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Comparison of Different Performance Index Factor for ABC-PID Controller

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Abstract

Design optimization could be very challenging partially due to complexity and non-linearity of the system in consideration. Conventional methods are limited merely to certain operational zones and have unsatisfactory design robustness property. Metaheuristic algorithms are becoming increasingly popular among control engineers. Over the last two decades ,several meta-heuristic algorithms have emerged for the optimization of PID controller .These algorithms are faster in convergence and optimize globally(unlike conventional methods).In this paper ,one such algorithm known as Artificial Bee Colony(ABC) Algorithm has been proposed to tune the parameters of PID controller in order to optimize the system .A comparative study of the system is done for different performance index i.e. IAE,ISE and ITAE .

Keywords: PID controller, Artificial Bee Algorithm (ABC), IAE, ISE, ITAE, DC MOTOR.

1. Introduction

DC motor is a vital component in most of the process control industries. Due to its excellent speed control characteristics, DC motors have been widely used in industries even though its maintenance cost is higher than induction motor.[2]As a result a lot of research has been done on DC motor and many techniques have evolved to make it more stable. One such method is the introduction of PID controller in the plant.

Proportional-Integral-Derivative (PID) controller is one of the earliest control techniques that is still used widely in industries because of its easy implementation, robust performance, simple construction and cost effectiveness. For achieving appropriate closed loop performance, three parameters of the PID controller must be tuned .PID controller can be tuned with conventional and intelligent methods. Conventional methods such as Ziegler and Nichols [3] and Simplex method can tune the optimal PID parameters for only linear and stable systems. Moreover they tend to produce big surge and large overshoot. The main drawback of this tuning method is that it is limited merely to certain operational zones and has an unsatisfactory design robustness property.

Nowadays, heuristic methods have been proposed as an alternative to conventional methods. These heuristic methods are nature inspired methods that are stimulated by natural and biological events such as bird flocking, fish schooling, animal herding, bacterial growth etc.Swarm intelligence is one of the branches of nature inspired methods which are used for function optimization. It is based on the collective behaviour of self-structured systems. These algorithms can be applied to variety of fields in engineering and social sciences for example controlling robots and unmanned vehicle, enhancing the telecommunication and computer networks, predicting social behaviours, optimization of parameters etc[5].

This paper proposes to tune the parameters of PID with one of the swarm intelligent algorithms named as Artificial Bee Colony Algorithm. Artificial Bee colony is one of the most recent and efficient Optimization methodology introduced by D.Karaboga in 2005.This algorithm is motivated by Foraging behaviour of honeybee swarms. ABC is a swarm-based intelligent stochastic optimization algorithm that has shows considerable performance in solving continuous, combinatorial and many more complex optimization problems. Stochastic optimization algorithms are those that implement unpredictability to encourage non-deterministic individuality, contrasted to entirely deterministic tactics. Current research topics include the extension of ABC for the optimization of hybrid functions, integer programming and engineering design problems, combinatorial and multi-objective optimization problems and clustering neural network training and image processing problems.

PID controller is designed for the DC motor plant with its parameters optimized by the Artificial Bee Colony Algorithm. The objective of this paper is to show that by using ABCA an optimization can be achieved and optimized system response for three fitness functions i.e.IAE, ISE and ITAE is compared in this paper.

2. Problem Formulation

Proportional, Integral and Derivative gains are combined to form the basis of PID controller. The feedback control system is illustrated in Fig.1.

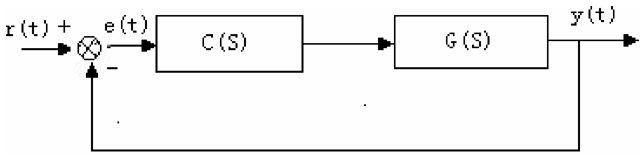

Fig. 1

Here, e is the error variable which is the difference between output(y) and reference variable(r). G(s) is the plant transfer function and C(s) is the PID controller transfer function that is given as:

$$C(S) = Kp + \frac{Ki}{s} + K_d s \quad (1)$$

Where Kp, Ki and Kd are respectively the Proportional, Integral, Derivative gains/parameters of the PID controllers that are going to be tuned. The plant used here is a DC motor model [1] which is a third order system given as:

$$G(S) = \frac{1}{S^3+9S^2+23S+15} \quad (2)$$

Various objective functions based on error performance index are used to evaluate the above algorithm. Performance index is calculated over a time interval .Performance index which are used to estimate the best parameters of PID are given by :
ISE Index:

$$ISE = \int_0^\infty e^2(t)\, dt \quad (3)$$

IAE Index:

$$IAE = \int_0^\infty |e(t)|\, dt \quad (4)$$

ITAE Index:

