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Robust Spectral Shaping for Time-Delay Systems

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Abstract:

Time delay systems in technological and other processes are assumed to contain delays - or latencies, in inner feedback loops, and not only in the input-output relationship. Such systems belong to the infinite-dimensional class, having an infinite number of characteristic roots (poles). By considering a designed control system with a controller, including a finite number of free (tunable) parameters, one has to cope with the problem of the suitable placement of the decisive part of the feedback. Robustness of such an assignment represents a significant point of view to this issue. This often leads to interesting optimization problems - with or without constraints, where the cost function might be non-smooth and/or non-convex, or even non-Lipschitz. Especially, neutral delayed systems can have very sensitive eigenvalues loci.

This dissertation thesis should be focused on the implementation of some known, as well as recent, universal or "ad hoc" algorithms to (partial) eigenvalue assignment for time-delay systems with the emphasis to robustness. Known methods should be accompanied by some original ideas, approaches or algorithms. It is expected to utilize optimization techniques, such as the Nelder-Mead algorithm, SOMA, PSO, ACO, etc. The theoretical results ought to be verified by using laboratory experiments.

Literature:

[1] ARAÚJO, J. M., C. E. T. DÓREA, L. M. G. GONÇALVES, J. B. P. CARVALHO and B. N. DATTA. 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 [online]. 2018, 37(2), 253-268. DOI: 10.1177/1461348418755614.

[2] FENZI, L. and W. MICHIELS. Robust stability optimization for linear delay systems in a probabilistic framework. Linear Algebra and its Applications [online]. 2017, 526, 1-26. DOI: 10.1016/j.laa.2017.03.020.

[3] GOMEZ, M. A. and W. MICHIELS. Characterization and optimization of the smoothed spectral abscissa for time-delay systems. International Journal of Robust and Nonlinear Control [online]. 2019, 29(13), 4402– 4418. DOI: 10.1002/rnc.4631.

[4] GONTIJO, D. S., ARAÚJO, J. M., SANTOS, T. L. M. and F. O. SOUZA. Proportional-integral-derivative-acceleration robust controllers for vibrating systems. Journal of Vibration and Control [online]. 2023, 29(5-6), 1243-1253. DOI: 10.1177/10775463211060898.

[5] LIN, R. M., MOTTERSHEAD, J. E., and T. Y. NG. A state-of-the-art review on theory and engineering applications of eigenvalue and eigenvector derivatives. Mechanical Systems and Signal Processing [online]. 2020, 138. DOI: 10.1016/j.ymssp.2019.106536.

[6] MICHIELS, W., 2023. Design of structured controllers for linear time-delay systems. In: BREDA, D., ed. Controlling Delayed Dynamics. CISM International Centre for Mechanical Sciences [online]. Cham: Springer, 2023, pp. 247-288. ISBN 978-3-031-00981-5. DOI: 10.1007/978-3-031-01129-0_8.

[7] MICHIELS, W. and S.-I. NICULESCU. Stability and Stabilization of Time-Delay Systems. An Eigenvalue Based Approach, 2nd ed. Philadelphia: SIAM, 2016. ISBN 978-1611973624.

[8] MICHIELS, W., NICULESCU, S.-I. and I. 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 [online]. 2023, 40(3), 403-428. DOI: 10.1093/imamci/dnad020.

[9] MICHIELS, W. and T. VYHLÍDAL. An eigenvalue based approach for the stabilization of linear time-delay systems of neutral type. Automatica [online]. 2005, 41(6), 991-998. DOI: 10.1016/j.automatica.2004.11.032

[10] VANBIERVLIET, T., K. VERHEYDEN, W. MICHIELS and S. VANDEWALLE. A nonsmooth optimization approach for the stabilization of time-delay systems. ESIAM: Control, Optimisation and Calculus of Variations [online]. 2008, 14(3), 478-493. DOI: 10.1051/cocv:2007060.

[11] VITE, L., M. A. GOMEZ, S. MONDIÉ and W. MICHIELS. Stabilisation of distributed time-delay systems: a smoothed spectral abscissa optimisation approach. International Journal of Control [online]. 2021, 95(11), 2911-2923. DOI: 10.1080/00207179.2021.1943759.

[12] VYHLÍDAL, T., W. MICHIELS and P. MCGAHAN. Synthesis of a strongly stable state-derivative controller for a time delay system using constrained nonsmooth optimization. IMA Journal of Mathematical Control and Information [online]. 2010, 27(4), 437-455. DOI: 10.1093/imamci/dnq.