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HapticTransit: Tactile feedback to notify public transport users

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ABSTRACT

To attract people to use public transport, efficient transit information systems providing accurate, real-time, easy-to-understand information must be provided to users. In this paper we introduce **HapticTransit,** a tactile feedback based alert/notification model of a system, which provides spatial information to the public transport user. The model uses real-time bus location with other spatial information to provide feedback about the user as their journey is in progress. The system allows users make better use of ‘in-bus’ time. It allows the user be involved with other activities and not be anxious about the arrival at their destination bus stop. Our survey shows a majority of users have missed a bus stop/station whilst undertaking a transit journey in an unfamiliar location. The information provided by our 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 also provided. This model forms the basis for further research for developing information systems for public transport users with special needs – deaf, visually impaired and those with poor spatial abilities.

KEYWORDS

haptic, pubic transport, user experience, modality, location based service.

1 INTRODUCTION

Governments are trying to encourage people to use public transport. A journey for a user of public transport involves various phases which are combined to make up their journey. A journey begins with: with planning the trip, finding the nearest bus stop 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 optionally providing some post journey feedback. This process has been discussed by many authors [1,2,3,4,5,6]. There are already many innovative systems to assist passengers in planning their journey on public transportation. One such example is a navigator service for public transport networks that uses a RFID based ticketing system Here the user selects their destination and then text messages are sent by the system to the user to guide them in real time [7]. In the past we have investigated provision of web based graphical interfaces for users to visualize real-time bus data by developing a journey planner combining pedestrian navigation with real-time bus tracking [4]. This is also delivered on mobile devices. As stated by Shalaik et al [5] the real-time data about bus arrival time at a particular bus stop is what the user is really interested in [5]. Much research for visually impaired public transport users is focused on pre-journey solutions, journey planning and 'at the bus-stop' real-time information [8].

Although transit agencies continuously work to improve on-time performance, such efforts often come at a substantial cost to ensure public transport use. One inexpensive way to combat the perception of unreliability from the user perspective is real-time transit information signage. Improvements to information related issues may encourage increased use of public transport. A system that provides various user groups with information about current location and time to the next stop while 'in-transit' is required. Such systems should also ensure that they provides information/feedback to the passengers and allocates sufficient time to allow them to disembark from the vehicle [4]. Various multimodal systems have been developed to meet such needs. A Travel Assistance Device (TAD), that aids transit riders with special needs in using public transportation, provides the passenger with customised real-time audio, visual and tactile prompts for exiting the transit vehicle by announcing actions such as `Get ready`` and `Pull the cord now!` [9]. These `in-bus' visual and/or auditory feedbacks [10] are the most popular methods for providing information

One of the key drivers of this paper is the use of tactile stimuli on mobile devices to alert passengers of 'in-bus' information. Tactile stimuli ('haptics') are used as an alert/notification system for informing the mobile phone users of incoming text messages or phone calls on their mobile devices. Haptics can also be integrated into systems where the location of the phone is known. The goal of this paper is to integrate haptics into the delivery of real-time 'in bus' information for public transit passengers. People using public transport systems need two kinds of basic information - (1) when, where, and which bus/train to board, and (2) when to disembark the vehicle. Haptic feedback integration into mobile GIS applications has many benefits [11]. Tactile feedback to provide pedestrians with navigation cues has shown great potential [12]. In Jacob et al [13] the integration of haptics into public transport systems ensures feedback in the form of the vibration alarm to alert the user about the arrival at their desired destination. Haptics enabled alert systems can also be used for pedestrians who are given subtle feedback when they are within specific distances of desired POIs (Points of Interest) which they can or cannot physically see ahead/around them. This can also be used by businesses to ``check-in'' to the user's device to advertise an offer or deal and subsequently the users get alerts on their mobile device.

The major motivations of this study are as follows: 1) Assistance: Prevent users from missing stops, 2) Information: provide real-time information which is found to be severely lacking in the transport networks of most cities, 3) Guidance: help tourists using public transport where routes are complex and difficult to understand, and 4) Personal security: development of mobile software applications which will not be required to be 'on display' in the user's hands throughout the journey.

