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Research on chaos PSO with associated logistics transportation scheduling under hard time windows

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Abstract: This paper study the associated logistics transportation scheduling problem with hard time windows and construct the mathematical model. Optimize the chaos PSO problem using the improved adaptive inertia weight factor method to improve the accuracy and efficiency of the algorithm. Comparing our method with the GA and standard PSO algorithm, our algorithm has better performance with solving such problem.

Keywords: chaos PSO algorithm; hard time window; associated logistics transportation scheduling problem

1 Introduction

Now, logistics industry has been an important economic sector in our country and develops in a rapid speed. Logistics need large amount of consumption to achieve space transfer of goods. This consumption which usually with long time and big distance is the biggest cost in the total logistics cost. From studying the logistics transportation scheduling problem can improve the efficiency of logistics transportation, decrease the logistics transportation cost, optimize the structure of logistics industry and has a wide range of practical significance. Transportation scheduling problem is an important factor in logistics problem. RVRP is a branch of the VRP(Vehicle Routing Problem). The problem of optimizing distribution path has practical significance.

Researchers from domestic and abroad have done a lot of work on logistics transportation scheduling problem. G.B.Alvarenga etc [1] proved that heuristic algorithm is better than precise algorithm from studying VRPTW with GA and partition function. Rita Macedo etc [2] solved the VRP with multiple direction and time windows through constructing pseudo polynomial model. Yannis Marinakis etc [3] studied hybrid generic PSO based VRP. In domestic, Chen Jin, Cai Yanguang, Li Yongsheng etc studied union transportation scheduling problem. Qu Yuan, Li Min etc studied the transportation problem with multiple distribution centers. The paper use the chaos PSO algorithm to study the associated logistics transportation problem with hard time windows.

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2 Problem description and mathematical model construction

In the actual situation, logistics companies need to meet the customers' request that goods must be distributed to the customer before a time or in a time range. That is called the logistics transportation problem with hard time windows. The logistics transportation problem with hard time windows in this paper is that goods must be distributed to the customers in a time range. It is a fail distribution if goods are distributed before or after the time range.

2.1 Question Description

The logistics transportation problem with hard time windows is described as follows: One logistics company with one logistics center, l customers, demands of customer q_i (i=1,2,..., l), m distribution vehicles with the maximum load Q_k (k=1,2,...,m) for one vehicle, distribution time range [A_i, B_i]. d_{ij} is the distance from customer i to customer j.

S_i is the time that distribution vehicle reach customer i. T_i is the time which is cost by distribution vehicle serving customer i. T_{ij} is the time cost of distribution vehicle travelling from customer i to custom j. n_k is the customer number served by vehicle k. There are associated constraints between customers' distribution time range. One distribution vehicle only can serve one customer. Distribution vehicle starts from the distribution center, distribute the goods to the customer and return the distribution center. The question is how to reasonably arrange the distribution vehicles and distribution paths to lowest the cost under the condition of meeting all the customers' needs.

Constraints are as follows:

(1)The distribution center is fixed and unique.

(2)The distribution process is close as the distribution vehicle starts from the distribution center and return the distribution center.

(3)The distribution is not in a full load situation and it has the maximum distribution load and maximum distribution distance.

(4)Every customer is served by one vehicle and all customers' distribution needs must be meet.

(5)The maximum load of the distribution vehicle and the demands of customer is known.

(6)The distribution vehicle must complete distribution task in the stipulated time range, else the distribution task is fail.

(7)Time window for each customer is known.

(8)Customers need distribute and fetch goods in the same time.

(9)There are associated constraints between customers' distribution time range.

