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Logistics Distribution Center Location Using Multi-swarm Cooperative Particle Swarm Optimizer

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Abstract: This study presented a new approach to solve logistics distribution center location problem. Multi-swarm Cooperative Particle Swarm Optimizer (MCPSO) (Niu *et al*., 2007) is adopted to selects a certain number of locations as distribution centers in a logistics system so as to minimize the total cost of the whole logistics networks. A hybrid parallel encoding method is used and thus logistics distribution center lacation problem is mapped to the process of is birds (particles) foraging. By competition and collaboration of the individuals in MCPSO the optimal lacation solution is obtained. The experimental result demonstrated that the MCPSO achieves rapid convergence rate and better solutions compared with standard PSO.

Key words: MCPSO, particle swarm 0ptimization, logistics distribution centers

INTRODUCTION

Distribution center selection is the fondation of a supply network. A good distribution center location can greatly boost the effect of transportation and lower the operating cost of enterprise, but also has a great influence on working effect and the control of whole logistic system. It also can distribute products to customers quickly, exactly and cheaply. When designing distribution centers, we need to consider its number, location, size and other factors. Location distribution problem is a NP-hard problem that frequently arises in the design of transportation and distribution systems.

The commonly-used approaches applied to distribution center location are Gravity method (Aykin, 1994), Lagrangian relaxation algorithm (Beasley, 1993; Salhi and Agar, 1998), Branch and Bound Method (Aykin,1995; Galvao and Raggi,1989) and so forth. Gravity method applies to a single distribution center location model; Lagrangian relaxation algorithm also obtain the suboptimal solution in Medium-scale problem, but its performance depends on the structure of the problem itself; Branch and Bound Method can get the global optimal solution. However, with increased scale of the problem solving efficiency is low and Branch and Bound Method is suites for some small-scale.

In this study, we proposed a new a MCPSO based approach to solve this problem. MCPSO is based on the study of biological symbiosis phenomena and firstly presented (Niu *et al*., 2007). In MCPSO, the whole population is divided into several sub-swarms. Each sub-swarm searches independently and exchanges information simultaneously which keeps a well balance of the exploration and exploitation in MCPSO. To validate the proposed algorithm, computational simulations were performed. With comparison with Particle Swarm Optimization (PSO) algorithm, the results showed that the proposed discrete MCPSO algorithm outperforms the PSO algorithm for solving the logistics distribution center location problem.

LOGISTICS DISTRIBUTION CENTER LOCATION MODEL

Generally, logistics distribution center location problem consists of single logistics distribution center location and multiple logistics distribution centers location. In this study we focus on the latter one which refers to select a certain number of locations as distribution centers so as to minimize the total cost of the whole logistics networks (Li *et al*., 2012). The costs include basic investment cost, flexible cost and fixed cost. Assume that there are m alternative locations and n demand point. The mathematical model of the logistics distribution center location problem can be described as follows:

$$\min F = \sum_{i=1}^{m}\sum_{j=1}^{n} h_{ij}x_{ij} + \sum_{j=1}^{n} f_j y_j \tag{1}$$

$$\sum_{i=1}^{m} x_{ij} \geq d,\ j = 1, 2, \ldots, n_{ij} \tag{2}$$

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$$\sum_{j=1}^{n} x_{ij} \le M_i, i = 1, 2, \dots, m_i \quad (3)$$

$$x_{ij} \ge 0, i - 1, 2, \dots; j = 1, 2, \dots, n \quad (4)$$

$$y_j = \begin{cases} 1 & \text{if the distribution center j is selected} \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

$$j = 1, 2, \dots, n$$

$$\sum_{j=1}^{n} y_j = p_j, j = 1, 2, \dots, n \quad (6)$$

where, F is the total costs, H_{ij} denotes unit transportation cost from supply point i to demand point j, x ij is the transportation amount from i to j, fj presents the fixed cost for construction of distribution center i, d ij is the demand amount of j, M i denotes the capacity of distribution center i, P presents the maximum amount of distribution centers that can be built

