

# SoWhat 1.6

## A Tool For Easy Simulation of Dynamical Systems

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### **Working with SOWHAT: An introductory example.**

The most important elements of SOWHAT will be exemplified using a simple model. We assume a dynamic system consisting of four first-degree differential equations and four functions which may be described as follows.

$$\dot{A} = aw_A - bA + fx$$

$$\dot{w} = cw - dw_AA + fx$$

$$\dot{x} = \sin(y + k)$$

$$\dot{K} = sY$$

$$Y = e^{\gamma t} A^\alpha K^\beta$$

$$y = Y/A$$

$$k = K/A$$

A dot above a variable signifies the first partial derivative of the variable with respect to time. SOWHAT provides a simulation of the time paths of the respective variables.

After executing the program under the Windows environment SOWHAT opens with its initial picture. By clicking the menu **Model** in the menu-bar with the mouse a pop-up menu appears

and the command **New** is chosen to begin a new simulation model. Alternatively, all commands may be selected with the suitable combination of keystrokes. Following Windows conventions a menu-point may also be chosen with the ALT-key in combination with the first (underlined) letter of the pop-up menu and then by choosing the respective letter of the menu-point. For the above example the combination ALT-M and N would suffice. The dialogue shown in Figure 1 then appears.

After entering the model's name in the **Name** field the model's equations are entered. To a certain degree it is possible to reproduce the model as it is given on paper. For the model presented here the SOWHAT notation would be:

$$\begin{aligned}
 A. &= a * w_A - b * A + f * x \\
 w. &= c * w - d * w_A * A + f * x \\
 x. &= \sin(y + k) \\
 K. &= s * Y \\
 Y &= \text{\textasciitilde}(sysE, gamma * dtime) * \text{\textasciitilde}(A, alpha) * \text{\textasciitilde}(K, beta) \\
 y &= Y/A \\
 k &= K/A
 \end{aligned}$$

Every entry of an equation is terminated with **Next**. The Euler number **sysE** and the Sinus **sin** are functions that have been provided by SOWHAT. The system variable **dtime** contains the time that have passed since starting the simulation. The equation

$$time = acttime$$

is additionally added to guarantee that the simulation time stored in the system variable **acttime** may be called upon as an output variable. It is possible to edit or modify the equations that have been entered by using **Previous** or **Next**. **Insert** lets you insert new equations into the system and **Delete** lets you delete equations from the system. The entry mode is completed with **End**. A *Lexical Scan* then checks the syntax of the equations. If a mistake is found, e.g. a missing

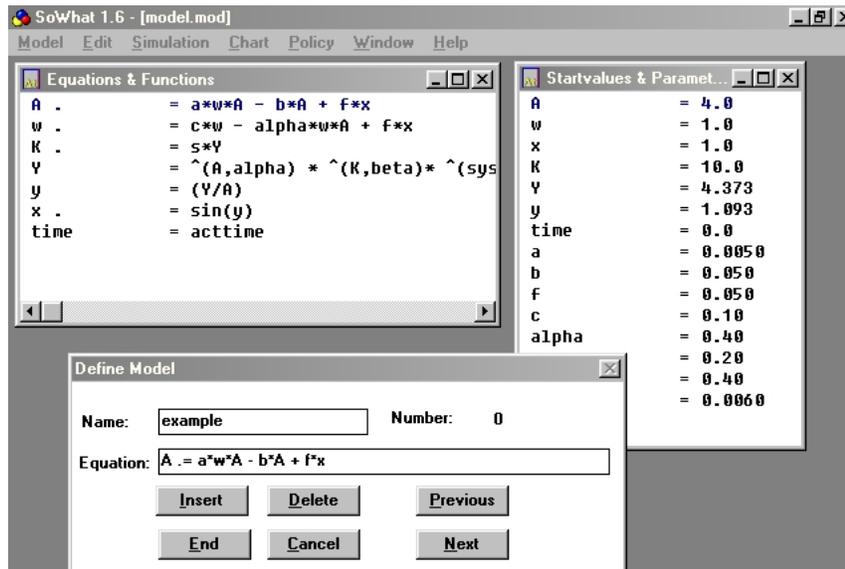


Fig. 1: The Model-Define Window

parenthesis, then a message box appears informing of the type and location of the error and the respective equation appears. If all entries are correct the program automatically opens the **Start Values**-dialogue in which the start values of the dynamic variables and model parameters are set. You may also move through the variables with **Previous** and **Next**. Endogenous variables are recognized by the program and are marked accordingly. These cannot be edited. To complete the input of the model you select **End**. The model is now completely specified.

