Intelligent control of greenhouse environment

ALIN MAZARE, LAURENTIU IONESCU, DUMITRU CAZACU
Department of Electronics, Computers and Electrical engineering, Faculty of Electronics, Communications and Computers
University of Pitesti
Str. Targu din Vale, No. 1, Pitesti
ROMANIA
alinmazare@yahoo.com, laurentiu.ionescu@upit.ro,
http://www.upit.ro

Abstract: - The paper aims at achieving intelligent control of greenhouses using a central system based on associative memory. In our approach, the control system and the greenhouse infrastructure together form a living system, an organism. "The brain" consists of central intelligent system and is based on hardware associative memories. It communicates with sensory cells scattered in the greenhouse and outside it as well as control cells. The cells are autonomous units in terms of power supply.

Key-Words: - **Intelligent greenhouse, Intelligent control, Associative memories, Hopfield network, ZigBee network, real time systems.**

1 Introduction

The paper aims at achieving intelligent control of greenhouses. The basic idea of the work paper is to optimize crop production by controlling the greenhouse environment.

In our approach, the control system and the greenhouse infrastructure together form a living system, an organism. "The brain" consists of central intelligent system and is based on hardware associative memories. It communicates with sensory cells scattered in the greenhouse and outside it as well as control cells. The cells are autonomous units in terms of power supply. The central system together with the cells are disposed in wireless ad-hoc network in which there is exchange of data and commands.

Below are listed some of the recent research concerning intelligent greenhouse. They experienced many control systems with artificial intelligence based on neural networks and fuzzy systems [1] for the control of inside the greenhouse climate. Wireless sensor networks are used to reduce the number of wires and eliminate problems arising from these. Together with the central system and actuators these provides intelligent control of greenhouse environmental parameters such as: humidity [2], [3], temperature [4], [5], [6], CO_2 and O_2 concentration [7], air distribution (homogenization) [8]. They also have made automation through intelligent control, in the process of soil fertilization [9]. Some researchers are focused, along with analysis parameters and operating environment for the purposes of their control, to the analysis of crops condition. The crop condition can "feel" through a network of "electronic nose" sensors [10], but also by visual analysis and automatic processing to detect abnormalities in plants or mushrooms such as stress due to the lack or abundance of water [11] or categorization [12].

As mentioned, along with optimizing crop production, which is the main target of intelligent greenhouse, intelligent central system can propose and secondary criteria of optimization, such as those referring to the reduction of energy consumption: directly, by reducing consumption through efficient management of components in terms of energy, but also indirectly by reducing water consumption [13].

3 Our solution

This section is divided in more subsection. First we present the general concept in our project and next we describe modules inside.

3.1 Greenhouse – macro organism

Our approach includes all items listed above in greenhouses with automatic and intelligent control but contains little more than that. We consider the greenhouse a macro organism. First we need a

healthy body. For a healthy body it must have a mechanism of self-regulation that is constantly alert to changes in the internal environment and flexible in responding to these changes (not based on a predetermined schedule).
Also, a body interacts with the world around. Even though we tend to consider the greenhouse a closed system in reality is not the case. It is integrated in an external environment, where they take water, heat and light. External factors cannot be ignored, it must react and depending on their.

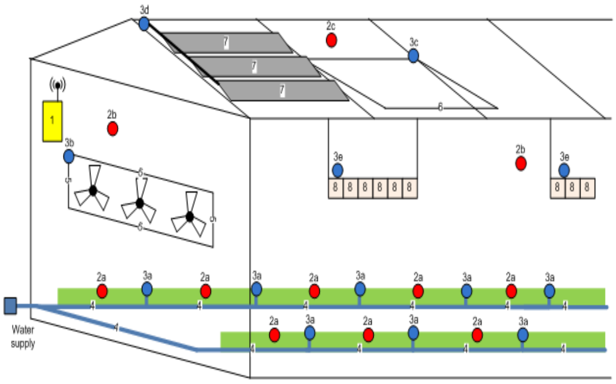

Figure 1. Concept scheme of our approach of intelligent greenhouse

Our project consists of two main parts, as shown in figure 1:

- Electronic control system (illustrated with rectangle and circles in figure);
- Infrastructure components operated in greenhouse.