STANDARD PSO

The fundament for the development of PSO is hypothesis that a potential solution to an optimization problem is treated as a bird without quality and volume which is called a particle, flying through a D-dimensional space, adjusting its position in search space according to its own experience and that of its neighbors. The ith particle is represented as $x_i = (x_{i1}, x_{i2}, \dots, x_{iD})$ in the D-dimensional space, where $v_i = (v_{i1}, v_{i2}, \dots, v_{iD})$; ld,ud are the lower and upper bounds of the dth dimension, respectively. The velocity for particle i is represented as $v_i = (v_{i1}, v_{i2}, \dots, v_{iD})$which is clamped to a maximum velocity v_{max}, specified by the user. In each time step t, the particles are manipulated according to the following equations:

$$v_i(t+1) = v_i(t) + R_1 c_1 (P_i - x_i(t)) + R_2 c_2 (P_g - x_i(t)) \quad (7)$$

$$x_i(t+1) = x_i(t) + v_i(t) \quad (8)$$

Although these researches have shown that PSO performs well for global search because it is capable of quickly finding and exploring promising regions in the search space, they take relative inefficiency in fine tuning solutions. Moreover, a potentially dangerous property in PSO still exists: Stagnation due to the lack of momentum which makes it impossible to arrive at the global optimum. To avoidthese drawbacks of the basic PSO, some improvements have been proposed. These improvements canenhance convergence of PSO toward the global optimum, to find the optimum solution efficiently. So, this study proposed Multi-swarm Cooperative Particle Swarm Optimizer (MCPSO) to solve logistics distribution centers location problem.

MCPSO FOR LOGISTIC DISTRIBUTION DENTER LOCATION

MCPSO: MCPSO is based on the study of biological symbiosis phenomena and firstly presented (Niu *et al*., 2007). The initial inspiration for the PSO was the coordinated movement of swarms of animals in nature. It shows the cooperative relationship among the individuals within a swarm. However, in natural ecosystems, many species have developed cooperative interactions with other species to improve their survival. Such cooperative co-evolution is called symbiosis, firstly coined by German mycologist. The phenomenon of symbiosis can be found in all forms of life, from simplecells (e.g., eukaryotic organisms resulted probably from the mutualistic interaction between prokaryotes and some cells they infected) through to birds and mammals (e.g., African tick birds obtain a steady food supply by cleaning parasites from the skin of giraffes).

According to the different symbiotic interrelationships, symbiosis can be classified into three main categories: mutualism (both species benefits by the relationship), commensalism (one species benefits while the other species is not affected) and parasitism (one species benefits and the other is harmed). We found that the commensalism model is suitable to be incorporated in the SPSO. Inspired by this research, a master-slave mode is incorporated into the SPSO and the Multi-swarm (species) Cooperative Optimizer (MCPSO) is thus developed.

In MCPSO approach, a population consists of one master swarm and several slave swarms. The symbiotic relationship between the master swarm and slave swarms can keep a right balance of exploration and exploitation which is essential for the success of a given optimization task. The master-slave communication model, as shown in Fig. 1, is used to assign fitness evaluations and maintain algorithm synchronization. In Fig. 1 each slave swarm executes a single PSO or its variants, including the update of position and velocity and the creation of a new local population. When all the slave swarms are ready with the new generations, each slave swarm then sends the best local individual to the master swarm. The master swarm selects the best of all received individuals and evolves according to the following equations:

$$\begin{aligned} v_{id}^{M}(t+1) &= w v_{id}^{M}(t) + c_1 * r_1 \left(p_{id}^{M}(t) - x_{id}^{M}(t)\right) \\ &+ c_2 * r_2 \left(p_{gd}^{M}(t) - x_{id}^{M}(t)\right) + c_3 * r_3 \left(p_{gd}^{M}(t) - x_{id}^{M}(t)\right) \end{aligned} \quad (9)$$

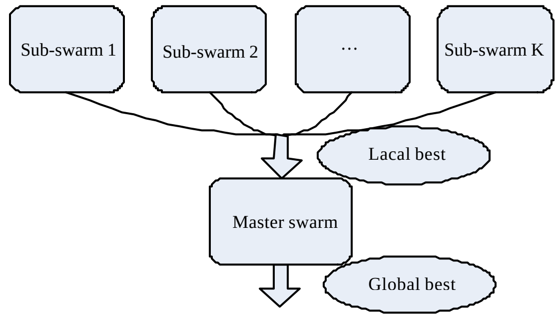

Fig. 1: Master-slave model

$$x^{M}_{id}(t+1) = x^{M}_{id}(t) + v^{t+1}_{id}(t+1) \quad (10)$$

M represents the master swarm, c_3 is migration coefficient and r_3 is a uniform random sequence in the range [0,1]. Note that the particle's velocity update in the master swarm is associated with three factors:

$P^{M}_{id}(t)$: Previous best position of the master swarm in dth
$P^{m}_{gd}(t)$: Best global of the master swarm in dth
$P^{S}_{gd}(t)$: Previous best position of the slave swarms.

