Point-to-point positioning tracking with optimized robust controller

Chong Chee Soon, Rozaimi Ghazali*, Shin Horng Chong, Chai Mau Shern

Centre for Robotics and Industrial Automation (CeRIA), Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: rozaimi.ghazali@utem.edu.my

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ABSTRACT – Precise motion is essential in the positioning control of the electrohydraulic actuator (EHA) system, especially in the automotive industry that involves manufacturing or fabrication processes. This paper presents the design of different control approaches which playing vital roles in the positioning tracking of the EHA system. Firstly, the conventional proportional-integral-derivative (PID) controller is designed, followed by the presentation of an improved PID controller called as fractional order PID (FO-PID) controller. Then the prominent robust controller, named sliding mode controller (SMC) is designed. Referring to the end results, the SMC has achieved the improvement of 24.43% compared to the PID controller.

1. INTRODUCTION

It is a fact that the precision is crucial in the positioning control of the electrohydraulic actuator (EHA) system, especially in the automotive industry that involves manufacturing or fabrication processes. When the precision factor is involved in a manufacturing process, the controller is vital particularly dealing with the EHA system that has a major uncertain condition in a practical system. The major uncertain condition, which is hard to be modelled and exists in the EHA system, including actuator friction, mechanism leakages, the compressibility of the fluid, and nonlinear pressure characteristics. These problems consequently increase the difficulties during the controller design, which simultaneously motivate academia and researchers to further examine and design a powerful controller that is able to overcome these problems before applied to the potential industrial applications.

A famous controller that is always applied in the industrial applications, known as proportional-integral-derivative (PID) controller is always the favourite choice for academia and researchers to studying and modified this controller with the integration of various kind of methods, including the modification of the structure in this controller, for instance the Fractional Order PID (FO-PID) controller that is proven to be more effective compared with the conventional PID controller [1].

Recently, increasing studies with respect to the integration of the computational tuning methods into the controller design have been proposed. With the integration of the computational tuning method, the prominent robust nonlinear controller, which is the sliding mode controller (SMC) is proven to be outperformed than the SMC with no proper tuning technique in the acquirement of the controller's gains [2].

In this paper, in order to produce a more insightful view of the performance and the capabilities of the controller, three different types of control approaches are presented and compared. The favourite controller in the industry field, which is the proportional-integral-derivative (PID) controller is first introduced. Follow by the improved PID controller, named Fractional Order (FO-PID) controller is designed. Then, the prominent robust controller in the control field called a sliding mode controller (SMC) is established. Instead of obtaining the controller's parameters without any appropriate technique, the well-known tuning technique in computer science, named particle swarm optimization (PSO) is utilized.

2. EXCEPTION

As the modelling of the EHA system has been well developed in the past, the discussion regarding the development of the EHA system and the PID controller will be excepted in this paper. The study of the SMC is conducted in the previous paper [3], and this paper will be focused on the brief discussion related to the concept of the fractional order, implemented in the PID controller.

2.1 Fractional Order PID Controller

Instead of the conventional PID controller, which is well-known in the control system that contains three parameters, two additional parameters which are the integrating order, λ and the derivative order, μ have been integrated into the integral and derivative gains of the PID controller. Commonly, the transfer function of the conventional PID controller is obtained as in Equation (1).

$$G(s) = \frac{U(s)}{E(s)} = K_p\left(1 + \frac{1}{T_i s} + T_d s\right) \qquad (1)$$

where K_p is the proportional gain, T_i is the Integral gain time in constant time, and T_d is the derivative gain in constant time. While the additional order that integrated to the FO-PID controller yields the transfer function as in Equation (2).

$$G(s) = \frac{U(s)}{E(s)} = K_p\left(1 + \frac{1}{T_i s^{\lambda}} + T_d s^{\mu}\right) \qquad (2)$$

where the order λ and μ are not necessarily the integer number. If the order λ and μ are assumed to be 1, the conventional PID controller is formed.

