Modeling of a greenhouse temperature : comparison between multimodel and neural approaches

I. Laribi, H. Homri, R.Mhiri

I.N.S.A.T de Tunis, Unité de Recherche RME ; Département Génie physique et Instrumentation,
B.P.N°676,1080-Tunis Cedex- Tunisie
Tel : (+216.71)703829
Email: ibtissem.maatoug@planet.tn - Homri_houneida@yahoo.fr - radhi.mhiri@planet.tn

Abstract- **The aim of this paper is to discuss different possibilities of modeling the temperature evolution inside an agricultural greenhouse. Our analysis is exploring a wide data measurements representing different profiles of inputs, outputs and disturbances. Our study particularly considers the situation where the control of the greenhouse temperature needs the use of a heating system.**

Two approaches have been considered in the present work: The first one is based on the multimodel techniques which reduce the system complexity by using a set of several simple linear models.

In the second approach we use the feed forward neural networks that allows elaborating a single black box model that can spread out to another variable and command.

Finally we have made a synthesis resting on the comparison between these two approaches by testing the performance of each one with the same data measurements.
This work shows that both approaches give satisfactory results. multimodel representation is more suitable to obtain different variables describing the internal state system and to develop appropriate controller . The neural network model is rather a black box model but it is easier to obtain and could well be used to simulate different output variables at the same time (temperature and humidity in our case).

Keywords: Agricultural Greenhouse, identification, modeling, multimodel approach, neural network.

I. INTRODUCTION

In the Mediterranean environment, a greenhouse requires the control of the climate in order to maintain the agricultural environment in appropriate conditions that satisfy the agronomic and economic objectives of the farmer.
To achieve the design of efficient controllers for the greenhouse, we need to develop models that describe efficiently the system to be simulated and controlled. These models must be related to the experimental influence of outside parameters such as air temperature, wind speed, etc...
Indeed, the control and analyses of the evolution of the various physical parameters conditioning the agricultural environment (temperature, humidity and sunlight…) require a real time control based on micro-computer and 4 control elements : the heating system, the cooling system, a ventilation system and a humidification system.
Identifying and modeling the global system under the four elements of control is not easy , because of the non-linearities of the system and disturbing influence. In order to simplify this task, we study the evolution of the system under only one element of control. In this paper we suggest to modelise the temperature under the action of the heating system. In fact, this sub-system is also non-linear and non-stationary system. We try at a first stage the multi-model approach in order to limit the complexity of the whole system while studying it under particular conditions. The choice of models and their number was based on human experience and analysis of a large number of measurements.
The second approach develops one neural networks model with one hidden layer in order to represent the system by one black box model.

I.1 Greenhouse Description

This application concerns an experimental greenhouse, located at the "Institut National de la Recherche Scientifique et Technologique (INRST)" at Borj Cedria area, a suburb 20 kms south of Tunis.
The experiment consists in developing an acquisition station and climatic control.
It involves a group of hardware and of software which permit the acquisition and numerical storage of the climatic data such as: temperature, humidity, solar radiation and wind speed.
The control system uses a personal computer. The measured values are continuously stored in the computer; the control algorithm switch on (or off) the appropriate systems in order to control different parameters(temperature, humidity).[1],[2],[3]

II. MODELING THE TEMPERATURE UNDER THE GREEN HOUSE

To develop a model of the temperature, we consider an input/output data of the process with different perturbation as illustrated on the following diagram

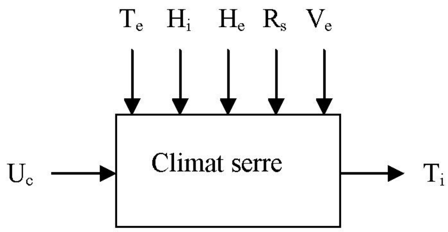


Fig 1: Input/output Diagram

With:

- T_i : Inside Temperature.
- H_i : Inside Humidity
- T_e : Outside Temperature
- H_e : Outside Humidity
- Ve : Wind speed
- R_s : Solar radiation
- Uc : Heating control

II.1 Model Linearization

The linearization of the temperature behavior around a functioning point leads to the following equation [6]

$$Ti(k) = a_1Ti(k-1) + a_2Ti(k-2) + a_3Ti(k-3) + a_4Uc(k-1) + a_5Te(k-1) + a_6Hi(k-1) + a_7He(k-1) + a_8Rs(k-1) + a_9Ve(k-1) \quad \textbf{(1)}$$

III. MODELING THE GREENHOUSE WITH MULTI-MODEL APPROACH

III.1- Introduction

The multimodel approach is interesting as it describes a complex process by a set of linear models which constitute a library of models. Each model represents a partial, local, and/or simplified description of the process. The choice of the model library needs a good knowledge of the process and its environment and has to be optimized by using all the available practical and theoretical resources.