The command **Options** in the menu **Simulation** allows you to pick various options available for the simulation. It opens the dialogue shown in Figure 2

The start and end time of the simulation may be chosen in the **Start** and **End** fields. The **Record**-step option sets the interval in which the calculated values will be recorded by the program. These values are stored in tables (charts) which may then be further processed.

The **Minimal**, **Maximal**, **Start** entries define the minimum and maximum step intervals and the initial step that the program uses internally for the Runge-Kutta algorithm. For every simulation you therefore have the possibility to choose the best combination from the trade-off between the accuracy (with small internal step intervals) and speed of the simulation (large step intervals), depending on the model chosen. With **Max Error** you can define the maximum

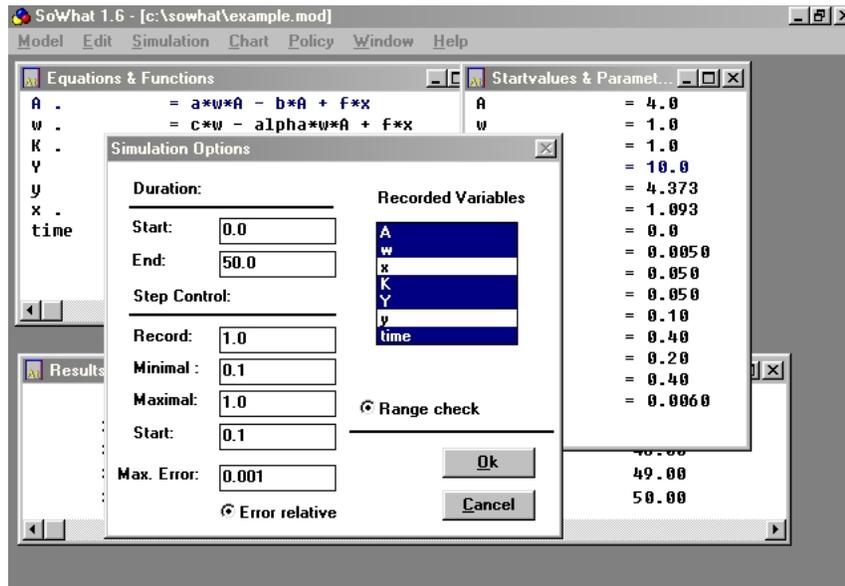


Abb. 2: The Simulation Options Dialogue

admissible simulation error. By choosing **Range check** every calculation step is checked so that the results remain within the limits of the digital number representation. In this way system failures due to mathematical errors will not arise.

In the window to the right the model's variables are determined. By clicking the desired variables the program will later provide these in form of entries of tables (charts). To complete the entry procedure click **Ok**. It is recommended that the model and the parameter values are saved before commencing the simulation. For this purpose choose **Save** in the Menu **Model**. A window is then opened in order to save the model by entering the name and path of the file.

The simulation can now be run with **Simulation Start**. While the simulation runs you may observe the development of the recorded variables in the **Results** window. The program is executed in the background so that you may work in a text program or print data while SOWHAT conducts the simulation. You are informed of the end of a simulation by the message **Simulation End** and an acoustic signal.

The **Charts** window contains the values of the recorded model variables in table form. In order to save the results use the command **Save** under the menu **Charts** and mark the charts that you wish to save. The charts are identified by the variable name and the simulation number.

For example A:0 contains the values of variable A of the first simulation run. Next you choose the data format which the chart file is to be saved in. Formats available are *Excel*, *TSP*, *ASCII* and the Milestones Data Format *MDF*. Deselect the German default **Comma as decimal delimiter** to use a point as decimal delimiter. Confirmation with **Ok** opens a new window in which file name and path are entered.