Particle encoding scheme: For this distribution center problem, the appropriate expression of particles in MCPSO algorithm is a key issue. After all, the essence of location problem of distribution centers is to determine best position of distribution center from a series of demand points. The object is to minimize the sum of all fees. Based on an expression of particles (Klincewicz, 1991) in this study, for the location problem of distribution centers with N demand points, each particle corresponds to a matrix of (2, N).

Design of fitness function: Penalty function method would be used to convert constrained optimization problem into sequence unconstrained optimization problem and at the same time a fitness function is designed.

In this study, penalty function is applied to deal with this constraint. A large positive number R is taken as a penalty factor to ensure that the total distribution volume of distribution centers is within its capacity. So the objective function is:

$$\min F = \sum_{i=1}^{m}\sum_{j=1}^{n} h_{ij}X_{ij} + \sum_{j=1}^{n} f_j y_j + R * \sum_{i=1}^{m} Max(X_{ij} - M_i, 0) \quad (11)$$

EXPERIMENTAL STUDY

A logistics network with 10 demand points is considered in this study and the distance between

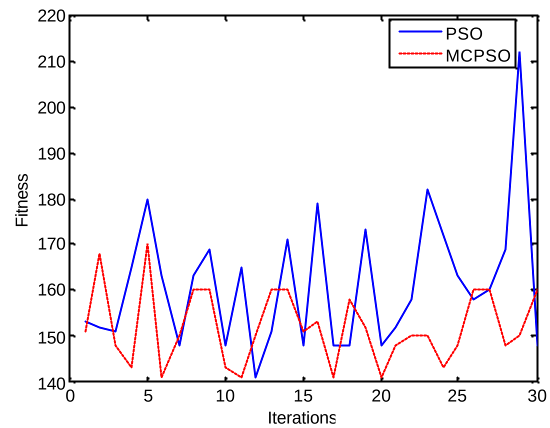

Fig. 2: Convergence graph for MCPSO and PSO

Table 1: Distance Between Demand Points

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

Table 2: Summary Results

Algorithms	Best	Average	Worst	Standard	t
MCPSO	141	154	178	9.4468	2.94
PSO	141	171	211	15.9446	1.43

demand points are shown in Table 1. It requires to select 3 points from these points as the distribution centers and the object is to minimize the sum of all fees. The fixed costs of construction of distribution centers in each demand point are 11, 16, 10, 14, 15, 13, 17, 12, 11 and 14 units. The capacity of every distribution center is 12 units and the demand of each demand point is 6, 4, 2, 3, 2, 4, 3, 5, 4, 3 units.

Table 2 presents the summary results of the computational experiments of PSO algorithm and MCPSO algorithm. Moreover, thirty fitness values obtained in thirty runtimes in PSO algorithm and MCPSO algorithm are shown in Fig. 1. It is obviously that the two algorithms both can achieve the best fitness value 141 units. However, in terms of convergence the MCPSO is better than PSO which can be seen from Fig. 2.

Based on Matlab 7.0, we apply MCPSO algorithm to solve this location problem. In MCPSO algorithm, number of colonies n = 4 and it concludes 3 Slave Colonies and 1 Master Colony. To validate its performance, the MCPSO algorithm is also compared with Particle Swarm Optimization (PSO) algorithm.

For fair comparison, in all cases the population size num of PSO and MCPSO was set at 400 (all the swarms of MCPSO include the same particles) and a fixed number of maximum iterations 200 is applied to PSO and MCPSO. A total of 30 runtimes for each experimental setting are conducted.

CONCLUSION

In this study, a new MCPSO algorithm is proposed to solve logistics distribution center location problem. Some logistics distribution center location problems are chosen to evaluate the effect of the new algorithm. Further more, with comparison to PSO algorithm, the simulation results show that the new discrete MCPSO algorithm obtains more effective results for logistics distribution center location problem. The proposed algorithm is simple and robust, at least for the test problems considered in this work. However, in this study we only made comparations with two algorithms. In the future work, it is expected to make a further study using some other swarm intelligence to illustrate the efficiency of our proposed method.

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