PERCEPT Based Interactive Wayfinding for Visually Impaired Users in Subways

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Abstract

In this paper we introduce a PERCEPT based interactive indoor navigation system that enables the visually impaired users to independently navigate in subway systems. The user carries an Android Smartphone that interacts with the subway environment in which we deploy Near Field Communication tags. Using the navigation instructions generated by PERCEPT system the visually impaired users can successfully navigate to their destination. The system has been deployed in Arlington subway station in Boston and has been successfully tested with visually impaired subjects.

Keywords

blind and visually impaired, wayfinding, Smartphone, Near Field Communication.

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Introduction

Sixty-one million Americans are considered to be at high risk of serious vision loss if they have diabetes, or had a vision problem, or are over the age of 65 (Pascolini et al. 2011). According to the American Diabetes Association diabetes is the leading cause of blindness in persons ages 20-74. An estimated 12,000 to 24,000 people lose their sight each year because of diabetes (American Diabetes Association 2011). The Veteran Administration estimates that by 2020, there will be over 1 million Veterans with significant visual impairment and legal blindness.

Independent navigation through unfamiliar indoor spaces is beset with barriers for the visually impaired. A task that is trivial and spontaneous for the visioned population has to be planned and coordinated with other individuals for the visually impaired. A sighted guide, an Orientation and Mobility (O&M) instructor, or some other person must be set in place before such a task can be successfully completed by someone who is visually impaired. Although many improvements and aides are available to assist the visually impaired to lead an independent life, there has yet to be developed a system that combines independence with accuracy and affordability of indoor navigation.

PERCEPT system, first generation indoor navigation system for the blind and visually impaired, developed at the University of Massachusetts (UMASS) 5G Mobile Evolution Lab can significantly alleviate the challenges introduced above [4]. PERCEPT system was developed with the cooperation of the Massachusetts Orientation and Mobility (O&M) division from Massachusetts Commission for the Blind (MCB).

Unlike a typical office building, a subway station has no general flow or layout. Moreover, the subway layout can change, depending on the time of day. For example, gates open during high traffic times are closed at other times. Escalators move in one direction and

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then the other. A visually impaired person could receive Orientation and Mobility (O&M) training for one route, only to find the route changed at a different time. Signage is usually placed high above eye level, away from the view of those with low functioning vision. The high level of ambient noises in the underground atmosphere makes it harder for the visually impaired to use their sense of hearing – to detect openings, follow the flow of traffic, and generally navigate through space.

There are a number of projects that propose indoor navigation systems for public transportation venues. In (Flores at al. 2014) the authors introduce an indoor navigation system for visually impaired users that includes an Inertial Measurement Unit (IMU) and Barometer in a Smartphone. AudioMetro (Sanchez et al 2010) is an audio-based educational software program for desktop computers allows blind users to plan and simulate trips in a Metro Network before they arrive to the subway stations. AudioTransantiago (Sanchez et al 2010) is a handheld application that allows users to plan trips and provide contextual information during the journey. ClickAndGo Wayfinding Maps (Duggan 2014) allows the user to download the instructions for a specific metro station.

These approaches have the following shortcomings. The approach introduced in (Flores et al. 2014) might provide inaccurate localization due to the nature of cellphone sensors in subway environments. Approaches presented in (Duggan 2014, Sanchez et al. 2010) cannot provide real-time navigation assistance. AudioTransantiago (Sanchez et al. 2011) asks users to input their current location manually, which might be very difficult in reality. In all approaches the navigation instructions have to be hand written.

In this paper we introduce PERCEPT based system which is a real time, accurate and affordable navigation system for the visually impaired in subway stations. PERCEPT system was piloted in Arlington Metro Station (AMS) of the MBTA (Dungca 2014).

