Using haptics as an alternative to visual map interfaces for public transport information systems

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ABSTRACT

The use of public transport for daily commutes or for journeys within a new city is something most people rely on. To ensure users actively use public transport services the availability and usability of information relevant to the traveler at any given time is very important. In this paper we describe an interaction model for users of public transport. The interaction model is divided into two main components – the web interaction model and the mobile interaction model. The web interface provides real-time bus information using a website. The mobile interaction model provides similar information to the user through visual user interfaces, gesture based querying, and haptic feedback. Improved access to transit services is very dependent on the effectiveness of communicating information to existing and potential passengers. We discuss the importance and benefits of our multi-modal interaction in public transport systems. The importance of the relatively new mode of haptic feedback is also discussed.

Keywords: public transit, GPS, haptics, AVL, real-time location, visualisation.

1 INTRODUCTION

One of the main objectives of any public transport system in providing information about its services is to provide relevant information in an accessible way through various kinds of media. The information must be provided while understanding that current or potential users are in different spatio-temporal contexts. Often the same types of information must be provided in different but easy to understand ways. If adequate attention is focused on the user needs then resultant services should match those needs and the public transport operator can deliver an efficient service. Usability is the extent to which a product or service can be used to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use [1]. Public transport operators should try to identify highly user friendly, usable methods, for provision of transit information for passengers. The most important pieces of information provided to transit users are: pre-trip planning services about stops and stations, the available services (buses, trains, trams, etc), accurate arrival times of service vehicles, and also in-vehicle information systems such as expected time of arrival at destination stops, and alerts for when the user is arriving at the destination stop. Additionally the guidance to the actual destination from the destination stop through pedestrian navigation system integration should also be considered thereby offering a complete end-to-end journey planning and assistance system. The increase of smartphone usage [42] means mobile interaction for passengers must also be considered for public transport services.

1.1 OUR PROPOSED MODEL

In this paper, we propose a model for using haptics as an alternative interface for the provision of public transport information to passengers with smartphones. For the purposes of a case-study we have focused on public transportation by bus. However, as we will explain in the paper our model is applicable to any mode of public transport. We chose bus transportation for a number of reasons including: the presence of bus transportation in almost every city in the world, the disruption caused to bus timetables due to buses sharing roads and streets with other motor vehicle traffic, and access to a real-world dataset of bus tracking information. Due to the increase in popularity of mobile interaction our model includes visual interfaces for mobile devices with the addition of haptic-enabled feedback. In any public transport system (in our case bus transportation) a journey begins with planning the trip, finding the nearest location to board the bus, finding the time the bus should arrive, waiting at bus stop, payment before journey, in journey activity, alighting from the bus, and finally moving to the destination. This process has been discussed by many authors [2,3,4,5,6]. In this paper, we describe a public transport interaction model which encompasses both web and mobile interaction techniques. We highlight the need for multimodal interaction techniques of communication and integrate a haptic interaction model for various phases in a user's journey. The structure of the paper is as follows. In section 2 we review literature covering research from both web and mobile interaction techniques for public transport users. In section 3 we describe our public transit interaction model. The system implementation is described in section 4. The user feedback and initial findings are discussed in section 5. We close the paper with some concluding remarks on the integration of haptics for public transportation information provision while providing a summary of possibilities for future work.

2 LITERATURE REVIEW

The traditional format for physical distribution of transit information in the public transit has long been printed media [7]. Transit information in paper form has long been distributed aboard buses, trains and in stations requiring significant human and paper/graphic resources when updates are made. Passengers are always seeking for a printed reference of routes, schedules, or other service information. These materials are typically published by transit agencies and offered freely. The lack of any access cost to passengers to these materials makes them the most popular means of dissemination the transit information. Despite their popularity all transit information disseminated through printed media require the continued publication of printed materials which requires costly and labor-intensive resources. Information about unexpected timetable or service changes cannot be disseminated quickly through printed media. These shortcomings have seen public transit agencies increase their efforts to investigate and develop new replacement media. As an alternative to providing transit information on printed media transit agencies have historically provided free telephone-based support for their passengers [7]. Today it is almost standard that real-time transit information is provided via the Internet and telephone [8]. Public transit agencies have increasingly implemented methods for passengers to access transit information using new media and personal mobile devices. In the recent past interactive-voice-response (IVR) phone interfaces and SMS interfaces were also used for providing real-time transit information. Transit agencies now almost always provide transit information on their web sites. Recently transit agencies have developed the means to distribute real-time information to mobile devices. Real-time public transportation tracking systems combine a passenger accessible web-based/mobile interface with back-end, wireless data-based hardware to continuously transit vehicle location to the Internet and compute estimated arrival times of these vehicles. The use of web interfaces has become the standard way to represent real-time transit data and provide real-time arrival times for services. Overall this has been perceived by passengers as an effort by public transportation agencies to improve quality of service. In the next section we will discuss some literature on web-based interfaces to public transportation information.

