

Design of PID Controller using PSO Algorithm for CSTR System

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Abstract

The paper Present to design PID controller parameters for an CSTR system using pso Algorithm. The design goal is to minimize the optimal parameters of the integral errors and reduce transient response by minimizing overshoot, settling time and rise time of step response. First an objective function is defined, and then by minimizing the objective functions using PSO Algorithm. The CSTR system is very important equipment in chemical and biochemical industry. Various control approaches have been applied on CSTR to control its parameters. We want to control concentration of chemical in CSTR system for Stability.

Keywords— CSTR system, Feedback System, PSO, PID Controller.

INTRODUCTION

To design a PID Controller for cstr system using PSO algorithm. The model of a Continuous Stirred Tank Reactor modal is used as a plant. The main objective is to obtain a stable, robust and controlled system using PSO. The CSTR system is modeled in Simulink and the PSO algorithm is implemented in MATLAB. Comparing with Genetic algorithm and Particle swarm optimization (PSO) method, the proposed method was more efficient in improving the step response characteristics such as, reducing the steady-states error, rise time, settling time and maximum overshoot of a CSTR system. CSTR involves complex reactions with high nonlinearity, and it is very hard to be controlled by the conventional methods. However, to avoid computational complexity brought in by such nonlinear controller. Pso Algorithm (PSO) based PID controller tuning is attempted for the concentration control of Continuous Stirred tank reactor (CSTR). Based on the Performance indexes

and criterion controller can be estimated. The Integral Square Error (ISE) criterion is used to guide Pso algorithm to search the controller parameters like K_p , K_i , K_d . Simulation is carried out with PID controller Structures. The comparison between PSO-based PID (PSO-PID) performance and the GA-PID is presented. CSTRs are very important equipment in the chemical and biochemical industry, offering a diverse range of researches in the area of the chemical and control engineering. Various control approaches have been applied on CSTR to control its parameters. Due to its strong non-linear behavior, the problem of identification and control of CSTR is always a challenging task for control system engineer [1].

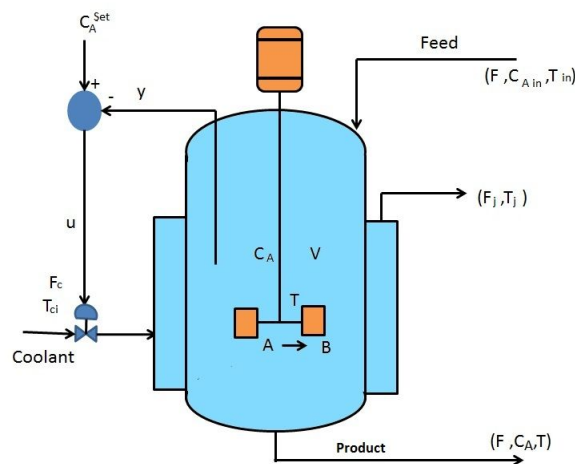


Fig 1 CSTR system.

PROBLEM FORMULATION

The Project is objected to design a PID controller for Continuous Stirred Tank Reactor. The cstr system has second order transfer function.. $T(s) = \frac{-1.17s+3.1472}{s^2 + 4.6429s+5.3821}$

