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Logistics Distribution Route Optimization Based on Improved Particle Swarm Optimization

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This article improves the logistics distribution route and improves the distribution as well as transportation efficiency. The article combines the features of logistics dissemination along with mathematical designing of dissemination automobile routing issue. The mountain climbing procedure with strong local search ability is introduced into the particle swarm optimization (PSO) procedure to improve the offered approach. Two mountain climbing schemes are offered in this article, and two different hybrid (PSO) procedures are constructed. The experimental outcomes reveals the performance of Hybrid PSO scheme 1 and hybrid PSO scheme 2 offered in this paper which are better than that of standard PSO. Hybrid PSO scheme 2 offers best potential in efficiently solving the routing issue of logistics dissemination automobile. After the issue scale grows, the optimization advantages of Hybrid PSO scheme 2 are fully displayed. It was observed from the experimental analysis that using hybrid PSO scheme 2 to solve the logistics dissemination automobile routing issue can greatly shorten the dissemination mileage.

Povzetek: Članek izboljšuje logistične distribucijske poti s hibridnim pristopom rojev delcev (PSO), kar znatno skrajša razdaljo distribucije in izboljša učinkovitost prevoza.

1 Introduction

Dissemination is a task derived from the transportation link in the logistics system. It is an important link in the logistics system. In the logistics movement, delivery is actually the transportation of goods. Therefore, transportation is often used to represent delivery. Transportation costs account for the highest proportion of all logistics costs. Generally, the social logistics costs are calculated through comprehensive analysis, in which the goods accounts for about, and the goods of some products is even higher than the production cost [1]. The survey displays that the transportation cost of automobiles in China is times that of Europe and the United States. The empty driving rate of transportation automobiles in China is about 37%, of which the empty driving rate of automobiles in automobile logistics enterprises is as high as, and there are some issues such as return empty driving, waste of resources and high transportation cost. It is not difficult to see that the potential for saving transportation costs is very large [2, 3]. Using scientific methods to examine a reasonable dissemination route is an important work in dissemination activities. Reasonable selection of dissemination routes is of great significance to enterprises and society. For enterprises, optimizing the dissemination route can improve the dissemination efficiency, make the best use of the dissemination automobiles, reduce the dissemination cost as much as possible, deliver the goods to clients on time and quickly, greatly improve customer satisfaction, and help enterprises improve efficiency [4, 5]. For the society, it can save transportation automobiles, alleviate traffic tension, reduce transportation pollution such as noise and exhaust emissions, and contribute to the protection of ecological balance and the creation of a better home.

PSO is a growing computing technology based on the intelligence of swarm. Similar to GA (genetic algorithm), it is a population-based optimization tool. The system initializes a set of random results and searches for the optimal value through iteration [6]. However, there is no crossover and mutation of GA, but elements search for the optimal elements in the result space. In the system, each alternative result is called an "element". Several elements coexist and collaborate in optimization to approximate the bird swarm to find food. Each element "flies" to a better situation in the issue space according to its own "knowledge" and the best "knowledge" of neighboring element swarm to search for the optimal result [7, 8]. Figure 1 displays the optimization diagram of a reasonable logistics and dissemination route.

This article basically aims at the goal of providing decision support for logistics dissemination enterprises. The paper analyzes the logistics dissemination and automobile routing issue in detail, and establishes the mathematical design of logistics dissemination automobile routing issue. The main contribution of this work is to answer the lack of local search ability of (PSO) procedure, mountain climbing procedure with strong local search ability. The article further utilizes

(PSO) procedure to improve the offered approach. Two mountain climbing schemes are offered in this work, and two different hybrid (PSO) procedures are constructed in order to improve the logistics dissemination route and improve the dissemination efficiency.

The rest of this article is arranged as: section 2 describes literature review and the research method expressing the mathematical model of logistics dissemination automobile routing and model of hybrid (PSO) procedure is provided in section 3. Section 4 presents the experimantation and discussion of the experimental observations and conclusion is provided in section 5.

