471a Explicit Real-Time Optimization

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Rising competition, energy prices and environmental demands make it increasingly necessary to operate chemical processes as close to optimality as possible. In order to remain close to optimality in spite of disturbances, two approaches may be considered [1]. The first approach is to obtain optimal operation via conventional real-time optimization. This implies that the optimal setpoints of the controlled variables are computed online and are updated at certain time intervals based on the last available measurements. Setting up, solving and maintaining an RTO system can be a very time-consuming and complex task, as the uncertainty in the model and parameters can have a severe impact and the new setpoints have to be available at a given time instant.

A different approach is to move all considerations and calculations off-line, in order to find self-optimizing control variables (certain measurement combinations). Controlling these variables keeps the process at or close to the optimal operating point in presence of disturbances without the need to re-optimize. Once these variables are obtained and the control structure is set up, the conventional RTO optimization problem can be reduced significantly and may even be completely replaced by the new Explicit-RTO layer.

To the authors knowledge, these optimal measurement invariants have only been considered systematically only for linear plants with quadratic cost functions. This work extends the ideas of self-optimizing control, particularly the concept of the null-space method [2] to systems described by rational functions.

Using polynomial elimination techniques based on Grobner bases it is possible to determine polynomials in the measured variables, which are used as self-optimizing control variables. Keeping these variables constant yields zero loss from optimality for arbitrary large disturbances, as long as the corresponding active set does not change.

The elimination method for non-linear polynomial models makes it not only applicable for small disturbance ranges, where the process can be approximated linearly, but also for large disturbances, when non-linearities are taken into account. As every non-linear process may be approximated by a higher order Taylor series, this method may also be used to find optimal invariants for other processes, described by more general equations.

The method was tested for a model of a four component system in an isothermal CSTR with two reactions, taken from [3]. The process in consideration has three regions defined by the set of active constraints, one unknown reaction rate as a disturbance and four measurements: The two feed flow rates, one outlet concentration and the heat applied to the jacket. Using the Computer Algebra package 'Singular' [4], a polynomial self-optimizing variable is found for each of the regions. E.g. in the first region, where only the applied heat is at a constraint, a polynomial of total degree 4 in the outlet concentration and one feed rate is found. Controlling this variable yields zero loss in the entire region. Moreover in this case-study it is found that the self-optimizing variables of the neighbouring regions can be used for determining the switching point between the active sets. This shows that it is unnecessary to track the NCO for this system by more complicated methods.

Designing a self-optimizing control structure might require more efforts in advance, but is straightforward to implement and to maintain in practice. Once the control structure is obtained and implemented, there is no longer need to invest in expensive real-time equipment in order to obtain optimal operation.

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