The paper is organized as follows. In section 2 we review literature about various aspects of public transport users – pre-journey behavior, real-time information and wait time, multi-modal communication techniques, in-transit display systems and the use of haptics as a modality for providing information to the user. Section 3 describes the haptic interaction model in the system and describes the various elements of the system. In section 3 the implementation of the HapticTransit alert/notification system is also provided. We discuss the results and key findings from the user survey and initial user trials in section 4. This is followed by some concluding remarks and the future direction of this work.

2 LITERATURE REVIEW

Most of the research work related to public transport systems usage is related to pre-journey solutions, which is either journey planning [4] or provision of real-time/time table information about buses at the bus stop and/or mobile devices[3,5,6].

2.1 Pre-journey behavioral intentions

The study by Fujii and Van [14] explores the behavioral intention to use the bus while considering the perceived quality of bus service, problem awareness, and moral obligation to use public transportation in Ho Chi Minh City (HCMC), Vietnam. Psychological factors related to various aspects of bus usage yielded four factors: moral concerns, negative expression, quality perception, and social status. Thus good quality information system and services can also ensure positive response and increased use of public transport. Dynamic 'at-stop' real-time information displays are becoming popular in modern public transport across the globe. Reactions and attitudes towards these systems are very positive. But there is a need to provide a comprehensive framework of the possible effects that these types of displays can have on customers. There are seven main effects and these are described by Dziekan and Kottenhoff [15]: (A) reduced wait time, (B) positive psychological factors, such as reduced uncertainty, increased ease-of-use and a greater feeling of security, (C) increased willingness to pay, (D) adjusted travel behavior such as better use of wait time or more efficient traveling, (E) mode choice effects, (F) higher customer satisfaction and finally (G) better overall image. The *OneBusAway* transit traveler information system [2] provides real-time next bus countdown information for riders of King County Metro, Seattle, USA, via website, telephone, text-messaging and smart phone applications.

2.2 Real-time information and wait time

Although previous studies have looked at traveler response to real-time information, few have addressed real-time information via devices other than public display signs. For this study, researchers observed riders arriving at Seattle-area bus stops to measure their wait time while asking a series of questions, including how long they perceived that they had waited. The study found that for riders without real-time information, perceived wait time is greater than measured wait time. However, riders using real-time information do not perceive their wait time to be longer than their measured wait time. Watkins et al [2] found in their study that mobile real-time information reduces not only the perceived wait time but also the actual wait time experienced by customers. Real-time information users in the study wait almost 2 minutes less than that arriving using traditional schedule information. Mobile real-time information has the ability to improve the experience of transit riders by making the information available to them before they reach the stop. The *UniShuttle* application [16] tracks public transport vehicles in a ticketless and partially unscheduled bus network. Passengers have the ability to view bus schedules in real-time. Koskinen and Virtanen [3] present concepts and experiences of using public transport real time information in personal navigation systems. The information needs are discussed from a point of view of the visually impaired. Three cases are presented: (1) using real time information about the bus to help the visually impaired to board and leave a bus at the right stop, (2) boarding a train and (3) following a flight status. The research has been done in a national NOPPA (Personal Navigation and Guidance for the blind) project piloting a guidance system for the visually impaired. The goal of the project has been navigation without additional installations to physical infrastructure. Zenker and Ludwig [17] describe a system that calculates a route to the next best public transport stop, which means of transportation to take, where to change transportation, and how to walk from the last stop to the goal location. Departure times are displayed to the user and they are informed, i.e. if they have to hurry to catch a bus.

