Relay Auto-tuners in Modelica

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Auto-tuning is the idea of obtaining suitable parameters concerning a PID controller automatically. The most common controller in industry today is the PID controller. By tuning its parameters properly it can solve control problems of various kind. This implies that the tuning part is crucial considering the design. Due to the fact that finding suitable parameters can be difficult, a tool for solving it automatically is of great interest. During the thesis work [3], an auto-tuner has been implemented in the modelling language Modelica in purpose of investigating its possibilities as a tool in a simulation environment.

Background

If choosing appropriate parameters, a PID controller is able to perform satisfactory results within several areas. Auto-tuners simplify the part of the control design considering the tuning. Since it has been successful in industry an interesting approach would be to investigate the performance in a simulation environment. If it proves to work properly even here there are large opportunities for further developments. This thesis [3] describes the implementation and evaluation of an auto-tuner in the modeling language Modelica.

Because auto-tuners have been developed during many decades there is a number of different structures to chose from. The aim with this thesis is to investigate one specific variant, presented in [2], the asymmetric relay auto-tuner.

In order to challenge its usefulness it is tested within different areas, where the complexity varies. For instance, the number of control loops in a model can differ. Does the number have an impact? Is the auto-tuner able to generate good parameters even if it is used in several loops during the same simulation?

Method

The experiment, performed by the auto-tuner, works sequentially and the goal in the end is to estimate a low order model describing the process. A typical example of an experiment is given in Figure 1. The relay makes the process oscillate and after a while the oscillation has reached a limit cycle. First when a limit cycle has been reached it is possible to obtain a low order model.

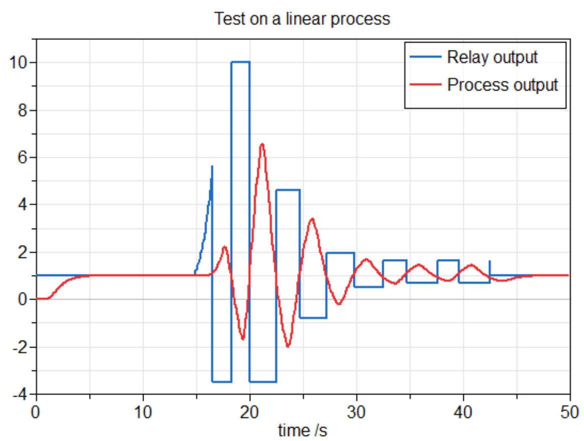

Figure 1: *The figure shows a walk through an experiment. The blue line is the relay output and the red line is the process output.*

A process might be of high order and tuning rules are often related to a low order model. The asymmetric relay auto-tuner brings forth a low order model, suitable for a certain tuning rule. The model is either a so called FOTD model (First order time delay model) or an ITD model (integrated time delay model) as represented with the parametrization given in equations (1) and (2). Which model that is chosen depends on the parameter τ, also called the normalized time delay. That parameter is related to the curvature of the process output during relay control. The normalized value is between 0 and 1. A low value on τ indicates that an ITD model is the best choice otherwise an FOTD model is the best choice to estimate the process with [2].

$$P(s) = \frac{K_p}{sT+1}e^{-Ls} \quad (1)$$

$$P(s) = \frac{k_v}{s}e^{-Ls} \quad (2)$$

Based on the estimated models in (1) and (2) PID parameters can be derived. Choice of tuning rule has in this thesis been AMIGO [1]. However if one wish to use another rule because of a certain specification, that is possible since the auto-tuner generates information on the estimated model as well as PID parameters.

Conclusions

The results do confirm the potential of auto-tuners when working in a simulation environment. Since the auto-tuner only has been tested against already existing models one should be aware of that it probably won't work flawless in general. Improvements are most likely accomplished if it is developed further.

Considering the control performance it has been proven that parameters generated by the implemented auto-tuner performs better in comparison to other variants, including the ones being used today. In Figures 2 and 3 results regarding one of the processes are shown, both in terms of control performance and control signal.

Three processes were used during the evaluation. One of them contained three control loops. Parameters regarding the different controllers in that model were obtained by introducing the auto-tuner in two ways. Firstly it was done in one of the loops at the time, secondly in all the three. The two parameter set-ups resulted in more or less similar control behavior, although the first variant came with little advantage in some cases.

To summarize things it is clear that the auto-tuner can be a helpful tool not only in industry but also in a simulation environment.

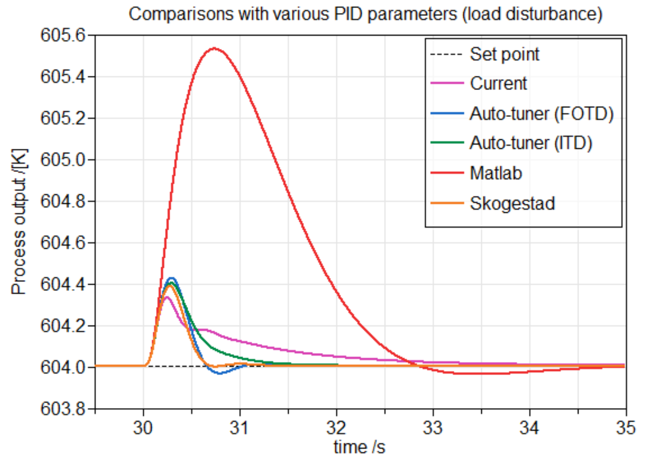

Figure 2: *Shows the response to a constant load disturbance.*

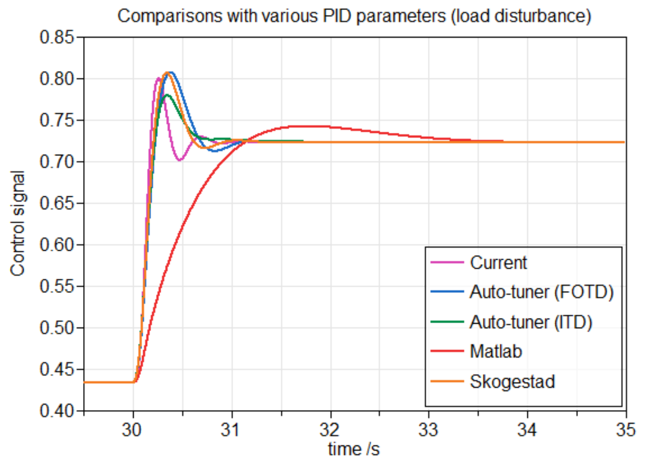

Figure 3: *Shows the control signal when a constant load disturbance is applied.*

References

[1] K. J. Åström and T. Hägglund. *Advanced PID Control*. pp. 64-69, 73, 76-78, 159-163, 186-189, 225-241. ISA - The Instrumentation, Systems and Automation Society, 2006.

[2] J. Berner. *Automatic Tuning of PID Controllers based on Asymmetric Relay Feedback'*. Licentiate Thesis, SwePub, EBSCOhost, viewed 8 February 2017. 2015.

[3] M. Björk and R. Levenhammar. *Relay Autotuners in Modelica*. Master's Thesis, Department of Automatic Control, LTH, Lund University. 2017.