2017

IO Vision – an integrated system to support the visually impaired

Sheetal Datt
Auckland University of Technology, sheetalamenhadatt@gmail.com

Mali Senapathi
Auckland University of Technology, mali.senapathi@aut.ac.nz

Farhaan Mirza
Auckland University of Technology, farhaan.mirza@aut.ac.nz

IO Vision – an integrated system to support the visually impaired

Sheetal Datt
School of Engineering, Mathematical and Computing Sciences
Auckland University of Technology
Auckland, New Zealand
Email: sheetalamenhadatt@gmail.com

Mali Senapathi
School of Engineering, Mathematical and Computing Sciences
Auckland University of Technology
Auckland, New Zealand
Email: msenapat@aut.ac.nz

Farhaan Mirza
School of Engineering, Mathematical and Computing Sciences
Auckland University of Technology
Auckland, New Zealand
Email: farhaan.mirza@aut.ac.nz

Abstract

There are many navigation systems for the visually impaired but few among them provide seamless integration of indoor - outdoor navigation. This paper reviews navigation systems that are currently available for the visually impaired and proposes the Indoor-Outdoor Vision navigation system (IO Vision) that will make navigation easier in both indoor and outdoor environments. The findings reveal that while there are many systems that support either the outdoor or indoor navigation, systems that provide seamless integration of both indoor and outdoor navigation are extremely limited. This study proposes the development of an integrated system that combines the features of indoor and outdoor systems. A long-term goal of this research is to develop a self-contained system that utilizes the principles of Geographical Positioning System (GPS) and Geographical Information System (GIS) in association with Radio Frequency Identifiers (RFID) and sensors to support the navigation of the visually impaired.

Keywords: Impairment, Navigation, Cloud Computing, Radio Frequency Identifiers, Assistive Devices.

1 Introduction

Visual impairment is a term that includes both an imperfect eye sight as well as complete blindness (Mehta et al. 2017). Some forms of partial blindness can be corrected by external wearable devices as well as through surgeries; however there are some kinds of visual impairments that cannot be treated at all or can lead to complete blindness when not treated in time as in Glaucoma and Diabetes. Under such situations it is challenging for the visually impaired people to lead a normal day to day life. Over decades, the most common device that has been aiding navigation of the blind and the impaired is the walking cane also referred to as 'white stick' (Koskinen and Virtanen 2004). However, it has a limited functionality as it can only identify the static obstacles that exist in the path of the user. An alternate to the white cane has been the guide dogs. However, the guide dogs are expensive to maintain (Koskinen and Virtanen 2004).

When navigation is considered from the point of view of a visually disabled person, we should realise that it is very challenging as it involves traversing across different environments like parks, parking lots and certain areas which are not defined properly. Keeping this in mind and with the development of science and computer technology, a wide variety of navigational aids referred to as Electronic Travel Aids (ETA) have already been developed. Some of these aids include Laser Cane, Sonic Path Finder, TYFLOS and NavBelt (Dakopoulos and Bourbakis 2010). These systems make use of a variety of ultrasonic and infrared sensors which have the capability to capture spatial data from the space around the visually disabled person and help exclusively in navigating in the outdoor environment. ME-NAV is a navigation system that allows for navigation in the indoor environment (Yayan et al. 2015). However, a major drawback with any of these indoor systems is that they are designed exclusively for an indoor environment. These devices also have inherent limitations as in they are expensive and may have issues associated with their angle of resolution. It also involves additional problems like issues involving platform interoperability and reusability (Giudice and Legge 2008). This indicates that there is a need to develop a system that will enable navigation in both the environments using a single device.

2 Review of Related Work

On a broader perspective, the expected navigation system for the visually impaired is to be categorized as 1. Indoor navigation system and 2. Outdoor navigation system. An ideal system would be one that would allow for both indoor and outdoor navigation. However, literature review reveals that emphasis is mostly on outdoor navigation. Several outdoor navigation systems are available in the market. The following subsections explain how the different solutions that have been designed so far can be categorized based on the literature review.