2.3 Multimodal communication techniques

Researchers have investigated multimodal communication with users of public transport. TravelMan [19] is a multimodal mobile application for serving public transport information in Finland. The application includes different kinds of input and output modalities (speech input and output, a Graphical User Interface (GUI), and contextual predictive text input). The main design principle of the TravelMan application was to ensure that different modalities can function in tandem with each other and support multiple, simultaneous or alternative modalities. The main output modalities used here (speech and GUI), were designed to work independently or simultaneously. Results from their related work [20] suggest that speech input outperforms other input methods, even with high error rates and slow response times. The authors however find that contextual predictive text input was the preferred method. Mobile devices, such as smartphones and personal digital assistants, can be used to implement efficient speech-based and multimodal interfaces [6]. The authors state that for special user groups (such as visually impaired people) to access specific information when using public transport, speech-based mobile applications is the only possibility. Their system offers services such as route guidance and service disruption information (e.g. roadwork information). The system is designed to function as an information aid for visually impaired people in everyday life and it contains several other services and features in addition to public transport information services. The external routing system and database returns, for each complete query, a detailed set of route information in XML format. The MUMS system, describedby Hurtig and Jokinen [18], is a mobile PDA-based route navigation system which allows the user to query public transportation information using spoken language commands and pen-pointing gestures on a map. The system responds with route information in speech and graphical output. The authors find that tactile systems such as input and interaction systems can benefit from speech in different ways: their main interaction mode is not regarded as language-oriented communication so speech can provide an additional value for the tactile interface users. The evaluation results of a multimodal route navigation system that allows interaction using speech and tactile/visual modes are presented. Various functional aspects of the system were studied, related especially to the I/O-modalities and their usage as means of communication. The authors compared the users' expectations before the evaluation with their actual experience of the system, and found significant differences among various user groups. Multimodal systems are usually considered advantageous over unimodal systems as they provide flexibility and give a more natural feeling to interaction. All the users, however, responded unanimously that a system with both speech and tactile/visual I/O-possibilities is preferable to a unimodal one [22]. The aim of the RAMPE project [23] was to design and experiment a system based on a light hand-held device for the assistance and information of blind people so that they can increase their mobility and autonomy in public transport. This system offers detection abilities and guidance in the spatial area surrounding the stop point and delivers relevant information using Wifi from these fixed stations to the mobile device of the user. Hurtig [24] describes a system that provides route information and navigational instructions via synthetic speech and map graphics. Users are free to use any chosen combination of input and output modalities, resulting in flexible and efficient task-based interaction. Hurtig [24] states that multimodality seems generally to improve performance, but mainly in spatial domains, such as map and navigation applications. Following on from this Hurtig and Jokinen [25] demonstrate a Multimodal Route Navigation System which combines speech, pen, and graphics into a PDA-based multimodal system [25]. Accessibility information for public transport users have also been an area where interesting research has been seen [26,27]. When people with reduced mobility (e.g. due to a disability, luggage, frailness) want to use public transport they face the problem of finding barrier-free travel that correspond to their special needs (eg: wheelchair access, ramps etc) [28]. An approach to adaptive route directions based on a combination of turn-by-turn directions and destination descriptions is presented in the work of Richter et al [29]. Work towards non-static, adaptive route direction services is provided here where instead of relying on information on a wayfinder's previous knowledge, here a wayfinder can adjust the type and detail of the presented information via dialog. The BAIM plus by Buhlet et al [30] is a system that provides information about schedules, vehicles and stations. This journey planner has a query interface with different user profiles (e.g. no limitation, wheelchair user, restricted in walking) which can be chosen in order to get customized suggestions for barrier-free travel connections as well as information about the accessibility of facilities to be used during the journey. Goto and Kambayashi [1] have developed a passenger support system for the public transport system based on information integration and dynamic personalization in multi-channel data dissemination environments for the visually impaired. Foth and Schroeter [31] investigates opportunities to enhance the experience of commuters in all aspects of their journey (planning the trip, waiting at bus stop, payment before journey, in journey activity, post journey feedback. Instead of focusing on efficiency and speed of each of these steps their focus is on making the public transport experience more enjoyable and meaningful, in particular through the innovative combination and interaction of technologies such as mobile devices and urban screens, real-time data and sensor networks, as well as social media and Web 2.0. Bantre et al [21] 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. Turunen et al [33] meanwhile presents approaches for mobile public transport information services such as route guidance and push timetables using speech based feedback.

