REAL-TIME OPTIMIZATION WITHOUT MODEL IDENTIFICATION

Alejandro Marchetti*, Benoît Chachuat*,[1], and Dominique Bonvin*

* Laboratoire d'Automatique, École Polytechnique Fédérale de Lausanne, Station 9, CH-1015 Lausanne, Switzerland.

Throughout the petroleum and chemicals industry, the control and optimization of many large-scale systems is organized in a hierarchical structure. At the real-time optimization level, decisions are made on a time scale of hours to a few days by a so-called real-time optimizer (RTO) that determines the optimal operating point under changing conditions. The RTO is typically a nonlinear program (NLP) minimizing cost or maximizing economic productivity subject to constraints derived from steady-state mass and energy balances, reaction kinetic relationships, thermodynamic equilibrium equations, physical property relationships, and physical equipment constraints [1, 2].

Because mathematical models with high accuracy are unavailable for most industrial applications, RTO classically proceeds by a two-step iterative approach, namely an identification step followed by an optimization step; variants of this two-step approach, such as ISOPE [3], have also been proposed for improving the synergy between the identification and optimization steps. In order to avoid the troublesome task of identifying a model on-line, fixed-model methods can be used. The idea therein is to utilize both the available measurements and a possibly inaccurate model to drive the process towards a desirable operating point: the process model is used for estimating the gradients of the cost and constraint functions, while the measurements are used to correct the constraint and/or cost functions in the RTO problem. In constraint-adaptation schemes [4, 5], for instance, this correction is done by simply offsetting the constraint functions. This way, the iterates are guaranteed to reach a feasible point upon convergence, although substantial sub-optimality may result.

In this presentation, we describe and study two improved fixed-model RTO schemes for reducing the optimality loss induced by inaccurate process models. In the first one, additional correction terms are inserted into the constraint and cost functions of the RTO problem, which are similar to those used in the ISOPE method, so that a KKT point is reached upon convergence of the algorithm [6]. However, their calculation requires that the cost and constraint gradients be estimated from the available measurements (e.g., via finite differences or dynamic perturbations). In the second approach, a static neighboring extremal (NE) controller [7] is embedded into a constraint-adaptation scheme. The role of the NE controller is to correct the constraint and cost gradients calculated from the inaccurate process model, while constraints adaptation ensures feasibility.

We illustrate the performance of the proposed RTO schemes with the case study of a two-stage process that purifies a gas mixture by absorption of its HCl and SO_2 components.

References

[1] T. E. Marlin and A. N. Hrymak. Real-time operations optimization of continuous processes. In *AIChE Symposium Series - CPC-V*, volume 93, pages 156–164, 1997.

[2] R. E. Young. Petroleum refining process control and real-time optimization. *IEEE Contr. Syst. Mag.*, 26(6):73–83, December 2006.

[3] M. A. Brdyś and P. Tatjewski. *Iterative Algorithms for Multilayer Optimizing Control.* Imperial College Press, London, UK, 2005.

[4] J. F. Forbes and T. E. Marlin. Model accuracy for economic optimizing controllers: The bias update case. *Ind. Eng. Chem. Res.*, 33:1919–1929, 1994.

[5] B. Chachuat, A. Marchetti, and D. Bonvin. Process optimization via constraints adaptation. in press: J. Process Contr., 2007.

[6] W. Gao and S. Engell. Iterative set-point optimization of batch chromatography. *Comp. Chem. Eng.*, 29:1401–1409, 2005.

[7] S. Gros. *On the Use of Neighboring Extremals in Optimization and Control.* PhD thesis, École Polytechnique Fédérale de Lausanne, 2007.

[1] corresponding author. Tel: +41 21 693 3844, Fax: +41 21 693 2574, Email: benoit.chachuat@epfl.ch