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Robust PID controller Design using Particle Swarm Optimization for Magnetic Levitation System

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Abstract- The PID controller is widely used in industries due to its simple design and stable operation**.** Though PID controller produces a controlled output for stable and unstable systems, the performance of the system under disturbance is poor. To make the PID controller robust under various environments, Particle Swarm Optimization (PSO) algorithm is used to design the controller. The simulation is carried out for a test system of magnetic levitation. The robust in terms of Integral Square Error (ISE) are poor The control of a magnetic levitation system using PSO based PID controller is proposed in this paper. To solve this problem PSO based tuning of PID controller is demonstrated. The results are compared with classical PID controller.

Keywords- PID controller, PSO, Magnetic Levitation system.

I. INTRODUCTION

Magnetic levitation is the process presents in many industrial applications such as vibration damping, transportation system, etc. The nonlinear nature of the system dynamics coupled with the actuator makes the system design to be complicated. The control problem deals with the design of the optimal controller for both off-line and on-line industrial applications by minimizing the cost function and other concerned objective function, while satisfying a given set of physical and operating constraints like robustness, etc. More than 90% of industrial controllers are still implemented based on PID control algorithms, because of its simplicity, clear functionality, applicability and ease of use offered by the PID controllers [1]. Proportional-Integral-Derivative (PID) control offers the simplest and yet the most efficient solution for many real world control problems [2],[3]. Three-term functionality of PID controller covers treatment of both transient and steady state responses. The popularity of PID control has grown tremendously, since the invention of PID control in 1910 and the Ziegler-Nichol's tuning method in 1942. Tuning of conventional controllers (P, PI and PID) is related to obtain an optimum setting of controller parameters. Ziegler-Nichols (ZN) and Cohen-Coon (CC) are the most commonly used conventional methods for tuning PID controllers [4] and neural network, fuzzy logic based approach, neuro-fuzzy approach and evolutionary computation techniques are the recent methods [5]. Various EAs such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO) [6] have been successfully applied for optimization problems. Chapter II describes the system model considered for simulation. Chapter III gives the introduction of Evolutionary algorithm and the Modified PSO algorithm. Chapter IV deals with the Controller structure. Chapter V shows the Simulation Results and the last Chapter VI gives the conclusion of the paper.

II. SYSTEM DESCRIPTION

Let us consider the unity feedback system consisting of the linearized model of the experimental magnetic levitation system. The linearized model of the magnetic levitation plant about an equilibrium point of $y = 0.018m$ is given as Equation (1).

$$P(s) = \frac{7.147}{(s-22.5)(s+20.9)(s+13.99)} \qquad (1)$$

To treat the robust H_∞ disturbance attenuation problem, the weighting function is chosen as per Equation (2).

$$W_s(s) = \frac{5}{s+1} \qquad (2)$$

III. EVOLUTIONARY ALGORITHMS

The field of evolutionary computation has experienced significant growth in the optimization area, thanks to the recent advances in computation. These algorithms are capable of solving complex optimization problems such as those with a discontinuous, non-convex and highly nonlinear solution space. Figure. 1 Typical flowchart illustrating an Evolutionary Algorithm.