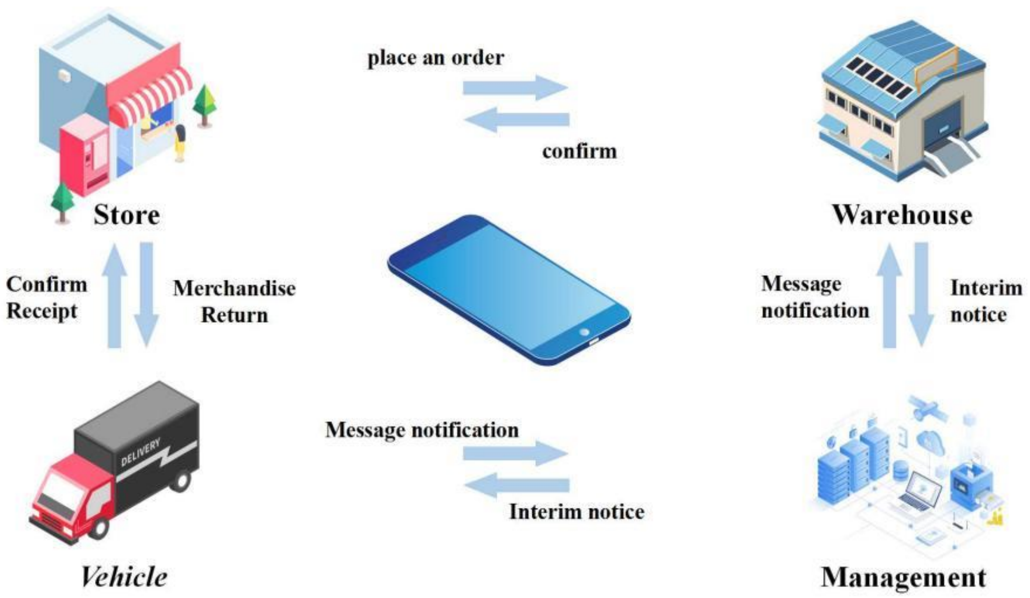

Figure 1: Optimization of the logistics dissemination route based on the improved element assembly procedure.

2 Related work

In terms of logistics dissemination route optimization, Muhammad, Muhammad *et al.* [9] used the improved GA to study the material dissemination issue, and the established dissemination mathematical design is also relatively simple. Wang *et al.* [10] used the improved saving method to study the optimization of material dissemination route, and did not consider the influence of cargo timeliness when establishing the objective task. Yuan *et al.* [11] used ant colony procedure to study the dissemination issue, focusing on the improvement of ant colony procedure and less research on the dissemination design.

As for the research of (PSO) procedure on route optimization, Moosavian and Lence [12] used (PSO) procedure to study the logistics dissemination issue, focusing on the improvement of the procedure, but the established dissemination mathematical design is relatively simple. Lagos *et al.* [13] applied (PSO) procedure to automobile routing issue and automobile routing issue with time window respectively. The research displays that (PSO) procedure can solve the issue quickly and effectively. Wan *et al.* [14] used the improved (PSO) procedure to solve the automobile routing issue. The comparison with GA and double population GA displays that the improved (PSO) procedure is an effective method to solve the automobile routing issue. Li *et al.* [15] applied the local (PSO) procedure to the non-fully loaded automobile routing issue. The research displays that the procedure improves the achievement rate of searching the optimal route and can solve the non-fully loaded automobile routing issue more effectively.

It can be seen from the relevant literature that the current research focuses on two aspects: the mathematical design and result method of logistics dissemination route optimization. The research on the mathematical design of dissemination route mainly focuses on how to more comprehensively and reasonably reflect the dissemination issue, and the commonly used result method is intelligent optimization procedure. However, most intelligent optimization procedures are easy to fall into local optimization and low search efficiency. Therefore, the improved design of intelligent optimization procedure and the reasonable establishment of mathematical design are the key to examine the advantages and disadvantages of route optimization methods.

3 Research methodology

This section includes the description of research methodology consisting of mathematical design of logistics dissemination automobile routing and design of hybrid (PSO) procedure.

3.1 Establish the mathematical design of logistics dissemination automobile routing

The automobile routing issue of logistics dissemination can be described as: several dissemination automobiles are used to deliver goods from a dissemination center to several clients. The location and cargo request of each customer are certain, and the load volume of each dissemination automobile is certain [16, 17]. It is required to reasonably arrange the automobile dissemination route, improve the objective task, and addresses the following assumptions:

1. The sum of the requests of each customer on each dissemination route shall not cross the load volume of the dissemination automobile.
2. An automobile can only select single route, but it can serve several clients.
3. A client has and can only have one automobile (car) to serve him.
4. Car starts from the dissemination center, sends the loaded goods to the corresponding clients along a driving route, and then returns to its own dissemination center.