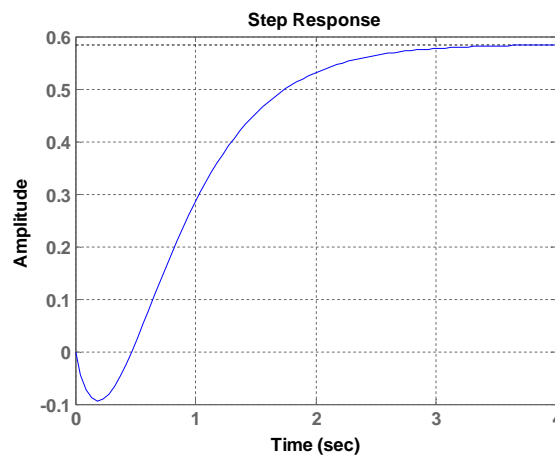


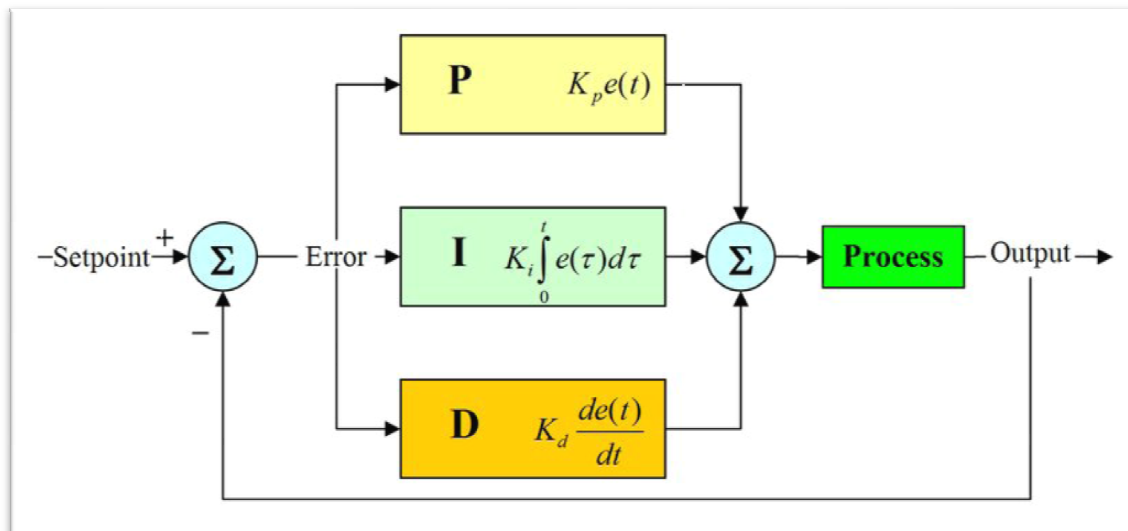
Fig 2: Step Response of CSTR system

Table 1: Parameter of Step response of plant Without PID

RISE TIME	SETTLING TIME	UNDERSHOOT
1.3744	2.7130	16.0688

PID CONTROLLER

Proportional-Integral Derivative (PID) controllers have been widely used for speed and position control of various applications. Among the conventional PID tuning methods, the Ziegler–Nichols method may be the most well known technique. For a wide range of practical processes, this tuning approach works quite well. However, sometimes it does not provide good tuning and tends to produce a big overshoot [2]. Therefore, this method usually needs retuning before applied to control industrial processes. To enhance the capabilities of traditional PID parameter tuning techniques, several intelligent approaches have been suggested to improve the PID tuning. In a PID controller, each mode (proportional, integral and derivative mode) has a gain to be tuned, giving as a result three variables involved in the tuning process. There have been a lot of approaches to search the parameters of PID controllers, including time response tuning, time domain optimization, frequency domain shaping. The speed response of the drive with PID controllers designed with the above techniques may be satisfactory but not necessarily be the best, since they do not pose any constraint on settling time, overshoot / undershoot etc.

**Fig 3:** PID Controller

PID is a feedback based controller which gets the error value and calculates the output based on the characteristics of the error. It is very widely used in plants as it is simple and gives good results. PID is used in a closed loop. It has three elements P, I,

D. Every parameter has gain by which we control the contribution. Proportional-Integral Derivative (PID) controllers have been widely used for speed and position control of various applications. Among the conventional PID tuning methods, the Ziegler–Nichols method may be the most well known technique. For a wide range of practical processes, this tuning approach works quite well. However, sometimes it does not provide good tuning and tends to produce a big overshoot.

PSO ALGORITHM

PSO is optimization algorithm based on evolutionary computation technique. The basic PSO is developed from research on swarm such as fish schooling and bird flocking. After it was firstly introduced in 1995, a modified PSO was then introduced in 1998 to improve the performance of the original PSO. A new parameter called inertia weight is added. This is a commonly used PSO where inertia weight is linearly decreasing during iteration in addition to another common type of PSO which is reported by Cleric. The later is the one used in this paper. In PSO, instead of using genetic operators, individuals called as particles are “evolved” by cooperation and competition among themselves through generations. [3] A particle represents a potential solution to a problem. Each particle adjusts its flying according to its own flying experience and its companion flying experience. Each particle is treated as a point in a D-dimensional space. The it particle is represented as $XI=(xi1, xi2, \dots, xin)$. The best previous position (giving the minimum fitness value) of any particle is recorded and represented as $PI=(pi1, pi2, \dots, piD)$, this is called pbest. The index of the best particle among all particles in the population is represented by the symbol g, called as gbest. The velocity for the particle i is represented as $VI=(vi1, vi2, \dots, viD)$. The particles are updated according to the following equations:

