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Control-oriented modeling and simulation: methods and tools

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Textbook abstract


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Modelling and simulation have a very long tradition in control engineering. For the complex control systems design the corresponding mathematical model development and its computer simulation are extremely useful and represent a high added value. Furthermore, modelling and simulation can be efficiently used also in the process of the design and validation of control methods. Although there are many sophisticated design approaches with a high level of theory, most engineering approaches have always been based on simulation-based experimentation. Beside mentioned, modelling and simulation can be efficiently used in some other areas which are usually not in the focus of control systems design: for the safe start-up and shutdown of the processes in industrial plants, for the operators training and their decisions support and in many other issues. Widespread digitalization of systems opens new challenging problems related to systems analysis and design, involving discrete event dynamics. Modelling and simulation can be used to address these challenges.

Just as we cannot imagine control systems design without modelling and simulation, we cannot imagine modelling and simulation without powerful software tools. It is well known that Matlab with the simulation toolbox Simulink and many other toolboxes is the most frequently used environment especially in the academic society but more and more also in industrial companies.

So the main idea of the book is to present some interesting and important areas in control (automation) which are inevitably connected with computer modelling and simulation engineering (CMSE) and to present the problem solving approach using Matlab and Simulink through many examples.

Second chapter deals with the most frequently used presentations of models. Two general presentations are introduced first, namely parametric and non-parametric models. The emphasis is given to the descriptions usually used in the analysis and design of control systems: differential equations, transfer functions and state space description. The second part of this chapter introduces Control System Toolbox which is indispensable in the presentation of mathematical models inside Matlab environment, during analysis, and also for control design of dynamic systems.

Third chapter is devoted to simulation. The basic approaches, how the mathematical models are converted into simulation models (programs, schemes) are presented. The concept of digital simulation is briefly introduced: conversion of parallel structures into sequential, numerical integration and sorting of model equations. This chapter introduces Simulink, simulation toolbox in Matlab, which can essentially unburden the user in solving mathematical models of dynamic systems. Three important simulation experiments are illustrated through several examples: parametrization, optimization, and linearization. These types of experiments are very frequently used in the phase of model(s) development, as well as in control design procedures.

Fourth chapter focuses to modelling for the purpose of dynamic systems control, or more precisely to experimental modelling also called system identification. The goal of identification is to determine system model based on available measurement data. Only the parametric identification methods of linear time invariant models are discussed in this book. Strejc's method is based on excitation with step test signals. It is very simple but only suitable for a relatively small class of processes. Model tuning methods are based on optimisation. The main part of the chapter is devoted to system identification based on linear regression. The main idea here is similar as in the case of model tuning methods but it does not involve optimisation and its problems. Rather, parameter estimation is done via analytical solution of a linear system of equations. Due to its simplicity and its flexibility this approach is very often used in practice.

Fifth chapter is an introductory chapter to control systems. It deals with basic control concepts. We introduce open and closed loop control, control in the operating point, reference tracking mode and disturbance rejection mode, steady state behaviour and stability of control systems.

Sixth chapter briefly describes most usually used industrial control algorithms. First the extended block diagram of the control system is presented. Then the types of industrial controllers are itemised. The emphasis is given to the continuous proportional-integral-differential (PID) controllers. The role of all terms is explained and illustrated with several examples in Matlab-Simulink and also in Dymola-Modelica environments. Difficulties with the derivative term implementation are discussed. As design (tuning) techniques tuning rules (Ziegler-Nichols open loop tuning, Ziegler-Nichols closed loop tuning known also the oscillation method, Chien-Hrones-Reswick method) and computer optimization are presented and illustrated with several examples. The chapter concludes with the presentation, how PID controller can be efficiently realised with digital algorithm. Two examples demonstrate the efficiency of Matlab-Simulink and Dymola-Modelica environments for the implementation of the discrete PI control of the electrical motor angular velocity.

Seventh chapter includes an introduction to discrete event systems and related simulation methods.

In contrast to predominantly continuously evolving systems described in previous chapters, many man-made systems including control systems exhibit dynamics, which is manifested through sudden discontinuous changes related to events. Examples of such systems include manufacturing and assembly lines in production facilities, transport systems on ground, water and in the air, military decision and command systems, as well as computer systems and digital communication networks. With ubiquitous digitalization the importance of these systems is rising and so are the needs for suitable analysis and design tools. Discrete event modelling and simulation tools can be used in many stages of system analysis and design, improving the understanding of discrete event systems and facilitating their construction, control, and optimization. The chapter includes introduction to discrete event systems and related topics from probability theory, and presents different approaches to discrete event simulation (event scheduling, activity scanning, process oriented simulation). The last part deals with queuing systems and with introduction of Matlab SimEvents library and corresponding simulation examples.

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