2.1 Electronic Travel Aids (ETA)

The ETA is a form of assistive technology with the main purpose of enhancing the mobility of the visually impaired (Dakopoulos and Bourbakis 2010). The major ETA devices that have been developed so far are as follows:

Way back in 1973 the *Laser cane* was developed based on the concept of optical triangulation. It mainly helped in detecting obstacles in the path of the user (Bolgiano and Meeks 1967). A few years later, a hand-held device was developed which was referred to as the *Mowat Sensor*. It had ultrasonic sensors and prompted the users via tactile vibrations (Brabyn 1982). Worn around the neck, the *Pathfinder*, is used in association with the long cane. It makes use of sound waves and prompts the user through a series of vibrations (Snaith et al. 1998). A few years later another hand-held sonar device referred to as *The Nottingham Obstacle Detector (NOD)* was developed. It prompts the user through auditory feedback via the octave of musical tones (Borenstein and Ulrich 1997). To allow for orientation and mobility of blind individuals the *Binaural Sonic Aid (Sonicguide)* was made. It is an eyeglass which is configured as a sonar type device. However, these devices are not used rampantly due to several reasons. Firstly, these devices need to be used in association with a walking cane. Owing to this fact, they are of no optimum use all by themselves and are used as secondary devices (Ifukube et al. 1991). Secondly, once the obstacle is identified in the path, it leaves it to the navigator to work his/her way around the obstacle (Warren and Strelow 2013).

2.2 Electronic Orientation Aids (EOA)

To overcome the disadvantages stated in the previous section, the second set of devices referred to as Electronic Orientation Aids (EOA) came into existence. They are another form of assistive devices that helps the impaired people to find way to their destination by providing information related to location and direction.

Some of the prominent EOA's that have been developed are NavBelt, NavChair and Guide Cane. *NavBelt* is a multi-sensor travel aid that was developed on the underlying concept of an Obstacle Avoidance System (Borenstein 1990). It consists of a belt of ultrasonic sensors that is worn around the waist, hence the name NavBelt. The *NavChair* gets its name based on its functionality. It incorporates the technology that was developed for robotic science. It is a wheelchair with ultrasonic sensors that allows users to drive the chair and prompts them with commands when it identifies an obstacle in its path (Faria et al. 2014). It makes use of ultrasonic sensors and a 'stimulus – response' technique (Narayanan 2016). However, the limitation of not being able to use it in a narrow pathway and the difficulty of finding storage space hinders it from being used widely. The *Guide Cane* is built on the similar lines of a NavChair. It is also a robotic guidance device for the blind and it makes use of the ultrasonic sensors attached to the end of a wheeled cane to detect and map obstacles. As this can be wheeled around, the blind and visually impaired user can change their direction effortlessly. Though, these devices do find place in the market, they have some limitations as in there is difficulty in conveying information to the user, are huge and bulky and have a limitation in terms of storage in public places.

2.3 Position Locator Devices (PLD)

With the growth in the science of GPS and GIS, the next set of devices came into being. They are referred to as Position Locator Devices (PLD). Using the concept of GPS and GIS, a new feature of aiding navigation to predetermined destination was added to these devices.

Several PLD devices exist in the market, but the most prominent amongst them are as follows:

WayFinder is based on the technology underlying the Google glasses. It consists of a GPS unit and finds the route through a defined set of waypoints. However, it is functional with only the Microsoft windows smart phones (Giudice and Legge 2008). Another PLD device is the *Trekker,* which is a navigation aid for the blind that makes use of the audio input and output. A major disadvantage with this system is that the user needs to concentrate on the auditory output provided. Another disadvantage is that it is compatible with the pocket PC's only. *Street Talk* is a PLD device that runs in conjunction with another device called PAC Mate which is specifically designed for the blind users. However, it is not used much as it requires Bluetooth to connect to the GPS receiver, and it is very expensive (Roentgen et al. 2008). A very popular outdoor navigation system which takes its input and output through speech was developed in Florida and is referred to as *Drishti*. It makes use of the concept of Differential GPS. A major limitation of this system is that it is very expensive and requires the notebook laptop to be carried around (Parente and Bishop 2003). Mobile Geo was developed for the windows based smart phones. It was the first solution specifically designed for aiding navigation for the visually impaired. The fact that it is functional with a specific brand of phones serves as a limitation (Meliones and Filios 2016) and lastly is the *Loadstone* which is an open source mobile software that was developed to aid in navigation of the blind. It too gets connected to the GPS maps using the Bluetooth. It also has the limitation of being functional with the Nokia s60 smartphone (Angin et al. 2010).

