Modeling and Simulation in Education

Yuri Senichenkov
senichenkov_yub@spbstu.ru
Student: I want to study modeling and simulation. What should I do if I have no relevant courses in my university? I am a user and my main interests are in applied area. I understand well, that modeling and simulation will help me, but where to start and what to choose?
where to start? what to choose?

Traditional way: Books + Tools by yourself

A new one: Recommended E-Books + Tools by yourself + Teacher
Distance learning.

Modeling and simulation for engineers

- **What?**
  - Modeling – models (mathematical models)
  - Simulation – tools (universal, specialized)
  - Sites – Global:
    - Coursera ([https://www.coursera.org/](https://www.coursera.org/))
    - Open Education ([https://openedu.ru](https://openedu.ru))
  - Sites – Local: university sites based on SAKAI, MOODLE
  - Books – Text-books, Training-books, Tutorials, e-books
  - Assignments – learning tasks, leaning models
  - Tests - halfway tests, final tests

- **Where?**

- **What do you need?**
Mathematics and Computer science for Engineers

Algebra
Mathematical analysis
Algorithmic languages
Probability and statistics
Numerical analysis
Theory of algorithms
Mathematical modeling
Computer modeling technologies
Bachelors
Distance learning.

Modeling and simulation for engineers

What?
- **Key words**: Modeling – Simulation
- **Sites – Global**: Coursera ([https://www.coursera.org/](https://www.coursera.org/)), 18/5100 %
  - Open Education ([https://openedu.ru](https://openedu.ru)) 6/723 %
Global: Coursera – modeling and simulation -18 courses

- Averaged-Switch Modeling and Simulation
  University of Colorado Boulder
  Rating: 4.7 (60) | Students: 3,2K

- Cyber-Physical Systems: Modeling and Simulation
  University of California, Santa Cruz
  Rating: 4.6 (27) | Students: 5,6K

- Simulation and modeling of natural processes
  University of Geneva
  Rating: 4.2 (205) | Students: 28K

- Power Electronics
  University of Colorado Boulder
  Rating: 4.7 (2,975) | Students: 97K

- Modeling and Control of Power Electronics
  University of Colorado Boulder
  Rating: 4.7 (70) | Students: 5,3K

- Introduction to High-Throughput Materials Development
  Georgia Institute of Technology
  Rating: 4.6 (144) | Students: 9,2K

- Modeling and Control of Single-Phase Rectifiers and Inverters
  University of Colorado Boulder
  Rating: 4.8 (11) | Students: 97K

- Techniques of Design-Oriented Analysis
  University of Colorado Boulder
  Rating: 4.8 (11) | Students: 97K
Key words: modeling and simulation + modelica
Cyber-Physical Systems: Modeling and Simulation
https://www.coursera.org/learn/cyber-physical-systems-1#syllabus

- Basic Modeling Concepts: Discrete-time and Continuous-Time Systems
- Modeling Cyber Components: Finite State Machines, Computations, Algorithms, and a First CPS Model
- Modeling Interfaces for Cyber-Physical Systems: Conversion, Networks, and Complete CPS Models
- Trajectories in CPS and Simulations: Time Domains, Executions, and Complete CPS Models
Cyber-Physical Systems: Modeling and Simulation

- Video -15 (total time 144 min); Material for self-study -1; Tests -2
- Video -12 (total time 72 min)- Material for self-study -0; Tests -0
- Video -13 (total time 109 min)- Material for self-study -0; Tests -0
- Video -11 (total time 88 min)- Material for self-study -0; Tests -0

Number of students: 5,629
Local (Russia): Open Education
6 courses

Mathematical Modeling in economics

Non-Linear Dynamics
Local (Erasmus): Modeling and simulation for engineers (InMotion)

- SPbPU – Winter school ([https://summerschool.spbstu.ru/schools/winter_school/](https://summerschool.spbstu.ru/schools/winter_school/))
- SPbPU – Summer school ([https://summerschool.spbstu.ru/](https://summerschool.spbstu.ru/))
Slovenia
Spain
Russia.
Russia. Hybrid systems. ISMA
Russia. Mathematical modeling of complex dynamical systems (Text- and training books)
Russia. Computer modeling of complex dynamical systems (Text- and training books)
Malaysia, Johor Bahru (UTM)

English version of text- and training books
face-to-face format

Winter school 2019
face-to-face format

Summer school 2019
Summer School 2021

Professors and lecturers:
- Prof. Yuri Senichenkov, Polytech (Russia)

Program partners:
- UNED: National University of Distance Education (Spain)

Contacts:
- summerschool@spbstu.ru
- +7 (812) 534-25-31
Dear student,

Welcome to the part of the course dedicated to modeling and simulation with Modelica! The course is structured into two parts: an introduction to the Modelica language and a project. After studying the lessons and completing the proposed activities, you will be able to:

- Design model libraries applying the object-oriented modeling methodology.
- Develop and use model libraries in Modelica.
- Use Modelica modeling environments for editing, debugging and translating Modelica models, experimenting with the model.

