Chapter 1
Change Rate Concepts and their Realization in the MM&S: A Computer Program for Modeling and Simulation of Dynamic Systems

Nguyen Van Sinh

Abstract The concept of "four element groups" means that all elements of a dynamic system can be divided into four groups: (1) constant elements, (2) state elements, (3) intermediate elements, (4) listed elements. This concept is realized in my MM&S-computer program with two facts. The first one is that four above mentioned element groups are correspondingly assigned four symbols: circle, square, rhombus, circle with three signs (these signs signal how we should handle this listed element at time point where its value has not been declared). These symbols are used to draw simulation scheme of interaction of the system elements. The concept of "change rate" means that every state element has a change rate as its attribute. Other elements of the system affect current state element by affecting its change rate. The current state element affects other elements of the system with its value. This concept is realized in my MM&S-computer program with the fact, that the links connect the state elements directly. In case if a state element has a incoming link, we understand that the change rate of this state element is being affected. Once change rate is an attribute of the state element, the value of the state element can be automatically used for the calculation of change rate. Realization of these above concepts make the simulation scheme of a dynamic system more clear and simple. This paper gives the reasoning for these concepts and also describes the model formats, model calculation in MM&S-computer program.

N. V. Sinh (✉)
Institute of Ecology and Biological Resources, 18 Hoang Quoc Viet,
Nghia Do, Cau Giay, Hanoi, Vietnam
e-mail: vansinh.nguyen@iebr.ac.vn

K. Elleithy and T. Sobh (eds.), *Innovations and Advances in Computer, Information, Systems Sciences, and Engineering*, Lecture Notes in Electrical Engineering 152,
DOI: 10.1007/978-1-4614-3535-8_1,

1.1 Introduction

Dynamic systems have been studied since long time ago [1–6]. The system elements have also been classified [1, 6, 7]. However the modeling and simulation software have been based on the black-box concept with inputs and outputs. An example is the widely used STELLA software of the ISEE SYSTEMS [8] (formerly High Performance Systems Corporation) [7]. The simulation diagram that is based on this black-box concept can not provide a good visualization of the system structure: even a real state element of the system must be presented here as a black-box with input and output; one can not recognize from the simulation diagram, whether an element is a constant or intermediate one, because they have the same symbol (a circle).

In a dynamic system we can find elements of different “mathematical nature”. Some elements do not change their value forever or at least during the time we observe the system. Some elements change their value but we can determine their value at any time by measuring, weighting, counting,…, though it is sometime very difficult. Some elements change their value and their value at a time can only be calculated from the value of the other elements. And finally, some elements change their value over time but their value are given at all or some time points of the time period when we observe the system (the values of the element are listed). Based on these facts a concept of “four element groups” can be formulated which means that all elements of a dynamic system can be divided into four groups:

1. Constant elements,
2. State elements,
3. Intermediate elements,
4. Listed elements.

Each state element changes its value over the time. The change rate of a state element can be negative or positve at a time. Not all the state elements have inflow and outflow. Instead, inflow and outflow are only typical for state elements of mechanical nature, the state elements of biological nature can grow. Based on these facts a concept of “change rate” can be formulated which means that every state element has a change rate as its attribute. Other elements of the system affect current state element by affecting its change rate and the current state element affects other elements of the system with its value.

These two concepts make the basis for the new design of the MM&S—a computer program for modeling and simulation of dynamic systems. The program is free available at the website of the Institute of Ecology and Biological Resources [9]. Further in this paper is the introduction to the new version of MM&S computer program as an explanation of how these above two concepts have been implemented.

