A Hybrid Particle Swarm Optimization Algorithm

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***Abstract*—Aiming at the the poor local search capability of Particle Swarm Optimization(PSO) algorithm, a hybrid particle swarm optimization algorithm is proposed. Firstly, the population is initialized by tent chaotic map to improve the diversity of the initial population. In the evolution process, the tabu search strategy is adopted to improve algorithm convergence rate. Combining the chaos optimization strategy, this algorithm could jump out of local optimization and improve the local search ability. The simulation results of constrained optimization problems are reported and compared with the typical PSO algorithm. Simulation results show that this algorithm could effectively avoid local optimization, have good global search ability and local search ability.**

Keywords-particle swarm(PSO); optimization algorithm; tent chaotic map; tabu search strategy

I. INTRODUCTION

Particle swarm optimization (PSO) algorithm is a new global optimization algorithm proposed by Kennedy and Eberhart in 1995[1,2,3]. The PSO algorithm has the advantages of simple structure, easy implementation by programming, is suitable for most optimization problems, and has good convergence speed. However, the convergence rate of the PSO algorithm is difficult to control, the convergence rates is low in the later period, with a premature convergence phenomenon. For the complex problems such as multi-peak function, the calculation accuracy is not high enough. Many scholars have improved the PSO algorithm and improved the performance of PSO algorithm to various degrees [4,5].

Chaos optimization algorithm has the advantages of good global ergodicity, randomness, initial sensitivity and so on. Many scholars combine the chaos map with PSO algorithm, and proposed improved PSO algorithm[6,7]. Tabu search strategy has the advantages of *climbing* ability, better performance and higher efficiency[8]. In this paper, by combining chaos optimization, tabu search strategy and particle motion process, proposed a hybrid particle swarm optimization algorithm (HPSO), which can enhance the local search ability, and speed up the global convergence rate.

II. TENT CHAOTIC MAPPING MODEL

At present logistic mapping and tent mapping are used more than other maps in chaotic systems. In contrast, Tent mapping has better traversal uniformity and faster iterations than Logistic mappings. Therefore, this paper use Tent mapping to produce chaotic sequence, the expression is as:

$$z(t+1)=T(z(t))=\begin{cases}2z(t), & 0\le z(t)\le 0.5\\ 2(1-z(t)), & 0.5<z(t)\le 1\end{cases} \quad (1)$$

Where, $z(t)\in[0,1]$.

By the Bernoulli shift transformation, the Tent mapping is represented as

$$z(t+1)=(2z(t)) \bmod 1 \quad (2)$$

The Tent mappings have a small cycle (0.2, 0.4, 0.6, 0.8) in the iterative process, and at the unstable period (0.25, 0.5, 0.75), the iterations is to the fixed point 0. In order to avoid the phenomenon, the tent mapping is to be improved as:

While $z(t)=0, 0.25, 0.5, 0.75$, $or\ z(t)=z(t-k)$,k=0,1,2,3,4

$$z(t+1)=z(t)+0.01\cdot rand(0,1) \quad (3)$$

The steps for generating the chaotic sequence of the Tent mapping are as follows:

Step 1 Initialize population and generate *n* random numbers in [0,1] intervals.

Step 2 Chaos transformation. According to the chaotic model, chaos transform is carried out to generate *n* chaotic variables.

Step 3 Map chaotic variables into variable intervals.

The chaotic sequence is mapped to the variable space to obtain the *j*-th component of the *i*-th entity in the initial population.

Step 4 While satisfies the end condition, stop and save the chaotic sequence.

III. HYBRID PARTICLE SWARM OPTIMIZATION

A. PSO algorithm

PSO algorithm is a kind of bionic intelligence based on group intelligence. The basic idea is to find the optimal solution through the cooperation and information sharing among individuals in the group.

The solution of each optimization problem in the PSO algorithm is called a "particle" in the *N*-dimensional search space. All the particles make up the particle swarm. The particle has the attributes such as position *Xi*, velocity *Vi*, and fitness.

The evolution equation of the PSO algorithm is that the *n*-th dimension velocity of the *t*-th generation particles are calculated by (1), and position of the *t*-th generation particles are calculated by (2).