2.2 Mathematical model

According the above description, construct the associated logistics transportation scheduling problem with hard time windows as follows:

The objective function：

$$\min Z = \sum_{k=1}^{m}\left[\sum_{i=1}^{n_k} d_{r_{k(i-1)}r_{ki}} + d_{r_{kn_k}r_{k0}}\, sign(n_k)\right]. \quad (1)$$

Constraint function：

$$\sum q_{rk} \le Q_k. \quad (2)$$

$$\sum_{i=1}^{n_k} d_{r_{k(i-1)}r_{ki}} + d_{r_{kn_k}r_{k0}}\, sign(n_k) \le D_k. \quad (3)$$

$$0 \le n_i \le l. \quad (4)$$

$$\sum_{k=0}^{m} n_k = l. \quad (5)$$

$$sign(n_k) = \begin{cases} 1, n_k \ge 1 \\ 0, n_k < 1 \end{cases}. \quad (6)$$

$$S_{r_{k(i-1)}} + T_{r_{k(i-1)}} + T_{r_{k(i-1)}r_{ki}} = S_{r_{ki}}. \quad (7)$$

$$T_i = \max\{A_i - S_i, 0\}, i = 1, 2, ..., l. \quad (8)$$

$$S_i \le B_i, i = 1, 2, ..., l. \quad (9)$$

$$S_{r_{ki}} < S_{r_{kj}}, T_{s_r} \in \{(i, j), i, j \in \{1,2,...l\}\} \quad \textbf{(10)}$$

Formula (1) is the objective function which represents the shortest distribution path of all vehicle in the logistics process. Formula (2) represents the total distribution goods are under the maximum load of all vehicles. Formula (3) represents each distribution path is under the every car's maximum distribution distance. Formula (4) represents the customers in one distribution path is under the total customers number. Formula (5) promises every customer is served. Formula (6) represents the vehicle is distributing when the serving customer number is equal or bigger than 1, the vehicle is now distributing when the serving customer number is less than 1 as sign(n)=0.Formula (7) represents the time of the distribution vehicle reach the next customer i $S_{r_{ki}}$ equals the sum of the time of the distribution vehicle reached the current customer $S_{r_{k(i-1)}}$, the waiting time in the current customer $S_{r_{k(i-1)}}$ and the time cost of travelling from current customer to the next customer $T_{r_{k(i-1)}r_{ki}}$. Formula (8) represents the constraint of the waiting time on the current customer that determined by the reaching time and the time window of current customer. Due to the hard time window, if the reaching time is before or equal the time window, the waiting time equals the reaching time minus the current time window, if the reaching time is after the time window, then the distribution is fail and the waiting time is 0. This formula promises the distribution vehicle must reach the customer before or equal the time window. Formula (9) promises the distribution process must before or equal the time window end time. Formula (8) and (9) works together to promise the logistics scheduling mathematical is under the constraint of hard time window. Formula (10) represents the associated relations between customers' time range as customer i must be served before customer j.

3 Chaos PSO algorithm dealing with logistics transportation scheduling problem with hard time window

3.1 Improved adaptive inertia weight factor adjusting chaos PSO algorithm

In order to deal with the problem of the logistics problem falls into the local optimal value to affect the general optimization results, the paper introduces an adaptive inertia weight factor adjusting method derived from adaptive weighting factor method.

To the n-dimensional particle swarm of objective function Z, Z_i represents the particle, the weighting factor of particle swarm is ω. Z_{avg} represents the average value of the particles, the computation method is shown as (11). Let the value of the optimal particle is Z_g, get the average value of the optimal particles as Z'_{avg}. Define $\Delta = \left| Z_{avg} - Z'_{avg} \right|$, then according the following three situations to optimize the weighting factor ω.

$$Z_{avg} = \frac{1}{n}\sum_{i=1}^{n} Z_i \quad . \tag{11}$$

First situation, Z_i is better than $Z_{avg}^{'}$

The particles meet the first situation are the excellent particles in the swarm. The kind particles are close to the global optimal particles. Relatively small weighting factor is suitable to this kind of particles. This kind of particles can use formula (12) to adjust adaptive inertia weighting factor.

$$\omega = \omega - (\omega - \omega_{\min}).\left|\frac{Z_i - Z_{avg}^{'}}{Z_g - Z_{avg}^{'}}\right| . \tag{12}$$

Second situation, Z_i is better than Z_{avg}, but worse than $Z_{avg}^{'}$.

