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Urban Microcirculation Traffic Network Planning Method Based on Fast Search Random Tree Algorithm

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ABSTRACT

Unbalanced urban development causes complex and diverse urban traffic conditions, which complicates microcirculation traffic network planning. To address this, a method based on fast search random tree algorithm is proposed. An urban microcirculation traffic network is constructed using directed graphs, and road network interference intensity and capacity are calculated. The interpolation collision detection method is used to determine the shortest path while considering constraint conditions. By incorporating target gravity into the RRT algorithm, a growth guidance function is obtained, optimising the planned path and completing urban microcirculation traffic network planning. Experimental results demonstrate accurate shortest path calculation with up to 11% delay reduction compared to existing methods. Energy consumption during planning is lower than 10 kJ, ensuring fair resource distribution within the urban microcirculation transportation network. These advantages highlight the practicality and effectiveness of this research method.

KEYWORDS

fast search random tree algorithm; microcirculation traffic; road network planning; shortest path; growth guidance function.

1. INTRODUCTION

Urban microcirculation traffic network planning refers to the development trend of establishing a diversified traffic system in cities to meet the needs of individual travel. Increasingly prosperous urbanisation, population growth and increased traffic [1] have placed tremendous pressure on urban transport, requiring innovative transport planning and design to ensure sustainable, efficient and safe urban transport development. Urban microcirculation transportation network is an urban transportation system based on advanced technology and a new service mode. It realises the green, intelligent and safe development of urban transportation through effective information management, intelligent traffic guidance and diversified traffic modes [2]. The complex and ever-changing traffic conditions within cities, such as narrow roads, mixed traffic between vehicles and non-vehicles, one-way streets and roadside parking, pose significant challenges to the layout and path planning of micro circulation transportation networks, and the microcirculation transportation network emphasises high-frequency and short distance transportation modes. Achieving efficient traffic organisation on limited road resources while meeting diverse travel needs is an urgent problem to be solved. With the acceleration of urbanisation, the demand for urban transportation continues to grow. Maintaining the sustainability and scalability of the micro circulation transportation network is also a key consideration in the planning process. At present, the research of urban microcirculation traffic network planning at home and abroad has made some achievements.

The fast search random tree (RRT) algorithm has profound significance and positive effects on urban micro circulation transportation network planning. As an efficient path search and optimisation tool, it can quickly find the optimal or suboptimal path that meets multiple target indicators (such as shortest path, minimum traffic congestion, minimum emissions etc.) in large-scale and complex urban transportation networks. This feature is crucial for solving many problems in current urban transportation.

The RRT algorithm can cope with the complexity and dynamics of urban micro circulation transportation networks and flexibly adapt to constantly changing traffic environments and travel needs through random sampling and incremental construction of search trees. This helps optimise traffic flow distribution, reduce traffic congestion and improve the operational efficiency of the transportation network. The RRT algorithm comprehensively considers multiple target indicators during the search process, making the planning results more comprehensive and balanced. This can not only meet residents' demand for travel time, but also reduce the impact of traffic emissions on the environment and promote the green development of urban transportation. It also helps to enhance the intelligence level of urban micro circulation transportation network. By integrating into the traffic management system, algorithms can analyse traffic data in real-time, dynamically adjust traffic signal timing and road resource allocation and achieve precise control and optimisation of traffic flow.

The specific innovations of this article are as follows:

1) Integrated directed graph and RRT algorithm for traffic network modelling:
   Traditional traffic network planning often relies on static or simplified network models, which are difficult to fully reflect the complexity and dynamics of urban micro circulation traffic. This article innovatively combines the directed graph method and RRT algorithm to construct the basic framework of urban micro circulation transportation network through directed graph. By utilising the efficient search ability of the RRT algorithm, dynamic optimisation of network paths is achieved. This fusion method not only retains the advantages of directed graphs in expressing traffic flow, but also fully utilises the ability of the RRT algorithm to quickly find feasible paths in complex environments.
2) The application of interpolation collision detection method in path search:
   In the process of path search, collision detection is a key step in ensuring the feasibility of the path. This article innovatively introduces the interpolation collision detection method, which preliminarily obtains the potential shortest path, effectively reduces the computational complexity in the search process and improves the search efficiency. At the same time, this method can quickly eliminate infeasible paths in the early stage of search, providing a good foundation for the subsequent optimisation process.
3) Improvement of RRT algorithm based on target gravity idea:

The traditional RRT algorithm is prone to getting stuck in local optimal solutions during the search process and has weak attraction to the target node. This article proposes an improved RRT algorithm based on the concept of target gravity. By introducing the target gravity term, the search tree can more effectively approach the target node during the growth process, thereby increasing the possibility of finding the global optimal path. This improvement not only enhances the search capability of the algorithm, but also makes the planning results more in line with actual transportation needs.

2. CURRENT WORK

At present, the research of urban microcirculation traffic network planning at home and abroad has led to some achievements.