The process can be described by the models M1, M2... Mn, with D1,D2... Dn Domain of validity of each model.
So if x (t) is the state variable, u (t) the control variable and y(t) the output variable. We have the following state representation:

Model Mi, validity domain Di:

$$x_i^{(1)} = f_i\ (x_i, u, t)$$
$$y_i = g_i\ (x_i, u, t)$$

$i \in [1 \ldots n]$

If the domains of validity are separated (fig 2) then coefficients v1, v2, ..., vn can take only values 0 or 1 and verify every time the following relation: vl+v2+...+vn=1.[4],[7]

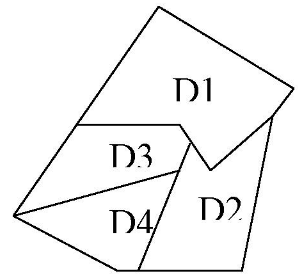
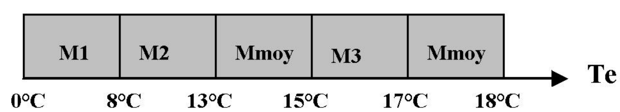


Fig 2: separated validity domains

III.2- Application

In this work we have studied 18 measurements related to March and May 2003. These measurements covered a large variation of external temperature in Tunisia from 5°C to 18°C by night and day .
The first step of the work consists in identifying the model of 18 different selected measurement sets with the method MCR [5].
Based on a human expertise, we found for each range of external temperature the model that represents the behavior of the greenhouse temperature.
The multi-model approach used is based on the method of separated domains validity.
The validation of the multi-model approach is verified for thirty measurement sets between year 1999 to the year 2003.
This study allowed us to arise 5 functioning zones, each one is characterized by a distinct model [6]:



M1: Zone with an external temperature inferior or equals 8°C

The model M1 that characterizes this zone i coming from the identification of the measurements 18/03/03

M2: Zone with an external temperatures between 8°C and 13°C

The model M2 that characterizes this zone is coming from the identification of the measurements 17/03/03

M.3: Zone which the external temperatures between 13°C and 15°C

The model Mmoy characterizing this zone comes from the average of all the identification parameters of the 18 measurements.

M4: Zone with an external temperature between 15°C and 17°C

The model M3 that characterizes this zone is coming from the identification of the measurements 19/05/03

M5: Zone with an external temperature an between 17°C and 18°C

The model Mmoy characterizing this zone comes from the average of all the identification parameters of the 18 measurements.

III.2.6 Parameters of each model

	a_1	a_2	a_3	a_4	a_5
M1	1,026	0,1883	-0,3575	0,5330	0,0732
M2	0,9982	0,2815	-0,3757	0,5872	0,0466
Mmoy	0,8704	0,2843	-0,2197	0,6023	0,04315
M3	0,8189	0,3111	-0,1766	0,6007	0,0475

	a_6	a_7	a_8	a_9
M1	-0,0132	0,0735	-0,0003	0,0082
M2	0,045	-0,0093	0,0015	0,0019
Mmoy	0,0064	0,008	0,0003	0,0067
M3	-0,0114	0,0108	0,0019	0,0051

TABLE I : Parameters of Models

IV. GREENHOUSE MODELING WITH NEURAL NETWORKS

IV.1- Introduction

During the last few years, artificial neural networks (ANN) have matured; today, they are used in many engineering area, such as pattern recognition, function approximation and system identification and control. The ANN is the interconnection between simple processing elements whose functionality is based on the principal of the biologic neuron. Neural networks have some practical proprieties such as the ability to learn or adapt the input/output relationship trough training (see figure3), to generalize the operation which is based on parallel processing [8], [12].