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Table 1. Comparison of indoor navigation approaches for public transportation venues

	PAPER (Flores et al. 2014)	**PAPER (Sanchez et al. 2010) Offline training**	**PAPER (Sanchez et al. 2010)**	**PAPER (Duggan 2014)**	**PERCEPT (Duggan 2014)**
LOCALIZATION TECHNIQUE	Sensors in Smartphones	N/A	User has to manually input current location	None	Near Field Communication (NFC) tags
LOCALIZATION ACCURACY	Not mentioned	N/A	N/A	N/A	Within an inch
NAVIGATION INSTRUCTIONS	Hand-written instructions	Hand-written instructions	Hand-written instructions	Hand-written instructions	Automated generation of instructions
HUMAN SUBJECTS TRIALS	Three visually impaired subjects	Ten visually impaired subjects	Six visually impaired subjects	Not mentioned	Over 40 visually impaired subjects
COST FOR USER	Low-using Smartphone application	Purchasing software for desktop	Purchasing pocket PC and application	Not mentioned	Low-using Smartphone application
DEPLOYMENT COST FOR VENUE	High-payment for generating hand written instructions	High-payment for generating hand written instructions	High-payment for generating hand written instructions	High-payment for generating hand written instructions	Moderate – NFC deployment and cost for digital mapping the environment
MAINTENANCE COST FOR VENUE (ADAPTATION TO CHANGES IN ENVIRONMENT)	High-payment for generating new instructions in case changes occur in the environment (e.g. closing of entrances)	High-payment for generating new instructions in case changes occur in the environment (e.g. closing of entrances)	High payment for generating new instructions in case changes occur in the environment (e.g. closing of entrances)	High payment for generating new instructions in case changes occur in the environment (e.g. closing of entrances)	Low – instructions are generated automatically and can accommodate changes in environment

In contrast to the approaches described in (Duggan 2014, Flores et al. 2014, Sanchez et al. 2011, Sanchez et al. 2010), PERCEPT can provide very accurate localization and includes automatic generation of navigation instructions. A comparison between approaches introduced in (Duggan 2014, Flores et al. 2014, Sanchez et al. 2011, Sanchez et al. 2010) is provided in Table 1.

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The paper is organized as follows. PERCEPT system is outlined in the next section. We then introduce the vision free interface and describe the trials.

PERCEPT in Subway Systems

PERCEPT system incorporates new paradigms, such as: a) “interactive spaces,” which interact with users in real time, as well as account for changes of the users’ location and transformations in the physical layouts; b) gesture-based user interface on the Smartphone that enables visually impaired users to interact with the space; and c) provision of detailed navigation instructions which incorporate safe navigation fundamentals.

The system includes the following components:

PERCEPT environment

Near Field Communication (NFC) tags are deployed in the environment at multi-modal sensory landmarks determined by the O&M instructor such as entrances, intersections, elevators, the subway fare gates, and subway fare machines. (see landmarks 1-8 in Figure 1). Using the Smartphone running PERCEPT application the user interacts with the environment by touching the NFC tags.

PERCEPT Server

The server hosts the system database as well as the instruction generation module. The user downloads from the server PERCEPT application and the navigation instructions and interacts with the user through the “vision free” user interface.

PERCEPT application

The user downloads the application from PERCEPT server prior to his/her arrival to the subway station. There is no Internet connection required in the subway station. The user interacts

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with the application using vision free user interface using Android "Talkback" accessibility service (See next section for details). The application flow that is presented in Figure 2 includes the following steps: 1) start the application, 2) select the destination using the "vision free" interface, 3) scan the NFC tags along the path at specific landmarks, and 4) receive audible navigation instructions.

