Chongqing Transportation Network Simulation and Research Based on Floyd Algorithm

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Abstract. In recent years, research on complex networks is in full swing, and transportation networks are also an important part of the research on complex networks. Since the 21st century, people’s living standards have increased substantially, transportation plays a key role in our lives, and public transportation is an indispensable product of transportation in modern cities, and it greatly facilitates people’s life and travel. This time, the Floyd algorithm is used to improve and apply the complex network, and MATLAB and pajek software are used to simulate, and the empirical research on Chongqing’s bus network is carried out. It is concluded that Chongqing’s bus network has small-world characteristics. With certain help, it can provide reference for the construction plan for relevant people.

1. Introduction
In the 1990s, "The Collective Dynamics of "Small World" Networks"[1] was completed by Professor Strogatz. In this work, the author introduced the formation principles of the characteristics of complex networks through a large number of models. A preliminary understanding of the small world and the characteristics of scale-free has been achieved. Later, more and more scientists have put forward conjectures and application practices about complex networks in various fields, and because of the special status of urban transportation networks in society, many scholars at home and abroad have begun Shift research attention to this aspect. Sanderson et al. gave a detailed description of the topology of the British railway network in 2016 and proved that the railway network has the characteristics of a small world[2]. In 2005, some scholars such as Gao Ziyou conducted inquiries and analysis on the scale-free characteristics and degree distribution index of Beijing Public Transport Network[3].

2. Experimental model construction and Floyd algorithm
Chongqing is one of the first public transportation cities in China. It is located in the southwestern part of my country and has a huge complex transportation network of land, water and air. The 2019 Chongqing Urban District Annual Summary Report compiled by the Chongqing Transportation Planning Research Institute shows that nowadays, Chongqing’s central urban rail network has gradually accelerated, and public transportation has become Chongqing’s city. The first choice for people’s travel. The public transportation system, which accounts for 58.5% of the residents’ travel sharing rate shown in the released report, is the most important means of transportation for Chongqing citizens to travel by bus and light rail. At the same time, because of the unique topography of Chongqing, public
transportation is not allowed. Land has become the main means of transportation that Chongqing depends on.

2.1. Analysis of Chongqing Public Transport Network

The public transportation network belongs to the complex network category, which mainly includes two parts: the bus station and the route. Among them, the node is mainly the bus station. If the two stations can be directly reached by taking a bus on the bus route map without transferring, they will be regarded as one of them. There are edges connected between [4]. A bus line will contain many bus stops, and the bus network model can be regarded as undirected. According to the actual situation, the distance between various bus stations in Chongqing is calculated. The result is that there are 500 nodes and 8746 edges in the bus model established this time. The model is analyzed and the digital characteristics of the model are counted.

2.1.1. Degree distribution

The degree of a node is the number of all nodes connected to the node, represented by $k_i$. It can be found that the importance of a node will increase with the increase of the value of the node degree, while the degree distribution in the network is not floating up and down around a certain value, but following a power-law distribution that gradually decreases as the $k$ value increases, which is commonly known as the scale-free characteristic [5]. There are $i$ nodes in the entire network, and the average of all degrees is recorded as the average degree $\bar{K}$. Formula 1:

$$\bar{K} = \frac{\sum k_i}{N}$$

The degree distribution of the model constructed this time is shown in Figure 1:

![Figure 1: Degree distribution of public transit complex network](image)

2.1.2. Average path length

The average path length in the network is the average value of the distance between all nodes in the network. Using this value, the number of nodes included in the average distance between a node and any other node in the network can be obtained [6]. If the average path length is represented by $L$ and the number of nodes is represented by $N$, then there is formula 2:
2.1.3. Clustering coefficient

The aggregation coefficients of all nodes are averaged, and the average value obtained is the clustering coefficient of the network [7]. In the network topology graph, the ratio of the adjacent points of the nodes with connecting edges represents the clustering coefficient of the network. The clustering coefficient can characterize the degree of intersection density in the bus line and measure the transfer efficiency of the bus system. Happening.