The major disadvantage with most of these navigation systems is that they are mostly meant for outdoor navigation and are tied to the device and are not compatible with the other devices (Dakopoulos and Bourbakis 2010). A study on any of the above devices indicates that they aid in either finding some sort of static obstacle in the path or in finding the path to the destination based on the GPS. We did not find any stand-alone system that would aid in both navigating to unknown locations, both indoors and outdoors and in identifying an obstacle in the path.

3 Limitations of Current Systems

The literature review shows that to have a navigation system that would meet all the requirements of the user, a visually impaired navigator would have to move around with a combination of all the above-mentioned devices. This means moving with a walking cane, an electronic travelling aid to ensure that they will be prompted about an obstacle in the path and separate devices depending upon their area of coverage. This is not a feasible solution. Moreover, the devices that have been discussed above depend upon image processing techniques and make use of spatial databases (Alghamdi et al. 2014) making them suitable for outdoor navigation. Since GPS signals are not suitable for indoor navigation, an important aspect that should be addressed is the implementation of the technique of how the information about the interior of any building can be retrieved (Fallah et al. 2013). This is required as the visually impaired people need to know the location of the staircase or the elevator, the doors, the washrooms, corners of a room and other important locations. These inputs are essential since unlike people with good vision, the visually impaired people need to depend on the instructions given by the devices for navigation. It is also observed that the current systems make use of complex technology as such the users must undergo training to be able to operate them successfully which is another inhibitory feature of the existing system (Narayanan 2016). As a solution, the IO Vision system is proposed, which integrates the outdoor and indoor navigation technologies.

Table1 compares the different navigation systems with that of IO Vision. It thus aims to express how IO Vision attempts to integrate the features of the existing systems. There are innumerable navigation products available in the market and the prominent amongst them have been mentioned above. Based on the comparative analysis done it is observed that the functionality of these systems is limited. While some systems have high cost, there are some systems that are not robust as such are not accepted easily by the impaired users (Dakopoulos and Bourbakis 2010). From the tabular comparison it can be concluded that the IO Vision system fulfils all the vital requirements.

	Wearable	Portable	Cost	Context Awareness	Robustness	Ease of Use
C5Laser Cane	✓	✓	Low	✓	×	×
Mowat Sensor	✓	✓	Low	×	✓	×
PathSounder	✓	✓	Low	✓	✓	×
NOD	✓	✓	Low	✓	×	×
Sonic Guide	✓	✓	Low	×	✓	×
NavBelt	✓	✓	Medium	✓	✓	×
NavChair	✓	×	High	×	×	×
Guide Cane	✓	✓	Low	✓	×	×
WayFinder	✓	✓	Medium	✓	✓	×
Trekker	✓	×	Medium	✓	✓	×
Streettalk	✓	✓	High	×	✓	×
Drishti	×	✓	High	✓	✓	×
MobileGeo	×	✓	Low	×	✓	×
LoadStone	×	✓	High	×	✓	×
IO Vision	✓	✓	High	✓	✓	✓

Table 1. Comparative study of blind navigation systems

4 Proposed System

To overcome the limitations of the current systems, the proposed system needs to have the following features.

4.1 Outdoor and Indoor Navigation

An appropriate navigation system for the blind and the visually impaired should allow for smooth outdoor navigation. This involves proposing the best and shortest path to the intended destination. It should help in interpreting the traffic patterns and signals, recognition of pavements and buildings (Brabyn 1982). A very important feature needed in the existing system is the integration of the outdoor navigation with the indoor navigation (Warren and Strelow 2013). It is important that the users should be able to navigate indoors within their houses as well as in shopping malls, educational institutions and unfamiliar locations easily.