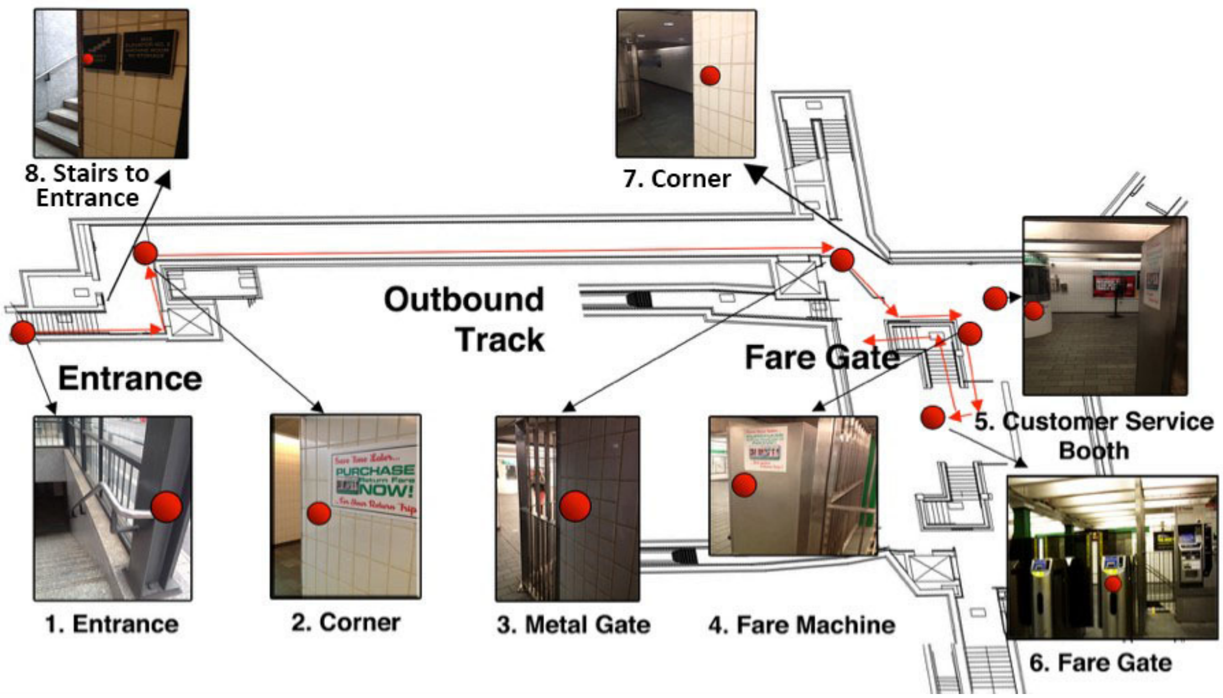

Fig. 1. Scenario in Arlington Station.

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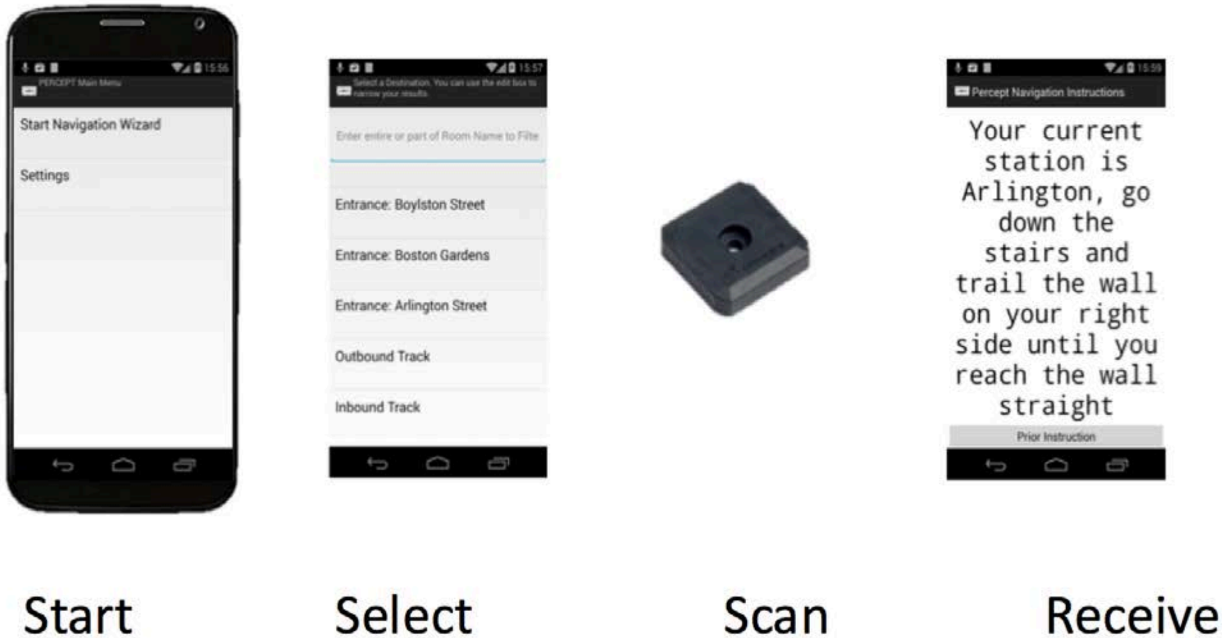

Fig. 2. PERCEPT Application Flow.

