Solving Location Problem of Distribution Center Based on Hybrid Particle Swarm Algorithm

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Abstract: A kind of coding is constructed for location problem of distribution center and then a hybrid particle swarm optimization algorithm is proposed, integrating the particle swarm optimization and the hill climbing algorithm. The particle swarm evolves in the integer space after being integer standardized. This algorithm can solve the problem of low precision and divergence of basic particle swarm optimization algorithm, so it has higher efficiency of search. Compared with basic particle swarm optimization algorithm and genetic algorithm, it has been proved that this algorithm is more effective.

Key words: Hill climbing algorithm, hybrid particle swarm algorithm, integer standardization, location of distribution centre.

1. Introduction

Logistics distribution center is the logistics base, which includes picking, packaging, warehousing, loading and unloading, sub-goods, processing, information services, delivery and other service functions. The distribution of distribution centers has a great impact on modern logistics activities. So, reasonable location of the distribution center can reduce the cost of transport of goods, thus greatly reducing operating costs. The most common problem about location of distribution center [1], [2] is to determine the optimal location of the distribution center in a series of candidate points, with the goal of minimizing the sum of the costs. In solving the problem of distribution center location, the commonly used quantitative analysis methods are the center of gravity method, CFLP [3] method, genetic algorithm [4], [5] and so on.

Particle swarm optimization algorithm [6], [7] is a new evolutionary computation method proposed by James Kennedy and Russell Eberhart in 1995, which belongs to solving the global optimization of group intelligence algorithm. Since its inception, it has received a high degree of attention from academia and has been very successful in many areas such as neural network training [7], traveler problems [8], vehicle routing and so on.

The basic PSO algorithm [9], [10] is simple and easy to implement, has good convergence performance, but also has the disadvantages of low precision and easy divergence. In this paper, the PSO algorithm and the climbing algorithm are combined to propose a hybrid PSO algorithm [11] to solve the problem of distribution center location. And compared with the basic PSO algorithm and genetic algorithm, the experimental results show that the algorithm has a better search effect.

2. Problem of Distribution Center Location

The distribution center is the most important hardware facility for logistics and distribution activities. All the logistics activities are almost entirely carried out with the center, which is a very important node in the supply chain. The positioning of the distribution center almost determines the cost required for the distribution business. Scientific and rational location not only can save the future business costs, more importantly, is able to provide customers with high quality and efficient logistics services. Therefore, the location problem of the distribution center plays a very important role in the whole logistics system research, which mainly belongs to the research problem of the logistics management strategy level. Distribution center location, includes a single distribution center location and multiple distribution center location. This article discusses multiple distribution center location. To set the distribution center, the so-called distribution center location selects a certain number of location in a number of known sites, so that the total cost of forming the logistics network is minimal, which includes basic investment costs, variable fees and constant costs. For this type of problem, with the nature of NP-hard problems, should not use linear model to deal with. Therefore, its mathematical model is usually expressed in discrete form. Assuming there are n demand points in the logistics network, it is necessary to set up m distribution centers, how to set the distribution center and their respective distribution range, so that the costs of the total distribution are the lowest. The planning models are as follows:

$$min\ U = \sum_{i=1}^{m} \sum_{j=1}^{n} h_{ij} X_{ij} + \sum_{j=1}^{n} F_j Z_j \tag{1}$$

$$\sum_{i=1}^{m} X_{ij} \geq d_j, \quad j = 1,2, \ldots, n \tag{2}$$

$$\sum_{j=1}^{n} X_{ij} \leq M_i, \quad i = 1,2, \ldots, m \tag{3}$$

$$X_{ij} \geq 0, \quad i = 1,2, \ldots, m; j = 1,2, \ldots, n \tag{4}$$

$$Z_j = \begin{cases} 1, j \text{ was selected} \\ 0, j \text{ was not selected} \end{cases} \quad j = 1,2, \ldots, n \tag{5}$$

$$\sum_{j=1}^{n} z_j = P, \quad j = 1,2, \ldots, n \tag{6}$$

Here, U represents the total cost of distribution, and h_{ij} represents the unit transportation cost from the distribution center i to the demand point j. X_{ij} represents the traffic from the distribution center i to the demand point j. F_j represents the fixed cost and management fee of the distribution center which is set at point j. d_j represents the demand for demand point j. M_i represents the capacity of the distribution center i. P indicates the maximum number of distribution centers that can be built.

