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A Novel Toolbox for Automatic Design of Fractional Order PI Controllers based on Automatic System Identification from Step Response Data

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Abstract: A novel toolbox for non-experienced users is developed and presented in this paper. The toolbox produces fractional order (FO) controllers to be implemented on various processes. To design the controller, the toolbox requires solely a step response data, experimentally obtained on the process. Based on this data, an automatic system identification algorithm is used that models the process as a second order plus dead-time (SOPDT) transfer function. Then, a FO controller is designed using the previously estimated model parameters and according to performance specifications, such as gain crossover frequency, phase margin and maximization of the gain margin. Several experimental step response data are used and several FO controllers are designed for different processes. The results validate the toolbox.

Keywords: automatic system identification, automatic design of fractional order controllers, experimental results, vertical take-off and landing

1. Introduction

Most of the times accurate modeling implies an increased complexity of the model. However, for a large range of processes simple SOPDT models provide sufficient accuracy and are easily used in the controller design procedure. To determine such a model, the engineer needs knowledge regarding system identification methods. An alternative approach, based on automatic system identification, has been developed and presented in [1]. The approach does not require any system identification expertise. The only process information required from the user is a set of step response data. The current manuscript presents a toolbox that uses an improved version of the algorithm in [1], along with an additional feature for the automatic design of a FO controller. The parameters of this controller are determined by imposing a set of performance specifications and using the model parameters as returned by the automatic system identification algorithm.

The method presented in this paper uses step response data to estimate SOPDT models:

$$G(s) = \frac{K}{(\tau_1 s+1)(\tau_2 s+1)} e^{-\tau_d s} \quad (1)$$

where τ_d is the process dead-time, K is the proces gain, τ_1 and τ_2 are the time constants. The automatic system identification algorithm is based on step response data, possibly corrupted. Numerical integration and computation of areas in the experimental step response data leads to an efficient and simple estimation of the model parameters. Once the model has been determined an indirect autotuning method is used to design a fractional order PI (FO-PI) controller:

$$C(s) = k_p\left(1 + \frac{k_i}{s^\lambda}\right) \quad (2)$$

where k_p and k_i are the proportional and integral gains and $\lambda \in (0,2)$ is the fractional order. The analytical equations for computing the k_p and k_i parameters as a function of $\lambda, \tau_1, \tau_2, \tau_d$ and K are determined such that certain gain crossover frequency ω_c and phase margin PM are obtained. The final controller parameters are selected such as the gain margin is maximized.

2. Results and Discussion

To validate the proposed method several experimental step response data are used, including that for a challenging Vertical Take-Off and Landing (VTOL) unit. The experimental unit is described in [2]. A step signal of 6.3V has been supplied to the VTOL unit and the resulting output signal was used to determine an accurate model as in (1). To tune the controller parameters, ω_c=0.4rad/s and PM=75° are imposed. The resulting FO-PI controller was then implemented on the actual unit and the experimental results are provided in Fig. 1. Disturbance rejection tests, as well as robustness tests will be carried out for the final manuscript.

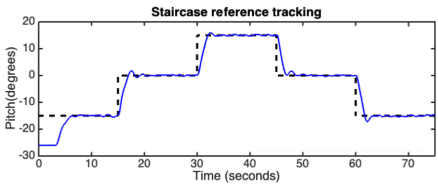

Fig. 1. Experimental results obtained on the VTOL unit using the proposed toolbox

3. Concluding Remarks

In this paper, a first toolbox combining automatic system identification and fractional order controller design is presented. The algorithm behind the SOPDT automatic system identification method is described. Then, the automatic design for a fractional order controller is developed. Several experimental examples, from a wide range of processes are provided to validate the proposed methods and the utility of the toolbox and its user interface.

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References

[1] DE KEYSER, R., MURESAN, C.I.: Robust Estimation of a SOPDT Model from Highly Corrupted Step Response Data. *European Control Conference* 2019, **1**: 818-823

[2] MURESAN CI, BIRS IR, DULF EH: Event-Based Implementation of Fractional Order IMC Controllers for Simple FOPDT Processes. *Mathematics* 2020, **8**(8): 1378