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# Bacterial Behavior Based Swarm Optimized PID Controller Tuning for High Order System

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**Abstract:** In the conventional methods it is difficult to select the right PID parameters in the initial stage, and these parameters need to be fine tune when the system is running. The main objective of this paper is to test the performance of the developed bacterial foraging leaning by particle swarm optimization algorithm PID controller tuning. Attempt has been made to realize globally minimal error squared error integral criteria in the step response of a process that is cascaded with PID controller by tuning the Kp proportional gain, Ki integral gain and Kd differential gain values. Generally, the selection of the controller coefficients is implemented by approximate methods, which in turn will not guarantee globally optimal solution for control applications. The values of Kp, Kd and Ki resulting through the BF, PSO and (BF-PSO) methods after ensuring the presence of all the poles of the transfer function confined to the left half of the S plane. The performance of the developed algorithm is experienced with transfer functions of systems of different orders. The cost function here is the square of integral error. The closed loop PID controller cascaded with the process is tuned for values Kp, Ki and Kd.

**Keyword:** Bacterial Foraging, Close Loop Controller, PID, PSO, Optimization.

## I. INTRODUCTION

Transformative calculation, offers down to earth focal points to the specialist confronting troublesome enhancement issues. These favorable circumstances are multifold, including the straightforwardness of the methodology, its powerful reaction to evolving situation, its adaptability, and numerous different aspects. The developmental calculation can be connected to issues where heuristic arrangements are not accessible or for the most part prompt unacceptable results. Accordingly, developmental calculations have as of late gotten expanded hobby, especially with respect to the way in which they might be connected for down to earth critical thinking. Generally assembled under the term developmental calculation or transformative calculations, we discover the spaces of hereditary calculations [2], advancement procedures [6], [7], developmental programming [1], and hereditary programming [3]. They all share a typical applied base of reenacting the advancement of individual structures by means of procedures of determination, transformation, and multiplication. The procedures rely on upon the apparent execution of the individual structures as characterized by the issue. Contrasted with other worldwide advancement systems, transformative calculations (EA) are anything but difficult to actualize and all the time they give sufficient arrangements. The stream diagram of an EA is shown in Fig. 1. A populace of applicant arrangements (for the advancement undertaking to be comprehended) is instated.

New arrangements are made by applying multiplication administrators (transformation and/or hybrid). The wellness (how great the arrangements are) of the subsequent arrangements are assessed and suitable choice system is then connected to figure out which arrangements are to be kept up into the people to come. The system is then iterated.

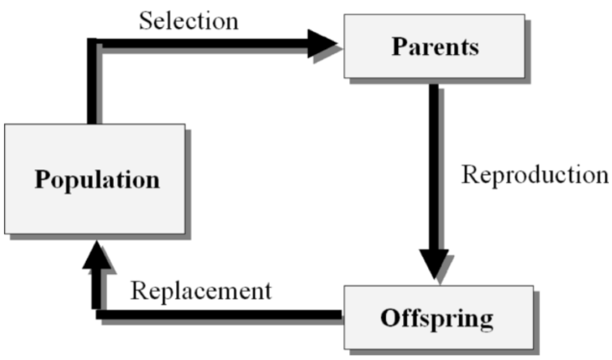


Fig.1. Flowchart of an evolutionary algorithm

The specific objectives of this research are the following:
1) To analyze the problems related tuning of PID controller in maintaining optimum response of a system and to recommend intelligent computing techniques to improve the quality of systems.
2) To develop an efficient methodology for solving complex problems of controlling response by using different evolutionary optimization algorithms.
3) To analyze and compare the results obtained using BGPSO with those obtained by conventional PID controllers.
4) To present specific recommendations on the type computational efficiency, performance characteristics and the provisions for tuning the control parameters of the algorithm based on the simulation results.

## II. RELATED WORK

There are a few outline strategies for deciding the ideal PID controller parameters of a given framework utilizing the particle swarm optimization (PSO) calculation. These works exhibited in point of interest how to utilize the PSO

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strategy to look proficiently the ideal PID controller parameters of given framework. The proposed works had unrivaled components, including simple usage, stable meeting trademark, and great computational productivity. Quick tuning of ideal PID controller parameters yields amazing arrangement. So as to help evaluating the execution of the proposed PSO-PID controller, another time-area execution paradigm capacity are additionally characterized. Contrasted and the hereditary calculation (GA), these techniques was in reality more effective and powerful in enhancing the stride reaction of a given framework [4].

