Design of PID Controller Based on PSO Algorithm

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Abstract

Particle swarm optimization (PSO) is a kind of adaptive stochastic optimization algorithm based on population search strategy. At present, it has been widely used in function optimization problems and has shown great potential. This article in the analysis based on the evolutionary principle of PSO algorithm proposed an improved particle swarm optimization (PSO) algorithm to improve the optimization performance, and compared with other algorithms, the algorithm of PSO. It is proved that the superiority of PSO algorithm, at last, the improved PSO algorithm and genetic algorithm are compared through MATLAB simulation proved the feasibility of the method.

Keywords

PSO algorithm, PID controller, Industrial control , Parameter.

1. Introduction

PID controller has been the most widely used controller in industrial control system, PID controller can be satisfied with most of the simple industrial process. But when the control system more complicated, or charged with the model of the object changes or due to the disturbance signal of the system stability and dynamic performance affected, the 3 proportion of fixed before the PID controller, integral and differential parameters is very difficult to satisfy the system requirements of a, so in the application of PID controller, the adjustment and optimization of three parameters has been the hot issues in the research of PID controller. The PID parameter tuning method based on the PSO optimization algorithm is a kind of practical value, high efficiency and accurate parameter optimization method. This algorithm has been listed as one of the topics discussed in the "international evolutionary computation conference" (CEC). The PSO algorithm is introduced into the PID parameter tuning technique, which provides a new way of thinking and method for the PID parameter tuning.

Particle swarm optimization algorithm is proposed by the United States computational intelligence research scholar Eberhart and psychology expert Dr. Kennedy in 1995. Particle swarm optimization algorithm is a kind of intelligent stochastic optimization algorithm, which is derived from the foraging behavior of birds. In the particle swarm optimization algorithm, each particle is represented by an abstract bird, which represents a possible solution to the problem. Particle search in the multidimensional solution space to simulate the foraging process of birds, so as to solve the problem to be optimized. PSO algorithm from the start had a definite social psychology characteristics, at the same time, the algorithm search formula is simple and easy to implement, from proposing to now more than ten years has been the rapid development and wide application, is still a hot topic in the research of swarm intelligence.

2. An overview of the PSO algorithm

2.1 Principles of the PSO Algorithms

Particle swarm optimization algorithm was first proposed by Eberhart and Kennedy in 1995. PSO solution is a particle solution space, each particle has a velocity to determine their moving direction and distance Then the particle swarm follows the current optimal particle, and finds the optimal solution in the solution space by iteration. In each iteration, the particle updates itself by tracking the two extremes. The first one is the optimal solution found by the particle itself, which is called the individual extremum(Particle B_{best}, P_{best}), and the other is the optimal solution of the whole particle swarm, which is called the global extremum(Global B_{best}, g_{best}).

Suppose in a D dimensional search space, there are S particles, the position and velocity of each particle are expressed as: X_j = (xi1, xi2, ..., x_{iD}), V_j = (vi1, vi2, ..., V_{iD}), i=1, 2, ..., S. The best location of each particle so far is denoted as P_j = (P_{11}, P_{12}, ..., P_{iD}), So far the best location in the whole particle swarm is P_g = (P_{g1}, P_{g2}, ..., P_{gD}). PSO algorithm with the inertia weight of each iteration, the particle I the first j dimension of the speed V_{ij}, and the location of X_{ij} according to the following expression update:

$$v_{ij}(t+1) = wv_{ij}(t) + c_1 r_{1j}(t)(p_{ij} - x_{ij}(t)) + c_2 r_{2j}(t)(p_{gj} - x_{ij}(t)) \quad (1)$$

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \quad (2)$$

there are some parameters that need to be adjusted of PSO, the following lists the parameters as well as experience settings:

(1) inertia weight

The inertia weight W makes the particles keep moving inertia, so that it has the tendency to expand the search space, and has the ability to explore the new area. Larger W value is conducive to global search, smaller W is conducive to local search. Choosing a suitable w can balance the global and local search capabilities, so that the optimal solution can be found with the least number of iterations.

