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Evolutionary algorithm based controller for double link flexible robotic manipulator

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ABSTRACT –The paper investigates the development of intelligent hybrid collocated and non-collocated PID controller for hub motion and end point vibration suppression of double-link flexible robotic manipulator. The system was modeled using multi-layer perceptron neural network structure based on Nonlinear Autoregressive Exogenous (NARX) model. The hybrid controllers are incorporated with optimization algorithm that is ABC and PSO to find out the parameters of the PID controllers. Numerical simulation was carried out in MATLAB/Simulink to evaluate the system in term of tracking capability and vibration suppression for both links. The results show that PSO revealed the superiority over ABC in controlling the system.

1. INTRODUCTION

Despite various advantages shown by flexible manipulator such as offers cost reduction, lower power consumption, improved dexterity, better maneuverability, safer operation and light weight, the undesirable vibration is the common shortcoming occurred in the structure. In order to satisfy the conflicting requirements, number of research on improving the control methods have been carried out.

Evolutionary Algorithms have been used in various areas including in developing tuning method of PID controller for flexible manipulator. For instance, hybrid PD-PD/Iterative learning Algorithm (ILA) tuned by Genetic Algorithm for single-link flexible manipulator (SLFM) is presented in [1], a multi-objective optimization using Differential Evolution (MODE) for PID controller of SLFM studied in [2], an improved Bacterial Foraging Algorithms (BFA) to tune the PID controller of SLFM is proposed in [3], Bee Algorithm is used to optimize the hierarchical PID parameter of SLFM in [4] and particle swarm optimization (PSO) algorithm to tune parameter of one PID controller of SLFM in [5].

In this paper, a hybrid PID-PID controller is developed for double link flexible robotic manipulator (DLFR) based on the NARX model plant as elaborated in [6]. The global search of ABC and PSO are utilized to optimize all the PID controllers' gains.

2. CONTROL SCHEME

The control scheme is shown in Fig.1. The PID_{i1} controller is developed for hub angle motion while PID_{i2} controller is applied for flexible body motion. The two loops of each link ($i=1,2$) are combined together to give control inputs that work simultaneously for the DLFR.

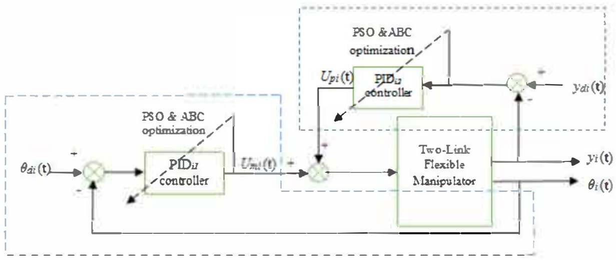


Figure 1 Hybrid controller structure of double link flexible robotic manipulator.

2.1 *Controller design*

The proposed control structure using novel evolutionary algorithms of PSO and ABC to tune the PID controllers' parameters. The objective functions of optimization are formulated based on the MSE of the hub angle error and end point vibration suppression. The details of algorithm as follow.

2.1.1 Particle Swarm Optimization (PSO)

PSO is initialized with a group of random particles and then searches for optimum by updating generations. The particle updates its velocity and positions with following Eq. (1) and (2).

$$V_{id}^{k+1} = W * V_{id}^{k} + C1 * R1 * \left(Y_{id}^{k} - X_{id}^{k}\right) + C2 * R2 * \left(Y_{id}^{k} - X_{id}^{k}\right) \tag{1}$$

$$X_{id}^{k+1} = Y_{id}^{k} - X_{id}^{k} \tag{2}$$

where V= particle velocity, X= particle position, W= Inertia weight, R_1, R_2 = random number and C_1, C_2 = learning factors. In this research, $C_1 = C_2$ is chosen as 2 and R_1, R_2 is between 0 and 1. The starting and end point of inertia weight, W set as 0.9 and 0.25.

2.1.2 Artificial Bees Colony Algorithm (ABC)

ABC is inspired by intelligent behavior of honey bees to look for the best food location. The fitness is calculated by the following formula (3), after that a greedy selection is applied between x_m and v_m.

$$fit_m(x_m) = \frac{1}{1+f_m(x_m)},\ f_m(x_m) > 0$$

$$fit_m(x_m) = 1 + |f_m(x_m)|,\ f_m(x_m) < 0 \tag{3}$$

where $f_m(x_m)$ is the objective function value of x_m. The quantity of a food source is evaluated by its profitability.

P_m is determined by the formula;

$$P_m = \frac{fit_m(x_m)}{\sum_{m=1}^{SN} fit_m(x_m)} \quad (4)$$

where, $fit_m(x_m)$ is the fitness of x_m. If the fitness value of is better than that of its parent, then update with otherwise keep unchanged.

