DAMOCIA-SIM, A GENERIC TOOL FOR RADIATION SIMULATION INTO MILD WINTER REGION GREENHOUSES

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Abstract: In order to simulate specific greenhouse structures in a general way, DAMOCIA-SIM uses “greenhouse definitions” and “experiment definitions”. It incorporates modern IT techniques and tools, with discrete-elements techniques. The simulation process is divided into independent phases, with alternative processes. The different transformations are executed by “connective independent” modules. Processes are managed by a special Handler. The tool features an overall multiagent architecture. Mathematical models include external-internal radiation, plastic response, shading and canopy effect. The tool generates radiation maps in the specified greenhouses, used to evaluate several passive structures.

Keywords: Greenhouses simulation tool. Multiagent architectures.

1 Introduction

The opening of the markets forces the renovation and technification of the greenhouse structures in our region, looking for a better product quality and harvest opportunity. These improvements require to enhance the microclimatic conditions into our greenhouses.. It requires a microclimatic conditioning different from the one used in North and Central Europe. In this environment, we developed a generic simulation tool, **DAMOCIA-SIM,** that computes the behaviour of specific instantiations of general greenhouse structures, centered now on the modellization of the radiation. This work, included into a more generic project (DAMOCIA), has been financed by the EU in the framework of the ESPRIT Special Action P7510 PACE and the Spanish Ministry of Industry in the PATI PC191.

The principal objective of **DAMOCIA-SIM** is to model the radiation behaviour of general greenhouse structures. This tool is complemented by DAMOCIA-Design. The radiation simulator uses as input the formal definition of the greenhouse (a specific one) generated with the design tool, and the desired simulation profile. The greenhouse definition is formalized using a declarative language. The definition is automatically obtained translating a user given high level definition, which is introduced via a window user interface, that includes some data validation and default assignment modules.

2 Used techniques

The tool uses finite-element techniques at two levels, greenhouse surfaces and volumes. In the calculation process the greenhouse structure is uncoupled, computing each of its surfaces independently.

The different transformations are executed by ‘connective independent’ modules. Each one is an independent and self-contained entity. Different modules communicate via ‘message passing’. This information is given with standard formats, called Interchange Data Structures (IDSs). The different processes are divided into independent phases, managed by a special module (Handler). This module calls different procedures (TSPs, Transformation Specific Processes), in an alternative and cumulative way. Figure 1 shows overall agent architecture of the modeller.

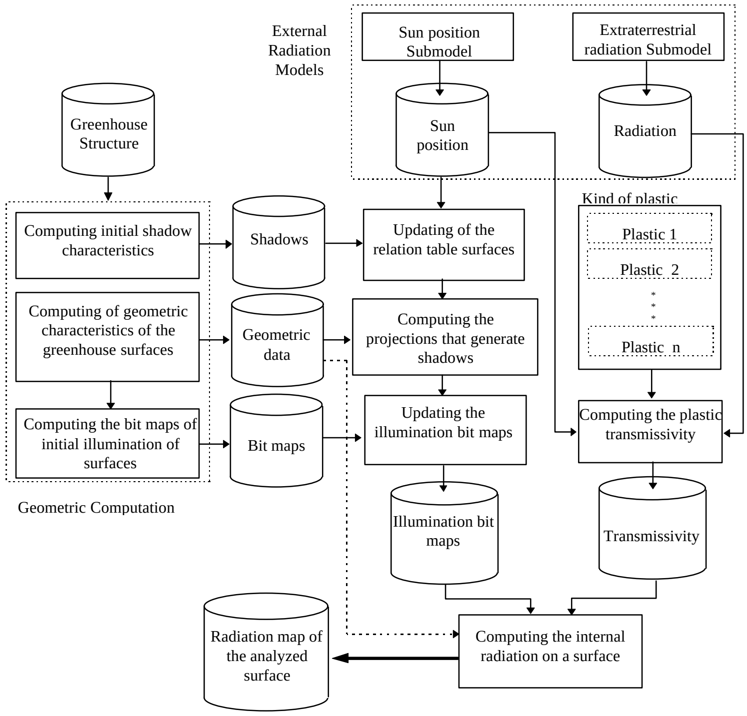

Figure 1. Overall agent architecture of the modeller.

