TrafficScan—Bringing Real-time Travel Information to Motorists

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Abstract

The TrafficScan system is an advanced transport system that provides motorists with real-time speed information on major roads in Singapore. This paper discusses how the Land Transport Authority of Singapore leveraged on technology and an innovative use of a taxi dispatch system to gather traffic data on the roads. The data is processed to give traffic speed conditions on the road network and these can be accessed online by motorists to plan their routes for a smoother journey. First launched in 1999, TrafficScan was subsequently enhanced to enable more data to be collected and improve the accuracy of traffic speeds reported by the system.

Introduction

Traffic speed is an important piece of traffic data. For traffic engineers, it complements other traffic data in reflecting the performance of the road network and warning of possible traffic incidents on the roads. For motorists, speed information reflects the driving experience. It is easily understood, unlike other traffic data such as traffic volume and density which are more difficult for them to relate to.

There is thus a need to develop more efficient and cost-effective ways of collecting traffic speeds over a wide area.

However, the collection of traffic speeds over a wide area and on a sustained basis is prohibitively expensive. Prior to 1999, the Land Transport Authority (LTA) of Singapore collected traffic speeds by either using loop detectors embedded under the road surface or conducting manual travel time surveys. Both methods have their disadvantages.

The installation of loop detectors is disruptive to traffic flow. These inductive loops are also easily damaged during road opening and resurfacing. Moreover the quality of the data depends on the number and coverage of the detectors, and the speeds obtained are spot speeds rather than travel speeds over the length of road. Travel time surveys, on the other hand, are both time-consuming and resource-intensive. Hence, the number of roads and the time periods surveyed are limited. Moreover, this method adds to traffic congestion and environmental pollution. There is thus a need to develop more efficient and cost-effective ways of collecting traffic speeds over a wide area.

The "Floating Car Data" (FCD) method offers a solution to collect speed data automatically through the use of highly distributed probe vehicles. These vehicles are usually equipped with Global Positioning System (GPS) communication modules. The FCD method follows a basic model: collecting data automatically from individual vehicles, aggregating the data at a central processing centre, extracting useful information, and redistributing the information to motorists. However, the adoption of FCD method has been rather slow, until more recently. This was due to the relatively high communication cost for data transmission as well as difficulty in bringing together a sufficient number of widely distributed probe vehicles.

In Europe, there were several FCD projects such as the OPTIS (OPtimized Traffic In Sweden) project in Sweden and the Taxi-FCD system in Germany. However, these were mainly small-scale trials or pilot projects employing few probe vehicles. The Taxi-FCD system established by the German Aerospace Centre in 2001 involved 2,300 taxis spread over 5 cities, while the OPTIS trial in 2002 had only 220 probe vehicles.

More recently, in August 2008, China Mobile launched a pilot project in Guangzhou in collaboration with Siemens Mobility Division. The system obtains information on traffic situation based on the positional data of 17,000 taxis transmitted via GPS. China Mobile then offers the traffic information to road users through its own hotline and via text messaging.

The TrafficScan System

The TrafficScan system, based on the FCD method, was first developed by LTA in January 1999 to automate the collection of traffic speeds on major roads in Singapore.

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What distinguished TrafficScan from the early FCD projects was that it made use of existing fleet of 11,000 taxis on the roads, which instantly gave LTA a large pool of probe vehicles widely distributed over the island. These taxis were equipped with GPS receivers that captured the taxis' positions, speeds and directions. The data was transmitted to TrafficScan via the taxi operator's taxi dispatch system using Mobitex wireless communication.

TrafficScan collected data whenever taxi drivers bid for taxi booking jobs (known as "job-bid data") and when it polled taxis for data in areas with insufficient job-bid data. The data was processed by TrafficScan and translated into traffic speeds for major roads in Singapore. This information was then made available online through LTA's website.

In May 2004, LTA set up the one.motoring website to serve as a one-stop online portal for all matters pertaining to motoring and road transport. The speed information from TrafficScan is now aggregated with other traffic information in the i-transport platform[1] and disseminated through the one.motoring website (www.onemotoring.com.sg). See *Figure 1* for the system diagram.

The one.motoring website uses an interactive map of Singapore to display real-time speed information on major roads, together with other traffic information such as road works, accidents and incidents on the roads. This allows motorists to make more informed travel decisions and plan their routes to enjoy a smoother journey. *Figure 2* is a screenshot of the interactive map.

Enhancing the System

In 2003, the taxi operators decided to migrate their wireless communication system to General Packet Radio Services (GPRS) which provides higher bandwidth at a lower cost. The use of GPRS greatly increases the amount of taxi data that can be collected by TrafficScan and thus, the potential for greater accuracy and reliability of TrafficScan speeds. To take advantage of this development, LTA worked with Steria Asia Pte Ltd in 2005 to enhance TrafficScan to improve the accuracy and availability of real-time traffic speeds.