Before setting the driving route, evaluate the quantity of automobiles used. It is based on the analysis that the more complex the loading (unloading) of goods and the more restrictions, the smaller the actual cargo volume of the automobile [18, 19]. The formula mentioned in Equation 1 is implemented to examine the quantity of automobiles K required:

$$K = \left[\frac{\sum_{i=1}^{L} g_i}{\alpha q}\right] + 1 \quad (1)$$

Where $[\sum_{i=1}^{L} g_i]$ means that the integer not greater than the quantity in parentheses, $\alpha \in (0,1)$ can be corrected according to the quantity of restrictions. Generally, the more restrictions, the smaller, and vice versa. The α general value is 0.85.

C_{ij} represents the transportation cost from customer i to customer j, such as time, distance, cost, etc. The quantity of the dissemination center is 0, the quantity of each customer is I (i = 1, ..., L), the quantity of each automobile is K (k = 1, ..., K), the cargo request of the i^{th} client is g_i, and the volume of the dissemination automobile is q.

Define the resulting values:

$$x_{ijk} = \begin{cases} 1 & Car\ k\ moves\ from\ i\ to\ j \\ 0 & otherwise \end{cases} \quad (2)$$

$$y_{ik} = \begin{cases} 1 & Car\ k\ serves\ clients\ i \\ 0 & otherwise \end{cases} \quad (3)$$

The goal of establishing the design is to minimize the total transportation cost. The transportation cost is directly proportional to the driving route of the automobile [20]. The smaller the operating route, the less the fuel ingestion of the automobile, the less the working time of the operator, and of course, the minimum the total conveyance cost. The following is a calculated design with the shortest driving route as the objective task for the logistics dissemination automobile routing issue:

$$min\ z = \sum_{i=0}^{L}\sum_{j=0}^{L}\sum_{k=0}^{K} c_{ij}x_{ijk} \quad (4)$$

$$\sum_{i=1}^{L} g_i y_{ik} \le q; \forall k \quad (5)$$

$$\sum_{k=1}^{K} y_{ik} = \begin{cases} 1 & i = 1,2,\ldots,L \\ K & i = 0 \end{cases} \quad (6)$$

$$\sum_{i=0}^{L} x_{ijk} = y_{ik} \quad j = 0,1,\ldots,L; \forall k \quad (7)$$

$$\sum_{j=0}^{L} x_{ijk} = y_{ik} \quad i = 0,1,\ldots,L; \forall k \quad (8)$$

$$x_{ijk} = 0\ or\ 1 \quad i,j = 0,1,\ldots,L; \forall k \quad (9)$$

$$y_{ik} = 0\ or\ 1 \quad i = 0,1,\ldots,L; \forall k \quad (10)$$

In the offered design:

Equation (4) is the objective task.

Equation (5) is the automobile volume constraint, and the total goods loaded by single automobile shall not cross its extreme carrying volume.

Equation (6) means that each customer has only one automobile to serve, and all tasks are completed by K automobiles.

Equation (7) indicates that there is and only one automobile arriving at a customer.

Equation (8) indicates that there is and only one automobile leaving a customer.

Equations (9) and (10) are integer restrictions.

3.2 Design of hybrid (PSO) procedure

Standard PSO process implementation process is as follows:

Step 1: Start the process with the element swarm, take the real quantity between 1 ~ (K + L-1) randomly for each dimension of each element situation vector x, and take the real quantity between - (K + L-2) ~ (K + L-2) randomly for each dimension of each velocity vector V, and set the parameters ω, C1, C2, R.

Step 2: Converts the situation vector of each element into the form of general route.

Step 3: Calculate the fitness rate of each element according to formula (6), and take the initial evaluation value as the individual extreme value $pbest_{i1}$, find the global extreme value gbest1.

Step 4: For each element, obtain the velocity V according to formula (7), and calculate the next assembly situation x according to formula (8). When calculating V and X, if it cross the range, take the value according to the boundary and convert x into the form of regular route.

Step 5: Calculate the fitness rate of each element according to formula (9) and compare it with $pbest_{id}$, $gbest_d$ and. If the fitness value is smaller, update $pbest_{id}$ or $gbest_d$.

Step 6: If the termination situations are not meet, step 4 is returned.