Boeing [3] used public and open data to study trends in street network design across the United States. By constructing a theoretical and measurement framework based on the quality of the street network, it was found that from 1940 to the 1990s, grid-like characteristics showed a downward trend, while cul-de-sac and block length increased. Since 2000, however, these trends have started to rebound, returning to historical design patterns. Still, controlling for topographic and built environment factors, the decade after 1939 has a lower grid-like character compared to the decade before 1939. High grid-like characteristics are associated with lower vehicle ownership, which is associated with miles driven and greenhouse gas emissions. This study shows that the internet grid street network is an important tool for reducing vehicle dependence and emissions. Therefore, active planning is essential to establish street patterns and has a long-term impact on the urban spatial structure. Yu et al. [4] designed a prediction method of urban and rural road network spatial evolution based on remote sensing data. According to the road width of main road categories, a single edge response edge detection method is used to extract remote sensing image edge data, and the scale factor is introduced to obtain the road network characteristics under the optimal scale segmentation. Based on the time order and space order of the virtual route, the basic model of spatial evolution prediction is constructed. By using the spatiotemporal autocorrelation function and its partial correlation function, the spatial and time autoregressive order and the spatial and time moving average order of the model are identified, and the correlation parameter values estimated by the maximum likelihood estimation method are combined to achieve the best performance of the prediction model. Sreekumar et al. [5] developed a multilevel traffic flow model that considers the feasible and accessible gaps for a single vehicle class to traverse downstream. The model takes into account the different shares of different vehicles. The concept of driving distance and the modified equilibrium speed function are used to model the interactions between multiple vehicle classes. The evolution of two types of traffic flows is demonstrated by using the high order finite volume approximation method. The model replicates outstanding empirical features exhibited by multiple classes of disordered traffic, such as overtaking and crawling. Changes in the share of small vehicles can affect queuing and emission characteristics and have a significant impact on road capacity. The model can also more realistically calculate dynamic grade-specific travel times under different vehicle components. Hussain et al. [6] developed a green LED dynamic luminescence (G-LED) system (a combination system with a countdown strategy) and evaluated it through driving simulator experiments. The efficiency of the proposed system is compared with a default traffic light condition with a green-yellow-red sequence (i.e. control condition) and a flashing green (F-green) traffic light (i.e. sequence: green-flashing green-yellow-red). Sixty-seven participants with valid Qatari driving licenses participated in the study. All participants went on a simulated run, replicating the real environment of the road.

The above methods have achieved good results at the present stage, but there is still a problem of insufficient overall planning, focusing only on some hot spots or specific travel needs, while ignoring the entire urban traffic network planning. Such local planning can easily lead to urban traffic imbalance and cannot be applied to the renewal and re-planning of network nodes, affecting the overall efficiency of urban traffic. Therefore, this paper proposes a planning method of urban microcirculation traffic network based on fast search random tree algorithm. Fast search rapidly exploring random tree is an effective optimisation method in microcirculation traffic network planning. The algorithm combines the characteristics of fast search and random tree, and can quickly find the optimal traffic path in large-scale network and take into account several target indicators, such as the shortest path, the minimum traffic congestion and the minimum emission. Through the rational layout of roads and transportation facilities, the traffic mobility is optimised to meet the diversified travel needs of urban residents.

3. URBAN MICROCIRCULATION TRAFFIC NETWORK PLANNING

The traffic network planning scheme design is shown in *Figure 1*:

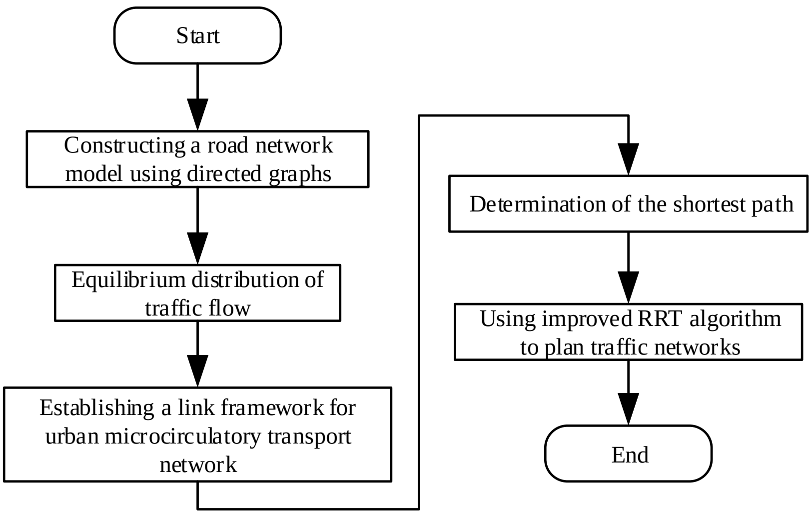

Figure 1 – Traffic network planning scheme

In the planning scheme shown in *Figure 1*, the urban microcirculation traffic network model is constructed by means of the directed graph method, and the interference intensity and capacity of the road network are calculated. Secondly, the interpolation collision detection method is introduced to obtain the final shortest path, calculate the number of shortest paths and set the constraint conditions. Then the fast search random tree algorithm is improved, the target gravity function is established, and the growth guidance function from the initial node to the target node is obtained. Finally, the new nodes after planning are extracted to complete the optimisation of traffic network path planning.

