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Computer modelling and simulation of dynamic systems using Wolfram SystemModeler

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Textbook abstract

Nowadays, to study complex processes and systems, along with a full-scale experiment, a computational experiment is used - methodology based on usage of applied mathematics and computer technology, combining advantages of both theory and experiment. A computational experiment has a number of indisputable odds over a full-scale one. The main specialty of computational experiment (computer simulation) is ability to virtually predict the properties of the object being modeled, depending on the various conditions of it's operation and variable design parameters. In addition, to study complex objects and systems using computational experiment is less expensive, and the time spent on its implementation is significantly less. Moreover, it can predict the results of critical tests, which may lead in reality to the loss of the investigated natural object. A computational experiment acquires exceptional importance in those cases when natural experiments or physical model experiments are impossible.

To conduct a computational experiment, it is necessary to build a reliable mathematical model that describes system or process under consideration with a given accuracy.

The construction of a mathematical model allowing to get correct results in the process of computer modeling includes following steps: creating a model, developing (choosing) a method for solving a mathematical problem, including the numerical methods used; devel opment of an algorithm for solving the problem; software creation for the implementation of the model and algorithm on the computer; conducting a computational experiment; calculation results processing, it's analysis, comparison (if possible) with the results of a full-scale experiment, working out of conclusions and recommendations.

The methodological universality of computer modeling makes it possible, on the basis of experience accumulated during development of mathematical models, numerical methods, computational algorithms and means of analyzing the results obtained, quickly and effectively solve various applied problems.

Tasks associated with modeling of dynamic processes and systems are of particular interest. In the textbook to this class of tasks is given primary attention.

In practice, to study complex multicomponent systems, a computational experiment is often carried out using specialized software packages.

The textbook is devoted to using Wolfram SystemModeler (WSM) environment for computer modeling of dynamic processes and systems, which mathematical models belong to the macro level and are described by differential and differential-algebraic equations.

The textbook consists of six chapters and has the following structure.

The first chapter introduces reader to the basic concepts of mathematical modeling. It introduces such important concepts as a model, types of modeling, idea of classification and basic properties of mathematical models. Special attention is paid to identifying differences between continuous, discrete and hybrid models.

The second chapter is devoted to the description of the Wolfram SystemModeler environment. The basics of working in the Model Center for creating your own model with components from the Modelica standard library, principles for creating your own components, and rules for performing a computational experiment in the Simulation Center are given.

The third chapter gives a general idea of the fundamental principles underlying any mathematical model, such as the laws of conservation in classical mechanics or variational principles. On these principles, so-called basic models could be built, which later serve as the foundation on which more complex hierarchical models are built.

In the fourth, fifth and sixth chapters, reader is invited to explore methods for solving single-component, multicomponent and hybrid problems using two alternative approaches: direct programming of mathematical models in Modelica and using component modeling technologies in standard libraries.

It should be noted that component modeling is discussed in more detail in training man uals on virtual laboratory practice: Virtual laboratories in Wolfram SystemModeler and A practical guide for performing virtual labs in Wolfram SystemModeler.

In the last three chapters, illustrative examples of dynamic systems models constructing are given according to the degree of its complexity.

The textbook is designed to support the course "Computer modeling and simulation of dynamic systems using the Wolfram SystemModeler environment", tought to bachelors in the training area "Applied Mathematics" (SMTU, Russia) and the course «Control systems» for bachelors in the training area «Mechanical Engineering» (UTP, Malaysia).

The knowledge acquired as a result of studying this textbook can be used by students in practice - for independent tasks and virtual laboratory work on modeling dynamic systems using the WSM environment.

While working on the textbook, materials from the software development company Wolfram Research, Inc. web site were used.

The textbook is written by creative team of authors from partner universities SMTU, Russia and UTP, Malaysia.