Electronic control system consists of:

- Intelligent central system (1),
- Intelligent central system interface (1),
- Sensory (2a) and command cells (3a).

Our solution has greater flexibility to respond to changing internal and external factors and a greater degree of autonomy.
Flexibility is given by intelligent solution that provides real-time response to a real environment. Although the greenhouse is considered a closed environment, in reality it always interacts with external environment. Internal conditions also suffer changes. Some of these changes cannot be predicted in advance.
Autonomy is the second characteristic of intelligent greenhouse. Autonomy, in this case, means the organism's (greenhouse) ability to adapt to any event occurring (external and internal) and give the appropriate response without human intervention. The situation may concern internal environment (inside the greenhouse), external environment (outside the greenhouse) or state of the system itself (e.g. state of the sensory cells, command cells). Also, autonomy refers to the low power consumption for the system.

3.2 System modules

Intelligent central system is based on associative memory (Hopfield network) that will support learning processes. Intelligent central system can:

- To receive a set of parameters that will have to apply to controlled ecosystem, but not as a fixed schedule but depending on environmental conditions,
- Be able to make associations between different environmental conditions (some unlearned) and actions that must be executed,
- To have an interface to retrieve data from sensors network and an interface to send commands to control devices.

Intelligent central consists of several associative memories based on Hopfield type neural networks (nearest to biological neurons) operating in parallel, each dealing with a specific area and activity in the greenhouse.

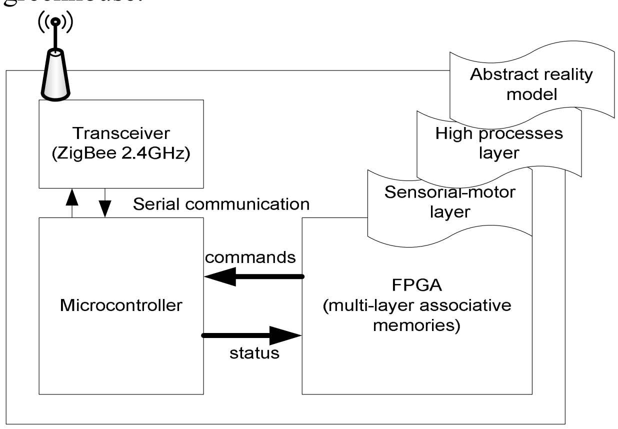

Figure 2 Intelligent central system diagram

Sensory network allows data acquisition concerning internal and external environment. For flexibility, we have designed a solution that is composed of sensory cells. A sensory cell contains the sensor itself and the microsystem performing data acquisition from sensor and wireless transmission to the central system. Connecting the sensor network with the central system is done by using a wireless ad-hoc network (ZigBee protocol). This allows to easily adding sensory cells, replacing those defects or change sensory network layout.
Control devices are also organized as a network of cells. A control cell contains an actuator (the solenoid valve or relay with the drive), drivers and controlled voltage sources needed and microsystem

ISBN: 978-1-61804-189-0

receiving commands from the central system (wireless).

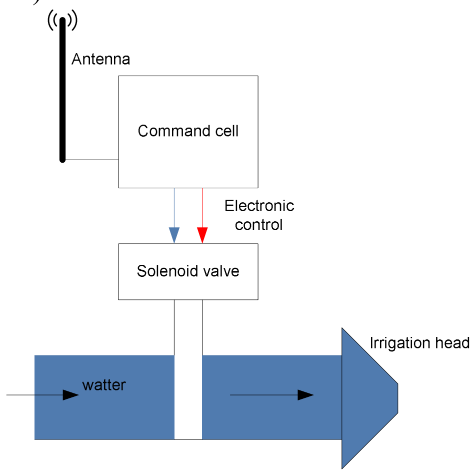

Figure 3 Command cell module

Control cells are also disposed in an ad hoc network that allows changing the command devices configuration.Changing environmental conditions can be possible only by command of the greenhouse infrastructure components. Irrigation tapes present terminals that are controlled by electronic. This can automatically adjust soil moisture. Air humidity and CO2 concentration adjustment can be done through transparent panels. Basically, by means of these, it is achieved external air circulation in the greenhouse.

