Choice of Emergency Logistics Center Location based on Particle Swarm Optimization

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Abstract

A programming model applied to location selection for an emergency logistics distribution center is established on the basis of shortest time. Then, particle swarm optimization (PSO) is introduced to solve the model. The selection of a distribution center is solved using the discrete PSO algorithm, and the distribution of goods is solved using the traditional PSO algorithm. A C++ program was written to solve the problem and enhance the efficiency and accuracy of the solution for the location selection problem. Experimental results show that the method is feasible and efficient..

Keywords: PSO, emergency logistics,logistics center,location

1 Introduction

An 8.0-magnitude earthquake occurred near Yingxiu, Wenchuan County, Sichuan Province on May 12, 2008. Two earthquakes occurred in Yushu County, Qinghai Province on April 14, 2010. The maximum magnitude reached 7.1. A 4.9-magnitude earthquake occurred in Yingjiang, Yunnan Province on January 1, 2011. Although the earthquake had a low magnitude, it caused considerable damage because it occurred right beneath the city with a shallow seismic source (<10 km). Based on rough statistics, the three earthquakes caused more than 100,000 deaths; more than 500,000 injuries; and more than 100 billion RMB in economic losses. Given the impossibility of accurately forecasting natural disasters (e.g., earthquakes), rapid and efficient disaster response is the key to control casualties and losses as well as to reduce human suffering. Reducing casualties and property losses in China as well as distributing supplies to destinations correctly and promptly after disasters are important problems that we need to address to support smooth rescue of the injured and enable post-disaster reconstruction.

Particle swarm optimization (PSO) is an evolutionary computation technology proposed by M. Dorigo, an Italian scholar, in 1991. PSO was used to study the predatory behavior of birds. Similar to genetic algorithm (GA), PSO is also an optimizer based on iteration. PSO derives a group of random solutions from system initialization and searches the optimum solution through iteration. GA searches the optimum solution through crossover and mutation, whereas PSO searches by making particles follow optimum particles in the solution space. Compared with GA, PSO is superior because it is easy to operate and has fewer parameter adjustments. Therefore, in this study, we use PSO to select a reasonable location for an emergency logistics center.

2 Location model of emergency logistics center

The location of the logistics center will influence transport time and cost directly. Therefore, the emergency logistics center should be located in an area with the shortest transport time to minimize the sum of material delivery time from material supply points to the logistics center, material processing time in the logistics center, and transport time from the logistics center to disaster areas. On this basis, a location model of the emergency logistics center was established in this study.

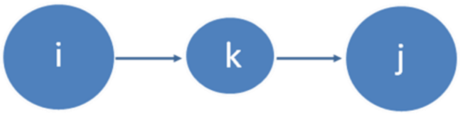

FIGURE 1 Emergency logistics distribution

For modeling convenience, the following hypotheses were made:

(1) The location of the emergency logistics center is only considered within certain alternative scopes.

(2) The quantity demands of different demand points are fixed and known.

(3) The capacity of the emergency logistics center can meet the demands.

(4) The transport time from the material supply points to the logistics center and from the logistics center to users is a linear function.

Therefore, the objective function of location selection for the emergency logistics center is expressed

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as follows:

$$\min T=\sum_{i=1}^{m}\sum_{k=1}^{q}C_{ik}X_{ik}+\sum_{k=1}^{q}\sum_{j=1}^{n}C_{kj}Y_{kj}+\sum_{i=1}^{m}\sum_{k=1}^{q}G_{k}X_{ik} \qquad (1)$$

$$\text{s.t. } \sum_{k=1}^{q}X_{ik}\le A_i, \qquad (2)$$

$$\sum_{j=1}^{n}Y_{kj}\le\sum_{i=1}^{m}X_{ik}, \qquad (3)$$

$$\sum_{k=1}^{q}Y_{kj}\ge B_j, \qquad (4)$$

$$\sum_{i=1}^{m}X_{ik}\le M_kW_k, \qquad (5)$$

$$W_k=G_k=\begin{cases}1 & \text{if choose } k\\ 0 & \text{if not choose } k\end{cases}, \qquad (6)$$

where Cik is the transport time from material supply point i to alternative point k; Xik is the transport volume from i to k; Ckj is the transport time from k to user j; Ykj is the transport volume from k to j; Gk is the processing time of unit flow at k; Ai is the supply capacity of i; Bj is the quantity demand of j; Mk is the maximum storage capacity of k; m is the quantity of material supply points; q is the quantity of alternative points; and n is the number of users.

3 PSO

3.1 BASIC PSO

In basic PSO, the solution of each optimization problem is expressed by a particle. Each particle has a unique location and speed. The optimum solution is derived from the solution space based on the particle best value (pbest) and global best value of the entire particle swarm (gbest). The +1st iteration of particles is updated based on Equations (7) and (8), as follows:

$$V_{id}^{k+1}=w\cdot V_{id}^{k}+c_1\cdot rand(\ )\cdot\left(p_{best}-X_{id}^{k}\right)+c_2\cdot rand(\ )\cdot\left(g_{best}-X_{id}^{k}\right) \qquad (7)$$

$$X_{id}^{k+1}=X_{id}^{k}+V_{id}^{k+1}, \qquad (8)$$

where V is the velocity of the current particle; X is the position of the current particle; rand() denotes the random number within [0,1]; w is the inertia weight; and c1 and c2 are the learning factors.