Mountain climbing scheme 1: for the global extremum in every generation assembly formed through standard PSO, the mountain climbing operation is implemented through domain search. This paper is realized by exchanging the situations of any two dimensions in the element situation vector. The specific operations are as follows:

1. For the global extremum in each generation, any two dimensions in the situation vector are randomly selected to exchange their situations.
2. Judge whether the fitness value becomes smaller after changing the situation. If it becomes smaller, replace the global extreme value with the individual after changing the situation.
3. Repeat 1 and 2 until a certain quantity of exchanges are reached.

The hybrid (PSO) procedure using mountain climbing scheme I is called hybrid PSO scheme I.

Mountain climbing scheme 2: in each iteration, the mountain climbing operation is implemented for each element through domain search. It is also realized by exchanging the situations of any two dimensions in the element situation vector. The specific operations are as follows:

1. For each element, any two dimensions in the situation vector are randomly selected to exchange their situations.
2. Judge whether the fitness value becomes smaller after changing the situation. If it becomes smaller, replace the individual extreme value of the element with the individual after changing the situation.
3. Repeat 1 and 2 until a certain quantity of exchanges are reached.
4. Compare the individual extreme value obtained after mountain climbing with the global extreme value. If the fitness value becomes smaller, update the global extreme value.

The hybrid (PSO) procedure using mountain climbing scheme II is called hybrid PSO scheme II.

Hybrid PSO scheme 1 and hybrid PSO scheme 2 are obtained by introducing mountain climbing procedure on the basis of standard PSO. The difference between the two procedures is that the time of introducing the mountain climbing procedure is different. The former is to climb the global extremum in each generation of population formed by standard PSO through domain search, and the latter is to climb each element through domain search in each iteration.

The purpose of introducing mountain climbing operation into (PSO) procedure is two: one is to enhance the local search ability of (PSO) procedure. The second is to prevent premature convergence without finding the optimal result. The local search ability of Hybrid PSO scheme 1 is greater than that of standard pso} Hybrid PSO scheme 2, which is fully proved in the later example analysis.

4 Results and analysis

This section describes outcome analysis obtained for from the offered design of route optimization based on PSO.

4.1 Example 1 analysis

The issue of example 1 is a dissemination system with 8 chain stocks and 1 Dissemination Center. The quantity of automobiles used for dissemination in the dissemination center is 2, and the automobile volume is eight tons. The distance among chain stocks (km) and its request (ton) are tabulated in Table 1. The dissemination center quantity is 0. It is compulsory to position appropriate driving routes to minimize the total transportation mileage.

The optimal total route observed through experimentation test is: 6-7-4-0-1-3-5-8-2, the corresponding driving route is:

Automobile 1: dissemination center - chain stock 6 - chain stock 7 - chain stock 4 - dissemination center

Automobile 2: dissemination center - chain stock 1 - chain stock 3 - chain stock 5 - chain stock 8 - chain stock 2 - dissemination center.

The optimized total driving area is 67.5 kms.

Due to the introduction of mountain climbing procedure, the convergence speed of hybrid procedure is much better than that of standard PSO procedure. The changes of the optimal element fitness values of standard PSO procedure, mixed PSO scheme I and mixed PSO scheme II with the quantity of iterations are shown in Figure 2, Figure 3and Figure 4 respectively. The observations through this Figure are that among the three procedures of standard PSO, mixed PSO scheme 1 and mixed PSO scheme 2, the convergence speed of mixed PSO scheme 2 is the fastest, the convergence speed of mixed PSO scheme is the second, and the convergence speed of standard PSO is the slowest.

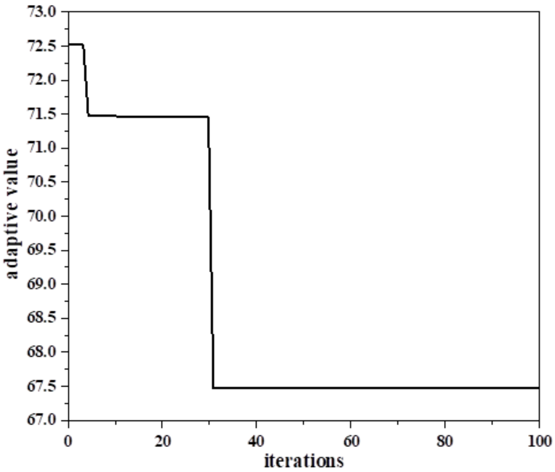

Figure 2: Growth of standard PSO optimal result.

