EXTENDED ABSTRACT
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Continuous-time Parameter Identification Using PI Controllers

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Abstract: For several decades, PID (Proportional-Integral-Derivative) control has succesfully been applied to numerous process control tasks to regulate processes. The PID controller has indisputably become a backbone of every automation system making itself available practically everywhere for controlling industrial processes. However, it has also other capabilities than just that for regulating processes by manipulating actuators. A PI controller can be designed to identify continous-time parameters for a given process model using process data. This paper proposes a PI controller -based identification method for identifying parameters of simple continous-time process models. The method is presented and simulation examples are shown to address its applicability for identification problems.

Keywords: PID control, identification, continuous-time.

1. INTRODUCTION

For numerical applicability and simplicity, most of the available system and parameter identification methods known in literature are given in discrete-time domain. The parametric models can be characterised in different ways depending on the model structures and chosen inputs and outputs. There are several rather thorough references on system identification such as the books by Söderström and Stoica (1989) and Ljung (1999).

Later, there has been active research on developing identification methods for continuous-time systems by Young (2002) and a bit earlier by Garnier and Mensler (2000) which was later updated by Garnier et. all (2006). A couple of years later, the methods and numerical routines were collected in the book by Garnier and Hugues (2008). However, several other transient-based or numerically simple methods had been developed and reported earlier e.g by Chen (1989) and Åström and Hägglund (1995).

PID controllers has a fundamental position in process control. It has spread basically everywhere as a relatively simple numerical routine to be implemented. Consequently, it is available practically in every automation system to be applied and adopted to various and, sometimes rather different, practical targets. It is a bread-and-butter tool and a true workhorse for every control design engnineer.

Both Åström (2000) and Visioli (2012) have published articles where they have considered the future of PID control and presented their views on the future trends of PID control research. It is quite interesting to see that in these publications, a PID controller is solely considered as a processs controller without considering any other functions that PID controllers might have. Vilanova and Visioli (2012) has neither expanded this control-oriented view in their latest, rather elaborate, book on PID control.

In addition to its control usage, a PI controller can be used as a workhorse for identifying continous-time system parameters. The basic idea on how to use a PI controller for model parameter estimation has been given in Friman and Airikka (2012). In their publication, the PI controller was streched to work as a numerical routine for providing model parameters for a dynamic simulator the models of which are being updated by real process data using PI controllers executed parallel to a DCS system.

The PI controller has an interesting resemblance with a common recursive parameter estimation formula where a previous parameter estimate is updated using an estimation error amplified by a estimator gain. This observation gives rise to a belief that maybe a PI controller can be used for system identification. The idea simply is to to feed the identification function subject to minimisation to a PI controller that provides a new parameter estimate for the given identification problem at each execution cycle. Then, the process model is updated by the parameter estimate to generate a new process model output for the next execution cycle. Finally, the parameter estimate converges if certain assumptions hold.

Figure 1 illustrates the concept of using a PI controller for parameter identification. The real process measurements (input u and output y) are taken at each identification execution cycle to a system model block. The continous-time system model block generates an estimated process output $\hat{y}$ using the given updated process data and the latest model parameter estimate θ. The modelling error (residual) $e = y - \hat{y}$ is taken to a cost function block that calculates the identification cost function J based on the residual e. Given a zero setpoint ($r = 0$) and the cost function value J as a measurement ($y_{PI} = J$), the PI controller yields an output which is the new model parameter estimate. The updated estimate is taken to the system model to produce a new model output for the next execution cycle.

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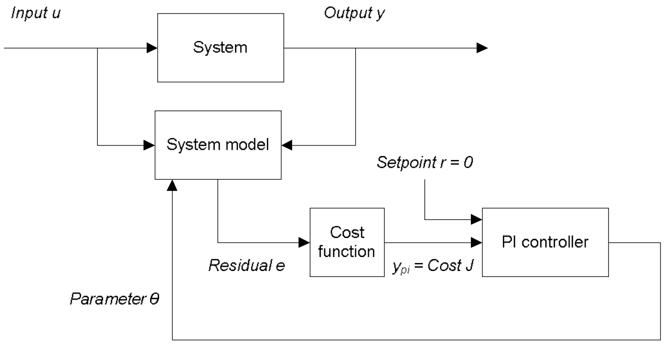

Figure 1. Principle of using PI controller for SISO (Single-Input-Single-Output) system model parameter identification.

As in PID control design, one PI controller can manipulate only one variable. The same applies to identification as illustrated in figure 1. However, there are ways to bypass this rescriction for allowing simultaneous identification of more than one parameter at a time. At its simpliest, the cost function block can be ignored or treated as a unit amplifier being only a bypass gate with $y_{pi} = e$. In that case, the PI controller receives a model residual itself as a measurement for regulating the system model parameter θ.

There are many things to be considered when designing PI controllers for system identification. Some of them are of general nature and, therefore, apply to any system identification method. For example, these common design issues are selection of model type to be fitted into process data, selection of model order, process data filtering and process excitation to allow sufficiently rich process data for identification. However, there are certain method-specific issues that need to be addressed and, therefore, they are treated in this paper in more details.

This paper gives proposes some cost function types to be used and discusses the selection of periodic execution cycle for the PI controller. In addition, PI controller tuning is considered to allow sufficiently fast convergence for identification. Selection of appropriate control impact direction (positive vs. negative) is essential and also initialisation of system parameter estimates is required. The discussed models for the presented PI controller –based identification method are Single-Input Single-Output models but they may have additional external disturbances that are measurable.

The paper gives the background behind the method making also comparison to a common recursive parameter estimation method. The assumptions with the constraints of the method are addressed and the basic design guidelines are given. The method is enlightened through a few simulation examples.

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