

Integrating Real-time Bus-Tracking with Pedestrian Navigation in a Journey Planning System

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1. Introduction

Automated Vehicle Location (AVL) systems provide real-time location information for emergency response, delivery services and freight transport. The advent of AVL systems has meant both public and private bus operators can implement systems to provide real-time passenger information, analyse their service performance and also to evaluate the quality of their operations. Traffic congestion, intersection delays, weather and operational conditions are some of the factors that make it difficult to predict the accurate bus arrival time in a real-time environment. In a joint project between NUI Maynooth and Blackpool Transport, a dynamic web application was developed to display and update vehicle locations (bustracking.co.uk) (Winstanley et al. 2009) and to provide predictive bus arrival times at stops.

A journey by bus is usually part of a longer door-to-door itinerary, usually involving walking before, after or between bus segments. The passenger is really interested in door-to-door journey times when making decisions about time of departure and which bus to catch. Therefore journey planners that combine the pedestrian and bus journeys are required and indeed several such systems exist, such as Transport Direct (2009), Traveline Midlands (2009), Google transit (2009). However these systems are mainly designed to plan journeys in advance and so base their decisions on the fixed bus timetable. For last-minute planning, and also for updating journey plans as-you-go, real-time bus locations and short-term predictions of bus arrival times at stops can be used to give more reliable journey times taking into account delays due to congestion, diversions and other factors. This paper describes an experimental system that combines bus tracking and pedestrian navigation.

2. Bus Tracking, Pedestrian Navigation and Journey Planning

Recent advances of geo-positioning hardware, computer software and mobile communications have combined to offer new opportunities for improved public transport services. Today many public transport agencies are using vehicle tracking to provide travellers with detailed, reliable, high-quality, real-time travel information. Mostly these use the Global Positioning System (GPS) and wireless communication systems (for example, radio data systems or GSM/GPRS) for communicating their vehicle location information and other details to a central server (figure 1). 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. These systems can also build up an archive of data that can be analysed and mined for information to show the behaviour of the transport system over time, indicating recurrent problems such as vehicle bunching and delays due to congestion. In addition, to qualify for public subsidies, operators must report Quality-of-Service (QoS) metrics to regulatory authorities. These are usually calculated manually but the existence of a full archive of data gives the potential for automation.

In a joint project between NUI Maynooth and Blackpool Transport, a dynamic web application has been developed to display and update vehicle locations (bustracking.co.uk) (Winstanley et al. 2009), to provide predictive bus arrival times at stops and also to automatically calculate QoS metrics. The system uses off-the-shelf GPS/GPRS integrated units programmed to transmit locations at regular intervals while the vehicle is in motion. The data is stored on a server and can be displayed through a standard web browser. The system is implemented using web technologies such as JavaScript, MySql, XML, PHP and Ajax.

