“D.6.5.4 - New version of the System Dynamics tool”

“WP 6.5: Cloud computing service for simulation based project management”

“WP6 - Modelling and simulation services”

MODRIO (11004)

Version 1.0

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Executive summary

System dynamics is a mathematical modelling technique for understanding how complex systems, such as socio-economic, financial, and climatic, behave over time. System dynamics models are structured from elementary units and relations between them. The causal loops formed in the model structure typically induce the principal behavioural properties of the model.

In the WP6 of the Modrio project, the Simantics System Dynamics modelling and simulation tool is developed further to support business cases in WP8. In this document, the new features (e.g., sensitivity analysis, web user interfaces, new solver, model import from Vensim) of Simantics System Dynamics are presented.

Summary

1. Introduction

System dynamics is a methodology to understand the behaviour of dynamic complex systems of different domains using modelling and simulation. The modelled systems can be, e.g., socio-economic, financial, climatic, or physical, just to name a few. System dynamics models consist of only a few basic types of variables which are used to construct stock and flow diagrams with feedback loops and delays.

As the deliverable D6.5.4, a new version of the Simantics and OpenModelica based system dynamics tool is developed. The tool development is directed to support business cases in WP8. The version update includes new features to help modellers in their basic modelling work, improves the performance of the tool, and fixes critical bugs.

The tool is currently used in the Modrio project (WP 8.9) to develop an interactive game based on a complex workforce management model. Based on the activity in the support forum [1], the tool has recently gathered some attention and has at least several external users.

The software is open source under EPL (Eclipse Public License). It can be downloaded at http://sysdyn.simantics.org [2]. Three demo videos have also been published. In the first video, the tool is used to model a basic system dynamics model [3]. In the second video, the advanced features of the tool are presented [4]. In the third video, the most important new features made in the Modrio project since the last published version of the tool are presented [5]. The URL addresses of the videos are http://youtu.be/HGYzrDr46tw, http://youtu.be/LFtjca2C5EI, and http://youtu.be/7yxD0Mf7-sk, respectively.

2. New features

In this chapter, the most important new features of Simantics System Dynamics 1.8.1, compared with the version 1.7, are presented. The user manual including the detailed documentation of all features of the tool is found in https://www.simantics.org/end_user_wiki/index.php/Simantics_System_Dynamics [6].

2.1. Vensim import

Models made in Vensim, the current market leader in the domain of system dynamics modelling software, can be imported to Simantics System Dynamics. The model import procedure is illustrated in Figure 1.

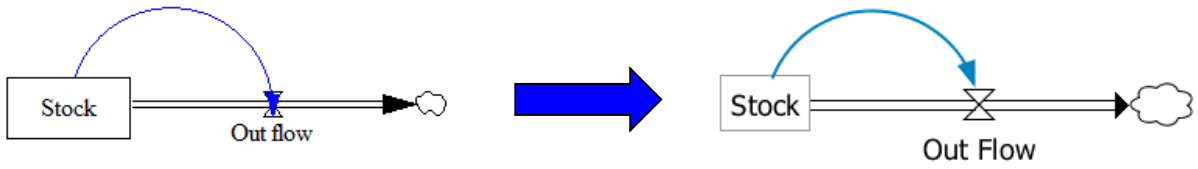

Figure 1. Vensim import

2.2. Web user interfaces

In addition to the regular UI of Simantics System Dynamics, web interfaces can be created for the models. A web interface is a simplified interface to the model giving the user the ability to change certain parameters and see their impact on a selected set of variables. Web interfaces can be used via a regular internet browser and since the model is running on an external server, the user doesn't need to install the tool. An example web user interface is shown Figure 2.

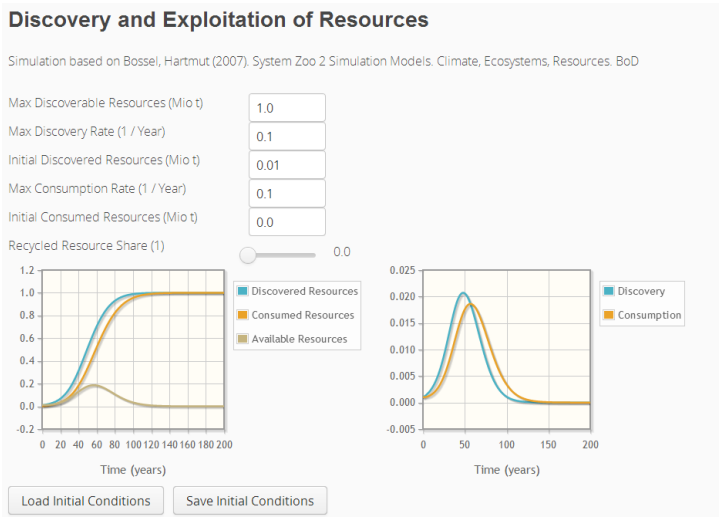

Figure 2. A web user interface

2.3. Internal custom Modelica solver

Prior to the current release, OpenModelica has been the sole solver of Simantics System Dynamics. For model development, it has been perceived as slow to simulate simple models due to the time needed to translate Modelica to executable code via C code generation and linking. Hence a custom internal Modelica solver has been developed. The internal solver is faster, but lacks some features.

