Experiments with a Public Transit Assistant for Blind Passengers

German Flores and Roberto Manduchi

Baskin School of Engineering
University of California, Santa Cruz
{ghflores,manduchi}@soe.ucsc.edu

Abstract. Public transportation is key to independence for many blind persons. Unfortunately, in spite of recent accessibility progress, use of public transportation remains challenging without sight. In this contribution, we describe a system that provides enhanced travel-related information access to a blind bus passenger. Users of this system can select a specific bus line and desired destination on a regular Android smartphone or tablet; are notified when the bus arrives; once in the bus, they are informed of its progress during the route; and are given ample advance notice when the bus is approaching their destination. This system was tested with four blind participants in realistic conditions.

Keywords: Assistive technology, public transit, location-based services

1 Introduction

Public transportation has a critical role in the independence of blind travelers [6]. Blind individuals who use public transportation have increased opportunities for education, employment, socialization and leisure. Unfortunately, in spite of significant accessibility advances (in large part resulting from legislation such as the American with Disability Act, or ADA), people who are blind face multiple difficulties when using public transportation [14, 10, 1]. In particular, access to travel-related information, a main factor contributing to the safety and comfort of public transit passengers, may be challenging without sight. When riding a bus vehicle or a train, one needs to know which bus or train line to take, its departure time, and where to board the vehicle; during the ride, one needs to constantly be aware of the progress made to destination, so as to be ready to exit the vehicle or train car at the desired stop. Some of these tasks (e.g., recognizing an approaching bus) are inherently visual. Others can be facilitated by non-visual (acoustic) means. For example, the ADA mandates that bus vehicles announce stops at transfer points, major intersections, major destinations, stops requested by riders with disability, and in general at frequent enough intervals such that people with visual impairment can orient themselves. In fact, not all stops are announced all the times, and the spoken announcements from the speakers may be difficult to hear by someone with a hearing impairment or in the case of loud ambient noise. In addition, persons who are anxious, unsure, or with some level of cognitive impairment, may need to hear the same announcement time and again [1].

In this contribution, we present a qualitative study with a system (Public Transportation Assistant, or PTA) that was designed to enhance information awareness for blind persons riding a bus vehicle. This system uses WiFi Access Points (AP) placed at bus stations and inside bus vehicles, which communicate with a regular Android smartphone (or, as in our experiments, tablet) carried by the user. This system does not require Internet connection or access to the smartphone's GPS. Bus stop APs provide a passenger who find himself or herself within the AP's WiFi range with information about the bus lines through that stop, timetables, and other types of real-time transit information (e.g. the estimated arrival time of the next bus). The in-vehicle AP communicates the current progress through the route and the stops that are reached by the bus. Users of this system can pre-select a bus line and a destination stop using an accessible interface. They are notified when the desired bus has arrived at their stop; once inside the bus, they receive early warning when the bus is approaching the desired destination. Information is presented to the user in the form of synthetic speech. At any time, users can interrogate the system to hear the latest announcement repeated, as well as any other available information.

We tested our system with four blind participants, who operated it while traveling by bus through a specific route in our campus. Each participant used the PTA system in a very realistic scenario, which involved catching two bus vehicles equipped with an AP, each time selecting a specific destination, and exiting at the correct stop. After the experiment, each tester participated in a semi-structured interview that focused on his or her experience with the public transit system (in particular, any accessibility issues) and on his or her opinion of the system they just tested. These interviews, together with observations from the experiments, shed light on the major problems faced by blind travelers using public transit, and provide a critical assessment of the functionalities of our PTA system.

