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Study on the Route Optimization of Military Logistics Distribution in Wartime Based on the Ant Colony Algorithm

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Abstract

Because of the impacts from the road conditions and the hostile attacking, the military logistics distribution in wartime should consider the pressure degrees of various demand points to the materials, so it is much more complex than the common logistics. Aiming at the actual situation of the military logistics distribution in wartime, the basic ant colony algorithm is improved in the article, and the software of MATLAB is used to simulate the improved algorithm. The result indicates that the algorithm possesses higher solving efficiency, and can fulfill the requirement of the route optimization of the military logistics distribution in wartime.

Keywords: Ant colony algorithm, Pheromone, Route optimization

The military logistics distribution in wartime directly influences the result of the war, and it is the focus to optimize the vehicle routes and enhance the speed and the security of the military logistics distribution for the military logistics industry. In this article, the actual requirements of the military logistics distribution in wartime are comprehensively considered, and the state transfer probability function in the ant colony algorithm is modified, and the unobstructed factor of the route and the importance factor of the demand point are added to make the algorithm be fit for the problem.

1. Description of the route optimization model of the military logistics distribution in wartime

The rout optimization of the military logistics distribution in wartime means to use the minimum time to carry the materials to the appointed place and ensure the safety of the materials by establishing reasonable logistics distribution route. Comprehensively considering various factors, this problem can be described as follows (Xie, 2008).

Use many vehicles to carry materials to the appointed place from the distribution center, and the position and the demand quantity of each demand point are certain, and the load of each vehicle is certain, and the requirements include that the vehicle routes are reasonably arranged to make the transportation routes to be minimum or the transportation time to be minimum, and each demand point should obtain the distribution service in time, and one vehicle can interview the place once, and one vehicle can only serve for one route, and the distribution vehicles start from and return to the distribution center.

In addition, because of some special situations such as vehicle condition, road condition and hostile attacking, the military logistics distribution in wartime must consider the compulsory places, the prohibitive places, the compulsory routes and the prohibitive routes to ensure the safety of the materials. After fully considering the restriction conditions and the optimized objects of above problems, the mathematical model of the route optimization of the military logistics distribution in wartime is established as follows (Zhu, 2006 & Zhang, 2008, P.83-86). First, define variables as follows.

$$y_{k_i} = \begin{cases} 1 \text{ the distribution of the demand point } i \text{ is accomplished by the vehicle } k \\ 0 \quad \text{or else} \end{cases}$$

$$x_{ijk} = \begin{cases} 1 \text{ vehicle } k \text{ runs from the demand point } i \text{ to the demand point } j \\ 0 \quad \text{or else} \end{cases}$$

The objective function is

$$\min z = \sum\sum\sum d_{ij} x_{ijk} \tag{1}$$

s.t. $$\sum_i g_i v_{k_i} \le q \qquad \forall k \tag{2}$$

$$\sum_i y_{k_i} = 1 \qquad i = 1,\cdots,l \tag{3}$$

$$\sum_i x_{kijk} = y_{ki} \qquad j = 0,1,\cdots,l \qquad \forall k \tag{4}$$

$$\sum_j x_{kijk} = v_{ki} \qquad i = 1,\cdots,l \qquad \forall k \tag{5}$$

Where, d_{ij} denotes the route length from the demand point i to the demand point j, g_i denotes the transportation quantity of the task i, and q is the vehicle load. The formula (2) is the capacity restriction of the vehicle, the formula (3) ensures that the transportation task of each client point is accomplished by only one vehicle, and all transportation tasks are accomplished by m vehicles together, and the formula (4) and the formula (5) limit that there is one and only one vehicle to arrive at and depart from certain one client point.

2. Solving the problem of the military logistics support route optimization in wartime by the ant colony algorithm

2.1 Introduction of the ant colony algorithm

The ant colony algorithm is the simulated evolution algorithm based on the research result of the real ant colony collective behaviors in the nature, and it has many features such as positive feedback, parallel computation and strong robustness, and it is effective to use this algorithm to solve the problem of route optimization (Li, 2004). This algorithm is mainly decided by two formulas, i.e. the state transfer probability and the pheromone updating. Suppose that *m* is the total amount of ant, *n* is the amount of the route node, and $p_{ij}^k(t)$ is the state transfer probability that the ants transfer from the demand point *i* to the demand point *j* at the time of *t*.