Particles meet the second situation are the general particles which is the majority of all the particles, the stability is relatively good and have good global and local optimization ability. To this kind of particles, we use segmentation method. At the early stage of the iterations, use the relative big weighting factor to optimize. At the end stage of the iterations, use the relative small weighting factor to optimize. According to the above consideration, use Cosine function to adjust the weighting factor. Formula (13) shows such method.

$$\omega = \omega_{\min} - (\omega_{\max} - \omega_{\min}).\frac{1 + \cos(\frac{(N-1)\pi}{N_{\max} - 1})}{2} . \tag{13}$$

N is the iteration time, $N_{\max}$ is the maximum iteration times.

Third situation, Z_i is worst than Z_{avg}.

Particles meet the third situation are relative worse in the swarm. This kind of particles has worse global and local optimization ability, easily to fall into early maturity. According to the characters of this kind of particles, use formula (14) to adjust.

$$\omega = 1.5 - \frac{1}{1 + r_1 \exp(-r_2 . \Box)} . \tag{14}$$

In formula (3.4), r_1 is used to control the upper limit of ω, r_2 is used to control the formula’s adjusting ability to ω.

3.2 Algorithm process

The idea of our method is shown as follows: First, use the standard PSO to initialization and generated particle swarm, get the preliminary optimal value. Then, do chaos optimization to the preliminary optimal value using chaos mapping method, get the optimal solution. The process of the algorithm is shown as Figure (1).

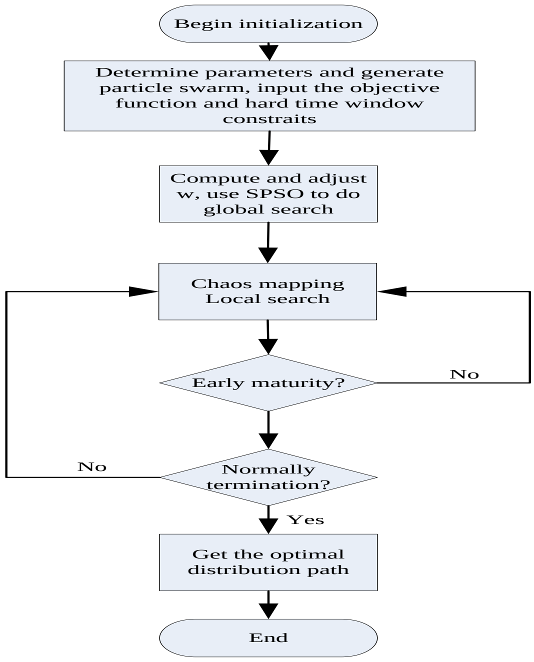

Fig. 1 CPSO Algorithm flowchart

The steps of our algorithm:

Step1. Initialization. Initialize the particle swarm, input the basic parameter of the distribution network. Determine the particle swarm scale n, study factor c_1c_2, the maximum and minimum value of inertial factor w, the maximum iteration times of chaos optimization.

Step2. Generate particle swarm. According to the basic parameter, generate particle swarm with scale n.

Step3. Execute the standard PSO algorithm, preserve the particle with preliminary good performance. Get p_g =(p_{g1} , p_{g2}, … p_{gm}) as p_{best}.

Step4. Do chaos optimization to the particles which are preserve from step 3 p_{best}, get chaos sequence, do chaos mapping, achieve chaos optimization. Find $p_{g.k}^{*l}$ and update the position of the new solution.

Step5. Early maturity judgment. Judge if the particle swarm fall into early maturity consistence. If fall into early maturity, select partial of the relatively good particle to continue step 4. If not fall into early maturity, go to next step. The early maturity particle swarm has two specific characters. The first is that particle swarm extremely accumulated. The second is that particle swarm has no change after several iterations. Formula (15) is used to compute the swarm fitness variance σ^2 of particle swarm.

$$\sigma^2 = \sum_{i=0}^{k} \left(\frac{f_i - f_{avg}}{f} \right)^2 . \tag{15}$$

Compare with the pre-defined minimum swarm fitness variance $\sigma^2_{\min}$, if $\sigma^2 \le \sigma^2_{\min}$, the particles extremely accumulate, fall into early maturity.

Step6. Stop condition of judge algorithm. Compute the optimal iteration times to get $p^{*l}_{g.k}$, if the result is bigger than the pre-defined maximum iteration time, the chaos optimization stops.

Step7. Get the global optimal solution, as the optimal distribution path.

Step8. Algorithm ends.

