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The Research of Emergency Logistics Routing Optimization Based on Improved Ant Colony Optimization

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Abstract. Emergency logistics system contains information on material reserves, emergency command and emergency distribution. In this paper, the aspect of emergency distribution only is analyzed in microscopic, mathematical model of emergency logistics distribution has been established in considering the traffic situation and shortage degree. On the aspect of model solution, improved ant colony algorithm, which can enhance the selectivity of finding the best solution in emergency logistics distribution routing, is used in solving the model.

Introduction

Because of frequency of disasters, emergency logistics has recently become a focus of government and academic sectors. Emergency logistics system contains information on material reserves, emergency command and emergency distribution. In this paper, the aspect of emergency distribution only is analyzed in microscopic, mathematical model of emergency logistics distribution has been established in considering the traffic situation and shortage degree.

On the aspect of model solution, ant colony algorithm takes a lot of time to find emergency logistics distribution routing optimization solution and complete the convergence of the algorithm, hence, improved ant colony algorithm, which can enhance the selectivity of finding the best solution in emergency logistics distribution routing, is used in solving the model.

The research of emergency logistics routing optimization provide well basis for emergency routing decision.

Emergency logistics routing optimization model

In order to facilitate the model's establishment, it is supported, single distribution center deliver to multi-affected points, all the vehicles starts from the distribution center, vehicles will not return to the distribution center after the distribution mission. Maximum carrying capacity and the average velocity of vehicles are known. Demand (demand less than the maximum carrying capacity)and the location of each affected point are known, and each affected point conveyed by only one vehicle. Because of unpredictable nature of disasters and the time-varying of relief situations after disaster, materials must be sent to the affected point before a certain moment, otherwise, road is not completely impassable because of unexpected circumstances.

$$T = \sum_{k=1}^{m'} T_k + \sum_{i=0}^{L} T_{kx} \tag{1}$$

Formula (1) is time target function, include tow parts: one is traveling time, the other is the unloading time. Where, L is the number of the affected points; m' is the number of the vehicles; T_k is the driving time of vehicle k ; T_{kx} is Unloading time of vehicle k at affected point i .

The distribution center will be numbered as 0, and affected points will be numbered from 1 to L . Define variable x_{ijk} and y_{ki} as:

$$y_{ki} = \begin{cases} 1, \text{point i is seviced by vehicle k} \\ 0, other \end{cases} \tag{2}$$

$$x_{ijk} = \begin{cases} 1, \text{ vehicle k travel from i to j} \\ 0, \text{ other} \end{cases} \tag{3}$$

$$T_k = \sum_{i=0}^{L}\sum_{j=0}^{L} t_{ij} x_{ijk} \tag{4}$$

Formula (4) is the driving time of vehicle k .where, t_{ij} is the time that vehicles driving from affected point i to affected point j .

$$t_{ij} = \frac{d_{ij}}{v} \times \varphi_{ij} \times \mu_i \tag{5}$$

Formula (5) is the time that vehicles pass by affected points ij , in which the degree of shortage and traffic situation for each affected points is also considered. Where, v is the driving velocity of vehicles, φ_{ij} is the situation of roads, it is indicated the road conditions of the distribution network, μ_i is the material shortage coefficient, it is indicated the level of demand for relief supplies of each affected point.

$$\sum_{i=0}^{L} g_i y_{ki} \le q \qquad k \in [1, m'] \tag{6}$$

Formula (6) is the total weight of relief supplies can not exceed the maximum carrying capacity of vehicles. Where, g_i is the quantity demanded of point i , q is the Maximum carrying capacity for vehicles;

$$\sum_{k=1}^{m'} y_{ki} = 1 \qquad i \in [0, L], k \in [1, m'] \tag{7}$$

$$\sum_{i=0}^{L}\sum_{k=1}^{m'} x_{ijk} = 1 \qquad j \in [0, L], k \in [1, m'] \tag{8}$$

$$\sum_{j=0}^{L}\sum_{k=1}^{m'} x_{ijk} = 1 \qquad i \in [0, L], k \in [1, m'] \tag{9}$$

Formulas (7), (8) and (9) guarantee that only one car passes by each affected point.

$$\sum_{i=0}^{L} x_{ijk} = y_{kj} \qquad i \in [0, L], k \in [1, m'] \tag{10}$$

$$\sum_{j=0}^{L} x_{ijk} = y_{ki} \qquad i \in [0, L], k \in [1, m'] \tag{11}$$

Formula (10) indicates the mission of the j demand point is accomplished by vehicle k transferring from affected point i . Formula (11) indicates the mission of the i affected point is accomplished by vehicle k transferring from affected point j

$$t_{ik} < t_{ei} \tag{12}$$

Formula (12) is the time demand of goods arriving at affected points. t_{ik} is the time that the vehicle k arrives at point i ; t_{ei} is the dead time of the distribution time for the affected points.