Using the commands in the **Edit** menu, data can be transferred to other programs through the Windows clipboard. For example, to transfer the results from the last simulation executed to a spreadsheet program chose the command **Copy Last Simulation**, open the spreadsheet software and chose a command for pasting of data (e.g. Edit Paste). Using the command **Copy Charts** you may copy any chart of previously executed simulations to the clipboard. Remember to deselect the German default **Comma** to format the data with decimal *point*. The command **Copy Model** copies the definition of the current model (consisting of differential equations, functions, parameter values and simulation options) formatted as ASCII text to the clipboard.

With the help of the **Change** command in the menu **Model** you can begin a new simulation with new variables and parameter values and modify or add to the model's specification as described above. Double-clicking the left mouse key on the equation to be changed in the **Equations & Functions** window or the start value in the **Start Values & Parameters** window switches the display to the respective item in the **Change Model** dialogue where it can be modified directly. With the command **Load** in the Menu **Model** previously produced SOWHAT models are loaded by clicking the respective model name.

Another speciality of SOWHAT lies in its interrupt capability. The Command **Change Value** stops a simulation in process. The Window **Simulation Interrupt** then appears as shown in Figure 3.

If the **End** button is pressed the simulation is completely terminated, however the results that have been recorded up to that point remain intact. Alternatively, the simulation may be started again with modified parameters or start values. After double-clicking the variable or parameter value to be changed in the window **Current Values** the window **Change Values** appears in which these changes can be made. The **Continue** button lets you proceed with the simulation. This feature provides a simple device for using SOWHAT for policy simulations and computer

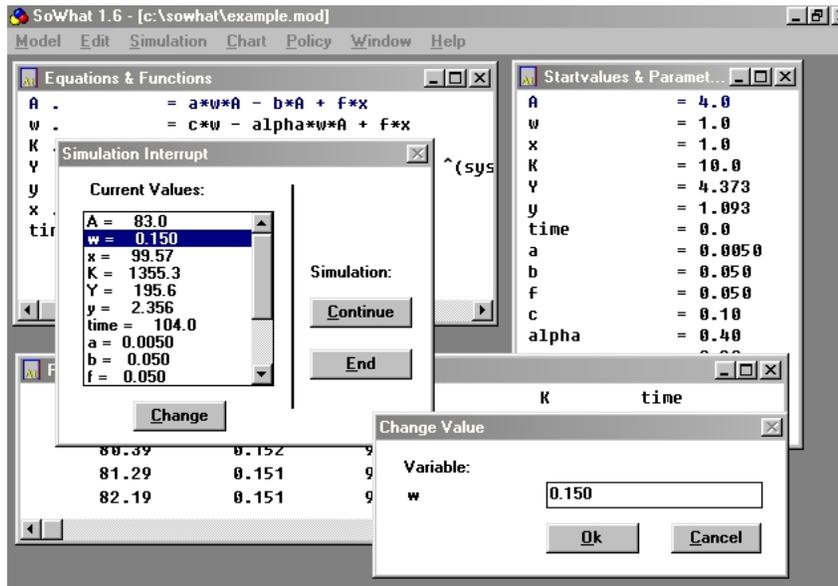


Abb. 3: The Simulation Interrupt -Window and Change Value Dialogue

based business games.<sup>1</sup>

Another feature of SOWHAT lies in the possibility of defining *parameter loops* which allow for a repeated run of a simulation. A parameter or start value may be changed by user-defined increments. For example, if you wish to have the simulation run for different values of the parameter  $s$ , then enter the following for  $s$  under the window **Start Values**:

[0.1&0.4]0.05

This has the effect of running the simulation a total of 7 times with the values of  $s$  changing successively from 0.1,0.15,0.2...0.4. The first line of the recorded chart contains the respective value of the parameter  $s$ . This lets you run SOWHAT for longer periods of time (e.g. during the night) with values changes automatically executed by the program.

SOWHAT provides an extensive Info-System for further information and help. It is reached via the command **Index** in the **Help** menu.

<sup>1</sup>The commands in the **Policy** Menu provide more advanced tools for system control and policy simulation. See the complete handbook and the respective entries in SOWHAT's **Help** menu.