AN AUTOMATED GREENHOUSE CONTROL SYSTEM USING ARDUINO

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Abstract: The world climate change has brought about unpredictable weather conditions that have resulted in the global food shortage being experienced. A possible solution to this problem will likely involve households growing a reasonable percentage of the vegetables and crops they need in a greenhouse which does not require too much land space. A greenhouse will normally produce more crops per square meter when compared to open field cultivation since the microclimatic parameters that determine crop yield are continuously monitored and controlled to ensure that an optimum environment is created. The automated greenhouse control system achieves monitoring and control of a greenhouse environment by using sensors and actuators which are under the control of a microcontroller running a computer program. The system is composed of two stations: Remote monitoring station and the Actuators/Sensors Station. The controller used in the actuators/ sensors station which ensures that the microclimatic parameters stay within pre-defined values as determined and set by the user is the Arduino prototyping platform.

The codes for the controller were written in the Arduino programming language, debugged, compiled, and burnt into the microcontroller using the Arduino integrated development environment (IDE). A scaled-down prototype of the system was built and tested. Automation of a greenhouse brings about efficient data acquisition and control of the microclimatic parameters. It also significantly reduces the labour involved in its maintenance thus making the system useful for rural farmers, small scale agriculturists, gardeners, and agricultural researchers.

Keywords: Greenhouse, Automated Agriculture, Embedded System, Arduino.

1. Introduction

Modern greenhouse technology deploys automation in agriculture which is now common place due to the low costs of electronic components required for its implementation. A lot of efforts have been made by many researchers to automate the traditional greenhouse system. In the work by Sumit et al (2012) an embedded system closely monitors the microclimatic parameters of a greenhouse round the clock and activates actuators when safe thresholds are exceeded in order to restore optimum conditions. Their design employs a Liquid Crystal Display (LCD) which is directly interfaced to a microcontroller that ensures that the user is continuously alerted about the conditions inside the greenhouse. Clearly, a system of this type can provide information to the user about the conditions inside the greenhouse only when the user is at the physical location. A Wireless Sensor Network (WSN) with smart irrigation capability is discussed by Mahmoud and Ala'a (2013). This system monitors the microclimatic parameters around each row of crops and activates appropriate pumps for irrigation when the moisture level drops below a safe threshold. The drawback of this system lies in its inability to control the other microclimatic parameters such as temperature and humidity which play a major role in the development and yield of crops. Also, the user can only view the conditions of the greenhouse at the physical location since it employs LCD. Rahali et al (2011) developed a system that is based on the Global System for Mobile Communication (GSM) that allows a greenhouse user to monitor and control the microclimatic parameters via Short Message Service (SMS). The main pitfall of the system is that the control action is not automatic; it is initiated by the user who may not always be attentive and this could have adverse effects on the crops. Two separate web-based WSN applications were respectively developed and discussed by Qiang and Ming (2008) and Mancuso and Bustaffa (2006). These systems allow a greenhouse user to monitor the conditions over the internet. Although the internet communication platform is almost always available, it requires that the accessing device such as a Universal Serial Bus (USB) MODEM should have enough download data capability which may not always be the case in developing countries.

