Design and Development a Control and Monitoring System for Greenhouse Conditions Based-On Multi Agent System

Seyed Hamidreza Kasaei
Young Researchers Club, Isfahan Branch (Khurasgan), Islamic Azad University,Isfahan, Iran
H.Kasaee@khuisf.ac.ir

Seyed Mohammadreza Kasaei
Young Researchers Club, Isfahan Branch (Khurasgan), Islamic Azad University,Isfahan, Iran

Seyed Alireza Kasaei
Young Researchers Club, Isfahan Branch (Khurasgan), Islamic Azad University,Isfahan, Iran

Abstract

The design of a multi-agent system for integrated management of greenhouse production is described. The model supports the integrated greenhouse production, with targets set to quality and quantity of produce with the minimum possible cost in resources and environmental consequences. In this paper, we propose a real time and robust system for monitoring and control of the greenhouse condition which can automatically control of greenhouse temperature, lights, humidity, CO2 concentration, sunshine, pH, salinity, water available, soil temperature and soil nutrient for efficient production. We will propose a multi-agent methodology for integrated management systems in greenhouses. In this regards wireless sensor networks play a vital role to monitor greenhouse and environment parameters. Each control process of the greenhouse environment is modeled as an autonomous agent with its own inputs, outputs and its own interactions with the other agents. Each agent acts autonomously, as it knows a priori the desired environmental set-points. Many researchers have been making attempts to develop the greenhouse environment management system. The existing environment management systems are bulky, very costly and difficult to maintain. In the last years, Multi Agent Systems and Wireless Sensor Networks are becoming important solutions to this problem. This paper describes the implementation and configuration of the wireless sensor network to monitor and control various parameter of greenhouse. The developed system is simple, cost effective, and easily installable.

Keywords: Multi Agent System (MAS), Environment Monitoring System (EMS), Greenhouse Environment, Embedded System, Wireless Sensor Networks (WSN)

1. Introduction

Biological systems in artificial environments consist of complex, not exactly defined, interacting processes. Those systems are usually treated with optimal control strategies that are applied separately to each process and not to the entire system as a whole.

The most important factors for the quality and productivity of plant growth are temperature, humidity, light and the level of the carbon dioxide. Continuous monitoring of these environmental variables gives information to the grower to better understand, how each factor affects growth and how to manage maximal crop productiveness [1, 2].

The optimal greenhouse climate and soil adjustment can enable us to improve productivity and to achieve remarkable energy savings [3]. In the past generation greenhouses it was enough to have one cabled measurement point in the middle to provide the information to the greenhouse automation system. The system itself was usually simple without opportunities to control locally heating, lights, ventilation or some other activity, which was affecting the greenhouse interior climate.

This all has changed in the modern greenhouses. The typical size of the greenhouse itself is much bigger what it was before, and the greenhouse facilities provide several options to make local adjustments to the lights, ventilation, heating and other greenhouse support systems. However, more measurement data is also needed to make this kind of automation system work properly. Increased number of measurement points should not dramatically increase the automation system cost. It should also be possible to easily change the location of the measurement points according to the particular needs, which depend on the specific plant, on the possible changes in the external weather or greenhouse structure and on the plant placement in the greenhouse [1-5].

MAS and WSN can form a useful part of the automation system architecture in modern greenhouses.

This paper is organized as follows. First we will describe the context of Multi Agent Systems, Wireless Sensor networks and their applications in monitoring and control of the greenhouse climatic conditions. Then we provide a description of the system architecture. After, we will describe the benefits of using this architecture. Finally, we will present some technical details and concludes.

2. Multi Agent Systems (MAS)

Multi-agent systems have been used in a wide range of applications, like control issues in robotics, distributed systems in telecommunications, intelligent e-commerce systems, artificial intelligence applications, etc. Recently MAS have also been used in biological and agricultural applications. In artificial intelligence, an intelligent agent (IA) is an autonomous entity which observes through sensors and acts upon an environment using actuators and directs its activity towards achieving goals [6]. Intelligent agents may also learn or use knowledge to achieve their goals. They may be very simple or very complex. Multi agent systems are based on the general concept of distributed processing.

