Systems Identification and Simulation

Study programme: N0714A270012 Control of Machines and Processes
Academic year: 2024/2025

1. Goals and methods of the systems identification and simulation. Basic terms - system, dynamic system, basic dynamic relations, separability principle. Model development process, terms black box, white box, grey box.
2. State model of the dynamic system, general structure. State of the system, steady state, state trajectory, types of the steady states. Linearization around the steady state. Linear dynamic system – state space model.
3. Transformation of the input-output model of the dynamic system in form of differential equation or transfer function into the state space model of the system. Transformation of the more differential equations and nonlinear differential equation describing the system into the state space model.
4. Typical nonlinearities – characteristics, description and modelling. Limited integration.
5. Curve fitting – approximation of the functions, linear regression, polynomial interpolation, least square method. Interpolation using cubic spline, periodic and cyclic spline function.
6. Numerical integration methods, numerical derivation methods.
7. Numerical methods for solving differential equations – one step methods, multi steps methods. Errors of the numerical solution of the differential equations, estimation of the error.
8. Stability of the numerical solution of the differential equations, stability area of the numerical methods for the solution of differential equations. Stiff systems. A-stable methods.
9. Mathematical-physical modelling, mathematical similarity, physical similarity, physical analogy.
10. Basic principles and laws used by the modelling of the mechanical systems doing linear and rotating motion. Basic elements of mechanical systems and their use by the physical modelling.
11. Modelling of the systems with more degrees of freedom, Lagrange's equations.
12. Basic principles of the modelling of the electrical systems, used physical laws and methods by the modelling of the dynamic properties – example DC-motor with permanent magnet. Basic elements of electrical systems and their use by the physical modelling.
13. Mathematical models of the basic circuits with operational amplifiers. Op-amp properties, realization of the transfer functions – controllers, filters.
14. Basic principles and laws of the modelling of the hydraulic systems. Modelling of the tank systems, control of the liquid level position.
15. Modelling of the fluid power systems. Hydraulic resistances. Mathematical model of the hydraulic cylinder, flow control valves.
16. Modelling of the thermal processes. Types of the heat transfer – conduction, convection, radiation. Basic elements of electrical systems and their use by the physical modelling. Mathematical model of the vessel with thermal capacity and thermal losses.
17. Deterministic method of the experimental identification – used input signals, technical feasibility. Evaluation of the step response to the rectangular impulse and to the ramp signal.
18. Step response approximation (Strejc's methods), approximation of the step response with time delay.

19. Step response and impulse response parameterisation methods.
20. Experimental methods of the evaluation of the frequency response (Bode plot).
21. Stochastic methods of the identification. Random process, stationary process, ergodic process, white noise. Testing signals, pseudo random signals. Characteristics of the realization of the random signal (average value, variance, probability density function, distribution function. Auto-correlation function, cross-correlation function. Power spectral density.
22. System identification using the random signal, Wiener-Hopf equation. Evaluation of the impulse and step response.
23. Mathematical models of the random process AR, ARMA and of the dynamic systems ARX, ARMAX. Evaluation of the model parameters using the least square method, weighting coefficients, exponential forgetting. Recursive methods of the identification.
24. Implementation and support of the experimental identification methods in the program MATLAB-Simulink.
25. Simulation programmes – classification, equation oriented programes, block diagrams oriented programes, physical modelling. MATLAB-Simulink. Application of the simulation models by the design and testing of the control systems. Hardware in the Loop Simulation, hardware for the real time simulation (dSPACE).

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