Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 83 (2016) 690 – 694

Procedia Computer Science

The 7th International Conference on Ambient Systems, Networks and Technologies (ANT 2016)

Ray: Smart indoor/outdoor routes for the blind using Bluetooth 4.0 BLE

Manuel Castillo-Cara[a,b,c,*], Edgar Huaranga-Junco[a,b], Giovanny Mondragón-Ruiz[a,b], Andree Salazar[b], Luis Orozco Barbosa[c], Enrique Arias Antúnez[c]

[a]*Computer Science Department - Sciences School - Universidad Nacional de Ingeniería, Av. Tupac Amaru, 210, Rimac, Lima, 25, Perú*
[b]*Center of information and communication technologies - Universidad Nacional de Ingeniería, Av. Tupac Amaru, 210, Rimac, Lima, 25, Perú*
[c]*Albacete Reserach Institute of Informatics - Universidad de Castilla-La Mancha, Campus Universiatrio s/n, 02071 Albacete, Spain*

Abstract

This work describes the implementation of a cost-effective assistive mobile application aiming to improve the quality of life of visually impaired people. Taking into account the architectural adaptations being done in many cities around the world, such as tactile sidewalks, the mobile application provides support to guide the visually impaired through outdoor/indoor spaces making use of various navigation technologies. The actual development of the application presented herein has been done taking into account that the safety of the end user will very much depend on the robustness, accuracy and timeliness of the information to be provided. Furthermore, we have based our development on open source code: a must for applications to be adapted to the cultural and social characteristics of urban areas across the world.

Peer-review under responsibility of the Conference Program Chairs

Keywords: Beacon ; Bluetooth 4.0 BLE ; blind ; smart path ; indoor route ; outdoor route ; navigation ; smart traffic light ; mobile devices

1. Introduction

According to the World Health Organization[1] (WHO), nowadays, there are 285 million people with visual impairment, of which 39 million are completely blind and 246 million have low visibility disabilities. To improve the social inclusion of these citizens, novel technological solutions are being explored and developed by many different organizations: research centers, industrial players and public agencies[2].

In this paper, we present a novel mobility solution to assist the visually impaired through their daily journey. The mobility assistant does not only provide guidance to the blind through his/her day-to-day journey, but it also serves as a valuable source of information to city managers. Many mobility assistants have been reported in the literature. Two of the main issues addressed by most works have centered around their usability and operability[3]. The latter refers

* Corresponding author. Tel.: +51-993966523
E-mail address: mcastillo@uni.pe

Peer-review under responsibility of the Conference Program Chairs
doi:10.1016/j.procs.2016.04.153

to their ability to operate both in outdoor and indoor environments[4]. Most outdoor solutions have relied on the use commercial GPS systems[5], while in the case of indoor environments, various technologies, such as RFID[6,7], wireless LANs[8] and computer vision[9,10] are being explored. As for their usability, system prototypes have been tested and evaluated in various sites. Such studies have taken into account, up to a certain extent, the cultural and architectural features of the target environments. The results have proven their potential on improving the quality of life of people suffering from visual impairments.

In an effort to provide a friendly environment to the visual impaired, many cities[11] have invested into traffic lights incorporating sound systems, tactile and accessible sidewalks. Many cities are already working on implementing smart traffic lights synchronized in real time based on the traffic and people mobility[12]. In fact, this feature makes part of the enhancements to the infrastructure of Smart Cities recommended by the ISO 37120:2014[13]. However, the high costs involved in the deployment of such facilities requires the careful planning and the development of low-cost reliable solutions. Power efficiency is another major issue to be addressed[2,14]. An overall solution also calls for the synchronization of a large number of devices enabling the timely and reliable operation of the overall solution.

In this context, our work has been implemented considering the limitations of other technologies. We have developed a hybrid system that visual impaired people may use in indoor/outdoor environments based on the use of GPS and Bluetooth 4.0 BLE technologies along with a mobile device[15]. The latter is mainly characterized by the low-power requirements, making it a cost effective and reliable solutions.

