PATTERNS AND PROCESSES IN FOREST LANDSCAPES

Consequences of human management

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AN EFFORT TO ENHANCE THE COMPUTER SIMULATION OF DYNAMIC SYSTEMS: AN EXAMPLE WITH MINI-WORLD MODEL

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ABSTRACT

The dynamic systems do have many components and a complex interaction structure. But achievements of the theory of system analysis made the nature of the dynamic systems clear: all components of a dynamic system can be classified in three groups; they are state component, intermediate component and constant component. This report presents computer program 'MM&S' – a new tool for modeling and computer simulation of ecological systems. The program allows to visualize the structure of dynamic systems in simulation diagram: three different images were used to represent components of the three above mentioned system components groups. A change rate was used to replace the input and ouput of state components. Moreover, some computer graphic techniques were used to enhance simulation graphs: we can better trace the changes of system components by changing the graph scale, by changing the graph drawing speed, or by pausing the graph drawing process.

Keywords: ecosystem, modeling, computer simulation

INTRODUCTION

Most of the dynamic systems do have many components and a complex interaction structure, independent if they are biological systems, like ecosystems, or mechanical systems, or systems of any other nature. But achievements of the theory of system analysis made the nature of the dynamic systems clear: all components of a dynamic system can be classified in three groups, they are state component, intermediate component and constant component. A state component changes over time but has its own value at every time point. Its rate of change depends on other components and sometimes on itself. The value of a intermediate component totally depends on the current values of other components. The constant component, as we can guess from its name, does not change its value during all the time the system is beeing analyzed. With development of my computer program - 'MM&S' (Mathematical Modeling and Simulation), I tried to visualize the structure of dynamic systems in simulation scheme: three different images were used to represent components of the three above mentioned component groups: state components, intermediate components and constant components.

A change rate, as a property of a state component, was used to replace the input and ouput of a state component. Moreover, some computer graphic techniques were used to enhance simulation graphs: we can better trace the changes of system components by changing the graph scale, by changing the graph drawing speed, or by pausing the graph drawing process.

Patterns and processes in forest landscapes. Consequences of human management
R. Lafortezza and G. Sanesi (eds.)

INTRODUCTION TO THE COMPUTER PROGRAM MM&S

After starting and running a model the main window of the program MM&S can have 4 child windows: text window, graphic window, simulation scheme window and table window, as showing in the figure 1. Both main window and the simulation scheme child window have toolbar. The functions of the icons on these two toolbar are shown in table 1.The model can be presented in text form, typed in a text window and save to a plain text file. The model can also be presented in the form of simulation scheme. Both a model saved in a text file or a model presented in a simulation scheme can be used to run.

BUILDING AND RUNNING 'THE WORLD MODEL' WITH USING THE COMPUTER PROGRAM MM&S

We use here the world model, developed by Bossel (1992), to show the modelling and simulation capabilities of the MM&S.

STEP 1 (IDENTIFICATION OF SYSTEM COMPONENTS)

The real world is a very complex socio-economic-environmental system. The world model only describes a simplified structure of the real world and presents interactions of its main components, they are: Population, Pollution and Consumption.

STEP 2 (THE DESCRIPTIVE MODEL)

We can identify following relationship between three components: population, pollution and consumption:

- Population growth causes Pollution increase.
- Population change depends on Birth Rate, Death Rate, Birth Control, Pollution, Environment Quality and Consumption.
- Pollution increase requires additional efforts to keep the environment to be clean and therefore will cause consumption increase.
- Pollution increase will harm the people's health and therefore will cause population decrease.
- Pollution increase causes decrease of Environment Quality.
- Pollution change depends on Pollution Rate, Recycling Rate, Environment Quality, Population and Consumption.
- Increase of Consumption will cause increase of Pollution.
- Consumption increase will cause industrial development, high salary and better health service. The child surviving rate will therefore increase and Population will grow.
- Consumption change depends on Pollution, Consumption Rate and Consumption Control.

STEP 3 (CREATING SIMULATION SCHEME)

We know that all components of a dynamic system can be classified in three groups, they are state components, intermediate components and constant components. In the simulation scheme a state component is presented by a square, an intermediate component is presented by a rhombus, and a constant component is presented by a circle. The relationship between the system components are presented by a short line or a curve.