3.1 Construction of transport network link framework

Urban microcirculation traffic network is a complex system composed of various roads, paths and traffic facilities. The link frame construction can abstract urban traffic network into a series of interconnected paths and nodes. By constructing this framework, we can accurately describe the relationship between different paths, the length and shape of paths, and the relative positions of nodes. By simulating the combination configuration of different links and nodes, and combining multidimensional data such as traffic flow, speed and congestion, a directed graph model is used to accurately describe their spatial relationships. By adjusting the length, shape and node positions of the link, and considering factors such as channel allocation, power control and signal-to-noise ratio, the link framework can dynamically evaluate the traffic efficiency and safety of the transportation network under various configurations. In order to realize the intelligent reconstruction of the traffic network structure so as to adapt to the constantly changing traffic demands, use the capacity formula to quantify the transmission and traffic capacity of links and optimize the link allocation. Including traffic flow, speed, congestion etc. helps traffic planners to accurately predict traffic flow [7-8], optimise road circulation and improve road use efficiency and safety.

A directed graph $Q=(W,U)$ is used to describe the urban microcirculation traffic network, where set W is composed of edges and set U is composed of nodes. The numbers of links and nodes in the traffic network [9] are set to G and S respectively, with $U=\{1,2,\cdots,S\}$ and $W=\{1,2,\cdots,G\}$, and node i has Z_i interfaces in the traffic network, where r_{ij} is used to represent the link connecting node i to node j. The channels form set $D=\{1,2,\cdots M\}$ in the traffic network, where M represents the number of available channels. Let the set $C=\{1,2,\cdots,P\}$ be composed of time slots, where P represents the total number of time slots allocated by various resources in traffic network planning [10]. Let $s(r_{ij})=\{s_{\min}(r_{ij}),\cdots,s_{\max}(r_{ij})\}$ represent the power corresponding to the link in the urban microcirculation traffic network, where $s_{\min}(r_{ij})$ and $s_{\max}(r_{ij})$ respectively represent the lower and upper limits of the link power under the normal operation of the urban microcirculation traffic network.

When both slot C_{ij} and channel D_{ij} are determined, $s_{ij}^{C_{ij},D_{ij}}$ is used to represent the transmitted power of the node in the link r_{ij}. A threshold is set so when the signal to noise ratio of the receiving node in the network link is higher than the threshold, the receiving node can receive the information transmitted over the network. Therefore, the signal to noise ratio κ_{ij} represents the interference intensity of the link in the traffic network flow [11-13]:

$$\kappa_{ij}=\frac{s_{ij}^{C_{ij},D_{ij}}\Delta D_{ij}}{\sum_{i,j}^{Q}s_{uv}^{c_{uv},D_{uv}}\Delta D_{uv}\delta(r_{ij},r_{uv})}\cdot E_0 \tag{1}$$

where ΔD_{ij} is the channel gain generated by link r_{ij} in the urban microcirculation traffic network; E_0 stands for white noise interference; $\sum_{i,j}^{Q}s_{uv}^{c_{uv},D_{uv}}\Delta D_{uv}\delta(r_{ij},r_{uv})$ indicates that link r_{ij} is interfered by other links in the urban microcirculation traffic network.

In order to better understand and analyse the flow status of the urban microcirculation traffic network, the link allocation of the traffic network [14] is completed by introducing the capacity formula. The capacity formula can be used to calculate the rate of information transmission, and it can also be used to measure the capacity in a traffic network. Based on the calculation results of formula (1), the capacity formula is introduced to establish the link framework of urban microcirculation traffic network as follows:

$$\sigma_{ij}=\kappa_{ij}\cdot\rho\cdot v_f \tag{2}$$

where ρ represents the saturated traffic density of the link; v_f represents the free flow speed of the vehicle on the link; σ_{ij} indicates the capacity of the link.

In urban micro circulation transportation networks, speed and flow are key indicators for evaluating network performance. The free flow velocity of a link reflects the maximum capacity of the road under unobstructed conditions, while the saturated flow density represents the maximum vehicle density that the road can carry under given conditions. By combining the two through capacity estimation and quantifying the actual traffic capacity of the link, it is possible to reveal the location of traffic bottlenecks, optimise traffic signal control and road layout, thereby improving the operational efficiency and safety of the entire transportation network.

