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Optimization of control system parameters with use of the new Lyapunov exponents estimation method

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Abstract of the doctoral thesis

The main subject of the thesis is application of the novel method of Lyapunov exponents (LE) estimation in the field of control systems. The possibility of adaptation of the method for tuning and optimization of control systems has been analysed. The performance of the method has been checked on a real object – an inverted pendulum.

The thesis starts with a theoretical background on dynamical systems. Basic definitions are provided and the variational equation is introduced. Using the solution of this equation, the definition of Lyapunov exponents is presented. Properties of the Lyapunov exponents are explained on the basis of matrix theory. The classical method of Lyapunov exponents estimation is introduced. The next topic of the thesis is the novel method of Lyapunov exponents estimation. The different approach to the LLE calculation is presented. The assets of the new method in comparison to the classical one are outlined. The possibility to extend the novel method to LE spectrum estimation is explained. In the further part of the thesis, attention is focused on control systems. Basic terms in the field of control systems are introduced. Classical methods of regulation are presented. Commonly used measures of control quality are explained. Adaptation of the new LLE estimation method to control systems is covered. Properties of the newly designed method in the field of regulation are shown. After general introduction to control systems, a particular control system, the inverted pendulum, is analysed. Equations of motion of the system are derived using Lagrange approach. The state space description of the system is created. Two different regulation approaches are considered: the velocity control and the force control. Linearization of the system in the neighbourhood od the equilibrium point is covered. In order to design an efficient controller, parameters of the controlled object must be estimated with an acceptable accuracy. The unknown quantities in the system are connected with the drive dynamics and with friction in the pendulum's bar bearings. The model of the drive has been obtained from analysis of its step response, whereas friction model has been derived from free vibrations. After identification of the control object, it is possible to design a controller. In order to obtain high control quality, the LLE-like performance index has been minimalized. In order to find controller parameters, the Differential Evolution optimization method has been applied. The minimization process resulted in the set of controller constants that assured decent regulation quality and shorter stabilization time than in case of typical, linear methods.

The thesis confirms the fact that the new LLE estimation method can be applied in optimization of nonlinear control systems. The method proves to be more effective than linear control methods due to the fact, that the optimization is performed for the whole trajectory, not for a fixed point only. Possible extensions of this work include applications in systems with time delays or in systems with discontinuities.

Keywords: inverted pendulum, Lyapunov exponents, controller, optimization

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