Advanced Automation System for Greenhouse Climate Control

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Abstract*—Although the cultivation of crops in greenhouses is considered as the best alternative to obtain quality crops, they often need constant supervising and maintenance unlike the outdoor cultivations. The best solution for this problem is to go for an automated system to monitor and control the micro climate in the greenhouse. Therefore, this research focuses on developing an advanced automation system in order to constantly monitor the crucial environmental conditions in a greenhouse and hence provide with good quality crops. The proposed system has the ability to monitor the essential factors for plant growth including the temperature, humidity, soil moisture and light intensity. In addition to that, it has a mechanism to control the above mentioned conditions using fogger systems and exhaust fans. Furthermore, a mechanism to inform the farmer constantly about the conditions happening inside the greenhouse is proposed via the Short Message Service (SMS) technology. The system was designed for a prototype structure and the experimental results obtained through the system and the analysis have shown that this automated system is very effective and suitable for home gardening and can even be extended to large scale commercial greenhouse cultivations in Sri Lanka*.

Keywords*— Greenhouse, Sensor Networks, GSM*

I. Introduction

With the rising population in the world, the demand for quality food crops rise day by day. However, the world’s cultivable land area is decreasing due to many reasons such as Industrialization, Rapid Urbanization and Pollution. In addition, not all crops can be grown in equal conditions in both tropical and non-tropical countries due to their varying climate conditions and the seasons. Therefore, off seasonal crop production under controlled climate conditions or more commonly known as greenhouse concept, is considered the best alternative to obtain optimum benefits from the available cultivable lands.

However, there are a few drawbacks of the conventional greenhouses as well. The most important of them is that they require constant monitoring, maintenance and care. As the seasonal rains will not reach the plants in the greenhouse it is required to pay a lot of attention to soil moisture levels. Therefore, it is important to constantly monitor the watering to the plants in the greenhouse which can be time consuming and even an added cost. Furthermore, the temperature of the greenhouse will also have to be monitored as it varies during different times of the year. The improper control of temperature and ventilation can lead plants to wilt or die. If the environment conditions inside the greenhouse can be automatically controlled, a lot of money and time can be saved. The concept of automated greenhouses can be considered as a solution to this problem. Using these systems, the crucial environmental factors like temperature, humidity, soil moisture etc. inside the greenhouse can be monitored and controlled continuously. Furthermore, we are able to predict the requirements for the plants for the next harvest by studying the monitoring and controlling data on the current harvest.

When considering about the situation in Sri Lanka, as in many other developing countries, the majority of the rural population is depending on Agriculture. Agriculture can be considered as the backbone of the Sri Lankan economy. The availability of adequate land and water resources and an excellent tropical climate provides a great advantage in agricultural purposes. However, the greenhouse concept in Sri Lanka is still in its initial stages and mostly in a research basis, not in a commercial basis. In addition, most of the greenhouse systems in the country belong to the conventional category. The few automated greenhouses that exist in the country belong to the private sector mostly and they use expensive equipment imported from foreign countries for the automation process. The reason for naming the system as an advanced automation system means a system which can be used as a fully automated monitoring and controlling the climate conditions of a greenhouse can be named as a step to improve the agriculture industry of Sri Lanka. It is a new approach the development of agricultural industry.

During the initial stage for research according to the data gathered from several Agricultural Centers, all of them were biased to the use of conventional methods for greenhouse cultivation process. There main problem was the cost they have to bare for the initial establishments of the greenhouse if it is fully automated. Therefore, the purpose of this research is to implement a low cost but advanced automation system to monitor and control the climate in greenhouses, which will be suitable to the tropical climate of Sri Lanka.

This paper is organized as follows. The related work is described in Section II. Section III describes the proposed system deployment scenario. Section IV describes the result analysis and conclusion. Results are presented to show the performance of the proposed system. All the future development suggestions are given in section V.

II. RELATED WORK

One research group from Philippine had proposed a WSN system based on ZigBee. There the paper had introduced the concept of ZigBee Wireless Sensor Network (ZWSN) application to the greenhouse monitoring and controlling system. The main problem they encountered through their research was that the previous researchers had used most control techniques in greenhouse regulated the environment according to the data by a sensor located in the center of greenhouse. The proposed system used the ZWSN technology and designs multiple sensor nodes to collect the data of temperature and air relative humidity inside a greenhouse. The system mainly consisted of ZWSN system and humiture monitoring center.