4 Experiment results and analysis

The experiments were did on PC using Matlab 7.0 to program.

One logistics company has one logistics center, 8 customers, Table 1 shows the location and distance between logistics center and each customer, Table 2 shows the demand of each customer and hard time window constraints. The number of distribution vehicle is 50, the maximum load is 10 ton. The unit transportation cost is 1. Customer 3 needs to be served before customer 1.

Table 1. Customer location chart

Distance	0	1	2	3	4	5	6	7	8
0	0	40	60	75	90	200	100	160	80
1	40	0	65	40	100	60	75	110	100
2	60	65	0	75	100	100	75	75	75
3	75	40	75	0	100	60	90	90	150
4	90	100	100	100	0	100	75	75	100
5	200	50	100	50	100	0	70	90	75
6	100	75	75	90	75	70	0	70	100
7	160	100	80	90	75	90	80	0	100
8	80	100	75	150	100	75	100	100	0

Table 2. Customer demand, service time and time window data

Customer	1	2	3	4	5	6	7	8
Demands	3	2.5	3.5	5	3．1	1	1.6	2.8
Serving time	1	2	1	3	2	2.5	2.5	0.8
Time window	[1,4]	[4,6]	[1,2]	[4,7]	[3,5.5]	[2,5]	[5,8]	[1.5,4]

The basic parameters used are as follows: the number of populations of particle swarm 50, c1=1, c2=1, adaptive weighting factor $w_{\max}$ =0.8, $w_{\min}$ =0.3, the maximum iteration time 150 times.

The optimal distribution paths got from the simulation experiments:

Distribution path 1: 0-3-1-2-0

Distribution path 2: 0-6-4-0

Distribution path 3: 0-8-5-7-0

The optimal total cost is Z=920.

To validate the performance of our algorithm, use GA and standard PSO to do 30 times simulation experiments. The number of populations is 50 and iteration time is 100 for both GA and standard PSO. The results are shown as figure 2 and table 3.

Table 3. Comparison of the three algorithms

Algorithm	Longest path	Shortest path	Average	Optimal solution time
GA	980.5	956.3	968.6	6
PSO	965.1	942.5	952.1	9
Our algorithm	945.6	920.1	932.2	18

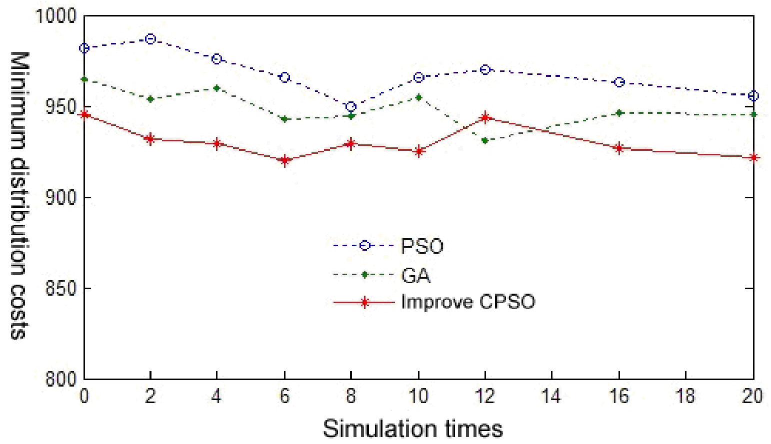

Fig. 2. Comparison of the three algorithms

From the above analysis, the algorithm proposed in this paper has good performance in dealing with associated logistics transportation problem with hard time window. Our algorithm effectively avoids the particles to fall into maturity, improve the global and local searching ability. Compared with GA and standard PSO, our algorithm has better performance in precise, accuracy, iteration efficiency and optimal solution.

5 Conclusion

This paper introduced the solution method associated logistics transportation problem with hard time window, constructed mathematical model. Introduced an adaptive weighting factor adjusting chaos PSO algorithm which derived from adaptive weighting adjusting factor method. The method can adjust the adaptive inertia weighting factor according different particles, can effectively improve the global and local searching ability. Finally do simulation experiment using Matlab. Experiment results show that our algorithm has better performance in dealing with associated logistics transportation problem with hard time window.

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