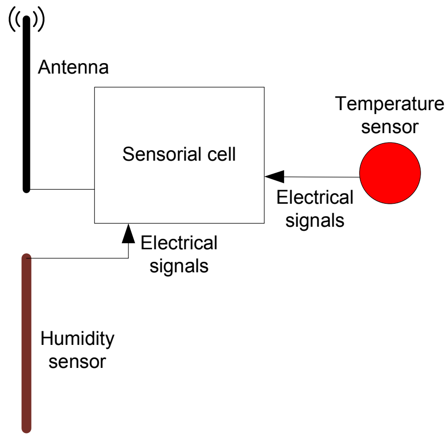

Figure 4. Sensorial cell module

These adjustments are done without affecting luminosity. For external brightness adjustment (that comes from the Sun) are used opaque panels. Greenhouse air circulation is determined by the fans. Artificial lighting is done through LEDs.

3 Experimental results

Implementation was done using a greenhouse at a smaller scale. Network consist on 6 ZigBee module (transceiver Chipcon CC2420, MCU Silabs) with central unit configured as network coordinator, 3 sensorial cells (2 with temperature sensor, 1 with light sensor) and 2 command cells, with relay on GPIO port – last five in end-point network configuration (figure 5).

Intelligent system form central unit is implemented on FPGA integrated circuit Xilinx Spartan 3E. To the experiment we implemented two Hopfield neural networks with 10 neurons each, to retain more words association.

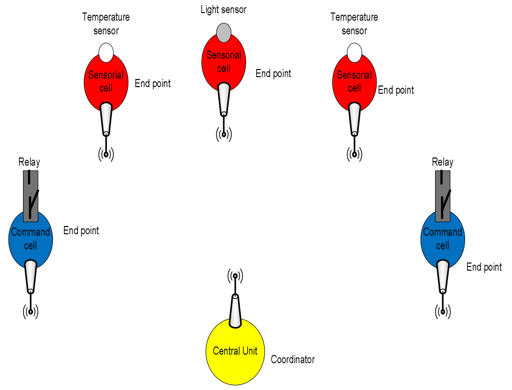

Figure 5. Sensorial cell module

The table below presents different neural networks configurations implemented on FPGA and area occupied on chip (FPGA Spartan3E XC500).

Table 1. Resources allocated on FPGA chip

Neurons	6	7	8	9	10
Flip flop	221	257	301	359	415
LUT	747	934	1149	1404	1675

The response time, at one iteration, for Hopfield neural network is presented in table below.

Table 2. Response time for intelligent central system (one iteration)

Neurons	6	7	8	9	10
Time (ns)	15.699	17.475	20.090	22.537	24.675

In the experiments for environment control we use two Hopfield neural networks in central unit which work in parallel. They were made to learn association words between input values received from sensorial cells and feelings states, as we can see in the table 3. The values provided by the sensors go to central system as words of 4 bits size each (range between 0 – minimum to 7 maximum). They are associated here with feelings. The learning process, which is performed in one single step for these networks, led to memorize the table 3. The system is then tested by subjecting it to different situations. The negative feelings (first two rows in the table) lead to drive appropriate commands to cells, while the positive feelings, tends to maintain the system state unchanged. The response time of the associative memory (Hopfiled network) falls in an average of 3

ISBN: 978-1-61804-189-0

iterations, so 75ns, until the system give a correct answer.

Table 3. Inputs – feeling associations

Feeling	Sensor1,3 (temp.)	Sensor 2 (light)
Very bad (dead hazard)	7,6,0	-
Danger	-	7,6,1,0
Food	5,4	-
Safety	-	4,3

Obvious, at this time is added communication time between central unit and command cells. The storage capacity – the number of association words which can be stored and correct reproduced – is, to our network configuration of 10 neurons, of 3.76 words. Thus, we can store safety (with 100% correct response rate) 3 association words / memory. In this case, we use 2 parallel memories (10 networks) where we can store 6 association words covering for table 3

4 Conclusion

The solution presented in this article brings several improvements to the control of a greenhouse: continuous monitoring without human presence, optimizing the use of water and electricity, optimize space allocation.

