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Weak Economic Emergency Logistics Routing Optimization Based on Chaos Ant Colony Algorithm

[1,2]Teng Fei and [1,2]Liyi Zhang
[1]Information Engineering College, Tianjin University of Commerce, Tianjin, 300134, China
[2]Information Engineering College, Tianjin University, Tianjin, 300000, China

Abstract: The emergency logistics with weak economy meets the prerequisite of emergent requirements, reducing cost and improving level of utilization. By optimization, emergency logistics with weak economy can decrease the cost of emergency logistics and make full use of the resource, in order to play a greater role in relief work and reconstruction for disaster area. This study comes up with path optimization model optimized by chaos ant colony algorithm. The effectiveness of this model is verified by GUI simulation.

Key words: Emergency logistics;weak economic;routing optimization;chaos ant colony algorithm

INTRODUCTION

Emergency logistics takes on the propertyof weak economy, however waste of emergency resources is not acceptable. Under such conditions, the emergency logistics with weak economy is worked out which meets the prerequisite of emergent requirements, reducing cost and improving level of utilization. (Feng, 2003) By optimization, emergency logistics with weak economy can decrease the cost of emergency logistics and make full use of the resource, in order to play a greater role in relief work and reconstruction for disaster area. This study comes up with path optimization model optimized by chaos ant colony algorithm. Also, the effectiveness of this model is verified by GUI simulation.

WEAK ECONOMIC EMERGENCY LOGISTICS PATH OPTIMIZATION MODEL

Weak economic emergency logistics path optimization model based on the principle of the weak economy and meet time requirements is to achieve the minimum distribution cost overhead. To simplify operation, make the following assumptions in establishing the model:

- Demand affected spots corresponding to the emergency center and points of each affected are known
- Transport distance is known, the speed is known
- Vehicles service for each affected point only consists of discharge without loading condition
- Each affected point is serviced only once by one vehicle
- Needs of all affected points can be met in terms of quantity and transport
- Demand of the single disaster point is less than the maximum vehicle load.Based on the above assumed condition, build up the mathematical model about the total cost of distribution as:

$$\min W = \sum_{k=1}^{m'} \left(\sum_{i=0}^{L} \sum_{j=0}^{L} c_{ijk} x_{ijk} + c_{0k} \right) \tag{1}$$

Constraint condition:

$$\sum_{i=0}^{L} g_i y_{ki} \le q \quad k \in [1, m'] \tag{2}$$

$$\sum_{k=1}^{m'} y_{ki} = 1 \quad i \in [0, L], k \in [1, m'] \tag{3}$$

$$\sum_{i=0}^{L} \sum_{k=1}^{m'} x_{ijk} = 1 \; j = [0, L],\; k \in [1, m'] \tag{4}$$

$$\sum_{j=0}^{L} \sum_{k=1}^{m'} x_{ijk} = 1 \; i = [0, L],\; k \in [1, m'] \tag{5}$$

$$t_{jk} = t_{ik} + T_{kx} + t_{ij} \quad k \in [1, m'] \tag{6}$$

$$\sum_{k=1}^{m'} \sum_{i=0}^{L} x_{0ik} - \sum_{k=1}^{m} \sum_{j=0}^{L} x_{j0k} = 0 \tag{7}$$

$$t_{ik} \le t_i^e \tag{8}$$

Corresponding Author: Liyi Zhang, Information Engineering College, Tianjin University of Commerce, Tianjin300134, China

$$t_{ij} = \frac{d_{ij}}{v_k} \times \varphi_{ij} \times \mu_i \quad (9)$$

$$c_{ijk} = C_k d_{ij} \quad (10)$$

where, W is the total cost of distribution; m is the number of emergency distribution vehicles; C_{ijk} is the cost of vehicle k traveling from affected point i to affected point j; C_{0k} is the fixed cost of vehicle k; x_{ijk} means whether vehicle k will travel from affected point i to affected point j. If it will, $x_{ijk} = 1$. Otherwise, x_{ijk} is 0. q is the load of distribution vehicles; g_i is the requirements of affected point i, $g_i \leq q$, y_{ki} means whether the mission of affected point i is completed by vehicle k. If yes, $y_{ki} = 1$. Otherwise, y_{ki} is 0. T_{ik} is the time that vehicle k arriving at affected point i; T_{kx} is the unloading time of affected point i; t_{ij} is the time vehicle k traveling from affected point i to affected point j. T^e_i the latest arrival time of affected point i. If the arrival time is late than it it means that the solution is invalid. V_k is the average speed of vehicle k; φ_{ij} is traffic coefficient. The bigger it is, the longer emergency distribution time is; μ_i is disaster relief materials shortage coefficient. The smaller it is, the shorter emergency distribution time is. C_k the cost of vehicle k.

