Control-oriented modeling and simulation practice with Matlab and Simulink
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Activity book abstract

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.

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 of examples is to supplement the book Control-Oriented Modelling and Simulation: Methods and Tools with six examples. Each example has the description, tasks and solutions with Matlab-Simulink environment. The appropriate Matlab and Simulink solutions are partly listed in the text of the book but are also added to the book as separate files. The examples are taken from the 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.

Example 1 deals with linear systems' presentations, transformations, and analysis. The problem is defined by a block diagram with four interconnected subsystems where different forms of mathematical descriptions are used. The tasks include the estimation of properties of each of the presented subsystems, the step by step calculation of equivalent input-output presentation and the estimation of important properties of the whole system. In addition two experiments, namely two parametrizations have to be performed. The first experiment is presenting the influence of one parameter to stability of defined subsystem, while with the second one the influence of the same parameter to stability of the whole input-output process is inspected.

Example 2 is devoted to the simulation of a nonlinear mathematical model and to the corresponding linear approximation while also adequate comparison of both models' responses to the defined input signal have to be realized. First simulation scheme of nonlinear model has to be developed which includes also the realization of described input signal. On the basis of calculated system response some important properties of nonlinear model should be detected (DC gain and time constant are changing regarding signals value). In the next step a structure and parameters of linearized model have to be estimated. Finally the responses of both models have to be compared around the neighbourhood of the chosen working point.

Example 3 deals with identification of a dynamical system. First, the model of the process is created and the measurements of the system simulated. Then, two identification approaches

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are taken. The first is empirical transfer function estimation (ETFE) which is a non-parametric identification method that results in the estimated frequency response of the system, and the second one is least-squares (LS) parameter estimation which produces a parametric model in the form of a transfer function. The results are compared and cross-verified. In order to show potential errors the obtained models are also compared to the actual model of the system which is of course known in the scope of this exercise. At the end, the performance of the algorithms is checked using different settings for design parameters.

Example 4 is devoted to the ON-OFF control of a heating control system. The first part of the example is devoted to the modelling of the temperature in a room. Then students must develop Simulink simulation scheme using also indirect approach with integrators for the room model. Then simulation results must be analysed with several quality indicators for different hysteresis functions, for different process delays, for different powers of the heater and also for different external temperatures. Matlab code for the execution of all simulations (using sim command for model execution in Simulink) must be developed. The students must also develop the model of the heating process in Dymola- Modelica and include it as the Dymola block into Simulink scheme for the overall control system.

Example 5 deals with the single loop and multi loop PID control of a three tank system. Students must develop block schemes and Simulink simulation environment for studying single loop control, feed forward compensation and cascade control. All three approaches should be simulated from the unified Simulink model by the aid of particular parameters. For the optimisation the calculation of the criterion function (time absolute error) must be included in the scheme. For the single loop control students must determine the PID controller parameters using two Ziegler-Nichols methods (process reaction curve and oscillation method) and with computer optimization, minimizing the specified criteria, all for the reference tracking mode and for the disturbance rejection mode. Then students must design also multi loop solutions: feed forward compensation for efficient disturbance elimination and cascade control for reference tracking and for disturbance elimination. All solutions must be analysed and also compared with simulation.

Example 6 deals with discrete-event simulation. It aims to practically introduce the use of Simulink-SimEvents library in modelling discrete-event and hybrid systems. Within the example a workstation is studied, which performs drilling of incoming workpieces. The problem is presented as a system with waiting queue and a single server. A simulation model is built with SimEvents library, and typical performance measures are observed. Compliance of the simulation results with theoretically derived expressions (e.g. Little's law) is checked. Finally, a proportional control loop is added to control the WIP level in the process buffer

(queue length) to a desired set point. The corresponding hybrid system is simulated to examine the control loop performance at various gain settings.

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