ISSN 1808-3765

DESIGN OF A WIRELESS SENSOR NETWORK FOR GREENHOUSES TEMPERATURE ANALYSIS

ROGÉRIO ZANARDE BARBOSA[1] AND JOÃO EDUARDO MACHADO PEREA MARTINS [2]

[1] *Faculty of Higher Education and Integral Formation (FAEF), 17400-000, Garça-SP, Brazil. E-mail: rogeriozanarde@gmail.com.*
[2] *Computer Science Department, School of Sciences (FC), São Paulo State University (UNESP), 17033-360, Bauru-SP, Brazil. E-mail: perea@fc.unesp.br.* Orcid iD https://orcid.org/0000-0003-1056-497X

1 ABSTRACT

This work presents a wireless sensor network designed with fifteen temperature sensors to monitor this parameter variation inside a greenhouse, where all temperature values were transmitted by radio to a distant computer that records it into a database that allows a detailed temperature analysis. The results showed that the network operated efficiently in the greenhouse and allows more accurate definitions relative to the optimal sensor locations for extreme temperatures verification, and also allow a precise description of temperature variation over time.

Keywords: WSN, climate, temperature, sensors

BARBOSA, R. G. AND PEREA MARTINS, J. E.M.
PROJETO DE UMA REDE DE SENSORES SEM FIO PARA ANÁLISE DA TEMPERATURA EM CASAS DE VEGETAÇÃO

2 RESUMO

Este trabalho apresenta uma rede de sensores sem fio, projetada com quinze sensores de temperatura para monitorar a variação deste parâmetro dentro de uma estufa, onde todos os valores de temperaturas foram transmitidos por rádio para um computador remoto, no qual foi gravado um banco de dados para permitir uma análise detalhada deste parâmetro. Os resultados mostraram que a rede operou eficientemente na estufa e permite precisas definições relativas às localizações ótimas dos sensores para a verificação de temperaturas extremas e também permite uma descrição precisa da variação de temperatura ao longo do tempo.

Palavras-chave: RSSF, clima, temperatura, sensores

3 INTRODUCTION

The weather influences directly the agricultural production and the temperature is crucial parameter for plants development (ÇAKIR and SAHIN, 2015), which justifies efforts to improve techniques for its measurement. In this context, the Wireless Sensor Networks (WSN) compose an efficient technological tool that can perform

Recebido em 10/03/2018 e aprovado para publicação em 10/09/2018
DOI: http://dx.doi.org/10.15809/irriga.2018v1n1p132-138

real time monitoring into a specific area and provide information to compose a data base with for researches, irrigation and decision-making (WANG; DAMEVSKI and CHEN, 2015).

A WSN is composed by a set of electronic sensing nodes spatially distributed over an area to measure one or more physical parameter (SRBINNOVKA et al., 2015). Each node is basically composed by one or more sensors, a processor, a radio transmitter and a power source, which design philosophy is focused on small size and low power consumption (KHAN, 2015). The nodes can exchange information with neighboring nodes in a range that can reach hundreds of meters or even few kilometers, and all this occurs without the use of electric cables, which creates an ideal model for agricultural environments.

Ferentinos et al. (2017), Akkas and Sokullu (2017) and Prabhu (2014), are typical examples of work where WSN are used to monitor weather parameters in greenhouses, which can be directly related to pests, diseases, production and management, These works are important to demonstrate the WSN, but, curiously, Zou et al. (2017) monitored the temperature inside green houses to create a mathematical model of estimation, however, this experiment could be facilitated by employing a wireless sensor network to monitor the local parameters.

The referenced works are selected examples of the Wireless Sensors Networks potential for agriculture, which justifies efforts in this subject improvement.

4 MATERIAL AND METHODS

Figure 1 shows the symbolic structure of the wireless sensor network (WSN) designed and mounted in this work, which had two *sensing nodes* that receive the signal from up to eight sensors and then sent the data to a node called the *coordinator*, which transfer all the data to a personal computer.

Figure 1. The Wireless Sensor Network logic structure.