2.1 WEB INTERFACES FOR PUBLIC TRANSPORT INFORMATION

Websites have become essential tools in delivering real-time transport information for public transportation agencies. Most transportation agencies have a web site where users can retrieve real-time, static information, including route schedules, vehicle locations, etc. Transit applications can be created as web applications receiving direct input from users via web browsers and then query the transportation agency databases or other sources of information to generate results. Web applications are under constant evolution. Over the past few years there are has been many improvements in client-side web browser technologies which improve the user interface experience. AJAX technologies [9] allow users to dynamically interact with content on the screen to quickly retrieve and display server-side data within the browser view itself. These user experiences enhancements have a great potential to deliver real-time transport information to users. There is now a proliferation of web map Applications Programming Interface (API) [10,11,12] which allow developers to overlay and combine data from different sources and make them appear on a top of interactive web-based maps. Data can be shown as points, such as bus stop locations, or as lines representing service routes. Map-based representations can assist in the visualisation of transportation data. They are particularly well suited to real-time updates. Combined with AJAX technologies the user is not required to interact with the map interfaces to retrieve updates. These updates to the map content can happen automatically on the browser. Icons on a map can represent vehicles and with no action by the user these icons can automatically move representing up-to-minute the last current location of vehicle. One of the first online bus tracking systems, BusView, was developed by Daniel D. et al [13]. This system displays real-time vehicle locations on a digital map for the University of Washington campus community. The system designed an advanced graphical transit information system using data from King Count Metro's existing automatic vehicle location (AVL) system. OneBusAway [14] is a set of transit tools focused on providing real-time arrival information on web-based maps and Internet-enabled mobile devices. This application made use of the increased availability of powerful mobile devices and the possibility of displaying transportation data in machine readable format. The NextBus system [15] uses GPS technology to deliver real time transportation information when and where passengers need it so passengers always know when the next bus will arrive. Each bus is fitted with a satellite tracking system. A web based geographic information system which disseminates the same schedule information through intuitive GIS techniques is described in [16]. Using data from Calgary, Canada, a map based interface has been created to allow users to see routes, stops and moving buses all at once. 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. 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. In a joint project between NUI Maynooth and Blackpool Transport [17], 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 services. The system uses off-the-shelf GPS/GPRS integrated units programmed to transmit location at regular intervals (45 seconds approximately) while the vehicles are in motion. The data is stored on a server and can be visualised through a standard web browser to provide 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 various quality 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 on maps based on the mapping provided by Microsoft Virtual Earth (Bing Maps). 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. The display shows adherence to the published timetable through colour coding. In the next section we provide an overview of the literature related to mobile interfaces as a means of providing public transport information.

2.2 MOBILE INTERFACES FOR PUBLIC TRANSPORT INFORMATION

Applications can be created for smart mobile devices for receiving transportation information. For mobile applications they require the user's current location. Today most smart phones are equipped with built-in Global Positioning System (GPS) receivers. This allows for more user-centric and context-sensitive application development. Mobile applications can take advantage of knowing the smartphone user's current location and then provide information such as the nearest bus stop or the estimated arrival times for the next bus at that stop. These applications bring considerable potential for improvement of the way that people use public transport systems and access information about the services. Shwu-Jing *et al* [19] have developed location aware mobile transportation information services with a map database for a public bus network. Their system provides map-based information of the nearest Mass Rapid Transit (MRT) station, the nearest bus stop of the bus route chosen by the user, and the nearest bus stop of the bus route that can take the user to their chosen destination. Maclean *et al* [20] have shown that a WAP-enabled cell phone is a suitable device for receiving real-time transit information. The development of a transportation vehicle information system that delivers estimated departure times for a large transit fleet is described. Here the physical restrictions of the mobile device were overcome by using an appropriate user interface design. The main issues include the small screen space and difficulty to read small text. The characteristics of the information delivered by the MyBus prediction system are better suited to mobile users such as bus passengers. The overall functionality is to transform a raw transit agency AVL feed into departure-time predictions for display on the MyBus website. The Wireless Markup Language (WML) has been introduced here as the new language for WAP-enabled devices. OneBusAway [14] provides a suite of tools to improve the usability of public transport information. It provides real-time arrival information for Seattle-area buses with details about the design and development of those tools. The main outcomes of their work were – increasing overall satisfaction with public transport, decreased waiting time, increased transit trips per week, increased feeling of safety, increased distance walked when using transit resulting in health benefits as well. Transitr is a transit trip planner (TTP) system from the University of California, Berkeley [21]. The system provides the shortest paths between any two points within the transit network using the real-time information provided by a third party bus arrival prediction system relying on GPS equipped transit vehicles. Users submit their origin and destination points through a map-based iPhone application or through a Javascript enabled web browser. The main functionality provided by the BusCatcher system described by Bertolotto *et al* [22] include: display of maps, overlays of routes plotted on the maps, user and bus location, and display of bus timetables and arrival times. Barbeau, J. *et al* [18,23] have developed Travel Assistance Device software for GPS enabled mobile devices. This system shows the estimated time to arrival of a bus while passengers are waiting at their bus stop. Additionally, the real-time vehicle locations are shown on the maps on the TAD website. Because both of these features are driven by the GPS location of the cell phone and the bus the passenger does not have to supply any additional information such as a bus stop ID or route number in order to receive information. Turunen *et al* [24] present approaches for mobile public transport information services such as route guidance and the supply of timetables using speech based feedback. Bantre *et al* [25] describes an application called "UbiBus" which is used to help blind or visually impaired people to take public transport. This system allows the user to request in advance the bus of his choice to stop and to be alerted when the right bus has arrived. Shalaik et al [5] have shown that transit information collected in real time can be shown on freely available mapping services such as OpenStreetMap (OSM) for tracking and monitoring purposes. The authors developed an application for Internet enabled mobile phones to receive real-time transit information. The system displays the transit information on an OpenStreetMap (OSM) web interface and delivers this information on the Google Android mobile device. Instead of publishing static information on the Internet the development of dynamic transit system applications which can be tailored to mobile devices are rapidly broadening the scope of public transportation information provision. The updated sources of real-time services information, such as feeds from automatic vehicle location (AVL) systems, can be used to create applications that inform public transportation users of the precise location of the transit vehicle they wish to catch or estimate the arrival times of the next vehicle at a particular bus stop.

2.3 QUALITY OF SERVICE FOR PUBLIC TRANSPORT INFORMATION

Qualities of Service (QoS) 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 passenger's point of view"[41]. 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.

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. This indicator is a key performance indicator since it denotes how much time the passengers had to actually wait 'in excess of' what one would have expected them to if the service were perfect. AWT is the average time that passengers actually waited. SWT is the time a passenger would wait, on average, if the services ran exactly as planned during the periods observed. EWT is calculated by subtracting Scheduled Waiting Time (SWT) from Average Waiting Time (AWT) and it is used as the measure of reliability. The greater the EWT is, the less reliable the service [17].

$EWT=AWT-SWT$

The system can automatically generate daily, weekly, monthly and annual reports of EWT for any stop.

In the next section we will describe our public transportation information provision model.