(2) learning factor

C1, C2 used to control the particle's own memory and the relative impact of peer memory. Appropriate selection can improve the algorithm speed and avoid local minimum.

(3) maximum speed

The resolution of the region between the current position and the best position. If it is too large, the particles may fly over the excellent solution space in the solution space; if too small, the particle can not be enough to explore the local excellent solution outside the interval, resulting in a local optimal value. The purpose of this kind of restriction is to prevent the overflow of computation; to realize the transformation of artificial learning and attitude; to determine the strength of the problem space search.

2.2 Improved PSO algorithm

From the standard particle swarm algorithm can be seen, the individual particles in the process of movement, not only from their own individual behavior learning experience, access to information, but also from the overall population behavior learning experience, access to information, but the process of obtaining information were the best individual as study object. In the standard particle swarm optimization algorithm, the failure experience of the worst individual in the learning group is considered. This update formula is changed to follow the individual extremum, the global extremum and the

individual's most difference, the overall difference update, so that the particle will get more information to adjust their status.

Formula (1)and (2) evolved into:

$$v_i^{k+1} = wv_i^k + c_1 r_1 (x_i^* - x_i^k) - u_1 r_1 (x_i^0 - x_i^k) + c_2 r_1 (x^* - x_j^k) - u_2 r_2 (x^0 - x_i^k) \quad (3)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (4)$$

Compared with the standard PSO, the new update strategy introduces two parameters, the influence factor U_1, U_2, which is used to describe the individual difference and the global minimum difference in speed update process. X_i^0 indicates the position of the worst solution in the particle itself, and X^0 indicates the position of the worst solution for the whole population. As for other parameters consistent with the standard PSO algorithm.

After introducing the particle swarm the difference, the advantages of the following aspects: from the point of view of the amount of information, each particle in the new algorithm from the worst value of their history the most difference and global, the particle searching the departure from the difference of position toward, accelerate the convergence speed of particle; from search term, particle swarm optimization (PSO) is no longer between the individual and global best value to search, but in individual extremum and global extremum and individual the difference, between the difference of global search, increase the diversity of particles in the population, converges to the global optimal performance improved.

3. Experiment simulation

In order to investigate the particle swarm optimization (PSO) algorithm for parameter optimization of PID controller tuning performance. For the following two second order delay object for simulation research, and genetic algorithm with the same performance index and some traditional methods were compared.

Object (1): $G_1(s) = \dfrac{1.6}{s^2 + 1.5s + 1.6} e^{-0.1s}$

Object (2): $G_2(s) = \dfrac{0.00581}{5s^2 + 2s + 1} e^{-0.2s}$

In the design of the control system, a variety of error integral criterion is usually used to measure the performance of the controller. The "best parameter" of the PID controller is the output response of the system under the given input, and the minimum value of the system can be obtained.

For the object (1), this chapter uses the stability time as the evaluation index of the PSO algorithm and the GA, which can get the PID parameters as shown in table 1.

Table 1 tuning results of various PID controller parameters

Method	K_p	K_i	K_d	T_s
Z-N	6.30	3.72	1.04	3.05
GA	3.18	3.40	1.61	1.81
PSO	3.03	3.21	1.80	0.63

Figure 1 for the object step response curve. From Figure1 we can be seen, using PSO algorithm to optimize the tuning of the controller can effectively improve the control performance, and improve the system response speed.

In order to investigate the robustness by PSO tuning of PID controller, this paper divides the object (1) of the gain and time delay changes respectively 2.0 and 0.2, the unit step response simulation was done by Table 1 by PSO tuning of PID controller parameters, the results are as shown in Figure 2 and figure 3. When the object (1) output in t=5s by 30% of interference, control system response as shown in Figure4, system after disturbance, can quickly return to the set value, anti disturbance performance and GA tuning results similar to, and better than Z-N method.