3 External radiation models

The objective of this subsystem is to compute the basic direct and diffuse radiation components over an horizontal surface and the direction components of the sunlight. It is constituted by: a) *A direct and diffuse radiation submode*l. It evaluates the components of the solar global radiation using theorical or experimental global radiation data. The tool can simulate any period of time. b) *A sun position submodel*. It computes the sun position for a proposed period and place.

4 Geometric computation and shadows between surfaces

This submodel, precomputes the behaviour of the greenhouse surfaces, independently of external factors.. Its objective is to determine which surfaces can be illuminated. Its main tasks are:

A) Computing the geometric features of each greenhouse surface. The specification of the greenhouse surfaces is extracted from the greenhouse definition, uncoupling, and placing them into the space.

B) Discretization of the greenhouse surfaces. We cover each surface with a grid of finite elements on local coordinate systems, following these steps: a) computing the change matrix, b) fixing the minimum window LRS coordinates, c) generation of the grid, d) computing the finite elements central points references, e) establishing the surface membership of the finite elements

C) Computation of shadows between surfaces. In order to determine the fully or partially illuminated greenhouse surfaces for a given sun position, we classify the normal surface vectors into nine orientation sectors. If the surface can be illuminated, the tool will compute the shadows. We obtain a surface interdependence table, showing the surfaces that can shade other surfaces. Then we obtain a new surface dependences table for each time quantum, taking into account the shadow overlapping.

5 Greenhouse structure shadows

So far, we have considered ideal greenhouse surfaces, but they contain structural elements that intercept the light. We have developed two models to compute their effect.

5.1 Wire grid shadow module. The intercepted light is computed using a uniform discount method. We differentiate two coefficients, the external side and internal side intercepted energy percentages.

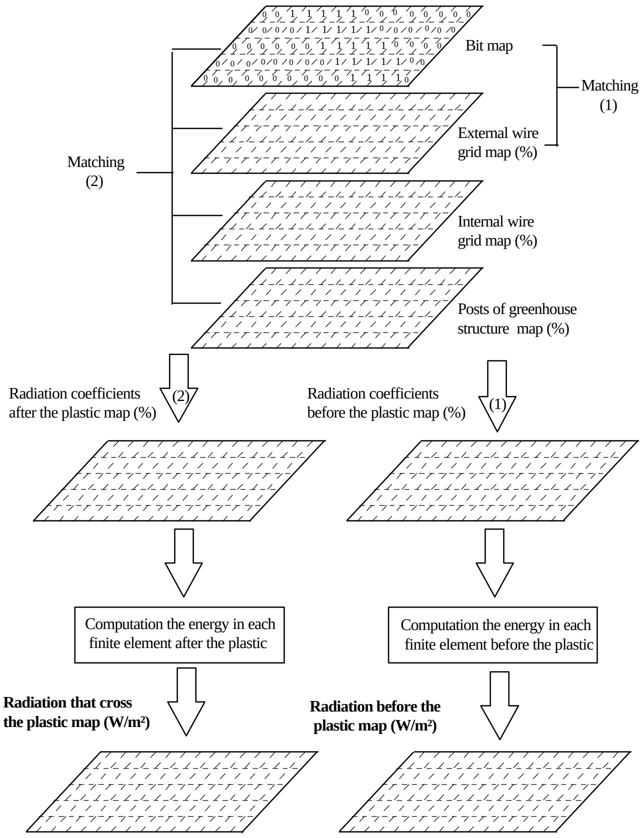

Figure 2. Shadow Modeling.

5.2 Structure post shadow module.

Using the low level definition of the proposed greenhouse, the tool selects the posts that hold the external surfaces; verifies the finite elements (fully or partially) shaded by them; computes the shadow percentage onto the elements; and multiplies the finite element energies by the percentage complements.

6 Greenhouse cover behaviour submodel

The effect of the plastic cover is modelled via a classical refraction model, computing a radiation intensity reduction, and a radiation front direction change. We have developed three alternative models: a) *Simple*, (without change of the radiation front direction), b) *Intermediate*, (changing the radiation front direction). c) *Complete*, (evaluating the reflection on the material cover). All the models use absorption and reduction coefficients.