3 PUBLIC TRANSPORTATION SYSTEM INTERACTION MODEL

To improve the public transport quality of service, the passengers must be provided with easy to use, highly accurate, and reliable information retrieval system based on their needs. Our public transportation system interaction model is shown in Figure 1.

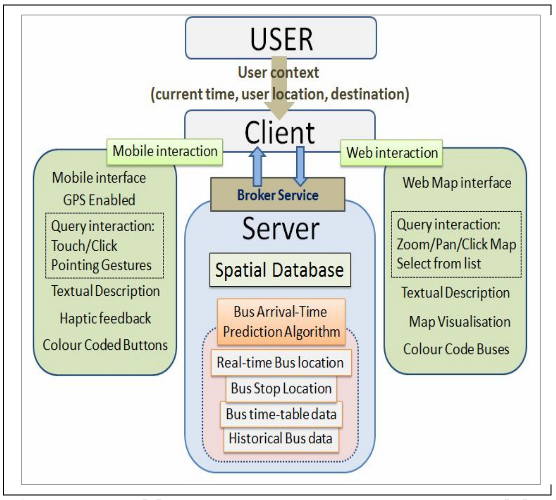

Figure 1: Public transit system interaction model

When using public transportation systems, users engage in a series of high-level activities that include planning, waiting, and moving [29]. Web-based systems for public transportation users are very popular and are of great importance to help users plan their travel and trips. The web based system is provided using a visual map interface displaying locations of bus stops and additional details about walk times to bus stops, bus arrival times, etc. The user interaction with such web-based systems is straightforward when the user is in front of a computer at home or in a closed environment. When the user is on the move and as they walks outdoors such a web-based desktop orientated model may not be ideal. In such cases an interaction system specifically developed for mobile clients is very important. The mobile interaction model in our system consists of a number of subsystems. These interactions between the user and the mobile device ensure activities for all parts of a user's journey. The 3 main phases in a user's journey include – a) pre-journey information about bus stop locations and bus arrival time, b) in-bus information system which provides assistance about the destination stop (using alerts/notification systems) to ensure user does not miss their stop and/or in-bus information about points of interest along the route if the user is a tourist and c) The 'pedestrian navigation phase', to get to the bus stop from the current user location and/or get from the destination bus stop to the actual final user destination (ie a specific shop, tourist attraction, etc).

Updated sources of real-time services information generated by automatic vehicle location (AVL) systems are used to create real-time bus tracking applications. A spatial database stores the road network and all the points of interests in the region. The location of bus stop locations and route geometries are stored in tables within this spatial database. A separate table is created in the spatial database to store the real-time location of the buses connected using the AVL. This information is used to provide the user with real-time information about arrival time and reduces passenger wait time at bus stops. The users want different kinds of information presented in different formats in a trip to suit their needs and the kind of user they are. The user context is also integrated into the system.

3.1 PRE-JOURNEY INTERACTION

At the start of the journey the user needs information about – which is the ideal bus stop to go to [27], when does the next bus leave in real-time [5] and how to get to the nearest bus stop and how long will it take to get there [4]. In Figure 3, the user's current location is taken to be L and the user's actual destination is set to be D. The expected arrival time of the next bus at the origin bus stop, B_o is to. The expected time the bus will reach the desired destination bus stop (B_d) is t_d. The time taken to walk from the user's current location (L) to the origin bus stop (B_o) is t_{wo}. Based on the time taken to walk to the bus stop, B_o the user is provided with information about the bus arrival time and the system advises the user about the appropriate actions to take. The arrival time of the bus at the origin bus stop B_o is t_o. If the user has a smartphone and is new to a city or is unaware about the bus stop to go to they can choose the 'point-to-query' element of the system where the user selects the destination and then scans the area to find the general direction of the bus stop B_o. The "scan" operation is performed as follows.

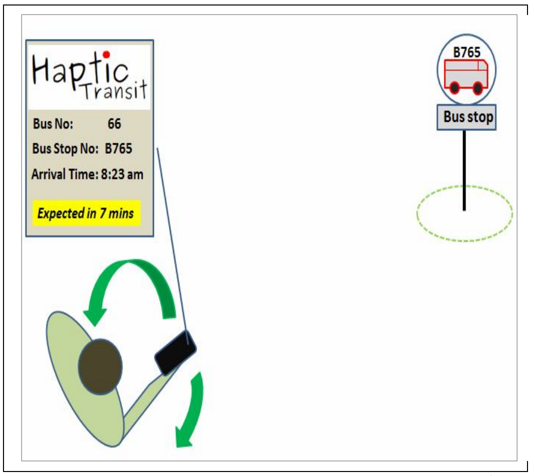

Figure 2: The user 'scans' the area to find the location of the origin bus stop, B_o

The user holds the phone parallel to the ground and moving it around them as shown in figure 2. The compass and the location information via GPS will help query the system and provide directional information to the bus stop. This feedback is provided by textual description with number and arrival time at the bus stop along with the walking distance and time taken to reach the bus stop. Haptic feedback in the form of vibration alarm is used to provide the user with information of the general direction of the bus stop when the user points the smartphone in the direction of the bus stop, B_o. Thus, this minimises the interaction with the visual interface while the user walks towards the bus stop thus ensuring faster travel to the bus stop. The user gets real-time information about the arrival time of the ideal bus to take to get to the bus stop B_d which is nearest to the actual destination (D) of the user. This sub-system within the public transit system for mobile provides the user with information about the bus stops, the arrival time of the bus at the origin bus stop based on the real-time location of the buses and also navigation assistance to get from the user's current location (L) to the bus stop B_o.

3.2 IN–BUS INTERACTION SYSTEM

HapticTransit is a tactile feedback based alert/notification model of a system which provides spatial information to the public transport user [28]. The model uses real-time bus location with other spatial information to provide user feedback about the user journey. The system allows users make better 'in-bus' use of time. It lets the user be involved with other activities and not be anxious about the arrival at the destination bus stop. Our survey shows a majority of users have missed a bus stop/station, and thus this system ensures such an information system can be of great advantage to certain user groups. The vibration alarm is used to provide tactile feedback. Visual feedback in the form of colour coded buttons and textual description is provided. This model on further research can provide the platform to develop such information systems for public transport users with special needs – deaf, visually impaired and those with poor spatial abilities.

