INTERNATIONAL DESIGN CONFERENCE - DESIGN 2002
Dubrovnik, May 14 - 17, 2002.

SIMULATION ON MULTIPLE DIMENSIONS FOR THE EVALUATION OF NEW DESIGNS. A PRACTICAL EXPERIENCE

Rafael Guirado, José F. Bienvenido and Isabel M. Flores-Parra

Keywords: Complex system simulation, canopy effect, greenhouse climate simulation

1. Introduction

One key point designing new industrial elements is developing prototypes. Years ago, the design process required to build multiples prototypes to evaluate the characteristics of the different alternatives considered. Actually, the existence of effective and efficient simulation frameworks lets us to reduce this expensive part of the design process, reducing the building of physical prototypes to few cases. This way, the design process is linked, actually, to simulation tasks and tools. This is the case of developing new greenhouse structures; it is interesting to evaluate the behaviour of new structures without their real building, which in some cases, as testing the possibilities of new areas, is really expensive.

Evaluating new structures, we restricted ourselves to the case of passive greenhouses, useful in mild climate areas (as our province and related countries in Latin-America). In these passive greenhouses, radiation is the main energy source and the base of the indoor temperature and other variable state as water vapor or CO_2 concentration [Bot 1983] [Bot 1989]. Our application problem is, this way, the study of the radiation into several greenhouse structures typologies in different parts of the world. The final objective of our work was to study the energetic behaviour of generic alternative greenhouse structures without building them. Early, we decide to develop the simulation tools using software-distributed techniques [Kirchner 1997] [Rodríguez 1999]. Our initial objective was to reduce the computing time and to use more specific tools. Finding during the analysis time, that, modelling the problem with a space/time distributed schema, we obtained not only a quicker tool but also a more flexible system [Bienvenido 1999].

Main input data of the simulation system are the greenhouse structure parameters, time period of simulation, cover and soil characteristics, and the radiation absorption model to consider into the greenhouse (it depends on crop and its growing) to simulate the greenhouse behaviour [Bienvenido 1997]. The greenhouse structure parameters are generated using our greenhouse design tool DAMOCIA-Design. The designer gives the rest of values using a problem definition interface, which generates the experiment definition. All these physical variables are complemented by an instrumental set of values that will condition how the simulation process is done (it includes the discretization parameters).

In our case, the modeling of the radiation into generic greenhouses, the whole simulation process is divided in 3 phases including 4 physical complex models, as shown on figure 1:

1. Calculation of the sun position (A) and intensity and direction (B) of the radiation that reaches the earth surface.
2. Calculation of the radiation that crosses the greenhouse cover (C). It considers its structure, the cover optic characteristics and the external reflections between cover surfaces.

3. Evaluation of the radiation evolution inside the greenhouse (considering the canopy and the cover and soil characteristics), generating maps of the incident radiation on each surface (D).