3.2 Determining the shortest path

Urban microcirculation traffic network usually contains a large number of roads and paths. By determining the shortest paths and then selecting the unobstructed ones from them, traffic - congested sections and bottlenecks can be avoided. In cities, traffic flow is unevenly distributed, and some sections or intersections are prone to congestion. Determining the shortest path can bypass these congestion points and choose a faster route, improving overall traffic mobility. This helps to improve the sustainability of urban transport systems. The shortest path is the shortest route from the starting point to the end point. The determination and quantity calculation of the shortest path are helpful to find the optimal scheme. It plays an important role in urban microcirculation traffic planning [15-16], traffic volume estimation, road velocity calculation etc., which greatly improves the scientificity and accuracy of urban microcirculation traffic network planning and provides decision-making basis for transportation planners.

To help optimise the traffic flow [17-19] and reduce congestion and travel time, before determining the shortest path, the curve travel path expansion process is set up to reduce congestion and improve traffic speed by increasing the flexibility of the curve. The expansion process of the curved driving track is shown in *Figure 2*.

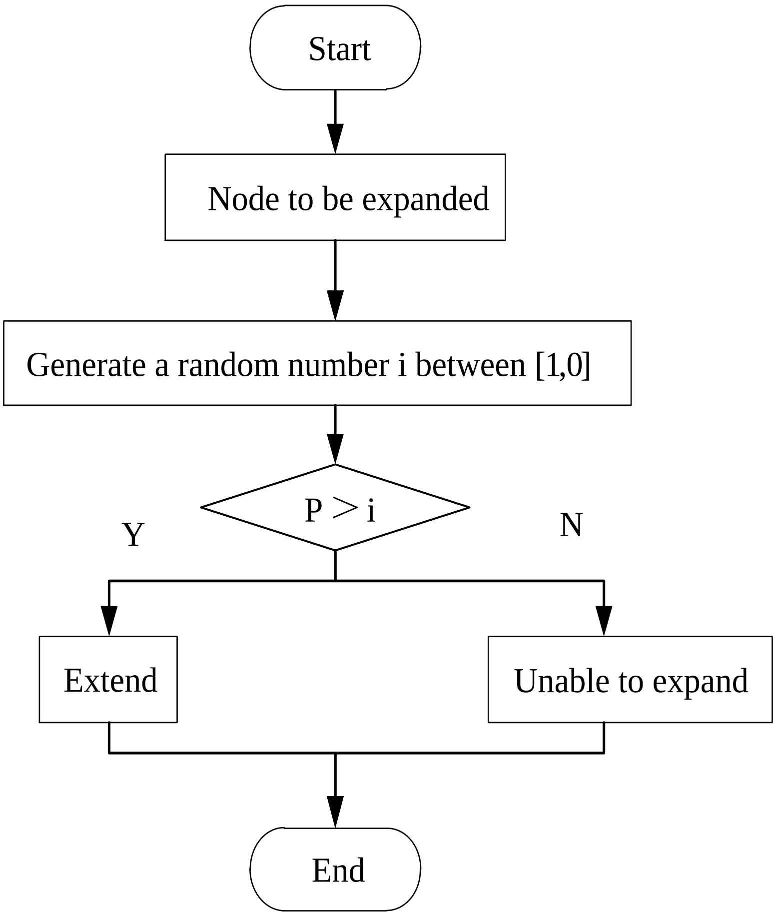

Figure 2 – Probability-based curve trajectory expansion process

As can be seen from *Figure 2*, in the process of shortest path search, vehicles are regarded as nodes. Most nodes are extended according to the normal vector outside the road edge surface, and the relevant expansion information is preserved in the nodes. Therefore, the vehicle information in the route is used to determine the key nodes, optimise the route layout of the traffic network and eliminate other redundant nodes based on this. The criteria for determining key nodes include:

1) The start and end of the path;
2) From the beginning of the path, the first node with a directional attribute;
3) Interpolating collision detection is introduced to optimise the path and generate the starting point, end point and inflection point of the path;
4) Start from the key vehicle with attribute vector n and search back. When there is a node with an angle greater than 40° between the attribute vector and the attribute vector of this key node, it indicates that the road edge surface near the location of the vehicle node on this path is likely to have large convex and concave phenomena. To ensure that the path is always near the road edge, this node is set as the key node of the path. The nodes x1 and x2 are shown in *Figure 3*.