3. RESULTS AND DISCUSSION

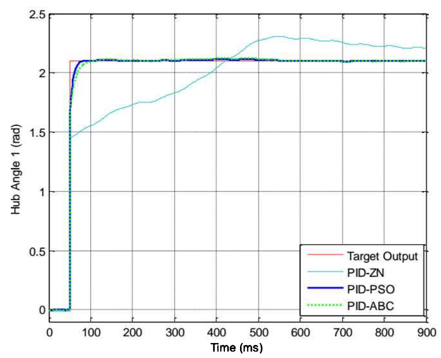
3.1 Hub angle control

The hub angles were controlled by the collocated PID controller individually. The DLFR system is required to follow a step input of 2.1 rad and 1.1 rad to test the hub tracking input of link 1 and 2 respectively. The controller parameters obtained and their performances are tabulated in Table 1.

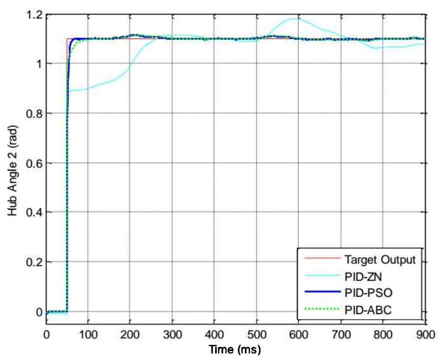
Table 1 Parameters and performance of hub input tracking for DLFR system.

		Parameters			Rise Time (s)	Sett. Time (s)	Over shoot (%)
		K_P	K_I	K_D			
ABC	L 1	6.54	20.5	49.43	0.076	1.08	1.94
	L 2	5.48	28.3	13.72	0.099	5.64	3.19
PSO	L1	3.65	57.9	3.46	0.058	1.16	0.89
	L 2	2.19	88.2	0.79	0.04	0.59	1.64
ZN	L1	2.09	0.54	2.01	2.97	7.15	4.69
	L2	4.15	1.3	3.32	1.46	5.45	5.45

The hub angle response for both link is shown in Fig. 2. PSO and ABC controller achieved a very significance improvement in term of percentage overshoot and settling time as compared to Ziegler-Nichols (ZN). However, in overall PSO lead the ABC in giving better results.



(a)



(b)

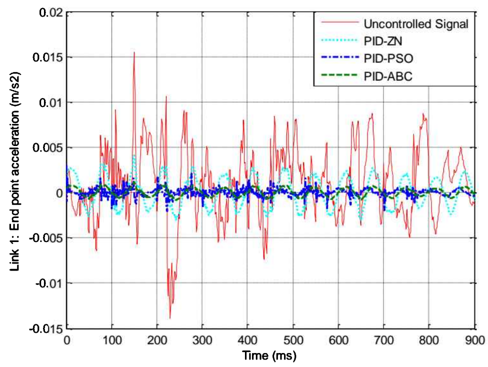
Figure 2 (a) Input tracking for Hub 1 (b) Input tracking for Hub 2.

3.2 Flexible motion control

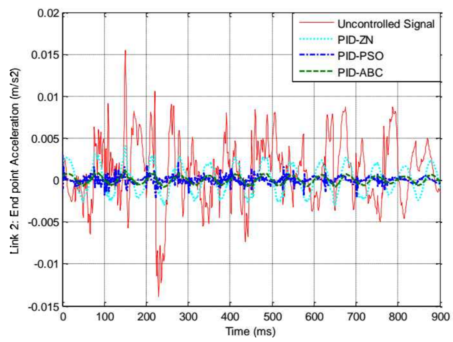
The collocated PID controllers were implemented to DLFR system to actively suppress the vibration at the end point of link 1 and 2 individually. The results are tabulated in Table 2 and the simulation results of vibration suppression are presented in Fig. 3. The vibration can be further suppressed by employing the ABC and PSO controller as compared to ZN. Overall, PSO shows the superiority over ABC.

Table 2 Parameters and performance of vibration suppression for DLFR system.

		Parameters			MSE
		K_P	K_I	K_D	
ABC	L1	30.03	56.07	88.95	7.919e-07
	L2	50.1	46.96	23.62	8.432e-08
PSO	L 1	2.07	498.1	2.04	3.948e-08
	L 2	8.06	817.9	1.03	4.315e-08
ZN	L1	7.2	21.176	0.612	2.822e-06
	L2	16	55.082	1.281	7.564e-07



(a)



(b)

Figure 3 (a) End point vibration suppression of Hub 1(b) End point vibration suppression of Hub 2.

4. CONCLUSION

In this work, the intelligent Hybrid PID-PID controllers have been developed for DLFR. The controllers have been compared with hybrid PID-ZN controller. The proposed control schemes have been tested through simulation in Matlab/Simulink environment. The proposed controllers are able to follow the reference trajectory and the vibration of the system is eliminated simultaneously through end point acceleration feedback. However, it is revealed that PSO controllers offer the best outcomes compared to ABC.

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