Proceedings of Symposium on Electrical, Mechatronics and Applied Science 2018 (SEMA'18), pp. 19-20, 8 November 2018

# Comparison Study for the PID Parameters Selection Method

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

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

**Keywords**: Parameter Selection; Ziegler-Nichols; Priority-based Fitness Scheme

**ABSTRACT** – Proportional-Integral-Derivative (PID) controller is the most popular and widely used controller in the industry. This is mainly because of its simplicity in the design process. However, there are three controller parameters need to be assigned in PID controller, often called this process as the parameters selection process. In this paper, a comparison study for the PID parameters selection process will be conducted among Ziegler-Nichols (ZN) method, conventional Particle Swarm Optimization (PSO) and Priority-based Fitness Particle Swarm Optimization (PFPSO) techniques. Results show that the PID performed better when the three controller parameters are selected using PFPSO technique rather than selected using ZN and conventional PSO methods.

## 1. INTRODUCTION

Controllers are designed and used in a feedback control system to improve system response or to achieved desired and prescribed response. Proportional-Integral-Derivative (PID) controller was developed by a Russian-American engineer Nicholas Minorsky in 1922. There are three PID controller parameters need to be selected through parameters selection process.

Ziegler-Nichols tuning method is probably the traditional heuristic tuning methods for tuning PID controller. It was proposed by Ziegler and Nichols in 1942 [1]. This method uses ultimate gain, $K_u$ and ultimate period, $P_u$ to calculate the PID controller parameters.

However, recent research on controller parameters selection process had shifted to computational tuning method. Particle Swarm Optimization (PSO) is one of the examples of computational tuning method which introduced by James Kennedy and Russell Eberhart in 1995 [2]. It was developed from the swarm intelligence and based on fish and birds flock movement behavior to find the food.

Another type of tuning method called Priority-based Fitness Particle Swarm Optimization (PFPSO) technique, which is an improved version of Particle Swarm Optimization (PSO). It was proposed by Jaafar in 2012 and apply to a nonlinear double-pendulum crane system [3]. The $P_{BEST}$ and $G_{BEST}$ values in this technique are updated according to the priority: settling time ($T_S$) and overshoot percentage (OS%).

In this paper, the PID parameters selection process is done by the Ziegler-Nichols method, conventional Particle Swarm Optimization (PSO) method, and Priority-based Fitness Particle Swarm Optimization (PFPSO) method. A comparison study is conducted on the Electro-Hydraulic Actuator (EHA) system which is a nonlinear system and the output performance is recorded.

## 2. METHODOLOGY

### 2.1 Proportional-Integral-Derivative (PID) Controller Design

PID controller is the most popular controller used in industry and often used as a benchmark by researchers. Figure 1 illustrates the PID controller structure. The top path is the proportional path, the second path is an integral path and the third path is the derivative path. The output of these three paths is summing up to produce a control signal (u) after multiplying with the error signal (e).

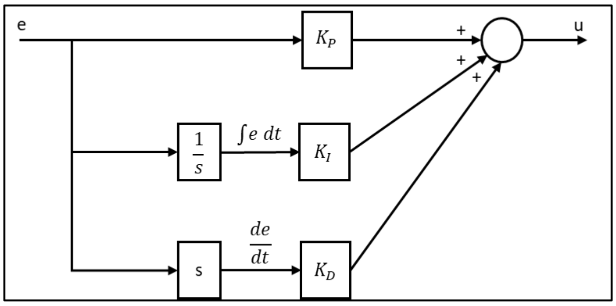


Figure 1 PID controller structure.

The overall PID control function can be expressed mathematically as in Equation (1).

$$u(t)=K_P*e(t)+K_I*\int_0^t e(t)\,dt+K_D*\frac{d\,e(t)}{dt} \quad (1)$$

### 2.2 Ziegler-Nichols (ZN) Tuning Method

Ziegler-Nichols method will first get the ultimate gain, $K_u$ and ultimate period, $P_u$ and then use these two values to get $K_P$, $K_I$, and $K_D$ values. The value of $K_P$, $K_I$, and $K_D$ values can be calculated using the formula in Table 1.

