Visualizing Public Transport Quality of Service

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1. Introduction

The recent advances of geo-positioning hardware, computer software and mobile communications have combined to offer new opportunities for improved public transport services. Today many transportation companies are using the Global Positioning System (GPS) and wireless communication systems (e.g. radio data systems or GSM/GPRS) for communicating their vehicle location information and other details to a central server (Predic et. al 2007) (Kane, Verma and Jain 2008). By tracking their bus fleet in real-time, operators can monitor schedule adherence and service efficiency, give better operational support and provide users with real-time service information. There are several bespoke systems commercially available that do this.

In order to improve services, as well as providing real-time information, these systems build up an archive of data that can be analysed and mined to explore and show behaviour of the transport system over time, indicating problems such as vehicle bunching and delays due to congestion. In addition, to qualify for public subsidies, operators must report Quality of Service metrics to government. These are usually calculated manually but the existence of a full archive of data gives the potential for automation.

Quality of Service (QoS) in public transport is a set of metrics used to measure the reliability and punctuality of bus services (Transport for London 2007). For a high frequency route (a route with five or more buses per hour) it is important for buses to run at evenly spaced intervals and not bunch. A standard metric, the Excess Waiting Time (EWT), is used to measure the additional wait experienced by passengers due to the irregular spacing of buses or those that failed to run. For low-frequency bus routes (a route with four or less buses per hour) passengers using the service tend to rely on the timetable. It is more important that services run as close as possible to the time specified on timetables. A metric that measures any deviation is required.

In a joint project between NUI Maynooth and Blackpool Transport methods are being explored to visualise the behaviour of vehicles in ways to allow the operator to better assess and improve the quality of their public service. The system uses off-the-shelf GPS/GPRS integrated units programmed to transmit location at regular intervals (45 seconds approximately) while the vehicle is in motion. The data is stored on a server and can be visualised through a standard web browser to show views representing current locations of vehicles in close-to-real-time. In addition tools are provided to visualise vehicle behaviour over time and to calculate metrics and summaries. The system uses web technologies such as JavaScript, MySql, XML, PHP and Ajax. In addition there is a public interface that can display and update vehicle locations in Microsoft Virtual Earth (bustracking.co.uk).

2. Visualization of real-time information

One of the most important challenges in visualization research is to determine how best to depict a set of data so that the information it represents can be accurately and efficiently understood. Both design and evaluation have key roles to play in this process. Some recent advanced public transportation systems (APTS) make use of various data visualization tools in a GIS context (Yu, Mishra and Lin 2006) (Hoar 2008) (Maclean and Dailey 2001). These tools concentrate on information for passengers and the real-time display of bus locations. In this paper we present a computer visualization prototype which is more aimed at public transport operators. It includes real-time tracking but also allows operators to view performance over periods of time and to help in decision making.

Visualization is a process of transforming data into a visual form enabling the user to better understand and extract the information contained. In transportation services, vehicle information can be visualized in an on-line or off-line environment through tables, maps, data plots and other graphical outputs (Zolfaghari, Jaber and Azizi 2001) (Okunieff, P.et al. 1997). To visualize real-time information, such as the current/last vehicle location, time at location, this is integrated with real-time data sources from the vehicles. The system displays real-time locations of buses pictorially, textually and, using the facilities provided by the Microsoft Virtual Earth API, with 2D and 3D map visualizations (figure 1). The displays can show adherence to the published timetable through colour coding (figure 2).

Figure 1. The public interface showing updating textual display plus moving locations on Microsoft Virtual Earth.

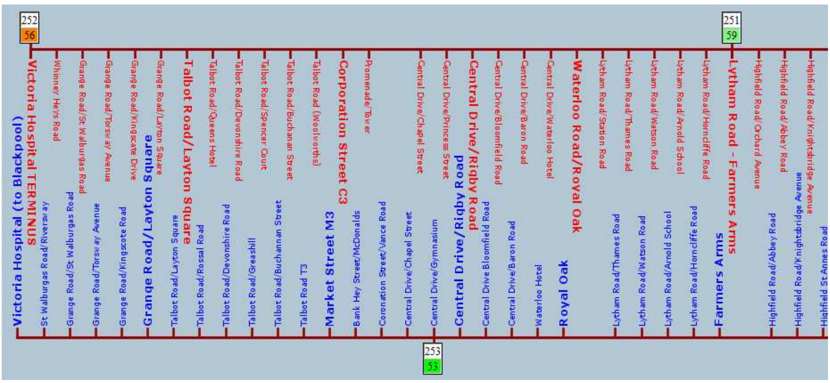

Figure 2. Route diagram visualisation, colours indicating adherence to timetable.