Regarding the implementation of the outdoor functionalities of the mobility assistant proposed herein, they comprise a smart traffic light controller and the development of an application based on the Google Directions API and Google Maps Geocoding API. The controllers have been designed to be installed at the traffic lights. They provide the required infrastructure to communicate with the mobile assistant application via Bluetooth. In this way, users may get timely and accurate information all along their journey. As for the indoor environments, the mobility assistant relies on the use Bluetooth beacons devices strategically placed to identify the different areas of a building. The application makes use of the pedometer and gyroscope sensors found in most smart phones. In this way, the user can be accurately guided through indoor spaces.

As for the user interface, being an application for the visually-impaired, it is launched by pressing the volume button. Finally, the user can interact with the application through a voice recognition system implemented using the TextToSpeech Google API.

2. Ray: A low-power smart mobile assistant for the blind

Recent developments have enabled the implementation of low-power controllers and communication interfaces. We have based our design on an AVR micro-controller. As for the communication interfaces, we have made use of Bluetooth 4.0 devices[16,17]. Bluetooth 4.0 devices can operate in two different modes: Bluetooth Low Energy (4.0 BLE) and Enhanced Data Rate (EDR 2.0). In both modes, the devices basically implement the sames tasks: digital transmission, tele-control and data acquisition. The main differences between both modes rely on the power consumption and the achievable data transmission range. Figure 1 shows the circuit diagram and the picture of the traffic controller and the Bluetooth 4.0 BLE device.

2.1. Smart Indoor routes

One of the main features of our mobile assistant has been centered on the design of a friendly and reliable service. Voice messages guide the users in indoor environments. Voice messages include ”Go ahead” or ”Turn left or right” indications. These services have been implemented based on the pedometer, gyroscope and Bluetooth interface already integrated into most smart phones. The latter is used to keep in touch with the Bluetooth beacons strategically placed in the building.

We define a Beacon-Zone, an ambient where a beacon can be detected. The beacons provide guidance through current area in which the user is located. In order to ensure the accuracy of the estimated position of the user, each Beacon-Zone has a CP (checkpoint). The users are then directed from one CP to another, i.e. a route is made of a sequence of the CPs. Figure 2 shows the experimental deployment of our solution. The coverage area of each beacon