The course content is based on the following two free textbooks:


Watch the "ebook access" video to find out how to access to these two textbooks.

The work plan is described below. It consists in a sequence of tasks, which include watching video lectures, reading selected parts, evaluation tests, and completing hands-on assignments.

**Work plan**

**INTRODUCTION TO THE MODELICA LANGUAGE**

1. Why Modelica?
   a. Watch the "Modelica: a standardization effort" video

2. Modeling methodology and tools
   a. Watch the "Introduction to Lesson 1" video
   b. Watch the "Physical modeling paradigm" video
   c. Watch the "Object-oriented modeling" video
   d. Watch the "Modeling environments" video
   e. Watch the "Getting started with Modelica" video
   f. Watch the "Dymola tutorial" video
   g. Watch the "OpenModelica tutorial" video
   h. Read Lesson 1 of [1]
Local (university level): Modeling and simulation for engineers (SPbPU)

- School-leaver: Modeling for beginners
- Bachelors (users): Mathematical modeling, Computer modeling
- Masters (developers): Object-Oriented-Modeling
- Post-graduate students: Research in OOM
Series of disciplines «Modeling»

- Mathematical modeling
- Computer modeling technologies
  - Tools for modeling and simulation
  - Applied modeling
- Designing of tools for modeling and simulation

- Bachelors
- Masters
- Post-graduated students
School-leave

- Modeling for beginners

Gun-Shell-Target

Choose Velocity and angle
Start flight
Did you get to the target?
No? Try again
Bachelors

- Modeling for beginners
- Mathematical modeling (Mathematica, Maple, Anydynamics)
- Computer Modeling (AnyDynamics, OpenModelica)

Masters

- Object-oriented Modeling (UML, AnyDynamics, OpenModelica)
Computer Modeling

- Bachelors
- Lectures-12
- Labs-12 (AnyDynamics)
- Labs-12 (OpenModelica)

- Isolated: continues, discrete, hybrid
- Component models: causal-acausal
- Components: agent-based
- Computational experiments
Dynamical and hybrid systems

- A flight of three-stage rocket
Component models with «oriented blocks» (A la Simulink)

Marine simulators
www.transas.com
Component models with «non-oriented blocks» (A la Modelica)

Electrical, mechanical, hydraulic and so on «physical» models
Multicomponent models with dynamical structure (no analogs)

Queuing system. Agent-based systems.
Tools (Used in Russian universities)

- **Equation-based**
- **OOM-based**
- **UML-based**

- **Isolated Components**: causal–acausal (oriented blocks «Physical»)

- **Agents**

- **Event-driven behavior**

- **Event-driven structure**
Local: Tools+books
- AnyDynamics
- AnyLogic
- GPPS, GPSS World
- ISMA
- OpenModelica (Dymola)
- Simulink
- SimInTech
- SystemModeler
Books: GPSS, GPSS World (In Russian)
Simulation modeling
<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Price</th>
<th>Publishing House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulink Самоучитель</td>
<td>V. P. Dyakonov</td>
<td>479</td>
<td>LitRes</td>
</tr>
<tr>
<td>Simulink и SIMULINK для радиоинженеров</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATLAB и SIMULINK для радиоинженеров</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATLAB и SIMULINK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATLAB 6/6.1/6.5 Simulink 4/5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulink 6/6.1/6.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulink Самоучитель</td>
<td></td>
<td>1681</td>
<td>Bukvoed</td>
</tr>
</tbody>
</table>
AnyLogic
Journals:
http://www.kio.spb.ru/journal/

**Computer tools in Education**

**Computer tools in School**
VIRTUAL LAB IN MODELICA FOR AIR POLLUTION CONTROL

C. Martín-Villalba¹, M. E. Manzur², A. Urquía¹

¹Universidad Nacional de Educación a Distancia (UNED), Spain
²Universidad Nacional de Tucumán, Argentina

Abstract

Interactive is a Modelica library whose goal is to facilitate the implementation of virtual labs based on Modelica models quickly and with little effort. Modelica is a free object oriented modeling language. The implementation of a virtual lab for air pollution control developed using Interactive 2.0 is discussed in this manuscript. This virtual lab has been developed to explain the dispersion of pollutants into the atmosphere to undergraduate students of Environmental Chemistry of the Universidad Nacional de Tucumán (Argentina). Main aspects in the virtual lab development process are addressed in this discussion, including: 1) application of a systematic methodology to adapt any Modelica model into a description suitable for interactive simulation; 2) composition of the virtual lab view using Interactive. Additionally, the use of this virtual lab in the Environmental Chemistry course is discussed. Interactive is freely available at www.euclides.dia.uned.es.