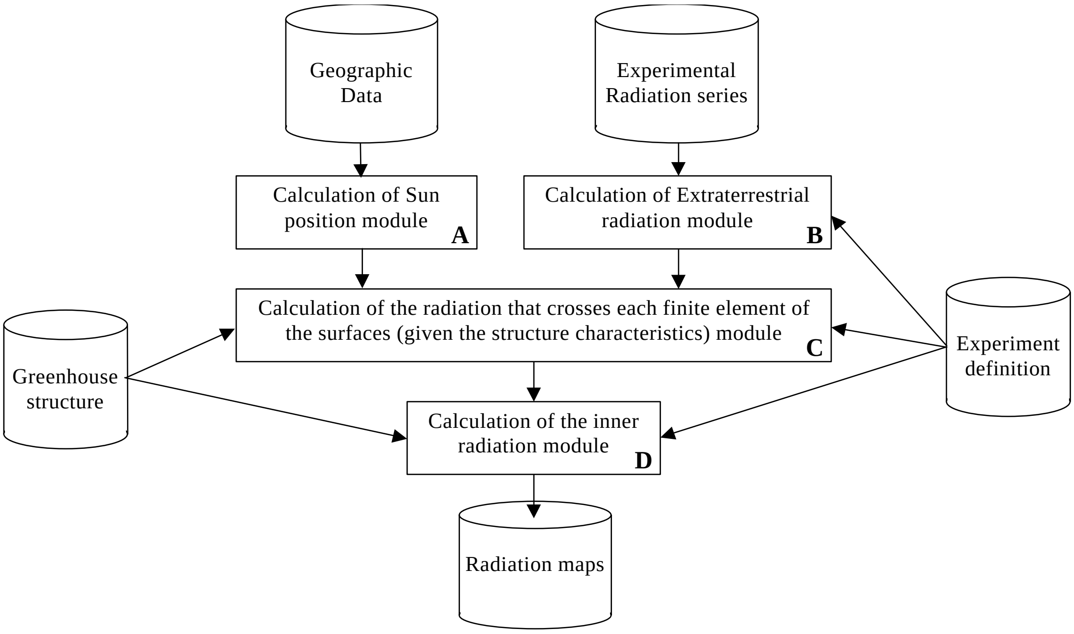

Figure 1. Main simulation modules and data blocks

2. Methodology

Our proposal, to simulate the radiation inside greenhouses, includes mainly using two techniques:

1. Distributed simulation.
2. Finite elements.

Simulating the behaviour of the radiation outside and inside the greenhouse is a complex task. We decided to use previous submodels developed by our team or found in the bibliography. This let us to divide the problem into a set of subproblems relative to physical models (as the sun radiation intensity or the optical behaviour of the plastic cover), or specific techniques (as finding projections of steel grids or evaluating shadows between different surfaces in space). As it would be visible in next section, this was a key factor of the resolution of the problem. It was possible, even, to use multiple developing tools taking advantage of the knowledge of different component of the team. We implemented the whole simulation tool using our DACAS architecture [Bienvenido 1998].

About the use of the finite elements computing techniques, we proposed, first, to discretize the time axis, in order to model the evolution of the radiation at a given location. Using meteorological data to generate sets of test data (including direct and diffuse radiation for clear and clouded days, with an experimental distribution).

Secondly, we proposed the discretization of the greenhouse surfaces on finite elements. This means that each finite element requires an independent processing, computing each finite element of the greenhouse surface as a source of radiation. General process consists of iterative cycles computing the incident radiation on each finite element of each surface.

Third, we evaluate the absorption of the radiation into the greenhouse by alternative configurations of the canopy [Guirado 1998]. We proposed a set of alternative submodels of absorption, presented in table 1 and figure 2, and modelled as different simulation methods. These new methods include the volumetric discretization of the inside of the greenhouse [Guirado 1999].

As described before, different steps of the simulation process use an expanding block of discretization dimensions (time, surface and volume). There are modules using time, time+surface or time+surface+volume discretization as simplified can be seen in figure 3.

Table 1. Absorption alternative submodels

Ref.	Submodel	Application	Calculation
(a)	No absorption	Greenhouses without canopy and low humidity.	No absorption inside the greenhouse. Radiation not affected inside the greenhouse.
(b)	Uniform Absorption	Greenhouses without canopy, high humidity, and scattered dust.	The absorption coefficient inside the greenhouse is not 0 (but uniform). The radiation traversing the greenhouse is reduced proportionally to the covered distance.
(c)	Uniform Absorption by layers	Greenhouses with canopy compactly distributed by layers.	Each greenhouse layer has a given absorption coefficient. The radiation that crosses each layer is evaluated using the associated absorption coefficient and covered distance.
(d)	Absorption with volumetric elements (3 models)	Greenhouses with high canopy and broad corridors between hedges.	The radiation absorbed by each volumetric finite element, is calculated in function of: (1) the top surface crossed fraction; (2) crossed fractions of the top and bottom surfaces; (3) fraction of the finite element crossed volume.