The research of improved ant colony optimization

Improved ant colony optimization. Based on these defects, introduce local pheromone update to avoid basic ant colony algorithm sinking into local optimum. Because of local pheromone update, it cause the chosen path affect subsequent ants little. The path has a little probability to be chosen again. Thus it has more probability that ants will choose the path never be chosen. So ants has stronger search ability.

Update the local information pheromone according to formula (13):

$$\tau_{ij} = (1-\xi)\times\tau_{ij} + \xi\times\tau_0 \tag{13}$$

Where, $\xi \in (0,1)$ is pheromone parameter, τ_0 is pheromone initial value.

Solved the model by ant colony optimization. Step1 NC=0 (NC is iteration), load_bus=0(load_bus is the maximum carrying capacity), $\tau_{ij}=0$, proceed parameters initialization.

Step2 Put m ants at the distribution center.

Step3 Calculate the transition probability of ant k according formula (14). Choose and move to the next city j, and add j to $tabu_k$ at the same time.

$$P_{ij}^{\ k} = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}\cdot[\eta_{ij}(t)]^{\beta}}{\sum_{s\in allowed_k}[\tau_{is}(t)]^{\alpha}\cdot[\eta_{is}(t)]^{\beta}} & j\in allowed_k \\ 0 & other \end{cases} \tag{14}$$

Where, $allowed_k = (1,2,..,n) - tabu_k$ is the city that ant k can choose currently. $tabu_k$ $(k=1,2,\cdots,m)$ is the taboo list of ant k, recording the cities that ant k has traveled through, to indicate ants' memo ability. $\eta_{ij}(t)$ is prior knowledge visibility. In the TSP study, is the elicitation information deliver from one city to another, and in general $\eta_{ij}(t)=1/d_{ij}$. α is the importance of residual information on path ij. β is the importance of elicitation information.

Step4 Update the local information pheromone.

Step5 Check whether the vehicle load reaches maximum carrying capacity. If so, the vehicle returns to the distribution center.

Step6 Check whether the arrival time t_i of distribution vehicle is less than the distribution dead time of affected point. If not, return to Step3. Otherwise, go on Step7.

Step7 Check whether $tabu_k$ is full. If not, return to Step3. Otherwise, go on Step8.

Step8 Calculate objective function, and record the best solution currently, update pheromone based on formula (15)

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t) \tag{15}$$

$$\Delta\tau_{ij}(t) = \sum_{k=1}^{m}\Delta\tau_{ij}^{k}(t) \tag{16}$$

$\Delta\tau_{ij}(t)$ is incremental pheromone on path ij during traveling. At the beginning, $\Delta\tau_{ij}(0)=0$. $\Delta\tau_{ij}^{k}(t)$ is the pheromone that ant k release on the path ij during traveling, which is determined by ants' performance. The shorter the path is, the more pheromone is released.

$$\Delta\tau_{ij}^{k}(t) = \begin{cases} Q/L_k & \text{section k of ants pass edge ij in the course of this tour} \\ 0 & else \end{cases} \tag{17}$$

Where, Q is constant, L_k is the length of the circuit which is formed by ant k in this traveling.

Step9 If $NC < NC_{\max}$, then $NC = NC+1$, empty $tabu_k$, and go back to Step2. If $NC = NC_{\max}$, end.

Simulation

The location of distribution center is (65, 25), providing 3 cars serve for 20 affected points. List 1 provides location, demand, end time, unloading time and shortage degree of each affected point. Maximum carrying capacity of each car is 250. Speed is $v = 40km/h$. Traffic coefficient of each path is provided by literature [1]. $\xi = 0.2$, the value of α,β,ρ is provided by literature [2]. The distance between each affected point and distribution center is calculated by range formula (17).

