Comparative study of tools for computer Modeling and Simulation (complex dynamical systems)

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Classification for educational purposes

• free	⟺	commercial
• Windows	⟺	Linux
• cloud technologies	⟺	campus network
• student computer	⟺	class-room

Ideally 

- FREE
- {*WINDOS,LINUX*}
- licensed copy
- for {*cloud technology, campus network*}
- of PRACTICALLY IMPORTANT software
- for using
- in Campus

Really 

PRACTICALLY IMPORTANT → Acceptable «approximation»

PRACTICALLY IMPORTANT	Acceptable «approximation»
Matlab	Scilab
Modelica	OpenModelica
Rand Model Designer	Trial Rand Model Designer
Simulink (oriented , «causal» blocks)	Trial Rand Model Designer
Modelica (non-oriented, «physical» blocks)	Trial Rand Model Designer

Basis of Mathematical Modeling

for engineers

(complex dynamical systems)

Variants
for Single-component models
a) A Tool for visual modeling
b) A Mathematical package
c) Mathematical package + Tool for visual modeling

Technologies of Computer modeling for engineers
(complex dynamical systems)

Variants
for multi-component models
a) OpenModelica
b) Trial Rand Model Designer
c) Simulink + StateFlow + SimPowerSystems(?)
d) SystemModeler

Examples: Mathematical packages

Mathematica

SystemModeler

WOLFRAM SYSTEM MODELER

Driving Insight, Innovation, and Results

Maple

MapleSim

MapleSim modeling and simulation software

- **Software – Control design: MapleSim is a physical modeling and simulation tool from Maplesoft built on a foundation of symbolic computation technology. This is a Control Engineering 2012 Engineers' Choice honorable mention.**
- It efficiently handles all of the complex mathematics involved in the development of engineering models, including multidomain systems, plant modeling, and control design. MapleSim reduces model development time from months to days while producing high-fidelity, high-performance models.
- www.maplesoft.com

Wolfram SystemModeler

- Build high-fidelity models using predefined components in an easy drag-and-drop environment. Perform numerical experiments on your models to explore and tune system behavior.
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- Drag & Drop Modeling

Quickly and intuitively create models using SystemModeler's drag-and-drop approach. Pick up components like transistors or springs, and drop them onto the canvas. Draw lines between components to indicate physical connections like electrical wiring or mechanical attachment. Click components to specify units and unit prefixes.

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- Hierarchical Modeling

Create hierarchical component-based models that follow the topology of the real-world system and that are easier to develop and understand than traditional "block-based" models. In SystemModeler, individual submodels are separately testable and reusable, allowing you to quickly explore alternative designs and scenarios.

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http://wolfram.com/system-modeler/

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- Multidomain Modeling

Real-world machines and systems are rarely confined to a single physical domain such as mechanical, electrical or thermal. SystemModeler models can contain any combination of interconnected components from any number of domains. Under simulation, these more realistic multidomain models can uncover important effects that would be missed using a less integrated approach.

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- Built-in Model Libraries

SystemModeler comes with a large library of standard Modelica packages built in, including components modeling translational, rotational and three-dimensional mechanics, electronics, logical and signal blocks, biochemical pathways and more. Libraries include full source code and documentation.

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- Hybrid Systems Modeling

Accurately model hybrid discrete-continuous systems by combining discrete signals and the built-in StateGraph library with continuous physical components. SystemModeler's numerical solvers detect and handle discontinuities in hybrid systems, so models with sudden events such as switches, collisions or state transitions are correctly simulated.

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- Simulation & Experimentation

Automatically translate models into optimized systems of differential equations suitable for immediate simulation. A point-and-click interface for adjusting model parameters allows rapid exploration without recompiling the model. Pause and resume simulations in progress, and synchronize simulations to run in real time.

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- Instant Visualization

Plot the value of a system variable with a single click. Plot multiple variables, create parametric plots and choose from built-in plot styles with a point-and-click interface. Attach visualization geometries from CAD software to components, and automatically create live 3D animations for models with 3D mechanical components. Connect to Mathematica for programmable custom visualization.