The team lead by Gao Qiang had designed a Web based Wireless Sensor Network management system for greenhouse [Qiang and Miang,2008]. Their main purpose was real time monitoring and controlling. Their main objective was to provide a human based and efficient platform for monitoring and control inside a greenhouse using sink node, wireless sensor nodes and wireless control nodes.

A team from India had done a research based on microclimate monitoring of the greenhouse temperature and humidity. In the proposed system WSN was based on IEEE 802.15.4 and XMesh. For network hardware equipment they had used sensor nodes which are preprogrammed in Tiny OS. They had analyzed the greenhouse crops' vapor pressure deficit (VDP), and other important climate parameters. To test the system's feasibility and judge its measurement and network performance in a real-world field situation, they had deployed it in a commercial chili-growing glasshouse.

The research done by Xu Dahua and Li Hua, they had proposed a greenhouse control system based on Agent. As they have mentioned Agent controlled system used in greenhouse is very rare [Xu and Li,2008]. They had proposed a multi agent system inside the greenhouse. The whole system was coordinated by a task scheduling center. Each Agent thread uses the different structural models according to the actual situation. They had developed a mathematical model based on the environmental parameters the greenhouse control all the data comes to the system because implementing precise computer environment was not applicable for the actual scenario.

Al-Aubidy, Ali, Derbas, Al-Mutairi, discussed about intelligent control algorithms to monitor the greenhouse system. They have proposed a fuzzy logic based control algorithm which analyses analog input values or in this case the sensor outputs in terms of logical variable that take on continuous values between 0 & 1. Furthermore, it has developed a computer program based on Visual Basic with a GUI help the user to easily monitor any greenhouse by a click of a button.

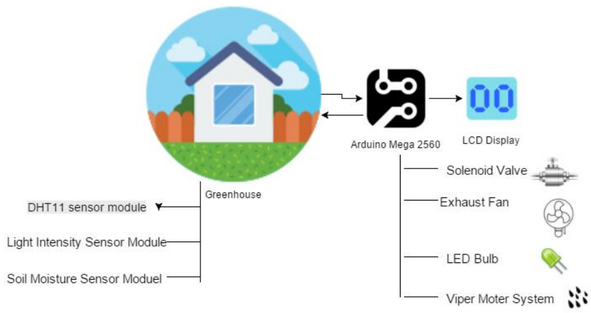

Figure 1: Overall System Design

III. PROPOSED SYSTEM

The proposed system was designed to measure the environmental conditions like Temperature Humidity, Light intensity, Soil moisture that are essential for the growth of the plants. Figure 1. Indicates the proposed system for greenhouse climate control.

The Arduino Mega 2560 board was used for the monitoring and the automation of the above parameters. The reason for choosing Arduino of this project was that it was very easy to program the necessary codes in order to gather the sensor data as well as activate the corresponding control mechanisms for each parameter. Furthermore, the Arduino board was cheaper when compared to the similar programming boards the communication between the sensors, the Arduino board and the controlling parts was done in the wired method.

Although most of the researches have used the Wireless Sensor Networks in other countries for the greenhouse automation concept, the data loss that can occur in the wireless communication is very high when compared to the wired method. The rate data loss can increase when the greenhouse cultivation is very dense. Furthermore, the cost of the sensors and other equipment needed for the system are very high if wireless sensor networks were used. This would result in the increase of the total cost of the entire system which would be an undesirable factor for the Sri Lankan approach for small scale cultivators. On the other hand, even though the wired method can be a bit messy, the data loss rate is very low and the accuracy is very high. Hence buying sensors of high cost was not needed. With a little care for the wiring system, this approach can even be extended for large scale greenhouse cultivations as well.

A. Temperature and Humidity Monitoring

Greenhouse temperature control is extremely vital. The temperature level needed by the plants differ from one type to other. The control of humidity is important to protect the plants from various diseases. The control of both humidity and temperature leads to better conductivity and movement of nutrient throughout the plant body [7]. The proposed system used DHT11 sensors to measure the temperature and the humidity.

Here, two sensors were used to measure outside temperature and the temperature inside the greenhouse. The Arduino was programmed in such a way so that if the temperature inside the greenhouse is greater that the temperature outside, the exhaust fans will turn on until the inside temperature is equal to the outside temperature. The standard temperature inside the greenhouse should be 25°C. Here for the prototype system, 4 PC fans were used.

The standard humidity content that should exist in a greenhouse is about 60%. The DHT11 sensor inside the greenhouse would measure the humidity inside the greenhouse. If the value is below the standard value, the fogger system would activate according to the program embedded to the Arduino board.