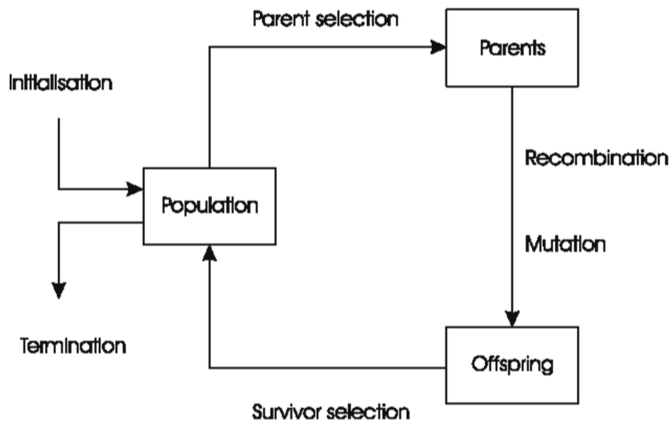

Figure. 1 Typical flowchart illustrating an Evolutionary Algorithm

3.1 Modified Particle Swarm Optimization (MPSO)

Kennedy and Eberhart (1995) proposed the PSO algorithm conceptually based on social behaviour of organisms such as herbs, schools and flocks. PSO is a pseudo- optimization method (heuristic) inspired by the collective intelligence of swarms of biological populations. The system initially has a population of random solutions. Each potential solution, called particle, is given a random velocity and is flown through the problem space. The particles have memory and each particle keeps track of previous best position and corresponding fitness. The previous best value is called *pbest.* Thus, *pbest* is related to a particular particle. It also has another value called *gbest*, which is the best value of all the particles *pbest* in the swarm. The basic concept of PSO technique lies in accelerating the particle towards its *pbest* and the *gbest* locations at each time step. Acceleration has random weights for both *pbest* and *gbest* locations.

3.2 MPSO Algorithm

The step-by-step algorithm of MPSO is given below.

Step 1: Initialize a population (N) of particles with random positions and velocities of d dimensions in the problem space

Step 2: For each particle, evaluate the desired optimization fitness function.

Step 3: Compare particle’s fitness evaluation with particles pbest.

Step 4: Compare fitness evaluation with the population’s overall previous best. If the current value is better than gbest (p_{gd}), then reset gbest to the current particles array index and value.

Step 5: Change the velocity and position of the particle according to Equation (3) and Equation (4) respectively. v_{id} and x_{id} represent the velocity and position of i^{th} particle with d dimensions respectively and *rand1* and *rand2* are two uniform random functions.

$$v_{id} = \omega v_{id} + c_1 * rand1 * (p_{id} - x_{id}) + c_2 * rand2 * (p_{gd} - x_{id}) \quad (3)$$

$$x_{id} = x_{id} + v_{id} \quad (4)$$

Step 5: Repeat from Step 2 until a stopping criterion is met, this is usually a sufficiently good fitness or a maximum number of iterations/function evaluations.

Recently PSO algorithm is used as an optimization tool in various fields [7].

IV. CONTROLLER STRUCTURE

Robust PID controller structure

The robust PID controller structure considered for ML system is given by Equation (5).

$$K(s) = 10^{x_1}\left(1 + \frac{1}{10^{x_2}\, s} + \frac{10^{x_3}\, s}{1+10^{(x_3-x_4)}\, s}\right), \quad x \in R^4 \tag{5}$$

V. SIMULATION RESULTS

In order to validate the performance of the PSO algorithm on the design of the PID controller a simple Magnetic Levitation system (ML) [8] is considered.

Table 1. Robust PID controller structure and its parameter range

Test system	**Controller Structure**	**Search space of design parameter**
ML	$K(s) = 10^{x_1}\left(1 + \frac{1}{10^{x_2}\, s} + \frac{10^{x_3}\, s}{1+10^{(x_3-x_4)}\, s}\right)$	$x \in R^4$; $(2,-1,-1,2)^T \le x \le (4,1,1,3)^T$

The controller variable $x \in R^4$ for ML system denotes the controller design parameter vector. Owing to the randomness of the evolutionary algorithms, statistical performances like the best, the mean and the worst value of objectives obtained in 10 independent runs are taken. For fair comparison, the population size (*N*) and maximum function evaluations (*Fevalmax*) as that of Constrained PSO (CPSO) [8] are used. The PSO parameters considered for the design is given in Table 2. The convergence of the PSO algorithm is shown in Figure 2. From the figure 2, it is clear that the algorithm converges and gives the optimum design values. The impulse response for the Magnetic Levitation system with the proposed controller is shown in Figure 3. The response settles to zero at the steady state.

Table 2. PSO parameters: Robust PID controller

Design variables (*n*)	4
Population size (*N*)	100
Fevalmax	40,000
Convergence criteria (*TolF*, *TolX*)	1e-4

The simulations are carried out with stopping criteria, maximum number of functional evaluations (Fevalmax).