It is based on an intelligent control system with hardware associative memory (Hopfield networks) so that enables real-time response.

As future research directions see extending our solution to control various types of greenhouses, and increase number of association words stored by increasing number and dimension of associative memories.

References:

[1] Yousefi, M.R., Hasanzadeh, S., Mirinejad, H., Ghasemian, M., A hybrid neuro-fuzzy approach for greenhouse climate modeling, 2010 IEEE International Conference on Intelligent Systems, IS 2010 - Proceedings, 2010, Article number5548375, Pages 212-217, ISBN: 978-142445164-7

[2] Xu, Z., Lou, B. , Shao, G., An intelligent irrigation system for greenhouse jonquil based on ZigBee wireless sensor networks, International Workshop on Internet of Things, IOT 2012;Changsha;17 August 2012, Volume 312 CCIS, 2012, Pages 200-207, ISSN: 18650929 ISBN: 978-364232426-0

[3] Liu, Y., Kong, L., Xu, B., Du, T., Hou, S., Kang, S., 2012 International Conference on Systems and Informatics, ICSAI 2012, 2012, Article number6223643, Pages 397-399, 2012, Article number6223643, Pages 397-399, ISBN: 978-146730199-2

[4] D. A. Visan,I. Lita, Ion Bogdan Cioc,"Temperature Control System Based on Adaptive PID Algorithm Implemented in FPAA", 34th International Spring Seminar on Electronics Technology - ISSE 2011, ISSN: 2161-2528, pp. 501 – 504

[5] Sabri, N., Aljunid, S.A., Ahmad, R.B., Malek, M.F., Yahya, A., Kamaruddin, R., Salim, M.S., Smart prolong fuzzy wireless sensor-actor network for agricultural application, Journal of Information Science and Engineering, Volume 28, Issue 2, March 2012, Pages 295-316, ISSN: 10162364

[6] Xiao, J. , Bei, J., Ming, K.J., Design for wireless temperature and humidity monitoring system of the intelligent greenhouse, ICCET 2010 - 2010 International Conference on Computer Engineering and Technology, Proceedings, Volume 3, 2010, Article number5485770, Pages V359-V363, ISBN: 978-142446350-3

[7] Shuying, M., Yuquan, M., Lidong, C., Shiguang, L., Design of a new measurement and control system of CO2 for greenhouse based on fuzzy control, CCTAE 2010, Volume 1, 2010, Article number5543648, Pages 128-131, ISBN: 978-142446945-1

[8] Chen, Y., Dai, W., Intelligent control technology for natural ventilation used in greenhouse, IFIP Advances in Information and Communication Technology, Volume 317, 2010, Pages 248-253, ISSN: 18684238

[9] Ma, W., Zhang, M., Zhou, Z., Chen, L., Wang, X., Mao, Y., Research and application of mobile precision irrigation and fertilizing compound machine for greenhouse and horticulture, 2010 World Automation Congress, WAC 2010, 2010, Article number5665565, Pages 211-217, ISBN: 978-142449673-0

[10] Ghaffari, R., Zhang, F., Iliescu, D., Hines, E., Leeson, M., Napier, R., Clarkson, J., Early detection of diseases in tomato crops: An electronic nose and intelligent systems approach, Proceedings of the International Joint Conference on Neural Networks, 2010, Article number5596535, ISBN: 978-142446917-8

[11] Kim, Y., Glenn, D.M., Park, J., Ngugi, H.K., Lehman, B.L., Hyperspectral image analysis for water stress detection of apple trees, Computers and Electronics in Agriculture, Volume 77, Issue 2, July 2011, Pages 155-160, ISSN: 01681699

[12] Clement, J. Novas, N. Gazquez, J.A., Manzano-Agugliaro, F. High speed intelligent classifier of tomatoes by colour, size and weight, Spanish Journal of Agricultural Research, Volume 10, Issue 2, 2012, Pages 314-325, Volume 10, Issue 2, 2012, Pages 314-325, ISSN: 1695971X

[13] Dieleman, J.A. , Hemming, S., Energy saving: from engineering to crop management, Acta Horticulturae, Volume 893, 30 April 2011, Pages 65-74, ISSN: 05677572