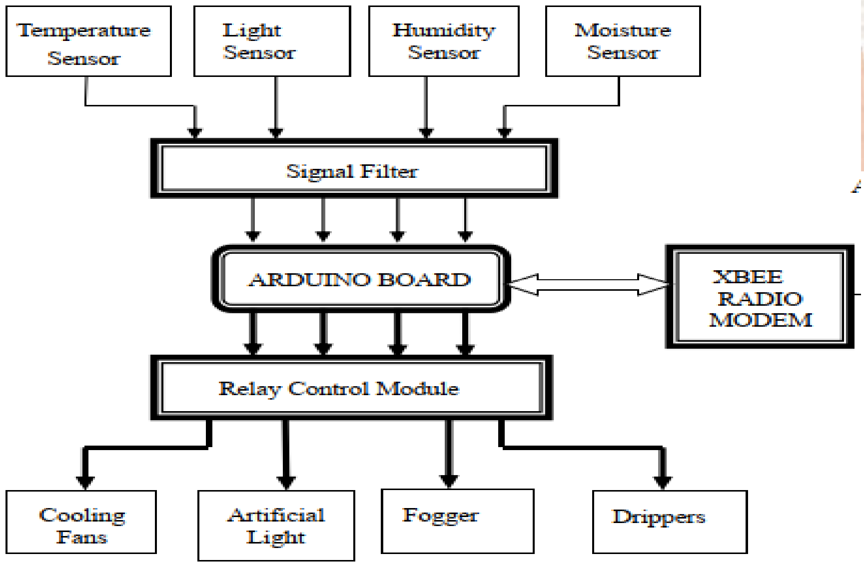
2. Materials and Methods

2.1 System Architecture

The automated greenhouse control system, whose block diagram is depicted in figure 1, is made up of Sensors/Actuators station. These units consist of sensors for light (Light dependent resistor), temperature (LM35), humidity (HIH4030) and moisture fan; Arduino microcontroller board and a personal computer (PC). The sensors/actuators station is the heart of the system that is responsible for regulating the greenhouse environment. The sensors acquire the environmental data. After the data have been filtered to remove noise they are made available to the Arduino board which then computes the current values of the controlled variables and compares them with the set thresholds. If any of the controlled variables is outside a safe limit the corresponding actuator is activated to restore the optimum condition. The Arduino board also reads the states of the actuators and transmits the information along with the current values of the controlled variables to the remote monitoring .

2.3 Automated Greenhouse Control System

The signal transmitted by the XBee at the sensors/actuators station is received and demodulated by the XBee in the remote monitoring station which then passes the information to the serial port and displays it in the terminal environment of XCTU software installed in a PC. This approach of creating a GUI requires no coding by the user and the information is still presented in a visually appealing format.



Sensor/Actuators station

Figure 1. Block Diagram of Automated Greenhouse Control System

2.4 Software Design

The control strategy for the system in this work is developed for the individual parameters to be controlled as follows:

(1) The temperature control requires the definition of two threshold limits: upper limit and lower limit. When the upper limit is exceeded a fan is activated to cool the greenhouse environment and when the temperature drops below the lower limit, the fan is deactivated while a heater is activated and vice-versa.

(2) Humidity control is defined by a threshold set by the user. When the humidity of the greenhouse enclosure falls below this threshold, a fogging system is activated and then deactivated when optimum condition is restored.

(3) The moisture control is defined by a threshold which ensures that if the soil moisture content falls below the set value drippers are activated, and then deactivated when optimum condition is restored.

(4) The lighting condition is controlled by two set points: upper limit and lower limit. The upper limit determines when the light is activated while the lower limit determines when it is deactivated. This strategy is primarily used to extend day light or compensate for inadequate natural lighting according to the desire of the user.

2.5 Program Flowcharts

The main flowchart for the program of the automated greenhouse control system is shown in figure 3. The flowcharts for the various subroutines are shown in figures 4, 5, 6, and 7. The program for the system was written in Arduino language which is actually a subset of the C/C++ programming language (Purdum, 2012). The program was written, debugged, compiled and burnt into the flash memory of the microcontroller on the board using Arduino IDE.