$$IATE = \int_0^\infty t|e(t)|\, dt \quad (5)$$

3. Artificial Bee Colony Algorithm

ABC algorithm was developed by inspecting the behaviour of honey bees scavenging for nectar and sharing the information of the location of food sources to other bees in the nest. Three groups of bees: employed bees, onlookers and scouts quest for the food altogether. Every kind of bee plays a different and an important part in the optimization process. Employed bees barter the information of the food source to onlookers in the hive for reference. The onlooker bee receives the coordinates for the food sources and decides from which of the locations to gather the nectar .A bee randomly searching for food sources in the search space is known as scout bee. For every food source there is one employed bee and a number of follower bees. The scout bee on finding the food source better than some threshold value performs a waggle dance so as to indicate and share this information with other bees of the hive. The algorithms runs through the following steps[4]:
Step 1: Firstly we initialize the positions of food sources i.e CS/2 where CS is the colony size being equal to 50, these food sources are equal in number to individuals or employed bees represented by x_{ij} given by following equation:

$$x_{ij} = x_{minj} + rand[0,1]\left(x_{maxj} - x_{minj}\right) \quad (6)$$

Step 2: The fitness of each individual is estimated using the following method:

$$fit_i = \begin{cases} \frac{1}{1+f_i} \text{ if } f_i \geq 0 \\ 1 + abs(f_i) \text{ if } f_i < 0 \end{cases} \quad (7)$$

Step 3: Each employed bee is placed at a different food source from others, search in the proximity of its current position to find a better food source. Each employed bee generates a new solution by the following formula:

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}) \quad (8)$$

Here, k ∈ {1, 2,…, 50} and j ∈ {1, 2,3} are randomly chosen indices. ϕij is a uniform random number from [-1, 1].

Step 4: Iteratively the fitness of both xi and vi is computed . Both the fitness's are compared and if the solution hasn't improved(v_i) we increase the trial counter else we replace x_i by $v_{i.,}$this strategy is known as greedy selection strategy.

Step 5:Calculate the probability values p for the solutions x by means of their fitness values by using the formula:

$$p_i = \frac{fit_i}{\sum_{i=1}^{\frac{CS}{2}} fit_i} \quad [9]$$

Step 6: Produce new solutions υi for the onlookers from the solutions xi selected ,then depending on the probability p_i evaluate them

Step 7: Generate new food positions (i.e. solutions), vi for each onlooker bee.

Step 8: Compute the fitness of each onlooker bee, xi and the new solution, vi. Apply greedy selection process to choose fitter one

Step 9: If a particular solution xi has not been improved over a predefined number of cycles, then select it for rejection. Replace the solution by placing a scout bee at a food source generated evenly at random within the search space using for j = 1, 2,……,50

Step 10: Keep track of the best food sources (solution) found so far.

Step 11: Check termination criteria. If the best solution found is acceptable or reached the maximum iterations, stop and return the best solution found so far. Otherwise go back to step 2 and repeat again.

4. Simulation Results

Table 1: Comparative Results of ITAE, IAE and ISE for ABC-PID controller.

Tuning Method	**Kp**	**Ki**	**Kd**	**Overshoot (%)**	**Settling Time**	**Rise Time**	**Peak Time**
ZN	115.364	175.86	9.454	70	10.8666	0.3136	0.9014
ABC-PID1 (IAE)	472.7115	54.8213	109.3897	46	2.6159	0.1206	0.2973
ABC-PID2 (ISE)	591.8524	78.6252	110	54	2.5202	0.11497	0.29581
ABC-PID3 (ITAE)	15.2375	10	17.1473	1	6.0104	4.2301	8.8101

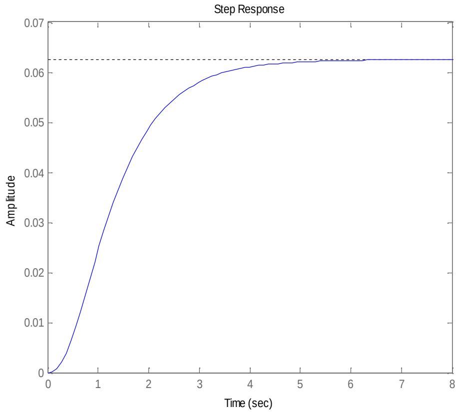

Fig. 2: Step Response of plant with unity feedback

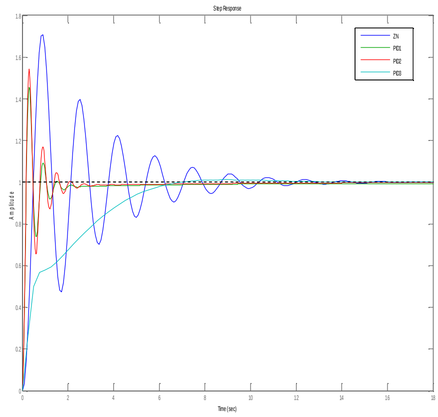

Fig. 3: Step Response of PID controller tuned with ABC

5. Conclusion

In this paper, ABC is applied to solve the problem of PID controller parameter optimization. It is found that the approach proposed could achieve optimal parameters, which can bring good control performance. The validity of the approach is shown by the simulation results shown in fig3; it indicates that applying ABC to optimize PID controller parameters is effective with response obtained for ITAE has least of overshoot and ISE having the least of rise time and peak time.

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