GA-fuzzy P^2ID Control System for Flexible-joint Robot Arm

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Abstract: This paper presents a GA-fuzzy P^2ID control system for the flexible-joint robot arm. This controller is designed based on the parameter adjustment using fuzzy logic and genetic algorithms. According to the simulations, the better performance has been achieved acquired that the robot moved smoothly and met its required objectives. The results of comparison between 8 parameters and 10 parameters can be conclusion that the 10 parameters have setting time little than 8 parameters. In usability can be use 8 or 10 parameters these one.

Keywords: Genetic Algorithm (GA), Fuzzy P^2ID Controller, Flexible-joint Robot Arm

1. INTRODUCTION

Smooth movements of the flexible-joint robot arm are depend on the controller that can indicate every specific moment. Because those movements are non-linear, if we use the controller which is suited the non-linear system, it will increase the system's efficiency [1]. Therefore, this paper presents the fuzzy P^2ID that can adjust for appropriate parameters using genetic algorithm (GA) to control the arm's movement. In general, the parameters adjustment usually is usually modified by the users, but this method takes too much time to obtain appropriate results. Since this type of controller has many parameters for tuning, using GA would be worthwhile in order to search for fruitful results. Detail development of the controller can be found in [2]. This paper aims to apply the method to control a flexible-joint robot arm for smooth and accurate movements. Next sections provides a brief detail behind the ideas.

2. FUZZY P^2ID CONTROLLER

Fuzzy P^2ID controller is the coordination between the fuzzy PI and fuzzy PD controllers, which both controllers will process parallel to each other. Those controllers will be proscribed by a switch that chooses which controller will be in charged. As soon as the system starts, the fuzzy PD controller gives the faster rise time comparing with fuzzy PI controller [3]. Then the process will reach the designed exchange point, the system will swap the control to the fuzzy PI controller because it provides the better output at steady state [4]. When the process reaches the indicated point as the stabilized condition, the fuzzy PI controller will be terminated, and if the output of the process is not in the steady state which means lower than 90 percents of the projected resulted, the fuzzy PD controller will stand by to take control. For this reason, this process is called fuzzy P^2ID control system.

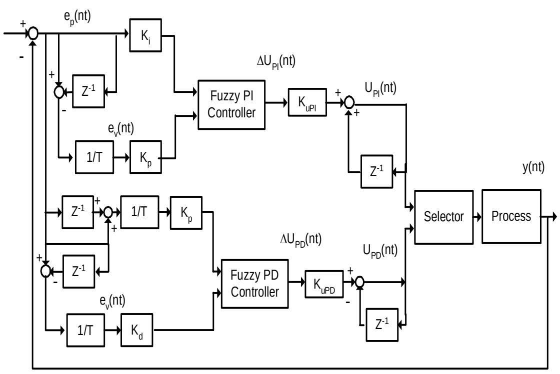

Fig. 1 Fuzzy P^2ID control system.

3. GENETIC ALGORITHMS

Genetic Algorithms [5, 6, 7] were duplicated from the natural evolutions. This method is efficiently applied to the problem solving; the importance of the method relies on how many potential members will survive as the suitable potentials to solve problems. Each generation will be created by population selection, and each member has the limited potential for fitting the problems' boundaries. Also, this method is combined with the genetic operation, which the best result will come for the last survived member.

Genetic operation is consisted of selection, recombination, mutation, and reinsertion. The first procedure initiates with the population creation randomly, the size of population depends on the problems. Next procedure is determining each member by using the objective function, or targeting function, which will not be restricted, it depends on types of problems to be solved. Then, there will be the inspection, if it doesn't find the answer; it will start creating the next generation members by obtaining the parent members which were selected from the fitness values. The selected parent members will be mixed together, and then all offspring will be mutated by using probability and then finding the value of each offspring and then bringing 3-6 best of them to replace the parent members as the next generation. This will be cycling like this till it finds the appropriate values.

The chromosome's length has eight variables which consisted of the fuzzy PD controller that has objected parameters: they are Kpd, Kd, Ld, Kupd, fuzzy PI controller, Kpi, Ki, Li, Kupi, which will give I = {Kpd, Kd, Ld, Kupd, Kpi, Ki, Li, Kupi} by substituting the values and the restriction of the parameters with the real numbers and the initial value of the parameter for starting the program. The initial parameter value is the initial population at 30, and the maximum generated value is at 30.

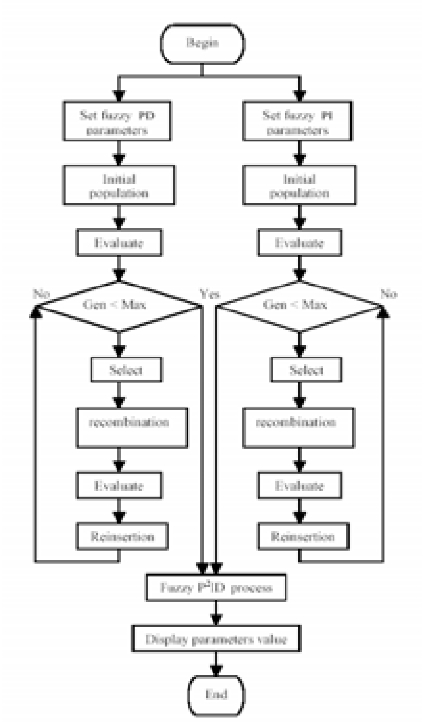

Fig. 2 Flow chart of the GA program for fuzzy P²ID controller.