The HapticTransit system provides assistance to the user to indicate when their destination bus-stop is approaching. Instead of providing the user with a map based system which provides detailed information which may/may not be of use to the user instead the users are informed using haptic feedback when their stop is approaching. This gives them enough time to prepare to disembark from the bus [28]. Along with the destination, the user also selects the information mode – destination only or tourist mode. This provides additional assistance with information/alerts about POIs along the way using haptic/visual feedback. The arrival time prediction algorithm is used to ensure that the expected arrival time at their destination bus stop is provided accurately. There is a broker service running on the server responsible for calculating the proximity of the user to their destination bus stop. The visual interface on the device provides the user with the time and distance to the destination stop. The system computes the time and distance to the user's destination stop and gives a subtle alert to the user when they are nearing the destination. This alert is provided by a low frequency vibration feedback. The alert is triggered when the user reaches the stop just before the destination stop. This enables the user to prepare to disembark the bus when the next stop is reached. The intensity of the vibration alert on the mobile device increases as the bus is approaching the desired stop. As an alternative the colour-coded button on the visual interface provides the user with information to represent far, close and very close using the red, amber and green colours. An amber button displayed indicates that the user is very close to their destination stop. A red button indicates that the user has reached the penultimate stop. Green indicates that the user still has some distance to travel. The HapticTransit model incorporates additional feedback along the route to improve the ‘in-bus’ interaction. If the user is a tourist and has selected the option of being informed when they are passing or are nearby an important POI along the way. The user is alerted by a unique vibration feedback corresponding to being close to a landmark/POI along the route. Along with haptic feedback visual feedback with name and description of the landmark POI is provided. The real-time bus arrival time algorithm computes the arrival time of buses at various bus stops [5]. The haptic feedback ensures that the user is not required to constantly interact or looking at the mobile device for assistance during the journey. This allows the user to enjoy the trip and will be informed about the destination stop and/or important landmarks along the route.

The model of the route is stored in the spatial database. Consider a route R is an ordered sequence of stops {B_o, B_0, ..., B_n, B_d}. The destination bus stop on a route is given by B_d and the terminus or destination stop is given by T_d. Each stop B_i has attribute information associated with it including: stop number, stop name, etc. Using the timetable/real-time bus arrival information for a given journey R_i along route R, we store the timing for the bus to reach that stop. The number of minutes it will take the bus to reach an intermediate stop B_i after departing from B_o is stored. The actual time of day that a bus on journey R_i will reach a stop B_i along a given route R is also stored. Figure 3 illustrates this with a sample route where t_0, t_1, etc are time taken to reach stop B_1, B_2, etc respectively. Other modes of public transportation including: long distance coach services, intercity trains, and trams can be easily incorporated by extending this model.

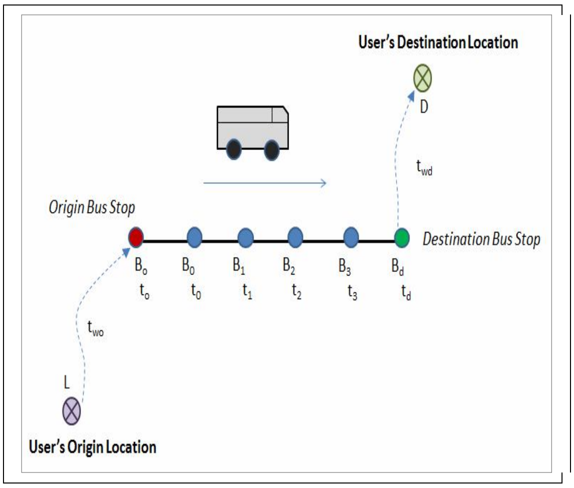

Figure 3: An example of how a route and the stops along that route are stored in the spatial database.

3.3 Pedestrian navigation phase

There are two stages in the trip where the user needs pedestrian navigation assistance. The first stage is getting from their origin location to the origin bus stop and then from the destination to the actual user destination. The time taken to travel from user’s origin, L to the origin bus stop B_o is t_{wo}. This is also shown in Figure 3. The user reaches the destination bus stop (B_d) in time t_d. The final phase of travel using public transport is the pedestrian navigation stage where the user needs to get from the destination bus stop to the actual destination (D). The time taken to travel from the destination bus stop B_d

to the actual destination, D is t_{wd}. The user must specify the requirements of their journey and provide information about their destination. The user chooses which mode of pedestrian navigation they want to use – visual or haptic feedback. Within the haptic feedback option the user can choose from two pedestrian navigation system options: the waypoint by waypoint shortest path information using haptic feedback (HapticNavigator) or the destination pointer system where the user is alerted (via vibration alarm) of the general walking direction of the destination (HapticDestinationPointer) where the user has to make decisions on the path to follow [30]. As shown by various authors [31,32,33] haptic feedback can be used at times when the use of other senses like hearing or vision is inappropriate. Users can navigate between any two locations using subtle haptic feedback [33,34,35,36]. The in-bus journey time, T_j is the difference between bus arrival time (t_d) at the destination bus stop and the bus arrival time (t_o) at the origin bus stop and this is represented as, $T_j = t_d - t_o$. Thus the total trip time, T is the sum of - the walking time from user's origin to the origin bus stop (t_{wo}), the in-bus journey time (T_j), and the walking time between the destination bus stop and the actual user destination (t_{wd}). Thus we represent the total trip time, $T = t_{wo}+T_j+t_{wd}$.In the next section we discuss the system implementation.