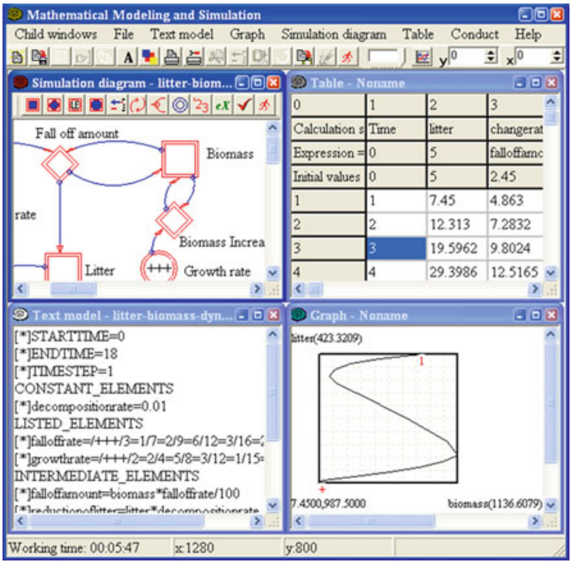


Fig. 1.1 Interface of the MM&S

1.2 Materials and Methods

Delphi XE Professional Workstation ESD (item number: 2010111885211109) of the Embarcadero company [10] has been used to create MM&S computer program.

Four child windows have been designed for handling different tasks:

1. Child window with text editor for processing text model;
2. Child window with paint box for drawing and viewing simulation graphs;
3. Child window with paint box for processing simulation diagram and integrated model;
4. Child window with table grid for displaying results of simulation calculation.

All these child windows are managed by a multiple document interface—the main window (Fig. 1.1).

To visualize the system structure on the simulation diagram, four images have been used in MM&S to represent elements of the four above mentioned element groups: a square for state elements, a rhombus for intermediate elements, a circle for constant elements and a circle with three plus/minus signs inside for listed elements (Fig. 1.2). This is the implementation of the first concept (the "four element groups" concept) in simulation diagram. From the simulation diagram we can recognize the element group of a certain element through its symbol.

The links in the simulation diagram show the interactions between system elements. The state elements don't have input and output, and incoming links of a state element specify the elements that affect its change rate. This means that the expression for calculating of the change rate of this state element has to include

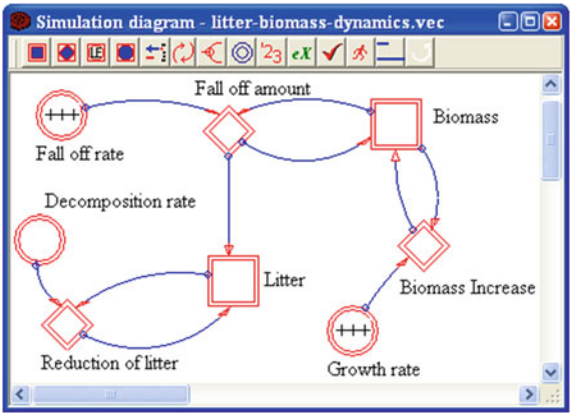


Fig. 1.2 The simulation diagram child window

these affecting elements. The outgoing links of a state element specify the elements that are affected by this state element. This is the implementation of the second concept (the "change rate" concept) in simulation diagram.

1.3 User Interface of MM&S

1.3.1 Declared file formats of MM&S

MM&S declared following file formats:

1. The Text model format: the extension is '.ptm'; the symbol is:

2. The Simulation graph format: the extension is '.stm'; the symbol is:

3. The Simulation diagram format: the extension is '.vec'; the symbol is:

4. The Table format: the extension is '.tbl', the symbol is

Once the MM&S program has been installed with using installation file, double clicking on a file name of one of this file types in Windows Explorer of Microsoft Corporation will cause MM&S starting with opening the file.

1.3.2 Buttons of MM&S and their functions

In MM&S we have two toolbars: one on the main window and the other on the simulation diagram child window. The functions of the most important buttons are as following:

Open button: display an open dialog box for choosing a file for its opening.

Save button: display an save dialog box for choosing a file for its opening.

Track bar: change the graph drawing speed (if graph child window is active).

Graph button: start the graph drawing procedure.

Up-down bar: change the size of the graph (if graph child window is active), or change the size of simulation scheme (if simulation scheme child window is active), or change the cell size of the table (if the table child window is active).

Symbol buttons: choose symbol to draw state element, intermediate element, listed element, constant element in the simulation scheme.

Link button: start drawing a link.

Delete button: start deleting an element in the simulation scheme.

Check button: start checking the integrated model of the current simulation scheme.

Run button: run a text model in a saved file (if clicking on this symbol on the toolbar of the main window) or run the integrated model of the simulation scheme (if clicking on this symbol on the toolbar of the currently active simulation scheme child window.

