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# Year 24 Final Report

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# Hybrid NFC and Vision Based Navigation System in Subways for the Blind and Visually Impaired

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We introduce an indoor navigation system for blind and visually impaired users. We deploy visual tags in the environment at specific landmarks and introduce a visual tag detection algorithm using a sampling probe and cascading approach. We provide guidelines to determine the visual tag size which is a function of various environmental and usage scenarios, which differ in lighting, dimensions of the indoor environment and angle of usage. We also developed a Smartphone based user interface for the visually impaired users that uses Android accessibility features.

The system architecture consists of the following system components: the Environment, and Android-based Smartphone (see Fig. 1).

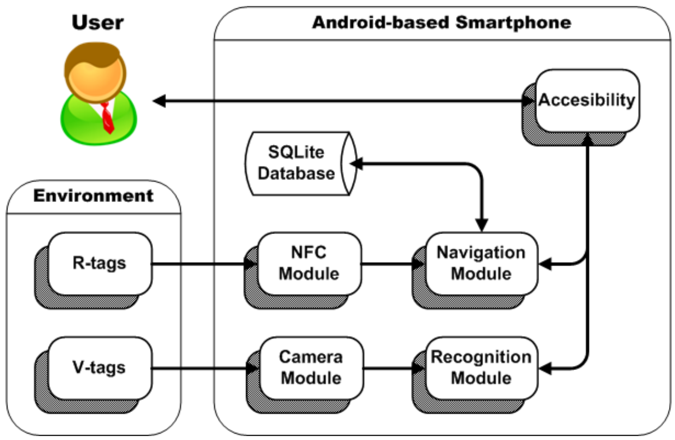


Fig. 1 System Architecture

***Environment***

**R-tags:** Passive RFID tags (R-tags) are deployed in the environment in strategic locations at eye-level height. Americans with Disabilities Act (ADA) Guidelines requires the signage to include high contrast raised letters between 1.6 cm and 5 cm, and embossed Braille. They are located on each possible destination (e.g. office doors, restrooms, emergency exits) and intermediate landmarks. Granularity was the main reason behind selecting this technology. Proximity of 2-3 cm is required to transfer data from the R-tag into the RFID reader. Other reasons for selecting these R-tags were their cost and the fact that they do not need any power source. On each R-tag we incorporate the room number in raised font and its Braille equivalent. **V-tags:** Paper printed visual tags (V-tags) are designed for remote detection through the camera embedded in the smartphone. V-tags are deployed above each R-tag and will allow the visually impaired users to find the R-tags from a distance. Using the V-tags, the users do not need to trail the walls to find the R-tags that help provide the navigation instructions. The users can find the R-tags from any place in the environment for up to 19 meters (65 feet).

***Android-based Smartphone***

Smartphone Application runs on the Android Platform. This application can run on any Android Smartphone that runs the Android Operating System 4.0 (Ice Cream Sandwich) or higher and that has an embedded Near Field Communication (NFC) Reader. Development and testing was performed on a Samsung Galaxy Nexus Smartphone. The Smartphone App includes five modules: **NFC Module:** Once the user puts the Smartphone close to the R-tag (near touch), the NFC reader will retrieve the R-tag unique ID. **Camera Module:** The embedded camera on the Smartphone captures the environment once the user pans the Smartphone running our application. The V-tag detection algorithm to find a V-tag will use this environment. More details are provided in Section V. **Accessibility:** Android operating system is designed to enable interaction with blind or visually impaired users. Accessibility features define new operation interface and voice feedback for this use. **Recognition Module:** This module is responsible for detecting the V-tag and providing the instructions how to reach the V-tag.

**User Interface**

The two Android accessibility features we use are talkback and explore by touch. The touch features enable a visually impaired user to navigate the Smartphone through the use of gestures as follows:

***Touch Gesture*****:** When a user touches the screen, if there is an item below their finger it will be focused. The focused item will then be read out to the user through text to speech output. This allows the user to first understand what they are touching through audio feedback and then they can make a decision if this is what they want to select by using a double tap gesture. ***Double Tap Gesture*****:** When a user double taps anywhere on the screen the focused item is selected. ***Swiping Gesture*****:** When a user swipes their finger in any direction they will focus on the next focusable item in the direction they swiped. ***Two Finger Gesture***: If a user is presented a list of items that is too long to fit on the screen, they will need to scroll. When the list is first populated on the screen the user is told through Text-To-Speech how many items are in the list displayed on the screen out of the total number of items in the list. From this feedback the user knows they will need to scroll. In addition, when the user reaches the end of the list on the screen a chirp sound will inform the users that they are at the end of the list. By placing two fingers on the screen and making a swiping up gesture the following items are then displayed and by placing two fingers on the screen and swiping down the prior items in the list are displayed.

**Visual Tag and Detection Algorithm**

As described above, we will place the V-tags in the environment just above each R-tag. The user will look for these V-tags using pan and wait mode and the Tag Finder will provide voice feedback how to reach the specific V-tag that is within the camera view. These V-tag guiding instructions are designed as two parts. If the tag is not in the central area (we define it to be the middle 1/2 height and width area), the application will notify the user to pan the cell phone. Fig. 2 shows the area partitions with their corresponding suggestions to user. For example, when the V-tag is located in the “Upper Left” tile, user can hear the notification of “slide your phone to the left”. If the tag is in the central area, the guidance module will calculate the distance between the phone and the tag using geometric projections, and then notify the user an approximate distance in integer feet, like “go straight for 8 feet”.

The indoor navigation system for the blind and visually impaired focuses on the visual tag detection and user interface. We introduced a reliable and robust visual tag detection algorithm which was tested in multiple scenarios which differ in environmental conditions such as lighting, and usage scenarios such as distance from the tag and angle. The performance results in terms of accuracy and detection time were excellent especially in good lighting conditions. We also provide guidelines to determine the visual tag size as a function of lighting, maximum distance, and angle. We have also developed a vision free user interface using Android accessibility features.

This research will impact indoor navigation systems for the blind and visually impaired enabling them to navigate independently through indoor transportation venues