The Journal on Technology and Persons with Disabilities

Smart Signage: Technology Enhancing Indoor Location Awareness for People with Visual Impairments

Hyun W. Ka, PhD and Satish Ravishankar, MS
Human Engineering Research Laboratories, Department of Veterans Affairs
Department of Rehabilitation Science and Technology, University of Pittsburgh
Robotics Institute, Carnegie Melon University

Abstract

We developed and evaluated a BLE-based indoor location awareness system called Smart Signage to provide blind and visually impaired people with better accessibility to the built environment. The Smart Signage system consists of three components; a user component, an environmental component, and a smartphone app. The user component implemented with a Bluetooth low energy beacon tag, which transmits radio signal representing user need every set interval to the environmental component within the set range, can be attached to conventional O&M aids like a long cane. The environmental component, which can be attached to existing tactile signs, continuously sees if the user component comes in and out, using an embedded Bluetooth low energy beacon receiver. When a person who walks with the user component is within the set range, the environmental component automatically plays a recorded voice or simple ticking sound. Based on the sound cue, the user recognizes what/where it is. The smartphone app is used to configure both the user and environment components. The user evaluation conducted with 9 participants found that the Smart Signage system had reasonable level of feasibility, acceptability and usability by showing the potential users had very positive opinions and attitudes toward the developed system.

Keywords

Indoor location awareness, smart sign, Bluetooth low energy, Internet of Things.

Introduction

Accessibility to the built environment significantly affects safe and independent daily life and community participations of people with disabilities (Shakespeare and Officer; Whyte; Imrie and Kumar). It is also an important consideration for a truly inclusive society. As a result of the American with Disabilities Act Accessibility Guideline (ADAAG), most public buildings are currently providing tactile (Braille and raised print) signs intended to help blind and visually impaired people gain easier access to their facilities. Surprisingly, however, these tactile signs are rarely used by visually impaired people because they have no proper way to locate them. Even if people with visual impairments could locate tactile signs, in many cases, they may not be meaningful, as only about 5% of visually impaired people in US are Braille literate (Johnson).

To address the above issues, several patents have been disclosed and some of them are already on the market. For example, Hart (Pat. No. 4,930,236) (Hart) and Hoshi (Pat. No. 4,934,079) (Hoshi) disclosed passive infrared-based detection technologies. Carter (C. M. A) used available visible light optical interruption as a detection technique. However, this approaches not only requires available visible light as a source being interrupted by the target, but is also susceptible to variations in ambient light levels. As commercial products, Talking Signs system (Bentzen and Mitchell) is the most well-known product, which was developed as an environmental labeling system to allow blind individuals to locate and identify landmarks, signs, and facilities of interest in the environment. It uses coded infrared transmitters as labels, and the user's handheld receiver converts the transmissions into speech. A prototype system ("Pathfinder," modeled on Talking Signs) was evaluated in a London subway station (Bentzen and Mitchell). Similar approaches have been taken in the European OPEN (Orientation by Personal Electronic Navigation) project (Seelman et al.), the SEAL Pilot-Light system, the Tele-Sensory Marco system, the RNTB Infra Voice, and the AudioSigns infrared orientation system. Verbal Landmarks system (Loomis, Golledge and Klatzky) used a series of infrared similar to the Talking Signs system. It adopted an inductive loop system that is activated when a portable receiver is within range (approximately 5 feet). When it is activated, a verbal message is generated. However, the message is non-directional and the feature of the messages is a little bit different from that of the Talking Signs. While the Talking Signs typically produce the room number or landmark, and allow users to use this information to navigate, this system gives instructions to specific goal states (e.g., "The bathroom is North 5 steps and to the right").

However, most of these products are not used in real world, because these commercial products are high cost and the users are required to have their handheld receivers in addition to their conventional orientation and mobility aids (i.e., canes and guide dogs). More importantly, most of them do not provide enough information necessary to be oriented effectively. Moreover, complexity of implementations and maintenance prevent various buildings and facilities from adopting such options actively.

As another solution to address the issue above, we developed a new design concept that originates from the perspectives of individuals with visual impairments who acquire location awareness by pinpointing sound source, designed a prototype system called Smart Signage, and evaluated the prototype system with visually impaired individuals and blinded volunteers. In this paper, we present the design concept and the research procedures.