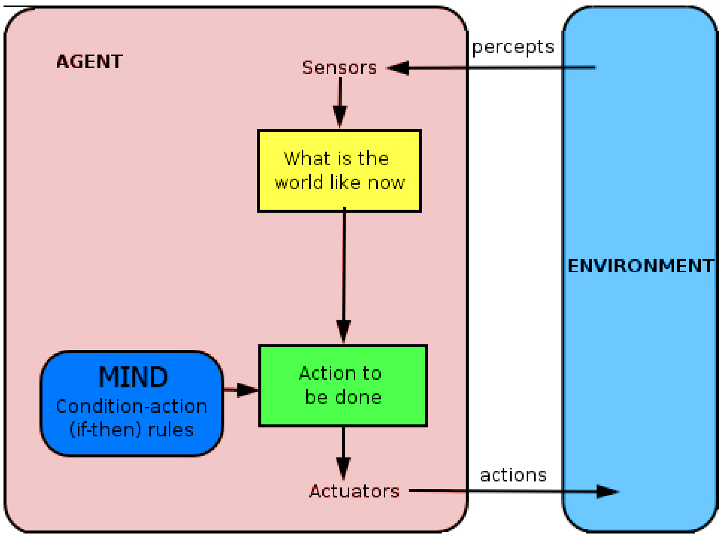

Figure 1. Agent Architecture

The multi agent method creates a non-structured environment using agents, these agents, in order to reach the global optimum, must be capable of performing transactions between each other, achieving several "deals", which is performed though a common vocabulary, a finite set of information exchange, a finite set of possible actions, penalties, etc. The power of each agent depends on the degree of contribution of its represented process to the final output of the entire system. Each agent communicates with the environment and adapts to its own internal state as well as to the state of the entire system. In this systems, for the realization of the multi agent architecture the JADE 4.1.1 (Java Agent DEvelopment Framework) have been used [7].

3. Wireless Sensor Network (WSN)

In the past generation greenhouses it was enough to have one cabled measurement point in the middle to provide the information to the greenhouse automation system. The system itself was usually simple without opportunities to control locally heating, lights, ventilation or some other activity, which was affecting the greenhouse interior conditions. This all has changed in the modern greenhouses. Wireless communication can be used to collect the measurements and to communicate between the centralized control and the agents to the different parts of the greenhouse. In advanced WSN solutions, some parts of the control system itself can also be implemented in a distributed manner to the network such that local control loops can be formed. Compared to the cabled systems, the installation of WSN is fast, cheap and easy. Moreover, it is easy to relocate the measurement points when needed by just moving sensor nodes from one location to another within a communication range of the coordinator device. If the greenhouse flora is high and dense, the small and light weight nodes can even be hanged up to the plants' branches. WSN maintenance is also relatively cheap and easy. In other hand, the measured data can be sent directly to the gateway node which is plugged in to the computer, or it can be transmitted in a multi-hop manner via router nodes, if the distance between the measuring nodes and the computer exceeds the length of a single radio link [8-14]. In this work, we applied a simple star topology, where sensor nodes measured soil and climate variables and communicated directly with the gateway node. The gateway node acted as a coordinator and received the measured data from the sensor nodes. It was located in the greenhouse entrance hall because the humidity there was 20-30% lower than inside the greenhouse. A laptop computer was connected to the gateway node by USB-cable. The greenhouse was divided into vertical blocks and the nodes monitored one block at a time. Figure 2 illustrates how the sensor nodes were deployed to the greenhouse block. The idea of the vertical deployment was to get a better understanding of the microclimate layers which typically exist in the greenhouse, and to figure out what kind of differences occur in the climate between lower and upper flora.

