Landmark-Based Multi-Objective Route Planning for Large-scale Road Net

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ABSTRACT

In this paper, for two objectives of the minimum driving distance and the maximum number of passengers compatible, a landmark-based multi-objective route planning algorithm (LB-MORPA) is proposed. LB-MORP incorporates the idea of a bi-directional random walk into the generation of the initial population, designs a new crossover and mutation operator for the evolutionary process, and predicts a set of the nondominated solution set to provide drivers with multiple route options. The comparison experiments with other classical multi-objective evolutionary algorithms prove that the LB-MORP has good performance.

CCS CONCEPTS

• **Theory of computation → Evolutionary algorithms**; • **Mathematics of computing → Combinatorial optimization**.

KEYWORDS

Ride-sharing, Route Planning, Multi-objective Optimization, Landmark, Evolutionary Algorithm

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1 INTRODUCTION

The emergence of ride-sharing nowadays has largely eased the pressure on the environment, congestion and resources. Multi-objective route planning (MORP) that takes into account the interests of passengers and drivers has become the top priority in the ride sharing problem. The methods of solving it can be divided into two groups: traditional mathematical methods and heuristic algorithms. Since the route planning problem is a nonlinear and highly complex NP-complete problem [2], it is difficult to solve the large-scale complex route planning problem by using traditional mathematical algorithms. And most of the existing multi-objective evolutionary algorithms convert multi-objective problems into single-objective problems without considering multiple objectives at the same time.

In this paper, we take into account the interests of passengers and drivers and establish a new model for the MORP. A landmark-based multi-objective route planning algorithm (LB-MORPA) is proposed. In addition, it is compared with other multi-objective evolutionary algorithms.

2 PROBLEM STATEMENT

The MORP problem studied in this paper is to search for an optimal set of solutions that obtained the minimum travel distance and the maximum number of compatible passengers at the same time. In the process of searching for the optimal solution, a series of constraints must be met.

The constraints of the MORP problem:

- The driving path $\{v_1, v_2, \ldots, v_n\}$ does not contain repeated nodes.
- The driving distance is within the range allowed by the maximum detour rate, which denoted as Dr(o). SP(v_1, v_n) denote the the shortest path distance from v_1 to v_n.

$$\frac{\text{Distance}\ (v_1, v_2, \ldots, v_n)}{\text{SP}\ (\ v_1,\ v_n)} < \text{Dr}\ (\text{o}) \tag{1}$$

- Node v_i and v_{i+1} are directly reachable, i.e., v_i and v_{i+1} have an edge connection in the road network.
- The starting point of the route is the pick-up point, and the ending point is the drop-off point.

The objective functions of the MORP problem:

- Minimum driving distance.

$$\text{Min}:\ \text{Distance}\ (v_1, v_2, \ldots, v_n) \tag{2}$$

- Maximum number of compatible passengers. $P_n\ (x_i)$ denotes the number of passages waiting at a given time at the location x_i, learning from the historical data. n is the number of nodes

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passed by the route P.

$$\text{Max}: \sum_{i=1}^{n} P_n(x_i) \quad (3)$$

3 THE PROPOSED ALGORITHM

For a solution, the values near the two ends have a greater impact on the entire solution, so we draw on the bi-directional random walk algorithm in the initial population. Assign values from both ends of the solution to the middle when constructing the initial solution. The crossover ideas for the MORP problem are: 1. If the two routes have intersections, the route is disconnected from one of the intersecting nodes, the new route is the reorganization of the segmented route after the disconnection. 2. If the two paths do not intersect, two nodes are randomly selected, and the shortest path is used to connect the two nodes to form two new paths. The mutation idea for the MORP problem are: 1. If there are unreachable points in the route, replace them with reachable points. 2. If the route does not contain unreachable points, one reachable point is randomly selected and replaced with another reachable point.

Some scattered hot spots (where have many compatible passengers) are landmark sets in the entire road network. At a given time, each location will contain the corresponding number of compatible passengers. We select a given number of locations from the road network as the landmark set of the entire road network, the locations selected as the landmarks have the following characteristics: 1. There are enough landmarks scattered throughout the road network evenly. 2. The landmark has a higher probability to find compatible passengers than the surrounding locations to increase the probability of drivers picking up passengers. After introducing landmarks in the order, the number of compatible passengers on the route will be increased, thereby greatly increasing the ride-sharing rate of the entire order. When planning a path for an order, first choose a landmark with appropriate orientation near the starting point of the order as the next destination to arrive at, then choose a landmark with appropriate orientation near the last landmark of the order as the next destination to arrive at, until the destination of the order appears near the location. The path is divided into sections after adding landmarks. For each section, a non-dominated path is generated using an algorithm based on NSGA-II, which uses the initial solution construction method, crossover operator and mutation operator proposed in this paper. The final recommended path for the order is the Cartesian product combination of all segments.

4 EXPERIMENTS AND RESULTS

The experiment is simulated on three real data sets, which are San Francisco [3], New York[1] and Singapore [4]. The parameters of all algorithms are as follows: the initial population is 80, the number of iterations is 500, the probability of crossover is 0.9, the probability of mutation is 0.5, the detour rate is 1.3. The selection operator is the binary tournament. Use the crossover and mutation proposed in section 3. Randomly select 10,000 test orders and repeat the experiment 50 times independently, and use the average value as the final result.

We compared the success rates of recommending multiple paths after introducing landmarks in three cities. As shown in Table 1, it can be clearly seen that no matter on which road network, introducing the landmark can significantly improve the success rate of planning multiple routes. Hypervolume (HV), SPREAD ,and the Success Rate of recommended multiple paths (SR) as evaluation indicators to compare with the classic multi-objective evolutionary algorithms MOEA/D, SPEA2 ,and FastPGA. The larger the HV value, the closer the solution set is to the entire Pareto front; the closer the Spread value is to zero, the better the diversity and distribution of the solution set; the greater the SR, the greater the probability of planning multiple routes. As shown in Table 2, it can be seen that LB-MORPA has the maximum HV value, minimum Spread value ,and maximum Success Rate value at the same time compared to the other three algorithms. In summary, LB-MORPA has a relative advantage for the MORP over other algorithms.

Table 1: Comparison of success rate after introducing landmarks in three cities

SR	San Francisco	New York	Singapore
No landmarks	0.572	0.589	0.302
Have landmarks	**0.842**	**0.747**	**0.654**

Table 2: Performance evaluation of MOEAD, SPEA2, FasPGA, and LB-MORPA

indicator	MOEAD	SPEA2	FastPGA	LB-MORPA
HV	0.01	0.19	0.14	**0.20**
SPREAD	0.92	0.66	0.74	**0.62**
SR	0.11	0.50	0.40	**0.57**

5 CONCLUSION

This paper aims at the minimum driving distance and the maximum number of compatible passengers and establishes a mathematical optimization model for the MORP problems, and LB-MORPA is proposed to solve this problem.

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