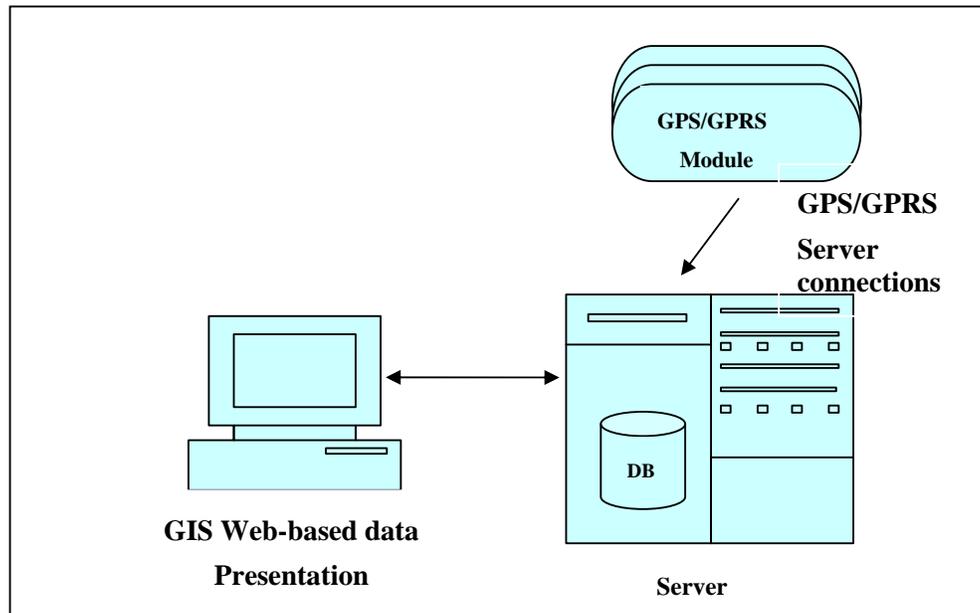


Figure 1. Data collection system

The GPS/GPRS units installed on buses provide location, direction and speed information. This is used to calculate how closely vehicles are following scheduled routes. Vehicle locations are displayed on a web base map (Google, MS Bing or OpenStreetMap) using icons automatically colour-coded to show how closely they are following their schedules. The same real-time data is used to generate displays showing predicted bus arrival times at stops.

Navigation dominates the greater part of the mobile mapping market. A recent article (Arrington 2009) claims that navigation takes over 70% of the \$2 billion worldwide mapping market. This has resulted in diverse user -oriented systems and applications that are focused on specific application domains (urban pedestrian, car, freight, and hiking). Most of the big mobile mapping providers (Google, Nokia, Microsoft, Yahoo and Navteq) include pedestrian navigation as a part of their service. Pedestrians have different requirements from vehicle navigation. They are not restricted by rules of the road; they are free to follow a greater variety of paths; they can cross open spaces; their low speed means that routing instructions need to be more detailed; they tend to have personal preferences (for example, avoiding busy roads or preferring not to cross open spaces in bad weather) that affect the route they take; and they move seamlessly in and out of buildings. At NUI Maynooth, a campus pedestrian navigation system is being developed (Ciepluch 2009) that takes these factors into account, creating user profiles for customised route finding and communicating the route to the user in non-cartographic interactions such as audio or haptic feedback.

No major city is without a comprehensive on-line journey planning system that usually not only returns routes but also uses the timetable to give a detailed timed itinerary. However, a bus trip is

usually part of a longer door-to-door journey with walking segments before, after and/or between bus rides. A few applications such as Transport Direct, TravelLineMidlands and Google transit provide the user with the functionality to compute complete journeys. However, these applications are mainly designed for planning journeys in advance using the bus schedule as given in the fixed timetable. As such they cannot take into account delays and cancellations or provide re-routing instructions on the fly.

3. Integrating Real-time Bus-Tracking with Pedestrian Navigation

An experimental system integrating bus tracking and pedestrian navigation into the same application has been created. The system is implemented using Cloudmade and Web Map Lite which uses OpenStreetMap data in their map tiles and provides an API which has various services like routing and geo-coding. The system provides door-to-door routing and timing information for the specified journey and is designed to be used during the journey to provide up-to-date best-journey information based on the real-time location of buses.

Given the current location of a vehicle we have assessed three different prediction models for estimating arrival times at bus-stops using:

- historical data to determine typical travel time over that segment of the route at the same time-of-day and day-of-week,
- a multiple regression model and
- a Kalman filter model based on recent bus locations.

In order to evaluate the performance of these predictions models, the Mean Absolute Percentage Error (MAPE) was used to measure the closeness between predicted and observed values. MAPE (Ren and Glasure 2009) represents the average percentage difference between the observed value (actual arrival time) and the predicted value (table 1). The historical data model has been shown to produce the smallest MAPE.

In the experimental system, the user inputs their start point (or current location) and destination and the system finds the nearest bus stop that he needs to go to take the bus to get to his destination. The system calculates the time taken to take the shortest path to the bus stop and, after calculating the next predicted bus arrivals at the stop, suggests departure times to synchronise with bus departures and the resulting total travel time.

Model	MAPE
Historical data Model	13
MLR Model	29
Kalman Filter Model	20

Table 1: MAPE values of Prediction Models

The system uses OpenStreetMap and Cloudmade to interact with the user but could use any of the common web mapping systems (Google, Bing, Yahoo). Figure 2 shows the web interface of the current system presenting a typical journey specification with several trip options.