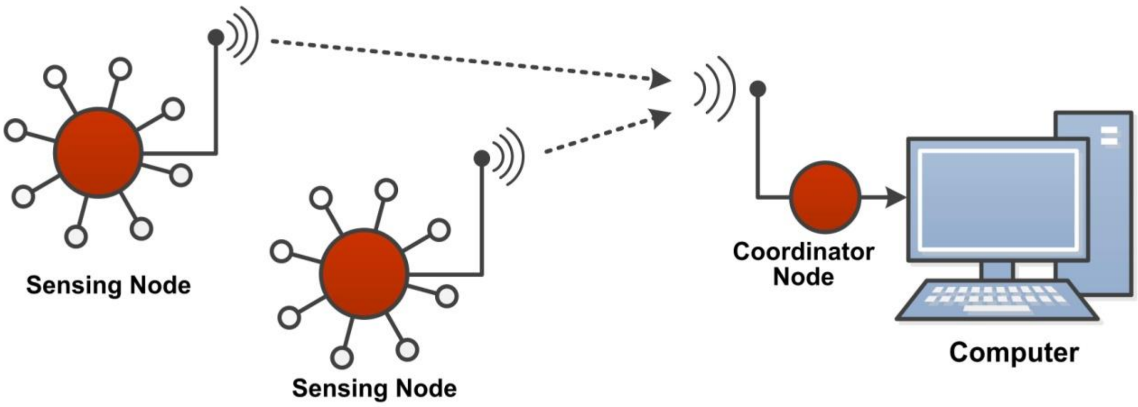
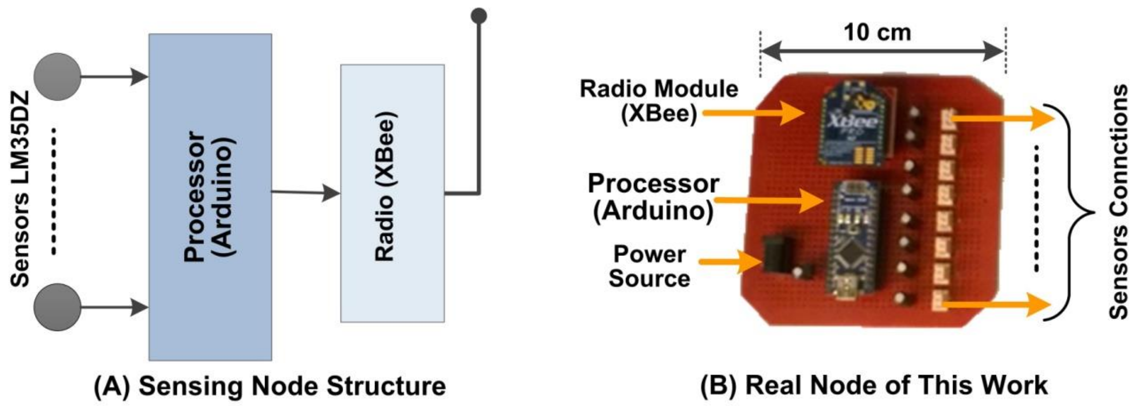


Figure 2 shows that each network sensing node was designed with sensors, a processing device and a radio communication module and operates with few electronic components, ensuring a small size low power consumption.

Figure 2. Structure and photo of a network sensing node.



The LM35DZ was the temperature sensor used, which has low cost, linear output signal with a sensitivity of 10mV/ºC and measuring range up to 100 ° C. Its accuracy that represents the maximum difference between the measured and the real temperature value is 1.5°C and, therefore, tests were carried out during fifteen days to verify the accuracy of each sensor. Each test measured the ambient temperature thirty times consecutively and the mean value was compared with a calibrated sensor. It computed a correction factor value for each sensor, which was later used to ensure a more accurate measurement in the greenhouse.

The radio module used operated with the ZigBee communication protocol (IEEE 802.15.4), where each radio module can be configured by software to operate as network coordinator, router or simple end device. The model used was XBee Pro S2B which has a transmission range of 1.6 km and can ensure a very good sensors spreading for a greenhouse monitoring.