2.4 In-transit information systems

Darren et al [10] focuses on 'in-transit' information provision, which could provide benefits to a wide range of user groups (eg: visually impaired, tourists). This work deals with the encouragement and promotion of the use of buses in Edinburgh, especially among visually impaired users and tourists / migrant workers. The authors report the key issues these groups encounter when using buses, and introduces Visual and Vocal Information Platform (VVIP) as a solution. VVIP is a dynamic location based system which offers passengers a visual and auditory display of where the bus is in relation to its next stop facilitating and improved bus travel experience. The Scottish Executive published research on how to improve public transport for disabled [32]. The most interesting finding was from the research carried out with visually impaired individuals who suggested that information in Braille or audio may encourage the use of public transport, and one of the main issues was "*bus drivers forgetting to inform passengers that they have arrived at their destination stop*". Thus the importance of providing certain user groups with information about current location and time to next bus stop was important.

Thus there is the need to have a system that provides these user-groups with information about current location and time to the next stop. The system should also ensure that it gives information/feedback to the passengers and give them sufficient time to disembark from the vehicle [10]. To achieve this, the authors use an auditory display that would give information about what the next stop is and length of time to next stop, therefore, making bus use as easy and comfortable as possible for the visually impaired. The authors [10] introduced localized visual interfaces in the buses that could assist passengers who have hearing disabilities (auditory problems) and also by supplying the same information using audio feedback. Information on tourist attractions, which are in close proximity of the bus location were displayed so that it could also be beneficial to different user groups/tourists. This research suggested that continuous auditory updates would "annoy the 'average' bus user" [10]. Darren et al

[10] conclude in summary that there are some very obviously negative aspects of auditory systems along with benefits. The key benefits of multimodal services listed by Hurtig and Jokinen [18] are - interpretation accuracy can increase since information is encoded in redundant or complementary modalities (e.g. combing text with tactile/ gestures), and different modalities bring in different benefits (e.g. combination of map with audio). The authors go on to state that although the differences may not be always pinpointed down to prior knowledge, predisposition, age, or gender differences, it is important to notice that the goal of building one single practical system that would suit most users is not reasonable. They stress that "a multimodal notification/alert system would be an important addition to scientific research in the field of public transport user and services" [35].

2.5 Use of haptics to provide useful information

We look at how location based haptic feedback can be integrated to public transport users [13] via GPS enabled mobile devices to provide alerts/notifications to the users about destination bus stops. Lee and Starner [34] present two experiments to evaluate wrist-worn wearable tactile displays (WTDs) that provide easy to perceive alerts for ``on-the-go users''. Their results indicate that when visually distracted users' reactions to incoming alerts become slower for the mobile phone but not for the WTD. Srikulwong and O'Neill [36] investigate using haptics to alert users about landmarks in a town or city. With training, participants were able to haptic signals for distinguish landmarks from directional signals and recognized over 80% of learned landmarks. They also found that participants did not show high rates of ``forgetting'' the haptic signals they had learnt. Amemiya et al [37] developed a novel handheld kinesthetic force-feedback device is based on the characteristics of human perception. It convey a sense of pulling or pushing the user towards a specific landmark or object and can be used to alert users that they are ``near'' a specific POI. This haptic direction indicator would help blind pedestrians intuitively and safely escape from dangerous area by means of haptic navigation.

In our paper we introduce 'haptics' as a modality to deliver spatial information (eg: near POI/landmark, arrival at bus stop etc) to mobile devices of public transport users. This work integrates user location (via GPS) and a spatial database along with feedback (alerts/notifications) in the form of visual (text and color coded buttons) and haptics (vibration alarm with varying frequency) about important POIs, landmarks, or tourist locations.

3 HAPTIC INTERACTION MODEL

In this section we describe the user interaction model of our system.