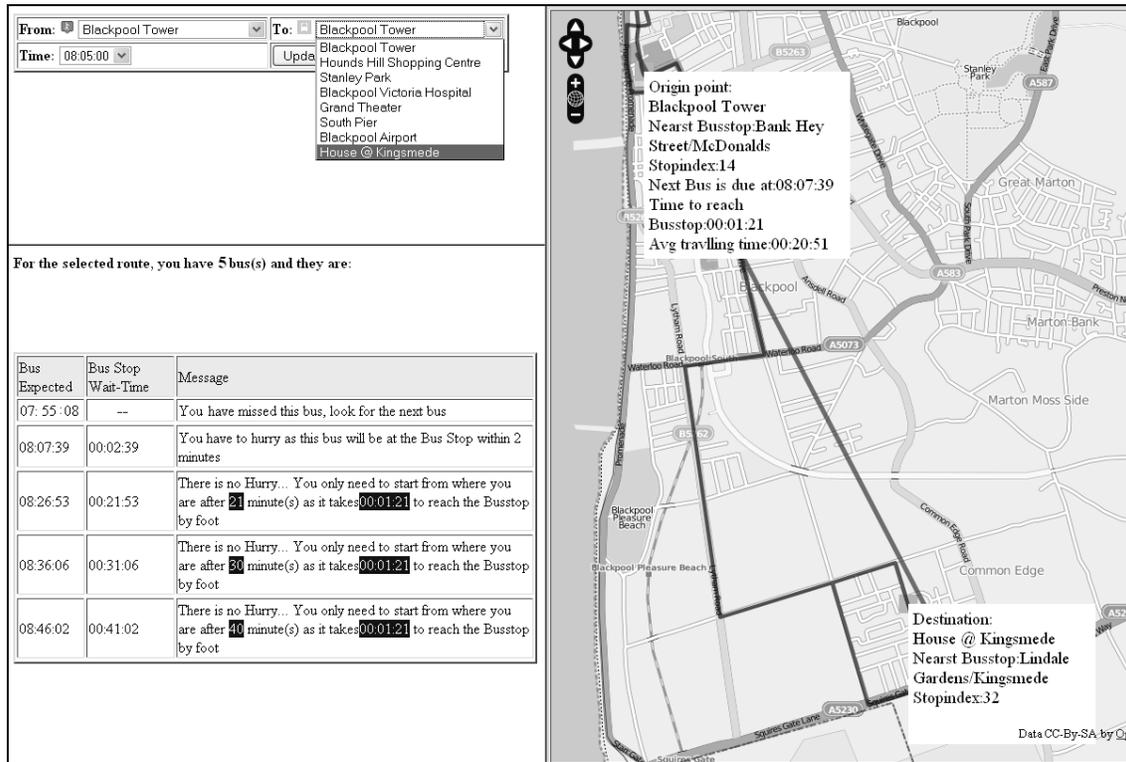


Figure 2. Bus tracking and pedestrian navigation in an integrated journey planning system

4. Conclusion

This system brings together the functionality of an AVL system and pedestrian navigation with bus arrival time prediction to provide the user a real-time door-to-door journey planning system. This system uses a historical data model for bus journey time prediction. We intend to make the web page more interactive and give the user options to select destination points on the map rather than from a list. We also plan to extend the system to make it work with a GPS-enabled mobile phone where the start point will be the current position of the user and the user only specifies the destination point. In addition we plan to incorporate the full pedestrian navigation options currently included in our campus navigation system.

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Biography

Bashir Shalaik is a postgraduate research student at National University of Ireland, Maynooth having obtained an MSc degree in Computer Science at the same institute. He is interested in Intelligent Public Transportation and GPS-based vehicle tracking systems.

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Adam Winstanley is the Head of Computer Science at National University of Ireland Maynooth and a senior research associate with the National Centre for Geocomputation. His research interests lie in several fields, including location based systems, intelligent transport systems; graphics recognition and electric vehicle control systems.