Table 1: The functions of some buttons on the toolbars of MM&S

Buttons	Function
1.	For opening a file
2.	Save button: For saving a file from active window
3.	For changing the speed of drawing a graph
4.	Graph button: For drawing a graph
5.	For changing the graph size
6.	For drawing icon of a system component: Click on one of these buttons, then click on a place in simulation scheme window where we want to put the icon.
7.	For drawing a connection: Click on this button on the toolbar, then click on the influencing component and hold the left mouse button down while moving the mouse to the influenced component, then release the mouse. The begin of a connection is marked with an blue circle and its end is marked with red color. To move a component or an end of a link, click on it and hold the left mouse button down while moving the mouse
8.	For deleting in text or simulation scheme window. Click on this button then click on icon of any system component, the icon will be deleted. To delete a connection, after clicking on this button we have to click on the marked cirles of the connection we want to delete
9.	Check button: For checking the completeness of the simulation scheme
10.	Run button, for running a model
11. eX	Export button: For exporting the model from a simulation scheme to a text file

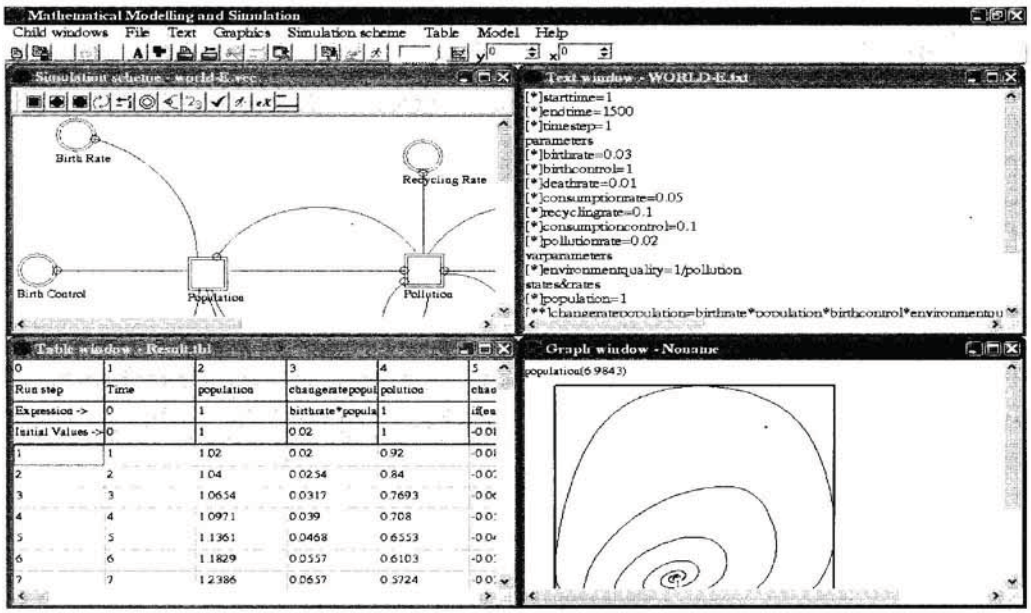

Figure 1: Main window and 4 possible child windows of MM&S

At first we choose 'Create new window' option from the 'Simulation scheme' menu to create new simulation scheme child window. Then we use the buttons on the toolbar of the simulation scheme window to draw a simulation scheme for our model as shown in the figure 1.

STEP 4 (QUANTIFYING THE SYSTEM COMPONENTS AND WRITING MATHEMATICAL MODEL)

Every system component has a corresponding variable to represent itself in the mathematical expression of the model. We are thus talking about state variables, intermediate variables and constants in a mathematical model. To quantify and conduct simulation calculation we firstly determine the time step for each calculation. In this world model we use a time step of one year because the birth rate and death rate are normally given for one year. We use relative quantifying method, e.g., the initial value of a state variable will receive a value of 1. The values of the constants have been estimated as folow: Birth Rate=0.03, Death Rate=0.01, Birth Control=1 (no control), Pollution Rate=0.02, Recycling Rate=0.1, Consumption Rate=0.05, Consumption Control=0.1.

The general equation for calculating value of state variables is:

$$State\_Variable\ (t)=State\_Variable\ (t-dt)+Change\_Rate(dt) \quad (1)$$

The equations for calculating the change rates of state variables in one time step (one year) and the intermediate variable Environment Quality are shown in figure 2.