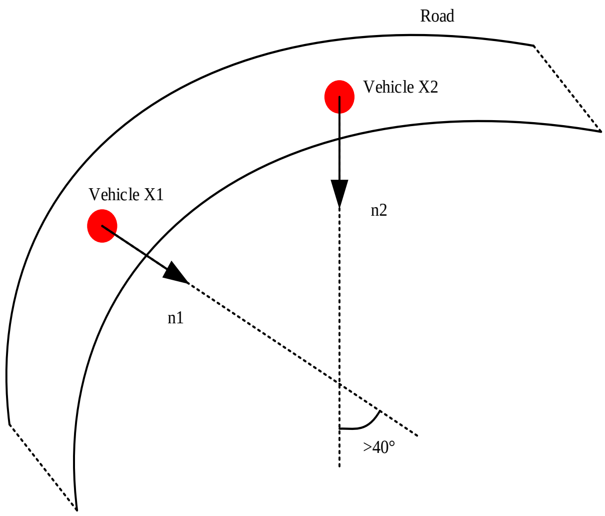

Figure 3 – Schematic diagram of the driving path on the curve

According to the definition of key nodes, interpolating collision detection is introduced to optimise the path to identify and retain the key nodes in the path and eliminate the redundant points in the path. The optimisation process is as follows: starting from the starting point of the path, the path points that do not belong to the key nodes are eliminated, the key nodes are retained, and then the interpolation collision detection is implemented between each key node. If the collision occurs between two nodes, the backtracking collision detection is performed on the latter key node based on the original path. Then the path guidance algorithm is used to predict the traffic flow, select the best path to optimise the traffic efficiency, find the shortest path and reduce the congestion and travel time. Thus, the objective function of obtaining the optimal and shortest path trajectories is:

$$\min r_{ij} = Y_{ij} \Delta T_{ij} \sigma_{ij} \left(|j-i| \right) \tag{3}$$

In the formula, ΔT_{ij} represents the delay time of the journey, $|j-i|$ represents the distance of the traffic route track, and Y_{ij} represents the constraint conditions of the mathematical model of the shortest path of urban microcirculation traffic, which are shown as follows:

$$Y_{ij} = \begin{cases} 1, W_{ij} & \in R(L,K) \\ 0, W_{ij} & \notin R(L,K) \end{cases} \tag{4}$$

In the above formula, W_{ij} represents the side road, $R(L,K)$ represents the set of optimal urban microcirculation traffic routes constructed, that is, the set of urban traffic shortest paths from the start L to the end K of the traffic route trajectory.

The two vertices f_i and f_j in the optimal traffic roadmap are constructed by $R(L,K)$, and the trajectory of any driving path is set to h, the length is $l(h)$, and $H(X, f_i, f_j)$ is used to represent the set of all possible trajectory paths. This set can also be called the path set of the two vertices f_i and f_j of the optimal traffic roadmap, and the expression is:

$$H(X, f_i, f_j) = \{Y_{ij}h| \ h \in f_i \cup f_j\} \tag{5}$$

According to the constraints of the urban traffic shortest path function, the distance of urban traffic path is ordered and the shortest path of urban traffic is calculated, which can be expressed as:

$$\min r_{ij}' = \{h| \ l(h_1) \le l(h_2) \le \ldots \le l(h_q)\} \tag{6}$$

As can be seen from *Equation 6*, in the optimal urban traffic roadmap, the first shortest path of urban traffic is h_1 with distance $l(h_1)$, and the second shortest path of urban traffic is h_2 with distance $l(h_2)$. Similarly, any shortest path q with distance h_q in $l(h_q)$ can be calculated according to the above equation. Therefore, the shortest path of urban microcirculation traffic network can be determined.

3.3 Global planning based on improved RRT algorithm

The determination of the shortest path is based on static road data and preset traffic conditions. However, there are some special traffic restrictions in the city, such as restricted areas, priority areas, vehicle type restrictions etc. These limitations may have an impact on the shortest path. Therefore, in practical applications, real-time traffic information needs to be taken into account to adjust route planning, avoid congestion and choose faster routes. The RRT algorithm is improved by introducing the idea of target gravity to plan the global path of urban microcirculation traffic. The improved RRT algorithm can realise global planning by increasing the number of random sample points and growth guidance function, and improve the efficiency and accuracy of traffic planning. The growth guidance function can help the algorithm to better explore the search space by considering the traffic flow, the shortest path and the number of factors, so as to avoid falling into the local optimal solution and to guide the path search process.

In the root node ε of each RRT tree, the same target gravity function $g(\varepsilon)$ is introduced, and the growth guidance function from the initial node through node ε to the target node is as follows:

$$\psi_\varepsilon = \alpha \cdot H \frac{r(\varepsilon)\|x_i - x_{i-1}\|}{\min r_{ij}'} \tag{7}$$

where: $r(\varepsilon)$ represents the random growth function from the initial node to node ε; α represents the coefficient of gravitational field; x_i indicates the target node; $\|\cdot\|$ represents the norm value of the geometric distance.

The shortest path for the new node to approach the target point is determined by formula (7). The expression is:

$$\min r(\varepsilon) = \psi_\varepsilon \frac{x_i - x_{i-1}}{\|x_i - x_{i-1}\|} \tag{8}$$

The urban traffic network optimisation model requires the support of multiple optimal paths. In order to ensure smooth traffic, it is necessary to reduce the number of optimal path plans so as to relieve congestion [20-22]. In order to evaluate the accuracy and reliability of shortest path planning, the path is optimised according to the ratio between the error value of the shortest path and the optimal path, so as to provide more accurate data support for subsequent traffic planning.