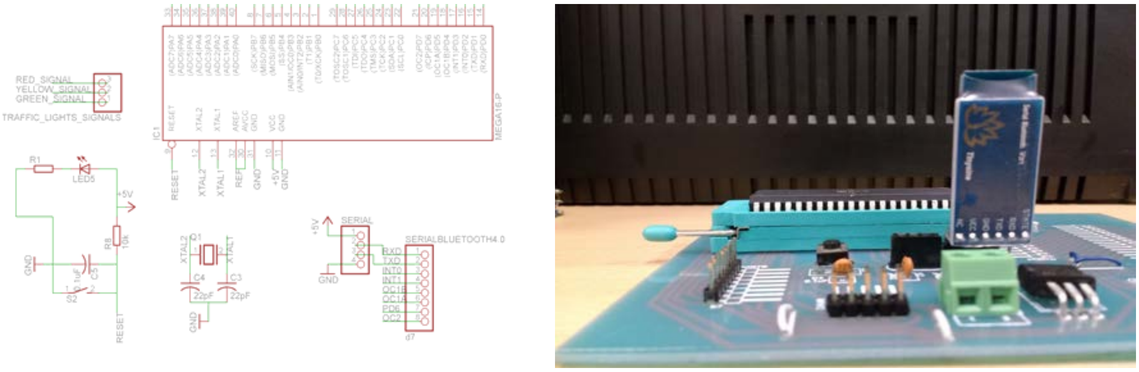

Fig. 1. Circuit diagram and traffic-light micro-controller

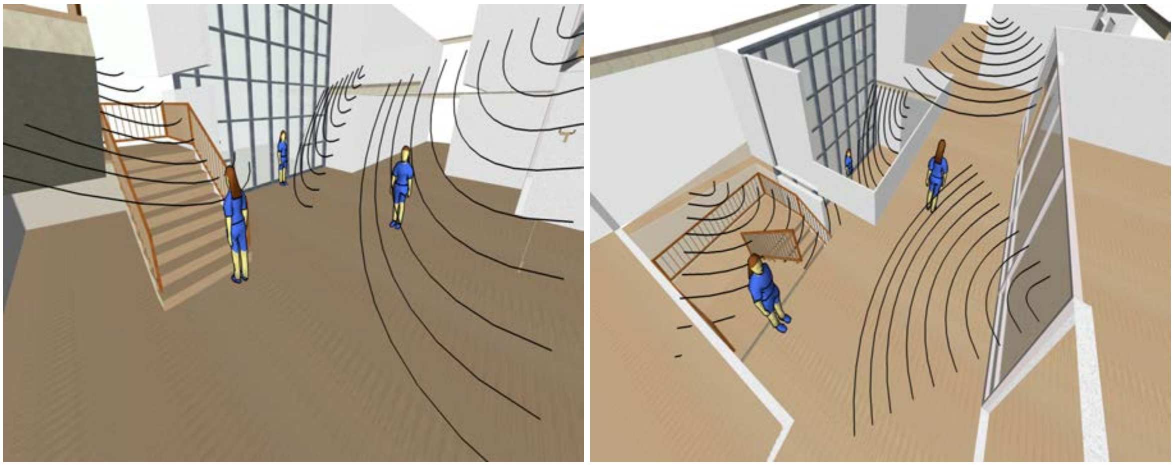

Fig. 2. Beacons coverage area in first and second floors

is also depicted in the figure. As the user moves throughout the building, the handover from one beacon to another one is made based on the level of the RSSI detected by the mobile assistant.

The configuration of the beacon sensors has been implemented bearing in mind once again the accuracy of the instructions to be provided to the end user and the power consumption. The broadcast interval was therefore set to 1*s* and the power transmission between 3 and 4*m*. Care was also taken to avoid the detection by the mobility assistant of two or more beacons with RSSI>-85dBm.

Table 1 shows the RSSI and standard deviation detected by the mobile assistant during a period of 1*min* at different distances from the reference beacon. As seen in the table, the level of the signal degrades rapidly as a function of the distance. It is therefore important to make use of a large number of beacons spaced one another at a distant no longer than 1.5*m*, i.e., there should be at least a 50% overlap between the coverage areas of two adjacent beacons.

Table 1. Signal in Beacon device.

Distance	Inside the pocket	RSSI (*dBm*)	Standard Deviation
10*cm*	No	-72.53	5.99
10*cm*	Yes	-77.59	6.46
1*m*	No	-85.46	6.36
1*m*	Yes	-90.45	6.92
3*m*	No	-95.15	5.68
3*m*	Yes	-98.78	6.33

2.2. Smart Outdoor routes

Current navigation systems make use of GPS coordinates, routes and directions. However, in the case of an application designed to assist visually impaired people, we suggest the use of an hybrid BNE4.0/GPS system. Our proposal makes use of BNE beacons strategically installed at the traffic lights. One of the main tasks of the traffic controller consists on changing of state whenever the traffic light switches from one state to another. The design has taken into account the power consumption. These changes are therefore handled through the input ports of the AVR micro-controller using an interrupt mechanism. In this way, the controller remains most of the time in the SLEEP mode. In the case of the ”Don't Walk” traffic light state (Red Light), the BLE device remains active and ready to transmit this event to the mobility assistants of the users located in close proximity to the traffic light.