4.2 Face and Obstacle Recognition

Apart from allowing navigation, a suitable system should essentially aid in identifying the obstacles in the path of the navigator. This would involve identifying an obstruction in the path, sudden approach of a vehicle and road traffic (Brabyn 1982). The face recognition feature includes capturing the data about the people around the impaired navigators and enabling them to identify a known people if they are in the vicinity. This can be accomplished by capturing the image and using the segments of the image as input (Sabe et al. 2008). Relevant parameters will be extracted from these segments and matched against the predefined ones to identify the object.

4.3 IO Vision Architectural Overview

The proposed system integrates the GIS and RFID concept to create an integrated system. It makes use of a handheld device, most appropriately a mobile phone, to aid in the following functions: take user commands and give feedback to user through the speech interface module, local computation, GPS positioning module, RFID interaction as well as cloud computation (Dabas and Gupta 2010). Several cloud instances work in association with the various resources on the web to be able to provide appropriate guidance both indoors and outdoors (Bhargava et al. 2011).

The various aspects of navigation will be addressed as follows:

4.3.1 Input Device

The proposed system requires a suitable open architecture like Android to build the navigation system so as to enable multi-tasking. The text to speech function is meant to provide simple interface for the visually impaired users (Quigley et al. 2009).

4.3.2 Mobile Server

A major problem that had been identified with the existing systems is the precise determination of the location of the user especially in an indoor environment since the Global Positioning System does not function indoors (Sammouda and Alrjoub 2015). As such the proposed navigation architecture would rely on the GPS for positioning, Wi-Fi access points and triangulation method to achieve accurate location identification in the mobile server allowing for location awareness.

4.3.3 Cloud Server

With the wide choice of cloud service providers available in the market, it is easy to incorporate the cloud computing in the navigation system (Chow et al. 2010). The cloud server needs to be connected to Google Maps for outdoor route maps, to different Geodatabases, to Cartogram and Micello for the indoor routes, the software that would aid in object recognition and to different RFID sensors (Pearson 2009). The exchange of requests and responses between the mobile server and the cloud server takes place over the web supported by different communication protocols (Tesendic and Boberic Krsticev 2015).

It is proposed that the blind navigators make use of glasses embedded with micro-cameras having time of flight technology integrated into them to aid in collection of data about the surroundings. These cameras make use of the modern three-dimensional imaging technology and have been incorporated in fields like space and obstacle detection for parking vehicles. The camera serves the purpose of obstacle detection and face recognition (Prusak et al. 2008).

Figure 1 indicates how the various aspects of navigation will be addressed.

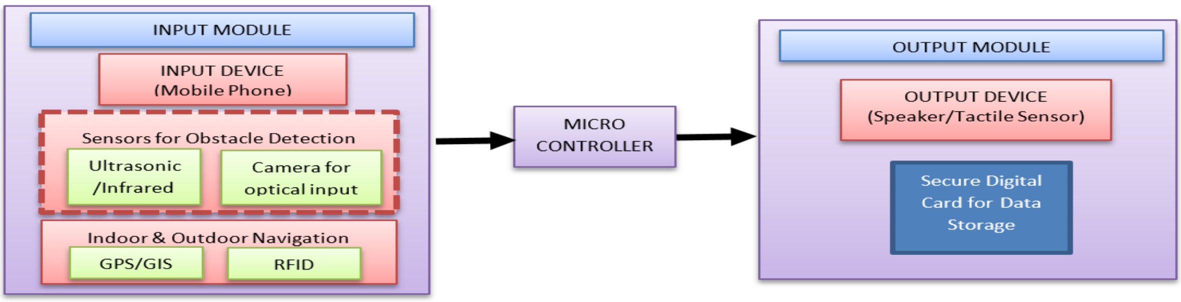

Figure 1: Input and Output module of IO Vision System

4.4 Functionality of the IO Vision System

The following section elaborates the functionality of the proposed navigation system for the blind and visually impaired.