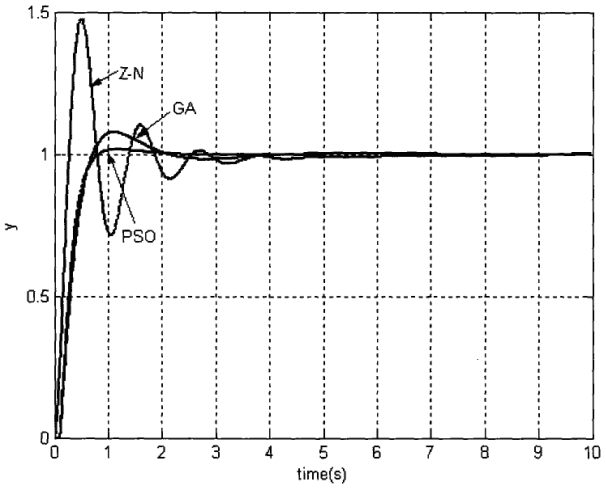

Fig.1 The unit step response curve of three kinds of tuning results of the object G_1

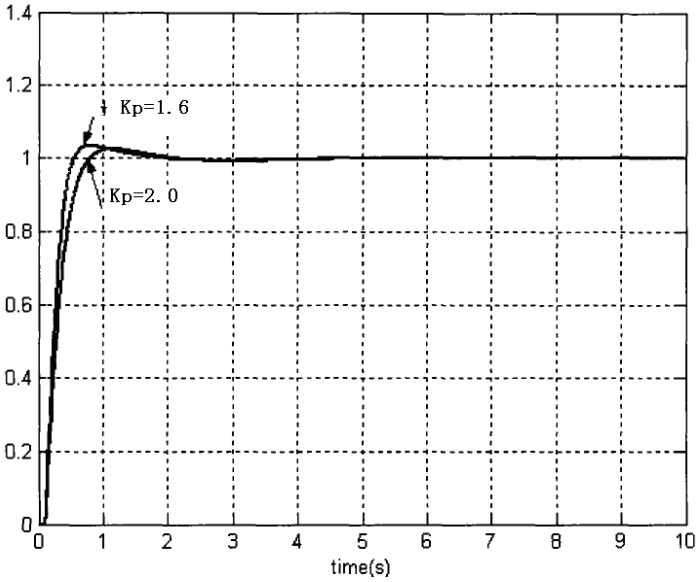

Fig.2 The unit step response curve of the object G_1 before and after the gain change

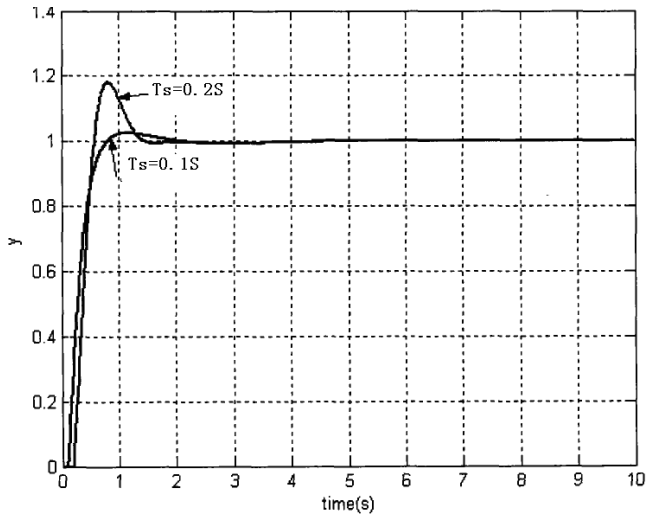

Fig.3 The unit step response curve of object G_1 before and after the time delay variation