2.4. Multivariable sensitivity analysis

It is common that a system dynamics model has parameters of which values are difficult to estimate. It is also natural for system dynamics models that some parameters have very little impact on the system behaviour, whereas only slightest fluctuations in the values of some other parameters cause the model to behave in a very different manner. With sensitivity analysis, the parameters that affect the model behaviour can be found and their effect on the model can be studied.

The tool uses Monte-Carlo method to run the sensitivity analysis. There is no limit of how many parameters can be varied simultaneously. The parameter value sets can be chosen either from uniform or (truncated) normal distributions. The method of selecting a parameter value set for the individual simulation runs from the distributions can either be done randomly or by using the Halton low-discrepancy sequence.

Sensitivity analysis results can be visualised using sensitivity charts, as shown in Figure 3. The yellow area contains 25% of the individual simulation runs, green 50%, blue 75%, and grey all simulation runs. E.g., in Figure 3 we see that the parameters that are varied effect very drastically on the behaviour of the « Available Resources » variable.

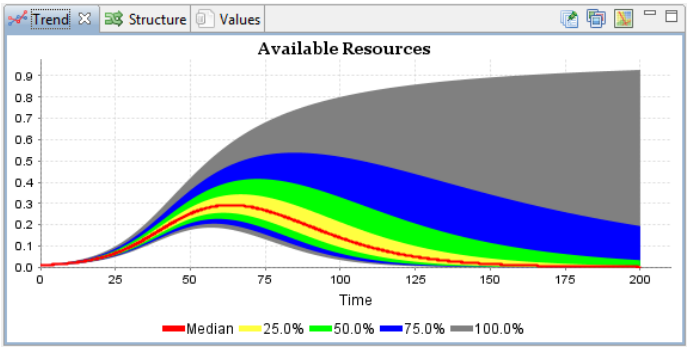

Figure 3. Sensitivity chart

2.5. Content assist (Ctrl+space)

To help writing the equations of variables, the equation editors have content assists similar to many programming tools, such as Eclipse and Visual Studio. The content assist suggests possible continuations for the equation. In Figure 4, the user has typed "Stock/M", so the content assist offers all available variables and functions which start with the letter M.

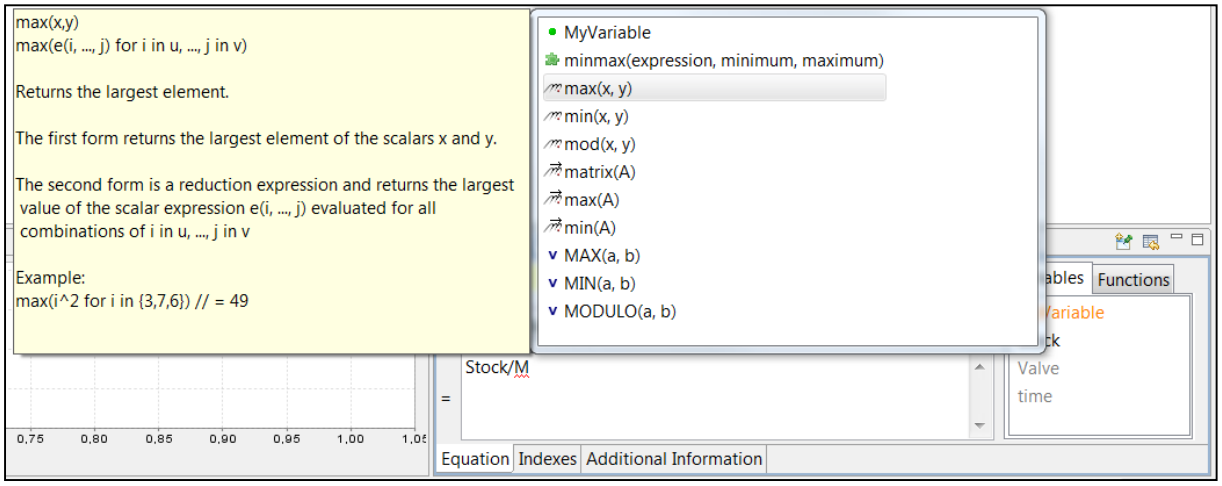

Figure 4. Content assist

2.6. Sample model library

A library of sample models is included to the tool. An example sample model is depicted in Figure 5.