The processing device used was the Arduino Nano that can connect up to eight LM35DZ sensors through its analog inputs that has 10 bits of resolution and can detect minimum signals variations of 5mV and, and therefore is able to catch signals variations relative of 0.5°C from the sensor. Besides, it presents of low cost and small physical dimensions.

The figure 3 shows the greenhouse used in this work, with the sensors already installed. The house was an arch ceiling type with 8 meters wide, 16 meters long and 4.0 meters of height. It was positioned in the East-West direction and built with steel structure arches and reinforced concrete posts. The sides were coated with an anti-aphid protection and low density polyethylene cover. The inner floor was coated with a white polyethylene protection and the outside floor of the floor without vegetation cover. Its location is in Garça city (SP, Brazil) with geographic coordinates at 22°12'38" south latitude and 49°39'22" west longitude, with an altitude of 683 meters.

Figure 3. The greenhouse with the installed sensors.

Figure 4 shows the mounted sensor structure, which was fixed under a plastic plate with an internal Styrofoam layer, which protected the sensor from the direct incidence of solar radiation and keeping it in the shade according to standards for temperature measurement.

Figure 4. Details and photo of the sensing structure with the LM35DZ.

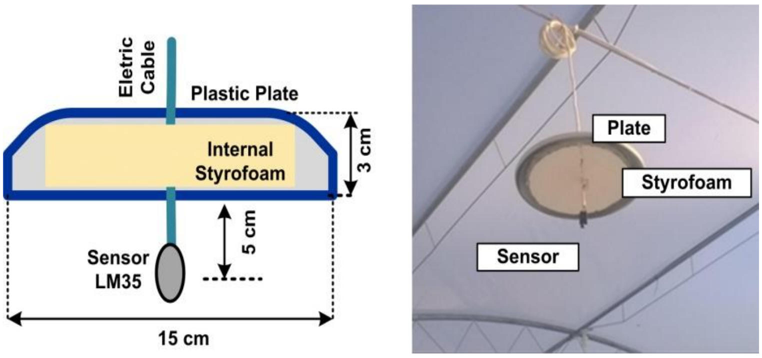
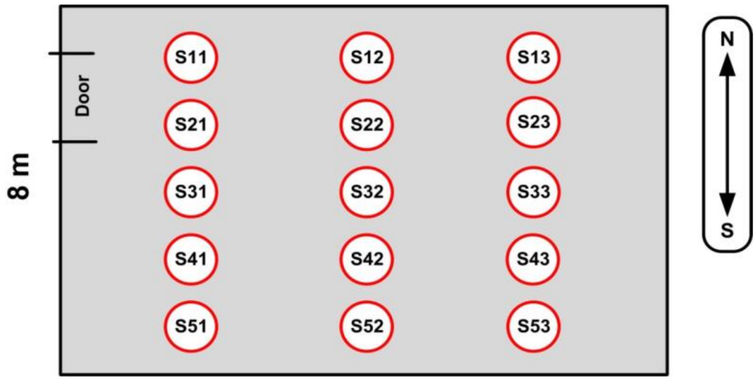


Figure 5 shows the sensors positioning in the greenhouse, which follows a matrix structure, forming a mesh where each sensor is named "S*ab*", where "*a"* is its row and "*b*" its column. The sensors were fixed at 1.7m height and symmetrical intervals along the vertical and horizontal axes.

Figure 5. Sensors positioning inside the greenhouse.