3.1 HapticTransit System

The HapticTransit system described in Figure 1 provides assistance to the user to indicate when their bus-stop is approachingwhen they are in the bus on a journey. Rather than providing the user with an outline of the travel time to their stop they are informed by haptic feedback, in sufficient time, when their stop is approaching [13]. The user selects their destination and the desired information mode: – destination only (no addditional information) while tourist mode provides with information and alerts about POIs along the way. The bus arrival time prediction algorithm forms an important system. The bus location and arrival time at bus stops are calculated using either direct extraction of information from timetables or by bus arrival time prediction algorithms. The broker service running on the server is responsible for calculating the proximity of the user to their desired stop. Time and distance information is also provided visually on the device. The system computes the proximity to the user's destination stop and provides a subtle alert about the approaching destination by providing a low frequency vibration feedback when the user has reached 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. A simple colour-coded visual display is also used to represent far, close, and very close using green, red, and amber colours respectively. 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 model incorporates additional feedback along the route to improve the 'in-bus' interaction. If the user has selected "tourist mode" then the user is alerted by a unique vibration feedback pattern about a landmark/POI along the route. In combination with the haptic feedback here they systemalso provides visual feedback with the name and description of the landmark/POI currently in the proximity of the user.. The real-time bus arrival time algorithm computes the arrival time of buses at various bus stops [5]. The use of the haptic feedback ensures that the user is not required to be interacting or looking at the mobile device at all times for assistance. The user instead enjoys the trip and will be informed about destination stop and/or important landmarks/POI along the route through tactile feedback.

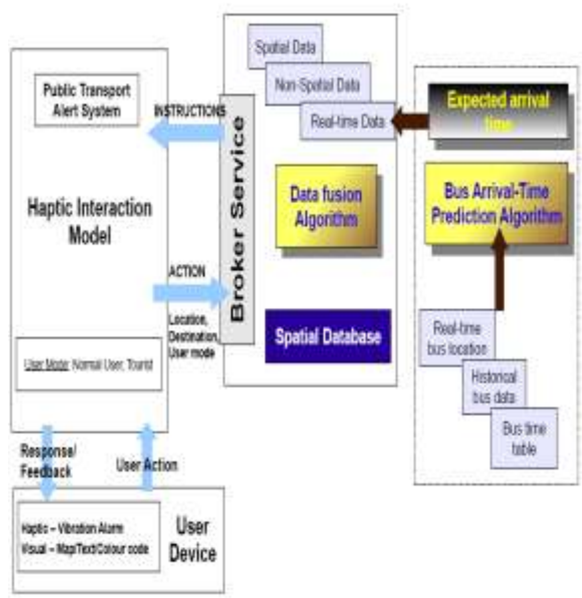

Figure 1. HapticTransit Model

The model of the route is stored in the spatial database. Each route *R* is an ordered sequence of stops $\{ds, d0, ..., dn, dd\}$. The departure stop on a route is given by *ds* and the terminus or destination stop is given by *dd*. Each stop *di* has attribute information associated with it including: stop number, stop name, etc. Using the timetable/real-time bus arrival information for a given journey *Ri* along route *R*, we store the timing for the bus to reach that stop. This can be stored as the number of minutes it will take the bus to reach an intermediate stop *di* after departing from *ds*. This can also be stored as the actual time of day that a bus on journey *Ri* will reach a stop *di* along a given route *R*. This is illustrated in Figure 2. This model extends easily to incorporate other modes of public transportation including: long distance coach services, intercity trains, and trams.

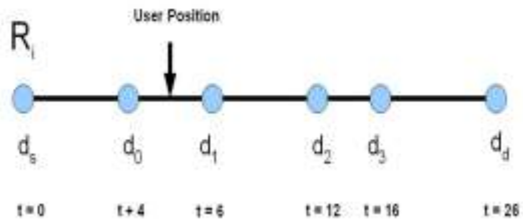

Figure 2. An example of our route timetable model for a given journey Ri.

