Breadth-first Search Based Bus Transport Transfer Algorithm

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Abstract: This paper uses the method of space P to model the bus transport network (BTN), by which an unweighted complex network model is obtained. The statistical characteristics of BTN are analyzed simply. Then by using the breadth-first search algorithm, we get all the least transfer routes between two inquired stations. Third we introduce the vertex weight, namely every station’s longitudes and latitudes. The edge weight—total straight-line distance between every two stations—will be got by computing the vertex weight. Further we model the BTN to a weighted complex network. A final transfer route which has the shortest total straight-line distance on the basis of the least transfer is obtained by this weighted complex network model and all the least transfer routes are got in prior. The practical data of Hangzhou City is used to testify the new algorithm’s efficiency.

Key-Words: Bus transport network; Small-world network; Weighted complex network; Transfer; Breadth-first search

1 Introduction

Recently studies of bus transport network (BTN) have drawn great researching enthusiasm from many scholars [1, 2]. The results of these studies show that BTN is a typical small-world network [3]. Buses are still the main public transportation tool in China, so bus transport transfer is one of the most primary problems which bus passengers care about. Bus transport transfer represents a search problem on the complex networks. Kleinberg has firstly researched on the searching capability of the complex networks theoretically, proving that small-world networks could be searched quickly [4, 5]. Then, Watts et al. have studied on this problem further [6]. So as a typical small-world network, BTN also has the quick searching capability. It says that bus transport transfer problem can be searched and solved quickly and efficiently.

According to the statistical result about psychology inquisition of passengers’ trip [7], the least transfer is the most important factor when passages go out, then the traveling distance, time, expenses and so on. Most recent researchers find the transfer routes based on the shortest path algorithm [8-10]. The routes they find are only concerned on the number of transfers, no any other factors such as the traveling distance, time and so on. In this paper we introduce the vertex weight, namely every station’s longitude and latitude. The edge weight—total straight-line distance between every two stations—will be got by computing the vertex weight. Then BTN is modeled to a weighted complex network. Based on all the least transfer routes got by using the breadth-first search algorithm and the weighted matrix of the weighted complex network model, a final route which has the shortest total straight-line distance on the basis of the least transfer is presented.

The paper is organized as follows. In the next section we present the statistical characteristics of BTNs of three major cities of China. In Section 3 we describe our transfer algorithm. In Section 4 this transfer algorithm is applied to the real BTN of Hangzhou. Conclusion is given in the last part, Section 5.

2 Statistical characteristics of BTN

The practical data of BTN of Beijing, Shanghai and Hangzhou are recorded from Internet [11]. By using space P [12, 13] method, we model BTN to an unweighted complex network. And adjacency matrix is used to denote the connections of the network. To analyze the adjacency matrixes of BTN of these three cities, we obtain the average clustering coefficient, average shortest path length, total number of bus stations and total number of bus lines which are showed in table 1.

The data in table 1 show that BTN has small average shortest path length and big average clustering coefficient, so it is a typical small-world network [3]. And we obtain the average number of least transfers (average shortest path length plus one) of these three cities. The average number of least
transfers is very small (between one and two), so people can travel from one station to another conveniently. It also shows that our algorithm is feasible.

<table>
<thead>
<tr>
<th>Table I Empirical statistical data</th>
<th>Beijing</th>
<th>Shanghai</th>
<th>Hangzhou</th>
</tr>
</thead>
<tbody>
<tr>
<td>average clustering coefficient</td>
<td>0.7326</td>
<td>0.7540</td>
<td>0.7205</td>
</tr>
<tr>
<td>average shortest path length</td>
<td>2.9283</td>
<td>3.0999</td>
<td>2.6516</td>
</tr>
<tr>
<td>total number of bus stations</td>
<td>6235</td>
<td>4139</td>
<td>1404</td>
</tr>
<tr>
<td>total number of bus lines</td>
<td>823</td>
<td>527</td>
<td>328</td>
</tr>
</tbody>
</table>

