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The Implementation of PID Using Particle Swarm Optimization Algorithm on Networked Control System

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Abstract-In this paper, we propose the implementation of PID on Networked Control System (NCS) using Particle Swarm Optimization (PSO) algorithm as tuning method. There are three modification of PSO that used in this paper. The first is Constant Inertia Weight of PSO (CIW-PSO), the second is Linear Difference Weight of PSO (LDW-PSO), and the latest is Random Inertia Weight of PSO (RIW-PSO). In the end, we present discuss the effect of delay on the performance of Networked Control System.

Keywords: PSO, NCS, delay, RIW-PSO, CIW-PSO, LDW-PSO

I. INTRODUCTION

NCS is a control system which input, output, and controllers are connected via network. NCS could also be interpreted as a closed-loop control system which connected through real time network [1]. The Advantages of NCS is capable to reduce the complexity of system that will reduce operating costs. NCS also provides flexibility in designing a system. It is easy to perform maintenance processes, increase the speed of the system, and provide easy remote controlling process [1] [2].

The use of network to control system allows the emergence of packet loss and delay during the process of data exchange between controllers, actuators, and sensors. On systems that are very sensitive to time, delays that affect to reduce performance can even damage devices if network delay exceeds the allowed limit. Let we assume time sampling as h_k, then in non-NCS case, time sampling can be formulated by equation 1. Where t_{k+1} is state time over time sampling data $k+1$ while t_k state time over data sampling k.

$$h_k = t_{k+1} - t_k \quad (1)$$
$$h_k = \bar{h} + d_k \quad (2)$$

Equation 1 is less able to represent value of time sampling on NCS cases because the delay of NCS is random. This time sampling value should be able to calculate random delay out of network. That makes value of time sampling of each data acquisition would be different from each other. According to [3] this time sampling value can be calculated using equation 2. In that equation, it can be determined by value of time idle plus random delay. Time idle is time lag in data transmission.

II. PARTICLE SWARM OPTIMIZATION

PSO algorithm is an evolutionary computation technique developed by Dr. Kennedy and Dr. Eberhart in 1995. PSO is a development of a genetic algorithm. This algorithm mimics the social behavior patterns of bird flock. This pattern is based on the intelligence of every individual and also influenced the collective behavior of the flock

PSO will model a problem into a problem space. Each individual or particle will have velocity and position. Each iteration, particles will evaluate its position and will move towards to target which is best position of the herd. This process is performed until maximum iteration is reached. Equation 3 is used to modify the velocity of each particles at t^{th} iteration and equation 4 shows the position of each particle.

$$v_{i,m}^{(y)} = wv_{i,m}^{(y-1)} + c_1.Rand\left(p_{best_{i,m}} - x_{i,m}^{(y-1)}\right) + c_2.Rand\left(g_{best_m} - x_{i,m}^{(y-1)}\right) \quad (3)$$

$$x_{i,m}^{(y)} = x_{i,m}^{(y-1)} + v_{i,m}^{(y)}.t \quad (4)$$

where:
i = 1,2, ..., n ; m = 1,2, ..., d ;

n = number of particles;d = dimension;
y = pointer iteration;

Vi, m (y) = i^{th} particle's velocity over m^{th} dimension while y^{th} iteration

c1, c2 = constant acceleration

w = inertia weight;

Rand = random number from 0 to 1

Xi, m (y-1) = position of i^{th} particle before y^{th} iteration

pbest = best position of i^{th} particle before y^{th} iteration

gbest = best particle position of all the particles in a population

In PSO, the velocity of the particles has a very important role in the search for values of the objective function so that in some cases velocity of the particles is usually limited. On the limitation of the particle velocity if it is too big it will cause the particles move past the best position, while if it is too small then it is likely not move towards the best position and will be trapped in a local position [4]. Acceleration constants c1 and c2 in Equation 6 represents the weighting of the stochastic acceleration pull each particle toward the local position and global position.

The process for implementing the global version of PSO is as follows:

1. Initialize a population of particles with random positions, number of particles, c1,c2 and velocities on d dimensions in the problem space
2. For each particle, evaluate value of objective function over given objective function
3. Each particle is compared based on its objective function at n^{th} iteration with best objective function. If current value is better than best objective function, then current value will be set as current value
4. Each particle is compared based on its objective function with objective function of population's overall previous best. If current value is better than the best, then reset the best to the current objective function.
5. Change the velocity and position of the particle according to equations (6) and (7), respectively
6. Loop to step 2 until a criterion is met.

III. PERFORMANCE OF MODIFIED PSO ON THE NCS

Tuning results of any modification of PSO can be seen in Table 1.

Table 1 Value of PID parameters for each modification PSO

	CIW PSO	LDW-PSO	RIW-PSO
Kp	4.53300886	1.328324426719	1.278989451209
Ki	31.81476773	22.170166161643	30.358578093926
Kd	0.173548411	0.075776119521	0.111416506131

The implementation results of the process of tuning PID parameters using a modification of PSO-PID can be seen in Figure 1.

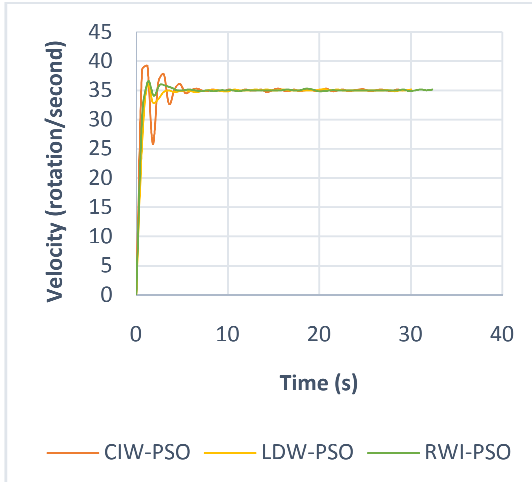

Fig. 1. Result of the PID implementation

From the picture above, tuning using RIW-PSO gives rise time, and its settling time is much faster when compared to the two other methods. Additionally LDW-PSO also produces very small overshoot. More complete results can be seen in the table 2 below.

