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PSO Based PID Controller for Hard Disk Controller

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Abstract: ***In today's fast growing world, there is an urgent need to increase the production rate in process industries which consists of numerous non-linear processes. Hence it is important to design a stabilizing controller. The aim of the paper is to design optimum Proportional- Integral- Derivative (PID) controller using Particle Swarm Optimization (PSO). In this paper the algorithm is applied to control the position head of the hard disk controllers using both PID and PSO-PID controllers. The performance of PID controller is compared with PSO-PID controller by calculating Overshoot value, Rise time, Settling time and Steady state error in both the cases. According to simulation and experimental results PSO-PID controller is proven to be more efficient and result also suggests that PSO converges with less number of functional evaluations.***

Keywords: Particle Swarm Optimization (PSO), Proportional- Integral- Derivative (PID), Ziegler Nichols Rule, Hard Disk

1. Introduction

PID controllers are the most widely used feedback controllers in process industries and it is strengthen by the fact that it is used in more than 80% of these industries. One of the major reasons for its world-wide acceptance is because of its optimal performance in most of the applications. There are many feedback controllers in the control theory but most of them need a good mathematical model of the plant you want to control in order that they work. PID controller does not need an elaborated model of the plant and they are easy to tune. It can be tuned by users without any extensive knowledge on controllers unlike most of the complicated new age controllers which shows minimal improvement in performance. The PID controller is an effective control system and performs three control tasks. The proportional (P) action is a type of linear feedback control and changes the input according to the generated controller error and the manipulated input is proportional to this error. The integral (I) action increases over time unless error is zero, and its purpose is to drive steady state error to zero. The overall controller output is the sum contribution of these three terms.

There are several methods for tuning these controller actions in PID controllers such as [1] & [2].

- Ziegler-Nichols Rule
- Cohen-Coon Rule
- Chien- Hrones- Reswick Rule

Methods such as the Ziegler–Nichols tuning method are experimental and require integral and derivative to be set to zero and then proportional gain to be increased till a finite value. Another method such as, Skogestad's method is model-based method where PID parameters are expressed as functions of process model parameters and we can get the result, without doing any experiment. Still, it requires verification, if the PID tuning is proper, by simulation. But all of the above mentioned tuning algorithms are comparatively intricate and pose a lot of difficulty in making the output response optimized with the worse vibration and overshoot.

Nowadays many researches are dedicated to improve the optimization of PID controllers and in this paper we propose a method for the parameter search of PID controller by Particle swarm optimization. The results of PSO-PID are compared with various tuning algorithms of PID in this paper and it was concluded that PSO-PID shows better performance. Thus, PSO-PID algorithm is one of the best methods for the tuning of PID controller.

Hard disk was controlled using both PSO-PID and PID controllers. Hard disk drives are important data-storage medium for computers and other data-processing systems [3]. An amalgam of age-old control techniques, such as Reference signal shaping for track-seeking stage [4], track following output feedback controllers and proportional-integral-derivative (PID) compensators in the track following stage are used to control tracking in the HDD systems [5] & [6]. But these classical methods are of no longer use, since, they cannot meet the demand of modern high speed and high memory hard disk drives. Many methods were previously proposed and tried to eliminate the dependency on classical methods or improve them. One such method was devised by Zhang and Guo [7] which incorporated the time optimal control idea for track seeking stage into the time-varying sliding mode control technique. Other methods like Linear quadratic Gaussian (LQG) and LTR approach were also tested. In this paper hard disc will be controlled using PSO-PID controller and the results will be compared with hard disc controlled with PID controller.

2. Algorithm

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. Each particle is treated as a point in a N-dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, pbest. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called gbest.

The basic concept of PSO lies in accelerating each particle toward its pbest and the gbest locations, with a random weighted acceleration at each time step.