$$V_{i,m}^{(t+1)} = W \cdot V_{i,m}^{(t)} + C_1 * \text{rand}() * (Pbest_{i,m} - X_{i,m}^{(t)}) + C_2 * \text{rand}() * (gbest_m - X_{i,m}^{(t)})$$

$$X_{i,m}^{(t+1)} = X_{i,m}^{(t)} + V_{i,m}^{(t+1)}$$

Where $c1$ and $c2$ are two positive constant. As recommended in Clerc’s PSO, the constants are $c1=c2=1.494$. While $\text{rand}()$ is random function between 0 and 1, and n represents iteration. Eq. is used to calculate particle’s new velocity according to its previous velocity and the distances of its current position from its own best experience (position) and the group’s best experience. Then the particle flies toward a new position. The performance of each particle is measured according to a pre-defined fitness function which is related to the Problem to be solved. Inertia weight, w is brought into the equation to balance between the global search and local search capability. It can be a positive constant or even positive linear or nonlinear function of time A guaranteed convergence of PSO proposed by Clerc set $w=0.729$. It has been also shown that PSO with different number of particles (swarm size) has reasonably similar performance. Swarm size of 10-50 is usually selected.

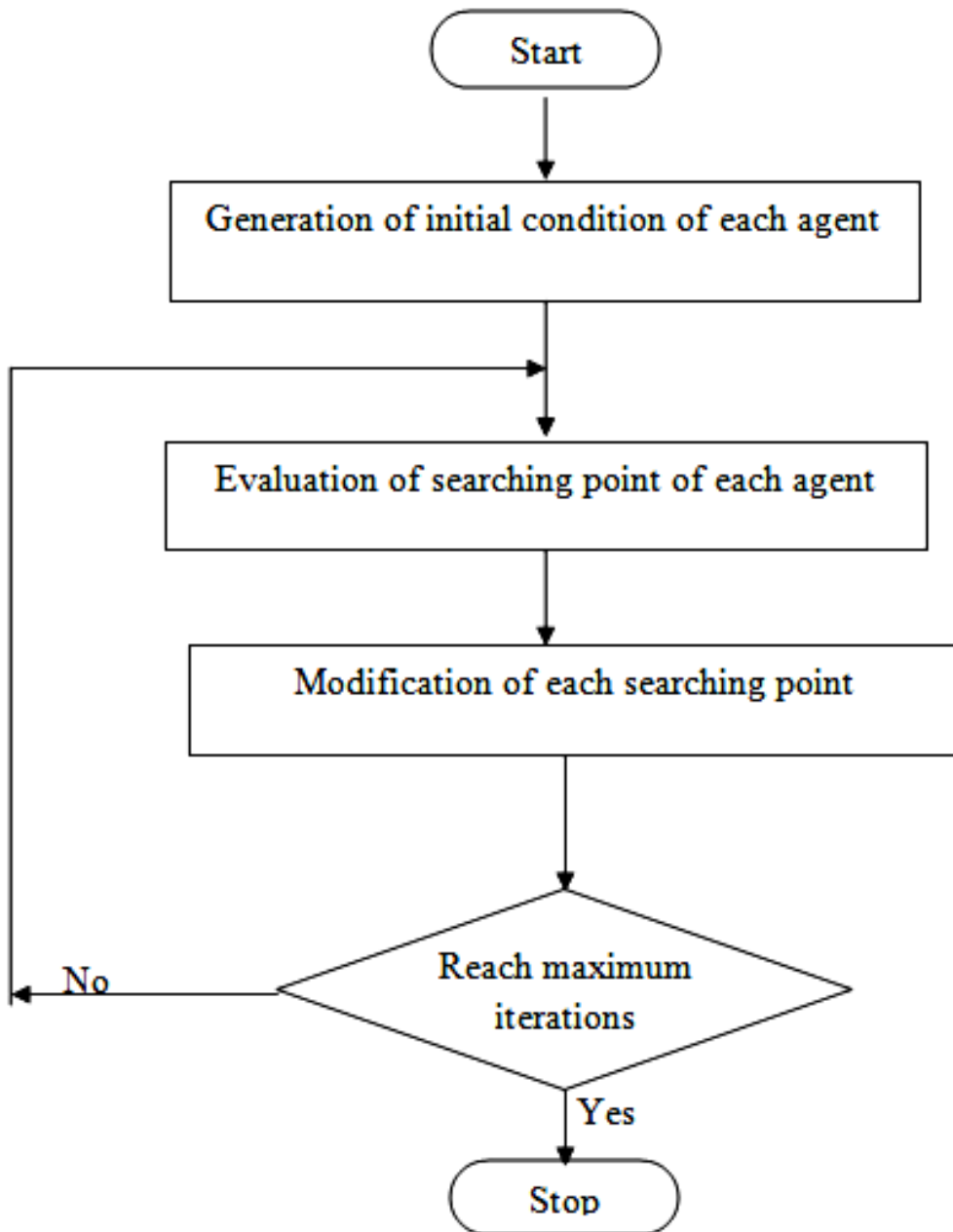


Fig 4: PSO Algorithm Process Flowchart

PERFORMANCE EVALUATION CRITERIA