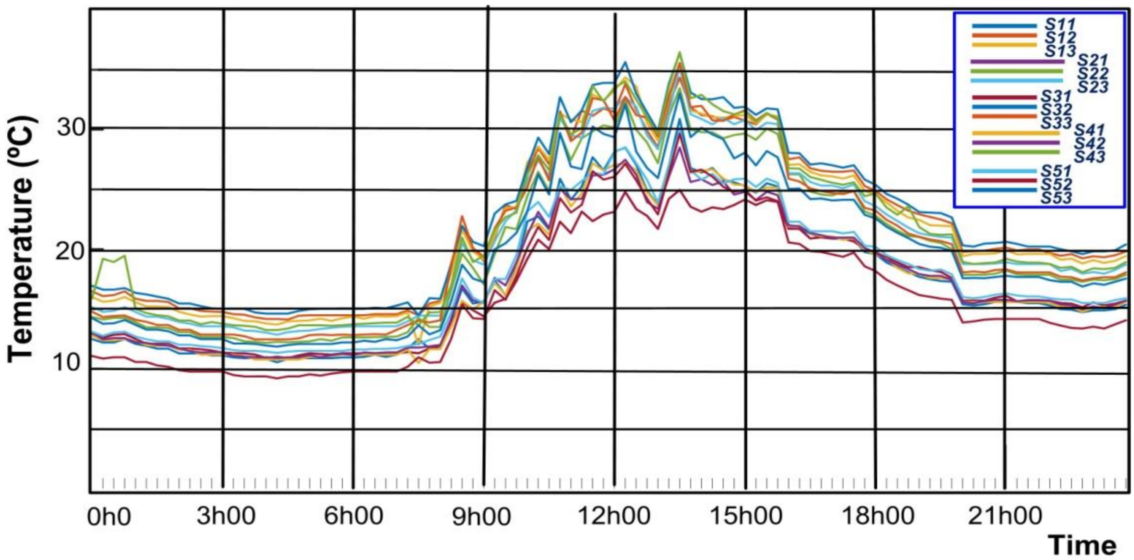


The work methodology was based on the temperature measurement in the greenhouse every fifteen minutes with an immediate data transmission for a computer where the data were recorded into a specific data base. This work includes the development of software to run on the Arduino board to perform de sensor data acquisition and its transmission, and another software to run on a personal computer, which receives the temperature data serially, organizes this data according to the sensor and then updated the database.

5 RESULTS AND DISCUSSION

Figure 6 shows the temperature variation measured with the 16 sensors in a 24 hours period on September 6, 2015, with sun rose at 6h22m and set at 18h08m, with a period of 11h42m.

Figure 6. The temperature variation in the greenhouse.



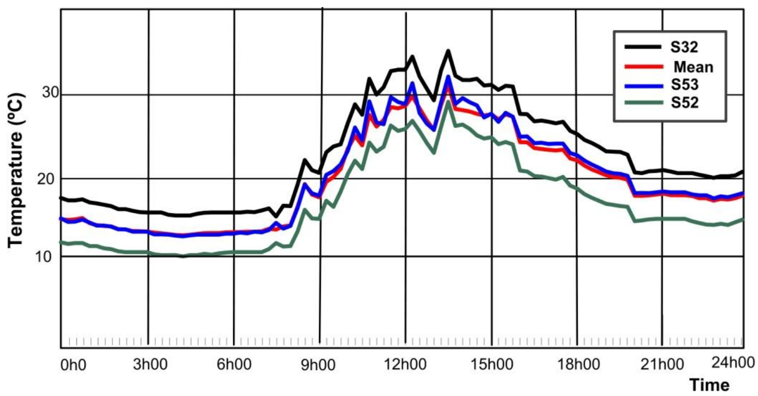
It was initially observed that all the sensors curve follow the same trend of temperature variation, which was an expected behavior and, therefore, demonstrates a coherence of the electronic measurement system.

At the beginning of the measurements, the S43 sensor shows a temperature peak where it abruptly varied at about 4°C and returned to its original value. Note that all other sensors, including the closest sensors, didn't present peaks, and therefore it can be interpreted as an electronic measurement fail. It demonstrates the importance of two or more sensors usage in the measurement process

At 13h00, all sensors present a decreasing temperature peak, where all temperatures fall abruptly and then returns quickly to their previous value. This collective behavior indicates that there was the influence of some external factor, such as opening doors, people moving or airflow. It is important to demonstrate that the exclusive maximum and minimum temperature measurement inside a greenhouse may provide inaccurate information in case of undesired peaks occurrences, and therefore the extreme values must be recorded in coherence with the temperature variation trend. Remember that there are phenomena, such as evapotranspiration, that can require extremes values to their computation.