3 Description of the transfer algorithm

3.1 Get the least transfer routes

Floyd algorithm is applied to obtain the shortest path length matrix $D$ of every two stations from the adjacency matrix $A$ of BTN. This matrix $D$ is equal to the searching steps matrix $T$ which denotes the number of searching steps of every two stations. For example, Fig. 1 presents a BTN of 3 lines. Line 1 is consisted of station 1, 2, 3 and 4; line 2 is consisted of station 2, 5, 6 and 7; line 3 is consisted of station 6, 8 and 9. Fig. 2 presents this BTN in space $P$.

Space $P$ method is employed to model the BTN presented by Fig. 1 to an unweighted complex network. Then we can obtain the adjacency matrix $A$ and the shortest path length matrix $D$.

$$A = \begin{bmatrix}
0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\
0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 \\
0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\
\end{bmatrix}$$

![Fig. 1 BTN of 3 lines](image1)

![Fig. 2 BTN in space P](image2)

![Fig. 3 The process of searching routes using breadth-first search algorithm](image3)
The value of $D_{i,j}$ denotes the shortest path length between station $i$ and $j$. It also denotes that the least number of transfers between station $i$ and $j$ is $D_{i,j} - 1$ (the same station need not to be considered transfer). Besides, for the breadth-first search algorithm, the number of searching steps $T_{i,j}$ between station $i$ and $j$ is denoted by the value of $D_{i,j}$, namely $T_{i,j} = D_{i,j}$.

When we use the breadth-first search algorithm to search the target vertex $t$ from the start vertex $s$, firstly we judge that if $t$ is in the neighbor vertices union of $s$. If yes, we stop searching; and else we examine the neighbor vertices of every neighbor vertex of $s$, judging that if $t$ is in these vertices union. We repeat this process until any neighbor vertex of the target vertex is found [14]. The process is shown in Fig. 3.

According to the concept of breadth-first search algorithm, we suppose to find the least transfer routes from station 1 to station 8, namely searching vertex 8 from vertex 1. The searching process is shown in Fig. 4.

So we have searched vertex 8 from vertex 1, and the transfer vertices: vertex 2 and 6 have been recorded. The transfer route from vertex 1 to vertex 8 is $1 \rightarrow 2 \rightarrow 6 \rightarrow 8$. Namely the transfer route from station 1 to station 8 is obtained, and this route is a least transfer route with transfer station 2 and 6. If there are several transfer routes which have the same number of transfers, namely there are several choices of transfer stations, we record all the transfer routes and transfer stations. Then we obtain all the transfer routes which have the same number of transfers (the least number of transfers).

### 3.2 Straight-line distance calculation

By using the breadth-first search algorithm, we obtain all the least transfer routes. Now we introduce the vertex weight, namely every station’s longitudes and latitudes. The edge weight—the distance between every two stations—will be got by computing the vertex weight. So we can model the BTN to a weighted complex network, and the value of weight is the distance between every two stations. Here the distance between every two stations represents the total straight-line distance between them, is not the real traveling distance. Because the paths which buses travel on are curves, the real traveling distance is the sum of the distance of these curves. But the total straight-line distance is an important reference of the real traveling distance between two stations. If the total straight-line distance between two stations is shorter than other’s, mostly the real traveling distance between these stations is also shorter.

