A path-guided audio based indoor navigation system for persons with visual impairment

Dhruv Jain, Akhil Jain, Rohan Paul, Akhila Komarika, M. Balakrishnan
Assistive Technology Group, Department of Computer Science and Engineering
Indian Insitute of Technology Delhi
New Delhi-110016, India
{cs1090187@cse, cs5110274@cse, rohan_paul, ee2080383@ee, mbala@cse}.iitd.ac.in

ABSTRACT

Independent path-based mobility in an unfamiliar indoor environment is a common problem faced by visually impaired community. We present the design of an infra-red based active wayfinding system for the visually impaired. Our proposed system: downloads the floor plan of the building, locates and tracks the user inside the building, finds the shortest path and provides step-by-step direction to the destination using voice messages. The audio instructions include active guidance for impending turns in the path of travel, distance of each section between turns, obstacle warning instructions and position correction messages when the user gets lost. Results from a needs finding study with visually impaired individuals formed the design of the system. We then deployed the system in a building and field tested it with users using a standardized before-and-after study. The comparison of the results demonstrated that the system is usable and useful.

Categories and Subject Descriptors: K.4.2 [**Computers and Society**]: Social Issues - Assistive technologies for persons with disabilities; C.3 [**Computer Systems Organization**]: Special-Purpose and Application-Based Systems—*Real-time embedded systems*

General Terms: Human Factors, Design, Experimentation, Measurement

1. INTRODUCTION AND RELATED WORK

Navigation and wayfinding to reach a desired destination is a considerable challenge for a visually impaired person particularly in an unknown indoor environment. Path finding is a composition of several cognitive processes like map building, landmark identification, obstacle avoidance and interaction with by-standers to ask directions. Most of the globally present signages are vision based and thus are inaccessible to them. Locating an accessible signage (tactile, audio) again poses a problem. Navigators currently rely on sporadic help from bystanders and use path integration to follow a given direction. This causes anxiety, embarrassment and makes them reluctant to go alone in an unfamiliar building. This was also corroborated in our own needs finding study.

Existing commercial navigation systems based on GPS(eg. StreetTalk[1]) have made navigation a lot easier in outdoor environments. But their major shortcoming is that they can only identify very specific landmarks encountered by the user and typically do not work in the indoor setting. Several attempts have been made to address the problem of indoor navigation for visually impaired. However, no single solution has found wide acceptability and long term deployment for use. Most of the systems present today are either only landmark identification systems with no path-based guidance(eg. RFID[4], Infrared based systems[2]) or are inaccurate for an indoor environment(eg. dead-reckoning[3], GPS). Few systems exists which are both omnipresent(which could localize the user accurately from any point in the building) and provide step-by-step path based wayfinding. Those who do meet both these criteria(eg. Building Navigator[5]), are very bulky to carry and expensive to operate.

In this work, we present the design and implementation of a portable and self-contained indoor navigation system currently deployed in a university building. Comprising of a network of wall mounted units and a user module coupled with a mobile application (Figure 1), the system downloads the map of the building, localizes the user in its vicinity, takes the destination as input from the user, and then helps him to independently navigate to his destination using step-by-step navigational instructions. The system was built via iterative feedback from visually impaired people at every stage from inception, specification to testing. Novel features of the system are:

- Step-by-step path-based navigation with active guidance for turns and important landmarks in the course of travel
- Continuous update on position awareness information catering to a visually impaired person's need particularly obstacle warning instructions and corrective directions when the user gets deviated
- Minimalistic and universal user interface which does not interfere with other routine activities and can also be easily operated easily by low-vision and sighted persons
- Reduced anxiety in finding and maintaining an optimal (distance wise) path, thereby allowing faster movement towards the goal

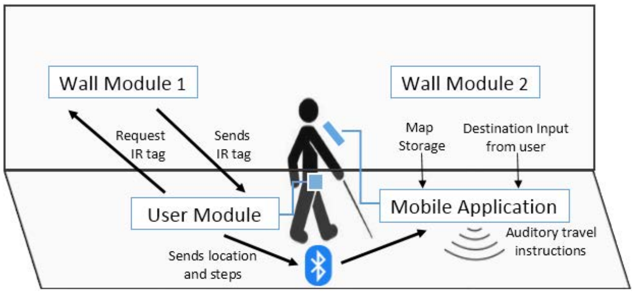

Figure 1: Working of the system.

