Experimental Profiling of Temperature and Luminosity inside Greenhouse using Wireless Sensor Network

Suman Lata and H. K. Verma

Department of Electrical and Electronics Engineering, School of Engineering and Technology, Sharda University
suman.lata@sharda.ac.in

Abstract. Monitoring and control of climatic variables inside a greenhouse (GH) play crucial role in quality production of crops in the greenhouse (GH). Measurement and monitoring of major GH variables, such as temperature, humidity, soil moisture, light intensity and CO2 in atmosphere, has been generally carried out using a central data acquisition system to which all sensors are individually wired. This technique involves huge cabling and lacks flexibility of adding sensors in future. This paper presents a detailed methodology and results of experimental measurement and profiling (both temporal and spatial) of temperature and luminosity inside a laboratory model of GH using a wireless sensor network (WSN). For the experimental work, the GH was divided into two rows, row 1 and row 2, with three zones of equal dimensions in each row. At the centre of each zone one wireless sensor node was placed for measurement and acquisition of temperature and luminosity in that zone. A WSN was created with these six wireless sensor (WS) nodes (or motes) and one network coordinator (NC). Profiling of temperature and luminosity was carried out under uncontrolled as well as controlled environmental conditions. Two controlled conditions were created. In the first case only temperature was controlled by placing a heater at the centre of GH. The second case involves simultaneous control of temperature and luminosity, for which an incandescent lamp was placed in each zone of row 1 while all the zones of row 2 were covered with a tinted plastic sheet. Data was gathered from all the six WS nodes in each controlled case as well as in uncontrolled environment. Surface profiles of both temperature and luminosity were drawn in Lab VIEW on the basis of collaborative processing of the data. The experimental results so obtained are correlated with the expected theoretical profiles. The use of WSN and Lab VIEW for collecting and processing the data, respectively, provides remarkable flexibility in terms of addition and deletion of WS nodes. Moreover, no wiring is needed for power or signals.

Keywords— Collaborative data processing, Greenhouse variables, Profiling, Wireless sensor node, Wireless sensor network

1. Introduction

A greenhouse is a specially designed farm structure which is built to provide a favourable climate, not only for better crop production but for the crop protection also. Technically speaking a greenhouse is a complex multivariable interactive system [1] [2]. It is multivariable because there are various physical variables which affect the climate inside the greenhouse. It is interactive as the physical variables are largely interdependent. The important variables affecting the growth and productivity of plants are temperature, humidity, light, soil moisture and carbon dioxide concentration. The optimal value of greenhouse air temperature depends on the intended level of the photosynthetic activity. Each plant species has its own optimal value of air temperature. Luminosity or light intensity is another important variable for the growth of the plants. Typically 10 to 12 hours of light intensity is required
by plants for the proper growth. It has to be maintained at the desired level in order to support photosynthesis at a better rate. Every plant has different luminosity requirement which has to be maintained inside the green-house. An Intelligent Greenhouse (IGH) can collect the information related to the various variables which are affecting the production of the crop and can control them as per needs.

Various greenhouse variables are sensed by suitable sensors and the response functions are performed by actuators. Initially in IGH installations, sensors, data acquisition system and actuators were distributed and a huge effort was required to interconnect them. The installations required many data and power wires, making the system complex and expensive [3] [4]. Also the addition of new sensors in such installations was difficult. With the rapid advancements in Wireless Sensor Network (WSN), these issues have been resolved. A WSN is a collection of sensor nodes connected by wireless medium to perform the distributed sensing. Compared to the cabled systems, configuring WSN is cheap, fast and easy. Also, the relocation of the nodes is easy in it. In case of relocation of node outside the direct range of the WSN, multi-hopping is used. This paper focuses on temporal and spatial profiling of two important variables affecting the growth of the plants, namely, temperature and luminosity, inside a laboratory greenhouse. In the second section of the paper the experimental setup has been described. The third section is dedicated to the results and discussions, which are followed by conclusion.