4 SYSTEM IMPLEMENTATION

The real-time location data of buses in Blackpool Transport were used to develop the web interaction interface and develop the bus arrival time prediction algorithms. 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 in a database server and can be visualised through a standard web browser to show views representing current locations of vehicles in close-to-real-time. For implementing our system using a visual map interface for desktop interaction, we developed a public interface that can display and update vehicle locations in Microsoft Virtual Earth web mapping API. The mapping API provides us with the functionality to provide 2D and 3D map visualizations. These visualisations can display bus vehicle adherence to the published timetable through colour coding as shown in figure 5. Figure 4a shows real-time locations of buses pictorially, textually and, using the facilities provided by the Microsoft Virtual Earth API. Transit user has options to switch between bus routes. A list of bus stops allows transit user to query about the next bus(s) for a stop of interest. Other options are available for transit users to allow bus route or stops to be displayed on the map. Through this interface, transit users can access many other services such as Trip planning service, Arrivals Times for all buses or allocate a particular bus on map. In addition to showing currents location of buses with real-time information of transit vehicles, Figure 4b provides transit operator with options of efficient tools to manage and evaluate transit vehicles performance. Tools for calculating QoS and summaries are provided. Bus bunching can also be detected on map or though the graphical view. Tools for reporting facilities are provided to generate on-line or off-line reports. In addition, tools are provided to visualise vehicle behaviour over time and to calculate various metrics and summaries. A PHP script running on the server acts as the broker service between the server and the client. On the database server the bus arrival time prediction model allows the applications to determine, with greater accuracy, the arrival time of bus at bus stops. This will reduce the passenger wait time and thus improve the overall quality of service. The mobile interfaces for three different kinds of interactions were developed – 1) displaying real-time public transport information 2) querying using the pointing gestures for bus stop location and real-time data and 3) pedestrian navigation phase during commuting using public transport. The applications were developed using the Android SDK. On running the applications, through the broker service (PHP script), the application accesses the database with real-time bus data and bus stop locations and provides the user with details about expected arrival time, time taken to walk to destination, the direction of the origin bus stop etc. To alert the passenger when they reach their destination, the in-bus haptic enabled mobile application provides the user with the expected arrival time at destination. Colour coded buttons representing distance to destination or haptic feedback when the user is nearing their destination provides the user with enough time to get ready to disembark from the bus. Here if the button colour changes to red, it shows that the user is at or very close (within a few metres) from the destination stop. The green colour button shows that the user is atleast 2 stops away from the destination bus stop while amber colour button shows that the next bus stop is the destination bus stop. The user can choose the 'tourist' mode to be notified using haptic feedback when the bus crosses points of interests along the route. The user can thus mark and identify these locations for visiting later. The HapticDestinationPointer integrates the digital compass and the GPS location in the phone and thus provides haptic feedback when the user points in the direction of the destination location.

5 FINDINGS AND REMARKS

To understand how people use public transport, both within their own city and as a tourist in other cities where they are not aware of their destination bus stops, a group of users (50) were sent an online survey form.

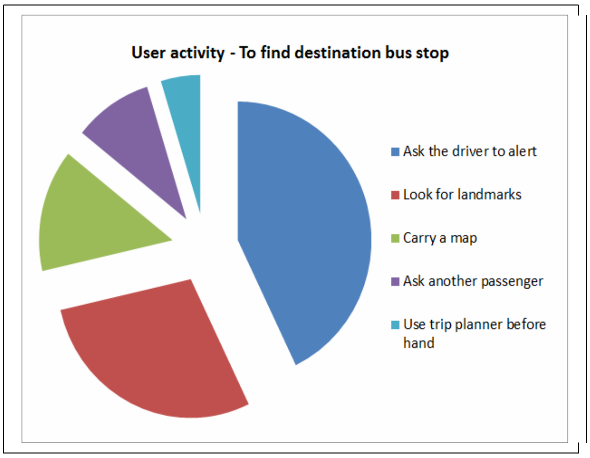

Figure 6: User responses to our survey about public transportation usage.

We received 45 responses. From all of the responses 40 people said they would ask the driver to alert them of their destination stop. The second most popular choice of finding the destination bus stop was to lookout for landmarks. A small percentage of users said they would use a trip planner before the trip. The results are presented in figure 6.

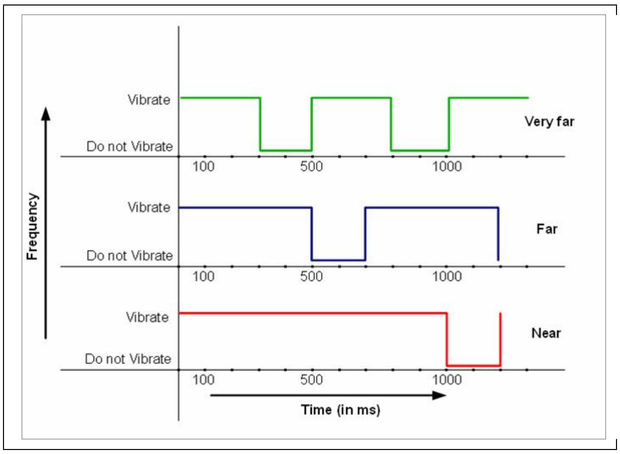

Figure 7: Vibration feedback to provide distance information when pointing in the direction of the destination

To investigate if users can successfully walk from a bus stop to the destination using haptics feedback, the HapticDestinationPointer [31] was used in some user trials. The users, provided with the application and using haptic-feedback, were successful in reaching the destination using haptic feedback when pointing in the direction of the destination. The haptic-feedback was provided using the vibration alarm with varying frequency and patterns. Figure 7 represents the vibration pattern used to represent distance information when pointing in the direction of the destination.

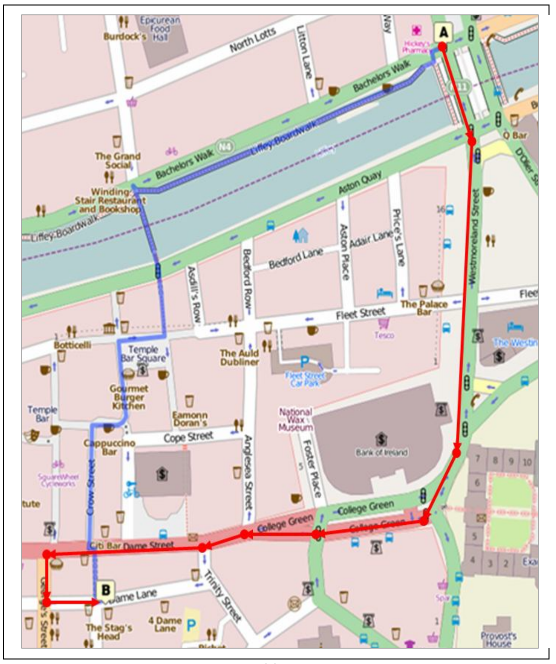

Figure 8: Route 1 - Different path than the shortest path

From our initial trials we see that on 3 different routes, the user chose routes that were (i) ‘completely different from’ (Figure 8), (ii) ‘almost similar to’ (Figure 9), and one that was (iii) ‘exactly the same as’ (Figure 10) the shortest path as provided by the Cloudmade routing service [37] from A (bus stop) to B (actual user destination).