4.4.1 Features supporting the outdoor functionality:

Apart from simply navigating from the source to the destination, which can be accomplished using the GPS/GIS system, the proposed system allows for context aware navigation by bringing into consideration - guidance at crossing intersections and notifying the user when a mobile or stationary obstacles is identified in the path (Giudice and Legge 2008). The approach that the proposed system offers is to capture data at the intersection using the time of flight camera mounted on the glasses which can be processed on the mobile phone using a cloud based road crossing algorithm to give suitable feedback to the user. For this the system can also make use of the ultrasonic and infrared sensors to pick up cues from the road at zebra crossing and traffic light signals.

4.4.2 Features supporting the indoor functionality:

An important feature that IO Vision adds to the existing systems is the ability to aid in indoor navigation. This will help the users to be able to move with ease in unfamiliar environments. A major challenge is the non-availability of maps providing intricate details such as those available for outdoor navigation. This happens because the GPS signals are not designed for indoor use and as such alternate technology is needed to gather indoor information.

4.4.3 Features supporting the face and object recognition feature:

A common approach of gathering information from the surroundings is Wi-Fi tracking but it would be limited in the range of distance it covers (Evennou and Marx 2006). We now have many organizations that perform the task of mapping the indoor area of houses and shopping malls and make them available online. Micello and Cartogram are two such companies that aid in mapping important indoor locations. Use of Cloud Computing makes it possible for the user to easily get connected to the sites that provide the mapping information. Radio Frequency Identifier's (RFID) prove to be another useful means that help in providing suitable and useful information to the users in navigation. The active and passive RFID tags need to be placed in several areas in the path of the navigator and the user's mobile phone functions as the RFID reader as we now have UHF RFID's that allow connecting to the mobile phone using the Bluetooth (Amemiya et al. 2004). It is essential that the users of the blind navigation system be provided with accurate and real-time information about the objects and the people surrounding them. A lot of effort has been put in classifying the objects using the RFID tags and complex algorithms (Lim et al. 2006). However, the new proposed system suggests the use of cloud computing in combination with the existing system to enhance the computational capability and get accurate outcome (Stoerig 1996). Figure 2 represents the implementation of the functionality of the IO Vision system.

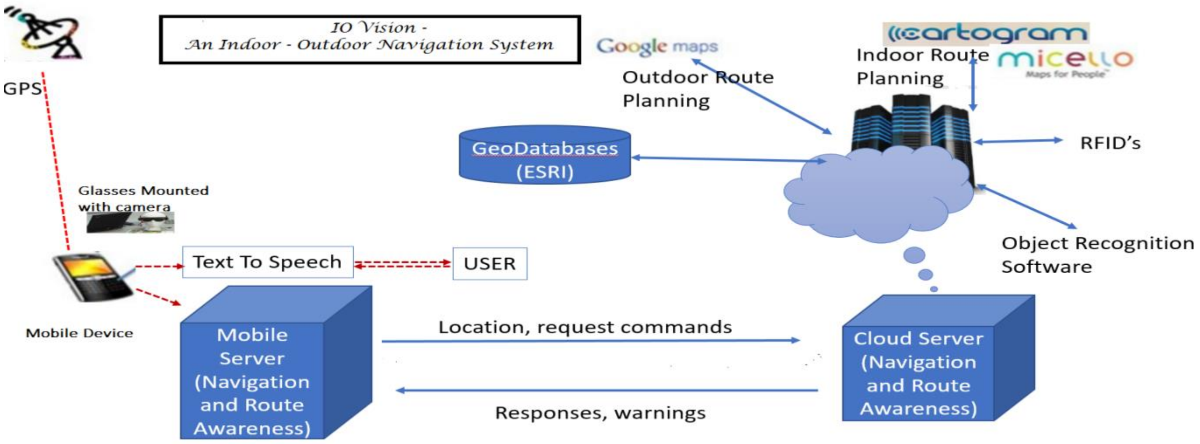

Figure 2: Components of the IO Vision System

5 Conclusion and Future Work

The paper proposed the design and architecture of a new concept of navigation system for the visually impaired. The advantage of the system lies in the fact that it will aid in both indoor and outdoor navigation without having to carry different devices to serve the dual purpose of use. The combination of different working units will provide for a real-time system monitoring of the position of the user and making navigation more safe and secure. It is believed that upon on the development of this system, the blind and the impaired people will be benefitted and the system will aid in moving in unfamiliar places, shopping malls and unknown terrains. The contribution of this paper is that it identifies many areas for future research that could lead to large-scale implementation of indoor navigation systems.