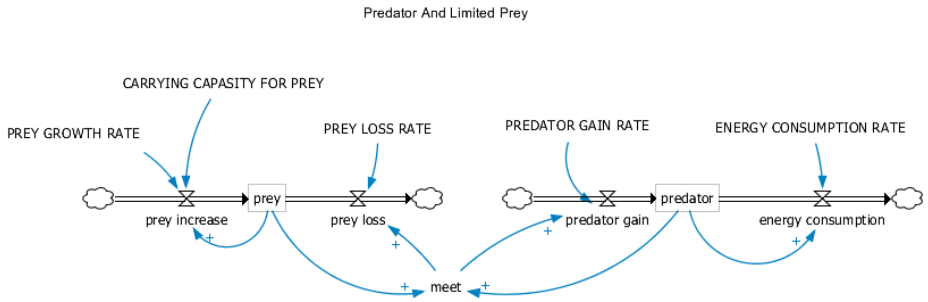

Figure 5. The predator-prey sample model

2.7. Molecules library

A molecule is a commonly used system dynamics structure. There is a library of a few molecule models and modules included in the tool. Three example molecule models are depicted in Figure 6.

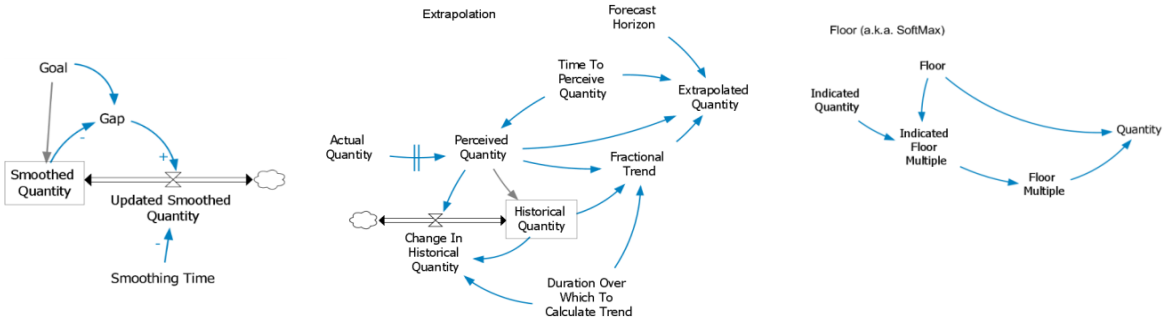

Figure 6. A few sample molecules

2.8. Unit validation

Unit validation helps finding bugs in a model. Unit validation checks that the units (e.g., kg, m/s^2, prey mass/month) of variables are consistent with the equations in which they are used. Figure 7 depicts a few error messages from the unit validation. E.g., on the first line, the unit of the « Tourist Loss » variable has been defined to be person/year, but the equation of that variable yields person/(year*year).

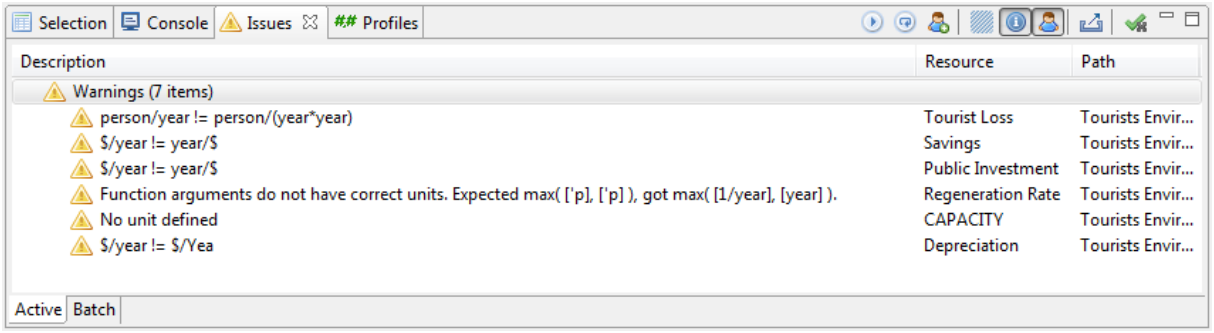

Figure 7. Unit validation warnings as shown in the Issue view

2.9. Real-time errors and warnings

The errors and warnings of the model are shown on diagram and the Issue view in real time, as shown in Figure 8. Errors and warnings can be, e.g., undefined expressions, syntax errors in equations, missing dependencies, and inconsistent units.

