Advanced control using decomposition and simple elements. DELETED MATERIAL

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Abstract

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1. MPC CRITIQUE. DETAILS DELETED

To understand this better, note that the best tool for linear uncertain systems with unstructured and parametric uncertainty is the (real) structured singular value μ, but the use of μ is only reliable for analysis, and even this problem is NP-hard (Braatz et al., 1994). For design, there is no method with guaranteed convergence to find the μ-optimal controller $C(s)$ for an uncertain linear system. The available DK-iteration method frequently diverges (e.g., Skogestad & Postlethwaite (2005)) and when it converges it results in an optimal controller approaching infinite order. Since this is the best we can do for linear uncertain systems, it means that none of the available MPC stability and design results hold rigorously (in terms of being tight and optimal) for realistic uncertain systems, not even in the linear case.

With MPC, to restrict the controller order, one may represent the uncertainty using a multi-model or scenario approach, but this is generally optimistic (and may even give instability), because the worst case, for example, the worst-case time delay, may be an intermediate value which is not in the assumed model set.

A completely different approach is to restrict the set of allowed control laws (including fixing the order of the controller) and search for the best controller

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parameters, e.g., multivariable PID parameters. However, this gives a very hard mathematical problem. The simplest is to use proportional control, $u = Ky$, and search for the optimal matrix K. However, even in the linear case with no uncertainty and a quadratic objective, the optimal static output feedback problem is unsolved and believed to be non-convex and NP-hard. (e.g., Sadabadi & Peaucell (2016)). This illustrates that the controller design problem does not become simpler by imposing limitations on the controller, like limiting the order (static output feedback) or requiring decentralized control (corresponding to specifying zero elements in the controller C). On the contrary, decentralized controllers are actually more complex to synthesize and implement than their centralized counterparts (e.g., Anderson et al. (2019)).

The mathematical problem is therefore usually simplified by *removing* decomposition restrictions, for example, by combining the control and optimization layers in Figure **??** into a single Economic MPC (EMPC). This makes it tempting for academic researchers to propose the use of EMPC, but for practical implementation and tuning this combination of layers is rarely a good solution. Thus, EMPC should only be used for small problems or if it is really necessary, for example, if we cannot achieve acceptable time scale separation between the optimization and control layers.

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