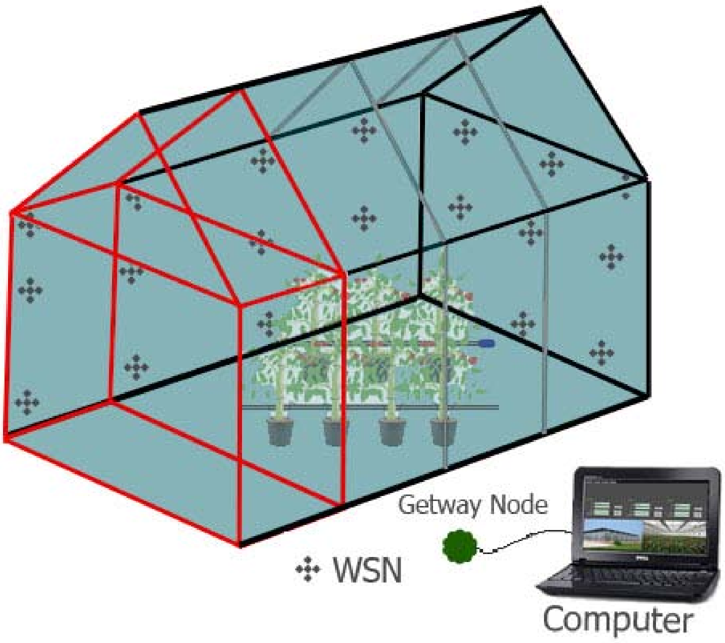

Figure 2. Experimental wireless sensors setup in greenhouse

4. Plant Developmental Factors

The productivity of the greenhouse depends on many different factors. Many research projects are focusing to these factors and their interdependencies. Grower can set the reference values to certain environmental variables, and then the greenhouse automation system targets to keep the variables in these values. The optimal levels of water and nutrient can also be defined [15].

Carbon dioxide (CO2) is a natural gas, which is dangerous for humans in high concentrations, but a lifeline for trees and plants. The air consists of nitrogen, oxygen and carbon dioxide. In the photosynthesis process, the plants convert CO2, water and light into glucose and oxygen according to (1)

$$6H_2O + 6CO_2 + Light \rightarrow C_6H_{12}O_6 + 6O_2 \quad (1)$$

Thus, CO2 is an important greenhouse climate variable, which enhances the growth of the plants. Sunshine and lights increase the amount of carbon dioxide. During the summer, the greenhouse gets the CO2 it needs from the natural air, when ventilation and roof windows are open [3]. In northern countries this opportunity does not exist during the winter. Grower can use pure extra CO2, or he can produce more carbon dioxide by CO2 burner. Some greenhouse heating systems re-circulate their CO2 emissions into the greenhouse making double advantages for the producer [16]. The optimal greenhouse air temperature depends on the intended level of the photosynthetic activity. Each plant species has its own optimal values of air temperature and active radiation of light, which enable the maximum photosynthetic activity (see Figure3). Soil nutrient and temperature plays also an important role.

A main concern in humidity and temperature control is to provide the best conductivity to active movement of water and nutrients through the plant. Humidity control is also an important tool to prevent the spread of plant diseases in greenhouses. Normally, the range of healthy relative humidity for the plants is from 50% to 70%. High air moisture reduces the required plant watering frequency. The greenhouse automation uses the watering and misting system, if the air moisture decreases under the targeted level.

The greenhouse protects the plants from the extreme weather conditions. However, if the period of daylight prevents the photosynthetic activity, the plants do not grow. Horticultural lighting allows the grower to extend the growing season. It enables a year-round producing of plants or makes it possible for the grower to start sowing in early spring and continue season till the first frost. Plants need about 10-12 hours light to improve growth. When the plants are producing flowers or fruits the supplemental need of light per day increases up to 16 hours. Figure 3 shows the photosynthetic activity in different wavelengths of light radiation [16].

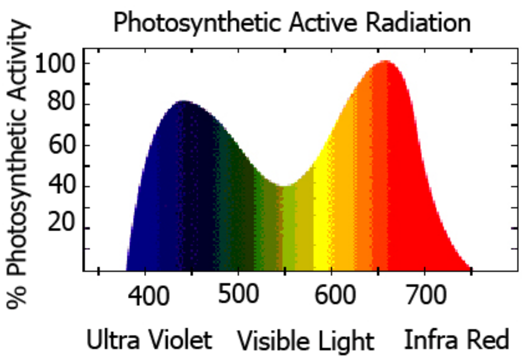

Figure 3. Photosynthetic activity in different wavelengths of light radiation.

5. Systems Architecture

The management of greenhouse condition includes several physiological processes that influence the growth of plants, such as lighting, temperature, humidity, soil nutrient and soil temperature, etc. The value of the final product incorporates not only quantity issues but also quality issues, which are difficult to be measured or even estimated. The environment of each agent is defined by the same parameters that define the physical environment in addition to internal states reported by each agent.