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$$v_{in}(t+1)=\omega v_{in}(t)+c_1r_1(p_{in}^k-x_{in}^k)+ c_2r_2(g_{in}^k-g_{in}^k) \tag{4}$$

$$x_{in}(t+1)=x_{in}(t)+v_{in}(t+1) \quad 1\le i\le M, 1\le n\le N \tag{5}$$

where M is the population size, N is the particle dimension, $x_{in}(t)$ is the position and velocity of the n-th dimension of the i-th particle in the t-th iteration, $v_{in}(t)$ is the velocity of the n-th dimension of the i-th particle in the t-th iteration. ω is the inertia weight, c_1 and c_2 are acceleration constant known as the learning factor, r_1 and r_2 are random numbers in [0,1] interval.

B. Population initialization

In order to keep the population diversity and individual distribution evenly, the Tent chaotic map is used to initialize the population.

Firstly, the chaotic sequence is generated by Tent chaotic map, and then the chaotic sequence is mapped to the solution space. Finally, all the solutions are ordered and the solution with better fitness is taken as the initial population.

C. Parameter design

(1) Inertia weight

In order to balance the global search and local search capabilities, design adaptive inertia weights. According to the adaptability, a large inertia weight is adopted in the early stage of the algorithm, and a smaller inertia weight is used in the later stage to improve the search precision.

According to the global optimal value of the current particle and the global optimal value in the previous iteration process, the inertial weight is adjusted according to the change of the global optimal value, and the particle evolution velocity factor k is set:

$$k=\frac{f_g(t)-f_g(t-1)}{f_g(t-1)} \tag{6}$$

Where, $f_g(t)$ is the fitness of the t-th global optimal value.

The inertia weight is adjusted according to the particle evolution rate factor as (7):

$$\omega(t)=(1+e^{-k})^{-1} \tag{7}$$

Where $\omega(t)$ is the inertia weight for the t-th iteration.

(2) Learning factor optimization

To improve the convergence rate of the algorithm, learning factors are processed by chaotic mapping.

$$C_i(t+1)=C_{\min}+(C_{\max}-C_{\min})\cdot z_i(t+1)$$

Where $C_i(t)\in[1.4,2]$.

(3) Random number processing

Using the Tent mapping to optimize r_1 and r_2, to ensure the randomness and ergodicity of parameter distribution. The update formula is:

$$r_i(t+1)=T(r_i(t)), r_i(t+1)\in(0,1), i=1,2 \tag{8}$$

D. Local Convergence Processing

When the premature phenomenon occurs, use Tent mapping to optimize the particles to jump out of the local optimum and improve the global search ability.

(1) Local optimal Judgment Mechanism:

Set a counter P, to count number of the current global optimal solution that occurred consecutive. Given a threshold c, while $P = c$, the algorithm is considered as local optimal.

(2) Chaos Optimization

When the particle population is in local optimal, the Tent mapping is used to optimize the currently generated particles. The optimal solution generated by chaos optimization is used as the global extremum, and jump out of the local optimum.

E. Tatu Search (TS) Strategy

TS algorithm is a kind of global heuristic search algorithm. In 1986, the system scientist Professor Fred Glover first proposed TS algorithm. By setting the taboo table, the solution generated in evolutionary process are stored in the solution set.

The solution in the taboo table is prohibited in the current iteration, to avoid repeated roundabout search. At the same time, set the “amnesty criteria”, pardon some of the taboo of the excellent state (operation), to avoid miss the evolution of the optimal solution.

The basic process of the tabu search algorithm are as follows:

Step1. Set the taboo table and select an initial solution X'; set the taboo length T_{max}, the termination condition, the candidate set Can_N(X'), and so on.

Step2. Identify candidate solutions. The optimal individual from the adjacent domain of current solution is determined as candidate solution.

Step3. Determine whether the candidate solution satisfies the requirement. If satisfied, it is set as the current solution, and put it into the taboo table.

Step4. Determine the taboo attribute of the candidate solution, select the best solution for the current solution, update the taboo table.

Step5. When the stop rule is satisfied, the calculation is stopped and the result is output; otherwise, return to Step2.