Suppose that in the shortest path, the shortest path accounts for n% of all planned paths, then the expression of the error value ϑ of the shortest path planning is:

$$\vartheta = \begin{cases} \frac{u}{p} \cdot \min r(\varepsilon) & u > 0 \\ 0 & u \le 0 \end{cases} \tag{9}$$

where p is the number of all paths and the number of optimised paths is s, then $u = s - p \cdot n\%$.

Then the ratio τ of the optimal path is:

$$\tau = (s + s_1 + s_2 - s_3) / p \tag{10}$$

where s represents the number of optimal network paths, s_1 represents the optimal shortest path, s_2 represents the conventional network path, and s_3 represents the longest path planning. Each path planning in the traffic network model is fixed, and if there are γ optimal paths that can be re-planned in real time, then:

$$\gamma = \begin{cases} \dfrac{h \cdot \vartheta}{\tau \cdot t} & t > 0 \\ 0 & t \leq 0 \end{cases} \tag{11}$$

where t represents the paths with more than 10 optimal paths that can be re-planned in real time, and h represents the number of optimal paths in the urban traffic network optimisation model.

Combined with the number of optimal paths above, the new node ζ is finally extracted to complete the global planning. The formula is as follows:

$$\zeta = \frac{\gamma}{x_{i-1}} \cdot \left(\frac{x_i - x_{i-1}}{\|x_i - x_{i-1}\|} + \frac{x_1 - x_{i-1}}{\|x_1 - x_{i-1}\|} \right) \tag{12}$$

4. EXPERIMENTAL DESIGN AND RESULT ANALYSIS

4.1 Experimental setup

An urban road network is selected as the research object. The road section length of this road network is 700 m, the road section width is 4 m, the total number of intersection nodes is 50, there are 2500 virtual vehicles, the average speed is 60 km/h, the average cycle of each signal light is 60 s, the interval time of signal lights is 30 s, and the simulation experiment of the setting experiment is 24 h. The scale of the road network simulation model is 1:100. The simulation was conducted on a PC with 2.50 GHz dual-core Inter(R) Core(TM) i5-2450M processor, Nvidia GeForce 630M graphics card and 4 GB memory and Windows 10 operating system. Matlab simulation software was used to verify the global path planning method of this study. The selected road network for the experiment and the microcirculation traffic network after research method planning are shown in *Figure 4*.

（a）Experimental road network

（b） Microcirculation traffic network after research method planning

Figure 4 – Road network before and after using research methods

4.2 Results and analysis

In order to further test the effectiveness of obtaining the shortest path by using the fast search random tree road network planning method proposed in this paper, the local road network shown in *Figure 4* is taken as the test object. The theory and measurement framework based on street network quality proposed in reference [3], remote sensing data network planning method proposed in reference [4] and multistage traffic flow network planning method proposed in reference [5] are used as comparison methods. The comparison results are shown in *Figure 5*.

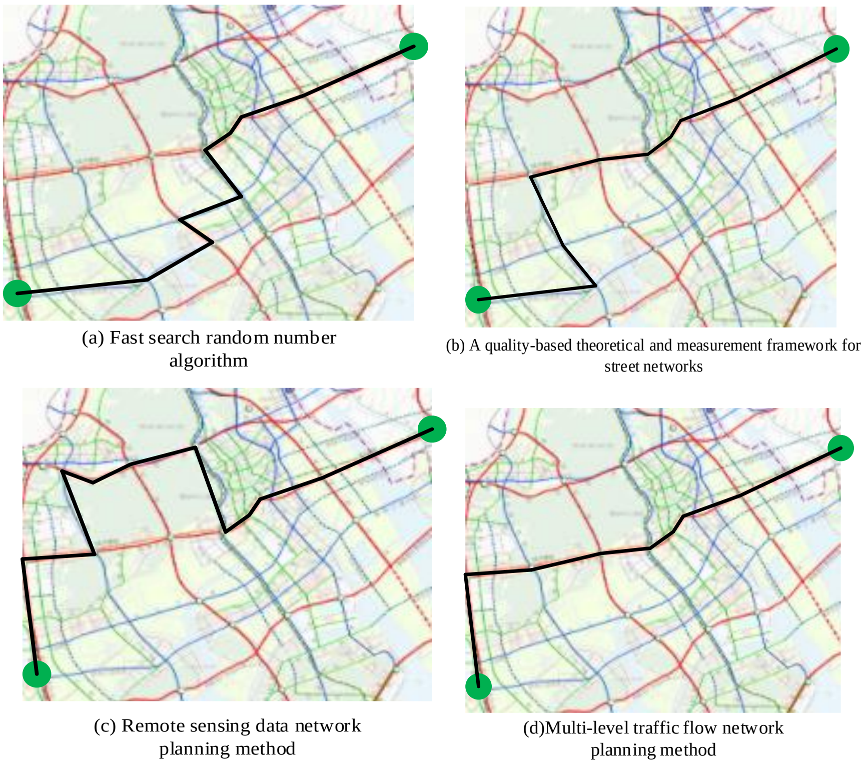

Figure 5 – Obtaining optimal path results under different methods

According to the experimental results in *Figure 5*, for the same starting point and destination point, the research method in this paper can plan a shorter path. Compared with the street network quality-based theory and measurement framework proposed in the reference, remote sensing data road network planning method and multi-level traffic flow road network planning method, the path distance is greater than that of the research method. It shows that the research method has significant advantages in path optimisation.