Table 1 PID controller parameters formula.

| Controller | $K_P$ | $K_I$ | $K_D$ |
|---|---|---|---|
| PID | $0.6*K_u$ | $2*K_u/P_u$ | $K_u*P_u/8$ |

### 2.3 Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is introduced by James Kennedy and Russell Eberhart in 1995. A number of particles that are moving around the searching space are used on the basic principle of the PSO algorithm to look for the best solution. Each particle will keep track of its coordinate in the fitness equation that has achieved by that particle. This value is known as personal best, $P_{BEST}$. Another value called global best, $G_{BEST}$ is tracked by the PSO. Each particle can be shown by its current position and velocity as shown in (2) and (3).

$$x^{i+1} = x^{i} + v^{i+1} \quad (2)$$

$$v^{i+1} = \omega v^{i} + c_1 r_1 (P_{BEST} - x^{i}) + c_2 r_2 (G_{BEST} - x^{i}) \quad (3)$$

where:

$x^{i+1}$ = position of particle at iteration k

$v^{i+1}$ = velocity of particle at iteration k

$\omega$ = inertia weight factor

$r_1, r_2$ = random numbers between 0 and 1

$c_1, c_2$ = acceleration coefficients

### 2.4 Priority-based Fitness Particle Swarm Optimization (PFPSO)

PFPSO technique is a combination of Priority-based Fitness Scheme and Particle Swarm Optimization. It was developed by Jaafar in 2012. The position and velocity of particles are updated continuously using Equations (2) and (3) according to the priority: settling time ($T_S$) and overshoot percentage (OS%) until the system meets the requirements.

### 2.5 Electro-Hydraulic Actuator (EHA) System

Electro-hydraulic actuator (EHA) system is a type of non-linear system due to its disturbance and uncertainties. Figure 2 illustrates the block diagram of the EHA system with a PID controller.

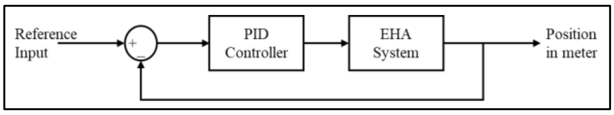


Figure 2 The block diagram of the EHA system with a PID controller.

## 3. RESULTS AND DISCUSSION

The PID controller parameters obtained through the Ziegler-Nichols (ZN) method, conventional Particle Swarm Optimization (PSO) and Priority-based Fitness Particle Swarm Optimization (PFPSO) technique are in Table 2.

Table 2 PID controller parameters.

| PID | ZN | PSO | PFPSO |
|---|---|---|---|
| $K_P$ | 987 | 351.9716 | 317.3733 |
| $K_I$ | 0.0150 | 7.3992 | 0.0215 |
| $K_D$ | 0.0038 | 0.5068 | 0.0796 |

In order to evaluate the performance of the PID controller apply to a nonlinear EHA system, a step reference input signal is fed into the system and observe the transient response of the system as in Figure 3. From Table 3, the PID controller parameters obtained through the PSO technique recorded the lowest overshoot percentage which is 1.2360%. However, PID-PSO has a steady-state error of 0.0378m which is far from our desired output as compared to the other two techniques. PID-ZN technique has the lowest steady-state error but also have the largest overshoot among three techniques. PID-PFPSO showed 1.7622% of overshoot percentage and 0.0001m of steady-state error.

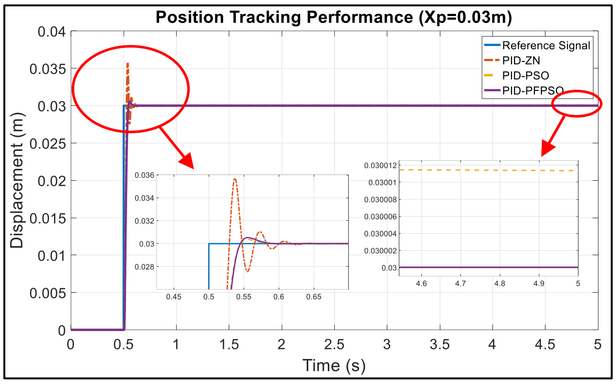


Figure 3 The output performance for step reference input signal.

Table 3 Controller Performance.

| Controller | Overshoot Percentage (%) | Steady-state Error, (m) |
|---|---|---|
| PID-ZN | 19.03 | $0.2534\times10^{-6}$ |
| PID-PSO | 1.2360 | 0.0378 |
| PID-PFPSO | 1.7622 | 0.0001 |

## 4. CONCLUSION

The PID controller parameters had been selected using three different methods and apply to a nonlinear Electro-Hydraulic Actuator (EHA) system. The performance of the PID controller under these three methods had been compared and analysed. From the overshoot percentage and steady-state error, it can be concluded that the PID is performed better when its parameters are selected through Priority-based Fitness Particle Swarm Optimization (PFPSO) technique.

## REFERENCES

[1] Ziegler J. G. & Nichols, N. B. (1942), Optimum settings for automatic controllers. *ASME Trans.*, 64(6), 759–765.

[2] Kennedy J. & Eberhart, R. (1995), Particle swarm optimization. *Neural Networks, 1995. Proceedings., IEEE Int. Conf.*, 4, 1942–1948.

[3] Jaafar H. I. & Mohamed, Z. (2012), PSO-tuned PID controller for a nonlinear double-pendulum crane system. in *IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 752, 515–519.