Table 1: Distance and request between chain stocks

Chain stock Quantity	**Requirement**	**Distance**								
		0	1	2	3	4	5	6	7	8
0	0	0	4	6	7.5	9	20	10	16	8
1	1	4	0	6.5	4	10	5	7.5	11	10
2	2	6	6.5	0	7.5	10	10	7.5	7.5	7.5
3	1	7.5	4	7.5	0	10	5	9	9	15
4	2	9	10	10	10	0	10	7.5	7.5	10
5	1	20	5	10	5	10	0	7	9	7.5
6	4	10	7.5	7.5	9	7.5	7	0	7	10
7	2	16	11	7.5	9	7.5	9	7	0	10
8	2	8	10	7.5	15	10	7.5	10	10	0

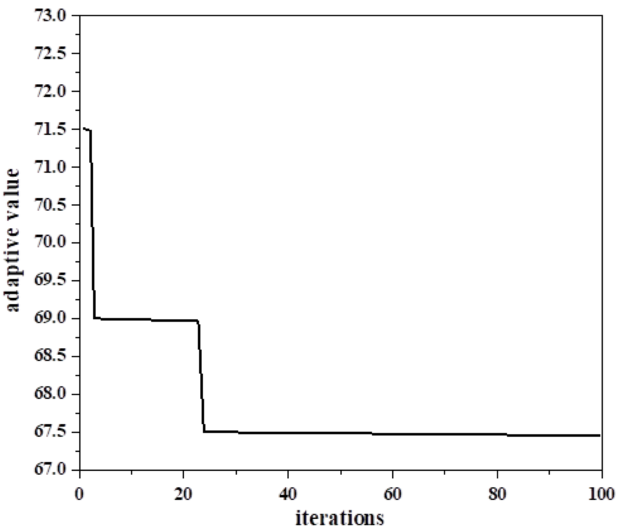

Figure 3: Growth of optimal result of Hybrid PSO scheme I.

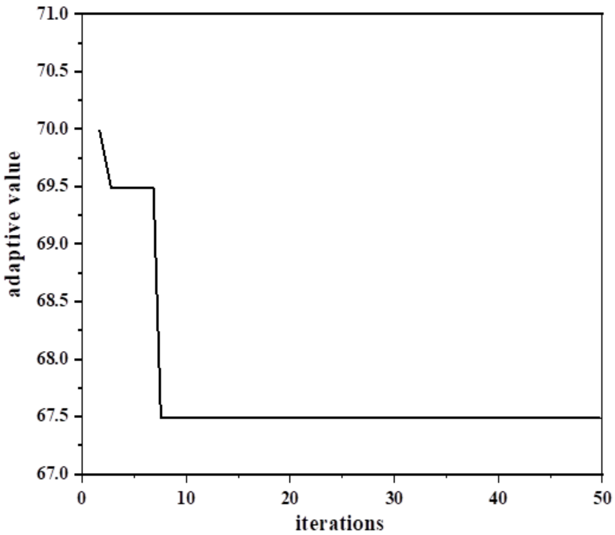

Figure 4: Growth of the second optimal result of the mixed PSO scheme.

The three procedures of standard PSO, mixed PSO scheme I and mixed PSO scheme II all carry out 20 operations, and the operation outcomes are that the standard PSO 20 operations and 5 operations reach the optimum. In the mixed PSO scheme 1, 20 operations and 8 operations reach the optimum, and the mixed PSO scheme 2 20 operations and 17 operations reach the optimum. It can be seen from the test outcomes that the stick PSO scheme 1 is better than the standard PSO under the same quantity of iterations. The reason is that the hybrid PSO scheme introduces the mountain climbing operation to the global extremum in every generation, which improves the local examination capability of the normal PSO. The quantity of iterations of Hybrid PSO scheme 2 is only half of that of standard PSO and hybrid PSO scheme 1, but the operation outcome is obviously better than that of standard PSO and hybrid PSO scheme 1. The reason is that hybrid PSO scheme 2 introduces mountain climbing operation for each element, which greatly increases the intensity of local search and makes up for the defect that (PSO) procedure is easy to fall into local optimization.