The test results of road network planning delay rate under different methods are shown in *Figure 6*.

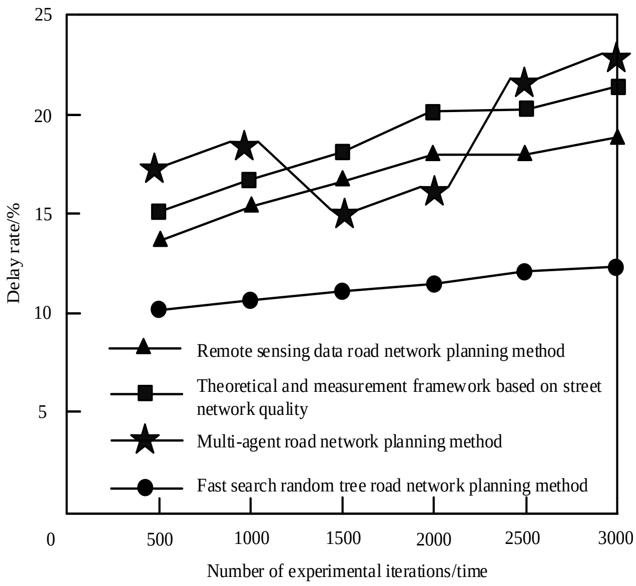

Figure 6 – Test results of urban traffic network delay rate

As can be seen from the test results in *Figure 6*, under the application of the street network quality-based theory and measurement framework and the multistage traffic flow network planning method, the urban traffic network delay rate is always higher than 13%, and at the 3000th iteration of the experiment, the urban traffic network delay rate increases to 15%~20%. When the remote sensing data network planning method is used to optimise the urban traffic network, the delay rate of the urban traffic network is the lowest 14% and the highest 22%, and the delay rate has strong fluctuation and poor stability. After using the fast search random tree network planning method to plan the urban traffic network, the maximum delay rate of the urban traffic network is only 11%, and with the increase of the number of iterations, the urban traffic network delay rate does not change much. On the whole, the research method has certain robustness.

The energy consumption of urban transport network refers to the energy consumed by urban transport activities, including road traffic, public transport and taxi traffic modes. The test results of road network energy consumption after urban transportation network planning with different methods are shown in *Figure 7*.

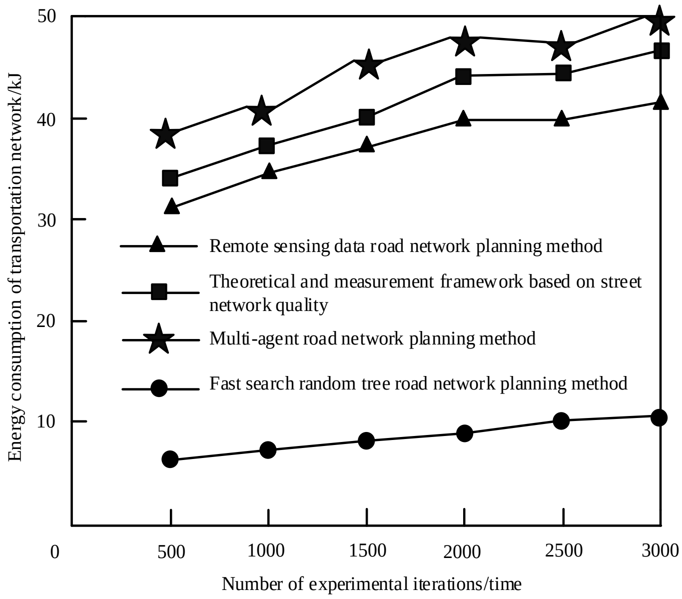

Figure 7 – Energy consumption test results of urban transportation network

As can be seen from the results in *Figure 7*, in the process of 3000 iterations, the traffic energy consumption of the fast search random tree road network planning method is lower than 10 kJ, which effectively reduces the energy consumed by urban transportation activities, indicating that the research method has a better optimisation effect.

In order to test the resource allocation effect of the fast search random tree network planning method, street network quality-based theory and measurement framework, remote sensing data network planning method and multilevel traffic flow network planning method, Jain fairness index F_I is introduced to carry out the test. Jain fairness index is used to measure the fairness of resource allocation, and its calculation formula is as follows:

$$F_I = \sum_{i=1}^{n} \left(\frac{T_i}{O_i}\right)^2 \tag{13}$$

where T_i represents the transmission capacity of the i link in the traffic network; O_i represents the actual throughput of link i in the network when all n links are in working state.