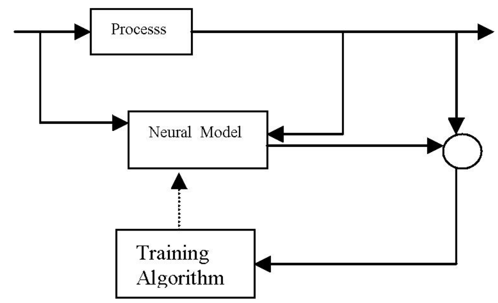


Fig 3: Training neural model

In general, to describe the ANN operation, at least three basic properties should be known namely: the transition function, the network topology and the method of training.
The neural networks have been used in modeling applications with significant success. This is due to their ability to approximate any linear or non linear function with a minimum number of parameters [10], [11].
Several studies have shown that a two-layered feed forward network has the ability to approximate any non-linear continuous function, provided that the hidden layer contains sufficient nodes [13].

IV.2- Application

The phases of an ANN conception are: the choose of the neural network type (selection depending on the type of application), the size of the problem (number of inputs and outputs variable and size of the identification data) an the method of training (supervised/unsupervised) [13], [12].
In this work, the design phase specifies initial parameters and initial conditions, the number of neurons, the number of layers (in our studies one layer), the connectivity of the layers, the transfer function (logsig and purelin) and the learning algorithm (trainlm).
To develop the greenhouse neural network model, we refer to mathematical equations elaborated from physicals analysis (gray box) [14].

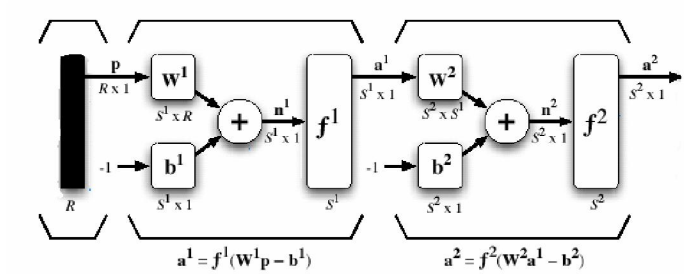


Fig 4: Neural network greenhouse model

The developed neural network has the following elements:

- Input layer : the input without modification
- The hidden layer : 7 neurons, Transfer function logsig
- Output layer : 2 neurons, Transfer function purelin

To obtain an efficient ANN, we need to consider a wide data measurements for the training stage. In this paper three sets of data measurements are used:

- The first data set were used for the training (18/03/03), the outside temperature were between 6 and 14°C
- The second data set were used for validation (15/03/03 and 01/03/01), the temperature variation is in the same interval (6 9°C), but were from a different year for the second data set.
- And the third data set was used for generalization the outside temperature were between 16 and 18 °C

V. COMPARISON BETWEEN THE TWO MODELING APPROACHES

We applied the two modeling methods on three data of measurement: the day of 15/03/03, the night of 29/05/03 and the night of 01/03/01. This choice allows us to cover a large variation of the external temperature that activates the heating system. The use of a measurement file of the year 2001 confirms that the two approaches can be generalized on all the measurements regardless of the disturbances or the type of culture inside the greenhouse.

V.1- Modeling of the day 15/03/03

For these measurements, the performances of the multi-model approach are comparable with the neural one.

