A Fish Swarm Ant Colony Algorithm for the Vehicle Routing Problem

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Abstract — In this paper, the basic ant colony optimization procedure is further developed by the idea of crowded factors in fish swarm optimization which can improve the global search ability to solve the Vehicle Routing Problem, or the VRP model. Experimental simulation shows that fish swarm ant colony optimization can solve VRP model effectively, quickly find the optimal solution, and improve the basic ant colony optimization ability and efficiency.

Keywords - fish swarm ant colony optimization (FSACO); ant colony optimization (ACO); VRP; path optimization

I. INTRODUCTION

Vehicle Routing optimization problem (Vehicle Routing Problems, referred to as VRP) by Dantzig and Ramser [1] is proposed for the first time, and still is a research hotspot of scholars both at home and abroad, is still in the combinatorial optimization research frontier in the field of study. For solving vehicle routing optimization model, the application of swarm intelligence optimization is more and more, including: ant colony optimization, genetic optimization and annealing optimization, particle swarm optimization (PSO) optimization, etc.

Basic ant colony optimization has many advantages, but there are still easy to fall into local optimum and slow convergence speed and other shortcomings. The idea of crowded factors by fish swarm optimization in this paper optimize basic ant colony optimization, improve the global search ability, solve VRP model, experimental simulation show that fish ant colony optimization to solve VRP model effectively, quickly find the optimal solution, to improve the basic ant colony optimization optimization ability and efficiency.

II. VEHICLE ROUTING PROBLEM

Vehicle routing optimization problem is to point to in meet the requirements of the vehicle load, under the condition of the goods from the point of distribution center to the various needs in order to achieve the lowest cost of distribution. Vehicle distribution cost mainly includes the distribution of fixed cost, distribution cost of transportation and overload. Therefore, the vehicle routing optimization model includes the three basic parts. In order to facilitate model is established in this paper, assuming that there is only one distribution center and the position is known, all distribution vehicle starting from the distribution center, distribution still back in after the completion of distribution center. The location of the weight of the vehicle is known, demand point and the demand is known, requirements on one and only one car is responsible for the delivery. According to the hypothesis model aimed at the lowest cost of distribution:

\[
\min Z = c_0 m' \sum_{i=0}^{L} \sum_{j=1}^{m} c_d \cdot x_{ij} + c_i \sum_{k=1}^{m} \left( \sum_{q=1}^{i} \left( g \cdot y_n - q \right) \right) \quad (1)
\]

Among them, Z on behalf of the shipping cost, \(c_0\) to drive the cost per unit, \(m'\) as the number of vehicles, \(L\) demand for the number of points, \(c\) the cost per unit for vehicle distance; \(d_{ij}\) \((i, j = 1, 2, \ldots, L)\) demand point \(i\) and demand point \(j\) the distance between the point; \(c_i\) for the overload punish coefficient; \(g\). For \(i\) demand point of demand, \(q\) is the maximum load for a car; \(k (k = 1, 2, \ldots, m')\) for the serial number of vehicles.

The distribution center number 0, Demand point Numbers for 1, 2, 3, ... \(L\), defined variable \(x_{ik}\), \(y_{ik}\)

\[
y_{ik} = \begin{cases} 1 & \text{is service by vehicle} \ k \\ 0 & \text{others} \end{cases} \quad (2)
\]

\[
x_{ik} = \begin{cases} 1 & \text{vehicle} \ k \text{ from} \ i \text{ to} \ j \\ 0 & \text{others} \end{cases} \quad (3)
\]

\[
\sum_{k=1}^{m'} y_{ik} = 1 \quad \text{if} \ i \in [0, L], k \in [1, m'] \quad (4)
\]

\[
\sum_{k=1}^{m'} y_{kj} = 1 \quad \text{if} \ j \in [0, L], k \in [1, m'] \quad (5)
\]

\[
\sum_{j=0}^{L} y_{ik} = 1 \quad \text{if} \ i \in [0, L], k \in [1, m'] \quad (6)
\]

\[
\sum_{j=0}^{L} y_{jk} = 1 \quad \text{if} \ i \in [0, L], k \in [1, m'] \quad (7)
\]
\[
\sum_{j=0}^{k} x_{ij} = y_{ij}, \quad i \in [0, L], k \in [1, m'] \tag{8}
\]

\[
\sum_{j=0}^{k} x_{ij} = y_{ij}, \quad i \in [0, L], k \in [1, m'] \tag{9}
\]

\[
\sum_{j=0}^{k} u_{ij} = \sum_{j=0}^{k} x_{ijk} = \sum_{j=0}^{k} x_{jk} \quad (i = 0, k') \tag{10}
\]

Formula (1) is the objective function, the first part is the fixed cost, the second part is the operation cost, and the third part is overload. Formula (4) ~ (10) is the constraint. Formula (4) said demand point cannot be more than the sum of load demand. Formula (5), Formula (6), Formula (7) according to each demand point can only have a car service, Formula (8) said demand point j task completed by k car, vehicles k are driven from the demand point i to demand point j, Formula (9) said demand point i task completed by k car, vehicles k are driven from the demand point j to demand point i, Formula (10) said the vehicle starting from the distribution center, distribution task after back to the distribution center.

