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BFO Approach Based Comparative Behavior of Different Performance Indices

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Abstract

Numerous fine-tuning methods have been proposed for optimal tuning of PID controller. Most popular among them have been Swarm Intelligence Algorithms also known as Meta-heuristic algorithms, which have the features of easy implementation, short execution time and robust mechanism of escaping from local optimum, is a promising tool for engineering applications. In this paper a tuning method for determining the parameters of PID controller for a system using a Bacteria Foraging optimization algorithm is proposed. Functional algorithm has been proved one of the best recently proposed swarm intelligence based tuning algorithm which pertains to optimization, proposed for numerical global optimization. BFO mimics the intelligent foraging behaviour of a bacteria or insect. This technique is utilized to optimize the parameters of PID controller used for tuning the system.

Keywords: Swarm intelligence, Bacteria Foraging Optimization, PID Tuning, Matlab and Closed loop feedback.

Introduction

The Proportional-Integral-Derivative (PID) controller has been proved the most popular controller of this century for its remarkable effectiveness, easiness of implementation and vast applicability. But it is also hard to tune the PID controller. A number of tuning methods are done manually which are difficult and time consuming. For using PID controller efficiently, the optimal tuning of its parameters has become a significant research area. Optimization problems have been resolved with the aid of numerous techniques. Today's, an alternative approach to the traditional methods for operations research, meta-heuristic methods are implanted to simplify optimization difficulties.

Nature Inspired strategies are those, which are inspired by natural and biological events for example, immune system, foraging behaviour of ants and other insects. Swarms can be considered as any collection of interacting agents or individuals and implemented strategy is inspired by intelligent behaviour of insects [2].Swarm intelligence algorithm promotes to develop modern meta-heuristics which can utilize insect's problem solution strengths [3].Such algorithms use population-based optimization approach which tend to find optimal solutions to the complex and difficult optimization problems by motivation from nature.

Bacteria Foraging Optimization (BFO) Algorithm has been applied for tuning the subjected parameters of PID controller [4]. This tuning method based on research of foraging behaviour of E.colli bacteria proposed by Kevin M.Passino and Liu exploits a bacterial foraging and swarming behaviour. It exhibits linked social foraging process along with distributed non-gradient optimization.On comparing with earlier proposed classical optimization methods, BFO has been found simple, quite easy to realize and has immense intelligent background as it is not only optimal for scientific research, but also fitting for engineering applications in exact. Therefore, BFO gained great attentions from evolutionary computation field and other sectors. In accordance with operation researches, it’s a population-based stochastic optimization technique and proved to be appropriate for the optimization of nonlinear functions in multidimensional space.

Experimental studies on tuning the parameters of PID controller for the ball and hoop problem show that applied BFO eradicated the flaws occurred in self tuning of PID by Conventional methods. The obtained responses signify higher fitness and quicker convergence.

1. Problem Formulation

PID controller consists of Proportional, Integral and derivative gains. The feedback control system is illustrated in Fig.1 where *r*, *e*, *y* are respectively the reference, error and controlled variables.

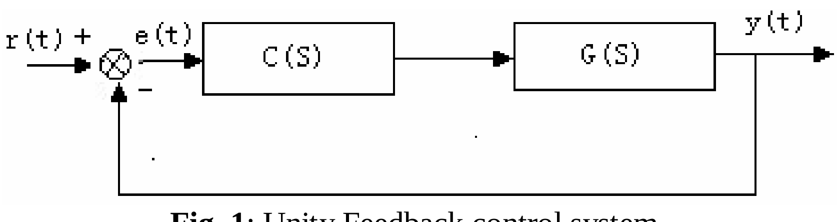

Fig. 1: Unity Feedback control system.

In the diagram of Fig.1, G(s) is the plant transfer function and C(s) is the PID controller transfer function that is given as:

$$C(s) = K_p + \frac{K_i}{S} + K_d S \quad (1)$$

Where K_p,K_i,K_d are respectively the proportional, integral, derivative gains/parameters of the PID controllers that are going to be tuned. The plant used here is a Ball and Hoop system [1] which is a fourth order system written as:

(2)

2. Proportional Integral Derivative Controller

PID controller is a generic control loop feedback mechanism widely used in industrial control systems. It calculates an error value as the difference between measured process variable and a desired set point. The PID controller calculation involves three separate parameters proportional integral and derivative values. The proportional value determines the reaction of the current error, the Integral value determines the reaction based on the sum of recent errors, and Derivative value determines the reaction based on the rate at which the error has been changing the weighted sum of these three actions is used to adjust the process via the final control element. The block diagram of a control system with unity feedback employing Soft computing PID control action.

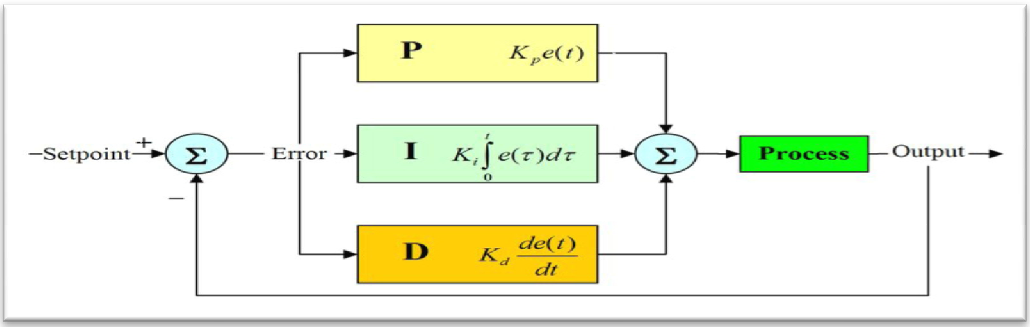

Fig. 2: Block diagram of PID Controller.

