Synthesis of a Greenhouse Climate Controller using AI-based techniques

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Abstract. **The methodology proposed in the paper deals with the use of Artificial Intelligence techniques in the modeling and control of some climate variabiles within a greenhouse. The nonlinear physical phenomena governing the dynamics of temperature and humidity on such systems are, in fact, difficult to be modelled and controlled using traditional techniques. The paper propose a framework for the development of a Multi-Input-Multi-Output (MIMO) Fuzzy Logic Controllers (FLCs) in modern greenhouses.**

I. INTRODUCTION

The popularity of computers for the management of greenhouses is still increasing even in those countries where the environment conditions are not prohibitive for the development of the plants. In the Netherlands computers are found everywhere which perform tasks like climate, boiler and irrigation control. The best known application in this field is climate control (temperature, humidity, CO2, artificial lighting). In fact, the main improvements in computer-based climate control are found in data logging, determination of climate set-points, monitoring and alarm functions.

A large amount of literature is available on these points concerning the application of classical methodologies of dynamic systems and control theory in the areas of the greenhouses modelling and control (see for example [1], [2], [3]).

The approach proposed here is oriented in the direction of artificial intelligence techniques and intelligent control methodologies for the analysis and synthesis of intelligent climate controllers. The main advantages obtainable using, for example, fuzzy logic and control, neural networks and expert systems are summarised as follows:

- The modelling of some complex behaviour can easily been achieved from an I/O data learning using Artificial Neural Networks (ANNs). This will avoid the analysis of those physical phenomena involving complex dynamics (see [4]).
- The use of Fuzzy Logic Controllers (FLCs) for the regulation of climate variables like temperature and humidity in artificially conditioned greenhouses represents a powerful way to minimise the heating-energy spending: which is the more important aspect of greenhouse climate control.
- Expert Systems, and particularly those Expert Systems including Fuzzy Rule-based Systems are essential in the implementation (and optimisation) of the expertise deriving from human experts within computerised greenhouses in order to avoid important damages to plants.
- Finally, human experts have the intuitive capability to evaluate the potential economic return of the plants at every stage of their development, while experts in biology can establish the more appropriate actions which have to be carried out in order to optimise the growth-development rate of the plants [5].

The objective of this work is to give some preliminary results in order to demonstrate the validity of the use of AI techniques described above in the field of greenhouse climate control.

II. MODELING THE GREENHOUSE

The first part of the work is based on the development of a computer simulator for the greenhouse based on physical considerations. The simulator has been developed using the SIMULINK™ tool within the MATLAB™ environment on the base of the work described in [6], [7] (see Fig.1).

For the sake of simplicity all physical parameters have been included into a data file referring to a fixed structure. The environmental conditions are simulated instead of using a meteo station considering some average values of external air temperature, wind speed, solar radiation, etc.

Modelling a greenhouse from a physical point of view requires a large computer effort due to the intrinsic complexity of the system and of the phenomena involved. A greenhouse is a distributed parameters system whose effectiveness strongly depends on several non-linear phenomena. In fact, the heat transfer inside the greenhouse depends, most of all, on the radiative and convectional effects. Moreover, the presence of many uncontrollable signals, due to

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weather, solar radiation, crop transpiration and so on, makes the validation of the model even difficult.