2. Experimental Setup

2.1 Greenhouse model and WS node placement

The experiment was carried out in a laboratory model of greenhouse measuring 1.80(L) x 0.90(W) x 0.90(H) in meters and divided into six zones in 2x3 arrangement. Plywood sheets were used for partitioning as indicated by dark lines in the Fig.1. The dimensions of each zone are hence, 0.6m x 0.45m x 0.90 m. One wireless sensor (WS) node has been deployed in each zone. Nodes 1, 2 and 3 were placed in row-1 while nodes 4, 5, and 6 were placed in row-2. All the nodes have been hanged from roof at a height of 0.30 meters above from soil surface. The layout of greenhouse along with the deployment of wireless sensor nodes is shown in Fig.1.

![Fig.1. Layout of greenhouse laboratory model with node placement](image)

The wireless sensor nodes, named as SENSEnuts, were from Eigen Solutions. The nodes are battery operated and are based on PAN protocol, which enables wireless transmission of data packets over IEEE 802.15.4. SENSEnuts has an API to access the network. It works on Zigbee protocol and uses 2.4 GHz ISM band. The gateway node was located at a distance of 10 meters outside the
greenhouse and connected to a computer with USB. The top and bottom views of the gateway module are as shown in Fig.2 and those of radio module are shown in Fig.3 [5].

![Fig.2. Top and bottom views of gateway module (a) Top view (b) Bottom view](image)

2.2 Sensor Details

The temperature sensor used in SENSEnuts node is TMP102. It is a two wire digital serial-output temperature sensor available in a tiny SOT563 packaging with SMBus compatibility [5]. It is capable of reading temperature to a resolution of 0.0625°C. The device is specified for operation over a temperature range of –40°C to +125°C. Luminosity Sensor used is ISL29023. It is an integrated ambient and infrared light to digital converter with SMBus compatible interface.

2.3 SENSEnuts Graphical User Interface (GUI)

SENSEnuts GUI is a program that runs on Windows Operating System. It is used to program the SENSEnuts Radio Modules as well as display the data received from the network. The GUI is a collection of three separate programs, each performing a separate function, namely Device Programmer, SenseLive and Print Window [6]. The Default program that opens at the start of GUI is a Device Programmer. It is a tool to program the SENSEnuts nodes according to the algorithm written in C language using Eclipse IDE. It also enables the user to read the MAC address of the node connected to the computer at the USB port. SenseLive is a graphical environment that displays the data which it receives from the network. It features two separate sections, one to display the latest data coming from the nodes and the other to create a database of all the messages received from all the motes which can be saved and analysed later on. Print Window, allows the motes, to display some custom messages on the GUI.

2.4 Methodology

All the nodes were programmed to send the data simultaneously. So the temperature and luminosity data were simultaneously acquired from all the 6 nodes. The gateway node coordinated as the master device which received data from all the sensor nodes for a pre-programmed time period. Data of temperature and luminosity under following conditions was collected:

2.4.1 Under uncontrolled conditions. Under this condition the environment of the greenhouse was left unaltered. All the nodes were kept in natural atmosphere.
2.4.2 *Simultaneous control of Luminosity and Temperature.* Under this condition an incandescent lamp was placed in each zone of row 1 and all the zones of row 2 were covered with tinted plastic sheet. This arrangement is depicted in Fig.4.

![Fig.4. Depiction of simultaneous control of temperature and luminosity](image1)

2.4.3 *Temperature control alone.* Under this condition a single heater was placed at the centre of the greenhouse at 35cm height from bottom. The arrangement is depicted in Fig.5.