3. Hybrid PSO Algorithm for Distribution Center Location

3.1. Particle Swarm Optimization

PSO algorithm is also an evolutionary algorithm, and similar to genetic algorithm, but it is not using genetic operators to update the chromosome gene, but a similar gradient descent algorithm to let the population to fly in the direction of the highest value of the fitness function. Basic PSO algorithm ideas: Each solution of the optimization problem is called a particle, and an adaptive value function is defined to measure the superiority of each particle solution. Each particle moves according to the "experience" of itself and other particles, so as to achieve the goal of searching the optimal solution from the full space. The basic PSO algorithm first initializes a set of random particles (random solutions), and then solves the optimal solution by iteration. Particles follow two current optimal values to update themselves, one is the best value found by the particles so far, called the individual optimal value $pbest$; The other is the optimal value found by the entire particle group so far, called the global optimal value $gbest$, and particles according to the following formula to update themselves:

$$V_i = \omega \cdot V_i + c_1 \cdot r_1 \cdot (pbest_i - x_i) + c_2 \cdot r_2 \cdot (gbest - x_i) \tag{7}$$

$$x_i = x_i + V_i \tag{8}$$

Here the first part of the (7) is the previous velocity of the particles; the second part is the "cognition" part, which represents the thought of the particles. The third part is the "social" part, which represents the mutual cooperation [12] and the sharing of information between the particles. ω is the inertia weight, c_1 and c_2 are the acceleration constants, and r_1 and r_2 are two random numbers in the range of 0-1. In addition, the velocity V of the particles is limited by a maximum velocity V_{max}. The velocity of the dimension is limited to the maximum velocity $V_{max,d}$ of the dimension if the current acceleration of the particle causes it to exceed the maximum velocity $V_{max,d}$ of the dimension.

3.2. Construction of Particle Expression

How to find a suitable particle representation method is a key issue to realize the algorithm.

Distribution center location problem is mainly about to determine the best location of the distribution center in a series of demand points, with the goal of minimizing the sum of the various fees. So for each demand point, there are two problems: Is it a distribution center? Which distribution center it belongs to? In this paper, we construct a particle representation method [13]. For a distribution center location problem with L demand points, each particle corresponds to a matrix of two rows and L columns. For example, suppose a logistics network has seven demand points, you need to choose three from them as distribution centers. If a particle's position vector X is:

Demand point number: 1 2 3 4 5 6 7

X_1: 0 1 0 2 3 0 0

X_2: 3 1 2 2 3 2 1

where X_1 indicates whether the demand point is a distribution center, 0 indicates no, a natural number i indicates that the i-th distribution center is established at that point, and X_2 indicates which distribution center the point belongs to. If a demand point is a distribution center, only consider its X_1 value, regardless of its X_2 value.

Then distribution center: 2, 4, 5. The status of the demand point:

2: 2, 7

4: 3, 4, 6

5: 1, 5

The velocities corresponding to the particle velocity vector V are denoted as V_1 and V_2.

3.3. Integer Standardization

We make the particles in the form of real numbers be an integer standardization, then, turn them into an integer matrix. For X_1, the top m points are assigned $m, m-1, \cdots, 1$ respectively, and the remaining $n-m$ points are assigned 0. For X_2, take an integer upwards, and if it exceeds its range 1-m, take the bounding value.

For example, a particle:

X_1 : 0.7 3.3 1.8 2.1 1.4 4.5 2.5

X_2 : 2.8 1.6 0.5 1.7 3.4 2.2 0.7

The Integrated particle:

X_1 : 0 2 0 0 0 3 1

X_2 : 3 2 1 2 3 3 1

3.4. Fitness Function

Distribution center location is a constraint problem, formula (3) is the capacity constraint to ensure that the total distribution center delivery volume within its capacity. In this paper, the penalty function method is used to deal with this constraint, take a very large positive R as penalty factor, R multiplied by the total capacity added to the objective function, the objective function is transformed into:

$$min\ U = \sum_{i=1}^{m}\sum_{j=1}^{n} h_{ij}X_{ij} + \sum_{j=1}^{n} F_j Z_j + R \cdot \sum_{i=1}^{m} max\left\{\sum_{j=1}^{n}\left(X_{ij} - M_i\right), 0\right\} \quad (9)$$

So we use this as a fitness function.

3.5. Hybrid PSO Algorithm

- Initialize a group of particles. Each dimension of the position vector X for each particle takes a real number between 1 and m (the number of distribution centers) randomly. Each dimension of each velocity vector V is randomly taken an integer between n and m.
- Integrate each particle and then convert it to the form of an integer matrix as in the previous section.
- Evaluate the fitness value of each particle, using the initial evaluation value as the individual optimal solution $pbest_{i1}$, and find the global optimal value $gbest_1$.
- For each particle, according to (7) and (8), obtain the velocity V and the position X of the next generation.
- After integer normalization of X, the fitness value is calculated and the hill climbing algorithm is operated on the particle. If the fitness value is smaller, the $pbest_{id}$ is updated until the predetermined number of the hill climbing algorithm operations is reached. Then compare $pbest_{id}$ and $gbest_d$, if the fitness value is smaller, update $gbest_d$.
- If the termination condition is not reached, return to step 4.

4. Example Analysis

There is a logistics network with 12 demand points [5], which requires that 3 points should be selected as the address of the distribution center to minimize the sum of all costs. And the distance between demand points is shown in Table 1. It is known that the fixed costs of constructing distribution centers at various points are 11, 16, 14, 14, 15, 13, 18, 12, 11, 14, 16 and 11 units respectively. The capacity of each distribution center is 13 units. The demand for each point are 5, 4, 2, 3, 2, 4, 3, 5, 4, 3, 2, 2 units. When the amount of transportation is fixed, the transportation cost is proportional to the transportation distance, so to simplify the calculation, the latter is used instead of the former.