Figure 1: Information flow in TrafficScan

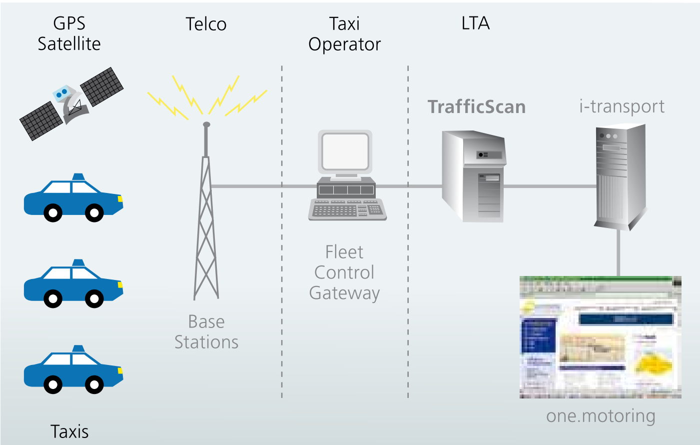


Figure 2: Interactive map on one.motoring website

The enhanced system—e-TrafficScan—was successfully launched in April 2006. The key changes and improvements to the system are discussed in the following sections.

Replacing Mobitex system with General Packet Radio Services

With the higher bandwidth that comes with the migration of the wireless communication system to GPRS, more taxi data can be collected. Instead of collecting data only when taxi drivers bid for taxi booking jobs, data can now be collected from taxis at regular intervals throughout the day, as long as the taxis are running on the roads. The interval for polling taxis for data is also reduced from 5 minutes to less than 3 minutes. As a result, the amount of data collected in a day has increased by 15 times. The hardware in both the taxi operator's system and e-TrafficScan has been substantially upgraded to allow more taxi data to be processed.

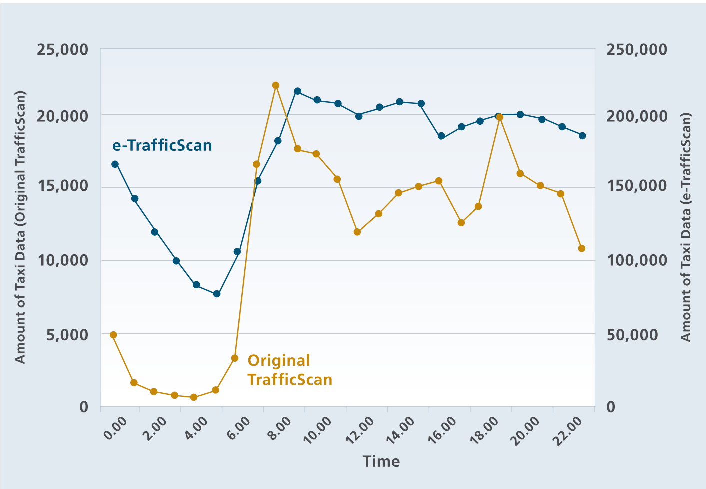
Figure 3 shows the amount of taxi data collected each hour. With e-TrafficScan, there is less variation in the amount of data collected during the day, unlike the original TrafficScan which showed peaks corresponding to peak hours for taxi booking i.e. around 8am and 7pm. Note that the scale for e-TrafficScan is 10 times that for the original TrafficScan.

Enhancement of algorithm

The TrafficScan algorithm was enhanced to track the travel path of each taxi. This allows e-TrafficScan to compute the travel speed of each taxi based on the distance travelled and time taken between two successive locations, instead of using spot speed as in the original TrafficScan. Although the spot speed of the taxi is still collected, it is only used when the travel speed cannot be computed.

The travel speed is more representative of the actual traffic speed experienced by motorists as it is related to the time taken to travel a particular path. In addition, it is subject to less variation than spot speeds. By tracking the taxi movement from one point to another, all road segments along the path travelled by the taxi will have a speed corresponding to the travel speed of the taxi. This improves the speed coverage of e-TrafficScan. See box story "Algorithm of e-TrafficScan" for a more detailed discussion of the enhanced algorithm.

Figure 3: Amount of taxi data collected every hour



Better representation of road segments

The number of road segments used for computing traffic speeds was increased from approximately 32,000 to 53,000. The average length of each segment was reduced from 170m to 102m. With shorter and more road segments, the average traffic speed from e-TrafficScan is more representative of the actual speed for each road segment.

The above enhancements to TrafficScan have improved the accuracy and coverage of traffic speed on the roads. Motorists are now able to access more accurate traffic

Figure 4: Coverage of speeds in central area in original TrafficScan

Figure 5: Coverage of speeds in central area in e-TrafficScan

speed information for more road segments. A comparison of *Figures 4* and *5* shows the significant improvement in the coverage of traffic speed information under e-TrafficScan (as shown by a reduction in the number of grey road segments where no data is available).

Manual travel time surveys which involved drivers going around the road network were conducted to assess the accuracy of speeds reported by e-TrafficScan. The results showed that the speed variance on expressways was 7% while that on arterial roads was 17%. This compared favourably with the original TrafficScan, which had a variance of 18% on expressways and 45% on arterial roads.

