Robust Fractional Order Gain-Scheduled Control Design for LPV Systems using an Adaptive Switching Law

Safia Kissoum[1], Samir Ladaci[2*], Abdelfath Charef[3]

[1]Department of E.E.A. National Polytechnic School of Constantine, Constantine, Algeria

[2]Department of Automatics, Ecole Nationale Polytechnique, Elharrach, Algiers, Algeria

[3]Department of Electronics, Mentouri Brothers University, Constantine, Algeria

*Corresponding author's e-mail: safo.kissoum@gmail.com

ABSTRACT

This paper presents a robust adaptive control structure design based on gain scheduled control. The proposed control configuration uses a set of switching predefined PID controllers to deal with fractional order linear parameter varying (LPV) systems. The switching law is based only on the models' outputs. A class of fractional second-order like systems is considered. Simulation example results and discussion illustrate the efficiency of the proposed method.

Keywords: LPV system, Gain scheduled control, Fractional order system

1 Introduction

Recently, fractional order systems have had a great impact on the engineering research community. The main motivation is their ability to improve both the performance and the robustness of the resulting models, especially in the control domain [1]- [3].

The main objective of this research is to propose a generalization of the robust gain scheduled linear parameter varying (LPV) PID controller [4], [5] to a class of fractional second-order LPV systems, considering robust stability, performances, closed-loop pole constraints and particularly the time varying nature of the plant. The measurement (estimation) of the varying parameter is obtained in real-time and used to adjust PID parameters.

The LPV PID controller design should be considered as an output feedback control that is usually used with LMI's to solve a non-convex optimization problem [6], [7]. However, in regard of the special configuration of the considered plant model (second order), the idea here is to tune the PID controllers and reformulate it as a convex state-feedback problem. After that, a coupled two-tanks second order system was will be subject of the proposed LPV-based control approach.

2 LPV control problem statement

$$G_{LPV_{ref}}(s) = \frac{1.1081\varphi_1}{s^2+0.5085(\varphi_1+\varphi_2)s+0.2585\varphi_1\varphi_2} \tag{1}$$

$$G_{\varphi}(s) = \frac{1.1081\varphi_1}{(s^2+0.5085(\varphi_1+\varphi_2)s+0.2585\varphi_1\varphi_2)^{\mu}} \tag{2}$$

Where μ is a real number such that $0 <\mu<1$.They are approximated by low order transfer functions using the singularity method of Charef [6]. Given the LPV system in Eq. (1) or the fractional order LPV system (2), find a gain scheduling PID controller that guarantees the stability and the high performances of 2nd order integer and fractional system.

3 Simulation example and discussion

A coupled two-tanks is the case study illustrating the proposed LPV PID design scheme. A coupled two-tanks is the case study illustrating the proposed LPV PID design scheme. In order to obtain the fractional model, we approximate the system represented in (2) by a 4th or 5th order transfer function using the

DOI: 10.21467/abstracts.163 ISBN: 978-81-965621-5-1 (eBook)

singularity method [6] and then the gains scheduling approach is applied to this system. The fractional order μ is chosen equal to: μ = 0,6. by computing the LPV PID controller gains with PID Toolbox in MATLAB, we obtain the closed-loop responses shown in Figure 1.

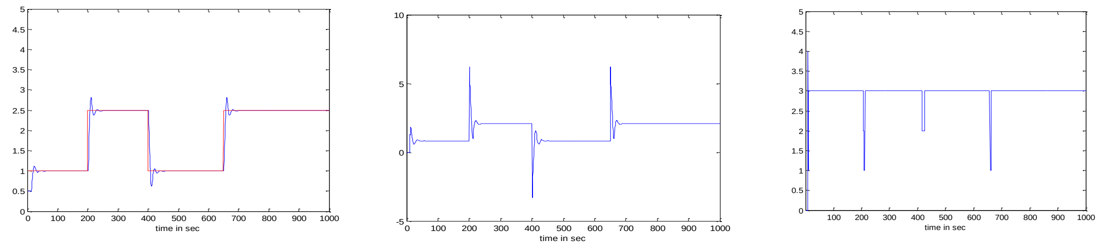

Figure 1: *Fractional order system response: (a) Output signal (b) Control signal (c) Switching index*

A very important advantage of the proposed fractional order model based controller is the elimination of the chattering phenomena and the high values of the control signals.

4 Conclusion

The main contribution of this paper is to propose an innovative approach to design a gain-scheduled PID for fractional order LPV systems, using an improved switching law based on the plant output. The fractional PID controller design can be viewed as a state-feedback controller. This approach has successfully been applied to a real case study based on the control of a two coupled-tanks with satisfactory performance results giving supplementary benefits: chattering elimination and lowering the amplitude of the control signals.

5 Competing Interests

The authors declared that no conflict of interest exists in this work.

How to Cite

S. Kissoum, S. Ladaci, A. Charef, "Robust Fractional Order Gain-Scheduled Control Design for LPV Systems using an Adaptive Switching Law", *AIJR Abstracts*, pp. 26–27, Feb. 2024.

References

[1] S. Djebbri , S. Ladaci, A. Metatla, H. Balaska, "Fractional-order model reference adaptive control of a multi-source renewable energy system with coupled DC/DC converters power compensation", Energy Systems, 1-41, 2018.

[2] Ladaci, S., Charef, A.: Fractional order adaptive control systems: a survey. In:Mitchell, E.W.,Murray, S.R. (eds.) Classification and Application of Fractals, pp. 261–275. USA: Nova Science Publishers 2012.

[3] T. Seghiri, S. Ladaci, S. Haddad: Fractional order adaptive MRAC controller design for high-accuracy position control of an industrial robot arm. Int. J. Advanced Mechatronic Systems, vol. 10, no. 1, pp. 8-20, 2023.

[4] L. Giarre, D. Bauso, P. Falugi, and B. Bamieh, LPV model scheduling identification for gain control: An application to rotating stall and surge control problem", Control Engineering Practice, vol. 14, no. 4, pp. 351-361, 2006.

[5] S. Zhang; J. J. Yang; and G.G. Zhu, "LPV gainscheduling control of an electronic throttle with experimental validation", 2014 American Control Conference, Portland, OR, USA, 4-6 June 2014.

[6] S. Ladaci, and A. Charef, "On Fractional Adaptive Control," Nonlinear Dynamics, vol. 43, no. 4, pp. 365-378, 2006.

[7] S. Kissoum, S. Ladaci, A. Charef, Smith Predictor PID-Based Robust Adaptive Gain-Scheduled Control for a Class of Fractional Order LPV Systems with Time Delays. International Journal of Dynamics and Control. 11: 3096–3108, 2023.

ISBN: 978-81-965621-5-1

Series: AIJR Abstracts
DOI: 10.21467/abstracts.163