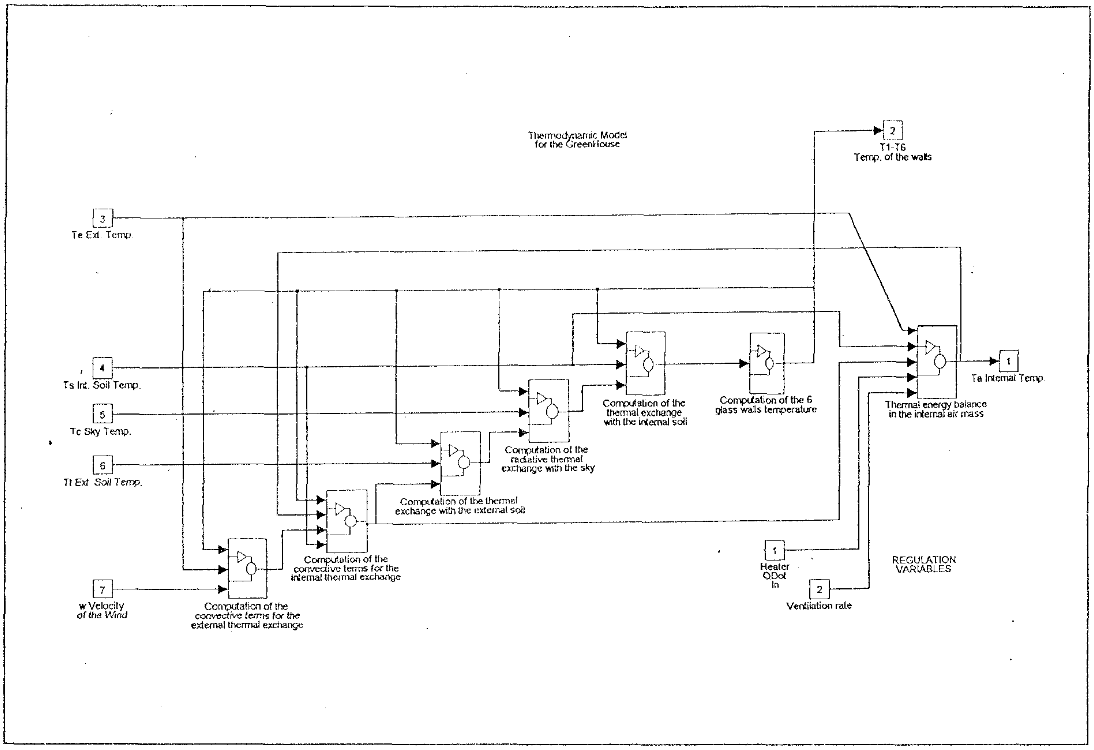

Fig. 1 The Simulink Model of the greenhouse dynamics

Using this model a comparative analysis has been carried out for both traditional *bang-bang* controllers and a MIMO FLC.

III. TRADITIONAL CLIMATE CONTROL

The second part of the work deal with the development of a suitable methodology for the temperature and humidity control.

The temperature is controlled by regulating the water temperature within an appropriate set of pipes uniformly distributed in the greenhouse, while the humidity is controlled indirectly by regulating the ventilation rate (which affects both the temperature and humidity).

Using the physical model reported in Fig.1 a first experiment has been carried out using a traditional control system based on a *bang-bang* technique.

This control system is based on a heater actuator which is turned on and turned off by a thermostat whenever the temperature error is outgoing the fixed regulation band.

The humidity depends on the internal air temperature and on the ventilation rate. This last variable is regulated in a very simple way by opening the windows of the greenhouse based on the measured wind-speed (this can also avoids some dangereous situations due to a high wind speed in the external environment).

Fig. 2 shows the SIMULINK model used for the simulation, while Fig. 3 reports the obtained results.

It has to be noted that decreasing the error bandwidth has an indirect effect on the energy consumption. So, intuitively, a bang-bang control technique is more expensive than a suitable *soft* control technique.

This is the main motivation for the use of a Fuzzy Logic Control (FLC) based system which is the subject of the next paragraph.

IV. FUZZY LOGIC CLIMATE CONTROL

The former approach implements a non-linear MIMO controller for the regulation of both temperature and humidity within the greenhouse, extending the concept of PID-fuzzy controller in the two-dimensional case.

As known from the Fuzzy Logic principles an FLC acts as a nonlinear system implementing a human-based reasoning for the computation of their output values.