Table 1. The Distance between Demand Points

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	1	6	7	4	3	4	6	6	9	8	9
2	1	0	5	6	5	4	5	7	7	10	9	10
3	6	5	0	3	6	9	10	12	12	15	14	15
4	7	6	3	0	3	10	11	13	13	16	15	12
5	4	5	6	3	0	7	8	10	10	13	12	9
6	3	4	9	10	7	0	6	4	9	10	6	6
7	4	5	10	11	8	6	0	2	9	5	4	9
8	6	7	12	13	10	4	2	0	10	6	2	7
9	6	7	12	13	10	9	9	10	0	4	8	13
10	9	10	15	16	13	10	5	6	4	0	4	9
11	8	9	14	15	12	6	4	2	8	4	0	5
12	9	10	15	12	9	6	9	7	13	9	5	0

Using the hybrid PSO algorithm and Matlab8.0 as a programming tool, the above problem is solved on a computer with an Intel (R) core (TM) i3-3110M CPU @ 2.40GHZ, a memory of 4GB and an operating system of Windows7. The number of particles is 80, and $\omega = 0.729, c_1 = c_2 = 1.49445$, the number of hill climbing algorithm is 50 and the penalty coefficient R is 10^8. The optimal solution of the problem is 161 units after iteration of 2000 generations, and the distribution center is 1, 2, 8, the delivery plan is shown in Table 2.

The optimal solution is consistent with the literature [6], the delivery plan is different, but also meet the constraints and requirements, is a feasible solution to the above problems.

Table 2. Final Delivery Plan

Delivery Center	Demand Points												Supply Quantity
	1	2	3	4	5	6	7	8	9	10	11	12	
1	5				2	4						2	13
2		4	2	3					4				13
8							3	5		3	2		13
Requirement	5	4	2	3	2	4	3	5	4	3	2	2	Total 39

In order to facilitate comparison, the basic PSO algorithm and the genetic algorithm (GA) program of the distribution center location problem were compiled. The basic PSO algorithm and GA method all adopt the same coding method as the hybrid PSO algorithm. The parameters of the basic PSO algorithm are the same as those of the hybrid PSO algorithm. The algorithm used in genetic algorithm is random league selection, arithmetic crossover, uniform variation, and the league scale is taken as 2. The number of chromosomes is 80, crossover probability Pc is 0.6, mutation probability Pm is 0.02. The three algorithms are scheduled evolutionary algebra are 2000, and run continuously for 20 times, the results shown in Table 3.

Table 3. Comparison of Results

Algorithm \ Times	1	2	3	4	5	6	7	8	9	10
Hybrid PSO	161	161	161	161	161	166	161	161	161	161
Basic PSO	161	161	165	161	161	166	161	161	161	161
GA	161	178	175	161	176	166	186	169	171	174
Algorithm \ Times	11	12	13	14	15	16	17	18	19	20
Hybrid PSO	161	164	161	161	161	161	163	161	161	161
Basic PSO	161	164	161	161	161	163	161	161	166	161
GA	181	161	161	173	166	161	181	177	167	171

In Table 3, the probability that a hybrid PSO algorithm obtains 161 is 85%, and the average result is 161.50. The probability of the basic PSO algorithm getting 161 is 75%, and the average result is 161.95. The probability of GA getting 161 is 25%, and the average result is 170.80. It can be seen that the hybrid PSO algorithm can effectively improve the shortcomings of low precision and easy to diverge of the basic PSO algorithm, under the same coding mode, the result is better than the basic PSO algorithm and much better than GA, which is a better way to solve the problem of location of logistics distribution center.

In addition, the average algebra of 161 obtained by hybrid PSO algorithm is 485, with average time of 6.1641s. The average algebra of 161 obtained by the basic PSO algorithm is 432, the average time is 4.8673s. The average algebra of 161 obtained by GA is 760, the average time is 21.5371s. Obviously, the hybrid PSO algorithm in algebra, time is much better than the GA. Just because of the added hill climbing algorithm, the amount of computation increases, required algebra and computing time increases compared to the basic PSO algorithm.

5. Conclusion

Logistics Distribution Center is an important part of modern logistics. When planning the distribution center, the reasonable distribution center location can greatly reduce the operating cost of the logistics system. In this paper, the PSO algorithm is combined with the hill climbing algorithm. Aimed at the location model of multiple distribution centers, a particle representation method of distribution center location is constructed and a hybrid PSO algorithm for this problem is established. The practical examples show that the hybrid PSO algorithm can effectively improve the low precision and easy to disperse of the basic PSO algorithm, and has higher search efficiency and better results. Compared with the same coding GA, the hybrid PSO algorithm results are obviously better. The hybrid PSO algorithm is simple and easy to solve, and has high solution quality. It is a better method to solve the problem of distribution center location.

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