System Identification for Robust Control of Processes with System Changes

---Application to an Extruder Temperature Control System---

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This study aims at integrating system identification for robust control with process control. We consider linear systems where the parameters normally vary slowly, but which may exhibit sudden and large changes. One example of such a system is an extruder where the parameters vary slowly e.g. due to temperature changes, and where the die sometimes is changed, leading to sudden and large changes. Due to a large number of possible dies, it is infeasible to develop models for all possible system configurations. It is therefore necessary to use system identification to develop models for the various configurations.

In this study, we compare two methods for identifying the system and achieving robust control. The first method utilizes system identification to identify both uncertainty weights and a nominal model in an alternating, iterative manner. For each iteration, a robust controller satisfying a given performance is constructed. Iteration is necessary both to achieve convergence in the alternating calculation of uncertainty weights and nominal model, but also to adapt to a slowly changing system. Each time the system configuration changes (e.g. a new die), this is detected and the iteration is restarted using the last nominal model as initial value. In the second method, system identification and synthesis of the robust controller are performed simultaneously in a non-iterative manner.

Below, we first give a description of the extruder system. Next, we give some more details of the first method for robust control, and finally we detail the second method for robust control.

Extrusion is a well-established method and widely used in the polymer processing industry. An extruder is composed of a large cylinder divided into several temperature zones, with a hopper at one end and a die at the other. Raw polymer is fed into the cylinder from the hopper. To achieve the desired product quality at minimal energy usage, a certain temperature gradient through the extruder is needed when melting the polymer. The melted polymer is transported through the extruder by a screw mechanism, and is pressed through the die and molded into the necessary shape. The extruder sometimes needs die changes to enable the manufacturing of a new product shape. With the recent growth in diversified small-quantity production, the problem with a large number of system changes increases. Because of this large number of possible dies to handle different products, but also because of small and large adjustments to the dies by the manufacturer, it is difficult to develop models for each production case. In this work, we study the use of system identification to reduce the development time for models for the various system configurations.

In the first method, we compute uncertainty weights and nominal model in an alternating sequence. Each iteration consists of computing a search direction followed by a line search. To determine the step length in the line search, we maximize a probability measure which measures the model fit. This computation of search direction and step length is performed for both uncertainty weights and nominal model iteration. When the configuration sensor detects a new die, the existing nominal model is used as initial nominal model for the new iteration, and uncertainty weights are computed. Next, the uncertainty weights are locked, and the nominal model is updated. Each iteration alternates between updating the uncertainty weights, and the nominal model, and in each case a search direction and a step length is computed.

In the second method, the nominal model is calculated from several sets of uncertainty weights which are based on experimental data. These uncertainty weights determine a set of uncertainty bands, and we compute a nominal model within the union of these uncertainty bands. The procedure for determining the nominal model is to optimize some index that measures the model fit. When the nominal model is found, a database of historic data is searched in order to find suitable uncertainty weights. An important aspect of this method is how to include new information in the historic database.

The two methods which are described above, are applied to a disturbance observer with an IMC-like structure in combination with industrial PID controllers. The ultimate goal is to reduce the adjustment time of system parameters on the extruder system.