**M Nagendra et.al (2012),** chipped away at multi-region power framework in nature. Thus investigation of multi-territory power frameworks (MAPS) is imperative. Essential issues of MAPS are Automatic Generation Control (AGC) which controls the framework recurrence and Automatic Voltage Regulator (AVR) that keeps framework voltage steady at appraised esteem. PID controller is a built up mechanical controller. There are numerous strategies accessible for tuning of PID controllers. Every one of these techniques are utilized as starting supposition for PID controller parameter settings. Later these settings are enhanced by calibrating. Presently a days reproduction programming projects are broadly famous. MATLAB Simulink is one of them. Subsequently we exploit reproduction instruments and propose a strategy for tuning of PID controllers utilizing recreation. This is a three stage strategy. Initial step decides the addition parameter. Second step deals with the transient execution. Third step bargains the enduring state execution. At last it results in great general execution. To begin with this technique is shown in point of interest for Automatic Voltage Regulator (AVR) of a disengaged power framework. At that point it is connected to a four territory power framework. These applications vindicate the proposed technique for tuning of PID controller [5].

**Sapna Bhati et.al (2012),** took a shot at a hereditary improvement with another wellness capacity strategy is proposed to outline a PID controller for the programmed voltage controller framework (AVR). The proposed wellness capacity is made by cost capacity to enhance the transient reaction of the controlled framework and enhance the increase. The proposed calculation connected in the PID controller outline for the AVR framework. Taking into account reproduction results, creator watched that the proposed hereditary calculation with this new wellness capacity can discover a PID control parameter set viably so that controlled AVR framework has a superior control execution [8].

**A. Karimi et.al (2013),** dealt with the historical backdrop of exploration of computational, numerous transformative calculations methodologies were proposed having pretty much achievement in taking care of different enhancement issues. The calculation is connected for numerical reenactments in view of improved PID control of a programmed controller voltage framework for ostensible framework parameters and step reference voltage information show the viability and proficiency of IHBMO methodology. Enhance Honey Bee Mating Optimization calculation and Genetic Algorithm (GA) and Big Bang-Big Crunch Optimization are connected to parameters streamlining of PID controller. Reproduction results is demonstrated that the execution of IHBMO is superior to anything GA and BB-BC, it is given that a best strategy to enhancement parameters of PID controller and the examination demonstrates the IHBMO-PID calculation has more productivity and power in enhancing the stride reaction of an AVR framework [9].

**Vivek Kumar Bhatt et.al (2013),** took a shot at a transformative processing approach for deciding the ideal estimations of the PID controller has been proposed. Legitimate tuning of such controllers is clearly a prime need as whatever other option circumstance will require a high level of mechanical mastery. This paper showed in point of interest how to utilize the PSO strategy to seek productively the ideal PID controller parameters of an AVR framework. The proposed calculation has been connected in the PID controller plan for the AVR framework. A MATLAB reproduction has been performed and a relative study between the proposed calculations with the PID Controller Tuner has been considered in the introduced work. In continuation of this, the proposed technique was undoubtedly more proficient and powerful in enhancing the stride reaction of an AVR framework [10].

**Mr. Omveer Singh et.al (2013),** attempted to build up a controller taking into account PID Controller and fluffy rationale controller to mimic a programmed voltage controller in transient solidness power framework investigation. The PID controller and the fluffy rationale controller are created to enhance the execution of the Automatic Voltage Regulator. The controller is composed in view of the scientific model of the framework utilizing Matlab recreation systems as a part of graphical interface utilizing simulix. It was mimicked a one machine control to check if the PID controller and the fluffy rationale controller usage was conceivable. After that the controller created was connected in field excitation framework to demonstrate its conduct, which results were contrasted with the outcomes acquired with the AVR itself. The AVR quality impacts the voltage level amid relentless state operation, and additionally diminishes the voltage motions amid transient periods, influencing the general framework steadiness [11].

## III. METHODOLOGY

### A. PARTICLE SWARM OPTIMIZATION

The molecule swarm improvement was proposed by Kennedy and Eberhart [12, 13]. The PSO can take care of multidimensional improvement issues. It depends on reenacting the social conduct of swarm of fledgling running, honey bees, and fish educating. By haphazardly instating the calculation with hopeful arrangements, the PSO effectively prompts a worldwide ideal. This is accomplished by an iterative method in view of the procedures of development and insight in a transformative framework.