STEP 5 (CONDUCTING SIMULATION)

INPUT THE MODEL IN TEXT FORMAT

We choose the option 'Create new window' under the menu 'Text' and write the model in the format as showing in figure 2.

```
[*]starttime=1
[*]endtime=1500
[*]timestep=1
parameters
[*]birthrate=0.03
[*]birthcontrol=1
[*]deathrate=0.01
[*]consumptionrate=0.05
[*]recyclingrate=0.1
[*]consumptioncontrol=0.1
[*]pollutionrate=0.02
varparameters
[*]environmentquality=1/pollution
states&rates
[*]population=1
[**]changeratepopulation=birthrate*population*birthcontrol*environmentquality*consumption-
deathrate*population*pollution
[*]pollution=1
[**]changeratepollution=if(environmentquality>=1)then(pollutionrate*consumption*population-
recyclingrate*pollution)else(pollutionrate*consumption*population-
recyclingrate*pollution*environmentquality)
[*]consumption=1
[**]changerateconsumption=consumptionrate*consumption*pollution*(1-
consumption*pollution*consumptioncontrol)
```

Figure 2: The text format of the model mini-world

The first three lines are dedicated to declaration of time frame of the model. The lines with key words 'parameters, varparameters, states&rates' that accordingly signal the begin of three sections of constant variables, of intermediate variables, and of state variables and their change rates do not begin with square brackets. In the lines that declare equations of change rates of

state variables the brackets contain two asterisks, in other lines the brackets contain only one asterisk.

INPUT THE MODEL IN SIMULATION SCHEME

To input the model in simulation scheme we open the created simulation scheme that has been saved in vector format. Double clicking on icons of system components in the simulation scheme will cause the program display the properties window of current system component (figure 3). In these properties window we can enter or change: name of system components, name of corresponding variables, values of constant variables, initial values of state variables, expression of change rate of state variables, expression of intermediate variables.

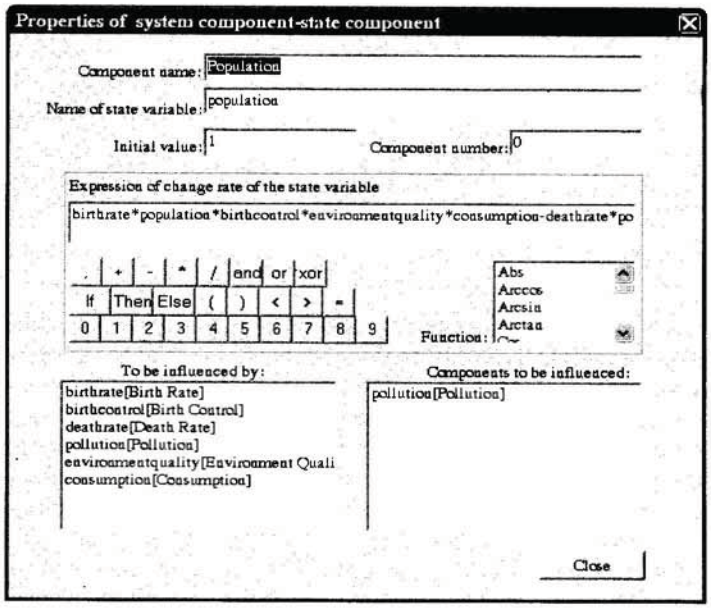

Figure 3: Properties window of a system component - state component

After entering all informations for system components we use the check button (button 9 in table 1) to check the perfectness of the model. If the model is flawless, we can export the model from the simulation scheme to a text file by using export button (button 11 in table 1) on the toolbar.

RUN THE CREATED MODEL

To run a model saved in a text file we click on the run button (button 10 in table 1) of the main window toolbar. After determining the file that contains the model and the file where the results should be stored, the program will conduct the simulation calculation. To run a model from a simulation scheme we click on the run button of the toolbar of the simulation scheme window that contains the simulation scheme. After entering time frame for the model and clicking on the button 'Continue' the program will conduct the simulation calculation.

DRAW SIMULATION GRAPH

Clicking on the graph button (button 4 in table 1) will cause the program to display the graph drawing dialog box (figure 3).