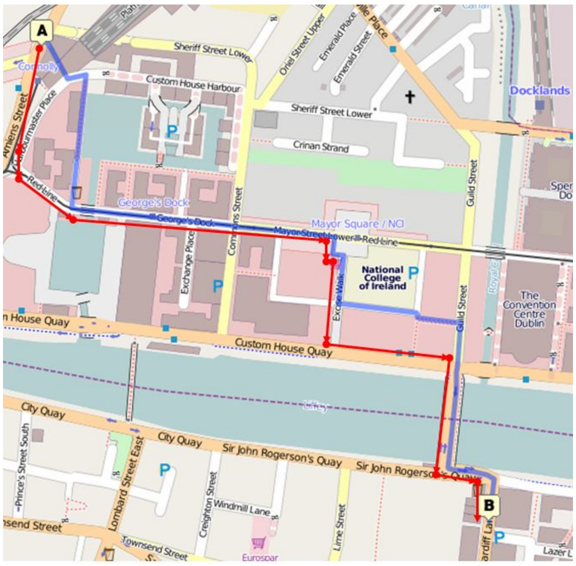

Figure 9: Route 2 - Almost similar path to the shortest path

The paths taken by the user based on the haptic feedback is plotted and we notice that on all three routes, the user stayed on major streets for most of the travel in an unfamiliar location before turning towards the exact destination location.

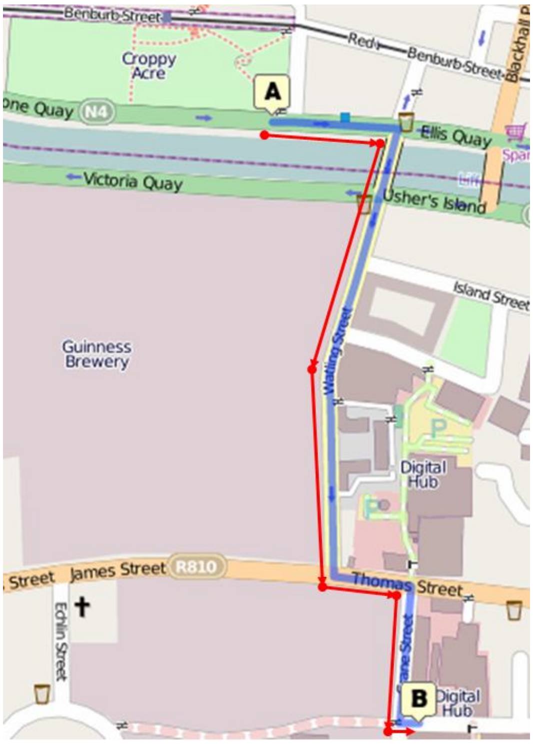

Figure 10: Route 3- Exactly similar path to the shortest path

Route 1 as shown in Figure 8 was the most complex route among the 3 as it was through the most dense and crowded parts of the city. The time required for completing route 1 as suggested by the routing service was 10 minutes and the user reached the destination in about 12 minutes. According to the routing service, it would take the user 15 minutes to complete route 2 (Figure 9), but using haptic feedback the user completed it in 13 minutes. This route consisted on long stretches and small bends in the path. The long stretches allowed the user to move much faster. The route 3 (as shown in figure 10) was the simplest route as the actual roads to take were aligned along the general walking direction and thus meant the user did not have to change the general walking direction to reach the destination. Thus the shortest path and the path taken by the user based on haptic feedback is the same with no substantial difference in time taken to complete the task. We compare the distance travelled and time taken to travel that distance based on the (i) routing service and based on (ii) the haptic feedback enabled navigation test as carried out by the user. The summary is provided in table 1. We see that although there isn't very significant difference in time taken/distance travelled to complete the task, the overall experience while navigating can be improved using haptics as it ensures *heads-up* interaction. The main positive outcomes from these trials are that the navigation was based on purely the user's judgment and the user was able to walk faster as it involved heads-up interaction with the real world as compared to the interaction with the mobile device (for the shortest path) which normally slows the user down [30].

Table 1: User navigation performance using haptic feedback compared to the routing service.

Route No.	Distance Travelled (metres)		Time Taken (mins)	
	Routing Service	Haptics	Routing Service	Haptics
1	860	890	10	12
2	1210	1220	15	13
3	720	720	8	7

6 CONCLUSION AND FUTURE WORK

Public transportation systems are among the most ubiquitous and complex large-scale systems found in modern society. There is a need for easy to use public transit information systems. There are certain groups of passengers such as the visually/mobility impaired, people with cognitive disabilities, senior citizens, and out-of-town visitors who might not be able to use current types of public transit information systems. Providing them with different kinds of interaction based mobile systems can be useful. We have seen here that haptic interaction can be useful for out-of-town passengers and this work can be extended to prepare smart interfaces to help the mobility impaired. To reduce the cognitive burden alternate means of information retrieval and feedback needs to be developed [38]. This paper has given an overview of the interaction model to access public transit information. The haptic-feedback based system assists in providing location based information in a subtle for passengers using public transport (specifically buses). The main benefit of this system is that passengers can now use the system on their mobile devices to reduce the anxiety about finding the nearest bus stop and the actual arrival time of buses and if an out-of-town visitor, missing their destination stops. The vibration alarm provided by the system helps notify passengers about the bus approaching their destination bus stop. The system also provides pedestrian navigational assistance to help users get from origin to the nearest bus stop and from the destination bus stop to the actual user destination. Enhancing the "in-bus" experience of the user is achieved by reducing interaction with visual/audio notification interfaces on the mobile device. The passenger can enjoy the trip and be involved with other activities while in transit. Another aspect of public transportation related to this work is theft on public transport as listed by a number of authors [39,40]. Not all users perceive and interpret visual information in the same way. We have seen in the results in this paper that we can improve the experience for users who use public transport information system by integrating haptic feedback as a modality. This can easily be extended to work with other public transport systems like trains/trams. In the three routes that the user had taken, we see different paths and navigation time. We wish to compare this performance with the actual route complexity and thus hope to draw some interesting results. As future work more user trials based on user profile like age, sex, spatial abilities, disabilities will be tested to understand how different people react to multimodal interaction systems on mobile. A complete door to door travel planner using haptics/gesture based interactions will form a central focus for future work.