Suppose any node in the network is i, and other nodes are connected to it by Li edges, then the neighbors of node i are the Li nodes. Since it is an undirected graph, the Li nodes have at most one edge \( L_i \), then the clustering coefficient of the node i is the ratio of the number of edges actually shared by the Li nodes to the total number of possible edges, which is formula 3:

\[
C_i = \frac{2 \sum_{i,j} l(i,j)}{L_i(L_i-1)} \tag{3}
\]

The clustering coefficient of the entire network can be obtained by averaging the clustering coefficients of all nodes. In reality, most networks have a clustering effect, and the clustering coefficient takes a value of 0 to 1, which is infinitely close to 0.

2.2. Floyd algorithm

Floyd algorithm is the most classic algorithm in dynamic programming. It can not only calculate the minimum path between two nodes in a weighted graph, but also can be applied to solve the problem of directed graphs and negative weight minimum paths[8]. In this paper, by further optimizing the algorithm, the complexity of the algorithm can be reduced, and the efficiency and practicability of the algorithm can be improved. The specific steps are as follows:

1) Establish a traffic network model-an undirected graph G(V, E), this model has k vertices, D as the adjacency matrix, first consider whether there is a distance from node i to node j that is L(i, j), if it exists, use this distance as the shortest distance from node i to node j; if it does not exist, set the distance to 0;

2) Compare the size of L(i0,j0) and L(i0,v0)+L(v0,j0), choose the shorter path between the two as the best path between nodes i and j, if it does not exist Then directly take L(i0, j0) as the optimal path;

3) Consider again whether there is a path (i0,……v1……,j0) between i0 and j0 that includes node v1 as an intermediate point, and compare it with the shortest path L(i0,v0) obtained last time +L(v0,j0) for comparison, take the shorter path between the two as the current shortest path;

4) By analogy, it has been compared until vk-1 is connected as the shortest path that can be obtained as an intermediate node, and the final adjacency matrix value is taken as the final result;

3. Experimental results

Table 1 shows the result data after Floyd algorithm optimization.

| Original value | Weight change | Algorithm improvement |
|----------------|---------------|-----------------------|
| 116.33 s       | 117.31 s      | 77.36 s               |
| 125.44 s       | 125.23 s      | 82.47 s               |
| 147.99s        | 148.23 s      | 95.11 s               |
| 149.23s        | 150.11 s      | 96.17 s               |
| 178.34s        | 179.15 s      | 102.74 s              |
It can be seen from the data in the table that even though the number of experimental data is still on the rise, the improved Floyd algorithm has a significant reduction in experimental simulation time, which greatly improves the efficiency of the algorithm.

From the perspective of Chongqing's overall transportation network, the degree distribution table of the entire network is shown in Figure 2:

Analyzing Figures 2, we can find that the node degree values are mainly in the range of 1-21, and are concentrated in the two degree values of 13 and 3, which are 33 and 29 respectively.

The network has a total of 500 nodes, with an average degree of 16.375, a diameter of 10, a global efficiency of 0.1344, an average clustering coefficient of 0.15695, and an average path length of 4.1109, which is less than 1/2 of the diameter, that is, the network has small-world characteristics.

Based on the written MATLAB program, calculate all the shortest paths output from nodes 1 to 500, and at the same time obtain the number of nodes passed, and select the first 5 nodes from high to low according to the results. The results are shown in Table 2:

Table 2. Ranking table of the shortest path occurrence probability of the global network

| Serial number | Node name                        | Number of occurrences of nodes as intermediate points | Probability of occurrence |
|--------------|----------------------------------|-----------------------------------------------------|---------------------------|
| 1            | Lianglukou                       | 15093                                               | 6.01%                     |
| 2            | Chongqing Railway Station North Square | 9878                                           | 3.97%                     |
| 3            | Xinpaifang West                  | 9033                                                | 3.63%                     |
| 4            | Shangxinjie Railway Station      | 7346                                                | 2.95%                     |
| 5            | Dayan Railway Station            | 6988                                                | 2.81%                     |

According to the data in Table 2, the frequencies passed by the 5 nodes shown in the table account for 1/5 of the data of all nodes passed by the shortest path, that is, the nodes in the table are the most loaded areas in the network.