- Standalone Simulation Executable
- Export & Publish Results
- BioChem Libraries
- Custom Components & Libraries

Tool comparison

✓ Supported ○ partially supported $ additional purchase required

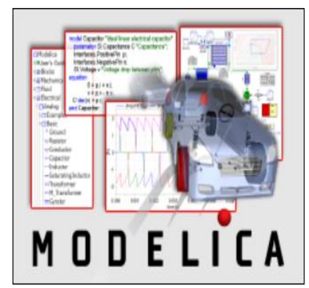
	SystemModeler	MapleSim*	Simulink*
Additional Requirements	Mathematica optional	*Maple required	*Matlab required
Modeling			
Hierarchical modeling that follows real-life topology	✓	✓	✓ $
Multidomain modeling	✓	✓	✓ $
Drag-and-drop model design	✓	✓	✓
Work with Modelica models	✓	○	
Combine Modelica code with drag-and-drop design	✓		
Include external C functions	✓		○
Built-in Model Libraries	SystemModeler	MapleSim	Simulink
Biochemical pathways	✓		
Electrical (analog and multiphase)	✓	✓	○ $
Magnetic	✓	✓	✓ $
Mechanical (translational, rotational, and 3D multibody)	✓	✓	○ $

Signal blocks (continuous, discrete, and logical)	✔	✔	✔
State graphs	✔		✔ $
Thermal (heat transfer and fluid flow)	✔	✔	○ $
Simulation	SystemModeler	MapleSim	Simulink
Hybrid continuous-discrete solver	✔	○	✔
Real-time solver	✔		✔ $
Sensitivity analysis solver	✔		
Initialize to steady state	✔		✔
Visualization	SystemModeler	MapleSim	Simulink
One-click plotting of any system variable	✔		
Automatic 3D mechanical visualization	✔	✔	
Custom visualization environment	Mathematica	Maple	Matlab
2D and 3D graphics language	✔	○	✔
Advanced 3D graphics (lighting, transparency, and more)	✔	○	✔
2D and 3D animation	✔	○	○

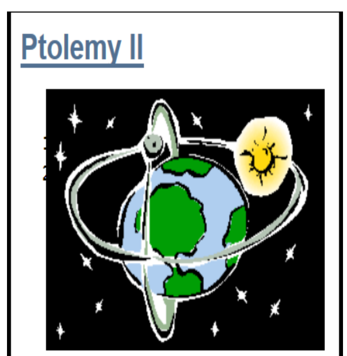
Standard formats (.avi and .mov)	✓		○
Instant interactivity	✓		
Analysis & Design	SystemModeler	MapleSim	Simulink
Analysis platform	Mathematica	Maple	Matlab
Programmable simulation control	✓	✓	✓
Parallelized parameter sweeps	✓		○
Model equation analysis	✓	✓	
Model equilibrium detection	✓	✓	✓ $
Control systems design	✓	✓ $	✓ $
Model calibration	✓	✓	✓
System optimization	✓	✓	✓
Connectivity	SystemModeler	MapleSim	Simulink
Reusable standalone simulation executable	✓		✓ $
Interactive HTML model	✓		✓ $

Examples: visual tools for modeling and simulation complex dynamical systems

- Simulink+Toolboxes



- Modelica-based tools
- Ptolemy



Modern requirements for visual tools for modeling and simulation of complex dynamical systems

- Object-Oriented approach (**O**bject-**O**riented **M**odeling)
- Universality (different types of mathematical models)
- Compliance with standard (for example UML)

Object-Oriented approach

Simulink+Tollboxes	partial
Modelica-based tools	yes
Ptolemy II	yes
RMD	yes

Dynamical and hybrid systems.

