Universität Stuttgart
Institut für Flugmechanik und Flugregelung

NONLINEAR SYSTEM ANALYSIS

Stability guarantees for nonlinear model-predictive control via sum-of-squares

Master thesis

Motivation
Stability of a closed-loop model-predictive control approach often relies on a reference-dependent, invariant terminal set. For nonlinear dynamics, computing terminal sets that are invariant is a nontrivial problem. Sum-of-squares methods provide a systematic way of certifying invariance for polynomial systems. A well-known drawback of SOS-based approaches is its *curse of dimensionality*, i.e., the stark increase of complexity for larger number of state variables and/or polynomial order. In that case, diagonally-dominant sum-of-squares (DSOS) might provide a more tractable alternative to SOS.

Problem formulation
Aerospace dynamical systems commonly entail about 6–8 states and require a certain degree of accuracy to represent nonlinear effects. This limits the use of sum-of-squares methods when certifying stability of model-predictive control schemes for nonlinear flight dynamics. This thesis seek to explore NMPC-related guarantees that can be computed using sum-of-squares methods, and solutions for those that cannot.

Tasks
- Literature review of tractable SOS methods for full-envelope flight dynamics
- Characterization of NMPC stability guarantees as sum-of-squares problems
- Implementation of analysis methods via SOS and DSOS (potentially using the existing bisosprob / sosfactory toolboxes)
- Evaluation of complexity, conservativeness, and closed-loop performance

Requirements
Have, or be willing to acquire,
- good understanding of nonlinear system and control theory
- some knowledge of convex and nonconvex optimization

The thesis can be written in German or English. Publication of results is envisaged.

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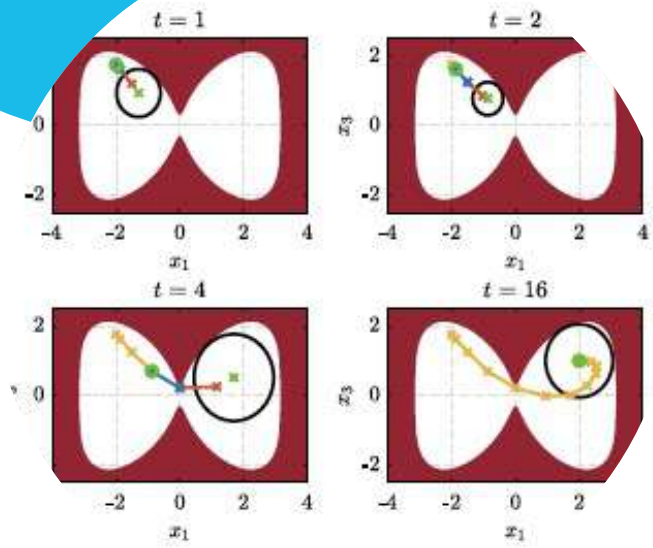

Figure from Cotorruelo *et al.* 2021

Literature

Chakraborty, A., Seiler, P., & Balas, G. J. (2011). Susceptibility of F/A-18 Flight Controllers to the Falling-leaf Mode: Nonlinear Analysis. *Journal of Guidance, Control, and Dynamics*, *34*(2), 73–85. doi: 10.2514/1.50675

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