Figure 6 shows a significant temperature variation at the sensing points inside the greenhouse, and therefore the definition of a position that best represent the general greenhouse temperature can be a critical issue. Figure 7 shows the highest temperature records (sensor S32), the lowest (sensor S52), the mean and the sensor closest to the mean value (S53). Therefore, these sensors position becomes a reference for the definition of measuring points inside the greenhouse.

Figure 7. Extreme and mean temperature values.



The figure 7 curves data were recorded with a wireless sensor network ant it proves that the network is an efficient process to indicate the best sensor positioning inside the greenhouse. After this definition the sensor network can be replaced for a few sensors number that can provide more accurate data due to their selective positioning. For the same greenhouse, the best sensors positioning can change throughout the year as a function of the climatic seasons or crop characteristics, however the analysis process with the sensor network can be repeated only at new stage beginning to redefine the best sensor positioning, and therefore a greenhouse regular map for sensors position can be defined with few experiment repetitions during the year.

6 CONCLUSIONS

The use of a wireless sensor network for temperature monitoring in greenhouses has proved to be an efficient technique for the generation of temperature data base that allows several analyzes on this parameter.

The exclusive record of only extreme maximum and minimum temperature values inside a greenhouse can produce inaccurate information due to possible occurrences of transitory and quick temperature that don't represent the effective temperature trend variation. The temperature may vary significantly within the greenhouse, and therefore the sensor network can be a powerful technique to define the best positioning for a temperature monitoring with few sensors.

7 ACKNOWLEDGEMENTS

Authors thank to the CNPq (Brazilian National Council for Scientific and Technological Development) for granting a doctoral scholarship to the first author, and to FAEF faculty in Garça city, SP Brazil, for the greenhouse loan.

8 REFERENCES

AKKAS, M. A.; SOKULLU, R. An IoT-based greenhouse monitoring system with Micaz motes, **Procedia Computer Science**, Amsterdam, v.113, p.603-608, 2017.

ÇAKIR U.; SAHIN E. Using solar greenhouses in cold climates and evaluating optimum type according to sizing, position and location: A case study, **Computers and Electronics in Agriculture**, Amsterdam, v. 117, p. 245-257, 2015.

FERENTINOS, K. P.; KATSOULAS, N.; TZOUNIS, A.; BARTZANAS, T.; KITTAS, C. Wireless sensor networks for greenhouse climate and plant condition assessment, **Biosystems Engineering**, Amsterdam, v.153, p. 70-81, 2017.

KHAN, I.; BELQASMI, F.; GLITHO, R.; CRESPI, N.; MORROW, M.; POLAKOS, P. Wireless sensor network virtualization: early architecture and research perspectives. **IEEE Network**, New York, v. 29, n. 3, p. 104-112, 2015.

PRABHU, S. R. B.; DHASHARATHI, C. V.; PRABHAKARAN, R.; KUMAR, M. R.; FEROZE, S. W.; SOPHIA, S. Environmental monitoring and greenhouse control by distributed sensor Network. **International Journal of Advanced Networking and Applications**, Tamil Nadu, v. 5, n. 5, p. 2060, 2014.

SRBINOVSKA M.; GAVROVSKI C.; DIMCEV V.; KRKOLEVA A.; BOROZAN V. Environmental parameters monitoring in precision agriculture using wireless sensor networks, **Journal of Cleaner Production**, v. 88, n.1, p.297-307, 2015.

WANG, J.; DAMEVSKI K.; CHEN H. Sensor data modeling and validating for wireless soil sensor network, Amsterdam, **Computers and Electronics in Agriculture**, Amsterdam, v.112, n.1, p.75-82, 2015.

ZOU, W.; YAO, F.; ZHANG, B.; HE, C.; GUAN, Z. Verification and predicting temperature and humidity in a solar greenhouse based on convex bidirectional extreme learning machine algorithm, **Neurocomputing**, Amsterdam, v. 249, p. 72-85, 2017.