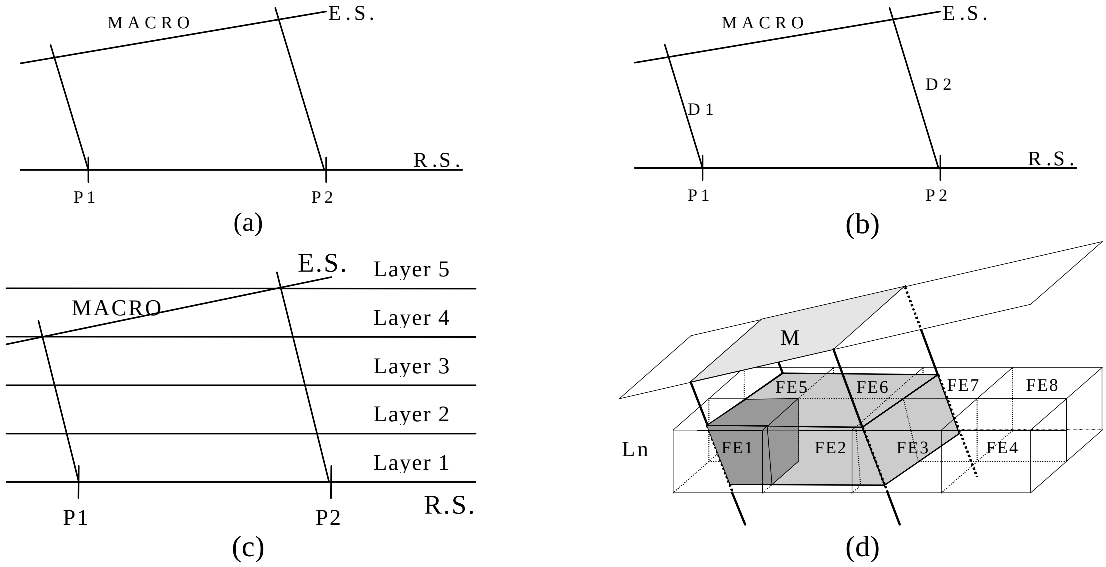

Figure 2. Representation of the behaviour of the canopy for the alternative submodels

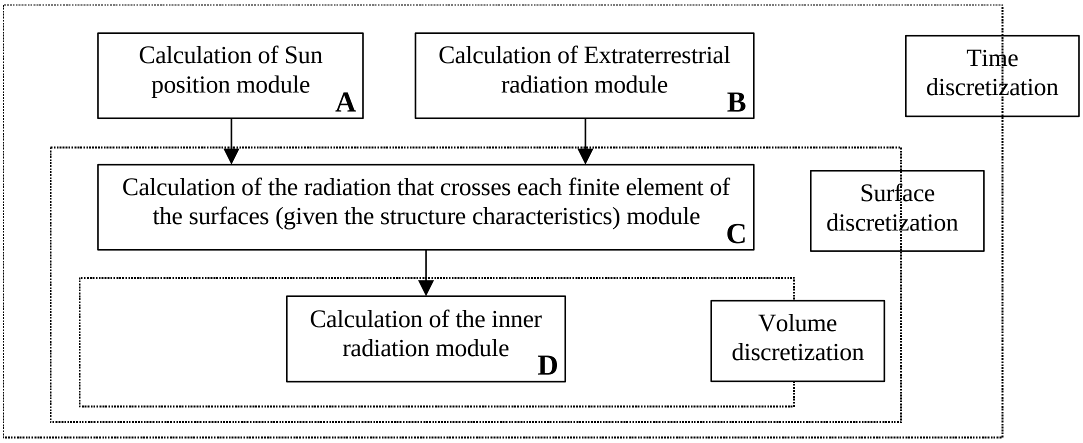

Figure 3. Discretization context of main simulation blocks

3. Simulation tool elements

Our simulation tool includes multiples submodels, which, as pointed previously, have been developed separately. They are integrated as shown in figures 4 and 5, which present the decomposition of main blocks C and D.

