Measurement for Intelligent Control in Greenhouses

P. Eredics

Department of Measurement and Information Systems
Budapest University of Technology and Economics, Budapest, Hungary
Email: eredics@mit.bme.hu

Abstract. *The paper describes the design of an environment monitoring system supporting the development of black-box model based greenhouse climate control. Despite many currently available control schemes, only black-box modelling can be carried out efficiently for small or medium size greenhouses. For this large amount of measurements is needed, calling for a new distributed measurement system architecture. A novel system described in this paper collects measurements from a greenhouse in many measurement points, and provides an interface for the development and testing of model based control solutions.*

Keywords: Distributed Measurement System, Greenhouse Environment Monitoring

1. Introduction

Greenhouses have transparent walls and roof and are widely used for vegetable production and growing flowers. Sun radiation is essential for photosynthesis of the plants, and also to keep the inner temperature within an acceptable range. In the cold season a heating system may also be necessary. Contrary in hot weather other actuators, like roof vents, shading systems, exhaust fans or evaporative cooling may be used to avoid overheating. Almost every greenhouse today has a control system using some kind of environment control computer (ECC). Yet despite the computing power control methods did not change much along with the technology. Even today almost all greenhouse control systems work with independent, set-point based PID controllers [1], which suffer from the missing synchronization of the actuators, and their dependence on the user to find the appropriate set-points.

Model based control

The efficiency of the control can be improved using more advanced models, see e.g. IntelliGrow [2]. There is much of research on complex control models in greenhouse environment, e.g. model predictive control [1]. Such models could provide better control, but they require accurate estimates of plenty of parameters to work. To this end a large amount of measurements is needed to find the correct model of the house. Regrettably they are also expensive in the measurements and calculations. Besides, these methods cannot be used in smaller size industrial greenhouses. Such houses have usually low budget, are mostly uniquely designed to best fit the grower's needs, making it hard to find houses with identical structures. The houses typically grow several types, and often changing plants, which makes the model of even the similar houses different, and always varying. In low utilization periods, some houses can even be split into used and unused compartments, also changing the model.

All this makes it difficult to create a general yet useful analytic model. The alternative is a black-box model, necessarily a learning system. A learning system can identify the model on its own, and is also able to follow model changes. The price is a large number of measurements needed for learning and operation. Traditional control and ECC-s can be used to obtain measurements from a particular house. BipsArch system provides generalized interface for computer access to different ECC-s [3], making it possible to develop and run sophisticate control on separate PC-s, but it cannot overcome main limitations of the ECC. An

ECC requires set-points for the operation (does not accept direct commands for the actuators), and models the house as a single thermal entity. Closer examination of plenty of industrial greenhouses shows that the inner temperature is not homogenous and specific thermal zones appear related to the greenhouse structure and operation.

It is widely accepted, that improvement of the quality of greenhouse control systems can be achieved using complex models. However the mentioned limitations of current systems make it necessary to consider a new system design, described in this paper. The requirements of such a system are reliability, multipoint measurement in the house, remote access capabilities, openness, incremental functionality, low cost and a user friendly interface. It also should be mentioned that as the traditional ECC based control is able to operate the greenhouse alone if the model based control fails. This component should be also present in the system.

2. Pilot Study and Measurement System Architecture

The direct goal of the design was a data acquisition system for a 100 m^2 area greenhouse producing extremely sensible young plants in the western region of Hungary.

The Zones

Fig. 1 shows the simplified structure of the greenhouse, with thermal zones labelled. Traditional control system would make measurements in only one or some of these zones. To help accurate modelling of the house, data should be collected from every indicated zone.

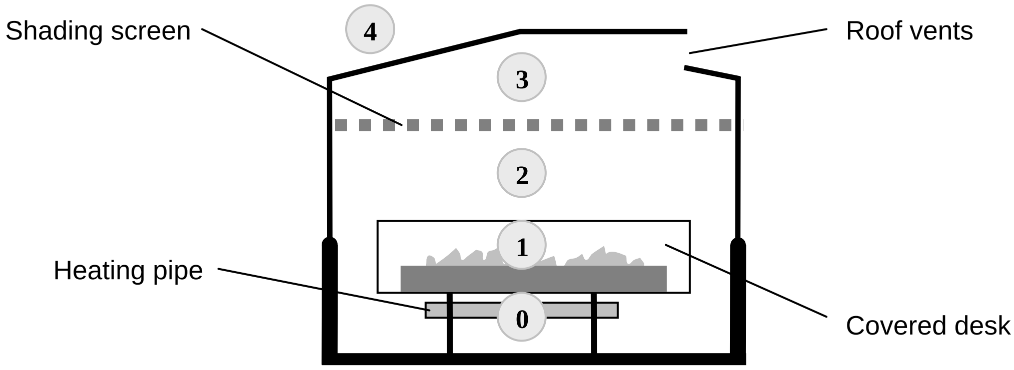

Fig. 1. Thermal zones (identified by their numbers) in a simplified greenhouse environment.