The number of minutes required for the bus to reach each intermediate stop is shown as *t*.

3.2 Implementation of the system

Our software implementation of the prototypes use well known components. The Android mobile operating system was used to develop and implement this model. A PHP script running on the server acts as the software broker service. While any source of spatial data could be considered we have used OpenStreetMap (OSM) as the main source of spatial data. OSM offers a very detailed street and road network it also provides a very rich database of POI and landmarks. PostgreSQL (PostGIS) is used as the spatial database. The PHP broker service is easily configured to extract spatial information from alternative sources of spatial data. This is outlined in flowchart format in Figure 3 where we see that in the web server the broker service and the database interacts and obtains input about arrival time at destination bus stop.

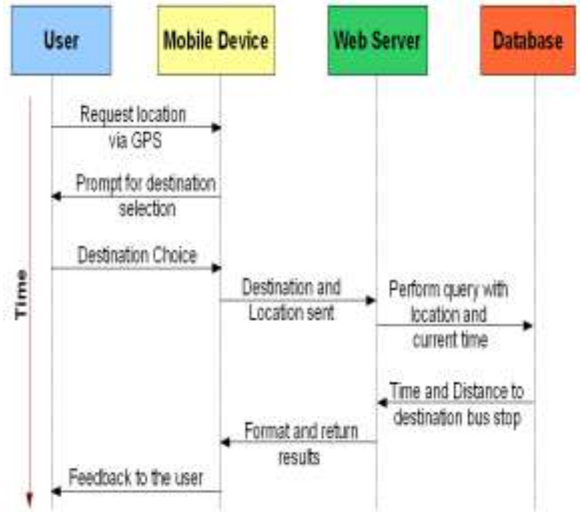

Figure 3. Flowchart depicting the flow of information with time.

On entering the bus or just before boarding the bus the user runs the application on their mobile device and selects the destination.

4 SURVEY AND FINDINGS

To quantify motivation for this work we conducted a survey on public transport usage. We contacted 50 people for the survey and received 45 responses. There are a number of important results from this survey, which was conducted online, which show that there is a need for an alert system similar to the one we have described in this paper. The majority (40 respondents) felt that the feedback from the in-bus displays is useful. Figure 4 gives a list of techniques that users said they would do to keep track of destination bus stop. We see that the majority of respondents 'ask the driver to alert them' or 'look for landmarks' to notify them about arrival at their expected destination bus stop. A small percentage of users said that they would use journey planner software before the trip and that these people would then carry a map or printed version of the route itinerary when they are on their bus. Figure 5 displays a summary of the types of "in-bus" activities that users indicated they are normally involved in. The majority of these users said that they would listen to music or just look out of the bus window.

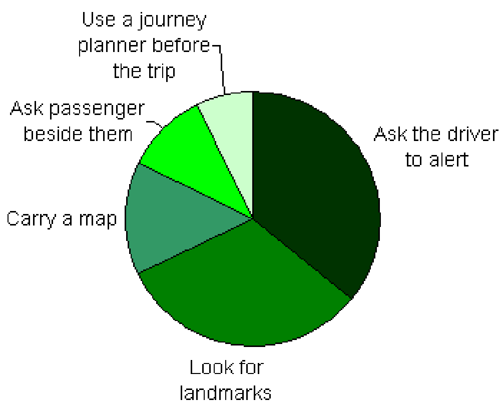

Figure 4. User activity to know the destination bus stop

The respondents of the survey reported that if they are traveling with a friend or family member(s) they would normally be in conversation with their travel companion. 33 of 45 respondents reported that they had missed their stop while traveling by bus at some stage in the past.