ACKNOWLEDGEMENT

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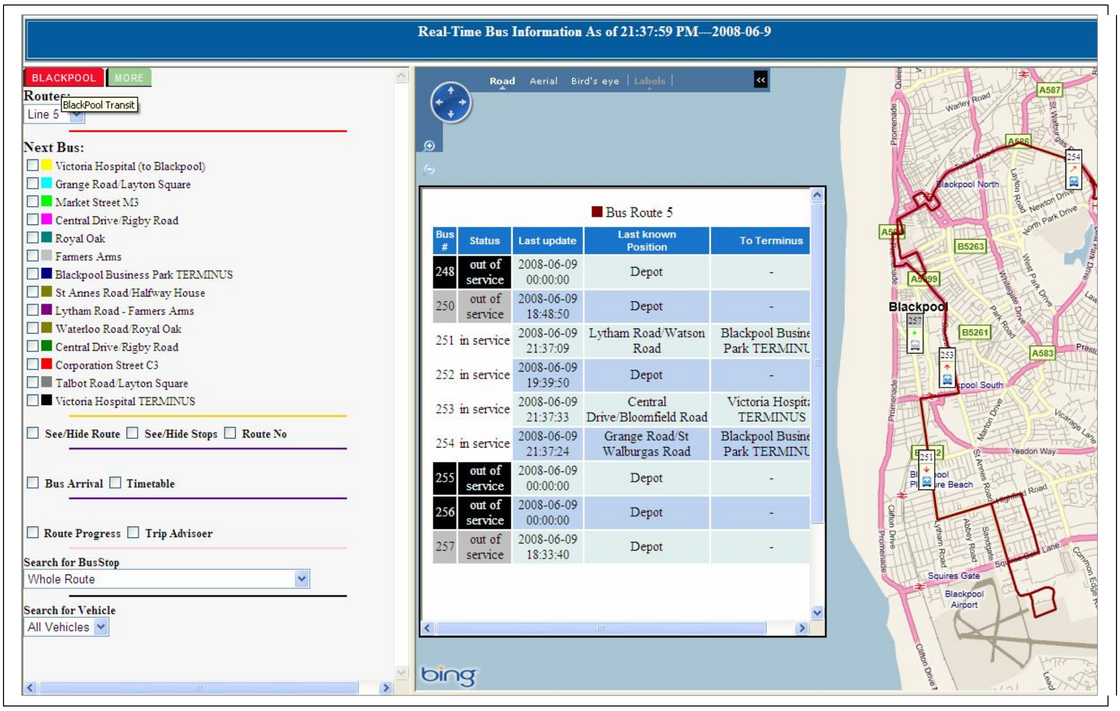


Real-Time Bus Information As of 21:37:59 PM—2008-06-9

Routes: Line 5 BlackPool Transit

Next Bus:

- ☐ 🟨 Victoria Hospital (to Blackpool)
- ☐ 🟦 Grange Road/Layton Square
- ☐ 🟩 Market Street M3
- ☐ 🟪 Central Drive/Rigby Road
- ☐ 🟦 Royal Oak
- ☐ ⬜ Farmers Arms
- ☐ 🟦 Blackpool Business Park TERMINUS
- ☐ 🟫 St Annes Road/Halfway House
- ☐ 🟪 Lytham Road - Farmers Arms
- ☐ 🟫 Waterloo Road/Royal Oak
- ☐ 🟩 Central Drive/Rigby Road
- ☐ 🟥 Corporation Street C3
- ☐ ⬛ Talbot Road/Layton Square
- ☐ ⬛ Victoria Hospital TERMINUS