4. FLEXIBLE-JOINT ROBOT ARM

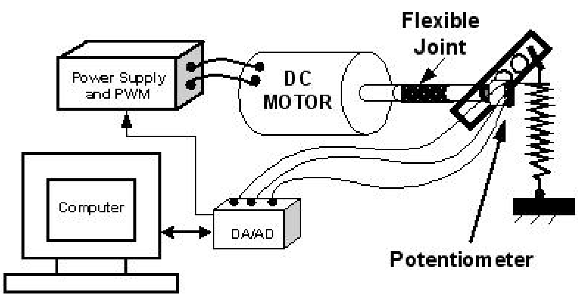

Fig. 3 Flexible-joint robot arm model.

The mathematical model [8] from Fig. 3 is shown as these following equations.

$$I_1\ddot{\theta}_1(t)+M(t)\ell g\sin[\theta_1(t)]+\bar{k}[\theta_1(t)-\theta_2(t)]=0 \quad (1)$$
$$I_2\ddot{\theta}_2(t)-\bar{k}[\theta_1(t)-\theta_2(t)]=u(t)$$

In which I_1 is the arm's rotational inertia, I_2 is the rotor inertia of the motor, $\theta_1(t)$ is the changing angle of the arm is angle of the motor's comparing with vertical axis, $\theta_2(t)$ is the changing angle of the rotor of motor axis, $u(t)$ is motor's torque, $\bar{k}$ is spring constant which used as the joint of the arm, $M(t)$ is the total mass of the arm varies by time which is the spring joining the arm, ℓ is the distance from the center of the rotational axis, g is gravity of the earth.

5. SIMULATION AND RESULTS

The simulation is the application of the fuzzy P²ID idealistic which adjusted the parameter values suited with the genetic algorithm in order to control the movements of the flexible-joint robot arm from Eq. (1)

There are two parts in this simulation; the first part uses the fuzzy P²ID controller which has been adjusted the 8 parameters values with the genetic algorithm as shown in Table 1, the second part uses the fuzzy P²ID controller which has been adjusted select-point and sampling-time of system with the genetic algorithm, then it calls the 10 parameters values as shown in Table 3. Then, comparing the results from both parts and determining the efficiency which indicated in Table 2 and 4.

Table 1 Parameter values acquired from the fuzzy P²ID controller which has been adjusted the 8 parameters values with the genetic algorithm. Given I_1 =0.030(kgm²), I_2= 0.001(kgm²), $\bar{k}$ = 31(Nm/rad), $Mg\ell$ = 0.8(Nm), Set point (degree) = 100, 180, Sampling Time (Ts) = 0.01xsec

Setpoint (degree)	Kpd	Kd	Kupd	Ld
100	2.7762	3.1111	19.2384	50
180	10.7762	5.1111	19.34	70
Setpoint (degree)	Kpi	Ki	Kupi	Li
100	0.9703	0.0211	2.3158	40
180	0.9703	0.0211	2.5	50

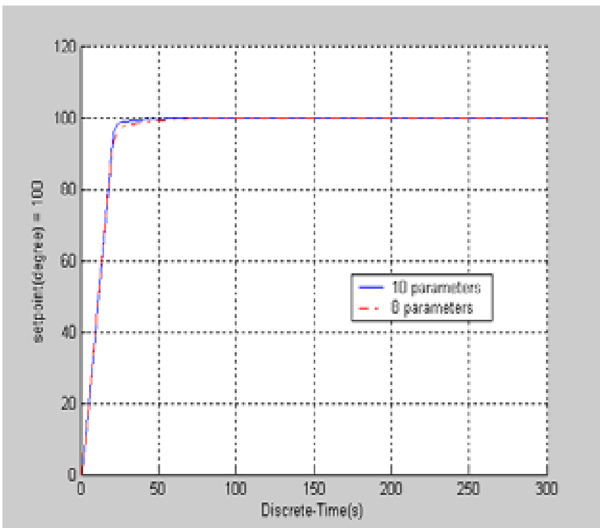

Fig. 4 The comparison of controlled position reaction acquired from the fuzzy P²ID controller which has been adjusted the parameter values with the genetic algorithm. The targeted values = 100

Table 2 Performance of the fuzzy P^2ID controller which has been adjusted 8 parameters values with the genetic algorithm.