For the purpose of meeting the safety and power consumption trade off, the transmission range has been fixed to $3m$ around a traffic light. It is worth to mention that most streets in the city of Lima are rather narrow. Table 2 shows the signal level observed during the tuning up process of our implementation. During our tests, we assumed that the user carries the mobility assistant in the pocket and that the BLE device operates in the low power mode.

Table 2. Signal level of the Bluetooth 4.0 BLE controller.

Distance	Inside the pocket	RSSI	Standard Deviation
10cm	No	-41.55	3.18
10cm	Yes	-47.57	3.37
1m	No	-57.04	2.49
1m	Yes	-65.30	4.31
3m	No	-67.81	3.12
3m	Yes	-71.40	3.77

As for the outdoor navigation assistance, we based our solution on the use of the Google maps API. Even though Google Maps always suggests the shortest path, we have to realize that the most convenient path to the blind may not be necessary the shortest one. In fact, our goal is to make use of the paths adequately adapted to the visually impaired. For this reason, we did have to adapt some of the functionalities of the Google Maps API. It is for this reason that we have focused on avoiding to go across areas characterized as difficult or not adequate for pedestrians, such as street intersections without traffic lights. Obviously if such alternate route is not available, the user will have to be guided throughout the shortest route.

Figure 3 depicts the functionality of a Smart Traffic Light incorporating our Bluetooth solution. We should realize that traffic lights in South America are deployed across the streets. That is to say, a pedestrian has to look at the traffic located across the streets. Furthermore, the end-use's itinerary has to be identified as well as his/her orientation. This is achieved through the gyroscope and by requesting a confirmation from the user on his/her intended journey. The figure also shows an example of one route suggested by Google Maps which has been modified by Waypoints in order to direct the user throughout a safer route. Furthermore, we have identified that ”T” shaped intersections require the use of beacons to guide the user throughput the proper intersections.

3. Conclusions and Future work

In this work, we have presented a prototype of a mobility assistant for visual impaired users. The mobile assistant has been designed taking into account the need for low cost solutions in the context of Latin American urban areas. We have therefore identified the shortcomings of some of the current services provided by Google.

Regarding the operation of the proposed solution in an indoor environment, we have identified that further studies have to been conducted on the accuracy and reliability of localization systems based on Bluetooth technologies. The use of filters and the tuning of parameters, such as the power level, should be clearly examined.

As for our future research plans, we will be focusing on incorporating other sources information allowing us to evaluate the economical and social benefits of outdoor solution in a close to real world scenarios. The access to relevant data made available by the municipalities should set the basis for such study.

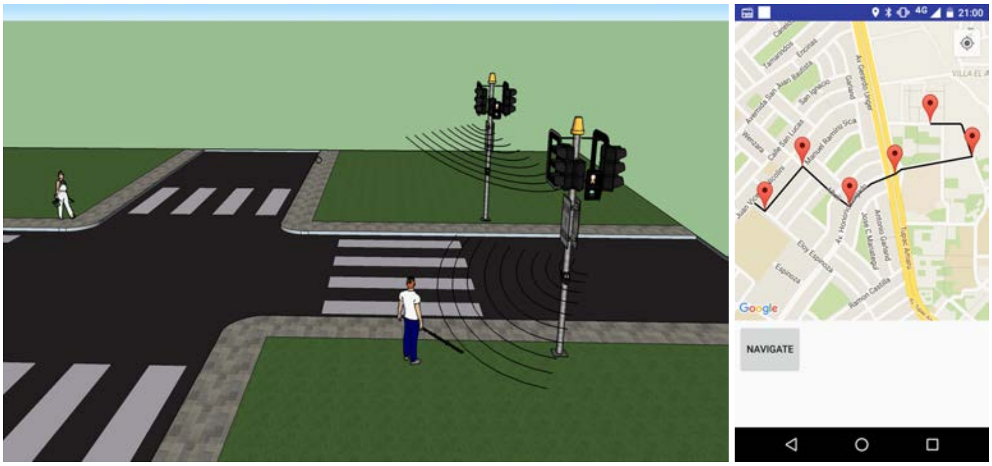

Fig. 3. Smart Traffic light and Waypoints in APP

Acknowledgements

This work has been partially funded by the ”Programa Nacional de Innovación para la Competitividad y Productividad, Innóvate - Perú” of the Peruvian government, under grant number FINCyT 363-PNICP-PIAP-2014 and by the Spanish Ministry of Economy and Competitiveness under grant number TIN2015-66972-C5-2-R.