Universality

Models with «input/output» components.
«causal»

different types of real dynamical systems and their mathematical models

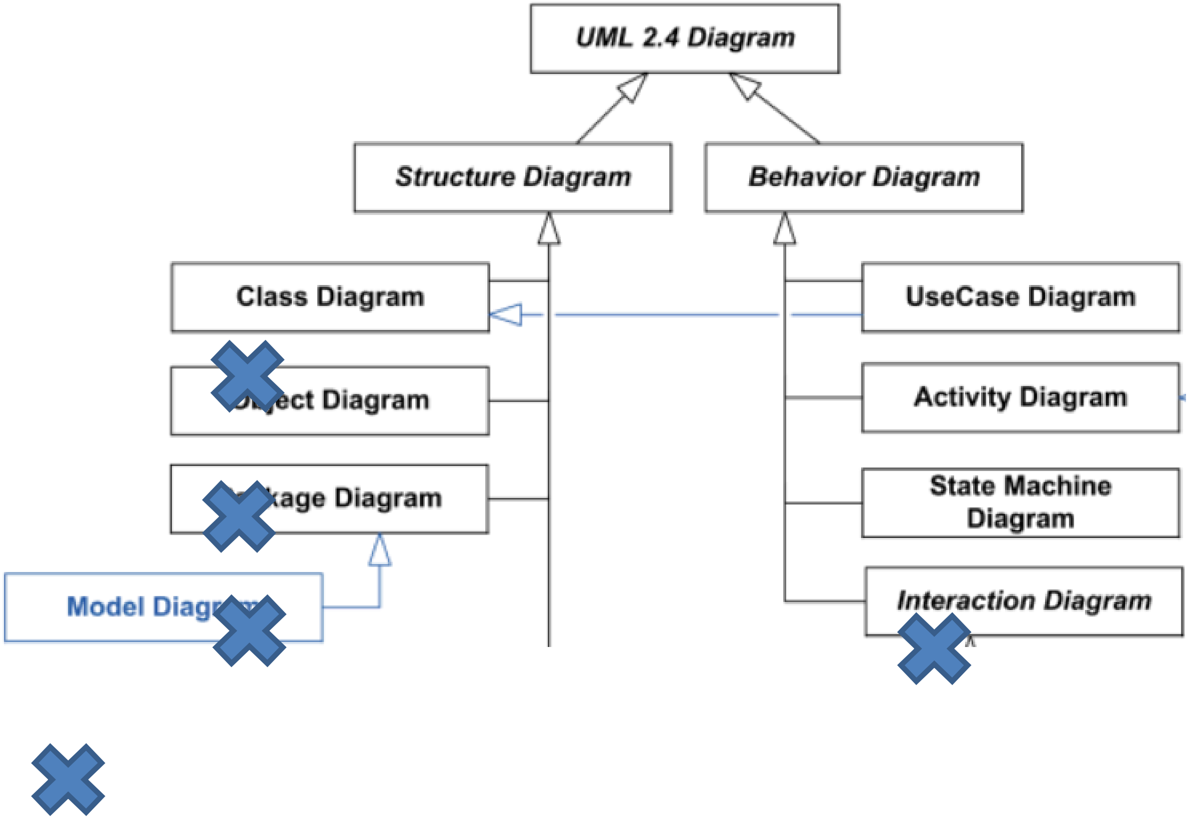
Models with «contact/flow» components.
«Physical»

Models with variable structure.
«agent-based»

Universality

Tollboxes (fof Simulink)	yes
Modelica-based tools	yes
Ptolemy II	no
RMD	yes

Compliance with standard (UML)



Compliance with UML

Simulink+Tollboxes	no
Modelica-based tools	partial
Ptolemy II	yes
RMD	yes

RMD's distinctive features

- models with variable structure
- Lazy building of final hybrid automaton (composition of component hybrid automata) for «physical» models
- Analyzing of type and structure of final systems of equations and using suitable numerical method for each block if system has block low-triangular form
- supplying information about numerical properties of solved system
- Automation of computer experiments

summary

The basis of mathematical modeling		
Maple	Mathematica	Any visual tool for single-component models
Technologies of Computer Modeling		
OpenModelica	Rand Model Designer Trial	Simulink