Robust Spectral Shaping for Time-Delay Systems

Supervisor: doc. Ing. Libor Pekař, Ph.D.

Consultant: ---

Department: Department of Automation and Control Engineering

Programme: Automatic Control and Informatics

Abstract:

Time-delay systems in technological and other processes are assumed to contain delays or latencies within inner feedback loops, not only in the input-output relationship. Such systems belong to the class of infinite-dimensional systems, having an infinite number of characteristic roots (poles). By considering a designed control system with a controller that includes a finite number of free (tunable) parameters, one must address the problem of appropriately placing the decisive part of the feedback. The robustness (i.e., a sufficient insensitivity to control system dynamics fluctuations or model uncertainties) of such an assignment is a significant perspective on this issue. This requirement often leads to interesting optimization (minimization or minmax) problems, with or without constraints, where the cost function might be non-smooth and/or non-convex, or even non-Lipschitz. In particular, neutral delayed systems can have very sensitive eigenvalue loci.

This dissertation should focus on the implementation of known and recent universal or "ad hoc" algorithms for (partial) eigenvalue assignment in time-delay systems, with emphasis on robustness. Some original ideas, approaches, or algorithms should accompany known methods, and the results should be compared to other robustness approaches. It is expected to use modified advanced and up-to-date optimization techniques, such as nature-inspired or technology-inspired metaheuristics, to cope with the formulated optimization tasks. The theoretical results should be verified through laboratory experiments.

Literature:

[1] ARAÚJO, José M; DÓREA, Carlos ET; GONÇALVES, Luiz MG; CARVALHO, João BP and DATTA, Biswa N. Robustness of the quadratic partial eigenvalue assignment using spectrum sensitivities for state and derivative feedback designs. Journal of Low Frequency Noise, Vibration and Active Control. 2018, vol. 37, no. 2, pp. 253-268. ISSN 1461-3484. DOI: 10.1177/1461348418755614.

[2] FENZI, Luca and MICHIELS, Wim. Robust stability optimization for linear delay systems in a probabilistic framework. Linear Algebra and its Applications. 2017, vol. 526, pp. 1-26. ISSN 0024-3795. DOI: 10.1016/j.laa.2017.03.020.

[3] GOMEZ, Marco A. and MICHIELS, Wim. Characterization and optimization of the smoothed spectral abscissa for time-delay systems. International Journal of Robust and Nonlinear Control. 2019, vol. 29, no. 13, pp. 4402-4418. ISSN 1049-8923. DOI: https://doi.org/10.1002/rnc.4631.

[4] GONTIJO, Danielle S; ARAÚJO, José M; SANTOS, Tito LM and SOUZA, Fernando O. Proportional-integral-derivative-acceleration robust controllers for vibrating systems. Journal of Vibration and Control. 2022, vol. 29, no. 5-6, pp. 1243-1253. ISSN 1077-5463. DOI 10.1177/10775463211060898

[5] LIN, Rong; MOTTERSHEAD, John E. and NG, T. Y. A state-of-the-art review on theory and engineering applications of eigenvalue and eigenvector derivatives. Mechanical Systems and Signal Processing. 2019, vol. 138, art. no. 106536. ISSN 0888-3270. DOI: 10.1016/j.ymssp.2019.106536

[6] MICHIELS, Wim. Design of structured controllers for linear time-delay systems. In: Breda, D., ed., Controlling Delayed Dynamics. CISM International Centre for Mechanical Sciences. Cham: Springer, 2022, pp. 247-288. ISBN 978-3-031-00981-5. DOI: 10.1007/978-3-031-01129-0_8.

[7] MICHIELS, Wim and NICULESCU, Silviu-Iulian. Stability, Control, and Computation for Time-Delay Systems: An Eigenvalue-Based Approach, Second Edition. SIAM, 2014. ISBN 978-1611973624.

[8] MICHIELS, Wim, NICULESCU, Silviu-Iulian and Islam BOUSSAADA. A complete characterization of minima of the spectral abscissa and rightmost roots of second-order systems with input delay. IMA Journal of Mathematical Control and Information. 2023, vol. 40, no. 3, pp. 403-428. DOI: 10.1093/imamci/dnad020.

[9] MICHIELS, Wim and VYHLÍDAL, Tomáš. An eigenvalue based approach for the stabilization of linear time-delay systems of neutral type. Automatica. 2005, vol. 41, no. 6, pp. 991-998. ISSN 0005-1098. DOI: 10.1016/j.automatica.2004.11.032.

[10] VANBIERVLIET, Joris; VERHEYDEN, Koen; MICHIELS, Wim and VANDEWALLE, Stefan. A nonsmooth optimisation approach for the stabilisation of time-delay systems. ESAIM: Control, Optimisation and Calculus of Variations. 2007, vol. 14, no. 3, pp. 478-493. ISSN 1292-8119. DOI: 10.1051/cocv:2007060.

[11] VITE, Leopoldo; GOMEZ, Marco A.; MONDIÉ, Sabine and MICHIELS, Wim. Stabilisation of distributed time-delay systems: a smoothed spectral abscissa optimisation approach. International Journal of Control. 2021, vol. 95, no. 11, pp. 2911-2923. ISSN 0020-7179. DOI: 10.1080/00207179.2021.1943759.

[12] VYHLÍDAL, Tomáš; MICHIELS, Win and MCGAHAN, Paul. Synthesis of strongly stable state-derivative controllers for a time-delay system using constrained non-smooth optimization. IMA Journal of Mathematical Control and Information. 2010, vol. 27, no. 4, pp. 437-455. ISSN 0265-0754. DOI: 10.1093/imamci/dnq025.