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Emergency Resource Scheduling Problem Based on Improved Particle Swarm Optimation

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Abstract
Emergency resource scheduling is a kind of NP combination problem which possesses important practical value. In order to overcome the problems such as long computing time and easy to fall into local best for traditional heuristic optimization algorithm, an Improved Particle Swarm Optimization algorithm (IPSO) is proposed, the algorithm uses the randomicity and stable tendentiousness characteristics of cloud model, adopts different inertia weight generating methods in different groups, the searching ability of the algorithm in local and global situation is balanced effectively. In the paper, the algorithm is used to solve the emergency resource scheduling problem, the mathematic mode is established and the solution algorithm is developed. The simulation results of example show that the algorithm has faster search speed and stronger optimization ability than GA and PSO algorithm.

Keywords: *emergency resource scheduling, particle swarm optimization, cloud model*

1. Introduction

With the rapid development of social economy and increasing levels of urban modernization, all kinds of emergencies have enormous influences on urban functions. Some unexpected events will seriously affect the life safety of the people, such as earthquakes, tsunamis, gas leak. Losses stemmed from ineffective emergency logistics account for 15% to 20% of the entire casualty and financial losses caused by sudden outbursts of natural calamities and human-contrived disasters.

Emergency resource scheduling is a special goods transporting activity which aims at providing emergency resource for emergencies, maximizing efficiency and minimizing damages caused by disasters. Emergency resource scheduling is an important component in dealing with accidents, which in time weighs great value in reducing losses, preventing secondary disasters and maintaining social stability.

When a natural disaster-stricken spot is in need of countermeasures from emergency resource transporting system, emergency vehicles should deliver emergency resource to demand spot within the least of time. Emergency resource scheduling is a typical case of optimizing combination, a tough issue concerning NP. It contains great complexities. Questions of the similar kind are hot studied by different branches of science, such as operations research, applied mathematics, computer application, graph theory and communication & transportation, etc. The time it takes to be solved is growing exponentially as its dimension is expanding, which is hard to be handled with traditional mathematic methods. In recent years, heuristic optimization algorithms such as Genetic Algorithm, Ant Colony Algorithm and Particle Swarm Optimization have been widely applied to solving such kind of problems [1-3]; however, these algorithms all have drawbacks like long computing time, easy to fall into stagnation and unable to do further computing. Therefore, how to construct optimized algorithm simple in formation and high in optimizing precision enjoys great significance in solving emergency resource scheduling problem.

Particle swarm optimization (PSO) is a set of new intelligent optimization algorithms which is simple calculation, fast convergence and easy to implement, etc [4]. The algorithm has been applied to VRP [5-6] and achieved very good results, but it exist such problems as being

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easy to stagnate and fall into local optimum. Therefore, in this paper, IPSO is put forward to solve the emergency resource scheduling problem. The result of experiments indicates that the algorithm can efficiently solve the problem.

2. The Mathematic Mode of Emergency Resource Scheduling Problem

2.1. Problem Description

There are plenty of emergency vehicles in the emergency rescue system. The vehicles will set off from the rescue center and deliver goods to several crisis-attacked sites (quantity=R). After delivery, the vehicles will return to the center. The maximum capacity for each vehicle is $P_k\,(k = 1,2,...,K)$. Find driving routes from the center to each demanding site meeting the following requirements [7]:

1) Overload is forbidden.
2) Delivery must be finished as soon as possible.
3) Supplies required by each demanding site must be delivered.
4) the cost of emergency center must be at minimum.

Supplementary conditions:

1) Adequate vehicles are available in emergency center, and the capacity of each has been given in the discussion;
2) There is only one emergency center and its location has been given in the discussion;
3) There is only one type vehicle in the center. Each crisis-attacked site is served by only one vehicle. Every site must be covered by the driving route;
4) the gross demand of each demanding site along the route cannot surpass the capacity of the vehicle;
5) In order to simplify the case, only the time consumed on road will be considered, irrespective of the service time.

2.2. Mathematic Mode

Here is the mathematic mode built according to the description above:
(1)---objective function (2)-(11)---constraint conditions

$$\min z = \sum_{k\in M} x_{k_0} c_k^f + \sum_{k\in M}\sum_{i\in s}\sum_{j\in s} c_{ijk}^t d_{ij} y_{ijk} \tag{1}$$

$$\sum_{i\in S}\sum_{k\in M} y_{ijk} = 1, \forall j \in N \tag{2}$$

$$\sum_{i\in s} y_{ihk} - \sum_{i\in s} y_{hik} = 0, \forall k \in M, \forall h \in S \tag{3}$$

