Multi-Scale Visualization Analysis of Bus Flow Average

Travel Speed in Qingdao

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Abstract. Public transportation is a kind of complex spatiotemporal behaviour. The traffic congestion and environmental pollution caused by the increase in private cars is becoming more and more serious in our city. Spatiotemporal data visualization is an effective tool for studying traffic, transforming non-visual data into recognizable images, which can reveal where/when congestion is formed, developed and disappeared in space and time simultaneously. This paper develops a multi-scale visualization of average travel speed derived from floating bus data, to enable congestion on urban bus networks to be shown and analyzed. The techniques of R language, Echarts, WebGL are used to draw statistical pictures and 3D wall map, which show the congestion in Qingdao from the view of space and time. The results are as follows:(1) There is a more severely delay in Shibei and Shinan areas than Licun and Laoshan areas; (2) The high congestion usually occurs on Hong Kong Middle Road, Shandong Road, Nanjing Road, Liaoyang West Road and Taiping Road;(3) There is a similar law from Monday to Sunday that the congestion is severer in the morning and evening rush hours than other hours; (4) On Monday morning the severity of congestion is higher than on Friday morning, and on Friday evening the severity is higher than on Monday evening. The research results will help to improve the public transportation of Qingdao.

1 Introduction

The increasing populations make the traffic congestion increasingly worse at this stage of domestic cities\textsuperscript{[1]}. It is a major source of desairs for road users, affecting individual commuters physically and mentally\textsuperscript{[2]}. To alleviate congestion, researchers have explored various methods and collected various kinds of traffic data, including taxi GPS data, subway IC card data, etc. While data acquisition is not a problem anymore, how to represent, analyze and visualize these large spatiotemporal data effectively presents major challenges to the research community\textsuperscript{[3]}. 

In this paper, we explore a variety of visualization methods to gain insight into the complex public transport\textsuperscript{[4]}. Public transportation is the leading of urban transport, which plays a key role in serving people travel\textsuperscript{[5, 6]}. Therefore, multi-scale visualization of bus flow can help us find the hidden problems existing in our city. So we can put forward constructive suggestions to improve the traffic.

The paper is organized as follows: Section 1 briefly introduces the floating bus data and the data processing. In Section 2, multi-scale visualization analyses of bus flow from the perspective of the main district, the four areas, the five business circles and the arterial roads in Qingdao are elaborated.
In Section 3, some factors causing congestion are summarized. Finally, we come to the conclusion of the paper.

2 Data

The data we use comes from Qingdao Public Transportation Group, which has around 5000 buses on the core roads of Qingdao. The data is recorded only when a bus passed through bus stations. There are 1 billion records, from September 2014 to September 2015, as shown in table 1.

Table 1. Data attribute structure of floating bus data

| busLineName | busStopName      | stationName | actDatetime     | stationNum | busId  |
|-------------|------------------|-------------|-----------------|------------|-------|
| 26          | Nanjing Road     | The Peri    | 2014-07-14      | 19         | DD102 |
|             |                  |             | 20:00:07        |            |       |
| 28          | Taidong One Road | CuoBuling   | 2014-07-14      | 7          | DD110 |
|             |                  |             | 20:00:10        |            |       |
| 11          | Polar ocean      | Zhenjiang   | 2014-07-14      | 14         | 1413  |
|             | world            | Road        | 20:00:13        |            |       |

The average travel speed is retrieved from the above data. It is the division of distance between adjacent stations and the average travel time taken by all buses passing the distance. Figure 1 shows the details of the calculation process.
3 Bus Flow Visualization Analyses in Qingdao

At present, bus travel in Qingdao accounts for over 32% among all the travel modes. Buses take more and heavier transportation role in residents’ daily lives. Besides, it can help avoid many modern city problems\(^7\). Full understanding of the space-time characteristics of bus flow can help promote urban road traffic network to maximize its potential effectiveness\(^8\).

3.1 Bus flow visualization analysis in the main district

Bus routes network in the main districts is theory-oriented “the south and north are hydrophobic; the west and east are dredging”. It looks like a boot and is in accordance with the structure of road network. The structure determines the mainstream of city buses is the inverted “T” type.