The higher the Jain fairness index F_I is, the more reasonable the resource allocation of the method is. When the value of index F_I is 1, it indicates that the resource allocation in the intelligent transportation network is absolutely fair.

The Jain fairness index F_I of different methods is shown in *Figure 8*.

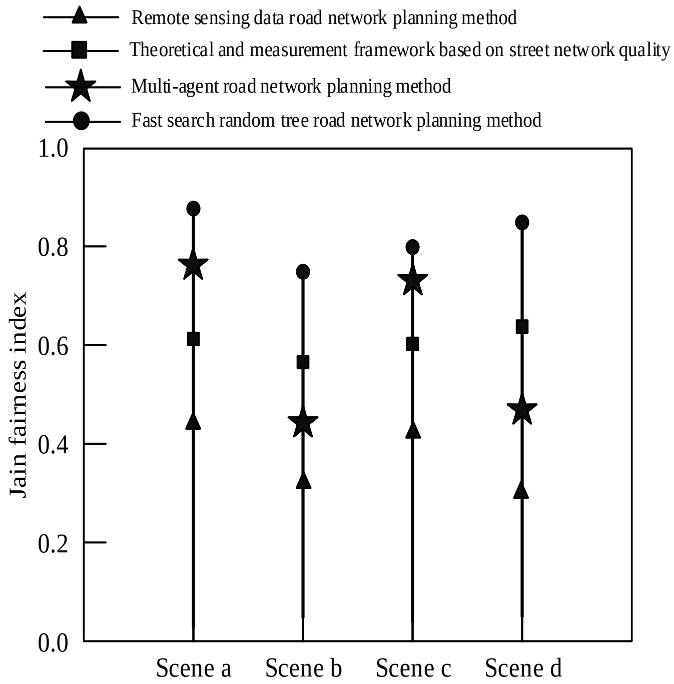

Figure 8 – Jain fairness index of different methods

The analysis of *Figure 8* shows that the Jain fairness index of the research method in this paper is higher than that of the other three methods in different scenarios. Urban transportation resources (such as roads, buses etc.) are fairly distributed among different regions or groups, and the service quality obtained by each region or group is relatively balanced, and there is no obvious inequality in service quality. This indicates that the effect of transportation network planning is good, which can meet the travel needs of different groups, improve the overall transportation efficiency and public transportation service level of the city, and indicate that the proposed method maintains a high fairness in the allocation of urban microcirculation transportation network resources.

5. CONCLUSION

In order to further optimise the effect of microcirculation traffic network planning, a planning method based on fast search random tree algorithm was proposed to realise urban microcirculation traffic network planning. The experimental results show that the low delay rate of urban transportation network can effectively shorten the energy consumed by urban transportation activities, and the Jain fairness index of the proposed method is higher than that of the other three methods in different scenarios. The results show that the urban microcirculation traffic network planning method proposed in this paper is effective.

However, many problems and challenges remain. For example, how to integrate different transportation mowdes reasonably and make better use of innovative technological means to improve the efficiency and convenience of urban transportation. Therefore, future urban microcirculation traffic network planning needs to be further studied and explored, constantly improve the traffic management mechanism and market-oriented operation mode and enhance the public’s acceptance and utilisation rate of microcirculation traffic.

The following are the limitations of the method used in this article:

1) Computational complexity: With the continuous expansion of urban scale, road networks have become more complex. The computational complexity of the method proposed in this article will significantly increase with the increase of network size, which may lead to low computational efficiency in the planning of transportation networks in mega cities.
2) Parameter adjustment and optimisation: The performance of the method is affected by multiple parameters, such as the setting of target gravity and the selection of search step size. The slow adjustment and optimisation process of these parameters may have an impact on the planning results.
3) Insufficient multi-objective optimisation: In actual transportation network planning, it is often necessary to consider multiple objectives simultaneously (such as minimising time, energy consumption and

congestion). Although this method has optimised the path to some extent, it may not be flexible enough when dealing with multi-objective optimisation problems.

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基于快速搜索随机树算法的城市微循环交通网络规划方法

于宁

摘要：城市发展不均衡导致城市交通状况复杂多样，给微循环交通网络规划带来难题。针对这一问题，提出一种基于快速搜索随机树算法的方法。利用有向图构建城市微循环交通网络，计算路网干扰强度和容量。采用插值碰撞检测法确定考虑约束条件的最短路径。通过将目标引力引入 RRT 算法，得到增长引导函数，优化规划路径，完成城市微循环交通网络规划。实验结果表明，与现有方法相比，最短路径计算准确，延迟降低 11%以上。规划过程中能耗低于 10kJ，保证了城市微循环交通网络资源的公平分配。这些优势凸显了该研究方法的实用性和有效性。

关键词：快速搜索随机树算法；微循环交通；路网规划；最短路径；增长引导函数