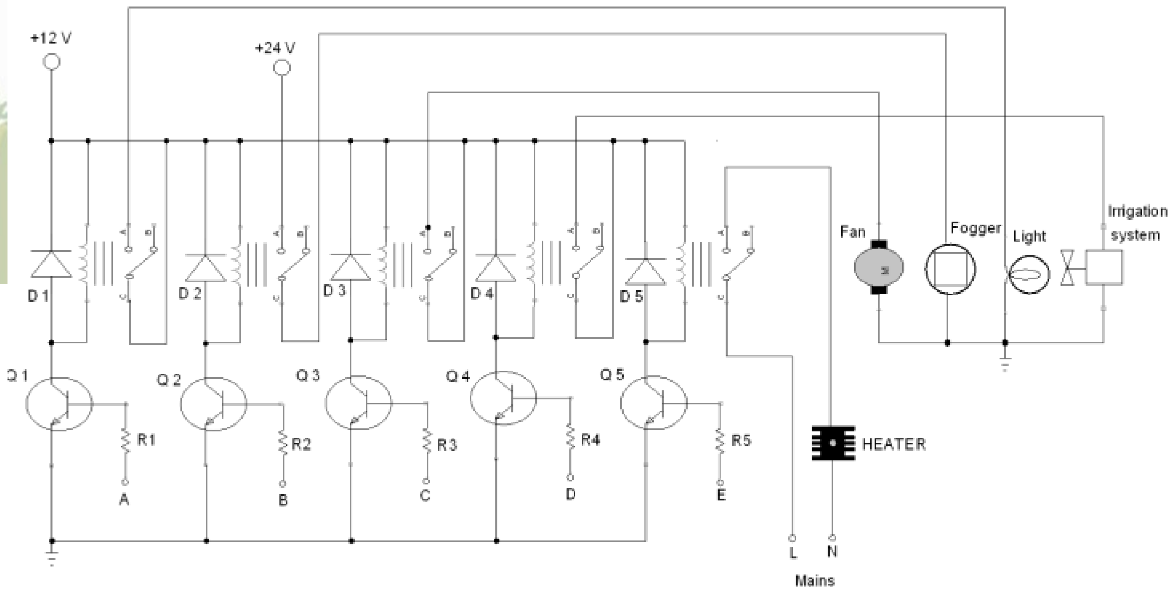


Figure 2. Schematic of Actuators Station of the Automated Greenhouse Control System