The objective function equation 1 means the total cost is minimum under the weak economy emergency logistics condition. Equation 2 means the total requirement of the affected point vehicle k served can not be more than the load of the vehicle itself. Equation 3 means each affected point can be visit once by only one vehicle. Equation 4 and 5 mean each affected point has only one vehicle to unload. Equation 6 means affected point i and j is served by vehicle k. And affected point i is the one before affected point j. Equation 7 means the number of out vehicles is equal to the number of back vehicles. Equation 8 means the disaster relief materials arrival time must be in the unilateral time window. Equation 9 the time vehicle k traveling from affected point i to affected point j with consideration of traffic conditions and shortage coefficient. Equation 10 means the cost of vehicle k traveling from affected point i to affected point j.

CHAOS ANT COLONY ALGORITHM

Chaos ant colony algorithm is to introduce the concept of chaos into ant colony algorithm. Chaos is a form of motion which performances under certain conditions in nonlinear dynamical systems,is random acts presented in non-equilibrium process system. Chaotic mechanism which is a simple non-linear is no fixed rule without random factors (Li, 2004).Because the foraging behavior of ants has the characteristics of chaos in the ant colony algorithm, the characteristics in ergodicity and randomicity of the chaotic algorithms are used in the ant colony algorithm,in order to make ant colony algorithm have the wider search range and faster search speed, thereby forming a new search algorithm-chaos ant colony algorithm. Chaos ant colony algorithm optimization results are better,because of introducing chaos initialization and chaotic disturbance into ant colony algorithm.

Chaos initialization: During early phase of basic ant colony algorithm, pheromoneswh of ants leaving in each path are identical,therefore, ants forage in the same probability at beginning. (Dorigo and Gambardella, 1997) Thus,it not only reduces optimizing efficiency,but also find the global optimum uncomfortably.If the initial value of the pheromone in the basic ant colony algorithm is based on the amount of chaos,the pheromone of each path leaving is different, ants can select the optimum path based on the number of pheromone to improve efficiency optimization.For chaos initialization,the typical of chaotic systems-logistics mapping as chaotic variables is chosen for the chaos initialization iterating as the equation 11:

$$Z_{ij}(t+1) = \mu Z_{ij}(t)\left[1 - Z_{ij}(t)\right] \quad (11)$$

where, μ is controls parameter the value of which is [3.56, 4] (Gao, 2005).When $\mu = 4$, $0 \leq Z_{ij}(0) \leq 1$, logistics mapping is completely in the chaotic state. Using full arrangement theory, each chaotic quantity corresponds with every distribution path, in which the initial value of the pheromone quantity of each path is given according to the chaos quantity.

Chaotic disturbance: To set an established cost in the basic ant colony algorithm can avoid unnecessary searches which poor solution brings,therefore, the efficiency and convergence speed search are improved. (Fan *et al.*, 2011)To introduce chaotic disturbance in pheromone updating can increase ergodicity of ants,so ants can find a better optimum solution and avoid falling into local optimum. Pheromone updating added chaotic disturbance equation is:

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t) + q_1 Z_{ij}(t) \quad (12)$$

where, Z_{ij} is the chaos variable which can be gotten from the iteration of equation (12), in which q_1 is coefficient, ρ is the volatile factor of global pheromone, of which the value is [0, 1) (Fei, 2010).Usually determining the volatile speed of pheromone. $\Delta\tau_{ij}(t)$ is the pheromone's increment of this circling in the pathway ij.Assume at the initial moment, $\Delta\tau_{ij}(0)$ = Chaotic variables, $\Delta\tau_{ij}^{k}(t)$ indicates the pheromone that ant k releasing in the pathway ij during the circling. The value is based on the performance of ants. The shorter the pathway, the more the pheromone is released.

Sloving the model:

Step1: Regarding NC = 0 (NC is iteration), load_bus = 0(load_bus is the load of vehicles) ,proceed parameters initialization and chaos initialization.