Export button: to export the integrated model of the simulation scheme to a file (*.ptm).

Switching button: to switch between displaying full element name and variable name.

1.3.3 Text Model Child Window

To create a new text model child window, from the main menu we choose 'Text model/New window'. In this child window we can enter or open a model of text format and edit it. In a model each element is represented by a variable.

The format of a text model in MM&S (see Fig. 1.1: the left bottom child window) is as following:

- The first three lines are dedicated to declaring the time frame of the model: the time when the simulation starts, the time when the simulation ends, and the duration of a simulation step. Each line starts with brackets and one star inside, then the key words (STARTTIME, ENDTIME, and TIMESTEP), equal sign, and the time values.
- The next part of the model begins with a keyword 'CONSTANT_ELEMENTS'. It signals that all constant elements of the model will be declared here. Every constant element is declared in one line: starting with brackets and one star inside, the variable name of the constant element, equal sign, and the value of the constant element at the end.
- The third part of the model begins with a keyword 'LISTED_ELEMENTS'. All listed elements are declared in this part. Every listed element is declared in one line: starting with brackets and one star inside that are followed by the variable name of the listed element, equal sign, forward slash and three plus/minus signs, and the declaration of the values of the listed element. Each value declaration begins with one forward slash sign that is followed by the time value, equal sign, and then the value of the listed element. The three plus/minus signs signal the neccessity of calculation of missing values based on the available ones for the time interval before the first available value (the first sign), for the time interval

between the first and the last available values (the second sign), and for the time interval after the last available value (the third sign). A plus sign means that the missing values should be calculated, the minus sign means that the value of zero should be assigned to the missing values in current interval.
– The fourth part of the model begins with a keyword ‘INTERMEDIATE_ELEMENTS’. All intermediate elements are declared in this part. Every intermediate element is declared in one line: starting with brackets and one star inside that are followed by the variable name of the intermediate element, equal sign, and the expression for calculating the intermediate variable at the end.
– The last part of the model begins with a keyword ‘STATE_ELEMENTS’. In this part every state element and its change rate are declared in two lines. The state element is declared in the first line: starting with brackets and one star inside, then the variable name of the state element, equal sign, and the initial value of the state element at the end. The second line is used for declaration of the change rate: starting with brackets and two stars inside, the name of the change rate (normally built by combining prefix ‘changerate_’ and the variable name of the state element), equal sign, and the expression for calculating the change rate at the end.

Following is the text model of Biomass-Litter dynamics:

```
[*]STARTTIME = 0
[*]ENDTIME = 18
[*]TIMESTEP = 1
CONSTANT_ELEMENTS
[*]decompositionrate = 0.01
LISTED_ELEMENTS
[*]falloffrate =/+++/3 = 1/7 = 2/9 = 6/12 = 3/16 = 2
[*]growthrate =/+++/2 = 2/4 = 5/8 = 3/12 = 1/15 = 4
INTERMEDIATE_ELEMENTS
[*]falloffamount = biomass*falloffrate/100
[*]reductionoflitter = litter*decompositionrate
[*]biomassincrease = biomass*growthrate/100
STATE_ELEMENTS
[*]litter = 5
[**]changerate_litter = falloffamount-reductionoflitter
[*]biomass = 1000
[**]changerate_biomass = biomassincrease-falloffamount
```

As we see, the format of text model has clearly shown the implementation of the “four element groups” and of the “change rate” concepts.

The text model should be saved to a file with extension ‘.ptm’. We can run the text model from a file by clicking on the run button of the main window toolbar or by choosing submenu item ‘Conduct/Run a model’.