3.2 DISCRETE PSO

Basic PSO is mainly applied to optimize the continuous space function, but is unable to optimize discrete space. Kennedy and Eberhart proposed a discrete binary PSO. In this discrete binary PSO, speed is defined as the probability of the corresponding position at 0 (or 1). Therefore, the discrete binary PSO uses Equation (9) to replace Equation (8) of the basic PSO, as follows:

$$X_{id}^{k+1}=\begin{cases}1 & rand(\ )\prec S\left(V_{id}^{k+1}\right)\\ 0 & rand(\ )\succ S\left(V_{id}^{k+1}\right)\end{cases}, \qquad (9)$$

where S(V) is the Sigmoid function, S(Vid) = 1/(1 + e) and rand() denotes the random number within [0,1].

4 PSO-based location selection for emergency logistics center

Location selection for the emergency logistics center includes two optimization problems, namely, selection of logistics center and transport distribution. Selection of logistics center is a discrete optimization problem, whereas transport distribution is a continuous optimization problem. As a result, we used discrete binary PSO for the former and basic PSO for the latter. The location model of the emergency logistics center was established based on the nested cells of discrete binary PSO and basic PSO. In this location model, Xik, Ykj, and Wk could be obtained (Xik is the source of goods of the logistics center and Ykj is the supply scope of k). In this manner, the structure of a logistic network can be determined during the effective location selection for the logistics center.

4.1 PARTICLE CODING

Considering two optimization problems in location selection for the logistics center, particle coding includes binary coding and real number coding accordingly. Selection of logistics center uses binary coding. Particles are expressed as X = (W1, W2, ···, Wk, ···, Wq); Wk and Wq have been previously defined. Particle length is equal to the number of alternative points for the logistics center. X = (0, 1, 1, 0, 1, 0) indicates that W2, W3, and W5 are selected as alternative points for the logistics center. Transport distribution uses real number coding. Particles are expressed as X = (X11, ···, Xik, ···, Xmq, Y11, ···, Ykj, ···, Yqn); Xik, Ykj, m, q, and n have been previously defined.

4.2 FITNESS FUNCTION

Penalty function method was applied to determine the constraints of the established location model of the emergency logistics center. The location model was converted into a constraint-free optimization problem, thus ensuring that the iteration point is within the feasible region throughout the optimization process and obtaining the optimum solution of the original model. The fitness function in this study is expressed as follows:

$$f = F + C\sum_{i=1}^{m}\left[\min\left(0, A_i - \sum_{k=1}^{q} X_{ik}\right)\right]^2 + M\sum_{j=1}^{n}\left[\min\left(0, \sum_{k=1}^{q} Y_{kj} - B_j\right)\right]^2 + N\sum_{k=1}^{q}\left\{\left[\min\left(0, M_k W_k - \sum_{i=1}^{m} X_{ik}\right)\right]^2 + \left|\sum_{j=1}^{n} Y_{kj} - \sum_{i=1}^{m} X_{ik}\right|^2\right\}, \qquad (10)$$

where C, M, and N are large positive integers.

5 Case study

In this study, we investigated location selection for the emergency logistics center of product oil distribution in Fuzhou City based on local logistics data of product oil to verify the feasibility and effectiveness of the proposed PSO algorithm. We assumed that a logistics system has three supply points (1, 2, and 3). The supply capacities of these three points are 40, 60, and 50, respectively. The logistics center has six alternative points (1, 2, ···, 6). The fixed cost and maximum capacity of these alternative points are listed in Table 1. In addition, the logistics center has 10 users. The demands of different users are shown in Table 2. Tables 3, 4, 5, and 6 indicate the different transport parameters.

TABLE 1 Alternative points for the logistics center.

Alternative point	L1	L2	L3	L4	L5	L6
Capacity of intermediate point	35	25	20	30	25	15
Processing waste at intermediate point	35	25	20	30	25	15

TABLE 2 Demands of different users.

Users	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Demands	15	5	15	15	10	20	5	20	15	30

TABLE 3 Transport time of unit goods from i to k.

i	k					
	1	**2**	**3**	**4**	**5**	**6**
1	12	7	10	11	2	6
2	4	8	5	10	13	15
3	9	13	4	3	12	8

Based on the previously presented data, PSO not only selects the optimum location for the emergency logistics center but also determines the optimum goods distribution in the logistic network. PSO optimized the emergency logistic network structure.

TABLE 4 Transport time of unit goods from k to j.

k	j									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	4	4	9	11	8	7	4	4	7	1
2	8	8	11	7	4	3	4	2	7	5
3	1	3	8	10	7	10	9	7	6	4
4	6	2	3	5	6	11	10	8	3	5
5	9	7	10	6	3	2	9	5	6	8
6	11	7	6	2	3	6	11	7	4	10

TABLE 5 Transport volume from i to k.

k/i	**1**	**2**	**3**
1	0	26	9
2	14	10	1
3	2	12	6
4	4	4	22
5	11	7	7
6	10	1	5

TABLE 6 Transport volume from k to j.

k	j			
	1	**3**	**5**	**6**
1	4	4	3	1
2	1	1	1	1
3	1	2	3	5
4	7	5	1	0
5	0	0	2	1
6	6	4	3	2
7	3	0	0	0
8	3	4	3	5
9	3	1	3	1
10	6	3	2	13

6 Conclusions

The emergency logistics center plays an important role in improving the operation efficiency of the logistic network during earthquake relief. How to deliver relief supplies to the destination in the shortest time and how to select a reasonable location for the emergency logistics center determine the performance of such a system. In this study, we propose PSO-based location selection for the emergency logistics center. This approach is confirmed to be effective by a case study. However, PSO has certain limitations. Future research will focus on combining PSO with other optimization algorithms.

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