3. CONTROLLER'S PERFORMANCES

The controller is useful in dealing with the system with major uncertainties and disturbances such as EHA system. To overcome the existing drawback of the system, the designed controller might reduce the actual required elements, for example, the voltage or power that generates torque to actuate the load or the application.

Therefore, in this paper, three different controllers have been designed and evaluated. Each controller has their own strength and weakness and performed differently as illustrated in Figure 1.

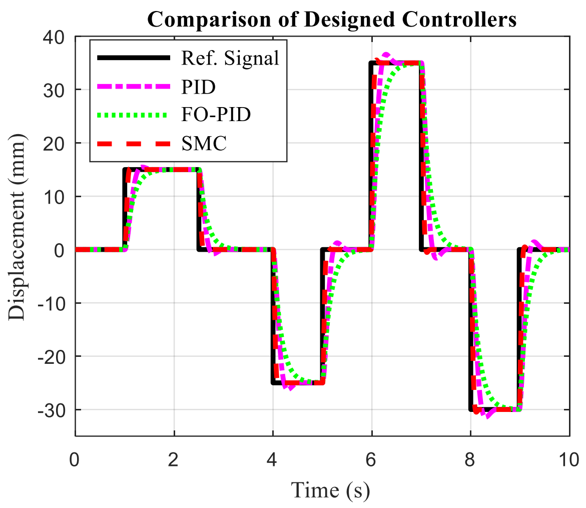

Figure 1 The performance produced by each controller.

Based on the performance demonstrated by these controllers, the error signal which is the different between the actual output with the desired output generated by these controllers is demonstrated in Figure 2.

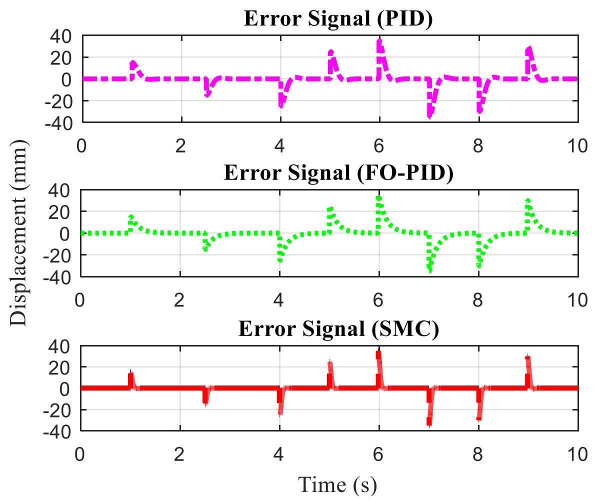

Figure 2 The error signals for PID, FOPID, and SMC.

Based on the numerical data as tabulated in Table 1, the SMC demonstrated the capabilities in providing the smallest error in the control of the positioning tracking.

Instead of using the conventional tuning techniques, the PSO computational tuning technique, which is very time saving and convenient has been used to acquire the controller's gains as listed in Table 2.

Table 1 Error obtained through each controller.

Controller	Root Mean Square Error
PID	14.8388
FO-PID	14.8085
SMC	11.2139

Table 2 Parameters of PSO tuning method.

Controller	Parameter				
	K_p	K_i	K_d	λ	δ
PID	10.0910	0.0013	-4.6985	1	1
FO-PID	34.8991	0.7052	8.5401	2.0296	8.1205
SMC	λ			θ	
	51.6241			358.7009	

4. CONCLUSION

The comprehensive study of the complex controller design is required which usually produces a satisfactory outcome especially dealing with the system that is complex with uncertainties such as EHA system. When it's come to the industrial field, the PID controller is usually used, which is much easier and simple to be designed. Depends on the required outcome, if the high precision result is required, the PID controller might be unable to achieve the required objective. This paper intends to assess the performance of the common use PID controller, the improved PID controller named fractional order PID controller, and also the SMC controller applied to the EHA system. It is observed from the result, the SMC is outperformed in the positioning tracking although the FO-PID controller is able to perform better than the conventional PID controller.

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