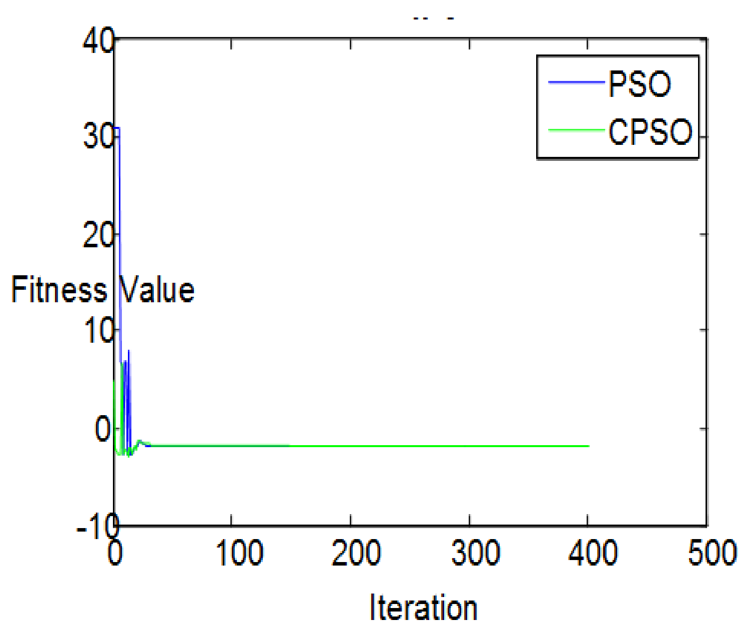

Figure 2. Convergence characteristics of EAs: ML System

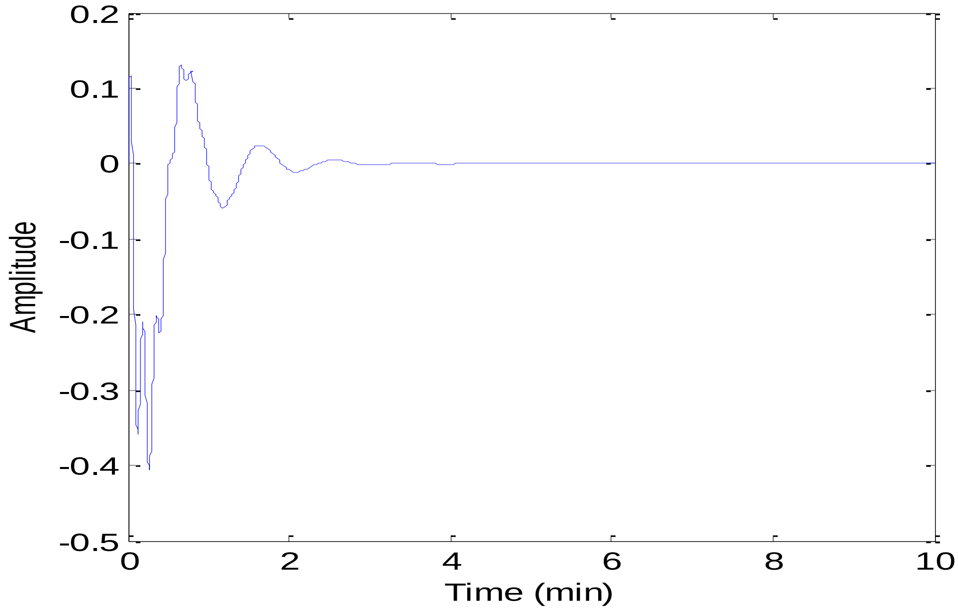

Figure 3. Impulse Response : ML system

VI. CONCLUSION

The proposed PSO based PID controller for the magnetic levitation system considering the robustness works better. The step response of the ML system and the convergence of the proposed EA algorithm show the performance of the EA algorithm and the controller.

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