Step 2: Put m ants on the Disaster Relief Distribution Centers

Step 3: Calculate the transition probability of ant k based on equation 13, choose and move the ants to the next city j based on the transition probability, and add j to $tabu_k$ at the same time. Check whether the vehicles' load is larger than the maximum load. If so, return to disaster relief distribution centers

$$P_{ij}^{k} = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}\cdot[\eta_{ij}(t)]^{\beta}}{\sum_{s\in allowed_k}[\tau_{is}(t)]^{\alpha}\cdot[\eta_{is}(t)]^{\beta}} & \text{if} j\in allowed_k \\ 0 & \text{other} \end{cases} \quad (13)$$

where, $allowed_k$ = (1, 2,....n)-$tabu_k$ indicates the set of cities that ant k can choose at present; $tabu_k$ (k = 1, 2,..., m) indicates that the list of ant's $\eta_{ij}(t)$ taboo, in which record the cities that ant k has passed by, illustrating the memory ability of artificial ants;$\eta_{ij}(t)$ is inspiration function that indicates the expectation of the transference from city i to city j, usually $\eta_{ij}(t) = 1/d_{ij}$; α is the importance of residual information in the pathway ij; β is the importance of the inspirational information:

Step 4: Check whether $tabu_k$ is full. If not, return to Step3. Otherwise, go on Step5

Step 5: Check whether time is met of Affected points,Calculate the target costs, record the current best solution

Step 6: Claim pheromone according to equation 12, when The minimum cost is less than the given cost

Step 7: If $NC<NC_{max}$, NC = NC+1, clear $tabu_k$ and go back to Step2. If $NC = Nc_{max}$, end

SOMULATION

Assume that there are only 4 free cars at the disaster relief distribution centers ,while other cars are undertaking distribution missions. The coordinate of the disaster relief distribution centers is known as (0, 0). After the disaster, the disaster relief materials should be distributed to 19 affected points from the disaster relief distribution centers Table 1 indicates the coordinate data of each affected point, quantity demanded, terminate time, and discharge time and shortage of each affected point. The maximum load of each vehicle is 90 tons. The velocity of vehicles is 60 km h^{-1}. Table 2 is traffic coefficient of the pathway between every affected point.

Using the GUI in this study, set Alpha = 1, Beta = 5, Rho = 0.6, Q = 100, the maximum load of each vehicle is 90 tons. iteration is 100 , the number of ants is 60, chaos factor is 1, chaos step is 4. select system with traffic situations, , the results of basic ant colony algorithm are shown in Fig. 1. Set Alpha = 1, Beta = 5, Rho = 0.6, Q = 100, The maximum load of each vehicle is 80 tons. iteration is 100 , the number of ants is 60, chaos factor is 1, chaos step is 4. select system with traffic situations, the results of chaos ant colony algorithm are shown in Fig. 2. Set Alpha = 1, Beta = 5, Rho = 0.8, Q = 100, The maximum load of each vehicle is 90 tons. iteration is 100 , the number of ants is 60, chaos factor is 1, chaos step is 4. select system with traffic situations, the results of comparing two algorithms under weak economic conditions are shown in Fig. 3.

In the Fig. 3 it can be seen that chaos ant colony algorithm can find lower cost under the emergency distribution of weak economic conditions and

Table 1: Data

Coordinates	Requirements	End time	Unloading time	Short degree
(4,8)	15	3.0	0.1	0.99
(5,-28)	18	4.5	0.2	0.98
(18,20)	20	2.0	0.5	0.65
(32,30)	8	3.5	0.4	0.76
(-30,12)	15	4.0	0.3	0.97
(42,-8)	10	5.0	0.5	0.85
(42,10)	25	4.5	0.2	0.67
(-10,22)	30	2.5	0.4	0.83
(-10,10)	17	1.8	0.1	0.94
(-8,-30)	6	5.5	0.3	0.92
(-28,-42)	2	4.8	0.5	0.86
(35,8)	24	5.8	0.4	0.87
(-22,0)	19	4.5	0.1	0.90
(-15,25)	20	2.5	0.3	0.73
(-20,10)	7	2.5	0.2	0.69
(-22,-12)	5	5.8	0.2	0.88
(-15,40)	22	3.0	0.3	0.95
(30,-25)	31	3.0	0.1	0.78
(12,12)	1	4.5	0.4	0.87