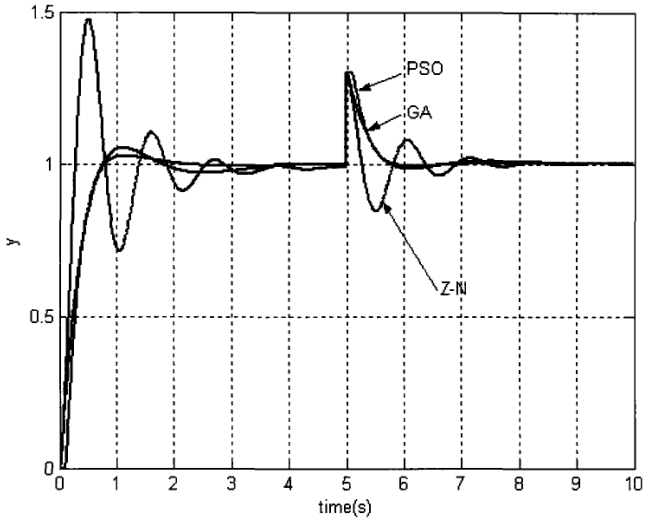

Fig.4 The unit step response curve of the object G_1 is disturbed

For the object (2), the integral of time multiplied by the absolute error (IATE) as the control performance index of the system by GA and PSO algorithm to optimize PID controller design, table 2 shows the tuning parameters, figure 5 is the order unit step response results.

Table 2 Parameter tuning results of two PID controllers for G_2

Setting method	K_p	K_i	K_d	*IATE*	Iteration number
GA	10.54	9.46	6.71	301.86	500
PSO	9.10	12.56	8.44	36.27	150

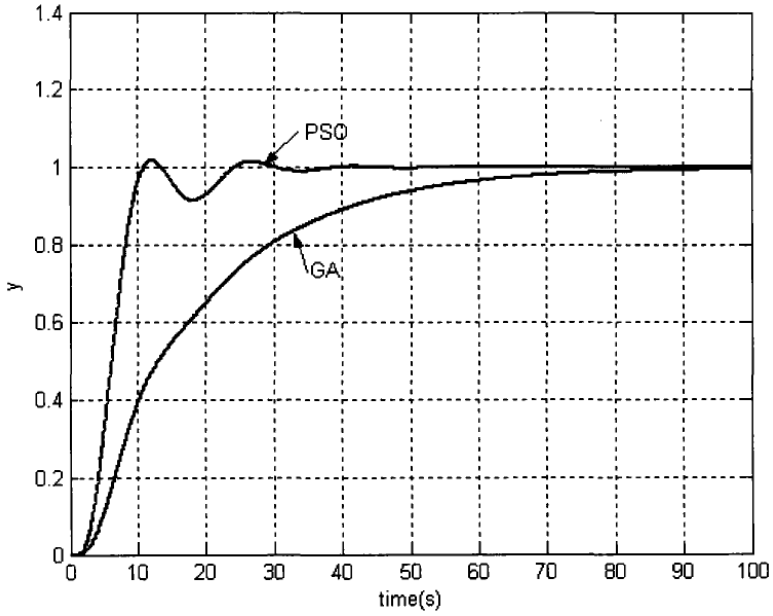

Fig.5 The unit step response curve of the two tuning results of the object G_2

As is shown in Fig 5, the PSO algorithm is applied to tuning of PID control system, system response rise time faster than GA obtained results and performance index value is better than GA algorithm. Therefore, by PSO tuning of PID controller has more appropriate parameters.

4. Conclusion

Particle swarm optimization (PSO) algorithm is widely used, has a good development prospects. PSO algorithm for the classical PID controller parameter tuning method designed control system is difficult to achieve a satisfactory performance, and often overshoot big adjustment for a long time, robustness is not strong and other shortcomings, and will be improved genetic algorithms are compared by MATLAB simulation proved the feasibility of the method. This article is based on improved PSO algorithm PSO algorithm evolutionary process of particle analysis, improved not only can be applied to the PID controller tuning parameters, you can also try to apply it to other areas, such as neural networks, nonlinear systems, logistics and sitting. You can try to use PSO PID controller parameter tuning online, and can be further improved PSO algorithm to find measures to increase its optimization results.

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