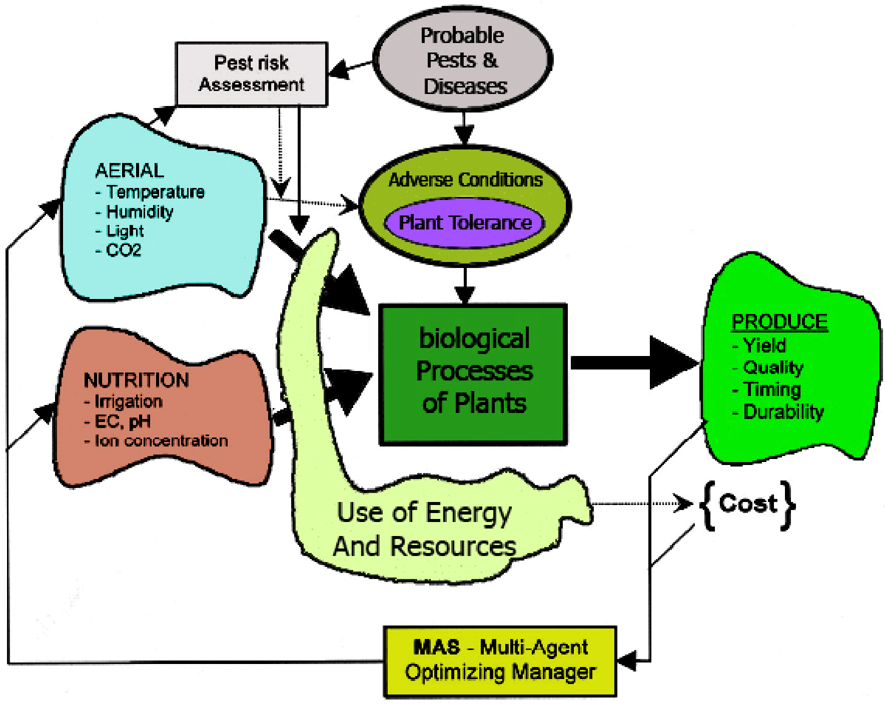

Figure 4. The multi-agent overall environment for integrated management

The agent's possible actions are defined by the available mechanisms and actuators and their effects to the environment. Thus, each controlled process of the greenhouse environment is modeled as an autonomous agent with its own inputs (its corresponding measured environmental parameters), its own outputs (the energy signals at its corresponding actuators) and its own interactions with the other agents. Each agent acts autonomously, as it knows a priori the desired environmental set-points. At the same time, there is cooperation between the agents, as all greenhouse environmental parameters are influenced by each other. In many cases there are controllability issues as the same actuator is used to control different variables, which may be in contradiction (i.e. ventilation for humidity and temperature). In this way, any possible conflicting decisions of conventional environmental control methodologies are resolved through negotiations between the agents so that the possible optimal integrated solution is achieved.

The negotiations between agents are subject to optimization based on "knowledge" that is derived from complete production models, yield models or even sparse models as expressed in fuzzy expert rules or practical rules of thumb. In addition, pest control and plant disease models provide additional information useful to the design of a successful strategy for optimal management [15] (illustrated in Figure 5).

The "environment" of the agents, hereby called a-environment, is characterized by the model of the physical system and its reaction to inputs, the production targets as expressed by the "user-goals" and the "production-knowledge" that guides the climatic environment, hereby called c-environment, to the targeted goals.

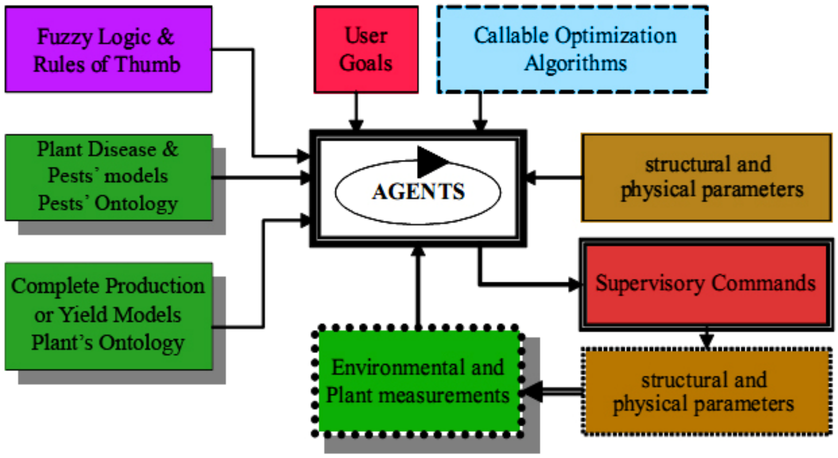

Figure 5. Multi-agent system information and knowledge scheme.