Sensors	Measured Parameter	Power Supply	Measuring Range	Accuracy	Output Signal
KY-015 Temperature and Humidity Sensor Module	Temperature	3-5.5 V DC	Temperature 0-50^{0}C	Temperature (+/-)2.0^{0}C	Digital
	Humidity		Humidity 20-90% RH	Humidity (+/-)4% RH	
FC-28-D Soil Hygrometer Detection Module	Soil Moisture	5V DC	0-1024	(+/-)2.5- 5%	Analog or Digital
Photosensitive Brightness Resistance Sensor Module	Light Intensity	3-5V DC	0-130000 LUX	(+/-) 0.12%	Analog or Digital

Table 1: Specification of Sensor Modules

B. Light Intensity Monitoring

The light condition is another important factor for the photosynthetic activity in the plants. The plants need about 10-12 hours of day light to improve growth. This increases when the plants are starting to produce fruits. Some of the common lighting systems used in greenhouse applications are High-Intensity Discharge (HID) Lamps, Fluorescent Lamps, and Incandescent Lamps. But for this prototype the LED lights were used. The light intensity sensor used in this system was the Photosensitive Brightness Resistance Sensor Module. Here, when the sensor value is above a certain threshold value, the LED lights would turn on.

C. Soil Moisture Monitoring

The soil moisture level is another important aspect for plant growth. The germination of seeds and root development depend on water availability in soil. A proper soil moisture level also makes it possible to overcome drying in critical stages of growth and hence secure good yields. Soil moisture is also critical to soil chemical processes. The

Figure 2: Irrigation System

nitrogen fixation depends on the availability of water in the soil. Therefore, soil moisture can contribute significantly to the availability of nutrients in a plant. At the current stage, the proposed system is designed only to monitor the moisture level of the soil in plant.

D. Irrigation System

The plants on the proposed system were fed with mixture of Albert solution and water which would provide the necessary nutrients. The amount of water required by one plant per day is around 500ml. However, this amount should not be fed at once because otherwise the plant would be dry for the rest of the day. Therefore, the system was designed as follows. The solenoid valve of water tank will turn on every two minutes and stay turned on for 5 minutes. After that it will be turned off for again 2 minutes. The solenoid valve of the Albert solution will turn on every two minutes. Then from the third tank the mixture will be directed to the plants through PVC pipes so that the plant gets enough water throughout the day.

IV. RESULT ANALYSIS AND CONCLUSION

The test results of the experiment were taken into considering 3 time periods; 10.00AM-12.00PM, 3.00PM-5.00PM and 7.00PM-9.00PM. Then the graphs were plotted with respect to the time axis. The soil moisture sensor indicated a higher value when the soil moisture in the plant was less. The value gets reduced when the soil moisture was increases. On the other hand, the light intensity sensor would indicate a higher value when the light intensity is high and vice versa. Here the condition control was done for the temperature and the humidity only. The other parameters were monitored but not controlled.

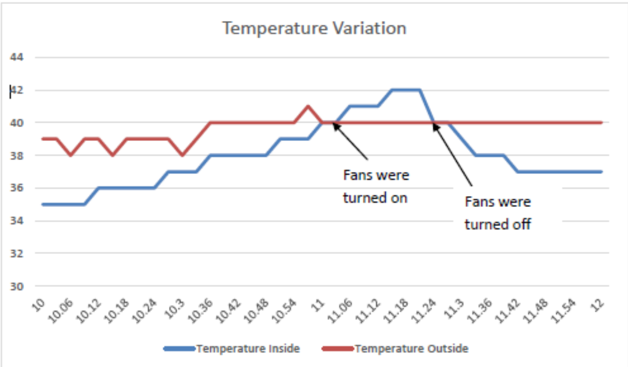

Figure 3: Temperature variation during the 10.00am -12.00pm session

In the 10.00AM-12.00PM session (Figure 3), initially the outside temperature was higher than the internal temperature. When the time passed, the internal temperature began to rise. When it went beyond the outside temperature, the fans were turned on. When the outside and inside temperatures were equal, the fans stopped working. However, the temperature did not decrease up to 25°C. This was a drawback in the system.