☐ See/Hide Route ☐ See/Hide Stops ☐ Route No

☐ Bus Arrival ☐ Timetable

☐ Route Progress ☐ Trip Advisoer

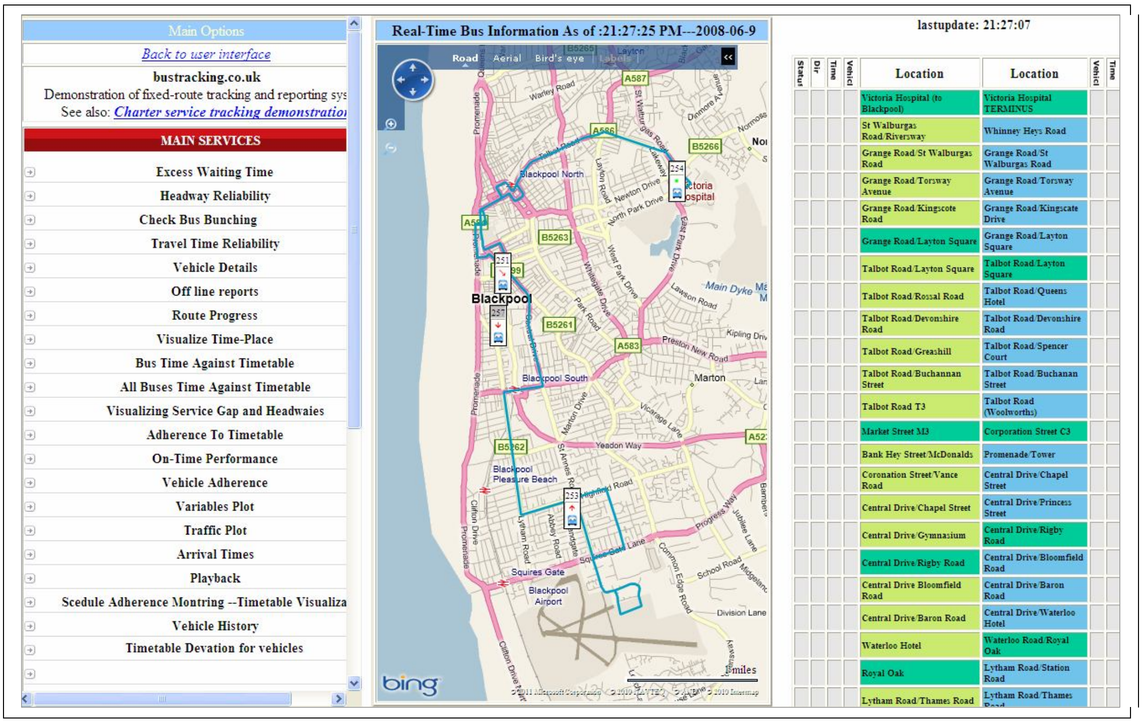
Search for BusStop: Whole Route

Search for Vehicle: All Vehicles

🟥 Bus Route 5

Bus #	Status	Last update	Last known Position	To Terminus
248	out of service	2008-06-09 00:00:00	Depot	-
250	out of service	2008-06-09 18:48:50	Depot	-
251	in service	2008-06-09 21:37:09	Lytham Road/Watson Road	Blackpool Busine Park TERMINU
252	in service	2008-06-09 19:39:50	Depot	-
253	in service	2008-06-09 21:37:33	Central Drive/Bloomfield Road	Victoria Hospita TERMINUS
254	in service	2008-06-09 21:37:24	Grange Road/St Walburgas Road	Blackpool Busine Park TERMINU
255	out of service	2008-06-09 00:00:00	Depot	-
256	out of service	2008-06-09 00:00:00	Depot	-
257	out of service	2008-06-09 18:33:40	Depot	-

Figure 4a: The Public interface showing updating textual display plus moving locations on Microsoft Virtual Earth.



Status	Dir	Time	Vehicl	Location	Location	Vehicl	Time
				Victoria Hospital (to Blackpool)	Victoria Hospital TERMINUS		
				St Walburgas Road/Riversway	Whinney Heys Road		
				Grange Road/St Walburgas Road	Grange Road/St Walburgas Road		
				Grange Road/Torsway Avenue	Grange Road/Torsway Avenue		
				Grange Road/Kingscote Road	Grange Road/Kingscate Drive		
				Grange Road/Layton Square	Grange Road/Layton Square		
				Talbot Road/Layton Square	Talbot Road/Layton Square		
				Talbot Road/Rossal Road	Talbot Road/Queens Hotel		
				Talbot Road/Devonshire Road	Talbot Road/Devonshire Road		
				Talbot Road/Greashill	Talbot Road/Spencer Court		
				Talbot Road/Buchannan Street	Talbot Road/Buchanan Street		
				Talbot Road T3	Talbot Road (Woolworths)		
				Market Street M3	Corporation Street C3		
				Bank Hey Street/McDonalds	Promenade/Tower		
				Coronation Street/Vance Road	Central Drive/Chapel Street		
				Central Drive/Chapel Street	Central Drive/Princess Street		
				Central Drive/Gymnasium	Central Drive/Rigby Road		
				Central Drive/Rigby Road	Central Drive/Bloomfield Road		
				Central Drive Bloomfield Road	Central Drive/Baron Road		
				Central Drive/Baron Road	Central Drive/Waterloo Hotel		
				Waterloo Hotel	Waterloo Road/Royal Oak		
				Royal Oak	Lytham Road/Station Road		
				Lytham Road/Thames Road	Lytham Road/Thames		

Figure 4b: The operator interface showing updating textual display plus moving locations on Microsoft Virtual Earth.

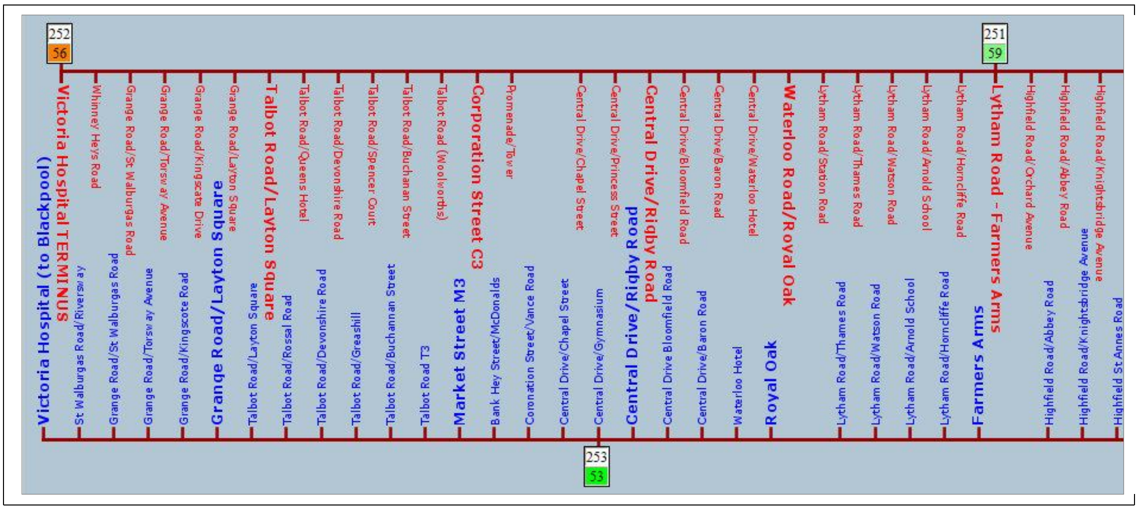


Figure 5: Route diagram visualization (colours indicating adherence to timetable)