Design Procedures

As the first step of the design, we researched end user needs and product requirements through the method of Quality Function Deployment (QFD) (Akao). This method presents the relationship between the end user needs and design requirements to transform end user needs into product/system requirements and technical specifications. To collect the end user needs, interviews with 15 end users, including 12 individuals with visual impairments and 3 building managers were conducted. Through telephone interviews, the following two open-ended questions were asked. (1)"What do you think are the most important factors in improving current signage systems?" (2)"What kind of functions do you want to be added to the signage system?" All interviewees were encouraged to give at least 3 answers to each question in order of importance.

From the results of the collected responses, a QFD matrix revealed critical user needs and identified important technical design requirements that are related to user needs. To generate the design ideas to meet the user and technical needs, brainstorming was used as a group creativity technique. With this method, a number of design ideas were generated to improve the indoor location awareness for people with visual impairments by means of a better signage system, including remote readable infrared, audible infrared, applied GPS technology, radio-based, ticking or verbal sound, computer vision based print/text recognition, Bluetooth low energy-based, speech recognition-based, applied smart card, sensor network, electronic cane with barcode reader, electronic guide dog, autonomously guided mobile robot, and electronic tactile pavement.

To evaluate feasibility and priority among the generated design ideas, the Pugh's selection chart method (Huang and Mak) was adopted, which compares alternative solutions against a set of criteria (user needs retrieved from the QFD matrix). From this assessment, the three top ranked ideas were selected. (1)Bluetooth low energy (BLE, also known as Bluetooth Smart), (2)ticking or verbal sound, and (3)sensor network. After further discussion, the three top ranked design ideas was combined into one integrated system. Through this approach, a final design idea was determined and a working prototype system called Smart Signage was implemented.

Implementation of Smart Signage

The smart Signage is a BLE based indoor location awareness assistance system. BLE is a wireless personal area network technology designed by the Bluetooth Special Interest Group (SIG) primarily aimed at novel applications in the healthcare, fitness, beacons, security, and home automation industries (Bluetooth-SIG). As it provides considerably less power consumption, reduced cost and simpler yet more efficient communication compared to conventional wireless technologies (i.e., Wi-Fi, GSM, ZigBee, classic Bluetooth, etc.) (Bluetooth-SIG), BLE as one of the most remarkable Internet of Things technologies has drastically gained in popularity. To establish a BLE-based interactive system, in general, the following 2 interrelated components are involved: tag and receiver. The BLE tag is a tiny device which periodically broadcasts radio signal (called advertising packets) containing its unique identifier, information about its status like remaining battery capacity, and user defined custom data or embedded sensor measures. Its ultra-low power consumption enables the tag to run for year(s) on a standard coin-cell battery and its transmission interval can be adjustable. The receiver is a BLE device which repeatedly scan the preset frequencies to receive the data currently being broadcasted from the tags and pass the received data as system commands or parameters to other modules. The BLE receiver can identify each tag, estimate the distance to it by measuring the received signal strength, monitor its own health, and interpret the user defined custom data. The most common use-case of BLE beacons is for retailers to provide their customers with product information, flash sales or deals (called micro-targeted advertising) when they come close to specific products or areas where the BLE tags are distributed and attached in their shop. General consumers can also use the BLE beacons to inexpensively automate their homes. For example, the beacons can be used to control lights in a house as soon as someone with a smartphone as a BLE receiver has entered it, or open doors or window shades.

The Smart Signage system consists of three components; a user component, an environmental component, and a smartphone app. The user component, which can be attached to conventional O&M aids like a long cane, includes a Bluetooth 4.0 BLE tag transmitting signal representing user need every set interval to the environmental component within the set range and a tiny push button used to resend a request to the environmental component. The environmental component, which can be attached to the service site, includes a PCB base containing a microprocessor, a BLE receiver, and a sound chip. It takes a continuous distance reading. The measuring distance can be adjustable by adjusting the on-board trimmer. The received signal strength is sued to see if the user walks in or out. The sound chip can store up to 10 seconds of sound and play it back to the user. Using the smartphone app, it is possible to configure both the user and environment components. When a person who walks with the user component is within the set range, the environmental component automatically plays a recorded voice or simple ticking sound. Based on the sound cue, the user recognizes what/where it is. The recorded voice is not turned on again until the person is away from the set range. The user can get the sound played again anytime by pressing the tiny button on the user component. A coin sized battery is used for the user component and environmental component, respectively.