$$\sum_{j\in N}\sum_{k\in M} y_{0jk} > 0 \tag{4}$$

$$\sum_{i\in s}\sum_{j\in N} y_{ijk} q_j \le Q_k, \forall k \in M \tag{5}$$

$$\sum_{k\in M}\sum_{i\in S}\sum_{j\in N} y_{ijk} q_j \le Q_0 \tag{6}$$

$$t_{jik} = d_{ij} / v_{ijk} \tag{7}$$

$$t_{ik} = t_{jk} + t_{jik} y_{jik}, \forall i, j \in S, \forall k \in M \tag{8}$$

$$t_{ik} \le l_i, \forall i \in N, \forall k \in M \tag{9}$$

$$y_{ijk} = \{0,1\}, \forall i, j \in S, \forall k \in M \tag{10}$$

$$x_{k0} = \{0,1\}, \forall k \in M \tag{11}$$

In the mode:

a) d_{ij} refers to the distance between node i and node j ($i, j = 0,1,2 \cdots S,$). When $i, j = 0$, d_{ij} refers to the emergency center;

b) v_{ijk} refers to the average speed of vehicle k from node i to node j;

c) t_{ik} refers to the time vehicle k needs to go to the demanding site i;

d) t_{ijk} refers to the time vehicle k needs to go from node i to node j;

e) l_i refers to the latest time of arrival of vehicle k;

f) n_k refers to the total number of demanding sites that vehicle k needs to serve. When $n_k = 0$, it means that the vehicle does not participate in the mission.

g) R_k refers to the set of demanding sites served by the vehicle;

h) c_k^f refers to the fixed cost of vehicle k when driving;

i) c_{ijk}^t refers to the unit cost of vehicle k from node i to node j;

j) Q_k refers to the loading capacity of vehicle k;

k) q_i refers to the demand of node i;

l) N refers to the set of crisis-attacked sites. $N = \{r \mid r = 1,2,...,R\}$;

m) M refers to the set of emergency vehicles. $M = \{k \mid k = 1,2,...,K\}$;

n) S refers to the sum of nodes. $S = N \cup O$.

x_{k0} and y_{ijk} are defined as follows:

$$x_{k0} = \begin{cases} 1 & \text{emergency vehicle k is in use} \\ 0 & \text{otherwise} \end{cases};$$

$$y_{ijk} = \begin{cases} 1 & \text{vehicle k drive from node i to node j, and } i \ne j \\ 0 & \text{otherwise} \end{cases}。$$

3. Improved Particle Swarm Optimization

3.1. Particle Swarm Optimization

Inspired by birds searching food in real world, PSO is proposed by Kennedy and Eberhart in 1995, as a new-born algorithm based on group theory, the basic principle of PSO is to fix individual action through sharing information and individual's own experience among groups to get the optimal solution of the problem.

The mathematicl descripition of PSO is: group constituted by n particles search in D dimension space. The location of the i particle is expressed as: $X_i = (x_{i1}, x_{i2}, ..., x_{iD})$, and the corresponding speed is expressed as: $V_i = (v_{i1}, v_{i2}, ..., v_{iD})$, and $P_i = (p_{i1}, p_{i2}, ..., p_{iD})$ is the optimal location searched by the i particle so far, and $P_g = (p_{g1}, p_{g2}, ..., p_{gD})$ is the optimal location searched by the whole particles right now. The update equations of the d dimensional speed v_{id}^{k+1} and location x_{id}^{k+1} of particle i at the k+1 Iteration are expressed as follows:

$$v_{id}^{k+1} = wv_{id}^{k} + c_1 r_1 (p_{id}^{k} - x_{id}^{k}) + c_2 r_2 (p_{gd}^{k} - x_{id}^{k}) \tag{12}$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \tag{13}$$

Where w is the inertia weight; c_1 and c_2 are the acceleration constant; r_1 and r_2 are the random independent numbers between 0 and 1.

3.2. Cloud Model

Proposed by academician Li Deyi [8], the cloud model combines the view of probability theory and fuzzy set theory, describes the uncertainty of the concept of the natural language and provides an effective means for the information processing by adopting both the qualitative and quantitative methodology.

Normal cloud model is the random set with stable tendency following normal distribution rule. There are such three normal distribution rules hidden in the normal cloud model as $N^3(Ex, En^2, Hn^2)$, three numerical features of cloud are expressed by expected value Ex, entropy En and ultra-entropy Hn respectively.

