Multi-Objective Evolutionary Algorithm for Path Optimization of Urban Express Vehicles

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Abstract. In view of the actual situation of delivering express delivery in the city. Put forward five objectives: the number of vehicles, total distance, maximum working time, early delivery time, delayed delivery time. Also designed three-stage multi-objective genetic algorithm. A large number of solutions were randomly generated in the first stage of the algorithm, and the approximate Pareto front was quickly found from the solution set with the extreme solution and elite strategy, while the local optimization algorithm is used to optimize the extreme solution. The second stage is divided into multi-objective problems according to the importance of the target, and the path of the unified distribution station is optimized by local optimization algorithm to obtain the relative optimal solution. The third stage corrects the obtained solution with mixed neighborhood, which makes the final solution meet the requirements of express delivery, and solves the occasional local optimal solution problem. Experiments show that this algorithm is superior to the two commonly used algorithms in multi-objective express delivery scenarios.

1 Overview

The core of logistics optimization is the vehicle routing problem (VRP). This paper considers the actual requirements of express delivery, and finally selects multi objective multi depot vehicle routing problem with time windows with time windows, (MOMDVRPTW)[1]. MOMDVRPTW under the premise of ensuring delivery time, multiple distribution stations and multiple optimization objectives are considered, which is suitable for express delivery scenarios. MOMDVRPTW is a NP-hard problem, so use heuristic algorithm to solve [2].

At present, there are many studies to explore the impact of different goals on VRP. The main objectives include total itinerary, total time, total cost, number of vehicles, quality of service and total profit [3]. Some studies have shown that shortening the maximum working time of a single vehicle can balance the workload and improve work efficiency, thus reducing the cost of employment [4]. On-time delivery can improve the quality of service, so we should reduce the time of early delivery and delayed delivery [5]. A EP-MOEA algorithm is proposed in this paper. based on a two-stage strategy [6], a result correction phase is added. So as to provide rapid urban express delivery path planning services.
2 Problem description

The path of express delivery can be represented by directed graph.

1) customer set $C$: each customer has a time window to receive express delivery, this article uses soft time window.

2) distribution station set $D$: each distribution station has business hours.

3) vertex sets $V=C\cup D$.

4) edge set $E$: each edge is a line between two vertices in the $V$ with two weights of distance and time. One solution can be represented by a set of paths, $R=\{R_0^1,R_0^2,R_0^3,R_1^1,R_1^2,R_1^3,R_2^1,R_2^2\}$ as shown in figure 1.

![Figure 1. Express delivery path map.](image)

Five objectives ($f_1$-$f_5$) that need to be optimized for urban express delivery are listed in Table 1.

| Target                  | Symbol |
|-------------------------|--------|
| Number of vehicles      | $f_1$  |
| Total distance          | $f_2$  |
| Maximum working time    | $f_3$  |
| Early arrival time      | $f_4$  |
| Delayed arrival time    | $f_5$  |

Table 1. Target of MOMDVRPTW.

After considering the objective quantization, the function is as follows

1) Vehicles ($f_1$):

$$f_1 = \sum_{i=1}^{NV_i}$$ (1)

2) Itinerary ($f_2$):

$$f_2 = \sum_{i=1}^{NV_i} \sum_{j=1}^{Dis(R^i)}$$ (2)

3) Working hours ($f_3$):

$$f_3 = \max_{i=1}^{NV_i} \max_{j=1}^{T(R^i)}$$ (3)

4) Total waiting time ($f_4$):

$$f_4 = \sum_{i=1}^{NV_i} \sum_{j=1}^{WT(R^i)}$$ (4)
5) Delay ($f_5$):

$$f_5 = \sum_{i \in D} \sum_{j = 1}^{N_j} DT(R'_j) \quad (5)$$

The solution obtained should also meet the following three constraints.
1) Maximum delay time constraint ($C_1$)
2) Return time constraint ($C_2$)
3) Vehicle capacity constraints ($C_3$)

### 3 Fast convergence

A traditional way to solve this multi-objective problem is to use heuristic algorithms to find the pareto frontier and thus obtain a relative optimal solution [7]. In order to improve the accuracy, this paper uses the method of local search to improve.

