A gain-scheduling-control technique for mechatronic systems with position-dependent dynamics

Paijmans Bart, Symens Wim
Flanders Mechatronics Technology Center
Celestijnenlaan 300B, 3001 Heverlee
Email: bart.paijmans@fmtc.be

Swevers Jan, Van Brussel Hendrik
Mechanical Engineering Department
Katholieke universiteit Leuven
3001 Heverlee

1 Abstract

This presentation proposes a gain-scheduling-control technique for mechatronic systems with position dependent dynamics. The proposed method fits in the framework of traditional gain scheduling, where several controllers designed for fixed operating points are interpolated to construct a global gain-scheduling controller. A new interpolation approach is proposed starting from an affine interpolation between the poles, zeros and gain of the local controllers as a function of the varying parameter, resulting in a simple affine state-space representation. The presented method is applied on an industrial pick-and-place machine which has position-dependent dynamics. Experimental results show the benefit of the proposed method.

2 Traditional gain scheduling

The main idea of traditional gain scheduling is to break the control design into two parts. First, local linear controllers are designed based on linearizations of the plant for several fixed values of the varying parameter. Second, a global parameter-dependent controller for the system is obtained by interpolating, or scheduling the local controllers.

Modern controller techniques, such as H-infinity algorithms, often result in high-order controllers when they are designed for complex mechatronic systems. Consequently, reliable techniques are required that can interpolate between high-order controllers. Many interpolation methods have been successfully applied by control engineers (e.g.,[1],[2],[3]). These methods are either ad-hoc methods which require a lot of trial and error, or they fail when the order of the system is too high. The method proposed in this paper is a systematic approach that can handle complex systems, because the controller representation is a simple affine state-space form.

3 Interpolation between poles, zeros and gains

The starting point is an interpolation between the discrete-time poles and zeros. Affine functions are proposed that contain a sum of a constant term and one varying term.

The varying term consists of a vector of coefficients multiplied with an analytical function of the scheduling parameter. This is shown in (1) for the vector of varying poles:

\[
\begin{pmatrix}
p_1(l) \\
p_2(l) \\
\vdots \\
p_n(l)
\end{pmatrix} =
\begin{pmatrix}
p_{0,1} \\
p_{0,2} \\
\vdots \\
p_{0,n}
\end{pmatrix} +
\begin{pmatrix}
p_{1,1} \\
p_{1,2} \\
\vdots \\
p_{1,n}
\end{pmatrix} \cdot f_1(l)
\] (1)

with \( p_1 \) till \( p_n \) the poles of the controller, \( p_{0,1} \) till \( p_{0,n} \) and \( p_{1,1} \) till \( p_{1,n} \) the coefficients and \( f_1(l) \) an analytical function of the scheduling parameter \( l \). Similar affine functions have to be made to describe the varying zeros and gain, but containing the same analytical function.

4 Transformation to state-space

The next step is to transform the affine functions of poles, zeros and gains into varying state-space matrices. The resulting state-space matrices (A,B,C,D) each have an affine dependence on \( f_1(l) \) and \( f_2(l) \). This is shown in (2) for the \( A \)-matrix:

\[
A(f_1(l), f_2(l)) = A_0 + f_1(l) \cdot A_1 + f_2(l) \cdot A_2
\] (2)

The proposed transformation is similar to the Matlab implementation of the command \texttt{zp2ss} (zero-pole-to-state-space) that transforms a zero-pole-gain representation of an LTI system into a state-space representation.

References