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Research on Temperature Control of Incubator Based on Chaotic Particle Swarm Optimization and Fuzzy PID

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Abstract: *In the process of performance testing of precision devices in the aerospace field, it is difficult to apply the traditional PID control to the high-precision incubators, which is unable to achieve the ideal control accuracy. For this problem, fuzzy PID is optimized by using nonlinear piecewise Logistic chaos mapping to initiate particle group, optimize the parameters of ACPSO-Fuzzy-PID and introduce shrinkage factor to ensure the convergence of the algorithm, making the overall and local search capability of particle group more efficient. Firstly, the algorithm was tested by standard functions, and finally, PID, fuzzy PID, PSO-Fuzzy-PID, ACPSO-Fuzzy-PID were contrast simulated by SIMULINK at a constant temperature of 75℃. Simulation results show that the ACPSO-Fuzzy-PID control system has faster response time, less overshoot, shorter adjustment time, temperature control fluctuation more stable and stronger anti-disturbance ability, which significantly improves the temperature control accuracy of the incubator in the aerospace field.*

Keywords: *Logistic mapping, Acpso, Fuzzy pid, Contraction factor, Chaos initialization, Adaptive adjustment*

1. Introduction

Temperature test box [1] is an experimental instrument that adjusts the temperature in the box to a given value or controls the temperature within a specified range in a certain way, and tests the test product under such conditions to check whether the characteristics of the product to be tested or the performance meets the requirements of the index. Current incubator in most areas can meet the demand of precision, but in the field of aerospace often need to some precision device performance test, often need higher precision incubator, because the incubator temperature control system belongs to the nonlinear time-varying, lag system, we can not accurately establish the desired model, and the traditional PID control [13] in the whole temperature control process shows obviously too long, temperature rise fluctuation, anti-interference ability, control effect is not ideal, seriously affect the accuracy of precision and precision device performance test effect.

Document [2] uses the combination of traditional PID and fuzzy PID control to solve the uncertainty, nonlinearity and lag of incubator temperature. It has strong nonlinear approximation ability, but there are still problems of too long temperature control and adjustment time and insufficient adaptive ability. Literature [3] and [7] introduced particle population to optimize the parameters of fuzzy PID, and the system response speed is significantly improved, but it is easy to make particles mature early or fall into particle optimum. Literature [4] ensures convergence in the original PSO algorithm. Literature [6] proposed the ACPSO algorithm, which improved the particle search performance. Literature [8, 9] proposes a dissipative particle population optimization algorithm to move the particles towards higher fitness. Literature [10] introduces an adaptive assisted particle swarm algorithm, adding the LA algorithm to simplify the collaboration, and effectively solve the high-dimensional multipeak problem. Literature [11] uses the nonlinear regulation mechanism to optimize the offline parameters of the fuzzy PID, which improves the control accuracy, but has problems such as too long adjustment time.

It is difficult to apply the traditional PID control to the high-precision incubator, and it cannot achieve the ideal control accuracy and so on. Therefore, a nonlinear binary segment Logistic chaotic particle group algorithm with shrinkage factor is proposed to optimize the Fuzzy-PID parameters; First, inertial weights are used to improve the global and local search capability of particle groups; Second, by introducing nonlinear binary segment Logistic chaotic maps, Combined with the ergodicity of the chaos, Chaos initialization of the particle; Then the three standard test functions of Sphere, Rastrigin and Ackley were selected for the algorithm effectiveness test, Finally, at a constant temperature of 75℃, SIMULINK was used for comparative simulations of PID, fuzzy PID, PSO-Fuzzy-PID, and ACPSO-Fuzzy-PID. Simulation results show that the ACPSO-Fuzzy-PID control system has faster response time, smaller overregulation, shorter adjustment time, smoother temperature control fluctuation and higher accuracy, which has certain practical application value for the temperature control of the incubators in the aerospace field.

2. Adaptive chaotic particle swarm algorithm

2.1. Adaptive chaotic particle swarm algorithm

The bipartite Logistic chaotic map [13] is used to determine the position and velocity of the initial population, and we select the optimal initial solution from a large number of initial solutions to improve the solution efficiency and quality of particle groups, so as to improve the diversity of the population and the ergodicity of particle search.

