Open Master Thesis Project

Robust Trajectory Generation based on System Level Parametrization

DESCRIPTION

While the design of robust linear controllers is already a very mature technology, there is very little work that has addressed robust trajectory planning. It is for this reason, that in practise (e.g. aerospace engineering) robust lower level controllers are still combined with non-robust trajectory generation, which can result in significant decreases in the robust performance. The challenge of robust trajectory generation is that uncertainties in the system also make the system trajectory uncertain, such that it is not trivial to optimize over this trajectory. Instead, it is necessary to optimize over the whole closed loop behaviour of a system under a control policy. For this reason, the direct optimization over the closed loop between a controller and a dynamic system shall be investigated in this thesis using the System Level Parameterization.

System Level Parametrization of feedback loops for finite horizon

Consider the (possibly time varying) dynamic system

$$x_{k+1} = \boldsymbol{A}_k x_k + \boldsymbol{B}_k u_k$$

with a finite time horizon N and define the stacked matrices

$$\boldsymbol{A} = \text{blkdiag}(\boldsymbol{A}_0, \cdots, \boldsymbol{A}_{N-1}, 0), \quad \boldsymbol{B} = \text{blkdiag}(\boldsymbol{B}_0, \cdots, \boldsymbol{B}_{N-1}, 0).$$

Consider furthermore a controller represented by a lower triangular Toeplitz matrix $\boldsymbol{K}$. Then the state-response $x^\top = (x_0^\top, x_1^\top, \ldots, x_N^\top)^\top$ to a disturbance $w^\top = (x_0^\top, w_0^\top, \ldots, w_{N-1}^\top)$ satisfies $x = \boldsymbol{Z}(\boldsymbol{A} + \boldsymbol{BK})x + w$, where $\boldsymbol{Z}$ is the downshift operator. Then the system response can be nonlinearly parametrized in terms of $\boldsymbol{K}$ as

$$\begin{pmatrix} x \\ u \end{pmatrix} = \begin{pmatrix} (\boldsymbol{I} - \boldsymbol{Z}(\boldsymbol{A} + \boldsymbol{BK}))^{-1} \\ \boldsymbol{K}(\boldsymbol{I} - \boldsymbol{Z}(\boldsymbol{A} + \boldsymbol{BK}))^{-1} \end{pmatrix} w$$

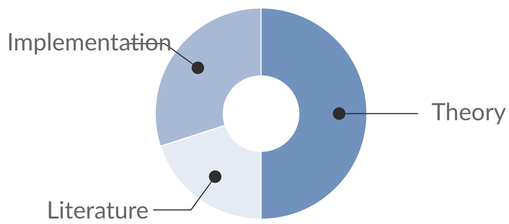
or linearly with a linear constraint using the system level parametrization as follows

$$\begin{pmatrix} x \\ u \end{pmatrix} = \begin{pmatrix} \Phi_x \\ \Phi_u \end{pmatrix} w, \qquad \begin{pmatrix} \boldsymbol{I} - \boldsymbol{ZA} & -\boldsymbol{ZB} \end{pmatrix} \begin{pmatrix} \Phi_x \\ \Phi_u \end{pmatrix} = \boldsymbol{I},$$

where the free parameters Φ_x, Φ_u are lower block triangular and $\boldsymbol{K} = \Phi_u \Phi_x^{-1}$ can be recovered.

Such linear parametrizations of the closed loop between controllers and dynamic systems are a celebrated result from 1976 (Youla parametrization), that has gained new attention in recent years. In this Master thesis, you will apply the system level parametrization to generate robust trajectories for sequentially linearized nonlinear systems.

PROPERTIES



AREA

Robust Control | Trajectory generation

PREREQUISITES

- Robust Control ●●●●○
- Control Theory ●●●●○
- Numerical Mathematics ●●●○○

BEGINNING

any time

CONTACT

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