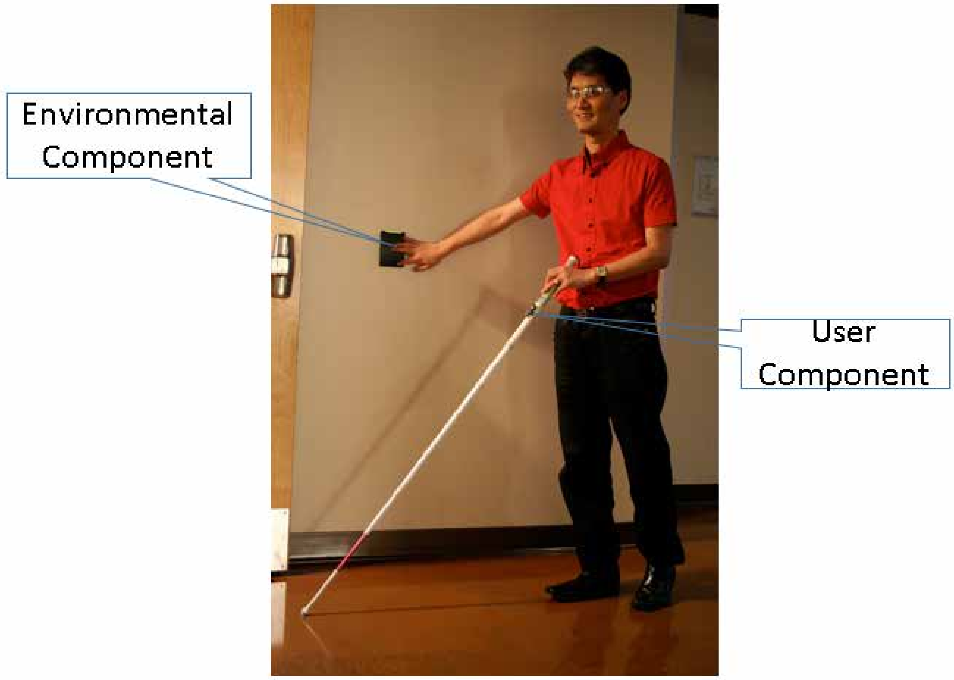

Fig. 1. Smart Signage.

Evaluation of Smart Signage

The user evaluation was conducted in the hallway at the Forbes Tower, an office building within the Department of Rehabilitation Science and Technology in the University of Pittsburgh. Nine volunteers participated in the user evaluation. As shown in Fig. 1, each participant has time to try out the user component, putting it in his/her pocket or attaching it to a long cane. Environmental components were placed on the wall along the hallway. The participant had to be blindfolded if he/she was a sighted person. Participants walked around the evaluation site with the user component for at least five minutes, evaluating the Smart Signage system by accessing the environmental components.

After the participant performed the evaluation, a quick interview session was made with the following open-ended questions: (1)"How do you feel about the interface of the user component?", (2)"How do you feel about the contents of information provided by the environmental component?", and (3)"How do you feel about the accessibility (distance, sound volume, etc.) of information provided by the environmental component?". From the hands-on practice and the interview session, it was demonstrated that Smart Signage system had reasonable level of feasibility, acceptability and usability by showing the potential users had very positive opinions and attitudes toward the developed Smart Signage system.

Discussion

In this research, we developed and evaluated a BLE-based indoor location awareness system called Smart Signage to provide blind and visually impaired people with better accessibility to the built environment. Acknowledging the great potential of the BLE beacons, several research groups have investigated the possibilities of using them to help visually impaired travelers navigate around the space. For example, Indoo.rs and LightHouse for the Blind and Visually Impaired are currently testing such a system in the San Francisco Airport (Lowensohn). UCAN Go and Calvium are working to use beacons to help visually impaired people navigate arts museums in Wales (Reid). Ifinity reports they have implemented a beacon-based indoor navigation system in the Warsaw Centre for the Disabled (M. C. S. A). Royal London Society for the Blind collaborating with ustwo is carrying out a BLE-based wayfinding project called Wayfindr (RLSB) to provide people with visual impairments a more independent navigation. They installed BLE beacons throughout a subway station, and when the users got into the station, a prototype smartphone app gave audio directions to them, interacting with the beacons. Researchers from IBM and Carnegie Mellon University's Cognitive Assistance Laboratory have developed a smartphone app called NevCog to help people with blindness and severe visual impairments (Dan). The app uses BLE beacons placed around Carnegie Mellon's campus (every 8-12 meters along all major walkways) to provide users with better location accuracy and more precise directions, rather than relying on traditional GPS technology which does not work for indoor navigation.