To better understand how the user interacts with PERCEPT system we will describe the navigation experience of our hypothetical user, Alice, in Arlington Station. Alice carries her Near Field Communication (NFC) enabled Smartphone with the PERCEPT application and the selected route. The App will provide navigation instructions either when the Smartphone touches the tag or when the user swipes the screen for next instructions. To get an idea of how the system will work, we will cover the first three landmarks (see Figure 1) in Alice's journey:

Entrance

Once Alice reaches the entrance to the station, she places her phone over the NFC tag located at the Entrance. When the phone scans the tag, the App says: "Your current starting station is Arlington, go down one set of stairs and trail the wall on your right side until you reach an intersecting wall. Turn left and trail the wall on your right side until you reach an intersecting hallway. You will find the next tag at the end of your right side wall. Scan the NFC tag or select next instruction button."

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Intersecting Hallway

After Alice identifies the opening she scans the tag and the App says: "Turn right and trail the wall on your right side until you reach the metal gate. This is a long hallway that will lead into the main lobby. You will find the next tag on your right side wall before the metal gate. Scan the NFC tag or select next instruction button."

Beginning of Metal Gate

After Alice identifies the metal gate, she scans the tag just prior to it and the App says: "Turn right and trail the metal gate on your right side until it ends. You will enter the lobby. You will find the next tag on the side of the Charlie Card ticket machine. Scan the NFC tag or select next instruction button."

Smartphone User Interface

The visually impaired user interacts with the NFC equipped Android Smartphone using "Talkback" accessibility service which is similar to "VoiceOver" on iOS. The user can navigate the device through gestures on the screen as shown in Figure 3. Using this accessibility service the users can interact with PERCEPT application as they would with other common applications (Mail, Web Browser, Messaging, etc…).

The user navigates the application by performing touch gestures on the screen

- Touch: Item touched is read to user
- Swipe Right or Down: Select Next Item
- Swipe Left or Up: Select Prior Item
- Double Tap: 'Clicks' selected item

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Fig. 3. Explore by touch user interface.

Trials

The user perspective is particularly important for our project. Given that our system is an assistive technology for the visually impaired, it needs to be designed and constantly improved with user feedback.

PERCEPT evaluation includes two phases: In phase A in which we have 5 visually impaired subjects we had initial testing which enabled us to understand the improvements needed for PERCEPT system. Such improvements include optimization of navigation instructions. After this revision we proceed to Phase B in which we called back the 5 subjects that attended in Phase A and additional 5 subjects. We are currently conducting Phase B trials.

Each trial comprises of the following parts:

Part I: Hands-on Orientation: it includes sit down orientation and on site experimentation:

1. Sit down orientation: The Instructor goes over PERCEPT app functionality and answers any questions the subject has. When the subject is comfortable they proceed to on site experimentation.

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2. On site experimentation: the subject uses PERCEPT App in Arlington station along routes that will not be included in the trial. The Instructor answers any questions the subject has and when the subject is comfortable we move to Part II described below.

Part II: PERCEPT trial: we ask the subject to accomplish four tasks that include two entrances (to/from) and two subway tracks inbound/outbound (to/from). During the trial the subject is asked to complete these tasks relying only on their mobility skills and PERCEPT App. The Instructor accompanies the subject at all times but will no longer answer any questions. In case the subject cannot proceed without assistance we determine this part of the trial as unsuccessful. Once the subject completes a task, the instructor provides the next task to accomplish. The trial ends either when all tasks are complete or the subject decides to stop

Part III: Post Trial Questionnaire: after the trials we collected the subjects feedback and experience using a qualitative questionnaire.

The results to date demonstrate that all visually impaired test subjects were able to navigate independently to all four destinations using PERCEPT. All participants thought that PERCEPT was easy to learn and utilize. Most subjects felt PERCEPT was very easy to pick up and use. The average duration of the orientation session is 30 minutes while some subjects required less than 10 minutes of orientation. A significant portion of orientation time was spent familiarizing subject with Android Accessibility, instead of actual PERCEPT app itself. We are continuing to improve PERCEPT usability through feedback received in the trials.

Some participants shared that without PERCEPT they would need to rely on sighted aid to get to some of the destinations given in the trial. All participants cited that PERCEPT gave them confidence when traveling without sighted aid within the station. All participants said they would use this system if it were available in the subway.

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Conclusions

In this paper we introduced PERCEPT based navigation system for blind and visually impaired users in subway stations. Arlington metro station pilot results were very successful encouraging us to proceed to our next research agenda which includes PERCEPT research, development and testing for any subway environment including large and diverse open spaces. Moreover, we will develop tools that will automate PERCEPT deployment in such environments decreasing the installation cost.

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