7 Internal radiation model

The main objective of this model is to obtain the incident radiation on an internal surface, based on the radiation, the absorption level and the reflections on the internal sides. The inputs are: a) the greenhouse cover crossing radiation, b) the time interval. The radiation values are compacted on macroelements, sets of similar behaviour finite elements. This includes two submodels:

A) Internal absorption submodel. It computes the radiation energy absorbed into the greenhouse. The alternative schemas are: *No internal absorption submodel* (no crop and low humidity). *Uniform internal absorption submodel*, (no crop normal humidity and dust conditions). It uses a constant absorption coefficient. *Absorption by layers*, (uniform distributed crop, normal humidity and dust conditions), the greenhouse inside is divided into layers with different absorption coefficients. *Absorption by volumetric finite elements*, (vegetable mass, high plants and wide corridors).The inner greenhouse volume is divided onto volumetric finite elements, with different absorption coefficients.

B) Internal reflected radiation submodel. In the next step, each receiver surface is converted into an emitter surface, requiring to calculate the reflected radiation. The inputs are:1) the received radiation, 2) the incident angle of the light front, 3) the material cover reflexion coefficient, 4) the material cover thickness and 5) the computing threshold (radiatium minimum or iteration number). Then we iterate internal radiation submodels until the computing threshold is reached.

8 Example. A real application

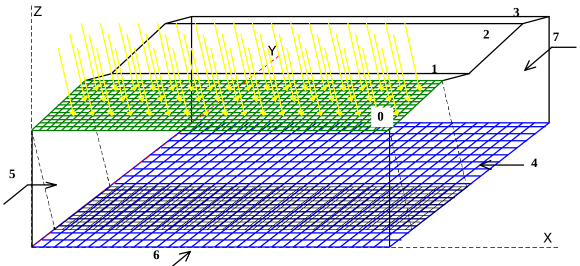

Figure 3. A sample surface modelling.

In this example, we have considered an empty INACRAL greenhouse without canopy effect. on June 21st, at 13:09. The results of the external radiation submodel are: global radiation 1014.55 W/m², diffuse radiation 166.59 W/m², direct radiation 847.96 W/m².The finite-elements are 0.5 x 0.5 m sized.The shadow submodel classifies the structures surfaces (0,1,2,3 and 6 illuminated; 4, 5 and 7 not illuminated).

The inputs of the plastic submodel are 0.18 mm of thickness, refraction coef. 1.51, absortion coef. 10. and the result is a set of transmissivity coefficients per macroelement.The internal radiation submodel, generates a projection of the different external iluminated surfaces on the internal surface. The final result is a map of the radiation in each finite-element of the analyzed surface, that can be represented on a colour radiation map:

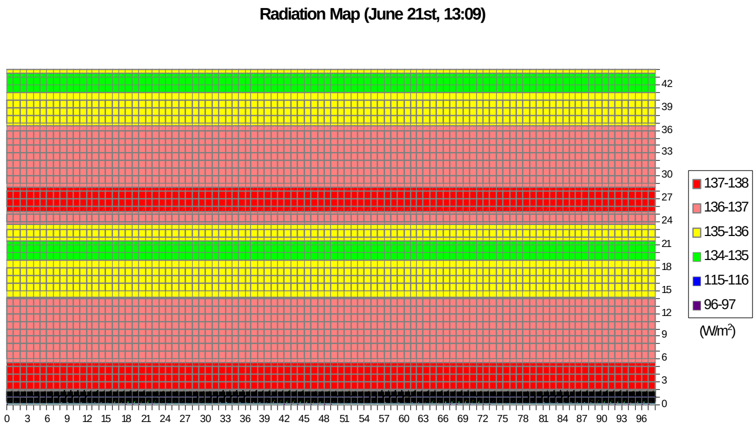

Figure 4. Greenhouse surface radiation map.

9 Conclusions

The use of new Information Technologies for simulating the behaviour of greenhouses seems viable for some microclimatic variables. The tool is applicable to several structure typologies in a general and expandable way. Planned further developments include to extend the scope of simulation, modelling other parameters (temperature, humidity, ...), adding new mathematical submodels and extending the modelled structure typologies. (expanding the DAMOCIA-Design semantic).

10 References

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