Keywords: Modelica, virtual lab, air pollution.

Citation: C. Martín-Villalba, M. E. Manzur & A. Urquía, “Virtual Lab in Modelica for Air Pollution Control,” Computer tools in education, no. 1, pp. 5–15, 2018.
КНИГИ ПРОЕКТА INMOTION
InMotioN: «Новые стратегии обучения инженеров с использованием сред визуального моделирования и открытых учебных платформ»

Сениченков Ю. Б.¹, Зупанчиč Б.², Уркиа А.³
¹Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия
²Люблинский университет, Люблин, Словакия
³Национальный университет дистанционного обучения, Мадрид, Испания

http://www.inmotion-project.net/index.php/ru/

BOOKS OF THE INMOTION PROJECT
InMotion: “New Engineer Learning Strategies Using Visual Modeling Environments and Open Learning Platforms”

Senichenkov Yu. B.¹, Zupančič B.¹, Urquía A.³
¹Peter the Great Saint-Petersburg Polytechnic University, Saint Petersburg, Russia
²University of Ljubljana, Ljubljana, Slovenia
³Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain

Abstract

The InMotion project sets as one of its goals the creation of new training courses for future engineers in mathematical modeling and computer technologies for modeling complex dynamic systems. New courses are based on textbooks and books of problems developed by project participants. In the future, books will be freely available to students in both English and Russian. This article provides a brief description of the project and presents the original introductions to the books. In addition to textbooks, eLearning courses have already been developed, which at the end of the project will be freely distributed on the Internet. Details on the project itself and the first impressions of the new courses developed will be presented in a future article.
Appendix. Tools.
AnyLogic for Academia

Virtual EURO SIM Simulation Seminar
May 2021
selected universities and research labs

75 out of world’s top 100 universities* teach and carry out research using our products, spreading word of mouth to business

*According to QS University ranking
resources for academia

Free version for students

Students can quickly start learning simulation modeling by downloading the free AnyLogic PLE - it offers example models and tutorials for learning the modern methods of simulation and for developing systems thinking skills.

Complete version for academia

For teachers, researchers, and students who need advanced tools for their projects, we provide AnyLogic University Researcher. With a free 30-day trial and special pricing for non-commercial use, it is a fully functional version of AnyLogic for conducting full-scale research.

Educational resources

AnyLogic educational resources include books, how-to videos, webinars, and academic papers. Furthermore, the AnyLogic community provides a rich network of general and specialist knowledge at Stack Overflow, ResearchGate, and LinkedIn.

AnyLogic Cloud for students

Use the free AnyLogic Cloud to collaboratively develop your models online, run them remotely, and present simulation results to your peers and teachers. You can also share your models with the Cloud community, or dive into the public model library and learn from others.
resources for academia

• AnyLogic academic toolkit
  The AnyLogic simulation toolkit features reading materials, videos, and guidance resources for teachers and students. It is intended to support educational and teaching processes by helping develop simulation skills with hands-on materials.

• Trainings and events
  AnyLogic conducts events all over the globe: scheduled and customized training, free introductory seminars, user meetings, and an annual conference of skilled modelers sharing their knowledge and experiences.
NETSTAR – software for discrete-event simulation

Copyright holder – «The Federal Research Center of Coal and Coal Chemistry of Siberian Branch of the Russian Academy of Sciences».

NETSTAR allows simulate systems with considering of dynamics and stochastic due to mathematical modeling language of Petri net.
Simulating conducted through design of places and transitions, which are connected by arcs. Moving of markers allows consider system state changes in time.

Setting the structure and parameters of the system through the graphical interface.

Simulating result: system state changes in time.
Simulating model of longwall coalmining (mine “Polysaevskaya”, Kuzbass, Russia). Experiments on model allowed to get rational technical and organizational solutions for improvement productivity of coalmine.
Applications of Hybrid Systems

- Mechanics;
- Electromechanics;
- Biosystems;
- Power Engineering;
- Chemical Kinetics;
- Solid Mechanics;
- etc.
Specification in ISMA

- **Textual Language of States**
  
  ```
  st1 [ (h1<=hv3) ] is
  V3~=0;
  h1'=(1/S)*( Qp - Q1 - Q2 - V3^Q3 );
  h2'=(1/S)*( Q2 + V3^Q3 - V4^Q4 );
  from init, st2;
  ```

- **Block-Textual Language**

- **Statecharts**

- **Textual and Visual Domain-Specific Languages:**
  - Chemical Kinetics
  - Power Engineering
Publications


This is a collection of general-purpose Rust programming libraries (Linux, Windows, macOS) for discrete event simulation.