Table 2 The implementation results of a modified PSO

	CIW- PSO	**LDW-PSO**	**RIW-PSO**
Set point (rotation/ second)	35.00	35.00	35.00
Rise time (second)	0.42316687 22472	0.86617400009 318	0.578657449 229058
Settling time (second)	4.47596600 14790	2.77762831589 324	3.124454351 738

Maximum Overshoot (Rotation/second)	13.527%	2.009%	6.652%
IAE	25.71875	17.40625	11.75

Table 2 shows the results of the implementation of three modified PID tuning PSO. The given values are the average values of ten experiments carried out for each modification of PSO. Rise time and settling time shown in this table are approximate using linear interpolation.

On NCS cases, unfixed delay will affect system performance. Therefore, control strategy is designed to be robust to delay of NCS. The test is performed to determine the ability of PID parameters obtained from the tuning process using PSO to change of delay change that occurred. Delay assumed as an unknown parameter magnitude.

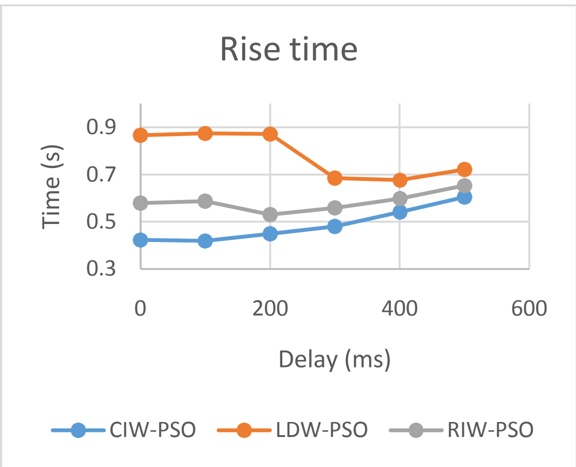

Fig. 2. The effect of delay to rise time

Figure 2 above shows the effect of delay to rise time. Seen in figure 2, Standard PSO has a rise time of less dominant when compared with other modifications. Despite the delay given to the system raised nonetheless rise time of standard PSO is not too long.

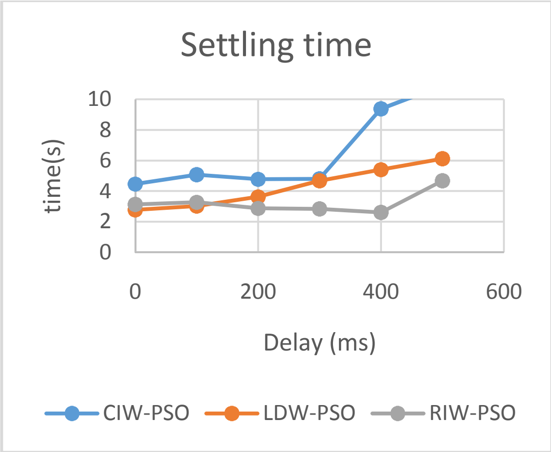

Fig. 3. The effect of delay on settling time

Figure 3 above shows the effect of delay to settling time from time response of the PID. While standard PSO is given in 500 ms then time response will be infinite, in other words the system will oscillate continuously. While RIW-PSO generates very fast time settling compared to another two modifications.

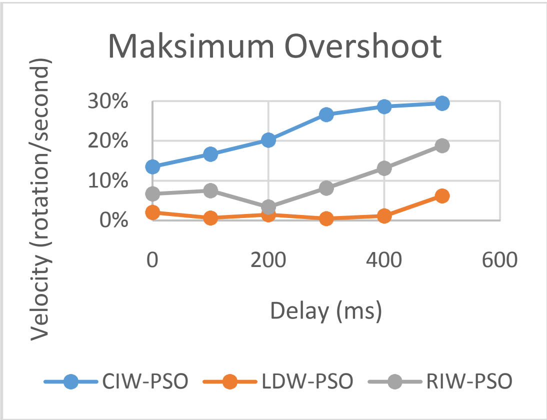

Fig. 4. The effect of delay to maximum overshoot

Figure 4 above shows the effect of delay to maximum overshoot. It can be seen that delay not really affects maximum overshoot produced by LDW-PSO. Another case with RIW-PSO has increased dramatically from delay 200 ms to 500 ms.

IV. CONCLUSION

Based on results of the design, implementation, and testing of the system it can be concluded that:

1. In the PID implementation process without any addition delay, the PSO LDW able to provide satisfactory control capabilities. With the PID parameters, Kp 1.328324426719, Ki 22.170166161643 and Kd 0.075776119521 respectively. PID parameters are obtained from the approach of the transient response with the following parameters, rise time at 0.86617400009318 seconds, settling time at 2.77762831589324 seconds, the maximum overshoot at 2.008929% rotations per second and IAE at 17.40625;
2. In term of the resistance to change of the delay RIW-PSO gives better time settling and IAE values compared to another forms of modified PSO. However, in term of the overshoot, LDW-PSO is able to deliver better results.

V. REFERENCES

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