3.3. Cloud Adaptive Adjustment Strategy

The size of particle swarm is set as N, the fitness value of particle X_i is f_i after iterating k times; the average fitness value is $f_{avg} = \frac{1}{N}\sum_{i=1}^{N} f_i$; when the average value of the fitness value better than f_{avg} is $f_{avg}{}'$ and inferior to f_{avg} is $f_{avg}{}''$, the fitness value of the optimal particle is $f_{\min}$; let $Ex = f_{avg}{}'$, $En = (f_{avg}{}' - f_{\min})/c_1$, $He = En/c_2$, En' =normrnd(En, He), w is calculated as formula (14), Wherein, as a control parameter.

$$w = \begin{cases} 0.2 & f_i < f_{avg}{}' \\ 0.8 - 0.5 * \exp(-(f_i - Ex)^2 / 2(En')^2) & f_{avg}{}' < f_i < f_{avg}{}'' \\ 0.8 & f_i > f_{avg}{}'' \end{cases} \tag{14}$$

4. Solution to Emergency Resource Scheduling Problem Based on IPSO

4.1. Coding Strategy of Particles

The position of particle corresponding with the answer to the question is the key idea of PSO. In the paper, a new particle encoding of 3-dimensional vectors X is constructed to emergency resource scheduling problem. In the vector X, the first dimension X_r of particles is rescue center information; the second dimension X_s of particles is vehicle information; the third dimension X_t of particles is traveling distance of the vehicle.

4.2. Decoding Strategy of Particles

To get to the travel path of the vehicle order, X_t must be adjusted. Adjustment function can be got according to the size sequence of vector X_t, that is to say, finding out X_t of the vehicle for customer i first, and then sorted from small to large in accordance with X_t, thus the driving path order of vehicle i is determined. For example, if there are 10 customers, 2 rescue centers, one of rescue centers has 2 vehicles, the other has 3 vehicles. If the position vector X of a particle is shown as Table 1, then vector X of the position after adjustment is shown as Table 2. So the corresponding vehicle routings are as follows:

rescue center 1: vehicle 1: 1→2
vehicle 2: 4→8
rescue center 2: vehicle 3: 3
vehicle 4: 6→7→5
vehicle 5: 10→9

Table 1. Vector X before Adjusting

customer	1	2	3	4	5	6	7	8	9	10
X_r	1	1	2	1	2	2	2	1	2	2
X_s	1	1	3	2	4	4	4	2	5	5
X_t	0.3	1.2	0.6	2.3	4.8	1.1	2.9	3.9	2.8	1.7

Table 2. Vector X after Adjusting

customer	1	2	3	4	5	6	7	8	9	10
X_r	1	1	2	1	2	2	2	1	2	2
X_s	1	1	3	2	4	4	4	2	5	5
X_t	1	2	1	1	3	1	2	2	2	1

4.3. Process Description of Algorithm

Step 1: initialize species, set the size n of each particle swarm and algorithm parameter (accelerating factor c_1 、 c_2, maximum number of iterations $N_{\max}$ and dimension of particles D, individual extremum $pbest$ and global extremum $gbest$).

Step 2: Each particle X_i in the particle swarm is executed as follows:

a) Update the speed and position X_i with the formula (9) and formula (10), among of them, w is calculated with the formula (11);

b) Calculating the fitness value f_i of X_i;

c) If X_i is better than the fitness value of $pbest$, then $pbest$ should be updated to the current position of X_i;

d) If X_i is better than the fitness value of $gbest$, then $gbest$ should be updated to the current position of X_i;

Step 3: Judge whether the current iteration number G is equal to or greater than the iteration number $N_{\max}$, if not satisfied, return Step2, otherwise, the current optimal solutions is output.

5. Analysis of the Simulation Results of Example

5.1. Example 1

A crisis-attacked area has 8 demand sites needing resource delivered from emergency resource center. There are 5 vehicles. The loading capacity is 8 ton for each vehicle. The fixed cost of each is 80 yuan. The average speed is 20km/hour. The average driving cost is 10yuan/km. The distance between sites, the demand q_i (unit: ton) and the latest arrival time l_i

(unit: minute) $(i = 1,2,...,8)$ are displayed in Table 4 (0 represents for the center, 1-8 represents for the sites).

Compute the example with GA, PSO and IPSO respectively on the same computer. The optimal scheduling plan is that 3 cars participate in the task. The driving route, distance and cost are shown in Table 4. Objective function changes according to iteration and its tendency is recorded in Figure 1.

Table 3. The Data of Distribution Center and Disaster Location

Crisis-attacked sites	Crisis-attacked sites 0	1	2	3	4	5	6	7	8
0	0	4	6	7.5	9	20	10	16	8
1	4	0	6.5	4	10	5	7.5	11	10
2	6	6.5	0	7.5	10	10	7.5	7.5	7.5
3	7.5	4	7.5	0	10	5	9	9	15
4	9	10	10	10	0	10	7.5	7.5	10
5	20	5	10	5	10	0	7	9	7.5
6	10	7.5	7.5	9	7.5	7	0	7	10
7	15	11	7.5	9	7.5	9	7	0	10
8	8	10	7.5	15	10	7.5	10	10	0
q_i		3	3	1	3	2	4	1	4
l_i		40	60	30	80	80	50	90	30