2 Related Work

Improving information access for cognitive or sensorially impaired travelers is the object of active research [1, 9]. Other systems and applications for the assistance of blind travelers taking public transportations have been described in the literature. For example, Ubibus [3] was designed to help a blind person catch the correct bus. Likewise, the Bluetooth-based application described in [13] ensures that the user is informed when a bus is arriving at a stop. The Travel Assistance Device (TAD) [2] and the app described by Silva et al. [15] both rely on the GPS in the user's smartphone to determine the user's position and to alert the user when the bus is approaching the desired bus stop. Unlike this previous work, our system is designed from the ground up to assist users throughout the whole travel, from the time they arrive at the initial bus stop until they reach their destination. Hara et al. [10] describe a crowdsourcing approach to building a database with the layout descriptions of bus stop locations. This information can be extremely useful to blind passengers, as also noted in our interviews.

3 PTA Technical Description

Our PTA system consists of two major components [7]: WiFi Access Points (APs), deployed inside transit vehicles and at bus stops, and an Android application that runs on Android devices. Each WiFi AP consists of a router that functions as a server and communicates with the Android application. The Android application functions as a client that manages connections, communication and overall user interaction. In addition, the in-vehicle AP communicates with an optional GPS device for positioning. This server-client model allows the system to work with multiple APs and Android devices.

3.1 Server

The server component of the system consists of a TP-LINK TL-WR1043ND wireless router reprogrammed with OpenWrt, a Linux-based fully writable file system with a package management software allowing for the creation of custom applications (packages). Two different types of APs were customized and deployed: an in-vehicle AP and a bus stop AP. In-vehicle APs were customized to work inside the bus; bus stop APs were customized to work outdoors. Each AP stores a local repository with the information to be transmitted during each connection request.

The WiFi manager was designed to accept multiple connection requests and facilitate data exchange between the AP and an Android device. For each connection request, the WiFi manager accepts the connection, performs a two-way handshake, and transmits either in-vehicle or bus stop related information to the Android device that requested the information. In-vehicle AP information consists of the bus name, bus route number, and the bus current location. Bus stop AP information consists of the bus stop name, bus stop address, bus route numbers that serve that particular stop, and other information such as timetables.

The GPS manager was designed to receive GPS coordinates from an external GPS module, determine if a given GPS coordinate is within range of a bus stop location, and send to the client the ASCII name of the location that corresponds to the given latitude and longitude coordinates. Since our routers do not have built-in GPS chips, we made use of the GPS chip found in a modern cell phone. A custom Android application was implemented to activate the GPS module in the phone and send periodic GPS coordinate updates to the bus AP at the rate of 1 coordinate per second.

3.2 Client

The client component of the system consists of an Android application deployed in a Nexus 7 tablet and designed to incorporate the following modules: WiFi connectivity requests, touch gesture interactions, local database queries, and text-to-speech synthesis. The most important functionality of the system is the reliable management of the scanning, connecting, switching, and disconnecting between bus stop and in-vehicle APs. Connection switches typically occur when the desired bus arrives at a bus stop, in which case the client switches connection from the bus stop AP to the in-vehicle AP. This switch occurs behind the scene – the user is never made aware that a switch occurred. If for any reason the user does not board the desired bus, the client automatically re-connects with the bus stop AP, giving the user the ability to specify a different destination.

The client user interface was designed to effectively communicate relevant information and provide the user with the proper set of instructions and confirmations for the desired task. It uses multi-touch gesture interactions to get user input and text-to-speech synthesis to give verbal feedback. The user interacts with the system in one of two modalities: system-prompted or user-prompted. System-prompted interaction occurs when the user first reaches the transmission range of an AP at a bus stop; after connection with the AP, the user is presented with a structured menu and asked to make a set of selections (such as which bus to take, or which stop to exit at). This is achieved by traversing a list of options using left (next item) or right (previous item) swipes, and selecting the desired item via a single tap. User-prompted interaction occurs when the user taps the screen and holds the finger on the screen for three seconds (tap-and-hold interaction), at which point a main menu is activated.