F. Improved Hybrid PSO (HPSO) Algorithm Flow

The basic idea of the improved hybrid PSO algorithm is to use the PSO algorithm as the main body to initialize the particle velocity and position by the chaotic sequence to generate the initial population; set the adaptive inertia weight, balance the global search ability and the local search ability; use the chaotic sequence generation Learning factors; through the speed and position of the particle optimization to obtain the purpose of optimization. In the process of particle evolution, the tabu search strategy is introduced to avoid the repeated access to the particles and improve the search efficiency. The precocious judgment is made by the early-maturing judgment mechanism, and the local optimization is achieved by chaos optimization to improve the global search ability. After repeated iterations, the final result is optimal. The algorithm flow is as Fig. 1:

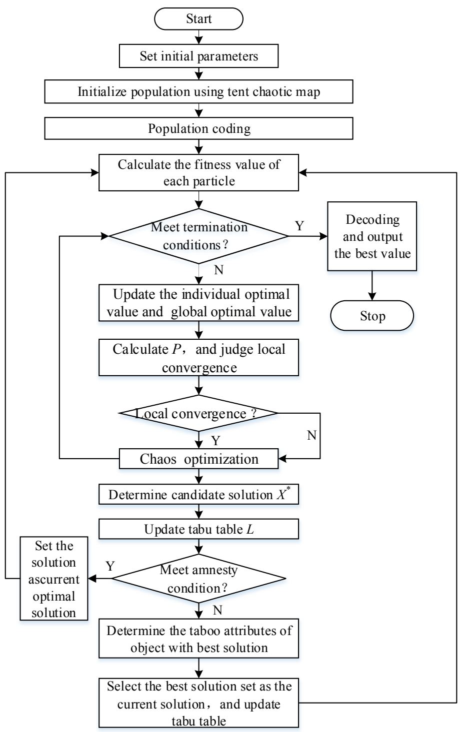

Figure 1. Hybrid PSO algorithm.

The basic steps of the algorithm are as follows:

Step 1. Set initial parameters. Set the population size, the maximum number of iterations, control variables, taboo length, amnesty conditions;

Step 2. Population initialization. Use chaos optimization method to generate the initial population.

Step 3. Carry out the population coding, set the taboo table to be null.

Step 4. Calculate the fitness.

Step 5. Particle optimization. The optimal position and global optimal position of the particle group are determined according to the state of the particle group, and the individual optimal value and global optimal value of the particle are updated.

Step 6. Determine whether meet the termination conditions, if it is satisfied, decode and output the result, otherwise continue to iterate.

Step 7. Determine the candidate solution. Determine the current optimal solution as a candidate solution, and add it to the taboo table, and replace the earliest solution entry into the taboo table. Update the taboo table.

Step 8. To determine whether the candidate solution to meet the amnesty criteria, if satisfied, will be lifted as the current optimal solution, update the taboo and the current state, into step 4; otherwise, the implementation of the next step.

Step 9. Determine the taboo attribute of the candidate solution, select the best solution for the current solution, update the taboo table, go to step 4.

Step 10. Determine whether the termination condition is satisfied, and if the iteration is satisfied, output the optimal solution; otherwise, return to step4.

IV. PERFORMANCE OF MIXED PSO ALGORITHM

In order to test the performance of mixed PSO algorithm, we program with Matlab R2014a, simulate the typical test function, and compare it with the genetic algorithm and standard PSO algorithm.

The typical test function are Rosenbrock Function and Rastrigrin Function.

Rosenbrock Function:

$$\begin{aligned} & f_1(x)=\sum_{i=1}^{n-1}[100(x_{i+1}-x_i^2)^2+(x_i-1)^2] \\ & \min f_1(x_1,x_2,\cdots,x_n)=0 \\ & s.t. \quad -30\le x_i\le 30 \end{aligned} \tag{9}$$

Rosenbroc Function is unimodal function, and the function value is flat in a long range near the global best solution.

The Rastrigrin Function:

$$\begin{aligned} & f_2(x)=\sum_{i=1}^{n}[x_i^2-10\cos(2\pi x_i)+10] \\ & \min f_2(x_1,x_2,\cdots,x_n)=0 \\ & s.t. \quad -5.12\le x_i\le 5.12 \end{aligned} \tag{10}$$

Rastrigrin Function is a typical multimodal function, 0 is the global minimum point, there are 10n local minima in the range of [-5.12,5.12].

