Robustness via constrained H_∞/H_∞ synthesis

Laleh Hosseini-Ravanbod [*] Dominikus Noll [*] Pierre Apkarian [†]

Robustness is one of the the most fundamental design specifications in feedback control, because in practice systems are always subject to uncertainty and mathematical models are never perfectly accurate. System equations may neglect high frequency components of the dynamics, parameters may be unknown of incorrectly identified, or systems may be subject to aging, sensor or actuator breakdown, and much else.

As long as little is known about the structure of the uncertainty, one may often obtain satisfactory results by de-sensibilizing the feedback controller with respect to perturbations. This basically assumes that the system is subject to a large set of possible uncertainties. Naturally, such an approach will to some extent degrade the system performance.

Ironically, the situation gets more complicated if a smaller but more specific set of perturbations is considered and the controller has to be made robust without degrading performance too severely. In this presentation we consider the typical case where the system equations are subject to parametric uncertainty. We focus on robust stability, where the controller has to give good nominal performance, and at the same time has to stabilize the system for uncertain parameters varying in an a priori known set.

A theoretical tool to assess this situation is the structured singular value μ proposed by J. Doyle in the late 1980s [2]. Unfortunately, a single evaluation of μ is NP-complete, which makes its use within an optimization procedure illusory. Here we show that a good compromise can be achieved when instead a semi-structured distance to instability is used as a heuristic. This leads to a constraint optimization program of the form

$$\begin{array}{ll} \text{minimize} & \text{Perf}(K) = \|T_{w\to z}(K)\|_\infty \\ \text{subject to} & \text{Rob}(K) = \|T_{\tilde{w}\to\tilde{z}}(K)\|_\infty \leq r \\ & K \text{ closed-loop stabilizing} \end{array}$$

which involves a performance and a robustness channel and is non-smooth due to the presence of composite functions of the H_∞ norm in both objective and constraint. We explain the rationale of our approach, [1], evaluate its conservatism, and discuss the bundle type algorithm used to compute optimal solutions.

References

[1] L. Hosseini-Ravanbod, D. Noll, P. Apkarian. Robustness via structured H_∞/H_∞ synthesis. Int. J. Control, in print 2011.

[2] K. Zhou. *Essentials of Robust Control.* Prentice Hall, 1998.

[*] Université Paul Sabatier, Institut de Mathématiques, Toulouse, France

[†] ONERA, Department of Systems Control and Flight Dynamics, Toulouse, France