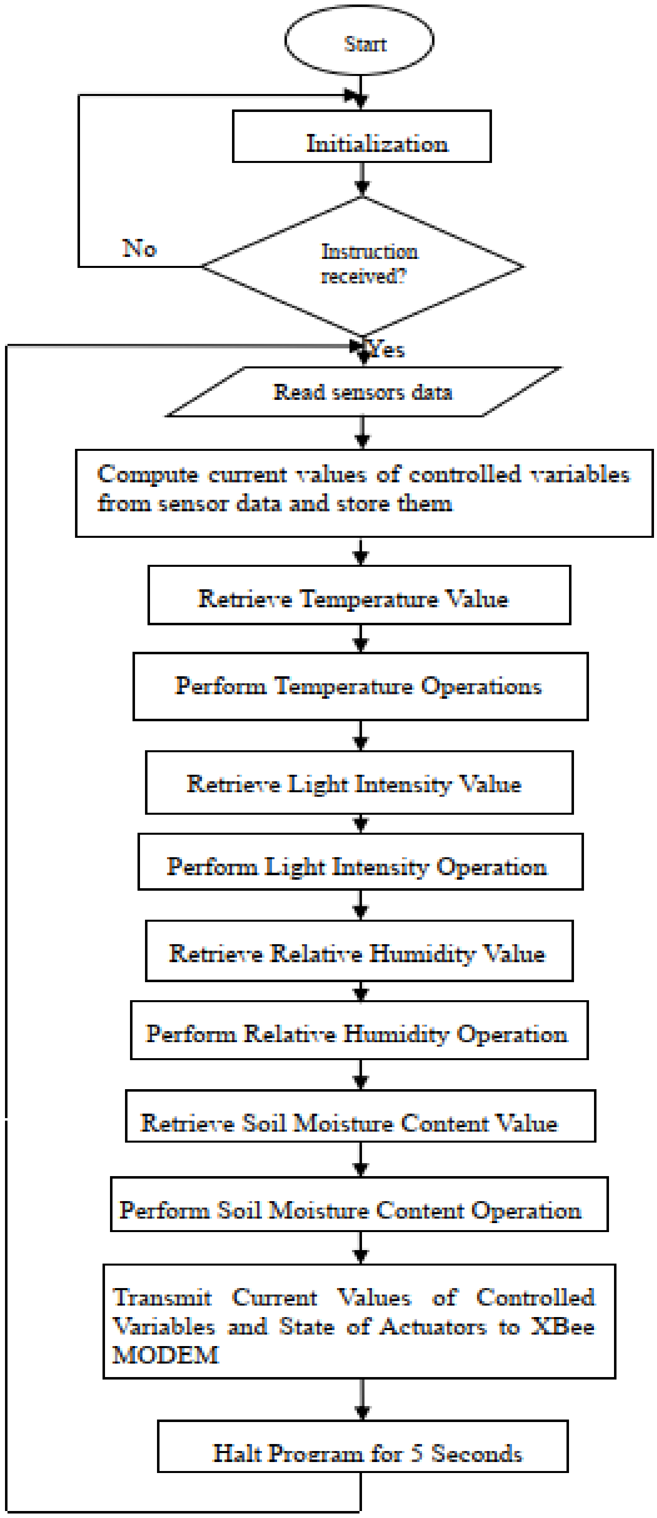


Figure 3. Main program flowchart for the Automated Greenhouse Control System

3. Results

A typical screenshot taken during program development and debugging is shown in figure 8. The top and bottom views of the system built on vero boards are shown in figures 9 and 10 respectively. The assembled system is shown in figure 11, while figure 12 shows the system mounted on a prototype greenhouse. The sensors/actuators station was set up on a bright sunny day and powered; a few seconds later the remote monitoring station started receiving and displaying information about the greenhouse conditions as shown in figure 13. The range of reliable transmission was around 40 m line-of-sight and 15 m with very thick and solid concrete walls posing as obstructions.