At the initial time, the amount of pheromone on each route is equal. Suppose that $\tau_{ij}(0) = C$, and C is the constant, and the ant $k(k = 1,2,\ldots,m)$ decides its transfer direction according to the pheromones on various routes in the movement, and the tabu list $tabu_k(k = 1,2,\ldots,m)$ is used to record the demand points that the ant goes across, and the set is dynamically adjusted with the evolution process of $tabu_k$. In the searching process, the ant computes the state transfer probability according to the pheromone and the illumination information on various routes. At the time of *t*, the state transfer probability $p_{ij}^k(t)$ of the ant *k* transferring from the demand point *i* to the demand point *k* is

$$p_{ij}^k(t) = \begin{cases} \dfrac{\tau_{ij}^\alpha(t)\eta_{ij}^\beta(t)}{\sum\limits_{s \in allowed_k} \tau_{is}^\alpha(t)\eta_{is}^\beta(t)}, & s \in allowed_k \\ 0, & s \notin allowed_k \end{cases} \tag{6}$$

Where, $allowed_k = \{N - tabu_k\}$ denotes the set of the demand points that the ant is allowed to select next, α is the information illumination factor which denotes the relative importance of the track and reflects the function of the accumulated pheromones to the movement for the ant, and its value is bigger, and the ant is more inclined to select the routes that other ants have gone across, and β is the anticipated illumination factor which denotes the relative importance of the visibility, and reflects the importance of the illumination information to the route selection in the movement for the ant, and its value is bigger, and the probability that the ant selects the demand point near it is higher, and the expression of the illumination function $\eta_{ij}(t)$ is $\eta_{ij} = \frac{1}{d_{ij}}$, and d_{ij} denotes the distance between two neighboring demand points. For the ant *k*, d_{ij} is smaller, $\eta_{ij}(t)$ is bigger, and $p_{ij}^k(t)$ is bigger.

To avoid much more residual pheromones submerge the illumination information, after each ant goes across one step or accomplishes the traverse of all *n* demand points, i.e. one cycle ends, the residual pheromones should be updated. At the time of $t + n$, the amount of pheromone on the route (i, j) can be adjusted according to following rules.

$$\tau_{ij}(t + n) = (1 - \rho) \cdot \tau_{ij}(t) + \Delta\tau_{ij}(t) \tag{7}$$

$$\Delta\tau_{ij}(t)=\sum_{k=1}^{m}\Delta\tau_{ij}{}^{k}(t) \tag{8}$$

Where, ρ denotes the dispersing factor, so $1-\rho$ denotes the residual coefficient of pheromone, and to prevent the infinite accumulation of information, ρ is limited in $\rho\in(0,1)$, and $\Delta\tau_{ij}(t)$ denotes the increment of pheromone on the route (i,j) in this cycle, and the initial time is $\Delta\tau_{ij}(0)=C$, and $\Delta\tau_{ij}^{k}(t)$ denotes the amount of pheromone that the ant *k* leaves on the route (i,j) in this cycle.

The Ant-Cycle model is adopted to deal with the route optimization in this article, and in this model,

$$t_{ij}^{k}=\begin{cases}\dfrac{Q}{L_k}, & \textit{if the ant k goes across (i, j) between t and t}+1\\ 0, & \textit{or else}\end{cases}$$

Where, Q denotes the intension of the pheromone, and it is constant, and it can impact the constringency speed of the algorithm to certain degree, and L_k denotes the total length of the route that the ant *k* goes across in this cycle, and it equals to the sum of various routes d_{ij} that the ant *k* goes across.

2.2 Improvement of the state transfer probability function

The state transfer function of the basic ant colony algorithm only considers the illumination factor and the anticipation factor, and combining with the actual situation of the urban traffic condition, Xie Min et al (Xie, 2008) added two factors in the function, but the route optimization of the military logistics distribution in wartime must consider the compulsory places, the prohibitive places, the compulsory routes and the prohibitive routes because of some special situations such as vehicle condition, road condition and hostile attacking, and the importance degrees of various demand points are different, so the demand points with higher importance degree should be first fulfilled.

Comprehensively considering above factors, two illumination factors, w_{ij} and z_{ij}, are added in the state transfer probability function, and a improved state transfer rule can be obtained as follows.

$$p_{ij}^{k}(t)=\begin{cases}\dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)w_{j}^{\gamma}z_{ij}^{\theta}}{\sum_{s\in allowed_k}\tau_{is}^{\alpha}(t)\eta_{is}^{\beta}(t)w_{s}^{\gamma}z_{is}^{\theta}}, & s\in allowed_k\\ 0, & s\notin allowed_k\end{cases} \tag{10}$$

Where, $w_j(t), j=0,1...n$ denotes the importance degree of the next demand point j at the time of t, and it shows the demand degree of the demand point j to the materials at the time of t, and $w_j(t)\in[0,1]$, and when the value of $w_j(t)$ is bigger, the demand of the demand point j to the materials is more urgent, and the materials should be carried to the demand point as soon as possible, so the selected probability is higher, and $z_{ij}(t)$ denotes the unobstructed degree of the road (i,j) at the time of t, and $z_{ij}(t)\in[0,1]$, and when $z_{ij}(t)=1$, the road (i,j) has not been impacted by the war at the time of t and the road condition is in the optimal state, and when $z_{ij}(t)=0$, the road (i,j) is destroyed very badly, or is forbade to entry because of hostile firepower, and in *(0,1], $z_{ij}(t)$ is bigger, the road (i,j) is wider and the probability that this road is selected is higher.