The algorithm parameters are set as follows: the population size is 100, the dimension n is 10 and 30, the number of iterations is 500, and the simulation number of times is 30, and the optimal solution and the optimal solution are compared.

Several algorithms are used to calculate the Rosenbrock Function and Rastrigrin Function, and the results are as follows:

TABLE I. RESULTS OF DIFFERENT ALGORITHMS

Functions	**Methods**	***n*=10**	***n*=30**
$f_1(x)$	PSO	8.1e-5	3.8 e-4
	HTPSO	4.9e-10	9.3e-8
$f_2(x)$	PSO	8.1e-4	5.3e-3
	HTPSO	2.7e-8	3.3e-7

By analyzing the results in Table I, the HPSO algorithm has more excellent efficiency and greater effect on complex optimization problem.

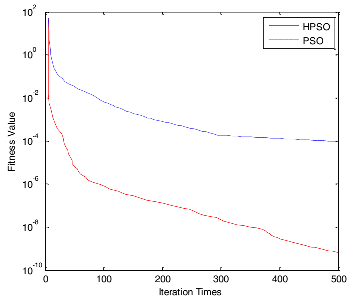

Figure 2. Convergence curves of of Rosenbrock (n=10)

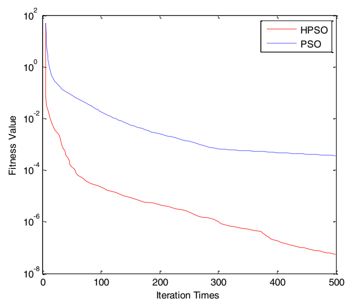

Figure 3. Convergence curves of of Rosenbrock (n=30)

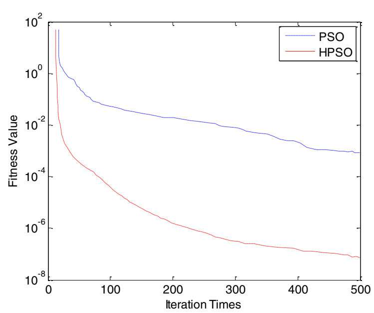

Figure 4. Convergence curves of of Rastrigrin (n=10)

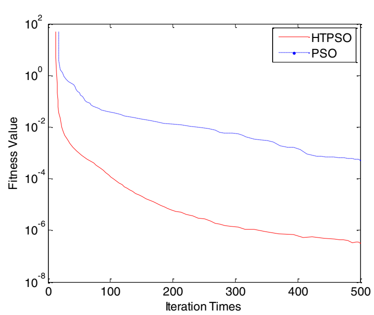

Figure 5. Convergence curves of of Rastrigrin (n=30)

The convergence curves of Rosenbrock Function and Rastrigrin Function are listed in Fig.2. to Fig.5.

By analyzing the convergence curves, the comparison results demonstrate that the HPSO algorithm proves to be effective and efficient, the performance of the HPSO algorithm is better than PSO algorithm. The convergence cure of PSO algorithm is to be stable after 100 iterations. It proves that the premature convergence is occurred.

Simulation results prove that the HPSO algorithm has better convergence and optimization performance. The HPSO algorithm is faster and has a strong global search capability and better local optimism than PSO algorithm. The HPSO algorithm is suitable for complex functions due to global optimization problems.

V. CONCLUDING REMARKS

Based on the characteristics of chaos optimization algorithm, tabu search strategy and particle swarm optimization algorithm, a hybrid particle swarm optimization algorithm is proposed. This algorithm makes full use of the ergodic characteristics of chaos optimization and maintains the diversity of the population. In the process of particle evolution, the tabu search strategy is used to improve the convergence speed of the algorithm. Combining the chaos optimization strategy, the global search ability of particle swarm optimization algorithm can be improved. Effectively avoid the premature problem faced by particle swarm algorithm. The simulation results of several typical test functions prove that the HPSO algorithm has better convergence and optimization performance. So the algorithm can solve the global optimization problem of multi-extremal function.

Further investigation of the impact of the hybrid swarm operation algorithm will be carried out. We intend to verify the algorithm complexity, and foster a wider use of this algorithm.

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