However, the aforementioned BLE-based accessibility projects have similar critical limitation as the currently available Talking Sign system, including lack of directional information and non-standard communication protocol relying on proprietary hardware and software. On the contrary, as the Smart Signage lets the environment recognize and provide the users with sound cue or audible information, they acquire better location awareness by pinpointing the sound source. In addition, as our solution is based on standard communication and data coding mechanisms defined by Bluetooth 4.x specification approved by Bluetooth Special Interest Group, it is possible for others to easily implement a more accessible indoor awareness service on a relatively modest budget. The BLE devices can be purchased at $10-$20 per unit. They last between 1-5 years depend on the brand/type and transmission frequencies and ranges. Moreover, by extending the design concept presented in this research, it is also possible to implement a much wider range of accessibility services for individuals with differing disabilities. For example, universal door access/control service as a personalized, accessible, responsive door access and control service for individuals with disabilities will be able to work as a manual or automatic door opener for people with mobility impairments depending on the severity of their disabilities, or serve as a talking sign for individuals with blindness. Safety alerting service will be able to provide individuals with disabilities with adaptive feedback when the user is approaching an environmental object (e.g., emergency warning triangle/cone, safety notice board) marked with an environmental component. Universal elevator button control service as a personalized, accessible, responsive access service will be operated by speech recognition for people with mobility issues, provide auditory feedback for the visually impaired, or give some instructions to a person with cognitive issue or to a novice wheelchair user. Accessible pedestrian signals service will provide longer pedestrian lights for people with mobility impairments or give auditory feedback for individuals with visual impairments.

Acknowledgements

This project was supported by the Quality of Life Technology Engineering Research Center, National Science Foundation (EEC-0540865).

Works Cited

A, Carter Melvin. System for Automatically Displaying Illuminated Pictures and Delivering Sound Messages Coordinated Therewith. Google Patents assignee. 1963.

A, MM Conferences S. "Golden Antenna for Virtual Warsaw." 2015. Web.

Akao, Yoji. "Quality Function Deployment." (2004). Print.

Bentzen, Billie Louise, and Philip A Mitchell. "Audible Signage as a Wayfinding Aid: Verbal Landmark Versus Talking Signs." *Journal of Visual Impairment and Blindness* 89 (1995): 494-505. Print.

Bluetooth-SIG. "Bluetooth Basic - Low Energy." Bluetooth SIG, Inc. 2016. Web.

Dan, Lt. "Researchers from Ibm and Carnegie Mellon Unveil Visual Assistance App." 2015. Web.

Hart, Frank J. "Passive Infrared Display Devices." Google Patents, 1990. Print.

Hoshi, Hatsuo. "Display Panel Device." Google Patents, 1990. Print.

Huang, George Q, and Kai-Ling Mak. "Web-Based Morphological Charts for Concept Design in Collaborative Product Development." *Journal of Intelligent Manufacturing* 10.3-4 (1999): 267-78. Print.

Imrie, R., and M. Kumar. "Focusing on Disability and Access in the Built Environment." *Disability & Society* 13.3 (1998): 357-74. Print.

Johnson, L. "The Braille Literacy Crisis for Children." *Journal of Visual Impairment & Blindness* 90.3 (1996): 276-78. Print.

Loomis, Jack M, Reginald G Golledge, and Roberta L Klatzky. "Systems for the Visually Impaired." *Fundamentals of wearable computers and augmented reality* (2001): 429. Print.

Lowensohn, Josh. "San Francisco Airport Testing Beacon System for Blind Travelers." 2014. Web.

Reid, Jo. "Verbal Maps and Human Intelligence." 2014. Web.

RLSB. "Wayfindr." Royal London Society for the Blind 2014. Web.

Seelman, Katherine, et al. "Sensory Aids." *Wiley Encyclopedia of Biomedical Engineering* (2006). Print.

Shakespeare, T., and A. Officer. "World Report on Disability." *Disabil Rehabil* 33.17-18 (2011): 1491. Print.

Whyte, J. "Enabling America: A Report from the Institute of Medicine on Rehabilitation Science and Engineering." *Arch Phys Med Rehabil* 79.11 (1998): 1477-80. Print.

Journal on Technology and Persons with Disabilities

ISSN 2330-4216

LIBRARY OF CONGRESS * U.S. ISSN CENTER
ISSN Publisher Liaison Section
Library of Congress
101 Independence Avenue SE
Washington, DC 20540-4284
(202) 707-6452 (voice); (202) 707-6333 (fax)
issn@loc.gov (email); www.loc.gov/issn (web page)