PERCEPT-II: Smartphone based Indoor Navigation System for the Blind

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Abstract— In this paper we introduce PERCEPT-II, a low cost and user friendly indoor navigation system for blind and visually impaired users. Using an Android Smartphone that runs PERCEPT-II application with accessibility features, the blind user obtains navigation instructions to the chosen destination when touching specific landmarks tagged with Near Field Communication tags. The system was deployed and tested in a large building at the University of Massachusetts at Amherst.

I. Introduction

The World Health Organization (2010) reported that 285 million people are visually impaired worldwide, of whom 39 million are blind and 246 have low vision [1]. Based on data from the 2004 National Health Interview Survey, 61 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 [2,3].

Since vision is the most important organ to sense the surroundings, its loss can significantly reduce the visually impaired individual orientation and mobility, especially in unfamiliar and complex indoor environments. Even with the help of a guide dog or cane, it is still a challenge for the visually impaired to independently navigate in such unfamiliar environments without help from sighted individuals. It is commonly accepted that the incapability of moving freely and independently can hinder the full integration of an individual into society [4].

There have been a number of research projects that can help the visually impaired navigate in unfamiliar indoor environments [5-17]. Most of these systems design and use new devices for their users, which mean extra cost. One of the prominent projects that underwent user trials with 24 visually impaired subjects is the PERCEPT project [13]. PERCEPT uses passive RFID tags (R-tags) deployed on different landmarks in the environment. PERCEPT user interacts with the environment using a glove and a Smartphone. Upon touching the R-tag using the glove, the Smartphone provides navigation instructions to the visually impaired users.

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PERCEPT-II builds on the success of PERCEPT system [13] and differs from it in the following aspects: a) The user carries only a Smartphone (no glove is required), simplifying the interaction with the system and lowering its cost; and b) we developed an Orientation and Mobility (O&M) survey tool that enables the Orientation and Mobility instructor to describe and mark specific landmarks in the building, reducing the system deployment cost. In PERCEPT-II we deploy Near Field Communication (NFC) tags [18-19] on existing signage at specific landmarks in the environment, e.g. doors, elevators, stairs, etc. The users obtain audial navigation instructions when they touch the NFC tags using their phone. We developed a "vision free" interface on the phone that enables the user to interact with the system using accessibility features built in the Android operating system.

The paper is organized as follows. In the next section we describe PERCEPT-II architecture. The O&M survey tool is introduced in Section III and the user interface is described in Section IV. Section V concludes the paper.

II. System Architecture

Fig. 1 depicts PERCEPT-II architecture. The server hosts the system database as well as the instruction generation module. PERCEPT-II client downloads from the server the navigation instructions and interacts with the user through the "vision free" interface that we describe in Section IV. The O&M survey tool introduced in Section III updates the database with the information captured by the tool such as the landmarks and the physical layout of the building (i.e., the building Blueprint). NFC tags are deployed in the environment on existing signage next to the Braille (see Fig. 2). Using the Smartphone running PERCEPT-II application the user interacts with the environment by touching the NFC tags.

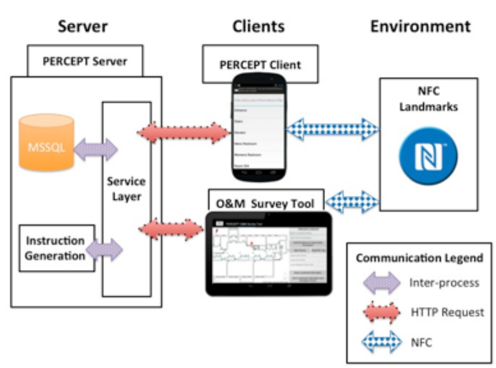

Figure 1. PERCEPT-II architecture

Figure 2. NFC tag on existing signage

III. Orientation and Mobility Survey Tool

The O&M survey tool application which runs on an NFC equipped Android tablet has the following functionality:

1. Input: At each landmark the tool enables the following input:
    a. Text annotations
    b. Audio annotations
    c. Picture annotations
    d. Reads and writes on the NFC tag associated with the landmark
    e. Building represented as a node-link structure and associated weights on the links
2. Processing: Generates navigation routes
3. Output: Stores all landmark information on the server database as well as the navigation routes

The tool user interface is provided in Fig. 3.