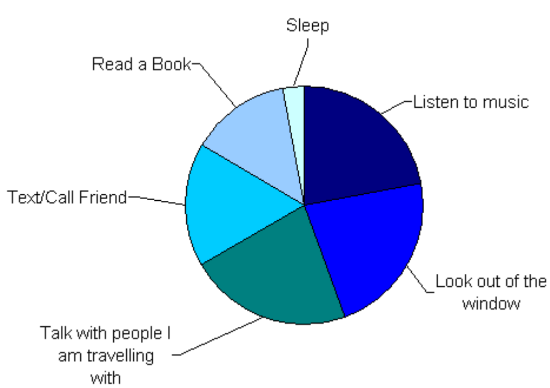

Figure 5. In-bus activity during a bus trip

The most commonly cited reason for missing a stop was attributed to darkness and traveling in hours of darkness. as since it was dark outside the users found it difficult to recognise (using landmarks and POIs) that they had reached their destination. The second most commonly cited reason for missing a stop was a result of the passengers falling asleep on the bus. The survey participants were also asked what form of alert feedback they would most prefer. From the survey 'displaying user position on a map' and 'vibration alert to inform them of the bus stop' were the most popular responses. In providing the reasons for choosing the vibration alert feedback the 30 out of 45 respondents explained that they chose this since they don't need to devote all of their attention to the phone screen. The participants explained that since the phone is in their pockets/bag most of the time, the vibration alert would be a suitable form of feedback. Our system provides three kinds of feedback to the user with regard to arrival at destination stop: textual feedback, the color coded buttons and haptic feedback. The textual and color coded feedback requires the user's attention. The user needs to have the screen of the application open to ensure he/she sees the information that has been provided. Thus the user will miss this information if they are involved in any other activity like listening to music, sending a text, or browsing through other applications in the phone. If the user is traveling with friends, it is very unlikely the user will have his attention on the phone [39]. Amongst the respondents, haptic feedback is the preferred mode for providing feedback to the user regarding arrival at destination stop. Haptic feedback ensures that the feedback is not distracting or embarrassing like voice feedback and it also lets the user engage in other activities in the bus. Haptic feedback can be used by people of all age groups and by people with or without visual impairment. It provides a very suitable modality for information for passengers who are unhappy with the use of continuous audio feedback modality [10].

5 DISCUSSION AND COMMENTS

This paper has given an overview of a haptic-feedback based system to provide location based information for passengers using public transport (specifically buses). The main benefit of this system is that passengers can use the system on their mobile devices to reduce the anxiety about missing their stops. The system is aimed at users who are unfamiliar with a particular bus journey or network. The vibration alarm provided by the system helps alert passengers about the bus as they approach their destination. The system also notifies them about POIs along their travel route for further information if they choose to have this provided to them. This assists in enhancing the in-bus' experience of the user, it involves less interaction with visual/audio notification system on the mobile device, and the passenger can enjoy the trip and be involved with other activities. Tourists, who normally find taking buses in a new location rather daunting, can use this system as an assistant while they absorb the city environment from the window of the bus. Another aspect of public transportation related to this work is theft on public transport. Several authors report an increase in smartphone theft in public transport vehicles [40, 41]. Using our system with haptic feedback drastically reduces the amount of time a user needs to have their phone out on display. With the vibration feedback to alert passengers of their stop location it is hardly necessary at all to have the phone device displayed in public throughout the journey. As some of our participants in our user trial put it: "we can look like locals rather than toursists". The real-time bus arrival time sub-system within our model provides more accurate expected arrival times for buses. To make the system software more generic we intend to extend the design of the timetable important functionality to consume XML, KML, etc. This would allow automated import of standards-based public transport schedules rather than manually storing the timetable into a database. This will provide quicker and more efficient extension to public transportation routes in any region. The final two aspects of future work are focused on user trials and energy consumption of the application. To demonstrate the success and use of our application in the real-world more extensive user trials will be carried out with a wider range of participants. The results of these trials will be published in a suitable journal. The continuous use of the vibrate function, GPS sensor, and data transfer to the server can drain battery resources rather rapidly. Consequently, our software for this application must be developed with battery efficiency in mind. Some authors have shown that when applications cause drain of the battery this can cause distress and potential annoyance for the user [42].

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