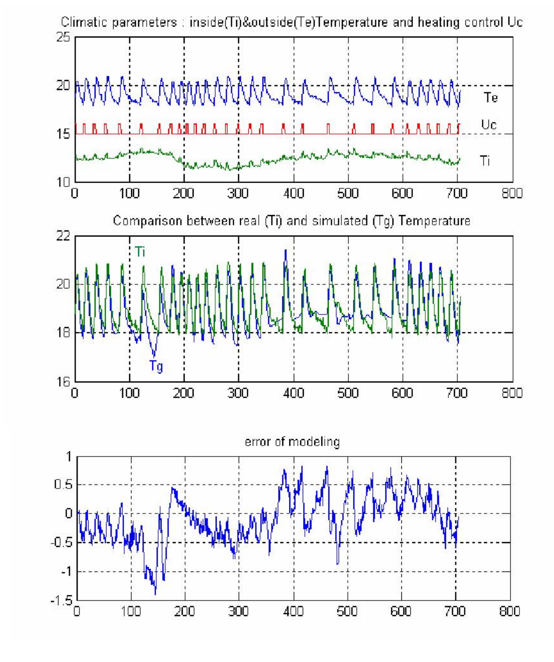


Fig 5: modeling of measurements 15/03/03: multi-model approach

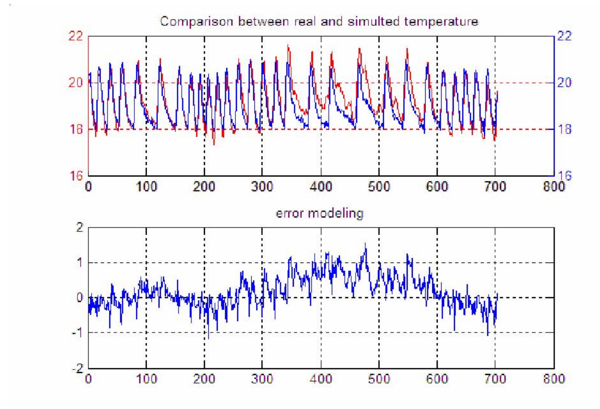


Fig 6: modeling of measurements 15/03/03: neural approach

V.2- Modeling during the night 29/05/03

To validate the two models, we applied them to other Tex interval.

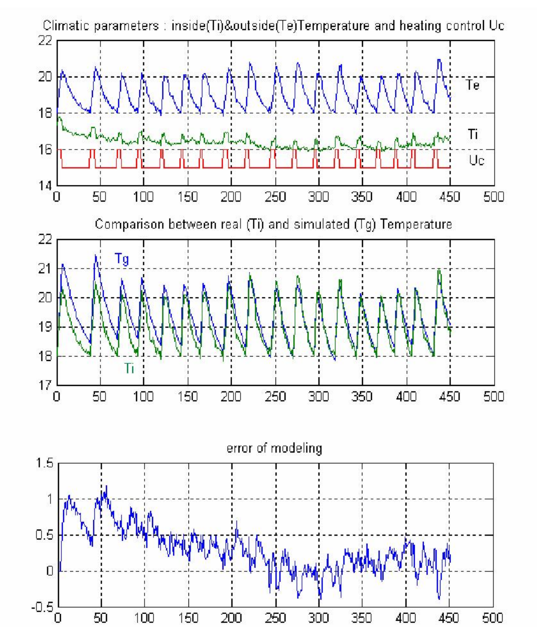


Fig 7: modeling of measurements 29/05/03: multi-model approach

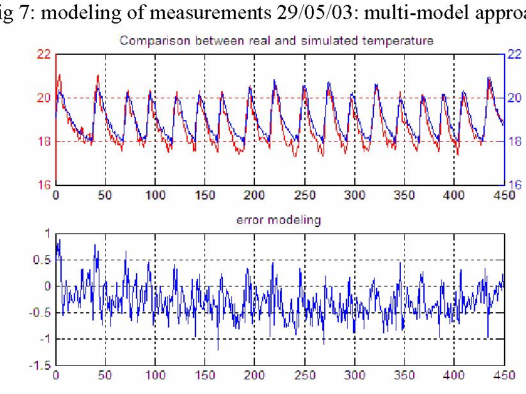


Fig 8: modeling of measurements 29/05/03: neural approach

V.3- Modeling of the night 01/03/01

In order to show the performances of the two methods, we try to modelise an old measurement (the night of 01/03/01). The performances are comparable.