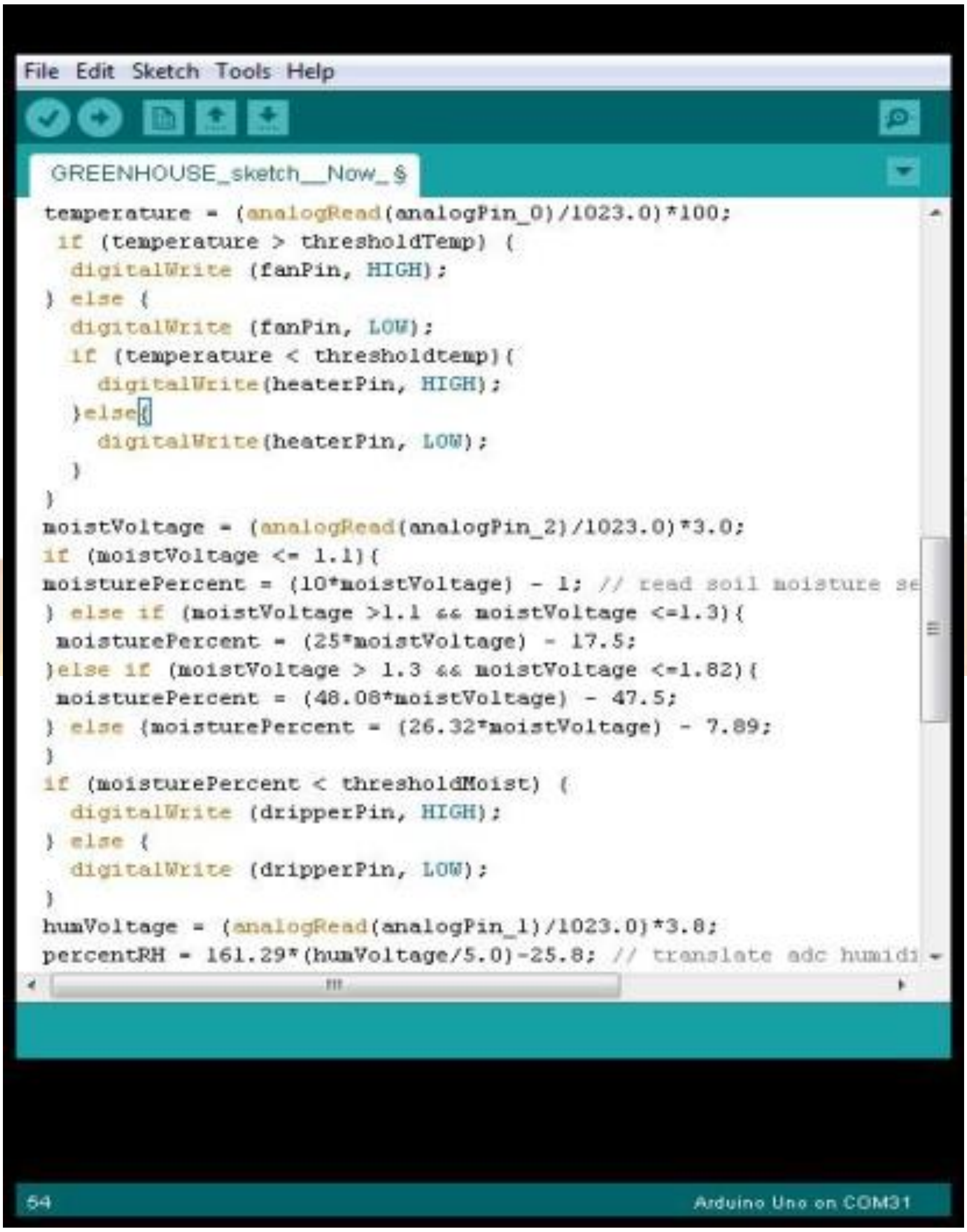


Figure 4. Typical Screenshot during Program Development

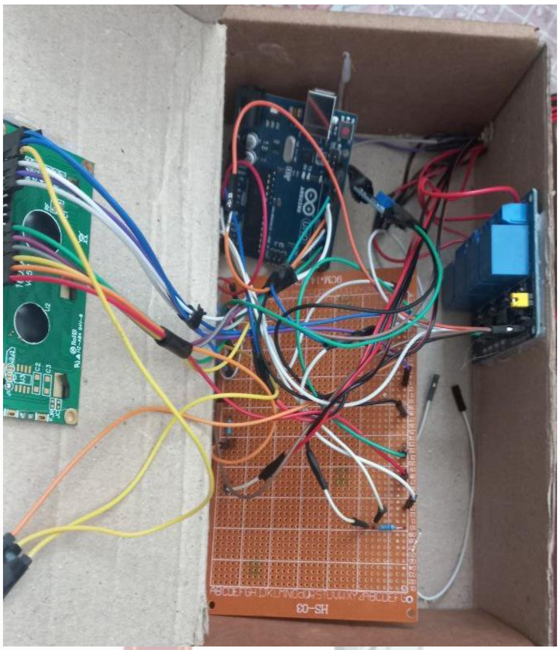


Figure 5. Top View of the System's Circuit Board

Figure 6. Prototype of Greenhouse with Automated System Mounted

4. Conclusion

The automated greenhouse control system that has been successfully designed and built is this work is meant to protect seedlings in nurseries from intruders, and also grow them to maturity should the need arise using a very small area of land as opposed to open field cultivation which may require more square meters of land to produce the same amount of crops. This system produces healthier crops since pests are usually kept away from the greenhouse enclosure. The system's reaction time to restoration of variations of microclimatic parameters suffers from a few seconds delay because of the program scan cycle and the electro-mechanical relays used. The system is fully automated as it does not require any form of adjustment from the user. The microclimatic parameters are also available at a remote terminal for the user to read and to monitor the performance of the greenhouse.

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