The simulator uses an unified approach (based on functional programming).

The simulator supports different modes (ordinary sequential simulation, distributed simulation, nested simulation).

The simulator implements the most popular simulation paradigms (event-oriented, process-oriented, GPSS-like blocks of transacts, partially agents) and also reactive programming based on the Observable pattern (to process the signals).
DVCompute Simulator, 
https://aivikasoft.com

- The simulation model is a composition of computations (monads, arrows, streams, continuations)
- The implementation uses so called “zero cost abstractions” (the computations are created on stack of the computer and then transferred to dynamic memory by demand)
- These computations are unified for all simulation modes, but we can choose any implementation of the event queue and mutable references
- GPSS-like blocks are defined via discontinuous processes, which are expressed in terms of discrete event handlers in its turn (everything works through the event queue)
The module of distributed simulation supports both the optimistic Time Warp method and the conservative one (MPI, super-computers)

The nested simulation is related to Theory of Games (imagine something like a chess play, where “moves” change the state of the discrete event simulation model)

Earlier the author, David E. Sorokin david.sorokin@gmail.com, created Aivika for the Haskell programming language. Now the goal is a higher speed of simulation with better portability among computer platforms
System of modelling of industrial and technological processes of functioning of the ship-building enterprises.

AS «Sirius» 2.0
Automated system Sirius (AS «Sirius» 2.0) is purposed for carrying out complete cycle of simulation surveys of shipyards functioning processes.

A simulation study includes inputting initial data, generating simulation models, setting up and conducting experiments, preparing reporting documentation based on the results of experiments in MS Word format.

The general purpose system of imitation (discrete-event) modeling GPSS World is used as a modeling core of AS «Sirius».

The formation of models is fully automated – the initial data entered by the user is converted by the model generator according to specially written algorithms into code in the GPSS World language, which is executed by the modeling kernel.

The supported types (technology) modeling – discrete-event.
Use of AS allows:

- To define whether production program of yard can be accomplished with set parameters of production system and construction technology
- To define duration of main vessel’s construction stages and comparison of the same with new scheduled dates of construction
- To detect yard production system’s bottlenecks
- To define manufacturing facility’s workload indexes (workload of technological, crane and transportation equipment, sections, shops, building berths) when accomplishing production program
- To assess consequences of temporary de-commissioning of separate facilities, included in scope of simulation model (equipment/section/shop)
- To assess efficiency of setting into work of separate facilities, included in scope of simulation model (equipment/section/shop);
- To make up production schedules: delivery of sheet and profiled steel from steel store (steel launch), delivery of equipment from mechanical facility, delivery of pipes from pipe processing facility.
Composition of initial data of AS «Sirius», required for simulation modeling:

- Yard production program
- Yard plan, including layout diagram, layouts and specifications of shops, sections and composition of their equipment
- Description and specifications of vessels under construction
- Split of vessels into assembly units and large-scaled assembly-installation units
- Data on binding of assembly and assembly-installation units to construction areas
- Principal production technologies as applied to main production branches
- Description and specifications of used crane, transport and technological equipment
- Equipment maintenance schedule
- Yard operation schedule, including shift-work (plant-schedule) of yard and its separate facilities
- External deliveries schedule of assembly and assembly-installation units
Output data of AS «Sirius» 2.0

The composition of the output data based on the simulation results:

- Data on the timing of the production program
- Diagram of the feasibility of the production program - comparison of the planned date with the simulation results
- Data on loading and utilization of production areas
- Data on loading and use of crane, transport and technological equipment
- Schedule of deliveries of rolled metal from the warehouse (including the required daily volumes of rolled metal start-up)
- Data on required buffer zones (to estimate the need for intermediate storage sites)
- Summary graphs of results (for a series of experiments)
- 2D animation of the process of building products
- Event log
Service oriented architecture
AS «Sirius» 2.0 user interface

- Production program data
- Data on ships under construction
- Production environment data
- Production layouts
The certificate № 2018614213 about the state registration of the computer program from от 03.04.2018 г.
It is given out by Federal Agency of intellectual property, patents and trade marks.

Copyright holder: JSC «Shipbuilding & Shiprepair Technology Center» (St.-Petersburg, Russia)