Table 2. The Optimal Scheduling Scheme of Example 1

vehicles	driving routes	driving time	driving time	total cost
vehicle1	0—1—3—2—0	64.5	21.5	295
vehicle2	0—6—4—0	79.5	26.5	345
vehicle3	0—8—5—7—0	118.5	39.5	475
total		262.5	87.5	1115

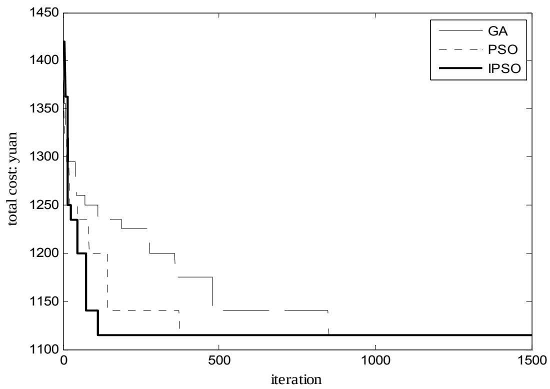

Figure 1. Performance Comparisons of GA, PSO and IPSO

5.2. Example 2

A crisis-attacked area has 20 demand sites needing resource delivered from emergency resource center. There are 4 vehicles. The loading capacity is 20 ton for each vehicle. The fixed cost of each is 100 yuan. The average speed is 25km/hour. The average driving cost is 12 yuan/km. The coordinate of emergency rescue center is 0 point (3km, 4km), position coordinates of demand sites (unit: km), the demand q_i (unit: ton)and the latest arrival time l_i (unit: minute) $(i=1,2,...,20)$ are displayed in Table 5 (0 represents for the center, 1-20 represents for the sites).

Table 5. The Data of Emergency Center and Emergency Location

order number	x coordinates	y coordinates	demand	latest arrival time	order number	x coordinates	y coordinates	demand	latest arrival time
0	3	4							
1	3.1	7.6	4	60	11	8.4	8	2	30
2	1	8.6	2	15	12	4.7	9.3	1	30
3	6.3	5.7	1	60	13	1.4	6.8	2	15
4	2	3.3	1	45	14	0.3	6.3	2	30
5	5.3	6.6	5	10	15	3.5	0.5	3	60
6	6	9.8	4	60	16	2.4	1.6	4	50
7	0.6	9.4	2	30	17	8.2	3.7	4	45
8	3	4.5	2	10	18	7.3	8.4	3	60
9	1.9	9.8	3	20	19	8.5	5.2	1	50
10	3.7	7.1	2	45	20	7.8	8.8	3	20

Table 6. The Optimal Scheduling Scheme of Example 2

vehicles	driving routes	driving time	driving time	total cost
vehicle1	0—5—20—11—19—17—18—3—0	56.42	23.51	382.12
vehicle2	0—8—13—14—4—16—15—0	47.55	14.8	277.55
vehicle3	0—2—7—9—12—6—10—1—0	46.65	19.44	333.24
total		150.62	57.74	992.91

Compute the example with GA, PSO and IPSO respectively on the same computer. The optimal scheduling plan is that 3 cars participate in the task. The driving route, distance and cost are shown in Table 6. Objective function changes according to iteration and its tendency is recorded in Figure 2.

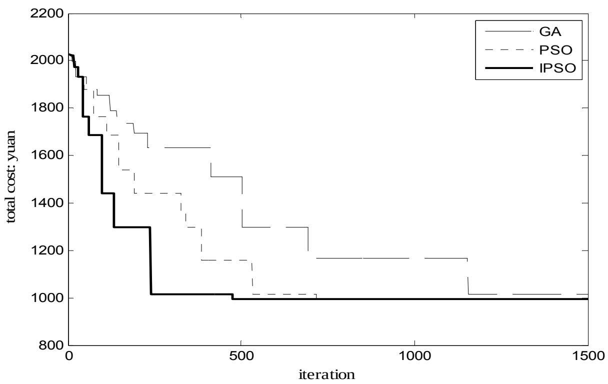

Figure 2. Performance Comparison of GA, PSO and IPSO

It is obvious from the result of the two experiments that the algorithm proposed in the thesis can detect the optimal solution to emergency resource scheduling problem swiftly and accurately. Its efficiency is better than that of GA and PSO. It is a new method to solve the emergency resource scheduling problem.

6. Conclusion

To solve the problem of NP in the emergency resource scheduling, an improved particle swarm optimation algorithm has been applied to the emergency resource scheduling is proposed in the thesis. The simulation results of example indicate that the algorithm can efficiently solve emergency resource scheduling problem through the comparison of GA and the PSO algorithm.

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