3.3 Application Scenario

In a typical applications scenario of our system, the user would first walk to a bus stop and start the PTA app on his or her smartphone. If the smartphone is within the transmission range of the AP in the bus stop, the application prompts the user to connect to the AP in order to receive transit information. If more than one instrumented bus stops are nearby (for example, two stops facing each other across the street), the application asks the user to select the AP he or she wants to connect to. Upon connection, the application provides information to the user as to the bus lines that go through that stop, and asks the user to select a desired one. Once a selection has been made, the user is again prompted to select a final destination for his or her trip from a list of bus stops that are traversed by the chosen bus line. After the user has selected the destination stop, this initial interaction phase is completed, and the user is instructed to wait for the bus to arrive. While waiting, the user can interrogate the system and ask to hear the remaining estimated time till bus arrival. Once the next bus vehicle of the chosen line arrives, and as soon as the user's smartphone is within WiFi range of the in-vehicle AP, the client software switches connection to this AP, and informs the user of the arrival of the desired bus. The user then enters the bus and finds a seat. The client application, now connected to the in-vehicle AP, receives information about the current bus location, and informs the user about upcoming stops as they are approached by the bus. The user can review the last information produced by the application at any time, and have the application repeat this information multiple times if desired. When the bus is approaching the stop before the final destination, a special announcement is produced; this is specifically designed to give the user ample time for all actions required before exiting the bus (pulling the cord to call the stop, getting up and moving towards the door, etc.). Finally, before the bus reaches the final destination, the user is prompted to get ready to exit the bus. Once the user has left the bus and the bus vehicle has departed, the system disconnects from the bus and puts itself into sleep mode, ready to be awaken when desired and to start the process again.

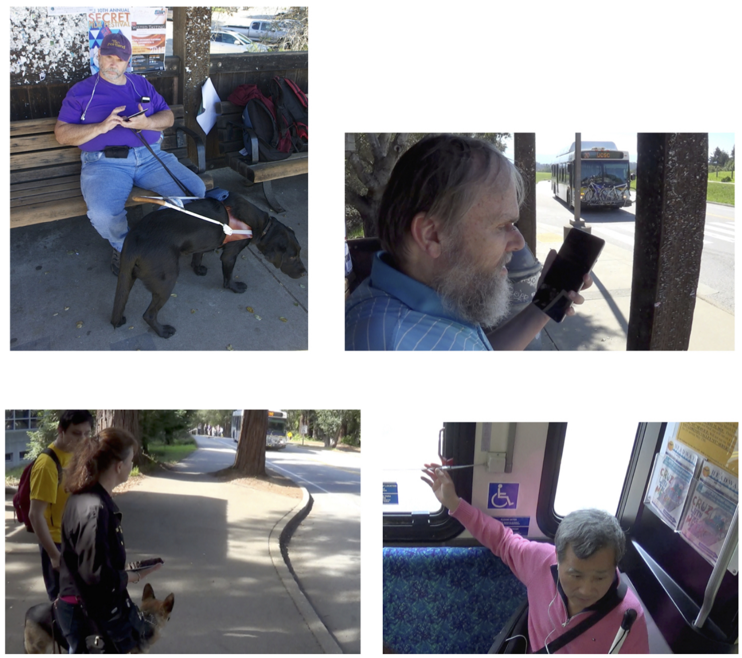

Fig. 1. Blind participants during the user studies.

4 Experiment Design

For our experiments, we instrumented three bus stops in our University campus and one bus vehicle. User studies were conducted on an individual basis during February and March of 2015. Four blind participants (Fig. 1) were recruited from the network of acquaintances maintained by the second author (three males and one female, ages: 55-67). Participants were offered the option to use earphones during the tests, rather than listening to the tablet's speaker. Only two participants decided to user earphones.