The current goal is to create the thermal model of the house, so we focus on the temperature and closely related radiation measurements. Zone 4 (external environment) is special because the control system can not change it. Zone 3 & 2 are separated only by an active shading screen. Zone 1 is the closest environment of the plants, in the current house usually inside veiled desks. Zone 0 (heating) is not a true thermal zone, but it can be best modelled as one.

Temperature measurements are collected in the current house from Zone 0 and 4 at a single point, from Zone 2 and 3 at two points, and in Zone 1 from all the desks. Two point measurements in Zones 2 and 3 are necessary, because the house is split sometimes into two sections. For larger, industrial size greenhouses more sections can exist, making more measurement points necessary. In the current house thus 21 temperature values, and two radiation values (from above and below of the shading system) are recorded.

Functional Architecture

The analysis of the requirements led to a layered system design, shown in Fig 2, corresponding to the gradual fusion of the measurement information. The 1st layer is the physical environment of the greenhouse. The measuring instrumentation and the actuators form the 2nd layer. The 3rd layer contains sensor and actuator control implemented on local microcontrollers. This layer is responsible for collecting the measurements and directly controlling the actuators on site. 4th layer is implemented on a PC for recording and storing measurement data. This layer communicates with the microcontrollers and also serves higher layers, thus playing the role of a communication channel with storage capabilities. 5th layer contains the user interface, and here is the place of the model based high level control. Incorporating traditional ECC based control gives increased reliability to the whole system, and is implemented at the 3rd layer, running on a master microcontroller.

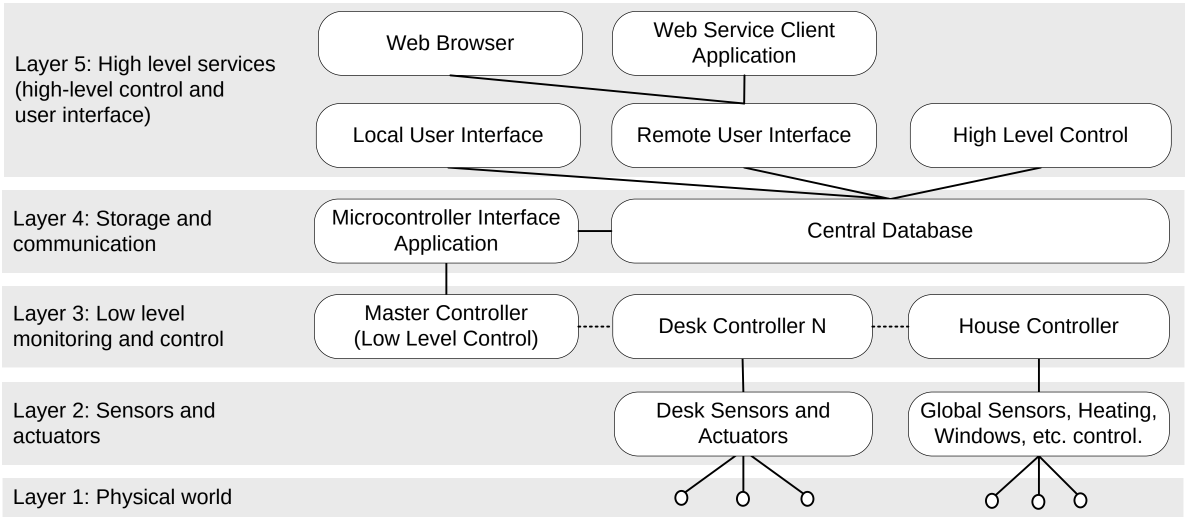

Fig. 2. System layers and the relation of the components implemented in the functional layers

Software and Structure

In the current implementation of the 3rd layer, we used ATmega microcontrollers: The master controller is running the low level control and communicates with a PC and the other parts of the controller network. Every four desks have a dedicated controller, for collecting local measurements, and controlling desk based actuators. (All desks have built in evaporating, and some desks have ventilating fans too.) There is another special microcontroller for controlling the global actuators of the house. The controllers communicate on an EIA-485 bus, while the master controller and the PC have an EIA-232 connection.