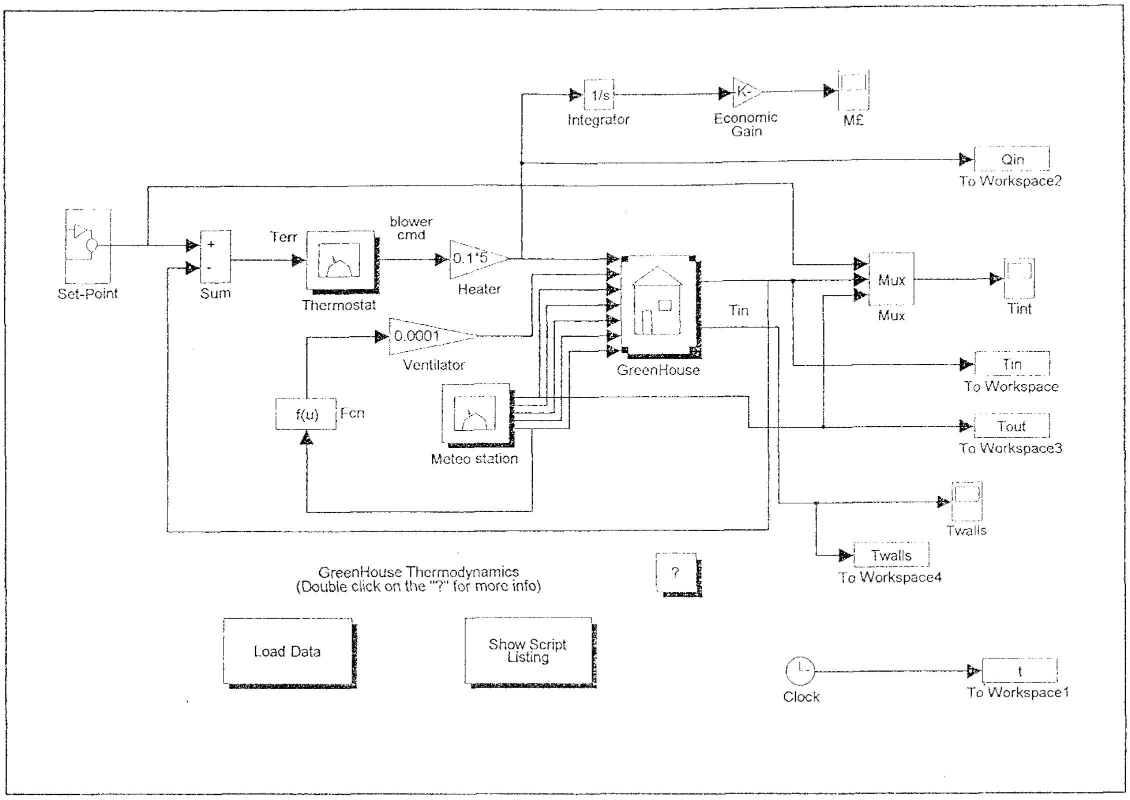

Fig.2 Synthesis of a traditional control system

More precisely, an FLC is able to compute an appropriate values for both the heater actuator values and ventilation rate by taking into account several informations coming from the actual system that are defined by a set of linguistic values (the fuzzy sets).
In the case beeing considered here we take into account the temperature error and the change in error, the wind-speed and the desired humidity, the actual energy spending, the external temperature.

The set of fuzzy rules has been obtained from a human expert by reducing and adjusting the start-up configuration to a suitable number of fuzzy sets for each input variable and of fuzzy rules.
The obtained FLC has 6 input and 2 ouput variables being composed from a set of 30 rules.

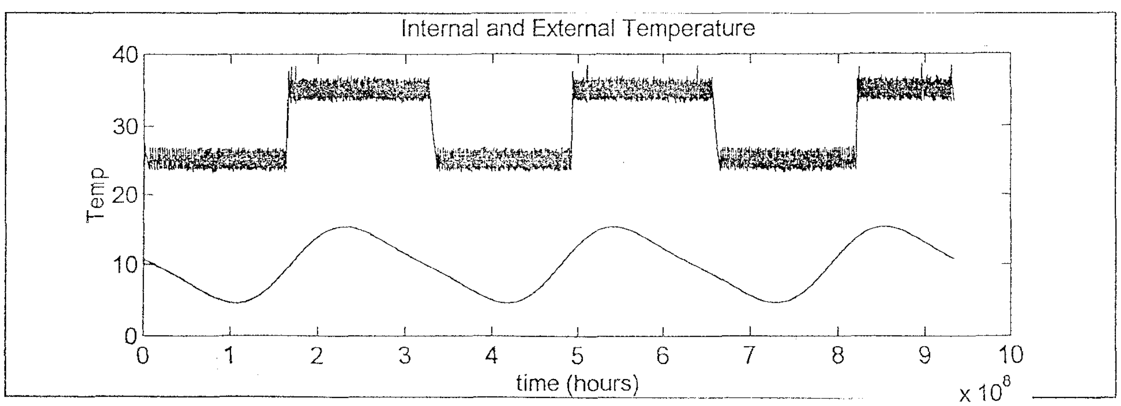

Fig.3 Results of traditional control

Finally, the evaluation of the controllers' performances has been performed taking into account both the global precision and the energy spending.
Results are reported on Fig. 4 concerning the waveform of the error and the energy spending.