4.2 Example 2 analysis

There are only 8 dissemination points in example 1. In order to further test the performance of Hybrid PSO scheme 1 and hybrid PSO scheme 2, a dissemination system with issue scale of 20 is randomly generated in this paper. The coordinates of the dissemination center are (45 kms, 45 kms), the location coordinates of clients are (x km, y km), X and y are actual quantities among 0 and 100, and the cargo request is a random quantity between 0 and 2. See Table 2 and 3 for the coordinates of 20 clients and their cargo request. The load volume of automobiles in the dissemination center is 8t, and the quantity of automobiles in the dissemination center is 3. It is required to reasonably arrange the dissemination route of automobiles to minimize the dissemination mileage. For ease, the distance among clients and the distance between clients and dissemination center are straight-line distance. The example includes 20 clients, and the total quantity of clients is up to 2.433 x 1018. Due to time restrictions, this issue cannot be realized by exhaustive method. The graphical representation of customer coordinates and their request is presented in Figure5.

Table 2: Customer coordinates and their request

Client quantity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Abscissa	42	57	41	70	96	91	62	72	76	26
Ordinate	14	32	99	47	58	88	79	10	8	54
Requirement	0.3	0.4	1.2	1.5	0.8	1.3	1.1	0.6	1.2	0.4

Table 3: Customer coordinates and their request (Continued)

Client quantity	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Abscissa	55	93	45	28	78	10	16	11	97	56
Ordinate	39	28	74	96	9	27	71	55	31	94
Requirement	0.9	1.3	0.7	1.9	1.7	1.1	1.5	1.6	1.2	1.5

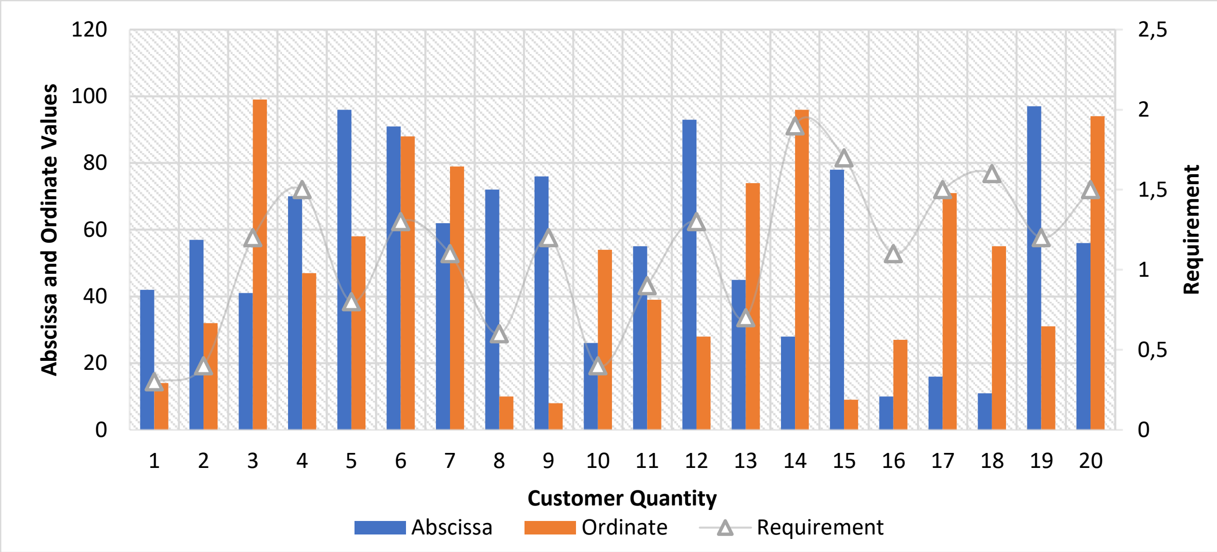

Figure 5: Graphical Representation of customer coordinates and their request.

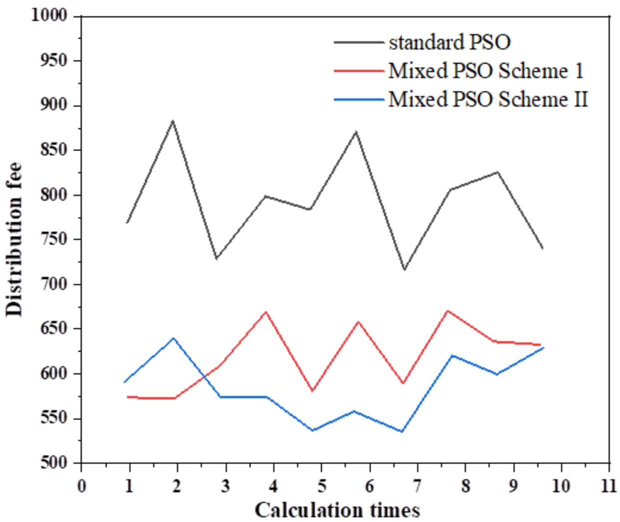

Figure 6: Comparison of outcomes of standard PSO, mixed PSO scheme I and mixed PSO scheme II.