The complete agents "environment" is shown in figure 6. Each agent receives the necessary environmental or plant condition measurements. While each agent keeps its autonomy and has its own "personal" goals, it interacts with the other agents through some specific communication language, in the "Agent discussion area", where the overall goal is taken into account. This interaction takes place under the presence of information from the existing models and the target goals. At that point, each agent has decided on its best strategy.

6. Arrangement of the Multi Agent System

A specific arrangement of the MAS is the one where each agent corresponds to one of the main controlled parameters of the physical system. These can be divided into two groups, the environmental agents (temperature, humidity, CO2 concentration, sunshine) and the soil condition agents (pH, electrical conductivity, salinity, water available, soil temperature and soil nutrient). When two or more agents enter the "agent discussion area", they exchange information about their state and they inform the other agents about possible actions that have to be taken in order for each agent to achieve its goals [15-18].

An optimization algorithm that takes into account the user goals and the outputs of the existing production, yield, plant diseases and pest control models, estimates possible consequences and results from several scenarios and the optimal resolution is found about the optimal ventilation rate. According to this result, a final decision is taken. This decision can have either the form of some actuator command or of some adaptation of a setpoint value.

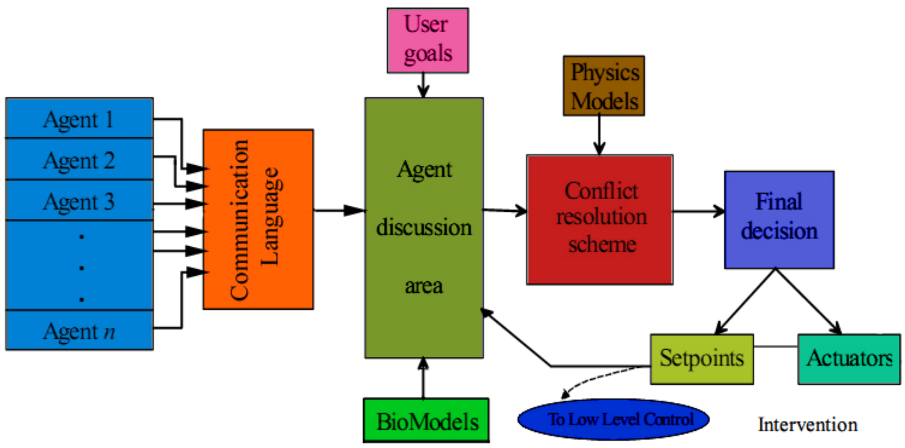

Figure 6. Structure of the MAS for integrated greenhouse management system.

The models that help in the MAS's decision-making process use information from the measurements of the physical system.

The basic features of the multi-agent system are the following:
It's an open system with high degree of adaptation to different kinds of products, as well as to different types of biological production (animal production, pisciculture, precision agriculture).

It can be easily expanded with the addition of new agents or the definition of new entities in the MAS ontology and new management goals.

It can cooperate with other low-level greenhouse management and control programs by a simplified data exchange through sharing a whiteboard.

6. Conclusion

In the past generation greenhouses it was enough to have one cabled measurement point in the middle to provide the information to the greenhouse automation system. The system itself was usually simple without opportunities to control locally heating, lights, ventilation or some other activity, which was affecting the greenhouse interior climate. The optimal greenhouse climate and soil adjustment can enable us to improve productivity and to achieve remarkable energy savings. In this paper we proposed a multi-agent methodology for integrated management systems in greenhouses. In this regards wireless sensor networks play a vital role to monitor greenhouse and environment parameters. Each controlled process of the greenhouse environment is modeled as an autonomous agent with its own inputs, its own outputs and its own interactions with the other agents. Each agent acts autonomously, as it knows a priori the desired environmental set-points. In this way, any possible conflicting decisions of conventional environmental control methodologies are resolved through negotiations between the agents so that the possible optimal integrated solution is achieved. The developed system is simple, cost effective, and easily installable.

Figure 7. The outcomes of the Monitoring and Control of the Greenhouse soil and climate Conditions for tomato crops.