In PSO, each potential solution is represented as a particle. A position and a velocity are associated with each

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particle. The position and velocity of the ith particle are given by

$$\vec{x_i} = (x_{i,1}, x_{i,2}, \dots \dots x_{i,n})$$
$$\vec{v_i} = (v_{i,1}, v_{i,2}, \dots \dots v_{i,n})$$

The length of each vector N represents the dimension of the problem or number of unknown variables. In each iteration, a fitness function is evaluated for all the particles in the swarm. This function should be carefully formulated to reflect the desired result. The position and velocity of each particle are updated according to individual best, xbesti , and global best, xbest, fitness as

$$v_i^{n+1} = \gamma^n v_i^n + c_1 \beta_1^n \left(x_i^{\text{best}} - x_i\right) + c_2 \beta_2^n \left(x^{\text{best}} - x_i\right),$$
$$x_i^{n+1} = x_i + \Delta t v_i^{n+1}$$

The superscripts n+1 and n denote the time index of the current and the previous iterations and β1 and β2 are random numbers that are uniformly distributed in the interval [0, 1]. These random numbers are updated every time they occur. The relative weights of the personal best position versus the global best position are specified by the parameters c1 and c2, respectively. Both c1 and c2 are typically set to a value of 2.0. The parameter γn is the "inertia weight" in the nth iteration. It is a number in the range [0, 1] that specifies the weight by which the particle's current velocity depends on its previous velocity, and the distance between the particle's position and its personal best and global best positions. It has been shown in [14] that the PSO algorithm converges faster if γ is linearly damped with iterations, for example starting at 0.95 at the first iteration and finishing at 0.4 in the last iteration. The velocity is applied for a given time-step t which is usually chosen to be one.

### B. BASIC BACTERIAL FORAGING OPTIMIZATION (BFO)

The choice conduct of microorganisms has a tendency to dispose of poor scavenging procedures and enhance effective scrounging techniques. After numerous eras a rummaging creature takes activities to boost the vitality got per unit time spent scavenging. This movement of scavenging drove the scientists to utilize it as improvement procedure. The E coli bacterium has a control framework that empowers it to hunt down nourishment and attempt to maintain a strategic distance from noxious substances.

### C. THE BACTERIAL SWARM OPTIMIZATION ALGORITHM

In 2001, Prof. K. M. Passino proposed an enhancement strategy known as Bacterial Foraging Optimization Algorithm (BFOA) in light of the searching procedures of the E. Coli bacterium cells [15]. Until date there have been a couple of effective uses of the said calculation in ideal control designing, symphonious estimation [16], transmission misfortune lessening [17], machine learning et cetera. Experimentation with a few benchmark capacities uncover that BFOA has a poor joining conduct over multi-modular and harsh wellness scenes when contrasted with other actually propelled enhancement procedures like the Genetic Algorithm (GA) [18] Particle Swarm Optimization (PSO) [19] and Differential Evolution (DE) [13]. Its execution is likewise intensely influenced with the development of inquiry space dimensionality. In 2007, Kim et al. proposed a half and half approach including GA and BFOA for capacity advancement [20]. The proposed calculation outflanked both GA and BFOA over a couple of numerical benchmarks and a commonsense PID tuner plan issue.

### D. HYBRID EVOLUTIONARY ALGORITHMS

As reported in the literature, several techniques and heuristics/metaheuristics have been used to improve the general efficiency of the evolutionary algorithm. Some of most used hybrid architectures are summarized as follows:

1. Hybridization between an evolutionary algorithm and another evolutionary algorithm (example: a genetic programming technique is used to improve the performance of a genetic algorithm)
2. Neural network assisted evolutionary algorithms
3. Fuzzy logic assisted evolutionary algorithm
4. Particle swarm optimization (PSO) assisted evolutionary algorithm
5. Ant colony optimization (ACO) assisted evolutionary algorithm
6. Bacterial foraging optimization assisted evolutionary algorithm
7. Hybridization between evolutionary algorithm and other heuristics (such as local search, tabu search, simulated annealing, hill climbing, dynamic programming, greedy random adaptive search procedure, etc)

## IV. RESULT AND DISCUSSION

In this work our objective was to check the performance of Bacterial Foraging behavior base PSO technique for finding an optimum value of Kp, Ki, and Kd gains for a PID controller. This objective is achieved by finding global minimum error in the step response of different types of transfer functions. Two kinds of transfer functions are considered Type0 and Type1. In the Type1 transfer functions no integral gain (Ki) is required to find because they already have low steady state error in step response. Hence for Type1 cases we have determine only Kp and Kd gains and for Type0 system we have determined all Kp, Kd and Ki gains.