### III. FISH SWARM ANT COLONY OPTIMIZATION (FSACO) TO SOLVE VRP PROBLEMS

**Crowded degree factor** is used to represent crowded gathered groups or not. In the introduction of basic ant colony optimization in the crowded degree factor, greatly enhance the global search ability of the optimization. This is due to the congestion degree factor can publish what solution for little or no, so that higher pheromone path will not soon to gather more ants, avoid falling into local optimal solution.

The congestion of fish swarm ant colony optimization level factor structure is as follows:
\[
h_y(t) = 1 - \tau_y(t) / \sum_{i,j} \tau_y \tag{11}
\]

\[
\delta(t) = \gamma e^{-bt} \tag{12}
\]

Where, \(\delta(t)\) is the threshold for the crowded degree, \(\gamma\) is extreme value close to the level, \(b\) is the threshold change coefficient.

If the ants by (12) to find a path, \(h_y(t) > \delta(t)\) said that the path to the crowded degree is low, can choose this path. Otherwise, will according to (12), choose another path.

Fish swarm ant colony optimization to learn the advantages of the two optimizations are the fish optimization of congestion level factor to optimize the ant colony optimization, in order to better solve the problem of VRP, the concrete solving steps are as follows:

1. \(NC=0\) (NC is the number of iterations), the vehicle load is 0, carries on the basic ant colony optimization parameters initialization;
2. Put m ant distribution center;
3. According to the type (13) to calculate the transfer probability of ant, select and move to the next city j, at the same time to add j to \(tabu_k\). Check whether the vehicle load is the maximum load. If reached, return distribution center;
4. Among them, \(allowed_i = \{1, 2, \ldots, n\} - tabu_k\) can be said that the ant k currently selected city collection;
5. \(tabu_k (k = 1, 2, \ldots, m)\) represents the first k ant taboo tables, records ant k has been the city, used to describe the memory of the ants. \(\eta_k (t)\) is a priori knowledge of visibility problems in the TSP heuristic information for the city transferred to the city, and generally \(\eta_k (t) = 1/d_k\). \(\alpha\) is important information on the extent of residual path \(ij\), \(\beta\) inspired the importance of information.

(4) According to equation (12) calculating the degree of congestion factor, if the congestion continues (5), otherwise return (3);
(5) Check whether full. If no, return to (5), otherwise continue (7);
(6) To calculate the objective function, record the current best solution;
(7) According to equation (14) pheromone update.
\[
\tau_y(t+1) = (1-\rho)\tau_y(t) + \Delta \tau_y(t) \tag{14}
\]

\(\Delta \tau_y(t)\) means that this pheromone increment on the traverse path. The initial time, \(\Delta \tau_y = 0\) = chaos value corresponding to the amount, \(\Delta \tau_y (t)\) represents only the first k in the path \(ij\) of the ants release pheromone traveling the process, its value depends on the performance of the pros and cons depending on the degree of ants. The more the shorter path pheromone is released.

\[
\Delta \tau_y(t) = \begin{cases} Q/L_o & \text{ant } k \text{ in } ij \\ 0 & \text{others} \end{cases} \tag{15}
\]

Wherein, \(Q\) is a constant, \(L_o\) represents the length of time to travel around the loop section formed ant.

8. If \(NC < NC_{max}\), \(NC = NC + 1\), empty \(tabu_k\), back (2).

### IV. COMPUTING SIMULATION

Assuming distribution center need to 20 demand point distribution, the coordinates of the distribution center (14.5, 14.5). Table 1 for each demand point coordinates and demand. The maximum load for delivery vehicles is 8 tons.