2. METHODOLOGY

Design process: To gain insights into the process of indoor wayfinding and desired specification for the proposed system, a needs finding study was conducted with five visually impaired persons (3 males and 2 females) aged between 21-35 years. The participants were asked to navigate a predefined track in two public places unfamiliar to them in Delhi and we noted the problems faced during navigation. It was observed that the users usually try to find signs, ask for help or resort to ad hoc approaches. They were confused regarding the correctness of their current course and were vulnerable to injuries during navigation. During the post-study interview, the users expressed the need for an audio-based guidance system which would give information about the *current location, impending turns and important landmarks to the destination* and approximate distance of each section between the turns. These key insights informed the design of our system.

System description: We chose to use mobile phone for interaction with the user since it is commonly used by the people. The user upon starting the mobile application, downloads the map of the particular building from our server on his phone in about 2 sec. He then connects the mobile application to the user module by tapping the touch screen. After a successful connection, the user has an option of either speaking his/her desired destination or typing the destination using the QWERTY keypad. As the user starts walking, the mobile application receives the current position and the number of steps data from the user module. Following the shortest path algorithm, the mobile application dynamically calculates the path to the destination and the user is informed about his/her current location and asked to move left/right/straight along with the number of steps to be traveled to go to the next critical location (viz. intersection, T point, lift etc.) on the path. The process goes on till the user reaches the desired location which is again conveyed to him/her. Further, while walking if the user takes a wrong turn, or deviates from the path, the application warns the user and the path is re-calculated from the user's current location to his destination.

3. EVALUATION AND RESULTS

The system was evaluated with 5 male and 5 female visually impaired uses randomly selected from two welfare organizations for the blind in the age-group of 18-40 years. The users had varied onset age of blindness and adequate knowledge about using a mobile phone. Participants mostly used cane and typically would ask for directions from sighted individuals while navigating. Two of the users were somewhat familiar with the building while the rest had no familiarity. Six out of 10 users had received O&M training in the past. A total of 42 wall-mounted modules were installed at average separation distance of 7m on multiple floors of a university building. The participants were asked to navigate on a predefined track *(path 1)* according to the study protocol highlighted in Figure 2 and the study parameters were noted.

Figure 2: Major phases of the study protocol.

Table 1: Average values of quantitative measure

Parameter	baseline	with system
Major deviations from path	2.67	**0**
Help seeking from volunteers	4.67	0.33
Time of travel	200.38s	**135.25s**
Number of steps taken	140.63	113.13

During the post-trial interview, all users mentioned that they were able to understand the usage of the device and reach their destination comfortably using the system. Significant reduction in all the reported quantitative parameters was observed as shown in Table 1.

Most users were comfortable with the user interface of the application. They appreciated the device giving instructions during wrong turns or in case of wide corridors and continuous confirmation of being on right path through vibration alerts. The average confidence level of the users(*Likert* scale responses) increased from 2.6/5 during baseline trial to 4/5 during the trial with the device. Users also acknowledged that the system is user-friendly, easy to learn and operate. Average learning time for the system was about 2.5 hrs.

4. CONCLUSIONS

In this work, we have shown that independent indoor navigation in unfamiliar environments is a potential problem for the visually impaired community. We reported the user-centric design implementation and user evaluation of a system which when deployed, can help the users effectively navigate in indoor environments. It provides step-by-step path based guidance using audio instructions and position correction information when the user gets deviated from the path.

5. REFERENCES

[1] StreetTalk VIP. http://www.freedomscientific.com/products/fs/streettalk-gps-product-page.asp.

[2] Talking Signs Inc. 2000. http://www.ski.org/Rehab/WCrandall/introts.html, June 2007.

[3] L. Fang, P. Antsaklis, L. Montestruque, M. McMickell, et al. Design of a wireless assisted pedestrian dead reckoning system - the navmote experience. *IEEE TIM*, pages 2342–2358, 2005.

[4] A. Ganz, S. R. Gandhi, J. Schafer, T. Singh, et al. Percept: Indoor navigation for the blind and visually impaired. In *IEEE EMBC*, pages 856–859, 2011.

[5] B. Tjan, P. J. Beckmann, R. Roy, N. Giudice, and G. Legge. Digital sign system for indoor wayfinding for the visually impaired. In *IEEE CVPR*, pages 30–30, 2005.