According to the network characteristics analyzed by the simulation results, the first 20 nodes are selected from high to low according to the clustering coefficient and degree value. The results are shown in Table 3:
Table 3. Global network node degree value and clustering coefficient ranking

| Serial number | Node name                        | Degree value | Clustering coefficient |
|---------------|----------------------------------|--------------|-----------------------|
| 1             | Lianglukou                        | 69           | 0.036232              |
| 2             | Jiazhou Road Track Station        | 56           | 0.049351              |
| 3             | Ranjiaba Railway Station          | 55           | 0.028283              |
| 4             | Yuanjiagang Railway Station       | 54           | 0.064291              |
| 5             | Dalongshan Railway Station        | 53           | 0.009434              |

According to the comparison of the data in Table 2 and Table 3, nodes with a large degree value are not necessarily nodes that have passed many times as intermediate nodes, but when these nodes are used as sites, they have very strong liquidity. If they appear in these places, the problem can easily change the bus line operation to prevent traffic jams.

Next, select the top 50 stations with the largest number of occurrences in the shortest path, and take them out in turn, record the value of the network characteristic parameters at this time, the results are shown in Table 4:

Table 4. The global network nodes are sorted according to the number of occurrences after being deleted in turn

| Serial number | Node name                        | Clustering coefficient | Average degree | Average path length | Global efficiency |
|---------------|----------------------------------|------------------------|----------------|---------------------|------------------|
| 1             | Lianglukou                        | 0.1555                 | 16.31          | 4.1432              | 0.13346          |
| 2             | Xinzhongbai Railway Station       | 0.15868                | 16.314         | 4.1558              | 0.13326          |
| 3             | Dalongshan Railway Station        | 0.15852                | 16.336         | 4.149               | 0.1335           |
| 4             | Shangxinjie Railway Station       | 0.15852                | 16.26          | 4.1431              | 0.13338          |
| 5             | Dayan Railway Station             | 0.16037                | 16.272         | 4.1397              | 0.13362          |

It can be seen from the above data that after a single node is deleted, the order of the average path size of the network from high to low is Lianglukou, Xinzhongbai Railway Station, Dalongshan Railway Station, Shangxinjie Railway Station, and Dayan Railway Station. Then delete the first 50 nodes in turn according to the degree value, and the results are shown in Table 5:

Table 5. The global network nodes are sorted according to the degree value after being deleted in turn

| Serial number | Node name                        | Clustering coefficient | Average degree | Average path length | Global efficiency |
|---------------|----------------------------------|------------------------|----------------|---------------------|------------------|
| 1             | Lianglukou                        | 0.1555                 | 16.31          | 4.1432              | 0.13346          |
| 2             | Dalongshan Railway Station        | 0.15852                | 16.336         | 4.149               | 0.1335           |
| 3             | Shangxinjie Railway Station       | 0.15852                | 16.26          | 4.1431              | 0.13338          |
| 4             | Daping                           | 0.15881                | 16.194         | 4.1306              | 0.13384          |
| 5             | Ranjiaba Railway Station          | 0.15917                | 16.278         | 4.1229              | 0.13406          |

From the above data, it can be seen that after a single node is deleted, the average path size of the network is from high to low: Lianglukou, Dalongshan rail station, Shangxinjie rail station, Daping, Ranjiaba rail station. Combining the data in Table 4 and Table 5, it can be found that the two tables
overlap the stations including Lianglukou, Dalongshan Rail Station and Shangxinjie Rail Station. From the above results, it can be seen that the three stations of Lianglukou, Dalongshan Rail Station and Shangxinjie Rail Station are the values and passing points of the entire network model. From a comprehensive point of view, the number of intermediate nodes is the most important place for circulation and as a traffic artery. When traffic congestion occurs at the above nodes, the overall circulation of the bus network will be greatly reduced.

4. Concluding remarks

As an important city in southwestern my country, Chongqing has caused the current traffic situation in multiple central locations due to its unique geological features. With the development of the city, the various types of transportation demand for residents to travel continue to increase, which means that the operation of the city needs to redistribute the supply relationship of public transportation facilities and improve the service mode of transportation operations. At this stage, the construction of the public transportation system cannot fully meet the development of the city. Demand, coupled with the influx of foreign personnel, has greatly aggravated the load on traffic roads, further aggravated the traffic jam on the ground, and made it difficult for residents to travel. Therefore, in the future, it is necessary to further study the potential control mechanism of traffic jams, use traffic big data and corresponding systems to conduct data research and judgment, intelligently manage the city's traffic travel, establish a city's traffic supervision and test center and a complete set of systems, and discover problems in real time, and provide scientific prevention strategies to prevent the paralysis of the urban transportation network.

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