References

[1]. M. Mancuso and F. Bustaffa, "A Wireless Sensors Network for Monitoring Environmental Variables in a Tomato Greenhouse," 6th IEEE International Workshop on Factory Communication Systems in Torino, Italy, June 28-30, 2006.

[2]. H. Liu, Z. Meng and S. Cui, " A Wireless Sensor Network Prototype for Environmental Monitoring in Greenhouses," Wireless Communications, Networking and Mobile Computing 2007 (WiCom 2007), International Conference on 21-25 Sept. 2007 .

[3]. N. Kularatna and B. H. Sudantha, "An environmental air pollution monitoring system based on the IEEE 1451 standard for low cost requirements," IEEE Sensors J., vol. 8, no. 4, April 2008, pp. 415 – 422.

[4].S.R. Madden, M.J. Franklin, and J.M. Hellerstein, "TinyDB: An Acquisitional Query Processing System for Sensor Networks," ACM Trans. Database Systems, vol. 30, No. 1, 2005.

[5]. W. Zhang, G. Kantor, and S. Singh Integrated wireless sensor/actuator networks in agricultural applications. In Second ACM International Conference on Embedded Networked Sensor Systems (SenSys), page 317, Baltimore, Maryland, USA, Nov. 2004.

[6]. Barreteau, O., Bousquet, F., Millier, C. and Weber, J. 2004. Suitability of multi-agent simulations to study irrigated system viability: application to case studies in the Senegal River Valley. Agricultural Systems 80: 255-275.

[7]. Giovanni Caire, Giovanni Iavarone, "JADE - Java Agent DEvelopment Framework", Nov.2011, Available at http://jade.tilab.com/doc/tutorials/JadeAndroid-Programming-Tutorial.pdf

[8]. Yoo, S.; Kim, J.; Kim, T.; Ahn, S.; Sung, J.; Kim, D. A2S: Automated agriculture system based on WSN. In ISCE 2007. IEEE International Symposium on Consumer Electronics, 2007, Irving, TX, USA, 2007.

[9]. Han, W.; Zhang, N.; Zhang, Y. A two-layer Wireless Sensor Network for remote sediment monitoring. In 2008 ASABE Annual International Meeting, Rhode Island, USA, 2008.

[10]. Anastasi, G.; Farruggia, O.; Lo Re, G.; Ortolani, M. Monitoring high-quality wine production using wireless sensor networks. In 42st Hawaii International International Conference on Systems Science (HICSS-42 2009): Waikoloa, Big Island, HI, USA, 2009.

[11]. Ayday, C.; Safak, S. Application of wireless sensor networks with GIS on the soil moisture distribution mapping. In Symposium GIS Ostrava 2009 - Seamless Geoinformation Technologies, Ostrava, Czech Republic, 2009.

[12]. Vellidis, G.; Tucker, M.; Perry, C.; Wen, C.; Bednarz, C. A real-time wireless smart sensor array for scheduling irrigation. Comput. Electron. Agric. 2008, 61, 44-50.

[13]. Wang, C.; Zhao, C.J.; Qiao, X.J.; Zhang, X.; Zhang, Y.H. The design of wireless sensor networks node for measuring the greenhouse's environment parameters. Comput. Computing. Technol. Agric. 2008, 259, 1037-1046.

[14]. G.Vellidis, M.Tucker,C.Perry, C.Kvien, C.Bednarz, A real-time wireless smart sensor array for scheduling irrigation, computers and electronics in agriculture 61, 2008.

[15]. L. F. Mendon¸ca, J. M. Sousa, and J. M. G. S´a da Costa.Optimization problems in multivariable fuzzy predictivecontrol. International Journal of Approximate Reasoning, 36:199–221, 2004.

[16]. G. J. Timmerman and P. G. H Kamp, "Computerised Environmental Control in Greenhouses," PTC, The Netherlands, Page(s): 15–124, 2003.

[17]. Norris, A.; Saafi, M.; Romine, P. Temperature and moisture monitoring in concrete structures using embedded nanotechnology/microelectromechanical systems (MEMS) sensors. Constr. Build. Mater. 2008, 22, 111-120.

[18]. A. Pawlowski, J. L. Guzman, F. Rodriguez, M. Berenguel, J. Sanchez, and S. Dormido, "Simulation of climate monitoring and control with wireless sensors network and event based control," Journal of Sensors, vol. 9, 2009, pp. 232 – 252.