The straight-line distance between two stations is computed by every station’s longitudes and latitudes. The computing formulation is presented as follow.

$$x = (jd_2 - jd_1) * PI * R * \cos\left(\frac{((wd_1 + wd_2) / 2)}{180}\right) / 180$$
$$y = (wd_2 - wd_1) * PI * R / 180$$

Distant = $\sqrt{x^2 + y^2}$

Here, $jd_1$, $wd_1$ and $jd_2$, $wd_2$ are the longitudes and latitudes of two stations respective, the unit is degree. $PI = 3.14159265$, $R$ is the semi diameter of the earth.
There are three rules must be obeyed when we compute the total straight-line distance $D_{s_{ij}}$ between every two stations:

A. $D_{s_{ij}}$ is computed by the formulation presented above, when station $i$ and $j$ are adjacent stations.

B. If station $i$ and $j$ are not adjacent, the total straight-line distance between $i$ and $j$ is the sum of the straight-line distance between the adjacent stations of these two stations. For example, to compute the total straight-line distance $(D_{s_{2,4}})$ between station 2 and 4 which shown in Fig. 1, is $D_{s_{2,4}} = D_{s_{2,3}} + D_{s_{3,4}}$.

C. $D_{s_{ij}}$ can be computed if there is at least one bus line that will halt at station $i$ and $j$, namely station $i$ and $j$ needn’t transfer. Otherwise, $D_{s_{ij}} = \infty$.

By using the formulation and rules presented above, we can obtain a weighted matrix of BTN. The value of weight is the total straight-line distance between every two stations. Comparing the total straight-line distance of every least transfer routes which are got in section 3.1, we can get a transfer route of the shortest total straight-line distance on the basis of the least transfer. And we have discussed that if the total straight-line distance between two stations is shorter than other’s, mostly the real traveling distance between these stations is also shorter. So this transfer route got by us is essentially the same to the route which has the shortest traveling distance on the basis of the least transfer.

4 Application

We obtain the real data of BTN of Hangzhou from Internet\[11]. Besides, we get the longitude and latitude of the bus stations of Hangzhou by Google Earth\[15] and electronic map\[16].

We use the real data of Hangzhou to testify our algorithm which described in section 3:

(I) From station 1 (Xiache crossing) to station 50 (Jiulisong). The transfer route is 1\(\rightarrow\)1367\(\rightarrow\)50 (Xiache crossing\(\rightarrow\)Midu bridge\(\rightarrow\)Jiulisong). The number of transfer is one. The shortest total straight-line distance is 11.577 km.

(II) From station 5 (Song city) to station 999 (Number 5 crossing of number 2 road). The transfer route is 5\(\rightarrow\)1386\(\rightarrow\)33\(\rightarrow\)999 (Song city\(\rightarrow\)East bus station\(\rightarrow\)Number 3 crossing of number 2 road\(\rightarrow\)Number 5 crossing of number 2 road). The number of transfer is two. The shortest total straight-line distance is 21.738 km.

(III) From station 692 (Yujia) to station 1361 (Fang mountain). The transfer route is 692\(\rightarrow\)311\(\rightarrow\)325\(\rightarrow\)326\(\rightarrow\)1361 (Yujia\(\rightarrow\)Zhuantang\(\rightarrow\)Guanxiang crossing\(\rightarrow\)Zhangjia bridge\(\rightarrow\)Fang mountain). The number of transfer is three. The shortest total straight-line distance is 36.562 km.

For these experimental stations, we make the real test of transfer and measure the real traveling distance. The results show that the transfer routes we got have the least number of transfers and have the shortest total straight-line distance. Besides, they are the routes which also have the shortest traveling distance. So the real data of Hang Zhou has testified our algorithm’s efficiency.

5 Conclusion

In this paper, we have proposed a bus transport transfer algorithm based on weighted complex networks. BTN is modeled to an unweighted complex network. All the least transfer routers between two inquired stations are obtained by the breadth-first search algorithm. Then we introduce the vertex weight, namely every station’s longitudes and latitudes. By computing the vertex weight, we get the edge weight which is the total straight-line distance between every two stations. Further BTN is modeled to a weighted complex network. Comparing the total straight-line distance of every least transfer routes which are got by the unweighted complex network model, we get a transfer route which has the shortest total straight-line distance on the basis of the least transfer at last. The practical data of Hang Zhou has shown that these routes also have the shortest real traveling distance and testified the algorithm’s efficiency.

References:


