INTEGRATION OF SYSTEM DYNAMICS MODELS AND GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

The problem of integration of temporal models and Geographic Information Systems (GIS) involves theoretical and technical aspects. Many GIS applications are advertised in terms of their modeling capability but such modeling tools are often unable to handle full integration of spatial and dynamic processes. This paper, however, presents new software, SimArc, able to interface a System Dynamics tool, Simile, and a GIS environment (E.S.R.I. ArcView). The tool enables users to link a model to input data from the GIS database, creating new GIS layers from any selected output variable of Simile model.

KEYWORDS

GIS, System Dynamics, modeling.

INTRODUCTION

The problem of integration between temporal models and Geographic Information Systems (GIS) involves theoretical (Karimi, and Houston 1996, Yates and Bishop, 1998) and technical aspects (Goodchild et all. 1993, 1996 and Huang and Jiang 2002). Scaling problems are often recognized as a complex issue to be faced. Many GIS software packages are advertised in terms of their modeling capability (ArcView Spatial Modeler Extension, Erdas IMAGINE Model Maker). However such modeling tools are often unable to handle a full integration of spatial and dynamic processes. In the field of ecological modeling several papers have been published discussing the importance of both spatial and temporal scales (Jarvis and Mc Naughton, 1986; van der Maarel, 1988; Falinski, 1988; Allen and Hoekstra, 1990; Grace, 1991; Fahrig, 1992; Levin, 1992).

The scaling problem and the issue of linking dynamic and spatial processes requires integrated logic and an appropriate software solution. In this context, this paper presents work done at integrating a System Dynamics environment able to model processes in time and a GIS. So the integration of static spatial information within a dynamic system is the key modeling issue addressed (Figure. 1).

SIMILE: A SYSTEM DYNAMIC SOFTWARE

Simile (www.simulistics.com) is a recent addition to the family of System Dynamics modelling environments. There are several system dynamic software tools (see Costanza 1998, 2001 for review) that allow the construction of models by graphical interfaces, thus not requiring the use of conventional programming languages. These tools are able to automatically generate executable programs. Well known packages are STELLA (www.hps-inc.com) with a wide application in the field of ecology and agriculture modeling, SIMULINK (www.mathworks.com) supporting tool for MATLAB, characterized by strong computational capacity and access to mathematical libraries, other products to be mentioned are POWERSIM (www.powersim.com) and ModelMaker (www.cherwell.com).

Compared to the above mentioned products, Simile presents very interesting enhanced capabilities well suited for ecological modelling work (Muetzelfeldt and Massheder, 2003), and it is able to compile the models in C++ and/or export models as library files (Figure 1)
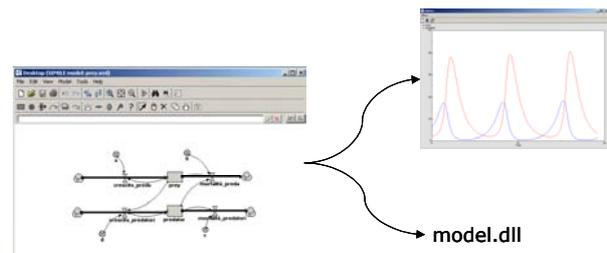

Figure 1: An example of graphical interface of a SIMILE model and types of outputs

SIMARC: SIMILE - ARCVIEW DYNAMIC LINK

The new software tool named SimArc (http://143.225.165.9/simarc/) was recently developed to interface models created by Simile with ArcView (E.S.R.I. Inc.) GIS environment. The tool enables users to link a model to input data from the GIS database. This essentially amounts to running a model in each polygon element of the ArcView map with inputs from layers of the relative shapefile and creating new GIS layers from any selected model output variable (Figure 2).
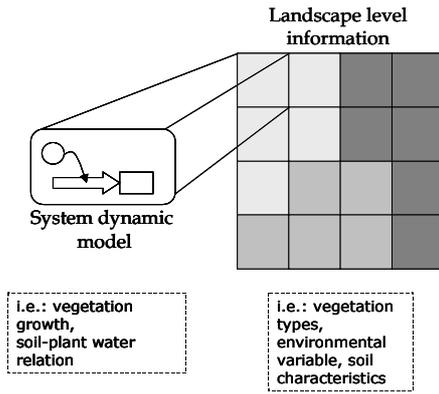
Figure 2: Upscaling to the landscape level in

In Microsoft Windows software can be linked by any of four different approaches (

Figure 3):

- Data file sharing
- Dynamic Data Exchange (DDE)
- Compiled model library (DLL)
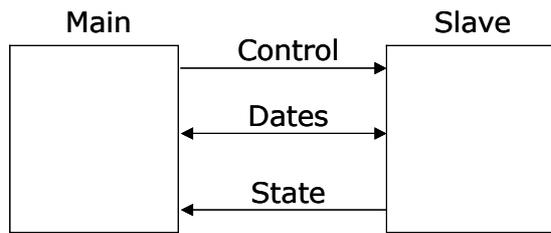- COM Automation (formerly known as OLE)