Setpoint (degree)	Rise time (s)	Setting time (s)	Overshoot (%)
100	0.1663	0.3234	0
180	0.2127	0.3346	0

Table 3 Parameter values acquired from the fuzzy P^2ID controller which has been adjusted the 10 parameters values with the genetic algorithm. Given, $I_1 = 0.030(kgm^2)$, $I_2 = 0.001(kgm^2)$, $\bar{k} = 31(Nm/rad)$, $Mg\ell = 0.8(Nm)$, Set point (degree) = 100, 180

Setpoint (degree)	Kpd	Kd	Kupd	Ld	Ts
100	2.7762	3.1111	19.2384	50	0.0099
180	10.7762	5.1111	19.34	70	0.0098
Setpoint (degree)	Kpi	Ki	Kupi	Li	Sel
100	0.9703	0.0211	2.3158	40	95.169
180	0.9703	0.0211	2.5	50	171.98

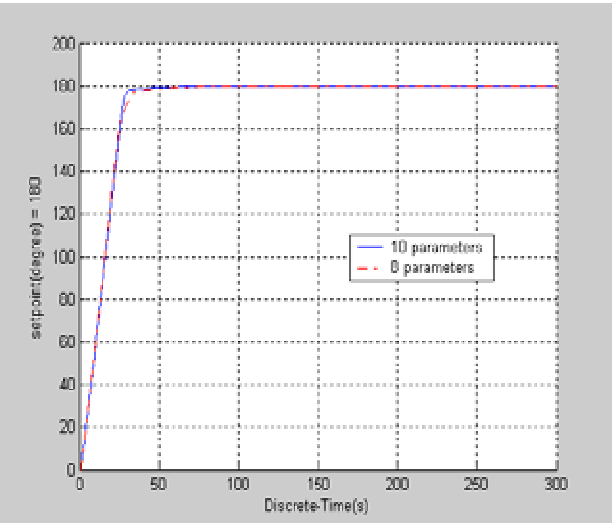

Fig. 5 The comparison of controlled position reaction acquired from the fuzzy P^2ID controller which has been adjusted the parameter values with the genetic algorithm. The targeted values = 180

Table 4 Performance of the fuzzy P^2ID controller which has been adjusted the 10 parameters values with the genetic algorithm.

Setpoint (degree)	Rise time (s)	Setting time (s)	Overshoot (%)
100	0.1673	0.2347	0
180	0.2127	0.2891	0

6. CONCLUSION

Table 2 and 4 show that the application of the fuzzy P^2ID controller which has adjusted the parameter values with the genetic algorithm brought up the satisfied results. The rise time and setting time are small, and the overshoot value is significantly small. It means that this idea has high efficiency in controlling the arm movements which creates the accurate and smooth arm's movements. Furthermore, the results shows that this idea brought up low errors.

Performance comparison between the adjusted 8 parameters and adjusted 10 parameters with the genetic algorithm concludes that the rise time values is nearly result but setting time values of 10 parameters little than 8 parameters, include respond without error. In usability can be use 8 or 10 parameters these one.

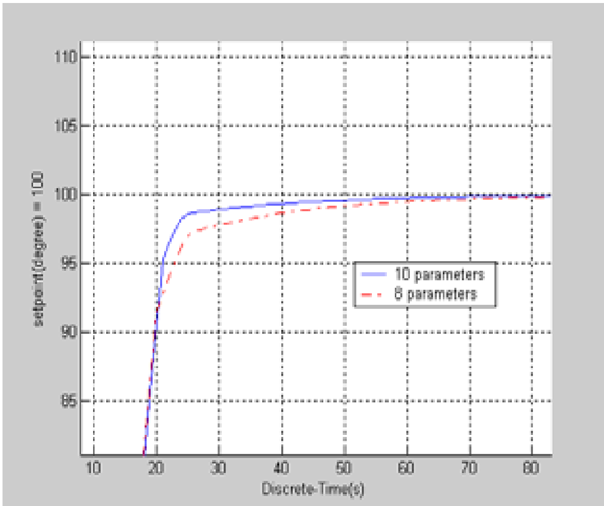

Fig. 6 Zoom in output from Fig. 4

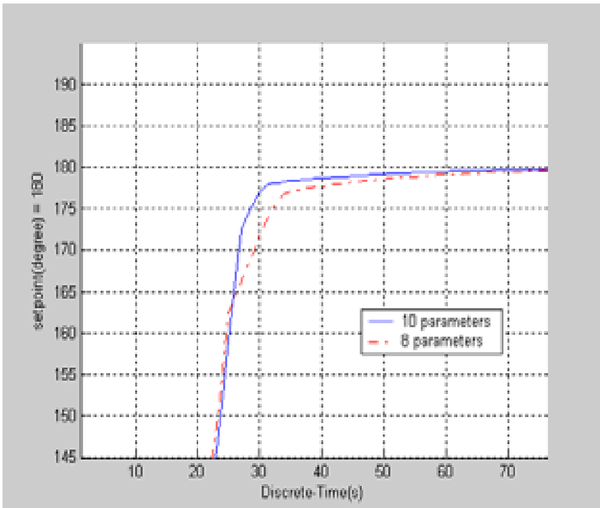

Fig. 7 Zoom in output from Fig. 5

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