After a participant had a chance to ask questions about the system and the experiment, he or she was accompanied by the authors to the first instrumented bus stop. The app was then started and the tablet handed to the participant, who was instructed to select a specific final destination, using the system's tap and swipe interface. While waiting for the bus, participants were encouraged to occasionally interrogate the system, asking for the waiting time till bus arrival. Once the bus arrived and the participant received confirmation by the system that this was indeed the desired bus, the participant was accompanied inside the bus, where he or she took a seat in one of the front seats reserved for people with disabilities. During the trip, the participant was informed by the system about each upcoming bus stop. Note that the same information was also announced by the speakers in the bus; however, our participants were able to hear the announcement multiple times, if desired, from the tablet. The participant was asked to pull the cord to call the final stop when he or she determined that the stop was approaching. Once arrived at destination, the participant was accompanied outside the bus, where he or she waited until the system announced that it had disconnected from the bus AP and would go in standby mode. The participant was then accompanied to another instrumented bus stop, located across the street, and asked to wake up the application again (by a tap-and-hold gesture). The whole process was then started again, with a different final destination. The whole test (including waiting for the bus to arrive and traversing the route eastward and westward) took between one and two hours. At the end of the test, each participant participated in a semi-structured interview that was audio recorded.

5 Discussion and Conclusions

The experiments and interviews conducted with blind users of our system have brought to light a number of accessibility problems with the public transportation systems, along with possible technological solutions. The participants' shared experience clearly shows that using public transportation can be challenging for people who are blind. Missing the bus or the desired stop are relatively frequent occurrences for blind travelers.

Our PTA system has been designed to provide the following functionalities: (1) Informing the user about the bus lines through a specific stop, timetables, and possibly real-time information; (2) Allowing the user to select a bus line and desired destination stop; (3) Informing the user when the desired bus vehicle arrives at the stop; (4) Providing real-time location information en route, with specific (and possibly customizable) warnings as the bus approaches the final destination. Users of this system can have the system repeat the information as many times as they want, which can be very useful for someone with hearing impairment, in noisy or confusing situations, or when one would benefit to hear the same information repeated multiple times for confirmation. Our main design goal was to provide the user with enhanced information awareness during a bus ride, in hopes that this would make the travel experience safer and more comfortable.

By and large, the system worked as expected, with the exception of a single connectivity problem, and some difficulties by two participants using the tap-and-hold interface. Both issues can be easily resolved, the first one by changing the logic to determine when to announce a connection, the second one by substituting tap-and-hold with another gesture, such as triple-tap. Our participants enjoyed all functionalities offered by the system and generally gave us very encouraging reviews. The main criticism, shared by all participants, was directed at the short advance notice given by the system when the desired bus is arriving at the bus stop. While they considered the bus arrival warning to be a very useful feature, they would prefer that this warning, currently produced a few seconds before the bus pulls in, were given earlier. Unfortunately, by its own nature, the current system is unable to produce a warning at a much earlier time, as connection with the incoming in-vehicle AP is needed before the warning can be generated. Detecting the bus arrival with longer notice would require polling a real-time online bus tracker such as OneBusAway [6] or NextBus.

Our participants also said that they would like the system to help them find the exact location of the bus stop, a functionality that our current technology cannot offer (at best, our system can provide a very approximate estimate of the distance to the Access Point, based on the received signal strength indication or RSSI).

While our system was shown to adequately support all desired functionalities (except for what noted above), other technological solutions are possible. In fact, one main disadvantage of the chosen technology is the need for installation of WiFi Access Points at bus stops and within bus vehicles. In same cases, WiFi APs are already installed, for example on long-haul bus lines. Installation of bus stop with WiFi APs have also been planned in some cities (e.g. San Francisco). In the case of existing APs, it is conceivable that these could be upgraded to offer similar services as our prototype.

Several of the same functionalities offered by our PTA system could be provided by a smartphone app that uses GPS data for localization, and has access to timetables and possibly real time information from the Internet. This solution would not call for any special infrastructure, but it would need good Internet connectivity and GPS signal. (Note that our system does not require Internet connectivity or access to the user's phone's GPS.) In addition, a purely smartphone-based application may not be able to notify the user in real time when the desired bus has arrived at a bus stop. Regardless of the technology ultimately chosen, we believe that our experiments have shown that a personal travel assistant, implemented as a smartphone app, has great potential to improve travel-related information access for blind users, and that our study has highlighted the main functionalities that such a system needs to offer to be really useful to blind travelers.

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