Figure 3: General software interaction

We used a mixed strategy to implement SimArc (

Figure 4), in fact ArcView calls SimArc through a DDE protocol, and it calls the Simile's DLL to run the model in each polygon of the map. Finally, SimArc produces a new .dbf file to contain the output of the simulation and show as new layers in the ArcView map.
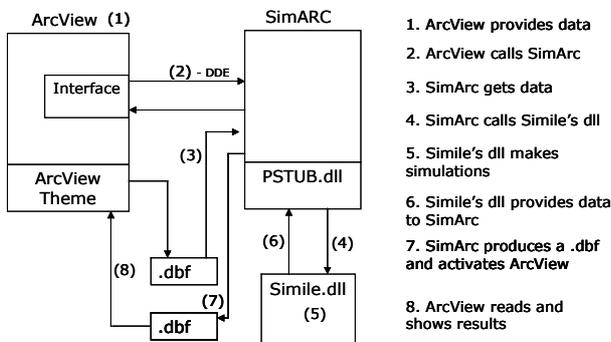

Figure 4: Data flow structure in SimArc

EXAMPLE OF INTEGRATED MODELLING ENVIRONMENT

Figure 5 shows a schematic representation of a simple SimArc application: a vegetation model is realized in Simile with just two input parameters from a GIS (temperature and water), and one output (biomass). SimArc links (by drag & drop commands) the input parameters with two ArcView maps to generate a new output map (vegetation biomass).
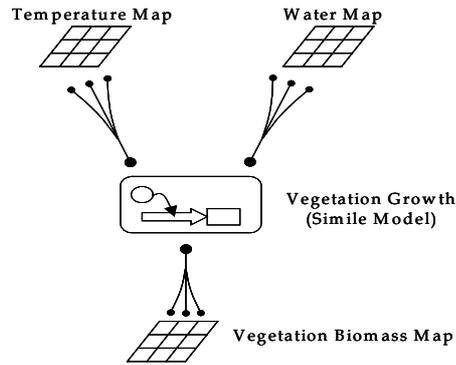

Figure 5: A schematic representation of a application from Simile and Arcview

Figure 6 shows a window of ArcView and the user interface of SimArc. In the SimArc window, on the left there is the list of all elements of Simile model, whereas on the right there are the layers information of .dbf ArcView file. It is possible to link an attribute of a layer in the ArcView map to an input element of the Simile model and, moreover, it is possible to define which variable of the Simile model of is the output as a layer of the map.
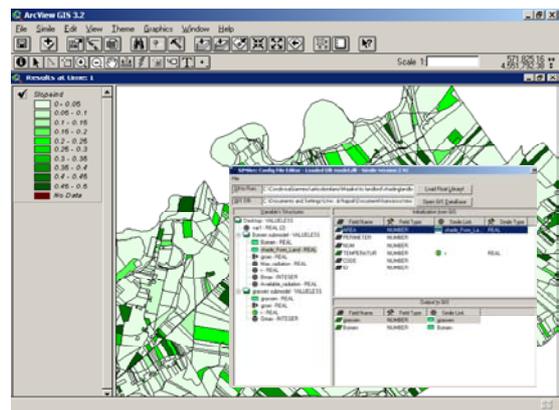

Figure 6: Screen shot of ArcView with the Simile extension. The SimArc window permits the connection of the Simile model to the ArcView map.

COMPUTATIONAL ISSUES

A Simile model with 32 elements (compartments, variables, flows) and a number of elements in ArcView of 40 polygons, required a running time less than 1 second for each time step (on a Intel Pentium IV 1GHz). The following table reports some running times for different case studies.

Table 1: Running Time of Different Simulations

Number of Simile elements	Number of ArcView polygons	Time (second)
32	40	0.8
32	~4000	1.3
32	~20000	3.1
81	~20000	5.3

CONCLUSION

SimArc links two powerful software packages, Simile (a System Dynamics modelling tool) and ArcView GIS, into an even more powerful synthesis.

Other modeling approachs consider the integration of spatial processes (Figure 7). To this aim we are developing a new, specific raster-based, spatial modelling system named 5D. The advantage of using this new, dedicated spatial modeling tool, instead of an established GIS package lies in its enhanced modelling capabilities, i.e. the possibility of making use of temporal simulations at both local and spatial scales in a highly integrated way. (A new Simile version enables integration with ArcGIS 8.0 by COM technology including use of Simile's inherent spatial capabilities.)
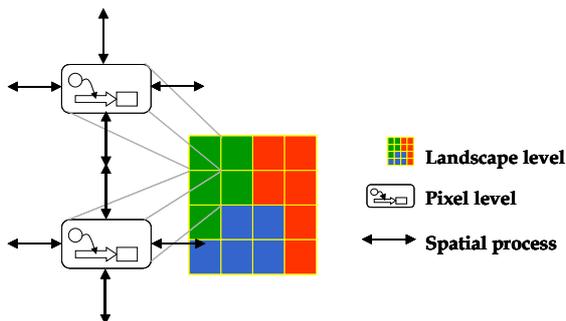

Figure 7: New software tools for integrated modeling require different System Dynamics models to interact, by different spatial processes, according to their position.

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