3. Visualization of vehicle behaviour

Historical as well as current vehicle behaviour is required for an assessment and improvement in service quality. The system can visualize the behaviour of vehicles in different easy-to-understand ways. The daily spatial-temporal behaviour of vehicles (vehicle locations in term of bus stops passed against time) is displayed as a series of line-graphs. As well as showing the regularity of the service, poor service phenomena such as vehicle-bunching and erratic service intervals are easily detected (figure 3). Similarly the scheduled timetable can be plotted in a similar way providing comparisons between advertised and scheduled services (figure 4) and clearly indicating when a bus is ahead or behind. This can be summarised through the calculation of rms values between the two curves to give an overall measure of timetable adherence (table 1). The plots can also be used to display another relevant variable through the thickness of the plotted line, such as in figure 5. The on-vehicle units have a serial interface allowing it to monitor and transmit data from other devices such as ticket-issuing machines, motor controllers and other sensors.

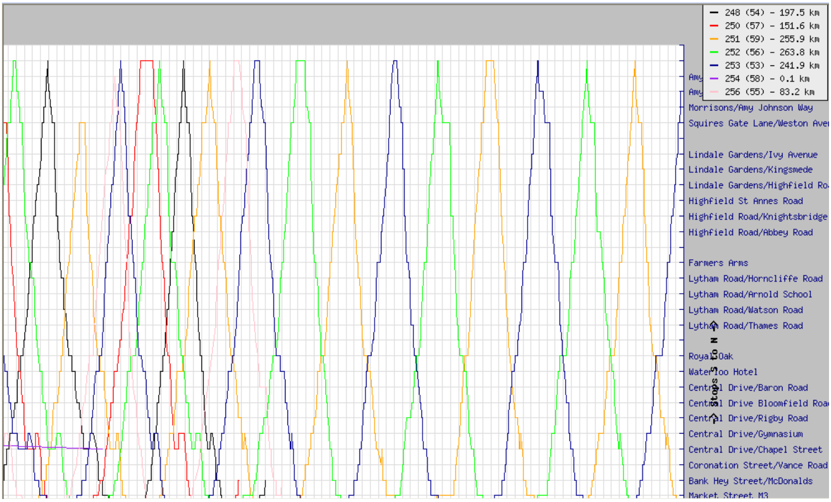

Figure 3. Extract of plot of vehicle locations, in terms of bus-stops passed, against time. Bunching of vehicles is easily detected.

4 Visualizing Quality of Service indicators (QoS)

Quality of service indicators are metrics that are used in evaluating public transit performance. These provide passengers and operators a measure of how reliable services are and help operators to improve schedule adherence and service efficiency. Similar the regulatory authorities usually require reporting of QoS metrics to comply with licensing rules and the conditions for operating subsidies. QoS is defined as the "overall measured or perceived performance of a transit service from the *passengers'* point of view" (Transport for London 2007).

With respect to QoS, frequency of service can be divided into two categories, *high* and *low* depending on the number of vehicles serving an individual route. For low frequency routes, defined as those with four or less vehicles per hour, it is important that the service runs exactly to the time specified on timetable and QoS is specified as the mean deviation of buses from their scheduled time. On high frequency routes (with five or more buses per hour), passengers tend to arrive at stops without consulting a timetable because they expect buses are running at evenly spaced headways. QoS is measured by calculating the average Excess Waiting Time (EWT) that passengers have waited above the theoretical waiting time given by the service interval.

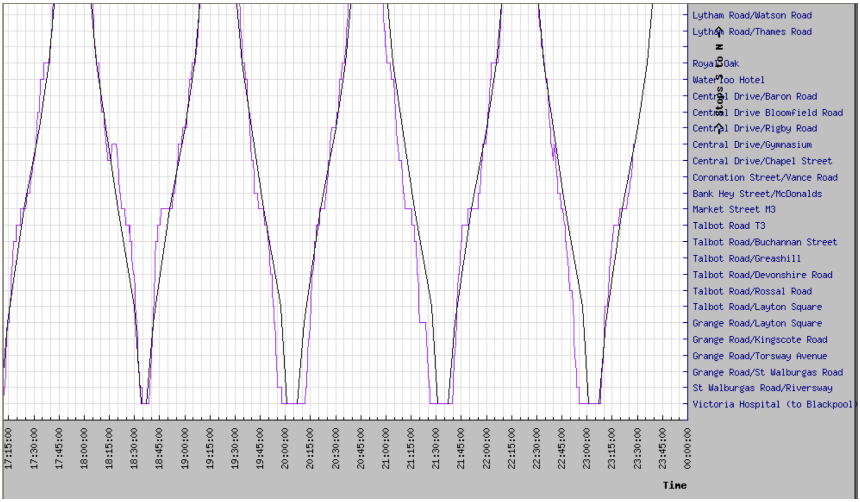

Figure 4. Extract of plot of vehicle location in comparison to scheduled timetable.