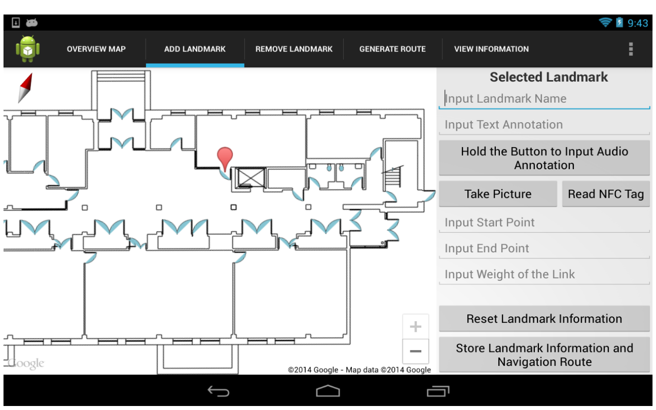

Figure 3. O&M survey tool user interface

In the remaining of this section we describe the functionality of the tool.

A. Landmarks, Weights and Attributes

We will generate the Node-Link structure that includes nodes that represent landmarks and links that represent the physical connections between the nodes. The tool will enable us to determine the nodes location as well as the weights on the links.

Nodes: The building's blueprint is overlayed on Google Map. When the user determines a specific landmark, e.g. a door) he/she can drop a marker on the blueprint to indicate the landmark. The location of the landmark, including its latitude and longitude will be stored in the database. At each landmark, the user can use the tool to take pictures of the landmark, record audio as well as input text. Moreover, since an NFC tag is deployed at each landmark, the tablet that runs the O&M tool scans the NFC tag to obtain its unique ID. All this information will be stored in the server database.

Weights: The weight on each link indicates the degree of difficulty to travel through the link [20-22]. For most cases, the weight will be the distance between the end and start nodes of the link. If there are obstacles in the physical space (such as chairs and tables) the weight on the link can be increased, representing the fact it is difficult to cross this link. In case there are dangers involved in crossing physical spaces (e.g. construction areas or very crowded areas) we denote the link weight as infinity so this link will never be crossed by the navigation route.

B. Navigation Route Generation Module

Using the Node-Link structure described above, we will use Dijkstra's algorithm to generate the route with the least weight between the source and destination nodes. The output of the algorithm is a series of landmarks that users will travel. Using the route generated by Dijstra's algorithm and the building landmark attributes we will generate the navigation instructions. The instructions will be converted into audio format before they are presented to the user.

IV. Smartphone User Interface

The user carries an NFC equipped Android Smartphone with a touch screen.

Smartphones are showing to be a very beneficial tool for visually impaired users in their daily lives. They use applications such as money reader, object recognition, color recognition, web browsing, reading emails and making calls.

Blind users can access these applications through a touchscreen since the applications interact with the user using accessibility features provided by the Android operating system. Therefore, to enable blind users to access PERCEPT-II application we designed the interface using accessibility features.

"Explore by Touch" is the main Accessibility Service used on Android to facilitate a vision-free use of the device. There are two ways to utilize explore by touch:

- Touching the screen to highlight the visual component you are touching, and
- Swiping gesture that moves a cursor to highlight visual components on the screen.

This method of highlighting is called hovering. When a visual component is hovered it can be selected by double tapping the screen. Fig. 4 illustrates the use of swiping gestures to hover on items in the list as well as double tap to select the hovered item.

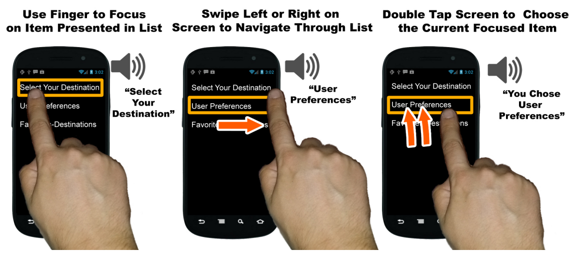

Figure 4. Explore by touch user interface

It is important that the layout of the user interface aligns with the Accessibility Services available in the Android operating system. By following this design the user can easily identify the purpose of each user interface component, how to interact with it, and its location in the user interface as it relates to the other visual components. The user interface illustrated in Fig. 5 includes:

A. Title

This title relays to the user the purpose of this screen. For example, if the activity on this screen involves destination selection, the title will read "Select the destination below". When the user navigates to a new screen, the title is spoken to them. The user immediately knows the purpose of the particular screen state and if at any time needs a reminder can hover over the title bar.