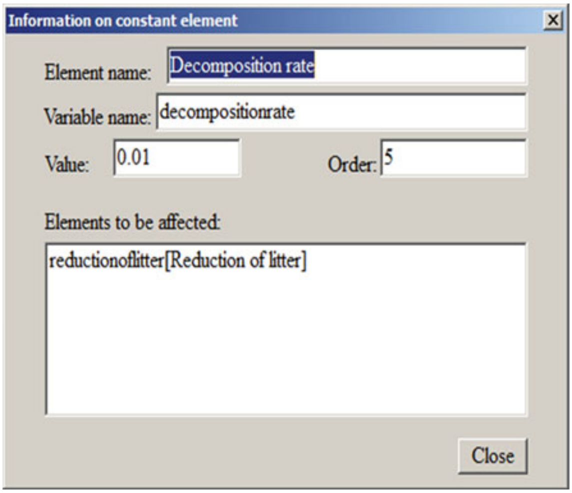


Fig. 1.3 Dialog box for constant element in simulation diagram

1.3.4 Simulation Diagram Child Window

This child window has its own toolbar with buttons for drawing simulation diagram (see Fig. 1.2). To draw an element symbol we click on the button with that symbol and then click on the place in the child window where we want to put it. To draw a link between two elements we click the left mouse button on the affecting element and keep the left mouse button down while moving the mouse to the affected element, then release the left mouse button. The start of a link is marked with a blue circle and its end is marked with a red arrow. To move an element or an end of a link, click on it and hold the left mouse button down while moving the mouse. To delete an element symbol, we click on the delete button then click on element we want to delete. To delete a link, we click on delete button then then click on the begin or the end of the link.

To enter the model into the simulation diagram, we double click on the symbols of system elements: in the appeared dialog boxes we type in the element names, variable names, values and expressions for calculating variables and change rates (Figs. 1.3, 1.4, 1.5, 1.6).

The simulation diagram should be saved to a file with extension '.vec'. To check the completeness of the simulation scheme we click on the check button. Once the simulation diagram is complete, we can run the model from the simulation diagram by clicking run button on the toolbar of the simulation diagram child window, or we can export the model from the simulation diagram to a text model file by clicking export button.

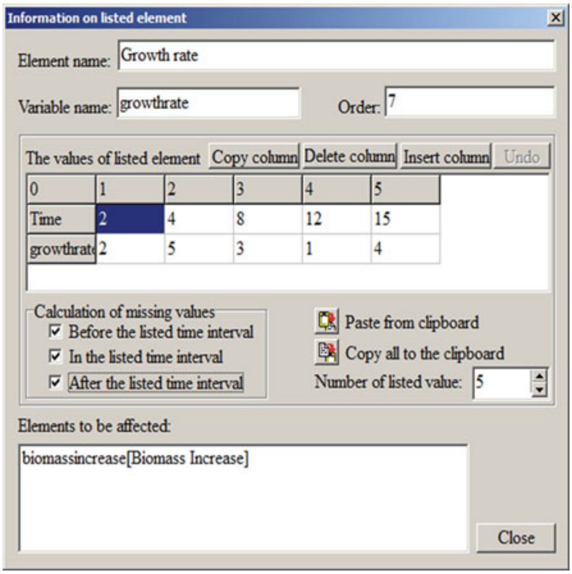


Fig. 1.4 Dialog box for listed element in simulation diagram

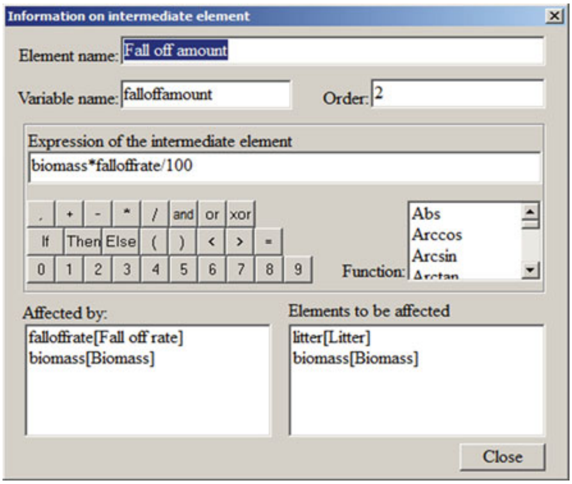


Fig. 1.5 Dialog box for intermediate element in simulation diagram

1.3.5 Simulation Graph Child Window

In MM&S we can simulate changes of the elements of a system by drawing time graph or phase graph (Figs. 1.7, 1.8). After simulation calculation we can draw graphs. To do this we can choose 'Conduct/Draw a graph' menu item or click on the graph button on the toolbar of the main window.

