Research on the Route Choice of the Urban Rail Transit Network based on the Imperialist Competitive Algorithm

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Abstract: In order to improve the rationality of the route choice for passengers’ travel, this paper presents an optimization method of the route choice for urban rail transit network based on the imperialism competition algorithm (ICA). Firstly, according to the generalized travel cost of passenger, build the route choice model. Next, on the basis of ICA, we select all the feasible paths as the initial states, then taking the transfer times as the constraint, choose the Empire from all the states, and the rest are the colonies. Furthermore, we design the process of empire assimilation as well as competition to obtain the best route. The experiment results show that the proposed method is feasible and the algorithm is effective.

Keywords: Urban rail transportation, route choice, generalized travel cost, ICA algorithm, optimization

1 Introduction

With the development of urban district, traffic congestion has become a problem that cannot be ignored. How to effectively improve the transport efficiency has become the principal means to alleviate such problem. To achieve this objective, we should improve the efficiency of passengers travel and reduce the transfer times to save the travel time or cost. Urban rail transit has become one of the main ways to alleviate traffic congestion, It has the characteristics of large transport capacity as well as timely and effectively transportation. Due to the complexity of urban rail transit, it is very important to choose the optimal route efficiently among the many paths. At present, there have been building or planning rail transit lines in the dozens of large and medium-sized cities of China [1], in which, the rail transit network has been formed initially in several large cities. For example, there have been 16 subway lines and 25 transfer stations by the end of 2015, which makes the total operating mileage up to 527 km[2]. It is expected that the rail transit lines will reach about 1000 km by 2020 in Beijing.

The key problem of solving the path choice of rail transit is the study of optimal route algorithm. At present, there are many optimization algorithms for route choice. In 2011, Liu Xu proposed the ant colony algorithm to solve the rail transit route selection model [3], and carried on the ant colony algorithm parameter discussion and the route search example verification. 2013, Cheng Bo et al. build a large road transport path selection optimization model, and proposed improved genetic simulated annealing algorithm for such problems to optimize [4]. Liu JianFeng et al. analyzed the passenger route choice behavior to construct a generalized travel cost function model, and proposed an effective path search algorithm based on depth search priority and branch definition[5]. Si BingFeng et al. constructed the urban rail transit network generalized cost function, and designed based on the effective path search algorithm, combined with the domestic urban rail transit seamless operation characteristics. [6]

In the paper, the ICA algorithm is used to solve the route choice model of the urban rail transit. The ICA algorithm, which draws lessons from the competition, occupation and annexation of the colonial colonies in the political and social colonial stage of human history, becomes the evolution of the imperial state, and is a global optimization algorithm[7]. Here, all individuals are called as the state, divided into two kinds according to the state power; the former is more than the latter.

There have been some achievements on the research of the imperialist competition algorithm. In 2007, Atashpaz-Gargari and Lucas [8] proposed a socio-political evolutionary algorithm, called the Imperialist Competitive Algorithm (ICA), in his work on algorithms on population optimization. In 2014, Hao Yan [9] takes the imperialist competition algorithm to non-probabilistic reliability analysis and optimization in his master's thesis, and achieved the desired results. In the same year, Wang Xiaoguang [10] applied the imperialism competition algorithm in the WSNs positioning scheme, and proved that the ICA (Imperialism Competitive Algorithm) has the advantages of high positioning accuracy and rapid convergence in positioning WSNs. In 2015, Song Wenjia [11] et al. solve this model in the equipment maintenance and the workshop scheduling integration optimization question by multi-objective mixed colonial competition algorithm (imperialism competition algorithm), design corresponding encoding, decoding, colonial assimilation process and multi-objective mixing Colonial competition algorithm, and use the weighted method to obtain a satisfactory solution. In 2016, Shao YongLiang [12] has proposed a method for solving the structural modal parameter identification by the imperialist competition algorithm, which effectively identifies the structural modal parameters, and
the recognition accuracy high. In the same time, Yang Jiaquan [13] et al. has proposed a method for solving power grid carbon emission optimization model by the imperialist algorithm. In addition, researchers proposed some methods for solving the optimization of cutting parameters and the optimization of the wireless sensor location scheme by the Empire Competition Algorithm.

Aiming at the problem of route choice in urban rail transit, this paper proposes an algorithm based on ICA, and the experimental results show its effectiveness. The research of this paper can serve as a reference for the research of ICA algorithm.

The rest of paper is organized as follows. In section 2, we present the route choice model of urban rail transit; following that in section 3, we discuss that the optimization process of solving the proposed model by the ICA algorithm. Section 4 is mainly about experimental parameter setting and results analysis. Finally, we discuss about future work and conclusion of our method in section 5.