2.3 Improvement of the object function

The route optimization of the military logistics distribution in wartime should not only require the minimum route length, but use the minimum time to accomplish the task when ensuring the safety of materials. Based on the established route optimization model of the military logistics distribution, the time factor is added into the objective function to obtain the improved objective function model as follows.

$$\mathrm{F}=\min(a\sum_{\mathrm{i}=tabu_k(0)}^{\mathrm{tabu_k(s\text{-}1)}}\mathrm{d}_{\mathrm{i,i+1}}+b\sum_{i=tabu_k(0)}^{tabu_k(s-1)}t_{i,i+1}) \tag{11}$$

Where, $\sum_{i=tabu_k(0)}^{tabu_k(s-1)}d_{i,i+1}$ is the length of the planed route, $\sum_{i=tabu_k(0)}^{tabu_k(s-1)}t_{i,i+1}$ is the passing time of the planned route. And t_{ij}

denotes the time required to pass the road (i, j), and in the article, $t_{ij} = \dfrac{v \cdot d_{ij}}{z_{ij}}$, and v is the vehicle speed when the road condition is good and there are not dangerous conditions such as hostile attacking, and it is a constant. $tabu_k(0)$ denotes the initial point, and $s = length(tabu_k)$ denotes the amount of the factor in the tabu list, i.e. the amount of the demand point, a and b are the balance of the route length and the passing time, and $a + b = 1$. The route length and the passing time are anticipated to be short. In practice, the planned route is a optimal combination combining above two factors.

3. Example of the algorithm

3.1 Basic steps of the algorithm

According to the above model, the route optimization model of the military logistics distribution in wartime includes following steps.

Step 1. Initialize the pheromones on each side as a very small constant. The start point of each ant is the distribution center, and set the distribution center into the tabu list at the same time.

Step 2. Judge whether the ant offer service for all clients, and if the service is accomplished, the ant returns to the distribution center and complete the construction of the route. Or else, select the next client, and judge whether the remnant capacity of the vehicle can fulfill the demand of the selected client. If it can be fulfilled, the ant serves for the selected client, and set the selected node into the tabu list. Then, update the pheromones on the corresponding side. If it can not be fulfilled, give up the selected client and return to the distribution center, and send another vehicle to serve again.

Step 3. Update all pheromones. Find the optimal route in this traverse and update all pheromones.

Step 4. If the setting search times have not used up, clear up the tabu list, and repeat above steps.

3.2 Experiment and analysis

Suppose that one oil warehouse needs transport oils to 19 demand points which are distributed in the square with the border length of 10 kilometer. The oil warehouse is in the midpoint of this region, and its coordinate is (0, 0). Suppose that the distribution center is the No.1 point, and the demands of various demand points are seen in Table 1, and the capacity of the vehicle is 9 tons. And the unobstructed factor of the road adopts the random data.

The adopted parameters include $m = 10$, $NC = 100$, $\tau_{ij}(0) = 0.01$, $\alpha = 1$, $\beta = 1$, $Q = 10$, $\rho = 0.6$, $\gamma = 0.7$ and $\theta = 0.3$. Run all steps ten times, and the optimal solution is 44.49km, and the corresponding route is

Route 1: 1→13→8→7→4→20→2→10→1;

Route 2: 1→16→6→14→17→12→11→3→19→1;

Route 3: 1→9→15→18→5→1.

It is obvious that the computation result of the ant colony algorithm is stable and avoids dangerous roads. So for the route optimization of the limitary logistics distribution in wartime, the improved ant colony algorithm can obtain ideal result.

4. Conclusions

The ant colony algorithm is a new bionic algorithm in the optimization domain. In this article, it is applied in the military logistics distribution, and the transfer probability function and the object function are improved. The experiment result indicates that this algorithm can quickly find the optimal solution and avoid the dangerous routes, and the calculation result is stable, and it can fulfill the requirements of the route optimization of the military logistics distribution in wartime.

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Table 1. Coordinates and demands of various nodes

No. of node	1	2	3	4	5	6	7	8	9	10
Abscissa	0	0	0	-2	-3	3	-4	-4	1	1
Ordinate	0	-1	3	-2	-3	-1	0	-1	-2	-1
Distributing quantity/t	0	1.5	1.8	2.0	0.8	1.5	1.0	2.5	3.0	1.7
No. of node	11	12	13	14	15	16	17	18	19	20
Abscissa	1	3	-3	2	1	2	2	1	-3	-1
Ordinate	3	4	0	0	-3	-1	1	-4	2	-1
Distributing quantity/t	0	0.2	2.4	1.9	2.0	0.7	0.5	2.2	3.1	0.1