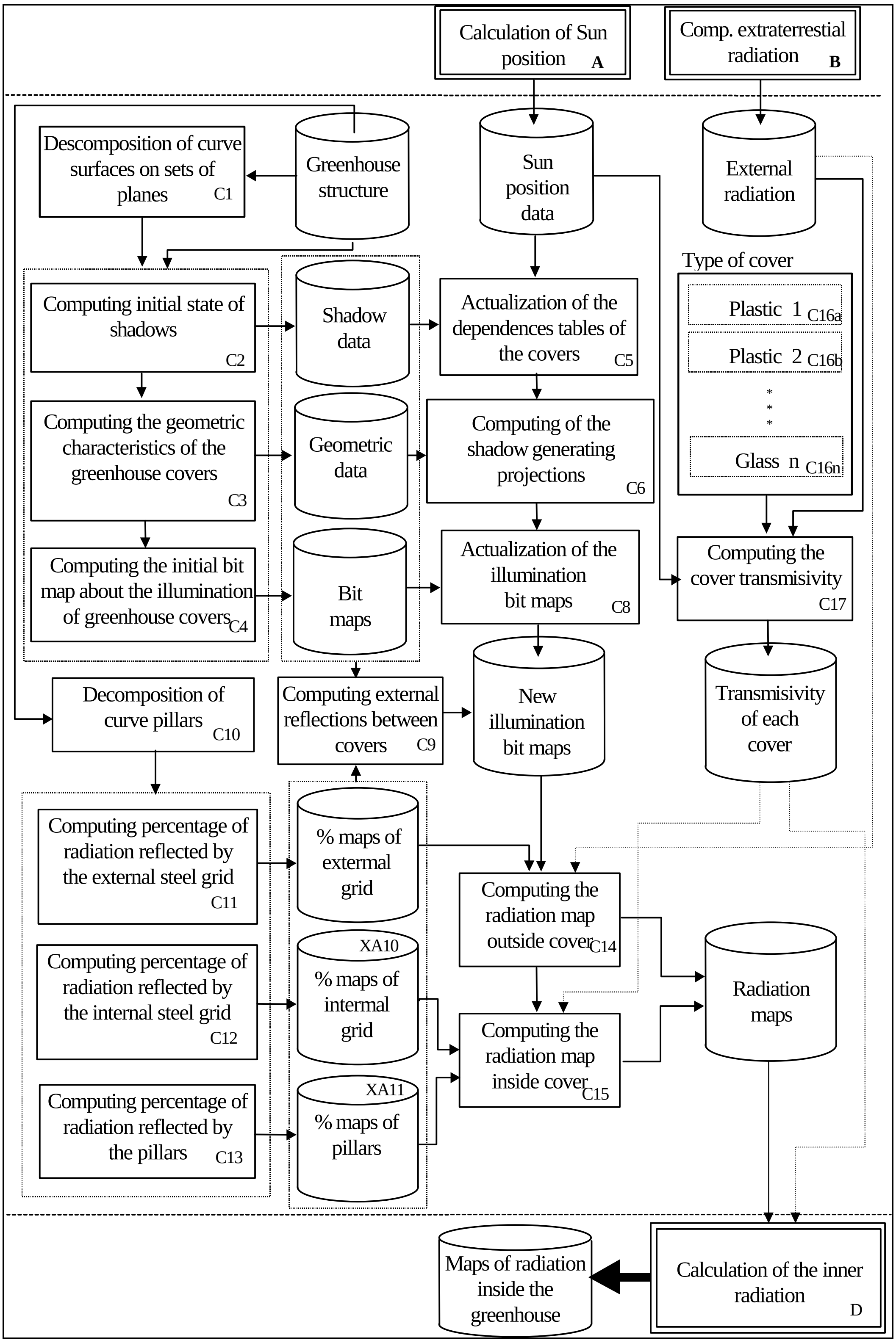

Figure 4. Block C main simulation modules and data blocks

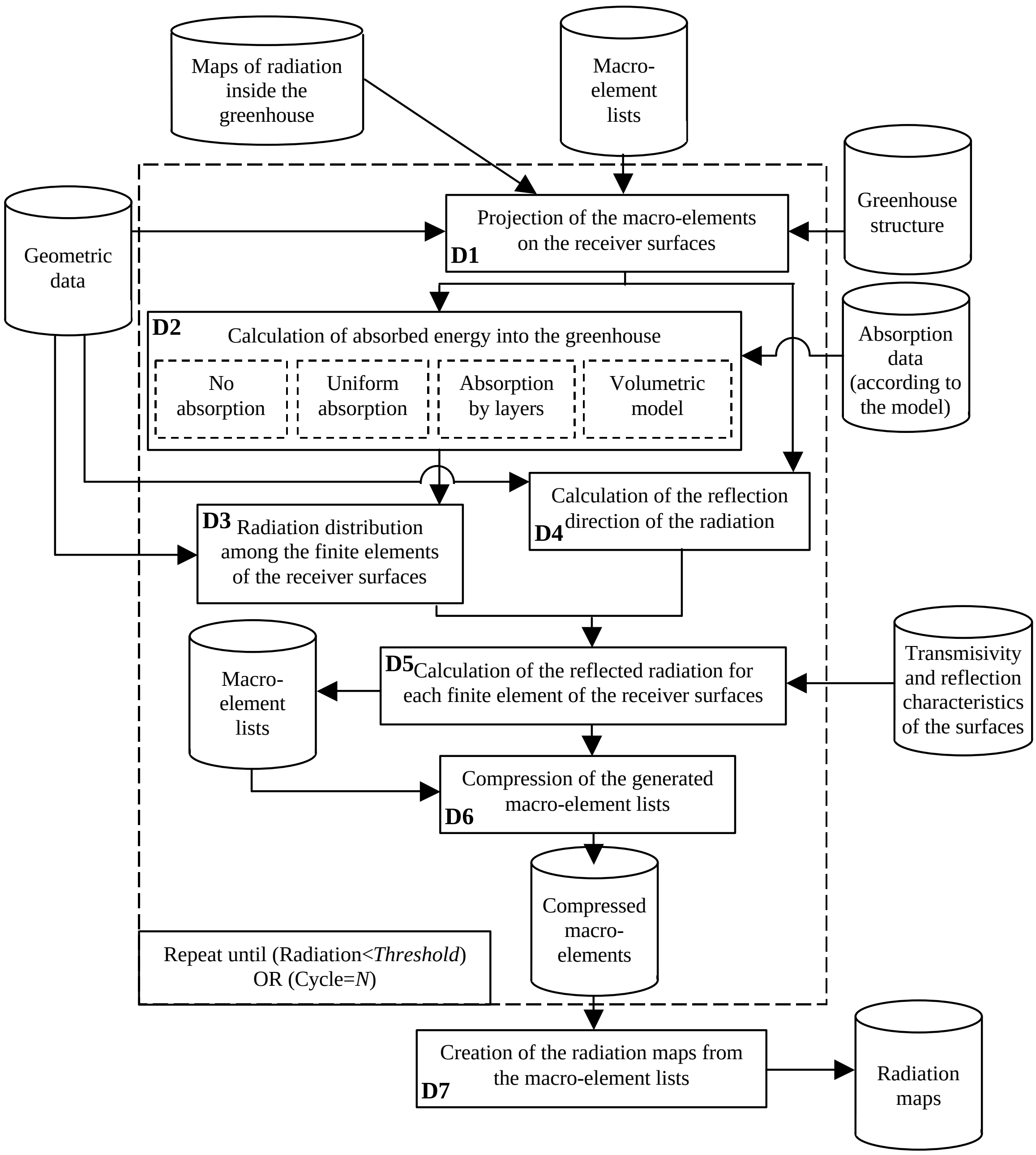

Figure 5. Block D main simulation modules and data blocks

Each C and D notated module has been implemented as an autonomous agent, using specific submodels. Macroelements are sets of discrete elements with the same radiation characteristics (at any computing cycle); which are computed as single elements reducing the computing time (mainly at the initial simulation cycles) [Guirado 2000].