2 Route Choice Model

According to the status of urban rail, you can ignore this factor because of the fare only related to the starting point. This paper makes analysis and modeling of the effects of rail transit route selection in the car time, transfer time, transfer times, transfer factor, and quantify the influence factors are unified by the cost function. However, different passengers are different in different circumstances of the impact of different factors, for example, in the morning and evening peak hours, passengers who need to take the rail transit to work time is higher, often choose to use a shorter path, but ignored or reduced the impact of other factors, passengers whose the time are more abundant may choose the path which the smaller crowded degree and more comfortable travel.

A. Generalized travel cost model

Therefore, we introduce the weight coefficient to reflect the importance of each factor to the passengers, so as to establish the generalized travel cost model of rail transit:

\[
U(F_{T_1}, F_{T_2}, F_M, F_Q) = \beta_1 F_{T_1} + \beta_2 F_{T_2} + \beta_3 F_M + \beta_4 F_Q
\]

s.t. \(\sum \beta_i = 1\), \(\beta_i \geq 0\)

Where, \(\beta_1\) represents the weight coefficient of the vehicle time cost, \(\beta_2\) refers to the weight coefficient of the transfer time cost, \(\beta_3\) is the weight coefficient of the transfer distance, and \(\beta_4\) means the weight coefficient of the congestion time cost.

The weighting factor is solved as follows:

\[
\beta_i = \frac{p_i}{p_1 + p_2 + p_3 + p_4}
\]

where, \(p_1, p_2, p_3, p_4\) are the ratio of the travel time, the transfer time, the transfer distance, and the congestion degree as the influencing factors of the route choice respectively.

B. Constraints

Due to the complexity of the rail transport, passengers choose the route for a certain convenience often will not take into account the transfer of the line, so here we take the number of transfer as a constraint.

Here, we use the number of transfers as the constraint of path selection. Therefore, the model of rail transit route choice established is shown as the following formula in this paper:

\[
\min U(F_{T_1}, F_{T_2}, F_M, F_Q)
\]

s.t. \(m \leq M\)

Where, \(M=4\).

3 Optimal Route Determination Based on the ICA

A. ICA principle

ICA is a kind of global optimization algorithm, which is a kind of global optimization algorithm, which is a kind of global optimization algorithm, which is a kind of global optimization algorithm, which can be used for the competition, occupation and annexation of the imperialist countries in the history of human society. Here, all individuals are called as the state, divided into two kinds which are empire and colonial countries according to the state power, the former is more than the latter.

B. Initialization

The first stage of ICA is initialization. In this paper, all the alternative paths are the total number of States, and the number of transfers is constrained to select the Empire, the rest are the colonial countries. The initialization state consists
of the n dimensional decision variables, that is, $F = [l_1, l_2, l_3, l_4, \ldots, l_n]$. The function value of the country is denoted by $N_{country}$. Where, the target combination method is used to measure the standardization of each country, the n country

The fitness is defined as follows:

$$c_i = \sum_{k=1}^{n} \left( u_k(i) / \sum_{i=1}^{N_{rank}} u_k(i) + 2(rank(i) - 1) \right)$$

(4)

There, Pareto optimal solution[14] set is set to 1, $c_i$ is the fitness of individual $i$, $u_k(n)$ (the above generalized trip function) is the k target value of individual $i$, $N_{rank}$ is the number of individuals in the same level Pareto solution set. $rank(i)$ is a random number between 0 and 1. The formula can distinguish the individual fitness of different Pareto levels. The energy of each country can then be calculated according to the following equation:

$$C_n = \max(c_n) - c_n$$

(5)

Where, $C_n$ is the cost value after the standardization of the n colonial country, that is, degree of adaptation.

The standardized cost $C_n$ represents the energy of the colonial state, for the smaller the cost, the greater the energy for the minimization problem. The colonies of the n colonial country can then be calculated:

$$N_{n} = N_{col}C_n / \sum_{i=1}^{N_{imp}} C_i$$

(6)

$N_{col}$ means the number of colonies, and $N_{imp}$ is the number of colonial countries. With the increase in costs, the number of colonies also increased.

C. The Empire assimilated its colonies

The second stage of the ICA is the assimilation of colonies. The assimilation process can be described as a continuation of the colonial state toward the empire until it is fully absorbed by the empire. As the following diagram:

Fig. 1: Colonies moving to the Empire

In the figure, the distance between the colonies and empires is $d$, and the colonies move randomly along the line of the empire for a distance $l$, a random number subject to uniform distribution:

$$l \sim U(0, \beta \times d)$$

(7)

Where, $\beta \geq 1$, generally 1.5. Colonial countries do not necessarily follow the direction of the vector to move the empire, so in order to expand the search range, the introduction of a random angle $\theta$, $\theta$ obey uniform distribution:

$$\theta \sim U(-\pi, \pi)$$

(8)

Here, $n$ generally takes as $\pi / 4$.