System Integration and User Interfaces

The central component of the higher layers resident on a PC is a MySQL database. The microcontroller interface application inserts periodically new measurements, and checks for configuration changes or commands for the lower layers. If the low level control's settings change or a command is issued, the master controller is informed. The central database can be directly accessed though a network connection from anywhere on the internet. It makes possible to develop and run the high level control on a dedicated computer at a distant location, e.g. in the owner's home environment. In such a setup the reliability of the high level control depends on the network conditions, but the reliability of the whole system is guaranteed in all cases by the low level control in the 3rd layer.

A modern greenhouse control and management system cannot exist without a user interface. The present system has multiple user interfaces to facilitate the interaction between the owner and the system. It has a simple display to show the current measurements in the greenhouse. To exercise remote management capabilities the system has a web based management interface. It contains a web server and a PHP web application. This design eliminates the need for a client application on the management computers. Measurement data is visualized with a Java applet in the browser window. Simple web services can be offered through the web server, making it possible to develop desktop applications for instant monitoring or alerting purposes. Fig. 3 shows a sample diagram from the implemented remote management system.

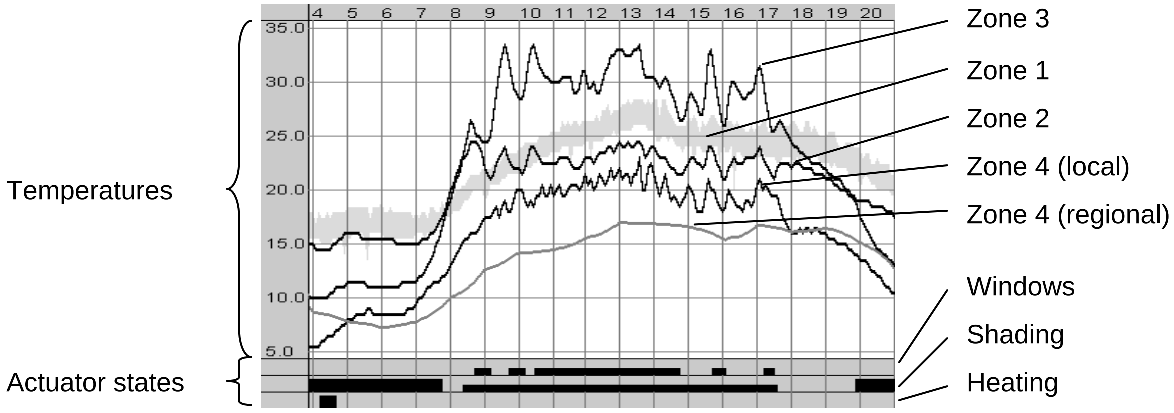

Fig. 3. Temperature data, recorded on 04-05-2008, visualized in the remote management webpage.

Data Processing and Intelligent Control

Measurements are continuously recorded from March 2008. During the winter 2009 the greenhouse held no plants for a month. In this period the goal of the control was to maintain the highest possible temperature with minimal use of costly heating. To utilize the most of the natural radiation a simple intelligent control application was developed. It could only control the shading screens. Control commands were computed by a decision tree with Zone 2 and 3 temperatures, and the trend of Zone 3 as inputs. This simple control application provided optimal control of the shading, and also verified the high level control interface.

3. Results

The system described above is aimed to serve as a supporting environment to develop (black-box) model based, high level control methods. It has three major benefits compared to other available solutions: it collects measurements in all important thermal zones of the greenhouse, it serves as an interface for direct access to the measured data and to control the actuators, and it can be simply accessed from remotely developed applications. The modular design of the system makes it possible to easily extend it with more sensors and microcontrollers, making it possible to monitor a much larger greenhouse without architectural modifications.

References

[1] M.Y. El Ghoumari, H.-J. Tantau, J. Serrano. Non-linear constrained MPC: Real-time implementation of greenhouse air temperature control. *Computers and Electronics in Agriculture,* 49: 345-356, 2005.

[2] J.M. Aaslyng, J.B. Lund, N. Ehler, E. Rosenqvist. IntelliGrow: a greenhouse component-based climate control system. *Environment Modelling & Software,* 18: 657-666, 2003.

[3] J.M. Aaslyng, N. Ehler, L. Jakobsen. Climate control software integration with a greenhouse environmental control computer. *Environment. Modelling & Software,* 20: 521-527, 2005.