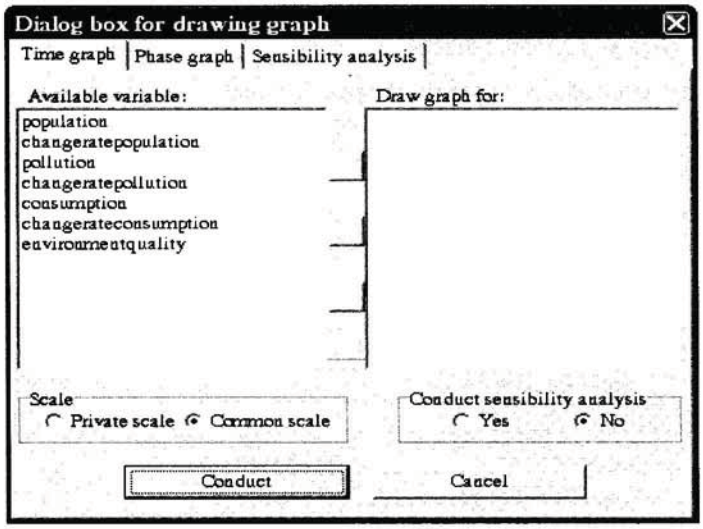

Figure 3: Dialog box for drawing graphs in MM&S

In this dialog box we can make arrangements for a sensibility analysis, or choose the variables to draw a time graph or a phase graph. If a sensibility analysis is intended, the arrangements for a sensibility analysis must be done and 'Yes' in the box 'Conduct sensibility analysis' must be selected before we choose the variables for drawing a time or phase graph. We can specify the scaling method for drawing a time graph. If private scale method has been selected, the graph of each variable with be scaled with using its own maximum and minimum values. The graphs of all variables will be scaled according to absolute maximum and minimum values of all variables if the common scale method has been selected. If arrangements for a sensibility analysis has been made and 'Yes' has been selected in the box 'Conduct sensibility analysis', as shown in the figure 4, the program will conduct simulation calculations for all the changing range of the parameter that we use for sensibility analysis and will draw the graph for every simulation calculation. As the result, we will see how the other system variables are 'sensible' to the change of the current parameter. While the program is drawing a graph, if we click on the graph the program will pause drawing graph and we can have a closer look at the changing process of a parameter. To force the program to continue drawing graph we click again on the graph. We can change the speed of drawing graph with using track bar on the toolbar (number 3 in table 1). Drawing graph in slow modus allows us to graphically follow the change of a variable. Possibility to change graph size is an important utility of the program. By magnifying the graph with using spin edit tool (number 5 in the table 1), we can have a better view of the changing process of system variables.

CONCLUSIONS

MM&S is a fully functioning environment for modelling and simulation of dynamic systems. The use of three icons for three groups of system components give a high transparency to the simulation scheme. The concept of change rate as a property of a state variable has two advantages: it allows to avoid the problem of negative input and positive output, and it makes the simulation scheme more clear. The possibility to run a model in a text file enables us to build and run very big models. The possibility to change the graph size much larger than the computer screen allows us to have better view of the changing process of system variables. The

method of common scale allows us to see the proportion of value and change of different system variables. The possibility to draw graph in slow modus and to pause drawing graph is the additional advantage in visualization of simulation process.

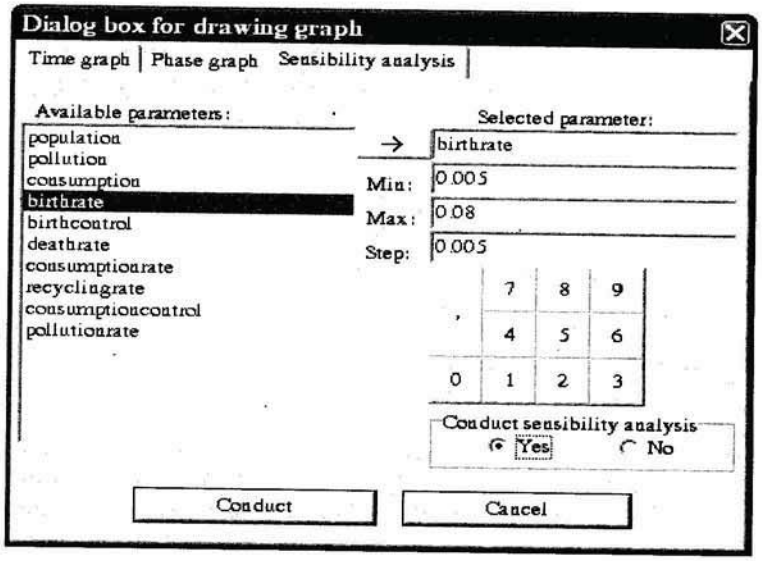

Figure 4: Arrangements for a sensibility analysis in MM&S

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