Table 2: Traffic coefficient

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	-	1.2	1.1	1.3	1.5	1.6	1.7	1.8	1.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.3
1	1.2	-	1.3	1.4	1.5	1.7	1.9	1.6	1.1	1.1	1.2	1.3	1.0	1.6	1.5	1.4	1.3	1.2	1.0	1.1
2	1.1	1.3	-	1.5	1.4	1.6	1.7	1.8	1.3	1.2	1.1	1.0	1.8	1.75	1.69	1.74	1.62	1.1	1.2	1.4
3	1.3	1.4	1.5	-	1.1	1.2	1.3	1.6	1.5	1.3	1.1	1.2	1.4	1.6	1.7	1.81	1.8	1.7	1.9	1.2
4	1.5	1.5	1.4	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.1	1.7	1.3	1.5	1.6	1.9	1.8	2.1	2.0
5	1.6	1.7	1.6	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	1.9	1.8	1.7	1.6
6	1.7	1.9	1.7	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	1.9	1.8	1.7
7	1.8	1.6	1.8	1.6	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	1.9	1.8
8	1.9	1.1	1.3	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	1.9
9	1.0	1.1	1.2	1.3	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
10	1.1	1.2	1.1	1.1	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
11	1.2	1.3	1.0	1.2	1.1	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
12	1.3	1.0	1.8	1.4	1.7	1.7	1.6	1.5	1.4	1.3	1.3	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6	1.7
13	1.4	1.6	1.75	1.6	1.3	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5	1.6
14	1.5	1.5	1.69	1.7	1.5	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4	1.5
15	1.6	1.4	1.74	1.81	1.6	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3	1.4
16	1.7	1.3	1.62	1.8	1.9	1.9	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2	1.3
17	1.8	1.2	1.1	1.7	1.8	1.8	1.9	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1	1.2
18	1.9	1.0	1.2	1.9	2.1	1.7	1.8	1.9	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	-	1.1
19	1.3	1.1	1.4	1.2	2.0	1.6	1.7	1.8	1.9	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	-

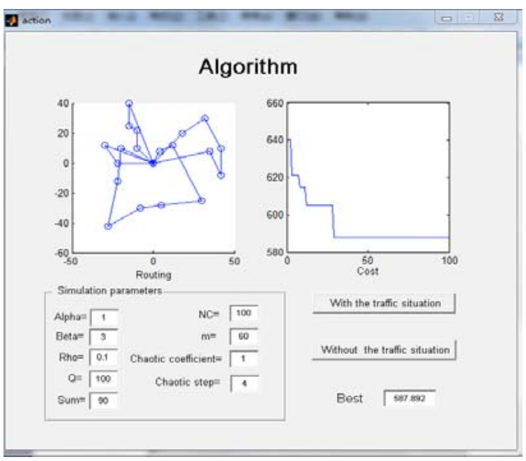

Fig. 1: Ant colony algorithm

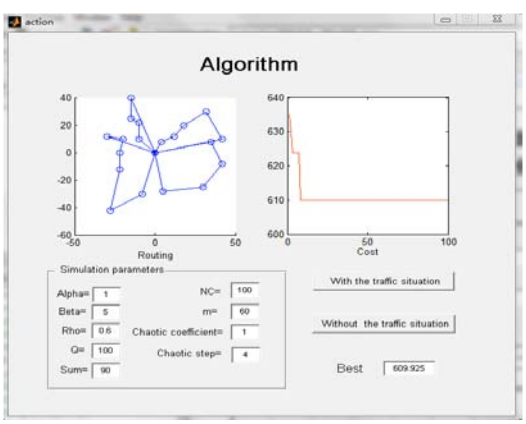

Fig. 2: Chaos ant colony algorithm

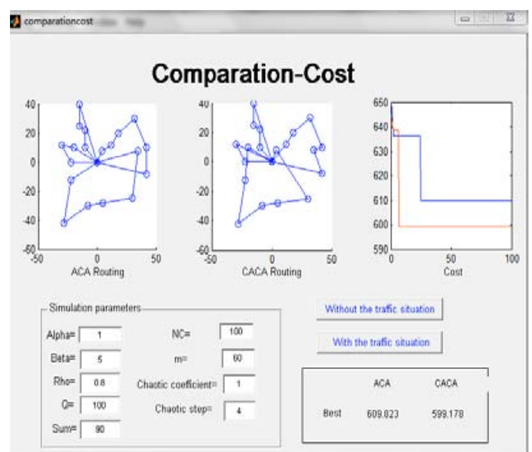

Fig. 3: Comparing two algorithms

convergence speed is faster than the basic ant colony algorithm. This is because chaos initialization improves search efficiency at the beginning of chaos ant colony algorithm, chaotic disturbance enhances the ant ergodicity.

CONCLUSION

This study works out one new hybrid algorithm named as the optimization of distribution path for emergency logistics by using chaos ant colony algorithm under weak economic conditions, of which effectiveness is confirmed by simulation. However, all research concern with distribution path in document just belong to preliminary stage. Distribution model is in the level of exploration as well as ideal. Many practical factors and constraint are not take into consideration. In future studies, the complexity of the model will be increased. And the combination of theory and practice will meet the realistic needs better.

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