After a large number of initial solutions are generated, the resulting solutions are sorted. The normalized euclidean distance of each solution (formula 6) is first calculated, and then the solution is sorted in ascending order according to that distance. Next, the more accurate extreme solution is obtained by the method of local search, as shown in algorithm 1.

$$d_x = \sqrt{\sum_{i=1}^{M} w_i \left( \frac{f_i(x) - Z_{i,x}}{f_i^{max} - f_i^{min}} \right)^2} \quad (6)$$

**Algorithm 1** Local Optimization Algorithm for Extreme Points

**Input** current extreme point $x$, target weight $f_{coi}$. Extreme Point $r$ after

**Output** Optimization
1. find the extreme point where each target takes the minimum value $x$, and create neighborhood $N(i)$ centered on it.
2. if the neighborhood $N(i)$ dominates the extreme solution $x$, $N(i)$
3. if the neighborhood $N(i)$ cannot dominate the extreme solution $x$, if (i). $f_{coi} > x$, $f_{coi}, x = N(i)$
4. assignment $r = x$

In order to control the number of solutions and improve the computational efficiency, the first stage uses the $\epsilon$-clean method to clean up the solution outside the $\epsilon$ neighborhood [10], so as to screen the valuable solution near the extreme solution. We will find the pareto frontier and get the relative optimal solution on the basis of these solutions. The fast convergence stage is shown in algorithm 2.

**Algorithm 2** R-NSGA-II Improved algorithm

**Input** Target number $M$, $Q_t$, population $P_t$, offspring population

**Output** population $P_{t+1}$ subpopulation $Q_{t+1}$.
1. initializes the population
2. $R_t = P_t \cup Q_t$
3. will $R_t$ non-dominant ranking based on different priorities for $M$ objectives
4. find out the extreme solution in the $R_t$ and use the local optimization method to make it accurate
5. $\epsilon$-cleaning method is used to clean the solution outside the neighborhood and generate the next generation $t+1$. 6. Judge whether the limit is reached, yes, it ends.
4 Target split

A second phase aims to optimize the pareto frontier obtained in the first phase so that it is as accurate and uniform as possible. At this stage, based on the MOEA/D algorithm, the multi-objective problem is decomposed into single-objective problems. Because the MOEA/D algorithm does not take into account multiple distribution stations, this paper based on the weight of different targets in the express delivery scene, adds local optimization algorithm, optimizes the distribution relationship between customers and distribution stations, and local optimization is shown in algorithm 3.

Algorithm 3 Local Optimization Algorithm for Target Split Phase

Input current solution x, archive A
Output latest solution x
1. according to the weight of the target, from 1 to optimize the ranking of the target
2. random exchange of some customers at two distribution stations
3. update the solution if the target value is smaller.

Because the MOEA/D does not take into account multiple distribution stations, it is necessary to use an additional path-based crossover operator. The crossover operator can save the information of the distribution station, as shown in algorithm 4.

Algorithm 4 MOEA/D Improved algorithm

Input Population Pt obtained A, the first phase of the input population NII,
Output archive Output latest archive A
1. generate weights based on the importance of the goal
2. new population Qt are generated using Pt based on the last generation of the first phase
3. select the optimal solution for each target weight in Pt and Qt.
4. local search algorithm

5 Result correction

Because of the large number of express delivery stations, the local optimal problem will be generated when the initial solution is obtained. To solve this problem, a method of neighborhood structure is cited in the third stage. Randomly delete some customers and then randomly insert them back into the route. Because of the large number of customers deleted and re-inserted, it can effectively optimize the distribution of customers and the problem of local optimal solution.

6 Result correction

6.1 Experimental parameters

Phase I, the number of customers set to 100. Phase II, the weight parameter is set to 495. Phase III, delete and re-insert the coefficient set to 0.65.

6.2 Experimental results

The HV and IGD performance of the proposed EP-MOEA (express delivery-moea) in express delivery scenarios is much better than that of MOEA/D and MOLS, as shown in table 2.
Table 2. HV and IGD comparisons.

|        | HV  | Mean value | IGD | Mean value |
|--------|-----|------------|-----|------------|
| EP-MOEA| 1.5167 | EP-MOEA | 1.48 |
| MOEA/D | 1.6011 | MOEA/D | 1.63 |
| MOLS   | 2.9697 | MOLS | 2.97 |

The EP-MOEA algorithm in this paper is more stable than the other two algorithms, and meets the specific requirements of express delivery. The comparison of HV is shown in figure 2. IGD contrast, as shown in Figure 2.

Figure 2. HV Contrast (left) IGD Contrast (right).

7 Concluding

Remarks a three-stage multi-objective evolutionary algorithm is designed to transform express delivery problem into MOMDVRPTW. Experimental results show that this algorithm can achieve better results with less computation time than the traditional algorithm. This algorithm is superior to other algorithms in IGD and HV. In the future research, the scene of collecting goods can be added to make the algorithm undertake more functions.

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