Several computer graphic techniques have been used in MM&S to enhance visualization: we can better trace the changes of system elements by changing the

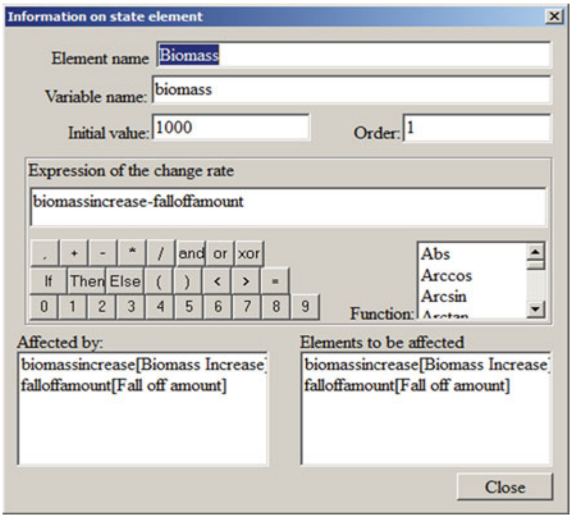


Fig. 1.6 Dialog box for state element in simulation diagram

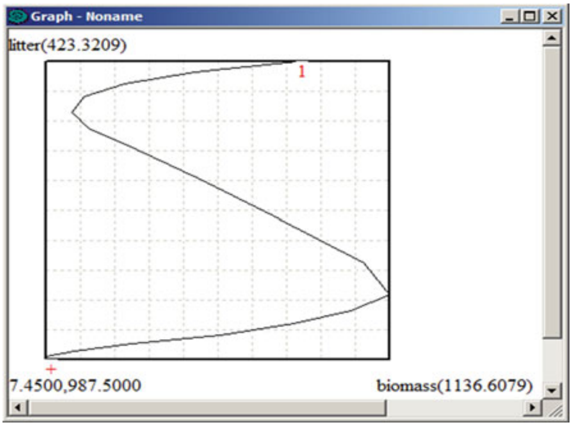


Fig. 1.7 Phase graph of biomass-litter dynamics

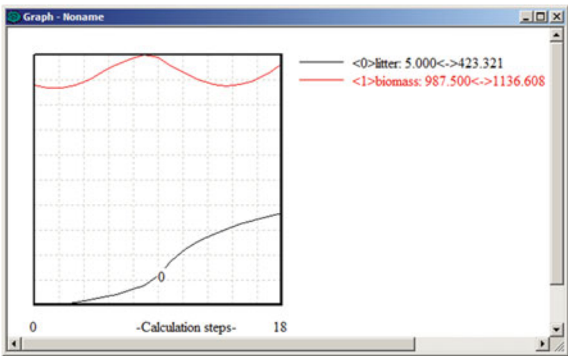


Fig. 1.8 Time graph of biomass and litter

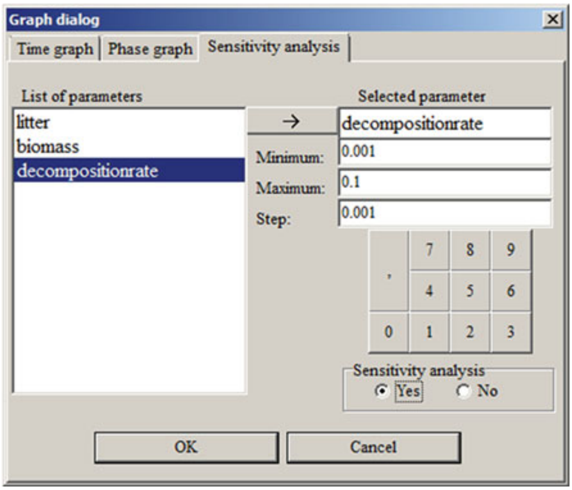


Fig. 1.9 Dialog box for drawing graph and sensitivity analysis

graph scale (with using up-down bar), by changing the graph drawing speed (with using track bar), or by pausing the graph drawing process (by clicking on the graph area while the graph is being drawn in slower mode).