Simulation \(c_o = 0,\ c = 1,\ c_i = \infty\), the fee is only related to vehicle running away. The distance of each demand point and the demand point and the distribution center, using type (16) to compute transport vehicle using (13) to calculate.

\[
d_y = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{16}
\]

Delivery required for the vehicle number according to the type (18), which take \(\lambda = 0.98\).
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\[ m' = \left[ \frac{\sum_{i=1}^{k} g_i}{\lambda q} \right] + 1 = \left[ \frac{23.7}{0.98 \times 8} \right] + 1 = 4 \quad (17) \]

Where, the integer \([\cdot]\), \(\lambda \in (0,1)\), can be adjusted according to the complexity of loading and what constraints, generally the more complex loading, \(\lambda\) is smaller, conversely, the greater the \([\cdot]\).

TABLE I THE EXPERIMENTAL DATA

<table>
<thead>
<tr>
<th>NO.</th>
<th>coordinates</th>
<th>Requirements</th>
<th>NO.</th>
<th>coordinates</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(12.8,8.5)</td>
<td>0.1</td>
<td>11</td>
<td>(6.7,16.9)</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>(18.4,3.4)</td>
<td>0.4</td>
<td>12</td>
<td>(14.8,2.6)</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>(13.4,16.6)</td>
<td>1.2</td>
<td>13</td>
<td>(1.8,8.7)</td>
<td>1.3</td>
</tr>
<tr>
<td>4</td>
<td>(18.9,15.2)</td>
<td>1.5</td>
<td>14</td>
<td>(17.1,11.0)</td>
<td>1.9</td>
</tr>
<tr>
<td>5</td>
<td>(15.5,11.6)</td>
<td>0.8</td>
<td>15</td>
<td>(7.4,1.0)</td>
<td>1.7</td>
</tr>
<tr>
<td>6</td>
<td>(3.9,10.6)</td>
<td>1.3</td>
<td>16</td>
<td>(0.2,2.8)</td>
<td>1.1</td>
</tr>
<tr>
<td>7</td>
<td>(10.6,7.6)</td>
<td>1.7</td>
<td>17</td>
<td>(11.9,19.8)</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>(8.6,8.4)</td>
<td>0.6</td>
<td>18</td>
<td>(13.2,15.1)</td>
<td>1.6</td>
</tr>
<tr>
<td>9</td>
<td>(12.5,2.1)</td>
<td>1.2</td>
<td>19</td>
<td>(6.4,5.6)</td>
<td>1.7</td>
</tr>
<tr>
<td>10</td>
<td>(13.8,5.2)</td>
<td>0.4</td>
<td>20</td>
<td>(9.6,14.8)</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Figure 1 for fish swarm ant colony optimization running roadmap, running route as shown in table 2. Figure 2 as the basic ant colony optimization running roadmap, running route as shown in table 3.

TABLE II FISH SWARM ANT COLONY OPTIMIZATION RUNNING ROUTES

<table>
<thead>
<tr>
<th>vehicle (k)</th>
<th>Running route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Distribution center - 18 - Distribution center</td>
</tr>
<tr>
<td>2</td>
<td>Distribution center - 20-11-17-3-4-5 - Distribution center</td>
</tr>
<tr>
<td>3</td>
<td>Distribution center - 6-13-16-15-19-8 - Distribution center</td>
</tr>
<tr>
<td>4</td>
<td>Distribution center - 1-7-10-9-12-2-14 - Distribution center</td>
</tr>
</tbody>
</table>

TABLE III BASIC ANT COLONY OPTIMIZATION RUNNING ROUTES

<table>
<thead>
<tr>
<th>vehicle (k)</th>
<th>Running route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Distribution center - 18 - Distribution center</td>
</tr>
<tr>
<td>2</td>
<td>Distribution center - 20-11-6-13-16-19 - Distribution center</td>
</tr>
<tr>
<td>3</td>
<td>Distribution center - 5-14-4-17-3 - Distribution center</td>
</tr>
<tr>
<td>4</td>
<td>Distribution center - 1-7-8-15-9-12-2 -10- Distribution center</td>
</tr>
</tbody>
</table>

Figure 3 is the minimum cost optimization curve graph for comparing two kinds of optimization. Through the experimental simulation as you can see, the fish is more effective in ant colony optimization in solving the questions of VRP, can more to save the shipping cost, and convergence rate is also improved.
V. CONCLUSION

This article will fish swarm optimization thoughts crowding factor applied to the basic ant colony optimization, we propose a new hybrid optimization - ant colony optimization fish will be added to the basic ant colony optimization crowding factor publicity, effective control of ants a path in the aggregation pheromone excessive, thereby increasing the overall performance of the search optimization. In this paper, ant colony optimization for VRP fish, experimental results show that the optimization for VRP problem to find the optimum solution or the optimal solution, able to find lower compared to the basic ant colony optimization for distribution costs. Fish ant colony optimization is proposed to improve the basic ant colony optimization is proposed a new way of thinking.

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