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Predictive functional control with reduced-order observer based PSO for pneumatic positioning control

A.R. Azira[1], Khairuddin Osman[1,*], Siti Fatimah Sulaiman[1,2], S.I. Samsudin[1], Amar Faiz Zainal Abidin[3]

[1)] Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka,Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Faculty of Electrical Engineering, Universiti Teknologi Malaysia,81310 UTM Johor Bahru, Johor Bahru, Malaysia
[3)] Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka,Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: khairuddin.osman@utem.edu.my

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ABSTRACT – The employment of Particle Swarm Optimization (PSO) algorithm in determining the best value of parameter alpha (Ψ) for Predictive Functional Control (PFC) used in pneumatic system was proposed in this study. A reduced-order observer was used together with PFC to estimate the internal states of pneumatic system. The performance of Predictive Functional Control with Reduced-order Observer (PFCRO) with and without employment of PSO were compared. The validation was done in simulation and experiment using MATLAB/Simulink. The results revealed that PFCRO using PSO gave better response in controlling the pneumatic positioning system compared to PFCRO without using PSO.

1. INTRODUCTION

Nowadays, most of the researchers focused on pneumatic actuator because of their advantages such as lightweight, low cost, easier maintenances and etc. However due to difficulties to control the position the researchers was conducted an experimental investigation to explore the best solution on this issues. This research was focused on the optimization techniques that were applied in the PFC in pneumatic systems. There are many types of optimization technique available [1]. One particular related literatures is a literature that implemented PSO and GA to tune the Fuzzy Logic Controller and applied to active suspension system [2]. The result shows that performance of PSO is better than GA because of converges to a maximum fitness value take a lesser time. In another literatures, the researcher tested two types algorithms which are PSO and FA with PI controller [3] applied in industrial system. The result shows that PSO give better performance than FA in term of control performance indicator. In 2010 the researcher have designed PFC with full-order observer [4]. The value of alpha are stated by the researcher by following fixed linear feedback law. Based on this researcher the PFC was developed with reduced-order observer (PFCRO) and after takes some consideration on both study in PSO performances PSO algorithm was selected in paper to tuning the value of alpha parameter in PFC because of its simplicity in implementation, performance and popularity in engineering applications. PSO used to find the best value of the alpha parameter that involved in the PFCRO.

2. METHODOLOGY

This study used liner double-acting type and new Intelligent Pneumatic Actuator (IPA) was developed by Ahmad 'Athif Mohd Faudzi [5]. Figure 1 shows five main components of IPA system which are; Laser stripe code with position accuracy of 0.169 mm and position accuracy of 0.01 mm and the actuator is 200 mm stroke and also can deliver maximum force up to 120 N, KOGANEI- ZMAIR optical sensor was used capable to detect smaller pitch of 0.01 mm, Pressure Sensor was used to check the pressure in chamber during performing the control action of cylinder, Valve represent as Pulse-Width Modular (PWM) signal will control the inlet and outlet air of the cylinder and Programmable System on Chip (PSoC) microcontroller act as brain to control system and to performs local control to suit the requirements or any related applications.

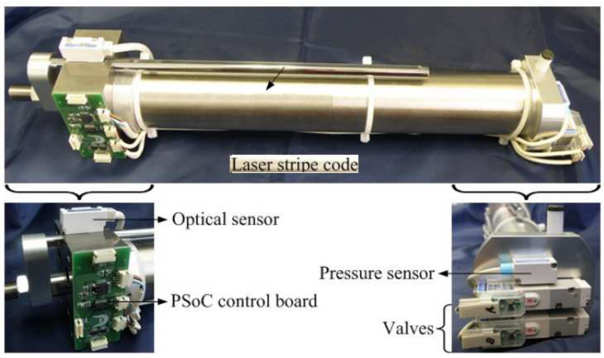

Figure 1 IPA system

The controllers and optimization method are designed using MATLAB/Simulink platform from position transfer function obtained by System Identification (SI) technique. 2000 measurements consist of input and output data with 0.01s sampling time was used for this purpose. The following third-order auto-regressive with exogenous input (ARX) model in the form of discrete-time open-loop transfer function was obtained as presented in Equation (1).

$$\frac{Bp(z^{-1})}{Ap(z^{-1})} = \frac{0.001269z^{-1} + 0.0004517z^{-2} - 0.0003498z^{-3}}{1 - 1.932z^{-1} + 1.09z^{-2} - 0.1577z^{-3}} \quad (1)$$

As previous study [4] PFC control law will be implement with reference trajectory equation. This law will be placing desired closed-loop dynamic into reference trajectory. Where *i* is value of *n, yk* is the most recent measured output and $\Psi(0 < \Psi < 1)$ is scalar time constant and a tuning parameter setting the desired closed-loop poles. Equation (2) is a predictive essence control strategy and must deal with set of coincidence points. The coincidence points have procedure to select the value of time constant, Ψ. The procedure start with choose the desired time constant, Ψ then find the associated control law for each n which gives closed-loop dynamic closet the chosen Ψ, then simulate the proposed law. Else reselect the time constant, Ψ and follow the step.

$$wk + i/k = rk - (rk - yk)\Psi i \quad (2)$$

To overcome this parameter tuning problem, Particle Swarm Optimization (PSO) algorithm will be implemented in this study.