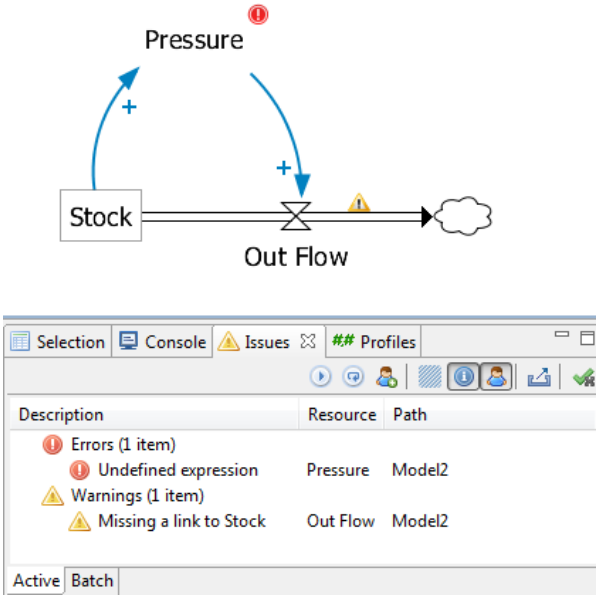

Figure 8. Errors and warnings as shown on diagram elements and in the Issue view

2.10. Shadow variables

A shadow variable acts as a link to an actual variable. Shadow variables are used to make the model configuration clearer, as less overlapping dependency arrows are needed.

2.11. Loop visualisation

2.11.1. Loop tool

The loop tool allows adding a comment element and binding it to a feedback loop in the model. The loop comment element is shown in the left hand side of Figure 9.

2.11.2. Structure analysis

The structure view allows viewing all the feedback loops in which a certain element belongs to, as shown in the right hand side of Figure 9.

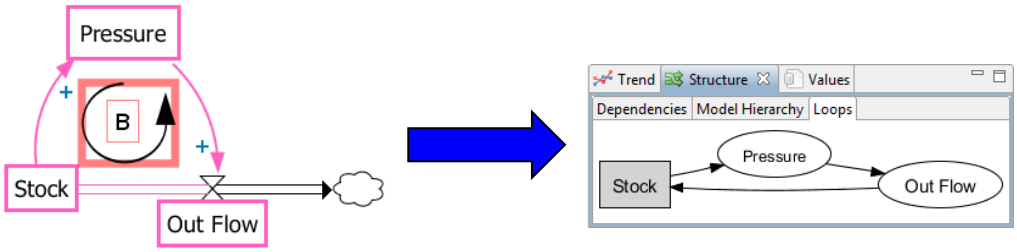

Figure 9. The loop symbol and the structure view

2.12. Resizeable diagram elements

In version 1.7, the size of the textbox of a diagram element was automatically defined based on the length of the name of the element, that is, adding a letter to the name increased the size and deleting one decreases the size of the element. In the current version, the user can grab a corner of the textbox of a diagram element and resize it. This allows multiline elements, as shown in Figure 6.

2.13. Search

The search (i.e., find) functionality is added to allow finding variables in the selected model or all models on the workspace. The search dialog is shown in Figure 10.

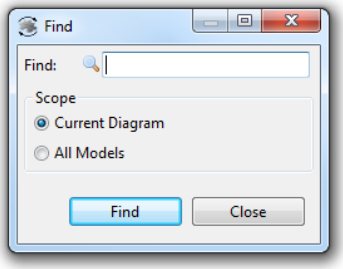

Figure 10. The search dialog

2.14. Custom stock equations

Previously the stock equations were determined automatically based on the input and output flows of that stock. This is the default features currently as well, but alternatively the stock equations can be determined by the user similarly to any other variable (auxiliary or valve).

2.15. Miscellaneous features

In addition to the abovementioned, some of the new features of Simantics System Dynamics are as follows:

- Renaming elements with F2
- Exporting and importing modules and function libraries
- Different colour for the initial dependencies pointing into stock variables
- Ability to change the OpenModelica solver
- Ability to change default colours of diagram elements
- Horizontal bar charts
- Save and save as... buttons
- Built-in perspectives
- Toolbar buttons: lock sketch, edit, add dependency, and add flow
- Dependency options, e.g., delay marks
- Paste special

3. References

[1] Simantics System Dynamics forum. Online: https://www.simantics.org/sysdyn-forum

[2] Simantics System Dynamics. Online: http://sysdyn.simantics.org

[3] Simantics System Dynamics - Basic modelling. Online: http://youtu.be/HGYzrDr46tw

[4] Simantics System Dynamics - Advanced features. Online: http://youtu.be/LFtjca2C5EI

[5] Simantics System Dynamics 1.8.1 - New Features. Online: http://youtu.be/7yxD0Mf7-sk

[6] Simantics System Dynamics - Documentation. Online: https://www.simantics.org/end_user_wiki/index.php/Simantics_System_Dynamics