Date: 2008-08-01

Imei No	Bus	Route	rms
357541000328460	256	53	1265
358279000289809	250	51	2546
358279000289825	251	57	74
358279000290989	253	59	1745
358279000298263	257	0	1035

Table 1. RMS values in seconds for different vehicles against their timetable

4.1 Arrival Time Prediction for Low Frequency Routes

An algorithm has been implemented to estimate bus arrival time. This algorithm involves using historical operational data on the route collected over several months and averaging bus travelling time (between bus stops) for each hour of each day of the week with the underlying assumption that buses will be running in same operational conditions at the same time each week. This averaged data is used to predict how long it will take an individual bus to get from where it is to a particular stop. The system also uses the travel time of the preceding buses, weighted by how recent they are, to factor in conditions that may be prevailing on that particular day. The effectiveness of this algorithm is currently being evaluated and will be presented. The system is demonstrated by implementing a web-based next-bus indicator.

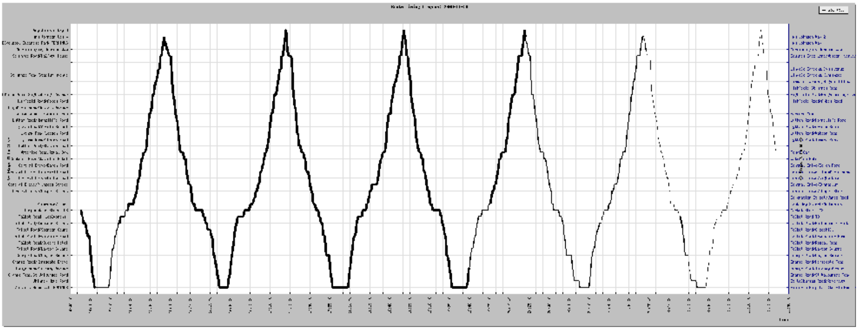

Figure 5. The thickness of the line on the plot can indicate variables such as battery voltage or passenger loadings by location and time.

Figure 6. Predicted arrival time based on historic data.

4.2 Excess Waiting Time (EWT) for High Frequency Route

A standard metric, the Excess Waiting Time (EWT) is commonly used to measure the quality of service. It can be defined as the average additional wait experienced by passengers due to the irregular spacing of buses or those that failed to run (Transport for London 2007). This is a key performance indicator since it denotes how much time passengers had actually to wait in excess of what we would have expected them to if the service were perfect. EWT is calculated by subtracting Scheduled Waiting Time (SWT) from Average Waiting Time (AWT) and it is this which is used as the measure of reliability. The greater the EWT is, the less reliable the service (Okunieff, P. et al. 1997).

$$EWT=AWT-SWT \qquad (1)$$

where AWT is the average time that passengers actually waited and SWT is the time a passenger would wait, on average, if the services ran exactly as planned during the periods observed. The system can automatically generate daily, weekly, monthly and annual reports of EWT for any stop. We are currently investigating ways to visualise its variation over time.

5. Conclusions

The current system provides several tools for visualising vehicle behaviour and calculating metrics for service quality. They provide views designed to allow easy detection of many of the symptoms of a poor bus service – bunching, late-running, missed services. They also automatically calculate metrics for reporting and comparing QoS. However, evaluation of how effective they are in a commercial operational environment is on-going and will be used as input to a revision of the system. Other planned work involves developing 3D visualisations and adapting techniques used in computer network QoS visualisation for this domain.

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Data for **Market Street M3** on **20/05/2008** from 8am - 6pm.

(a)	(b)	(c)	(d)
08:06:00			
08:35:00	29	14.5	420.5
08:46:00	11	5.5	60.5
09:21:00	35	17.5	612.5
09:37:00	16	8	128
10:04:00	27	13.5	364.5
10:14:00	10	5	50
10:53:00	39	19.5	760.5
11:11:00	18	9	162
11:35:00	24	12	288
11:42:00	7	3.5	24.5
12:23:00	41	20.5	840.5
12:37:00	14	7	98
13:05:00	28	14	392
13:13:00	8	4	32
13:54:00	41	20.5	840.5
14:03:00	9	4.5	40.5
14:32:00	29	14.5	420.5
14:43:00	11	5.5	60.5
15:23:00	40	20	800
15:36:00	13	6.5	84.5
16:04:00	28	14	392
16:20:00	16	8	128
16:54:00	34	17	578
17:05:00	11	5.5	60.5
17:37:00	32	16	512
17:48:00	11	5.5	60.5

Total (Sum of square of headway/2) 8211
Time between 1st and last observed bus is 582
Average Waiting time in minutes 14.1082474227

Number of Buses scheduled per hour 6
Scheduled Waiting times (SWT) in minutes 5

Excess Waiting Time= 9.10824742268

Figure 7. Automatic calculation of Excess Waiting Time.

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Biographies

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