3. Tuning of PID using BFO-based Optimization

Bacteria Foraging Optimization (BFO) algorithm exploits a variety of bacterial foraging and swarming behavior, including a discussion of connecting social foraging process along with distributed non-gradient optimization strategy. In the bacterial foraging optimization four motile behaviors are mimicked:

Chemotaxis: Chemotaxis process is achieved through swimming and tumbling. With the aid of rotation of the flagella in each bacterium, it decides that bacteria should move in a predefined direction (swimming) or in a diverse direction (tumbling), in the whole life span of the bacterium. To signify a tumble, a unit length random direction, ϴ(j) is generated which will be used to label the direction of progress after a tumble.

(3)

Where $\Theta^i(j,k,l)$ represents the ith bacterium at jth chemo tactic kth reproductive and lth elimination and dispersal step. C (i) is the size of the step used in the random direction precised by the tumble. “C” is termed as the “run length unit”.

Swarming:-A bacterium should search the optimum pathway of food searching and should try to magnetize other bacteria so that they can reach the desired place more swiftly. Swarming makes the bacteria assemble into groups and hence move as concentric patterns of groups with peak bacterial density.

Reproduction: - The least fit bacteria depart its life and each-other fittest bacteria split into two bacteria. Such bacteria are located in the similar site which makes the population of bacteria constant.

Elimination and dispersal: - The existence of a population of bacteria changes either gradually by spending of nutrients or abruptly due to some other influence in a local environment. Events can eradicate or spread out all the bacteria in a section. Actually, they have the impact of destroying the chemo-tactic progress, but in disparity, they also support it. Since dispersal may consign bacteria near excellent food sources. Elimination and dispersal helps in dropping the conduct of stagnation (i.e., being trapped in a untimely solution position or local optima).

4. Performance Evaluation Criteria

Furthermore, performance index is defined as a quantitative measure to depict the system performance of the designed PID controller. Using this technique an 'optimum system' can often be designed and a set of PID parameters in the system can be adjusted to meet the required specification. For a PID- controlled system, there are often four indices to depict the system performance: ISE, IAE, IATE and MSE. They are defined as follows:

ISE Index: $ISE = \int_0^\infty e^2(t)\,dt$ (4)

IAE Index: $IAE = \int_0^\infty |e(t)|\,dt$ (5)

IATE Index: $ITAE = \int_0^\infty t|e(t)|\,dt$ (6)

ITSE Index: $ITSE = \int_0^\infty t|e^2(t)|\,dt$ (7)

Therefore, for the BFO-based PID tuning, the performance indices (Eqs. 3-7) will be used as the objective function. In other word, the objective in the BFO-based optimization is to seek a set of PID parameters such that the feedback control system has minimum performance index.

5. Simulation Result

Table 1 Optimized PID parameters Table 2 Step response performance for PID

Tuning Method	Kp	Ki	Kd
BFO-PID1 (IAE)	3.4825	0.0219	1.6197
BFO-PID2 (ISE)	3.0198	0.0598	1.0226
BFO-PID3 (ITAE)	3.9288	0.8257	2.9713
BFO-PID4 (ITSE)	3.2452	0.5522	4.3229

Overshoot (%)	Settling Time	Rise Time	Peak Time
16.53	8.5372	2.3583	5.2952
18.96	37.66	2.6106	5.9772
43.11	15.0148	1.8270	5.1360
22.3856	15.7453	2.0404	6.8077

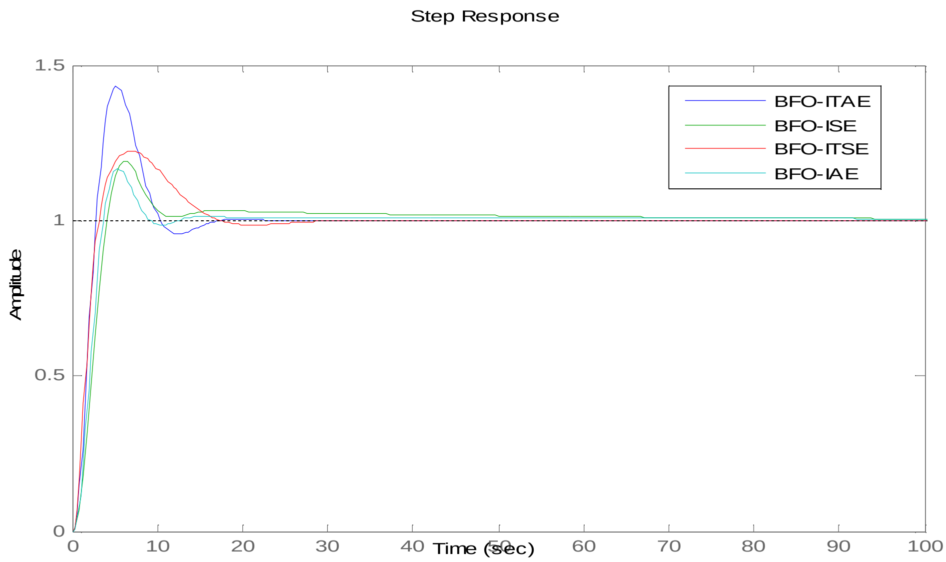

Fig. 3: Comparison of Different Performance Indices of the BFO-PID Controller system.

6. Conclusion

From the outcomes, the benefit of using a modern optimization approach is observed as a complement solution to achieve the desired performance of the PID controller to those of conventional methods which fail to tune the non-minimum phase systems. The designed PID controller using BFOs based optimization stabilizes the ball and hoop system. Furthermore, the BFO-based PID controllers which are optimized with different performance indices have almost similar performances but IAE has least overshoot, least settling time and IATE has minimum rise time.

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