D. Revolution

In this paper, ICA applications, we will set the revolution rate of 0.3, 30% of the Empire Group, the colonial countries will randomly change their position.

E. Exchange of Colonies and Empires

After assimilation, check the cost function of each colony. If the cost function $U$ of the colony is lower than the cost function of the empire, they perform the positional swapping and then compete with the empires below. If not, then directly below the imperial competition.

F. Competition

The total power of the Empire is determined by the Empire and its colonial forces, and the total value of an empire can be expressed as:
\[ F_n = c_n + \varepsilon \text{mean}_n f_n(i) \]  

(9)

Where \( F_n \) is the total cost of the \( n \)th imperial bloc, \( c_n \) is the cost of the \( n \)th imperial bloc, and \( f_n(i) \) is the cost of the \( i \) colony of the \( n \) imperial bloc. \( \varepsilon \) represents the influence of the colony on the imperial group, \( \varepsilon \) is proportional to the influence of the empire group, \( \varepsilon = 0.1 \) in this paper.

Empire competition first need to select the empire of the weakest of the colonies, and then calculate the possibility of occupation of the various groups of the empire, that is, the following formula:

\[ P_n = 1 - \frac{F_n}{\sum_{i=1}^{N\text{imp}} F_i} \]  

(10)

In order to classify the probabilities of the above-mentioned empires, the vector \( P \) is introduced:

\[ P = \left[ P_1, P_2, P_3, ..., P_{N\text{imp}} \right] \]  

(11)

The vector \( M \) follows a uniform distribution and has the same specifications as the vector \( P \):

\[ M = \left[ M_1, M_2, M_3, ..., M_{N\text{imp}} \right] \]  

(12)

Let the vector \( Z = P - M \), then:

\[ Z = \left[ P_1 - M_1, P_2 - M_2, P_3 - M_3, ..., P_{N\text{imp}} - M_{N\text{imp}} \right] \]  

(13)

The largest element in the vector \( M \) will occupy the colonies of the empires mentioned above.

G. Eliminate the weakest empire

After a certain number of competition, if an empire no longer has a colony, then destroy it, other empires continue to compete.

H. Convergence

At this point there are two cases the end of the algorithm, one for an empire left, that all countries are in the same position, the algorithm is the optimal solution; there is a case, reach the maximum number of iterations set, set the maximum in this article The number of iterations is 100.

4 Experiment and result analysis

In order to verify the performance of the algorithm, this section selects the Beijing city rail transit in the military museum to Dongzhimen between the two sites of the bus route, and according to the actual situation set the corresponding parameters.

A. Model parameter setting

Travel options are as follows:

<table>
<thead>
<tr>
<th>Path Selection</th>
<th>In the car time/min</th>
<th>In the car time/times</th>
<th>Transfer distance/km</th>
<th>Transfer distance/km (normal)</th>
<th>Transfer distance/km (peak)</th>
<th>Congestion (normal)</th>
<th>Congestion (peak)</th>
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<tr>
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<tr>
<td>6</td>
<td>57</td>
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<tr>
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<tr>
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<td></td>
<td>0.1</td>
</tr>
</tbody>
</table>

B. ICA algorithm parameters setting
In this paper, the initial number of ICA is 15, the number of empires is 4, $\beta=2$, the revolution rate is 0.3, $\gamma = \pi/4$, and the number of iterations is 100.

C. Results analysis

Set the initial number of countries 15, by the constraint $M \leq 4$, then there are four empires began to compete (where red star represents the path 1, yellow star represents the path 2, blue star represents the path 3, and green star represents the path 4, the rest circles are colonies):

![Diagram showing four empires competing for dominance.](image)

**Fig. 2:** Four path contention

When the congestion degree is normal, 100 iterations are randomized to obtain the empire of the final competition, that is, path 1 is the best route choice:

![Diagram showing path 1 as the dominant route.](image)

**Fig. 3:** Path 1 wins the competition

As congestion is at its peak, 100 iterations are randomized to obtain the empire of final competition; the path 4 is the best route choice:
Fig. 4: Path 4 wins the competition

Where the maximum number of iterations is reached, the number of iterations cannot be increased until the desired result can be obtained. However, the number of iterations cannot be too large and the running time is too long.

5 Conclusion

Based on the constraints of transfer times, this paper establishes the path selection model of urban rail transit with generalized travel cost as the objective function, and then optimizes the travel route by the imperialism competition algorithm. The research contents and achievements of this paper can provide inspiration and reference for the model of other competitive problems solved by imperialism competitive algorithm.

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References