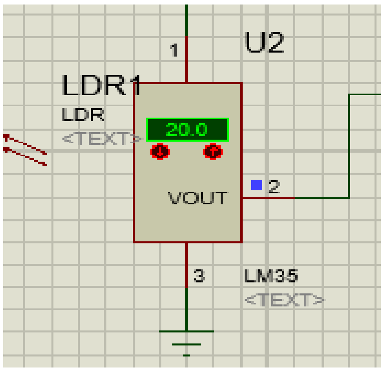

Figure 6: LM35 set to 20℃

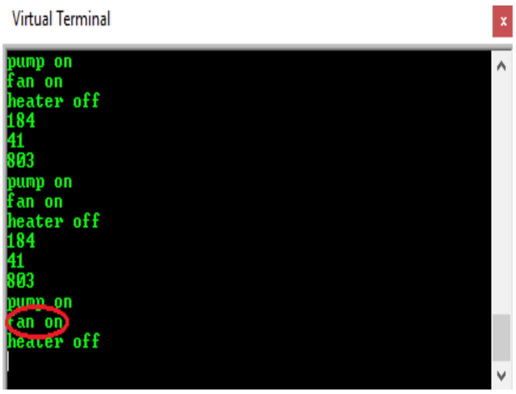

Figure 7(a): "Fan Off" and "Heater ON" Message Display

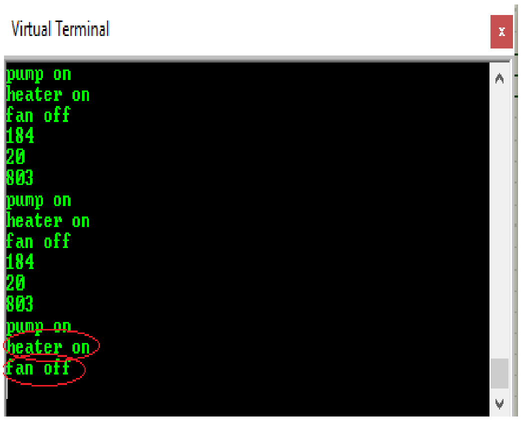

Figure 7(b): "Fan On" and "Heater OFF" Message Display

b. Soil Moisture Sensor Simulation and Analysis: In this stage, the potentiometer (Figure 8) is used to monitor the water level in the soil. The soil water threshold value is set to 40% for simulation purpose. Hence, when the water level is lower than the set value, the virtual terminal displays a "pump ON" message as in Figure 9(a). However, when the water level is higher than the set value, the virtual terminal displays a "pump Off" message as in Figure 9(b).

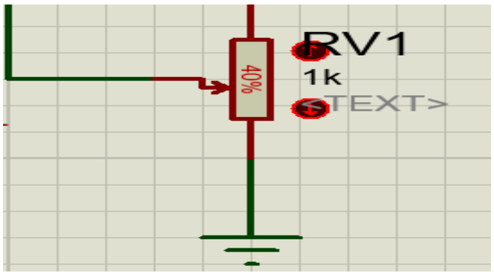

Figure 9: Potentiometer set to 40%

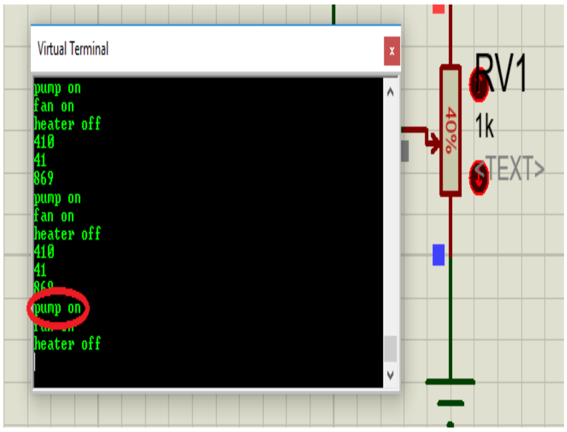

Figure 9(a): "Pump ON" Message Display

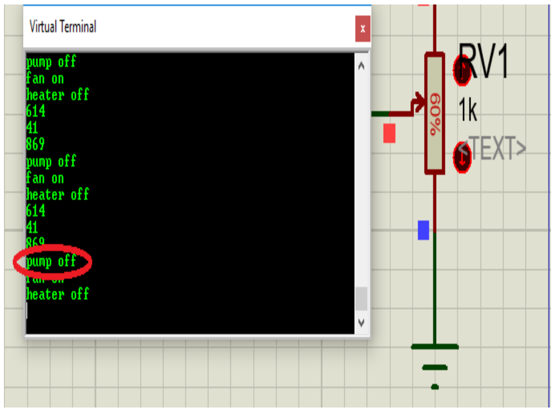

Figure 9(b): "Pump Off" Message Display

c. Light Intensity Simulation and Analysis: In this system analysis, a light dependent resistor (LDR) is used. This resistor is connected to pin PC0/ADC0 of Arduino Uno Atmega328P. The shading motor is the response unit that is being tested. Here, the threshold value is set 30% for simulation purpose. Hence, when the light intensity is lower than the set value, the virtual terminal displays a "back" message as in Figure 10(a) to move back the curtain and let the light comes inside the greenhouse. However, when the light intensity is greater than the set value, the virtual terminal displays a "forward" message as in Figure 10(b) to move forward the curtain and block the light from coming inside the greenhouse

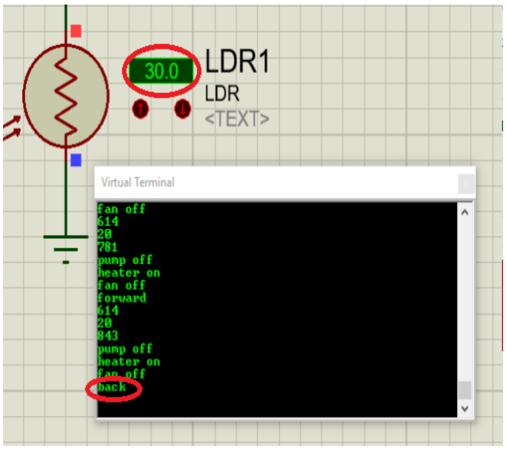

Figure 10(a): Curtain "back" Message Display

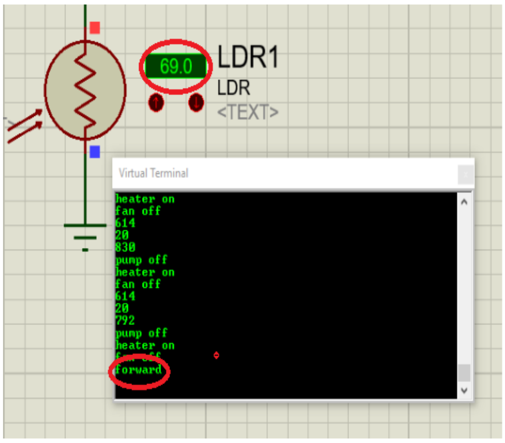

Figure 10(b): Curtain "forward" Message Display

V. CONCLUSION AND FUTURE WORK

In this project, an intelligent greenhouse monitoring and control system was developed and successfully simulated in Proteus software. This built system will help small-scale and rural agriculture to prosper as the crop growth conditions will be closely monitored and instantly controlled accordingly. Moreover, the implementation of this system means less manpower, save human energy, less field visit and people will get more leisure time. As future work, a prototype will be implemented and field test will be conducted for its validation. Finally, it is suggested to include the GPRS module in the prototype to locate the exact part of the field that needs an exceptional care.

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