![Fig.5. Depiction of control arrangement for temperature control alone](image2)

3 Results and Discussion

3.1 *Profile under uncontrolled conditions*

The variations of temperature and luminosity as obtained from six sensors placed at centre of the six zones of the greenhouse with time are as shown in Fig.6 and Fig.7, respectively. The temperature line graphs indicate that the temperature inside the greenhouse is almost the same in all the zones as expected. As observed from the luminosity line graph, Sensor 1 placed in zone 1 has recorded highest luminosity as there was more natural light. Luminosity has been recorded in lux and it can be seen that the luminosity varies from zone to zone.
Fig. 6. Temperature variation with time under uncontrolled condition

Fig. 7. Luminosity variation with time under uncontrolled condition

The corresponding surface profiles of temperature and luminosity are shown in Fig. 8 and Fig. 9 respectively. The X coordinate is the horizontal distance of the sensors which is 0.30 and 0.90 and 1.50 meters, Y coordinate is the vertical distance at which sensors are placed which is at 0.225 and 0.675 meters from the door. Z coordinate shows temperature / luminosity obtained from the sensors. For plotting the spatial profile linear extrapolation has been used unless mentioned otherwise. The surfaces profile of temperature shows a flat profile which indicates that the temperature is almost the same in all zones of GH. The surface profile of luminosity shows a conical shape, which indicates that the luminosity data obtained is not equal from all the sensors. It varies in zones. The peak in the profile was corresponding to very high value of luminosity obtained from sensor of zone 1.
3.2 Profile under simultaneous control of Luminosity and Temperature

The line graphs showing the variation of temperature with respect to time inside the greenhouse for
row-1 zones and row 2 zones is shown in Fig.10. The surface profile for it is shown in Fig.11. The line graph and surface profile of luminosity inside the greenhouse is as shown in Fig.12 and Fig.13, respectively. Luminosity values measured by the sensor have been extended up to the nearest wall as the row -2 sensors were covered by opaque sheet while plotting the surface profile. The luminosity recorded by sensor nodes 4, 5 and 6 was very low and no significant increase in temperature was seen.

![Fig.10. Temperature variation with time measured by row-1 and row 2 sensors under simultaneous control](image1)

![Figure 11: Surface profile of temperature at 10:30 a.m. under simultaneous control](image2)
The sensors placed in row-1 recorded very high luminosity as well as the temperature. Highest recorded luminosity in row 1 was 25069 Lux from sensor placed in zone 2. Highest recorded luminosity in row 2 was 134 lux from sensor placed in zone 6. For zones of row 1 temperature was very high and varied with change in luminosity. Highest temperature recorded was 62°C from sensor placed in zone 2. Thus it can be seen the sensor which recorded highest luminosity also recorded highest temperature. For zones of row 2 temperature remained constant at 35°C with small variations initially. There was increase in average temperature inside GH. It means, with incandescent lamps, there was an increase in the luminosity which also resulted in increase in the temperature.
3.3 Profile under temperature control alone

The line graphs of the temperature and luminosity under this condition are shown in Fig. 14 and Fig. 15 respectively.

**Fig. 14. Temperature (with heater) variation with time under temperature control only**

![Graph showing temperature variation over time with different sensors.]

**Fig. 15. Luminosity variation with time under temperature control only**

![Graph showing luminosity variation over time with different sensors.]

The surface profile of temperature and luminosity under this arrangement of control is as shown in Fig. 16 and Fig. 17, which revealed that the average temperature inside the greenhouse increased as compared to uncontrolled condition.
4. Conclusion

Measurement and profiling of the temperature and luminosity inside the experimental greenhouse have been done successfully using WSN. The profiling of each variable has been carried out in both temporal and spatial domains. To ensure correct profiling, data from all the node were acquired...
simultaneously (by avoiding any intentional time delay in reading two successive nodes). Collaborative data has been used for visualization of the profiles. Use of WSN for collecting the physical variables inside greenhouse provides remarkable flexibility in terms of addition and deletion of WS nodes. Also, no effort is required to connect the sensors and data acquisition systems in WSN. The LabVIEW, used here for data acquisition and collaborative processing, offers the advantages of graphical programming and multitude of functions for visual presentation of data.

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