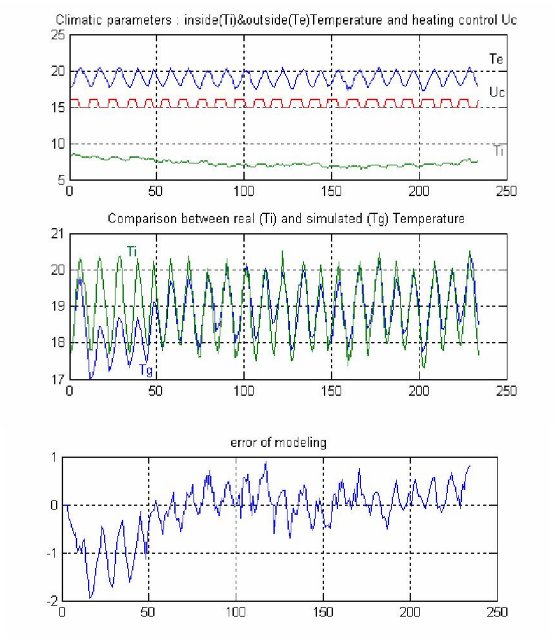


Fig 9: modeling of measurements 01/03/01: multi-model approach

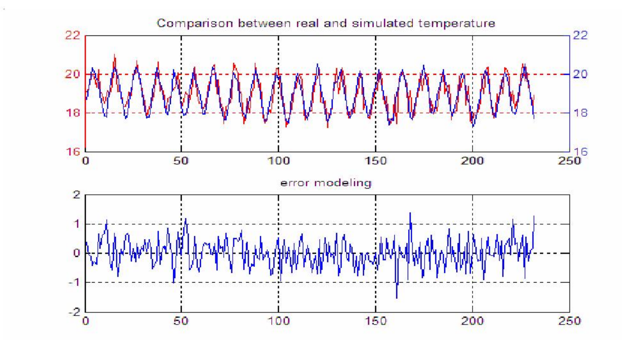


Fig 10: modeling of measurements 01/03/01: neural approach

V.4- Results and discussion

We carried out the comparison between the two approaches according to the two criteria: average error and the variance. Performances are comparable in the two methods: we have a check followed from the real career of the internal temperature: variance did not exceed the 0,35 for two methods, and average error stayed in acceptable margins (lower then 0.5°C).

	Average error		variance	
	MM	RN	MM	RN
15/03/03	0.3309	0.3700	0.1628	0.1939
29/05/03	0.3396	0.3677	0.1007	0.1073
01/03/01	0.3976	0.3966	0.3044	0.2376

TABLE 2 : Performances of the two methods

MM: Multi-model approach
RN neural approach

VI. CONCLUSION:

In this paper, we tried to treat the modeling of the climate inside an agricultural greenhouse in which temperature control needs the action of the heating system.
Two approaches are used: the multi-model modeling and the neural one; the first approach allowed us to constitute a library of four precise models for an exact range of external temperature. The library of models allows us to simulate the behavior of the greenhouse under a large range of external temperature (5°C to 18°C, night and day).

The second approach is based on the use of the artificial neural networks which allowed us to develop only one black box models which can spread out for another variables (humidity) or another commands (one models for the heating and cooling)

Both approaches give satisfactory results. multimodel representation is more suitable to obtain different variables describing the internal system state and to develop appropriate controller . The neural network model is rather a black box model but it is easier to obtain and could well be used to simulate different output variables at the same time (temperature and humidity in our case).

REFERENCES:

[1] Souissi M., Annabi M., "Commande par logique floue du climat d'une serre agricole" ENTROPIE, n°229,pp.24-30,(2001)

[2] Feki E., Mhiri R., Annabi M., Ghorbel A., « Control of greenhouse climate » 2nd IMACS international multiconference CESA'98, Nabeul-Hammamet, Tunisie, Avril 1998

[3] Jemâa R., Feki E.,Ben Salem A.,Ghorbel A., « Optimisation de la conduite énergétique et hydrique d'une culture de vigne sous serre » 5ème séminaire sur la physique énergétique (SIPE'5), Béchar, Algérie Novembre 2000.

[4] Feki E., Mhiri R., Ksouri M. « Application de la commande multi-modèle pour le contrôle de la température sous une serre agricole », Revue internationale ENTROPIE , n°242 – 2002, pp 64-74

[5] Landau I.D. : « Identification et commande des systèmes », 2ème édition, Technip, Paris 1993

[6] Laribi I., Mhiri R. « Modélisation du climat de la serre agricole sous l'action de la commande de chauffage », 5ème journées scientifiques des jeunes chercheurs en génie électrique et informatique GEI Mars 2005 à Sousse

[7] Ksouri Lahmari M., (1999), « Contributions à la commande multimodèle des processus complexes », Thèse de troisième cycle, ENIT, N° 2553, Tunisie.

[8] Jean François Jodouim « Les réseaux de neurones : Principes et définitions » Edition Hermes

[9] Eric Davlo et Petric Naim « Des réseaux de neurones » Edition Eyrolles

[10] G.Dreyfus, J-M.Martinez, M.Samuelides, M-B.Cordon, F.Badran, S.Thiria, L.Hérault « Réseaux de neurones : Méthodologie et application » Edition Eyrolles 2004.

[11] I.rivals, L.Personnaz « Black Box modelling with state space neural networks », neural adaptive control technology, World scientific (1996), pp 237-264

[12] Baily D.L and Thomson D.M « Developing Neural Network Application », A.I Expert, September 1990, pp 34-41

[13] Baily D.L and Thomson D.M « How to develop Neural Network Application », A.I Expert, June 1990, pp 38-47

[14] Yacine Oussar, Gérard Dreyfus «How to Be a Gray Box: The Art of Dynamic Semi-Physical Modeling», Neural Networks, vol. 14 (2001), pp2-27