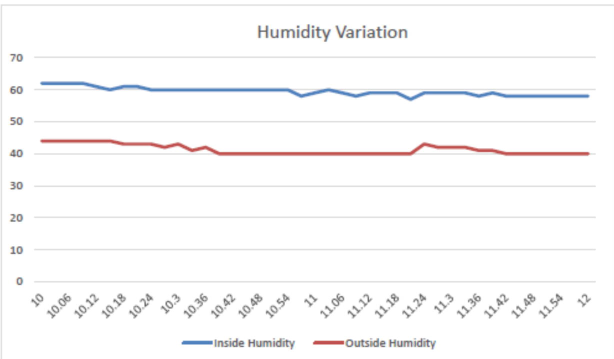

Figure 4: Humidity variation during the 10.00am -12.00pm session

Furthermore, the humidity dropped below the threshold value of 60% in a few instances and the sprinkler system turned on for approximately 6 minutes in each instance. However, the sprinkler system failed to function according to the manner that was expected. The humidity variation is indicated in Figure 4.

According to the readings of the sensors, in the session between 7.00PM-9.00PM (Figure 5), the soil moisture was lesser than the expected value. When the irrigation system started to work, the value indicated by the soil moisture sensor started to decrease which indicates that the moisture of soil is increased.

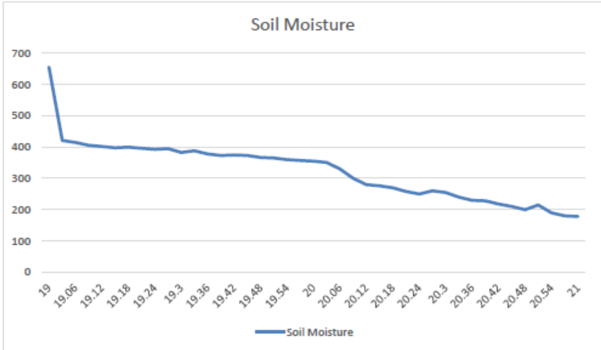

Figure 5: Soil Moisture variation during the 7.00pm - 9.00pm session

When the experiment was begun the light intensity value was below the threshold value of 800 (Figure 6). As the time passed, the value started to increase gradually.

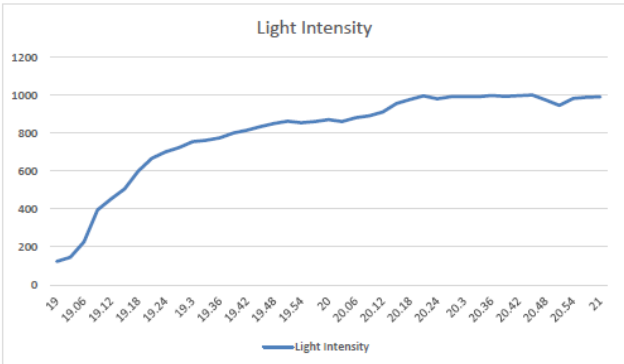

Figure 7: Light intensity variation during the 7.00pm - 9.00pm session

After the experimenting session the graphs were plotted by taking a batch of 40 readings for each time period. During the experiment for results analysis, it was observed that the automated system responds to the changing climate condition inside the greenhouse. However, there was a slight mismatch in the results obtained for the temperature monitoring and control system. In the temperature controlling system, our prototype was only able to bring the inside temperature to be equal with the outside temperature because of the heat equilibrium. It became an issue in Ratmalana area because the ideal temperature required for the crop that we selected was about 25°C and it was practically difficult to achieve in this area. As a solution we have to implement an Air Conditioning system inside the greenhouse.

Furthermore, the temperature and humidity sensor we used in this prototype had a slow responding time which was a disadvantage in collecting data. This drawback would have been eliminated by using a sensor with a higher accuracy and responding time.

On the other hand, the water Sprinkler system started to work properly when the Relative Humidity goes below the setup threshold value 60%. During the night time LED bulbs were lit when the light intensity. Hence, as a conclusion it can be stated that the process of monitoring and automating the greenhouse was conducted successfully for some extend.

V. Future Work

Next phase of the research is to implement this system in Agriculture Center in Bindunuwewa. They have given the permission for us to implement the system in one of their greenhouses. For that implementation it is necessary to develop a system to generate heat inside the greenhouse because in some seasons the temperature starts to decrease drastically at night time. Furthermore, it is necessary to develop a cooling system as the exhaust fans were not enough to cool down the system faster. Moreover, it is better to develop a feedback system by inserting a camera (CCTV) to monitor the inside system.

VI. Acknowledgment

First and foremost, we would take this opportunity to express our profound gratitude and deep regard to the academic staff, non-academic staff and the colleagues of the Department of Electronics and Telecommunication Engineering. We would also like to thank staff of the Agriculture Research Center, Kahagolla and the In-service Agriculture Research Center, Bindunuwewa for their valuable information that helped us a lot in our project.

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