The performance of developed Bacterial Foraging PSO algorithm (BSO) and basic PSO is tested for a system transfer function of different order. We have considered seven transfer functions named as TF1 to TF7. For each transfer function we have run our BSO and PSO algorithm several times and we found five best results giving minimum error are shorted out for both algorithm and finally we have compared the best response of BSO against the PSO.

In the subsequence section we will discuss the results of our different transfer functions or discuss the detail and compared in the form of step response plot and peak over shoot values for both algorithms.

The TF1 transfer function has following equations it is a fourth order system with Type1 without having 0.

$$\text{TF1} = \frac{S+5}{S^4 + 17S^3 + 60\,S^2 + 10\,S}$$

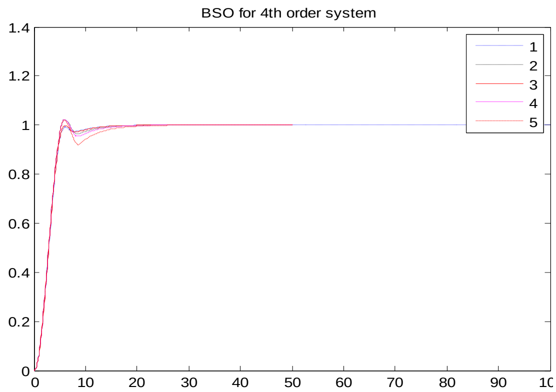


Fig. 2 (a) Step Response for BSO based optimum PID value

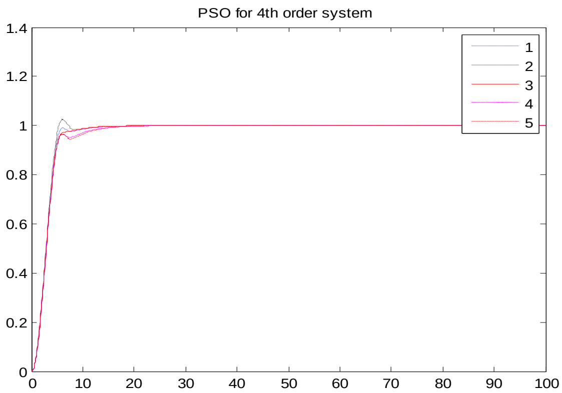


Fig. 2 (b) Step Response for PSO based optimum PID value

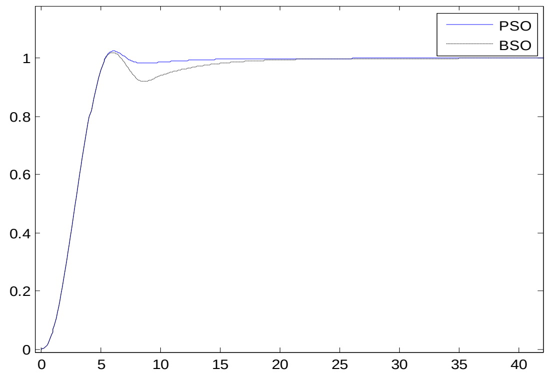


Fig. 2 (c) Comparison of Step Response for BSO and PSO based optimum PID value

Table 1: Controller performance for different system cases

| | **Peak overshoot by PSO:** | **Peak overshoot by BSO:** |
|---|---|---|
| Case1 | -0.000000000000196 | -0.000000000000158 |
| Case2 | 0.024897113162271 | 0.023107101222726 |
| Case3 | -0.000000000000158 | -0.000000210061198 |
| Case4 | -0.000000000001012 | 0.022295867486398 |
| Case5 | -0.000000000001429 | 0.020736526713352 |
| **Min. Peak Over shoot** | **0.024897113162271 (case 2)** | **0.020736526713352 (case 5)** |

## V. CONCLUSION

PSO has the higher cost function as compared to BSO. In all cases (BSO) results in a lower overshoot compared to PSO. In future we can check our results for considering other performance parameters of system response like settling time, rise time and steady state error. We can also consider performance indices as an objective to see system performance. There are many recent modifications are present in PSO these can also be included to generate our BSO algorithm for tuning of PID controller.

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