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NCO tracking and self-optimizing control in the context of real-time optimization

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ABSTRACT

This paper reviews the role of self-optimizing control (SOC) and necessary conditions of optimality tracking (NCO tracking) as presented by [1]. We show that self-optimizing control is not an alternative to NCO tracking for steady state optimization, but is to be seen as complementary. In self-optimizing control, offline calculations are used to determine controlled variables (CVs), which by use of a lower layer feedback controller indirectly keep the process close to the optimum when a disturbance enters the process. Preferably, the setpoints are kept constant, but they may be adjusted by some optimization layer. Good CVs reduce the need for frequent setpoint changes. When selecting self-optimizing CVs, a set of disturbances must be assumed, as unexpected disturbances are not rejected in SOC. On the other hand, the presented NCO tracking procedure adapts the inputs at given sample times without a model or any assumptions on the set of disturbances. However, disturbances with high frequencies or those which do not lead to a steady state are not rejected. By using NCO tracking in the optimization layer and SOC in the lower control layer, we demonstrate that the methods complement each other, with SOC giving fast optimal correction for expected disturbances, while other disturbances are compensated by the model free NCO tracking procedure on a slower time scale.

1. Introduction

Most processes in industrial practice are operated in such a way that the operators set the setpoints for PID controllers that keep the controlled variables (CVs) at the desired setpoint. Which measurements are chosen as CVs is mostly based on process knowledge and best practices. However, due to stronger competition and environmental regulations, it has become increasingly important to operate the processes close to optimality. In many cases, steady state operation accounts for the largest part of the operating cost, and significant economical improvements can be achieved by operating the plant optimally at steady state.

Depending on how this is realized, the methods for achieving optimal process operation generally may be categorized into one of the following three categories:

- Model used online (e.g. real-time optimization (RTO) [2]).
- Model used offline (e.g. self-optimizing control (SOC) [3]).
- Explicit model not used (e.g. NCO tracking [1]).

In all cases, measurements are collected online, with the aim of driving the process towards optimality. In the first approach, online optimization, measurements from the process are used together with a mathematical model in a two step procedure, where first the model and the disturbances are updated, and then the new optimal setpoints are determined by solving an optimization problem online [2].

In the offline approach, expensive online computations are avoided, and optimal operation is achieved by designing a "smart" control structure. This controlled variable (CV) selection procedure's objective is to transform the economic objectives into control objectives [4]. A process model is used to support decision making in control structure design, but it will not be used online. Self-optimizing control [5] belongs into this category.

A third strategy avoids using an explicit process model, but uses measurements to obtain gradient information about the process. This information is used to update the inputs to obtain optimal operation. Necessary conditions of optimality tracking (NCO tracking) as presented in [1] and extremum seeking control [6] represent this category. This idea is relatively old [7], but has recently gained increased attention.

These approaches to achieve steady state optimal operation have been developed by research groups with different backgrounds for different kinds of problems. The authors feel that there has been some confusion about the use, interplay, applicability and practicability of some of the concepts.

Our paper is structured as follows: The next three sections briefly describe the setting and the ideas from self-optimizing control and NCO tracking. In particular, this work focuses on the null space method as described in [8], which uses a model offline, and

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