A basic PSO algorithm is then:
1. Create a 'population' of agents (particles) uniformly distributed over X.
2. Evaluate each particle's position according to the objective function.
3. If a particle's current position is better than its previous best position, update it.
4. Determine the best particle (according to the particle's previous best positions).
5. Update particles' velocities:
v= inertia + cognitive + social
$v = v + c_1 * rand * (pBest - p) + c_2 * rand * (gBest - p)$
where
p: particle's position
v: path direction
c_1: weight of local information
c_2: weight of global information
pBest: best position of the particle
gBest: best position of the swarm
rand: random variable
6. Move particles to their new positions:
p = p + v
7. Go to step 2 until stopping criteria are satisfied

There are many advantages of using PSO algorithm as it is insensitive to scaling of design variables, simple to implement, easily parallelized for concurrent processing, derivative free, very few algorithm parameters and very efficient global search algorithm

3. Approach for Solving This Problem

Following were the steps performed to execute this algorithm:

1. Implied a Ziegler Nicholas criterion on the given transfer function to find out the tuning parameters of the PID algorithm.
2. Then find out the timing parameters of the system.
3. Since the tuning parameters found out by the Ziegler Nicholas criterion does not provide the optimized solution, so we applied PSO algorithm on the PID with the range of ±10% in the values of the kp, ki and kd.
4. Then the timing parameters where calculated for each iterations and the list of the parameters calculated are:
- Overshoot value
- Rise Time
- Settling time
- Steady State Error
5. Compute the evaluation value of each and every individual present in the population with the help of the evaluation function
f=1/W(K)
where,

$min_{K:\ stabilizing}\ W(K)= (1- exp(-\beta)).\ (M_p+ E_{ss})+ exp(-\beta).\ (t_s- t_r)$

6. Compare each individual's evaluation value with its pbest. The best evaluation value among the pbest is denoted as gbest.
7. Velocity Function as
$v_{j,g}^{(t+1)} = w.v_j^{(t)} + c_1^* rand()*(pbest_{j,g} - k_{j,g}^{(t)}) + c_2^* Rand()*(gbest_g - k_{j,g}^{(t)})$
j=1,2,3….
g=1,2,3….
where
$w= w_{max} - ((w_{max} - w_{min})/iter_{max}).\ iter$
where
itermax total number of iterations
iter current iteration value
t pointer of iterations (generations)
$v_{j,g}^{(t)}$ velocity of particle j at iteration t,
$V_g^{min} <= v_{j,g}^{(t)} <= V_g^{max}$
w inertia weight factor
c1, c2 acceleration constant
rand(), Rand() random number between 0 and 1
w_{max}, w_{min} upper and lower boundary for inertia weight factor

$pbest_j$ best location of particle j
gbest global best solution's location determined by all the particles

8. If $v_{j,g}^{(t+1)} > V_g^{max}$, then $v_{j,g}^{(t+1)} = V_g^{max}$ [8]
$v_{j,g}^{(t+1)} < V_g^{min}$, then $v_{j,g}^{(t+1)} = V_g^{min}$

9. Modify the member's position of individual K
$k_{j,g}^{(t+1)} = k_{j,g}^{(t)} + v_{j,g}^{(t+1)}$,
$k_g^{min} \le k_{j,g}^{(t+1)} \le k_g^{max}$ [9]

When the maximum number of iterations where reached the individual that generated the gbest was considered as the optimal solution and all the results were recorded.

A block diagram showing the overall work flow is given in the figure 1 shown below:-

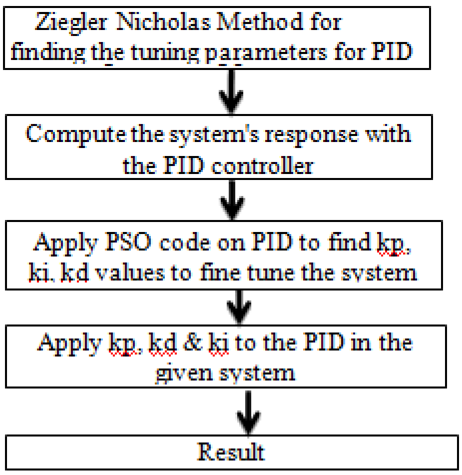

Figure 1: Block Diagram showing steps used in methodology

4. Problem Statement

Transfer Function of the position hand of Hard Disk Controller (shown below)