The future scope of work includes developing a system which can be functional without having to explicitly interact with the system. This would enable the user to concentrate on other tasks like obstacle and hazard detection, thus accommodating to the user's abilities and minimizing any interference from the environment. It is also suggested that the future navigation systems should be easy to use, should be of low cost and should allow integration of the context aware information for route planning.

6 References

Alghamdi, S., van Schyndel, R., and Hamilton, M. 2014. "Blind User Perspectives on a Navigational Autonomy Aid," *International Workshop on ICTs for Improving Patients Rehabilitation Research Techniques*: Springer, pp. 248-259.

Amemiya, T., Yamashita, J., Hirota, K., and Hirose, M. 2004. "Virtual Leading Blocks for the Deaf-Blind: A Real-Time Way-Finder by Verbal-Nonverbal Hybrid Interface and High-Density Rfid Tag Space," *Virtual Reality, 2004. Proceedings. IEEE*: IEEE, pp. 165-287.

Angin, P., Bhargava, B., and Helal, S. 2010. "A Mobile-Cloud Collaborative Traffic Lights Detector for Blind Navigation," *Mobile Data Management (MDM), 2010 Eleventh International Conference on*: IEEE, pp. 396-401.

Bhargava, B., Angin, P., and Duan, L. 2011. "A Mobile-Cloud Pedestrian Crossing Guide for the Blind," *International Conference on Advances in Computing & Communication*.

Bolgiano, D., and Meeks, E. 1967. "A Laser Cane for the Blind," *IEEE Journal of Quantum Electronics* (3:6), pp. 268-268.

Borenstein, J. 1990. "The Navbelt-a Computerized Multi-Sensor Travel Aid for Active Guidance of the Blind," *Ann Arbor* (1001), p. 48109.

Borenstein, J., and Ulrich, I. 1997. "The Guidecane-a Computerized Travel Aid for the Active Guidance of Blind Pedestrians," *Proceedings of International Conference on Robotics and Automation*, pp. 1283-1288 vol.1282.

Brabyn, J. A. 1982. "New Developments in Mobility and Orientation Aids for the Blind," *IEEE Transactions on Biomedical Engineering*:4), pp. 285-289.

Chow, R., Jakobsson, M., Masuoka, R., Molina, J., Niu, Y., Shi, E., and Song, Z. 2010. "Authentication in the Clouds: A Framework and Its Application to Mobile Users," *Proceedings of the 2010 ACM workshop on Cloud computing security workshop*: ACM, pp. 1-6.

Dabas, C., and Gupta, J. 2010. "A Cloud Computing Architecture Framework for Scalable Rfid," *International Multi-Conference of Engineering and Computer Scientists*.

Dakopoulos, D., and Bourbakis, N. G. 2010. "Wearable Obstacle Avoidance Electronic Travel Aids for Blind: A Survey," *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* (40:1), pp. 25-35.

Evennou, F., and Marx, F. 2006. "Advanced Integration of Wifi and Inertial Navigation Systems for Indoor Mobile Positioning," *Eurasip journal on applied signal processing* (2006), pp. 164-164.

Fallah, N., Apostolopoulos, I., Bekris, K., and Folmer, E. 2013. "Indoor Human Navigation Systems: A Survey," *Interacting with Computers* (25:1), pp. 21-33.

Faria, B. M., Reis, L. P., and Lau, N. 2014. "A Survey on Intelligent Wheelchair Prototypes and Simulators," in *New Perspectives in Information Systems and Technologies, Volume 1*. Springer, pp. 545-557.