Quantification of system performance is achieved through a performance index. The performance selected depends on the process under consideration and is chosen such that emphasis is placed on specific aspects of system performance. 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, ITAE They are defined as follows:

$$ISE = \int_0^{\infty} e^2(t) dt$$

IAE Index:

$$IAE = \int_0^{\infty} |e(t)| dt$$

ITAE Index:

$$ITAE = \int_0^{\infty} t|e(t)| dt$$

SIMULATION AND RESULTS

Transfer function of UNDER -DAMPED CSTR system:

$$T(s) = \frac{-1.17s + 3.1472}{s^2 + 4.6429s + 5.3821}$$

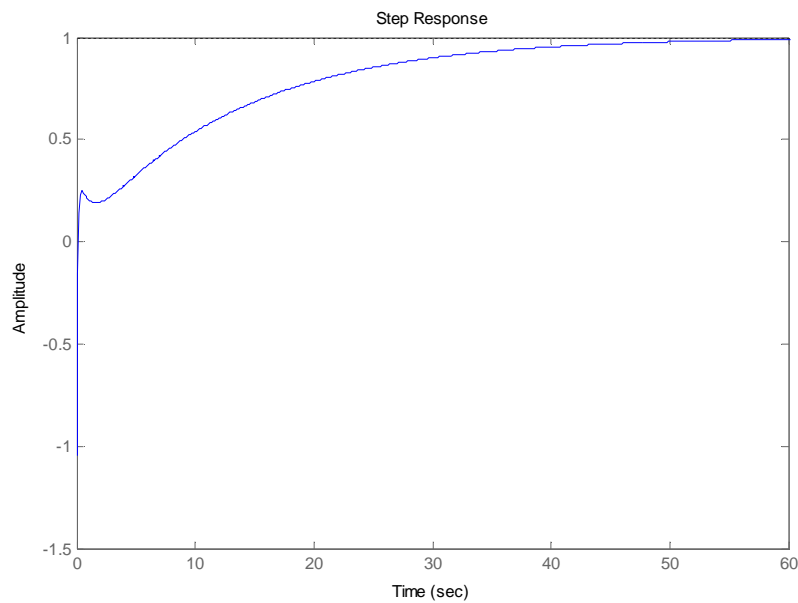


Fig 5: Step Response of PID Controller Using Pso Algorithm

Table2. Parameter of Step response of plant with PID

Rise Time	Settling Time	Overshoot	Undershoot
20.6336	41.7534	0	104.7443

Table 3: Parameter gain of Pso Algorithm Tune PID control system

kp	Ki	kd
0. 2329	0. 1339	0. 4580

VI. Conclusion

The tunable results obtained are compared with the un-tunable results obtained from pso algorithms (PSO). This comparison shows that there is an acceptable agreement between these results.

We can see from the results that there is error between step response of PID controller of CSTR system. To reduce error we apply the PSO optimization algorithms. We design the PID controller parameters for CSTR system.

We observe the system performance of PID controller of CSTR system.

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