In this paper, the range of chaos variables is changed to (-1,1) to improve the ability of the chaos search process. However, if the range of the chaotic variables becomes (-1,1), the computation will appear infinitesimal values during the iteration. So the equation (9) is modified as follows:

$$x_{n+1}=\begin{cases}4\cdot\mu\cdot x_n\cdot(0.5-|x_n|)\\ -1<x_n\le 0.5\\ 1-4\cdot\mu\cdot(|x_n|-0.5)\cdot(1-|x_n|)\\ 0.5\le x_n\le 1\\ 0\le\mu\le 4\end{cases}\tag{1}$$

$$X(i+1,j)=\begin{cases}4\cdot 4\cdot X(i-1,j)\cdot[0.5-X(i-1,j)]\\ -1<X(i-1,j)\le 0.5\\ 1-4\cdot 4\cdot[X(i-1,j)-0.5]\cdot[1-X(i+1,j)]\\ 0.5\le X(i-1,j)\le 1\end{cases}\tag{2}$$

$$V(i+1,j)=\begin{cases}4\cdot 4\cdot V(i-1,j)\cdot[0.5-V(i-1,j)]\\ -1<V(i-1,j)\le 0.5\\ 1-4\cdot 4\cdot[V(i-1,j)-0.5]\cdot[1-V(i+1,j)]\\ 0.5\le V(i-1,j)\le 1\end{cases}\tag{3}$$

Adaptive optimization implements the following steps:

Step1: Start parameter setting: population size m, number of iterations t, maximum and minimum inertia weights $\omega_{\max}$ and $\omega_{\min}$, learning factors c_1 and c_2, and contraction factor α.

Step2: Set the number of initialization iterations t, initialize the population using the logical mapping; set the adaptive inertia weight value according to the iteration process.

Step3: Calculate the adaptive value for each particle based on the objective function.

Step4: Update the position and speed of the particles according to equation (2), (3). The particle fitness is calculated and updates the individual and global optimal position and velocity size, comparing the adaptation values of each particle to the current individual optima. If the particle fitness is less than the individual optimum, retain the current particle optimum or the individual particle optimum is retained and update the individual particle optimal position and velocity size. In this paper, the comprehensive index ITAE, the absolute product integral of time and incubator temperature deviation, is used as the fitness, and the smaller the value, the better. The ITAE index can comprehensively evaluate the dynamic and static performance of the system, and ensure the overshoot and adjustment time of the system. The calculation formula of ITAE is as follows:

$$JTAE = \int_0^\infty t\left|e(t)\right|dt \tag{4}$$

Step5: Determine whether the convergence conditions are achieved. If converging, go to step 8. Otherwise, continue to the next step.

Step6: Adaptive chaos optimization. Select some high-value particles for chaos operation, calculate fitness values, update position and speed.

Step7: Determine whether the termination search condition is satisfied. If the search is stopped, the global optimal value is retained. Otherwise, return to step 3, going to the next iteration.

Step8: Outputs the best value, speed, and position for each particle.

2.2. Algorithm validity test

In order to verify that the performance of ACPSO algorithm is better than that of PSO algorithm, further performance test of ACPSO algorithm is required, so a standard test function is selected to compare the performance analysis of ACPSO and PSO. The test function is defined as follows:

$$f_3(x) = -10\exp(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}) - \exp(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)) + 20 + e \tag{5}$$

Then, MATLAB software has tested PSO, P S O and ACPSO, the number of particles is 100, the maximum number of iterations is 100, and POS and ACPSO, As shown in Figure 1:

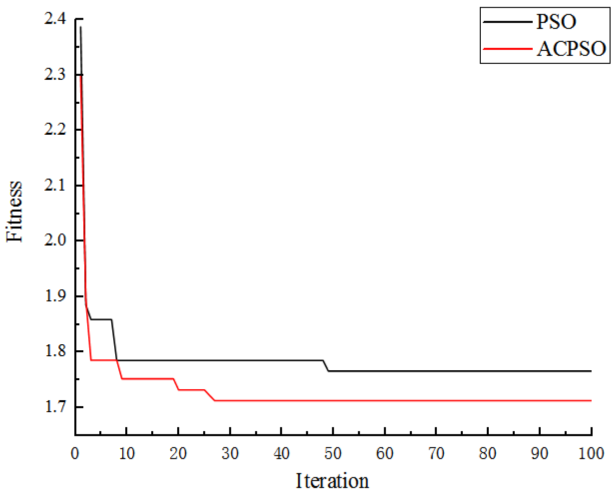

Figure 1: The Ackley function test curve

According to the test results of the Ackley function in Figure 1, both algorithms converge very fast, and PSO is easy to fall into the local optimal stop search, while ACPSO can continue to find the global optimal solution by jumping out of the local optimal position, with fewer iterations, higher accuracy and faster search speed.