Figure 2 is an isosurface (a three-dimensional contour surface) generated with Msic3D package of R software, which can show where the congestion generates, how it spreads, and where it terminates. An isosurface shows points of equal value in a 3D volume\(^9\).

![Figure 2. 3D isosurface of average travel speed in the main district](image)

We can see the dynamic process of congestion from the space and time perspective. Figure 2 shows that congestion starts at 7:00 am, and spreads out during the morning peak hours (7:00 -9:00), and then fades away. A similar trend can be seen in the isosurface during the evening peak hours (17:00-19:00). Moreover, there is longer time of congestion in the evening than in the morning. Many areas experience severe congestion along the coastal edge, such as around May Fourth Square, Ba Da Guan Scenic Area, and Qingdao Railway Station.

3.2 Bus flow visualization analysis of the four areas

The main district is divided into four areas, including Shinan area, Shibei area, Licang area and Laoshan area.

Figure 3 is a K line chart generated by Echarts similarly. It is usually used to draw the direction of
stocks. In this paper, we illustrate the traffic instead. In the graph, the line is used to represent the max speed with its top and the min speed with its bottom among all the week. The longer the line is, the greater the change is. We can find there is a bigger change in the morning hours than in the evening hours. So the evening rush hours are relatively stable on the whole week. The box is used to represent the speed of Monday and Friday. If the speed of Monday is lower than that of Friday, the box will be light blue; conversely, the box will be light red. The figure shows an interesting comparison between Monday and Friday in the four areas. On Monday morning the severity of traffic congestion is higher than Friday morning, but on Friday evening the severity is higher than Monday evening. There is a large difference because on Monday morning people just begin their work from outskirts of the city. However, on Friday evening people have finished work for the week, and they may undertake a long journey on weekend, or go out to enjoy the evening. Overall, it is smooth in the Laoshan and Licang areas, compared to the Shinan and Shibe areas.

3.3 Bus flow visualization analysis of the arterial roads

Arterial roads are the framework of urban road network. They are connected to the city’s major districts and play key roles in urban transportation. We select six arterial roads to analyze bus flow in Qingdao.

Figure 4 is a 3D wall map made in browser with technologies of WebGL. Under the wall, it is a picture of Baidu map. The figure gives an overall view of the congestion process (accumulating, propagating and subsequently dissipating) in individual links [9].

We can see the high congestion occurs on Hong Kong Middle Road, Shandong Road, Nanjing Road, Liaoyang West Road and Taiping Road. The congestion will spread in space from one section...
to its adjacent section, which leads to the condition of going slow. In the morning and evening rush hours, congestion is the most severe. It will also spread to the other hours.

**Figure 4.** Different traffic condition on the arterial roads

Figure 5 shows the difference between the peak and off-peak period of the arterial roads. Compared to Figure 4, we can find a similar rule.

(a) In the rush hours  
(b) Not in the rush hours

**Figure 5.** Heat map of average travel speed on the arterial roads

### 4 Influence Factors Analysis

#### 4.1 The road design of districts.

Shinan and Shibei areas belong to the old districts, with dense road networks and narrow sections. The terrain conditions and historical evolution bring many paths, dead end highways and plug roads, with poor connectivity. Licang and Laoshan areas are built later. Their roads are wide. There is relatively reasonable road design and corresponding daily motor vehicle throughput ratio.

#### 4.2 The spatial layout of the city.

The spatial layout of Qingdao is multi-centric strip shape. The four areas have their business centers (such as shopping plazas, large supermarkets, and offices), entertainment infrastructures (such as parks, playgrounds), and education facilities (such as schools of primary and secondary). Residents’ stable
patterns of social life, work, school and other activities lead to high congestion in a specific period such as morning and evening rush hours.

4.3 The intensity of population.
In business circles, railway stations, the beaches, intense and flowing population lead to the bad traffic.

5 Conclusions
This paper illustrates the condition of bus flow in Qingdao using different visualization techniques. Large space scale visualization allows us to have a cognitive understanding of congestion from the macroscopic perspective, while the short space scale provides us details of congestion from the microscopic perspective. At last, we summarize some factors which give rise to congestion, including roads, city layout, and population, etc. The analysis of bus flow can promote the traffic administrative department to make a decision to tackle congestion problems.

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