B. Content

The content is the center piece of the user experience. It contains various user interface components that either provide information to the user or allow the user to perform an action. When the user is selecting each component, whether it be through swiping or hovering, the user needs to understand what type of visual component it is. When the user hovers over the button that it will say not only the button name but also the fact that it is a button itself. Users familiar with "Explore by touch" will then realize that this is a clickable object.

As shown in Fig. 4, the content is presented in a list. It is important to remember that the end user is consuming this information one by one and therefore the flow of the user interface should be conducive to the way the user is "viewing" the information.

C. Navigation Bar

Navigation Bar includes the universal navigation buttons (Home, Back, and Quick App Navigation) This bar in most cases is always present throughout the Android Visual Interface. The HOME and APP SELECTION button will pause your application's current app screen and return the user to the home screen or a particular app. The BACK button will close the current activity.

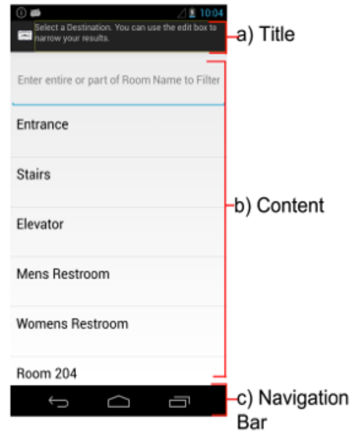

Figure 5. User interface layout

V. Testing and Results

We have deployed PERCEPT-II in the first two floors of UMASS Amherst main administration Building (approximately 6,500 square meters per floor). It is a complex building with 65 possible destinations, multiple restrooms per floor, stairs, multiple elevators, a center court and a total of 94 landmarks. The building is illustrated in Fig. 6 and the second floor schematics is provided in Fig. 7.

Figure 6. Whitmore building at UMASS Amherst campus

All the signage in the building is ADA compliant. The NFC tags have been deployed on this signage next to the Braille, as shown in Fig. 2.

We have done technical testing in two dimensions: the correctness of the navigation instructions and the correctness of the user interface.

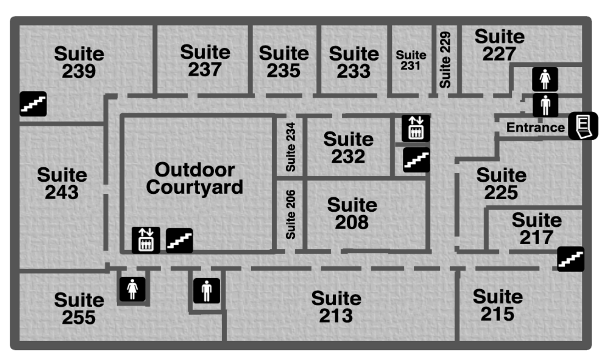

Figure 7. Schematics of floor 2

All generated navigation instructions have been successfully tested manually by traversing on the building blueprint the routes provided by the navigation instructions.

We have tested the user interface with multiple sighted users that are familiar with accessibility features of the Android operating system. During these tests the phone screen was obstructed. The sighted users were asked to perform certain functions such as choosing a destination from the list, manually entering a destination through the virtual keypad, use the quick menu to navigate to a specific destination such as a restroom, room, elevator, entrance, etc. We tested both aspects of the explore by touch accessibility service (see Fig. 4): using gestures or hovering to select certain components on the screen.

VI. Conclusions

In this paper we introduced PERCEPT-II system that provides affordable and easy to use indoor navigation system for the blind and visually impaired. The user only needs to have an Android phone running PERCEPT-II application. Since we use NFC tags deployed in the environment the cost of the system for building owners is low. The system which was deployed in the first two floors of a large building on campus was tested for correctness of the navigation instructions as well as "vision free" interface. We also introduced an Orientation and Mobility survey tool application that enables the Orientation and Mobility instructor to mark up the environment with different landmarks. This tool also enables the instructor to annotate these landmarks with information such as audio, video, and text.

Our next steps will involve testing the system with blind and visually impaired users. Such testing will help us debug and optimize the user interface of the application for "vision free" usage.

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