Optimization-based design of structured LTI controllers for uncertain and infinite-dimensional systems

Soutenance de thèse – DA SILVA DE AGUIAR

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Résumé

The control of complex systems often requires model approximation amenable to available theory and computational tools. Synthesis based on overly reduced models in order to comply with limited synthesis techniques may even altogether fail. This may necessitate refining the approximate model. This is specially true for the design of finite-dimension linear time-invariant controllers for infinite-dimensional systems due to spillover effects. For this reason, either robust control, which takes the mismatch between actual and approximate systems into account, or data-driven control which avoids parametric models altogether, should be employed.

Parametric Robust Control synthesis is a NP-hard problem, where relaxations have to be used. These relaxations come with a degree of conservatism and with adverse effect on closed-loop performance. A main objective of this thesis is therefore to develop novel relaxations for robust structured controller synthesis for systems subject to parametric and complex dynamic uncertainty, which allow to avoid or reduce conservatism.

The first proposed strategy is an outer relaxation technique based on scalings or multipliers in tandem with small gain constraints leading to a single augmented model where scalings and controller are tuned simultaneously. The second approach is an inner relaxation method using worst-case scenarios for performance and stability, based computationally on specialized nonsmooth optimization techniques. This leads to an iterative multi-model synthesis, where all models have the state-space order of the nominal model. Finally, a third method combines the power of inner and outer relaxations in a hybrid technique.

In the data-driven control framework, frequency response based synthesis has already proved its versatility for performance optimization, but restricted to open-loop stable systems or pre-stabilized systems. This precludes dealing with unstable infinite-dimensional systems, whose response may be obtained for example from physical laws. Therefore, the second objective of this thesis is to dispense with open-loop stability and develop new methods for frequency response design of structured control laws for unstable or stable infinite dimensional systems.

To accomplish this goal, firstly a bisection method based on Nyquist stability criteria was produced to estimate the spectral abscissa of such systems. A method to estimate impulse response energy over a finite horizon was also developed. In the following, three techniques for designing stabilizing controllers are introduced based on minimization of the spectral abscissa, the impulse response energy, and of the shifted H_∞ -norm of the closed-loop system.

The novel robust control techniques were tested on a bench of challenging examples and compared among others to the well-known μ-synthesis method. The results indicate that while outer relaxations excel on pure dynamic uncertainty cases, the inner relaxation proposed achieves the best certified robust performance in general, followed by the hybrid approach. Similarly, the data-driven control techniques were tested on a variety of unstable and stable systems of finite and infinite dimensions with the three data-driven techniques reaching equivalent stabilization success rates.

Mots clés
Robust control, Data-driven control, Infinite-dimensional systems, Nonsmooth optimization