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{17}$$

Table1. Experimental Data

NO.	coordinate	Requirements	End time	unloading time	Shortage degree
1	(20,85)	45	6.8	0.1	0.99
2	(5,45)	25	9.5	0.2	0.98
3	(42,15)	25	2.0	0.5	0.65
4	(38,5)	51	3.5	0.4	0.76
5	(95,35)	45	2.5	0.3	0.97
6	(85,25)	25	1.5	0.5	0.85
7	(62,80)	65	4.5	0.2	0.67
8	(58,75)	45	4.3	0.4	0.83
9	(50,82)	25	5.2	0.1	0.94
10	(18,80)	25	5.8	0.3	0.92
11	(25,30)	23	10.5	0.5	0.86
12	(15,10)	45	4.0	0.4	0.87
13	(45,65)	23	6.2	0.1	0.90
14	(65,20)	17	1.0	0.3	0.73
15	(31,52)	59	2.8	0.2	0.69
16	(2,60)	15	8.5	0.2	0.88
17	(5,5)	37	6.0	0.3	0.95
18	(57,29)	41	1.6	0.1	0.78
19	(4,18)	55	8.0	0.4	0.87
20	(26,35)	35	10.8	0.3	0.81

Ant colony algorithm running routes are shown in Fig. 1.

Distribution Center－affected point 14－affected point 18－affected point 15－affected point 16－affected point 1－affected point 10－affected point 2－affected point 11;Distribution Center－affected point 6－affected point 5－affected point 7－affected point 8－affected point 9－affected point 13;Distribution Center－affected point 3－affected point 4－affected point 12－affected point 17－affected point 19－affected point 20.

Improved ant colony algorithm running routes are shown in Fig. 2.

Distribution Center－affected point 14－affected point 18－affected point 15－affected point 10－affected point 1－affected point 16－affected point 2－affected point 11;Distribution Center－affected point 6－affected point 5－affected point 7－affected point 8－affected point 9－affected point 13;Distribution Center－affected point 3－affected point 4－affected point 12－affected point 17－affected point 19－affected point 20.

Fig.3 shows that the improved algorithm solution model is better than basic ant colony algorithm. Because introducing local pheromone in basic ant colony algorithm which overcomes the defects of basic ant colony algorithm: local stagnation and local optimum, global search capability of ants improves.

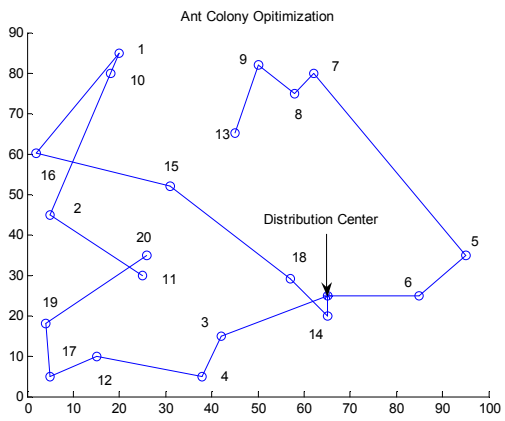

Fig.1. Ant colony algorithm operating

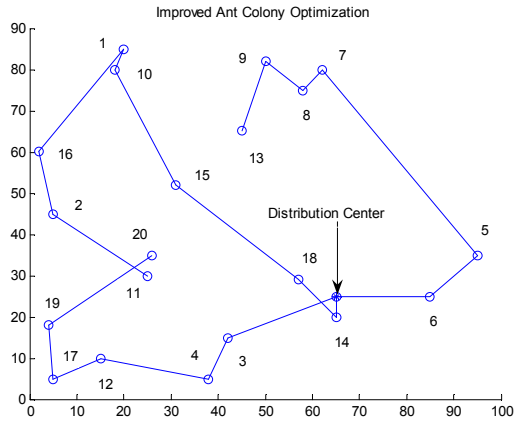

Fig.2. Improved ant colony algorithm operating map

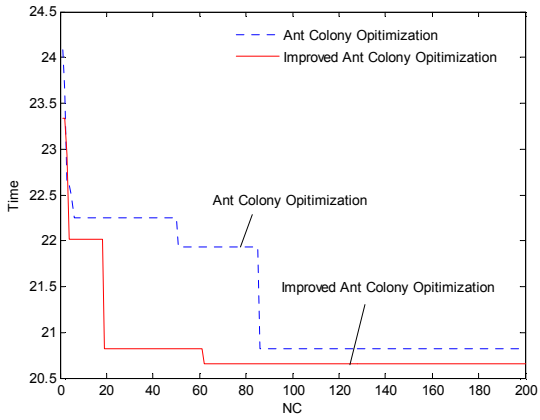

Fig.3. The optimal solution optimal curve

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