G(s) = (K * e (-theta * s)/ (T * s +1)

where, K=14.9, theta=80, T=360

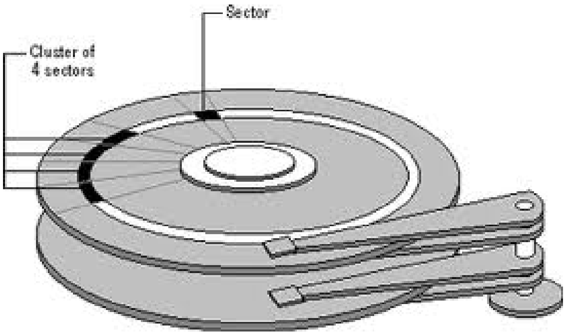

Figure 2: Hard Disk Controller

5. Simulation Results

1. kpmin=0.4; kpmax=0.6
2. kimin=0.04; kimax=0.06
3. kdmin=2.97; kdmax=3.1
4. population size = 50
5. inertia weight factor wmin=0.4 and wmax=0.9

Figure 3 and figure 4 explain the output characteristic of the system when operated with PID controller and PSO-PID controller respectively. Rise time, settling time, peak time, overshoot and peak value from the figures given below was calculated and the obtained results are shown in Table 1 given below.

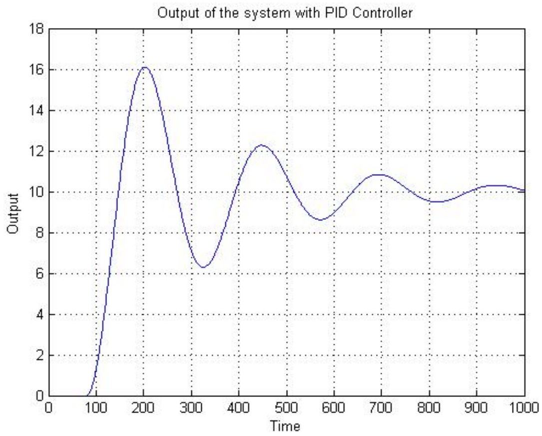

Figure 3: PID Algorithm result

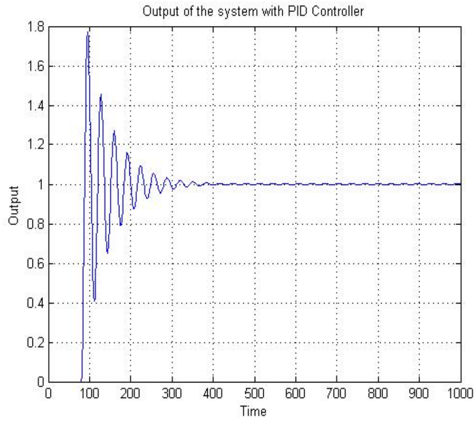

Figure 3: PSO-PID Algorithm result

Table 1: Comparison of Performance of PSO-PID and PID

Timing Parameters	Case I (PID)	Case II (PSO-PID)	Dominating Case
Rise Time	44.938011064	5.511056672	II
Settling Time	9.658126e+02	3.07139e+02	II
Overshoot	60.140771001	76.93830294	I
Peak	16.095665946	1.769383131	II
Peak Time	202	95	II

6. Conclusion

From the above table we can observe clearly that in case of PSO-PID, rise time, settling time, peak and peak time are much more improved than in the case of PID. Though the overshoot value of the case I (PID) is less than that case II (PSO-PID) but by the various values changes it is clear that the PSO applied PID gives a much better controlling results for the hard disk then the normal PID controlled hard disk. These results help us to reduce the irregularities presented by the hard disk controller and thus it can be controlled in an efficient manner. It will also help to have an optimal control of the various control systems.

7. Future Scope

In PSO-PID method overshoot value should be further decreased. So focus must be on overshoot value in order to improve this method. This method must be compared with all the other prevailing methods used in the controller of hard disk. It can effectively replace PID controllers.

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