PSO algorithm based on swarm behavior was developed in 1995 by Kennedy and Eberhart [6]. The proposed model of PSO for the application of Predictive Functional Control and Reduced-order Observer for Pneumatic Positioning System is as in Equation (3).

$$x_i(t) = \alpha \quad (3)$$

where x represents agent position in the search space, i is the agent identification, and t represents the iteration number. It can be seen that PSO is used to tune single parameter, α which is time constant, Ψ.

PSO will select the best of value of alpha, Ψ according to these priorities:

Priority 1: Sum of absolute error
Priority 2: Overshoot
Priority 3: Settling time
Priority 4: Rise time

3. RESULTS AND DISCUSSION

Table 1 tabulated the results of PFCRO with and without PSO from simulation (Sim) and experiment (Exp). The value of alpha, Ψ selected by PSO give less e_{ss} compared to e_{ss} that alpha value are manual selected even though in simulation both give 0% overshoot. T_s using PSO more faster compared to T_s without PSO. Where T_r in Sim with PSO give better performance than without PSO, but in Exp T_r without PSO gives better performance than with PSO. This is because of performance selected by PSO depending on priority explained in section 2.

Table 1 Result for PFCRO with and without PSO

Strategy	**PFCRO with PSO**		**PFCRO without PSO**	
Alpha,	**0.9023**		**0.9000**	
Performance	**Sim**	**Exp**	**Sim**	**Exp**
(mm)	0	0.1300	0	0.4500
(%)	0	0	0	0
(s)	0.7638	0.9228	0.8166	0.9455
(s)	0.5040	0.6633	0.5665	0.6568

Figure 2 and Figure 3 shows the simulation and experimental results of PFCRO with PSO.

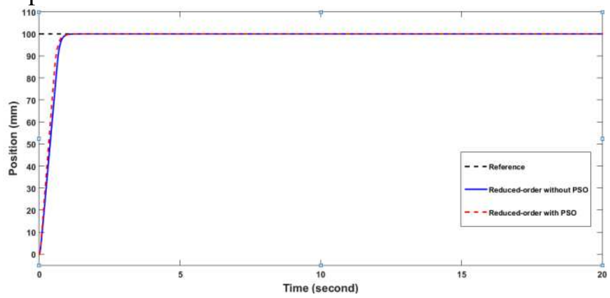

Figure 2 Simulation

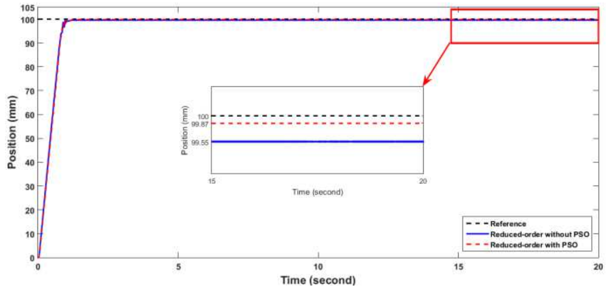

Figure 3 Real-time experiment

The graph clearly shows that values that selected by PSO are given better performance than PFCRO without PSO.

4. CONCLUSIONS

In conclusion, the performance of pneumatic positioning system controlled by PFCRO with PSO gave improved transient response compared to PFCRO without using PSO (manual tuning).

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REFERENCES

[1] S. S. Rao, *Engineering Optimization*. 2009.

[2] K. Rajeswari and P. Lakshmi, "PSO optimized fuzzy logic controller for active suspension system," *Proc. - 2nd Int. Conf. Adv. Recent Technol. Commun. Comput. ARTCom 2010*, pp. 278–283, 2010.

[3] K. Osman *et al.*, "Proportional-Integrative Controller Design of Pneumatic System Using Particle Swarm Optimization," 2013.

[4] K. Osman, A. 'Athif Mohd Faudzi, M. F. Rahmat, N. D. Mustafa, and K. Suzumori, "Predictive Functional Controller design for pneumatic actuator with stiffness characteristic," *Proc. 2013 IEEE/SICE Int. Symp. Syst. Integr.*, pp. 641–646, 2013.

[5] A. À. M. Faudzi, K. Suzumori, and S. Wakimoto, "Development of Pneumatic Actuated Seating System to aid chair design," *IEEE/ASME Int. Conf. Adv. Intell. Mechatronics, AIM*, pp. 1035–1040, 2010.

[6] R. Poli, J. Kennedy, and T. Blackwell, "Particle swarm optimization," *Swarm Intell.*, vol. 1, no. 1, pp. 33–57, 2007.