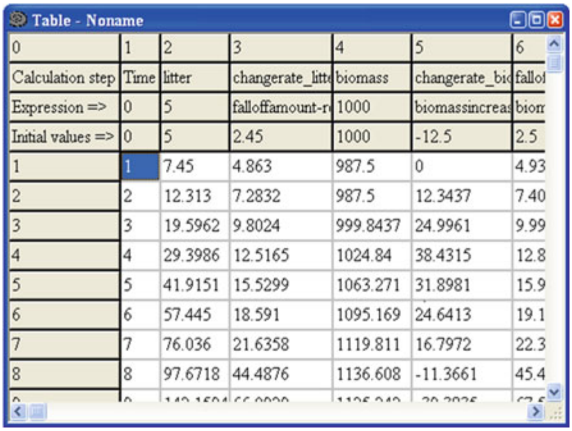
By setting range for the initial value of a state element or for the value of a constant element (Fig. 1.9) before drawing graph, we can make analysis on sensitivity of other system elements to the changes of these elements. The software will conduct simulation calculation for all the changing range of the constant element or of the initial value of the state element that is used for sensitivity analysis and draw graph after each calculation. The effect of changing graphs shows us the sensitivity of the system elements to the changes of the element that has been chosen to make sensitivity analysis. While doing the sensitivity analysis we can also pause drawing graph or draw graph in a slower mode to have a closer look on the changes of the system elements.

The graph can be saved in the picture format (*.bmp) or in the stream format (*.stm). When the graph has been saved in the stream format, we can open it in MM&S and draw in slower mode, pause drawing graph or change the size of the graph, without simulation calculation (standalone simulation graph).

1.3.6 Table Child Window

After conducting simulation calculations, MM&S automatically post all the results in a new table child window (Fig. 1.10). The table can be saved to a file with extension '*.tbl'.

In the first fixed row we can see the number of the column. The names of the variables are displayed in the second fixed row. The third fixed row is used for displaying the values of constant elements, or the initial values of state elements,



0	1	2	3	4	5	6
Calculation step	Time	litter	changerate_litt	biomass	changerate_bi	fallo
Expression =>	0	5	falloffamount-r	1000	biomassincrea	biom
Initial values =>	0	5	2.45	1000	-12.5	2.5
1	1	7.45	4.863	987.5	0	4.93
2	2	12.313	7.2832	987.5	12.3437	7.40
3	3	19.5962	9.8024	999.8437	24.9961	9.99
4	4	29.3986	12.5165	1024.84	38.4315	12.8
5	5	41.9151	15.5299	1063.271	31.8981	15.9
6	6	57.445	18.591	1095.169	24.6413	19.1
7	7	76.036	21.6358	1119.811	16.7972	22.3
8	8	97.6718	44.4876	1136.608	-11.3661	45.4

Fig. 1.10 The table child window

or the expressions for calculating the values of the intermediate elements or of the change rates of state elements. The initial values of system elements are calculated if needed and displayed in the fourth fixed row.

The first column of the table contains the number of the calculation steps. The other columns contain the results of simulation calculation.

We can copy the table and past to other word processing software, or save the table in a text file by choosing menu ‘Table/Save in text file’, or save the table in a Excel file by choosing menu ‘Table/Save in excel file’.

1.4 Conclusions

By using four symbols to represent elements of the four element groups (a square for state elements, a rhombus for intermediate elements, a circle with three plus/minus signs inside for listed elements, and a circle for constant elements) MM&S enhances very much the visualization of the system structure. From the simulation diagram we can recognize the “mathematical nature” of each system element.

Change rate as an attribute of a state element in MM&S replaces the input and output of the softwares that have been designed based on the black box concept. In MM&S the links connect the state elements directly. In case if a state element has an incoming link, we understand that the change rate of this state element is being affected.

MM&S allows two formats of models: text model and model incorporated in the simulation diagram.

The graphic techniques (slower drawing of graph, pausing drawing of graph, pausing sensitivity analysis, or enlarging graph) allow user to better trace the change of system elements while drawing graphs or doing sensibility analysis.

Standalone simulation graph makes the results of the simulation more portable. The results can be saved in text or excel formats what makes it easy to report the modeling and simulation results.

Acknowledgments The Vietnam Academy of Science and Technology has supported this work.

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