References

1. World Health Organization. Visual impairment and blindness [on-line]. Fact Sheet N282, Updated August 2014 [date: 23th January 2016]. Available: <http://www.who.int/mediacentre/factsheets/fs282/en/>.
2. Nicholas A. Guidice, Gordon E. Legge. The Engineering HandBook of Smart Technology for Aging, Disability, and Independence. Chapter 25 Blind Navigation and the Role of Technology. 2008.
3. UTC Spotlight. University Transportation Centers Program. Smartphone-Based System Improves Safety and Mobility for Visually Impaired Pedestrians. Minnesota. September 2014.
4. K. Yelamarthi, D. Haas, D. Nielsen and S. Mothersell. RFID and GPS Integrated Navigation System for the Visually Impaired. IEEE 978-1-4577-0768-1/11. 2011.
5. Y. Zhao, X. Xue and T. Zhang. Receiver-channel based adaptive blind equalization approach for GPS dynamic multipath mitigation. Chinese Journal of Aeronautics. Volume 26, Issue 2. pp. 378-384. April 2013.
6. M. Murad, A. Rehman, A. A. Shah, S. Ullah, M. Fahad and K. M. Yahyal. RFAIDE An RFID Based Navigation and Object Recognition Assistant for Visually Impaired People. IEEE 978-1-4244-7773-9/10. 2014.
7. H. Fernandesa, V. Filipea, P. Costa and J. Barrosoa. Location based Services for the Blind Supported by RFID Technology. Procedia Computer Science. Volume 27. pp. 2-8. 2014.
8. J. Cecilio, K. Duarte and P. Furtado. BlindeDroid: An information tracking system for real-time guiding of blind people. Procedia Computer Science. Volume 52, Issue 1, pp. 113-120. 2015.
9. S. Wang, H. Pan, C. Zhang and Y. Tian. RGB-D image-based detection of stairs, pedestrian crosswalks and traffic signs. Journal of Visual Communication and Image Representation. Volume 25, Issue 2. pp. 263-272. February 2014.
10. ML. Mekhalfi, F. Melgani, A. Zeggada, FGB. De Natale, MAM. Salem and A. Khamis. Recovering the sight to blind people in indoor environments with smart technologies. Expert Systems with Applications. Volume 46. pp. 129-138. 15 March 2016.
11. Smart City Barcelona. Smart traffic lights [on-line]. Emitting sound for blind people and providing green corridors for Fire Brigade vehicles. [date: 23th January 2016]. Available: <http://smartcity.bcn.cat/en/smart-traffic-lights.html>.
12. I. P. Olivera, R. Souza, F. Junior, L. Sales, F. Ferraz. A Vision of Traffic Lights for Color-Blind People. SMART 2015 : The Fourth International Conference on Smart Systems, Devices and Technologies. 2015.
13. ISO 37120:2014. Sustainable development of communities - Indicators for city services and quality of life. Document published on: 15th may 2014.
14. Siemens. Using a Smartphone App to Assist the Visually Impaired at Signalized Intersections. Munich. 16th December 2014.
15. CF Liao. InMoBS pilot project - Inner-city mobility support for the blind and visually impaired. University of Minnesota. August 2012.
16. J. Decuir, Changing the way the world connects Bluetooth 4.0: Low Energy, Standards Architect, CSR plc; IEEE Region 6 NW Area chair. 2010
17. Bluetooth. Specification of the Bluetooth System, Bluetooth SIG Inc., 2013.