3. Simulation and result analysis

In this paper, the first-order inertial lag link is used to approximate the temperature control system of the incubator, that is, the transfer function is:

$$G(s) = \frac{e^{-10s}}{800s+1} \tag{6}$$

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At a constant temperature of 75℃, PID, fuzzy PID, PSO-Fuzzy-PID, ACPSO-Fuzzy-PID were simulated by SIMULINK in Figure 2, and the results are shown in Figure 3. According to the simulation results, the fuzzy PID of binary segment chaotic particle swarm optimization has obvious advantages over other algorithms in overregulation, rising regulation time, control accuracy and response time, and the whole control process is very stable.

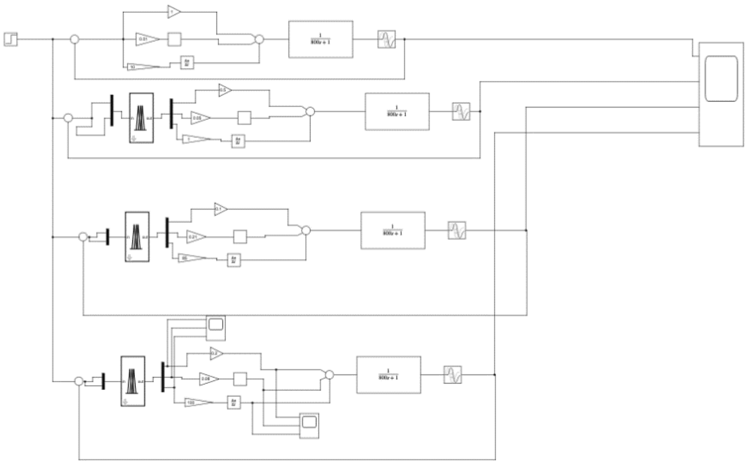

Figure 2: SIMULINK simulation comparison diagram

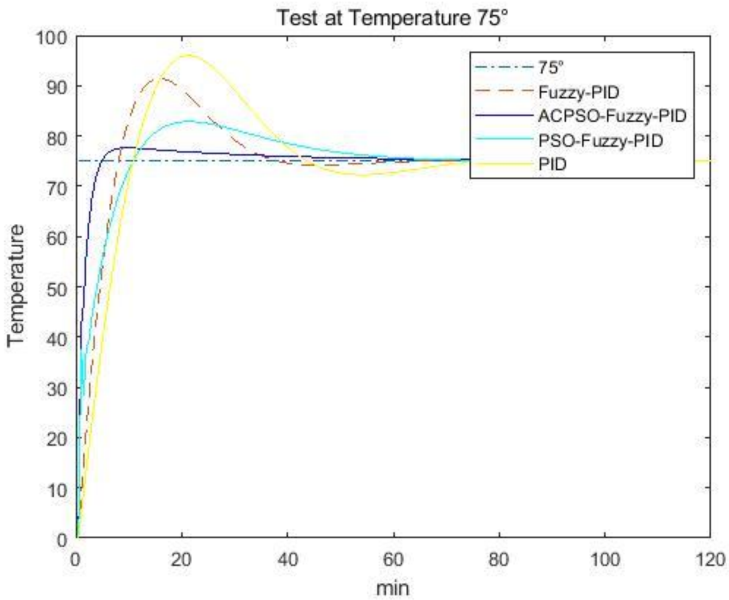

Figure 3: 75℃ simulation results

4. Conclusion

In the process of performance testing of precision devices, the incubator temperature control system has slow temperature increase, difficult parameter adjustment, long adjustment, long response time and low control precision. This paper proposes that the control method of fuzzy PID optimization of binary chaotic particle swarm is applied to the incubator temperature control. A nonlinear bipartite Logistic chaotic particle swarm algorithm with shrinkage factor is used to increase the search range and overcome the rapid and premature convergence of the traditional particle swarm algorithm; At the same time, the addition of inertial weight improves the global and local search ability of particle groups; The effectiveness of the algorithm is also tested, Finally, the algorithm is applied to the Fuzzy-PID to achieve the accurate control of the incubator accuracy, This method has a faster response time and a smaller overshoot than other methods, With a shorter adjustment time, The advantages of more stable temperature control change fluctuation and higher precision, Can effectively improve the accuracy of the incubator products in the aerospace field, And the performance test of precision devices has a strong

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practical value.

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