LTA's annual operating cost for the system was also reduced by 65%, which was significant given the improvements made. This was primarily the result of the advancement in wireless communication technology which allowed higher bandwidth and more computational intelligence at a lower cost.

Conclusion

As early as 1999, the TrafficScan system enabled LTA to collect round-the-clock traffic speeds over a wide area. LTA's innovative approach—using taxis on the road to achieve a large number of widely distributed probe vehicles, and transmitting data through the taxi dispatch system to cut down on data transmission cost—allowed it to overcome the two key difficulties associated with the adoption of the FCD method. However, the accuracy and coverage of the original TrafficScan were limited by the technologies available then.

With the subsequent enhancement to TrafficScan in 2005, it is now more efficient and cost effective to collect traffic speeds over a wide area, round-the-clock on a sustained basis.

LTA continues to work on improvements to TrafficScan. Today, e-TrafficScan uses taxis as probe vehicles. In future, the group of probe vehicles could be expanded to include other public and commercial transportation such as buses and commercial vehicles. Other potential areas of improvement include the employment of fuzzy logic to the TrafficScan algorithm in the areas of mapping, path finding and speed reconstitution, and making TrafficScan information available through other dissemination channels such as dynamic navigational devices.

Algorithm of e-TrafficScan

Overview

The algorithms in the e-TrafficScan system are divided into two major stages. The first stage handles the processing of the incoming taxi data while the second computes the average travelling speeds on the roads using data collected within the 5-minute intervals .

The processing of incoming taxi data includes coordinate conversion, location-to-road mapping, travel path finding and travel speed calculation. This gives a set of speed samplings for each road segment which is used as input for the second stage.

In the second stage, the system computes the travelling speed for each road segment by averaging the speed samplings within each 5-minute interval. The confidence levels for the speed samplings are also calculated using Student t-distribution. If the confidence level is not satisfactory, the system gathers the samplings from neighbouring road segments to re-compute the travelling speeds.

For road segments without speed samplings, and hence not able to produce the average travelling speed, their travelling speeds will be reconstituted from historical speeds or from current speeds of neighbouring road segments.

Coordinate Conversion

The GPS unit in the taxi produces only taxi locations in WGS84 coordinates, which is based on the World Geodetic System for determining GPS positions on Earth. We need to convert them into SVY21 coordinates (which is based on a local reference system for determining positions on the Singapore map) before mapping the location to the road segments. The requirement for e-TrafficScan system is to use SVY21 coordinates for all geographical information.

Taxi Location-to-road Mapping

The location of the taxi is not very useful unless we associate it to the road segment that the taxi is travelling on. This provides speed information for that road segment as well as the ability to establish the path between the current and the previous location. We can generate more traffic information using the travel path of the taxis.

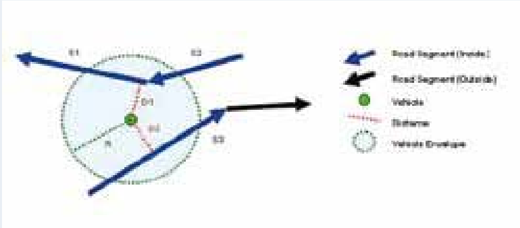
Hence, the algorithm that searches for a matching road segment for each taxi location received is very important. It has to be accurate and more importantly, it has to be very fast. Due to the huge number of road segments and taxis, the system has only a split second to narrow down to a few potential road segments.

The system stores the road segments in a spatial data structure to facilitate the process of matching location to the road. The regions covered by each geographical object are pre-computed and used as the index for fast retrieval.

Each time a taxi location is received, the system computes an envelope around the location where possible road segments may reside. It then pulls out the set of road segments that intercept with the envelope using their geographical properties. These road segments have to go through a selection process before the best matching road segment is chosen.

The figure below shows the basic taxi location-to-road matching selection. The road segment with similar direction and the shortest distance from the location is selected as the road segment the taxi is located.

Taxi location-to-road matching calculation



Travel Path Finding

To calculate travelling speed, the path of the taxi between time t and t-1 must be known. Given the GPS locations of the vehicle at the start and end of the journey, the shortest path connecting the two points is computed using the A-star path finding algorithm.

The A-star path finding algorithm (heuristic graph search algorithm) is implemented in the e-TrafficScan system. The speed and efficiency of the algorithm enables the system to process up to 54,000 taxi data in 5 minutes.

Speed Reconstitution

The purpose of reconstitution is to produce speed information for road segments where there is no data. This ensures that motorists get reliable speed information round the clock.

Speed reconstitution is achieved either by using historical data (time-based reconstitution) or by using data from the neighbouring roads (space-based reconstitution).

In time-based reconstitution, the current traffic speed is assumed equal to the historical traffic speed from the last 5 to 15 minutes. In space-based reconstitution, speed samplings from neighbouring road segments are used to compute the current traffic speed.

Note

1. i-transport platform is an interactive and integrated platform for the management of traffic control and advisory infrastructure for the entire road network.

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