V. CONCLUSIONS

The work represents a first attempt to apply an AI technique within a greenhoouse. Due to the physical dynamics involved within a greenhouse the synthesis of a climate controller becomes a complicate task using traditional control techniques. Fuzzy Logic represents a useful tool for solvig this problem.
From experiments carried out, FLC gives the best performances in terms of precision, energy and also robustness.
Work is still in progress in order to implement a biological model of the plants' growth depending on environment parameters so that it will be possible to automatically establish the best control policy and to compute the optimal values for the set-points. Finally, the economic return could be estimated using a neural network-based forecasting technique.

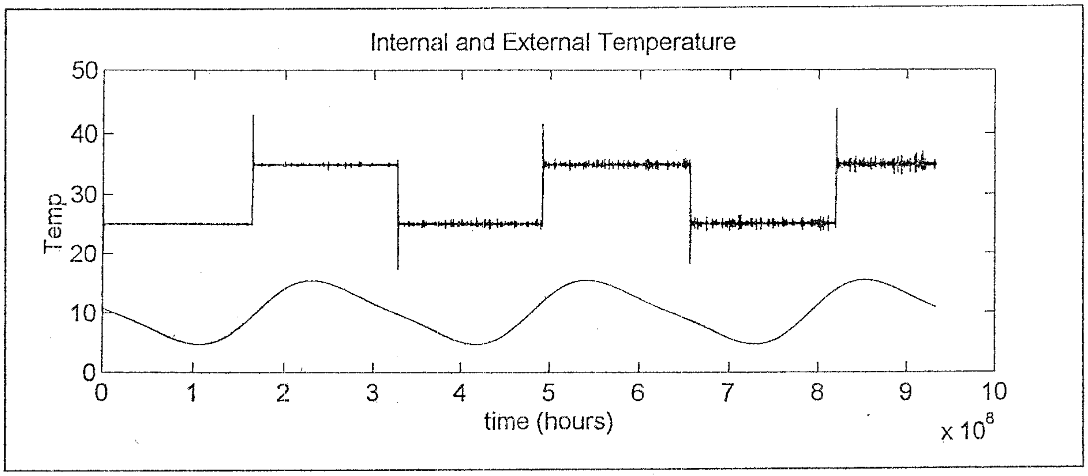

Fig.5 Results of Fuzzy Logic Control

REFERENCES

[1] Businger, "The glasshouse (greenhouse) climate", in *Physics of Plant Environment*, 1963, pp.277-318.
[2] *The solar greenhouse book*, ed. by J.C. Mc Cullagh, Rodale Press-Emmaus, 1978
[3] Joilliet, "HORTITRANS, a Model for Predicting and Optimizing Humidity and Transpiration in Greenhouses", Journal of Agriculture. Engineering Research, 1994, Vol.57, 23-37
[4] I.Seginer, T.Boulard, B.J. Bayley, "Neural Network Models of the Greenhouse Climate", proc. of the 1993 Int. Winter Meeting - ASAE
[5] Clouaire, T. Boulard, M.J. Cros, B. Jeannequin, "Using empirical knowledge for the determination of climatic setpoints: an artificial intelligence approach", *The Computerized Greenhouse*, Chap.9, 1993, pp.197-223
[6] Beccali, A.Giaccone, G.Panno, "Modello di calcolo per l'analisi del comportamento termico delle serre - Prima parte", Energie alternative HTE, anno 4, n.18, luglio-agosto 1992, pp.283-289
[7] Beccali, A.Giaccone, G.Panno, "Modello di calcolo per l'analisi del comportamento termico delle serre - Seconda parte", Energie alternative HTE, anno 4, n.19, settembre-ottobre 1992, pp.405-415.