Topic ID: 316-ARI-EN-02

Zero-Pole Assignment for Time Delay Systems Control with Uncertainties Considered

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

Consultant: ---

Department: Department of Automation and Control Engineering

Programme: Automatic Control and Informatics

Abstract:

Controlled systems are inherently affected by uncertainties due to nonlinearities, fluctuations in physical parameters, ambient conditions, etc. In addition, their models suffer from inaccuracies and require simplifications of physical reality. These factors have to be taken into account when designing controllers in practice. Time-delay systems include latencies in their internal feedback loops. They belong to the class of infinite-dimensional systems. This feature poses multiple obstacles to analyzing and controlling the system dynamics, mainly due to an infinite number of response modes and non-minimum-phase behavior.

Based on the facts above, robust control design for time-delay systems remains a challenging task in control engineering. This research question can be addressed using standard, well-established tools (such as sensitivity functions, robust performance, robust stability, stability margins, etc.), advanced principles (such as pseudospectrum and smoothed spectral abscissa), or a combination of both. Hence, the student is to adopt, compare, and enhance these approaches. The spectral properties of the control system should be emphasized. Besides, a method that includes not only poles but also feedback system zeros, recently proposed by the supervisor, should be applied, worked on, and further analyzed.

Literature:

[1] ARAÚJO, José Mário; DANTAS, Nelson J.B.; DÓREA, Carlos E.T.; RICHIEDEI, Dario and TAMELLIN, Iacopo. Pole-zero placement through the robust receptance method for multi-input active vibration control with time delay. Journal of Sound and Vibration. 2025, vol. 599, art. no. 118850. ISSN 0022-460X. DOI: 10.1016/j.jsv.2024.118850.

[2] 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.

[3] 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

[4] 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.

[5] 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.

[6] 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.

[7] 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.

[8] PEKAŘ, Libor and MATUŠŮ, Radek. A suboptimal shifting based zero-pole placement method for systems with delays. International Journal of Control, Automation and Systems. 2018, vol. 16, no. 2, pp. 594-608. ISSN 1598-6446. DOI: 10.1007/s12555-017-0074-6.

[9] TORRES-GARCÍA, Diego; MÉNDEZ-BARRIOS, César-Fernando and NICULESCU, Silviu-Iulian. Stabilization of second-order non-minimum phase system with delay via PI controllers: Spectral abscissa optimization. IEEE Access. 2024, vol. 12, pp. 170851-170867. ISSN 2169-3536. DOI: https://doi.org/10.1109/access.2024.3499748.

[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.