Modules C16 and D2 include different alternatives of simulation, which are computed as alternative computing methods. This schema is applied to all the modules in order to use different physical models and accuracy.

4. Conclusions and future works

Main conclusions include:

- Our proposal of multidimensional finite element treatment let us to simulate extremely complex simulation problems, as the radiation inside greenhouses.

- Combining a distributed architecture, as DACAS, with the multidimensional discretization it is possible to accelerate the developing process (reusing previous modules). Discretization is linked to the subproblems instead of being associated to the whole problem.
- Adding a simulation tool to the greenhouse design one let us to evaluate more structure alternatives for specific situations, reducing risks and costs (empirical relation is 1:6).

Future works include to model new problems (as the plant grow) and distributing the computing between multiple low cost CPUs to accelerate the simulation process.

References

Bienvenido, J.F. et al., “DAMOCIA-SIM, a Generic Tool for Radiation Simulation into Mild Winter Region Greenhouses”, Proceedings of First European Conference for Information Technology in Agriculture, Efita’97, Copenhagen, Denmark, 1997, pp. 179-182.

Bienvenido, J.F., Corral, A., Marín, R., Guirado, R., “DACAS: A Distributed Architecture for Changeable and Adaptable Simulation”, Proceedings of International ICSC Symposium on Engineering of Intelligent Systems, EIS’98 , Vol. 3, Artificial Intelligence, Tenerife, Spain, 1998, pp. 101-107.

Bienvenido, J.F., Guirado, R., "Distributed Simulation of Direct Radiation into Mediterranean Greenhouses", IFAC'99 Proceedings, IFAC & Pergamon, ISBN 0-08-043222-0, 1999, pp. 407-412.

Bot, X. “Greenhouse Climate: From Physical Processes to a Dynamic Mode”l, Wageningen, 1983.

Bot, G., “Greenhouse Simulation Models”, Acta Horticulturae (ISHS) Vol. 245, 1989, pp.315-325.

Guirado, R. et al. "Multimodel Simulation of the Canopy Effect on an Inner Radiation Model for Parameterized Greenhouses", Proceedings of International Conference Engineering of Decision Support Systems in Bio-Industries, Bio-Decision'98, Montpellier-Narbone, France, 1998, Poster.

Guirado, R., Iribarne, L.F., García, J.R., Bienvenido, J.F., "Distributed Simulation of Greenhouse Climate: Canopy Models", Efita'99, ed. Schiefer, G., Helbig, R., Rickert, U., ILB, Bonn, Germany, 1999, pp. 89-97.

Guirado, R., García-Lázaro, J.R., Bienvenido, J.F., "A Distributed Simulation Model of the Inner Radiation into Mediterranean Greenhouses", Proceedings of International ICSC Congress on Intelligent Systems and Applications (ISA'2000), Wollongong, Australia, 2000.

Kirchner, T.B.”Distributed processing and simulation modeling”, Simulation Practice and Theory, vol. 5, 1997, pp. 35-47.

Rodríguez, F.; Corral, A.; Bienvenido, J. F. “Application of Distributed Techniques in a set of tools for climatic sensor signal validation and Data Analysis: DAMOCIA-VAL and DAMOCIA-EXP”, Advances in Intelligent Systems: Concepts, Tools and Applications, S. Tzafestas ed. Kluwer Academic Publishers, 1999.

Rafael Guirado Clavijo, Associate Professor
University of Almería, Dpto. Lenguajes y Computación
Ctra. Sacramento, S/N, La Cañada de San Urbano, Almería (Spain), E-04120
Telephone: ++34 950 015 681
Telefax: ++34 950 015 129
Email: rguirado@ual.es