The example includes 20 clients, and the total quantity of clients is up to 2.433 x 1018. Due to time restrictions, this issue cannot be realized by exhaustive method. The graphical representation of customer coordinates and their request is presented in Figure 5.

The three procedures of standard PSO, mixed PSO scheme I and mixed PSO scheme II all carry out 10 operations, and the operation outcomes are shown in Figure 6. It is observed that the optimal value obtained by standard PSO is 717.79. The average value of 10 results is 793.28. The optimal value of Hybrid PSO scheme 1 is 575.68, and the average value of 10 times is 620.94. The optimal value of Hybrid PSO scheme 2 is 535.90, and the average value of 10 results is only 588.52.

4.3 Discussion

It can be seen from the figure that after the issue scale increases, the performance of Hybrid PSO scheme 1 and hybrid PSO scheme 2 is also better than that of standard PSO method. Due to the introduction of mountain climbing operation for each element, the performance of Hybrid PSO scheme 2 is much better than that of standard PSO and hybrid PSO scheme 1. High quality results are obtained after 10 times of result. Using hybrid PSO scheme 2 to solve the logistics dissemination automobile routing issue can greatly shorten the dissemination mileage. This method is an effective method to solve the logistics dissemination automobile routing issue. Through the analysis of calculation outcomes of example 1 and example 2, the following conclusions can be drawn:

The local search ability of Hybrid PSO scheme 1 is greater than that of standard PSO} Hybrid PSO scheme 2. Due to the mountain climbing operation of each element, the local search ability of Hybrid PSO scheme 1 is greater than that of Hybrid PSO scheme 1 and standard PSO. The introduction of mountain climbing procedure makes up for the defect that (PSO) procedure is easy to fall into local optimization. Due to the introduction of mountain climbing procedure, the convergence speed of hybrid procedure is much better than that of standard PSO procedure. Among the three procedures of standard PSO, mixed PSO scheme 1 and mixed PSO scheme 2, the convergence speed of mixed PSO scheme 2 is the fastest, the convergence speed of mixed PSO scheme is the second, and the convergence speed of standard PSO is the slowest.

When the population size is roughly the same, the hybrid PSO scheme 2 is also better than the standard GA and the two population GA. When solving the automobile routing issue of logistics dissemination, the performance of Hybrid PSO scheme I and hybrid PSO scheme II are better than standard PSO, and the performance of Hybrid PSO scheme II is the best. Hybrid PSO scheme 2 can quickly and effectively solve the logistics dissemination automobile routing issue. Using this method to solve the logistics dissemination automobile routing issue can greatly shorten the dissemination mileage. The procedure is simple and easy to program. It is a useful and realistic optimization technique to resolve the logistics dissemination automobile routing issue.

5 Conclusion

In this paper, the mathematical design of logistics dissemination automobile routing issue is established. Aiming at the lack of local search ability of (PSO) procedure, the mountain climbing procedure with strong local search ability is introduced into (PSO) procedure to improve the offered procedure. The hybrid (PSO) procedure is applied to the automobile routing issue of logistics dissemination. Combined with the features of logistics dissemination, two mountain climbing schemes are offered, and two different hybrid (PSO) procedures are constructed. For the global extremum in each generation, the climbing operation is introduced to form stick PSO scheme 1, and the climbing operation for each element forms Hybrid PSO scheme 2. The standard PSO, hybrid PSO scheme 1 and hybrid PSO scheme 2 are used to solve the logistics dissemination automobile routing issue. The example analysis displays that the hybrid PSO scheme 1 and hybrid PSO scheme 2 offered in this paper have better performance than the standard PSOA method in solving the automobile routing issue. It can efficiently resolve the logistics dissemination automobile routing issue. After the issue scale rises, the optimization advantages of Hybrid PSO scheme 2 are fully displayed. The article reveals that hybrid PSO scheme 2 is effective to solve the logistics dissemination automobile routing issue and can greatly shorten the dissemination mileage.

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