Giudice, N. A., and Legge, G. E. 2008. "Blind Navigation and the Role of Technology," *The Engineering Handbook of Smart Technology for Aging, Disability, and Independence*), pp. 479-500.

Ifukube, T., Sasaki, T., and Peng, C. 1991. "A Blind Mobility Aid Modeled after Echolocation of Bats," *IEEE Transactions on biomedical engineering* (38:5), pp. 461-465.

Koskinen, S., and Virtanen, A. 2004. "Navigation System for the Visually Impaired Based on an Information Server Concept," *Mobile Venue* (4).

Lim, H., Choi, B., and Lee, J. 2006. "An Efficient Localization Algorithm for Mobile Robots Based on Rfid System," *SICE-ICASE, 2006. International Joint Conference*: IEEE, pp. 5945-5950.

Mehta, U., Alim, M., and Kumar, S. 2017. "Smart Path Guidance Mobile Aid for Visually Disabled Persons," *Procedia Computer Science* (105), pp. 52-56.

Meliones, A., and Filios, C. 2016. "Blindhelper: A Pedestrian Navigation System for Blinds and Visually Impaired," *Proceedings of the 9th ACM International Conference on PErvasive Technologies Related to Assistive Environments*: ACM, p. 26.

Narayanan, V. K. 2016. "Characterizing Assistive Shared Control through Vision-Based and Human-Aware Designs for Wheelchair Mobility Assistance." INRIA Rennes-Bretagne Atlantique; INSA Rennes.

Parente, P., and Bishop, G. 2003. "Bats: The Blind Audio Tactile Mapping System," *Proceedings of the ACM Southeast regional conference*, pp. 132-137.

Pearson, S. 2009. "Taking Account of Privacy When Designing Cloud Computing Services," *Proceedings of the 2009 ICSE Workshop on Software Engineering Challenges of Cloud Computing*: IEEE Computer Society, pp. 44-52.

Prusak, A., Melnychuk, O., Roth, H., Schiller, I., and Koch, R. 2008. "Pose Estimation and Map Building with a Time-of-Flight-Camera for Robot Navigation," *International Journal of Intelligent Systems Technologies and Applications* (5:3-4), pp. 355-364.

Quigley, M., Conley, K., Gerkey, B., Faust, J., Foote, T., Leibs, J., Wheeler, R., and Ng, A. Y. 2009. "Ros: An Open-Source Robot Operating System," *ICRA workshop on open source software*: Kobe, p. 5.

Roentgen, U. R., Gelderblom, G. J., Soede, M., and de Witte, L. P. 2008. "Inventory of Electronic Mobility Aids for Persons with Visual Impairments: A Literature Review," *Journal of Visual Impairment & Blindness* (102:11), p. 702.

Sabe, K., Kawamoto, K., Ohashi, T., Fukuchi, M., Okubo, A., and Gutmann, S. 2008. "Obstacle Recognition Apparatus and Method, Obstacle Recognition Program, and Mobile Robot Apparatus." Google Patents.

Sammouda, R., and Alrjoub, A. 2015. "Mobile Blind Navigation System Using Rfid," *Computer & Information Technology (GSCIT), 2015 Global Summit on*: IEEE, pp. 1-4.

Snaith, M., Lee, D., and Probert, P. 1998. "A Low-Cost System Using Sparse Vision for Navigation in the Urban Environment," *Image and vision computing* (16:4), pp. 225-233.

Stoerig, P. 1996. "Varieties of Vision: From Blind Responses to Conscious Recognition," *Trends in neurosciences* (19:9), pp. 401-406.

Tesendic, D., and Boberic Krsticev, D. 2015. "Web Service for Connecting Visually Impaired People with Libraries," *Aslib Journal of Information Management* (67:2), pp. 230-243.

Warren, D. H., and Strelow, E. R. 2013. *Electronic Spatial Sensing for the Blind: Contributions from Perception, Rehabilitation, and Computer Vision*. Springer Science & Business Media.

Yayan, U., İnan, F., Güner, F., Partal, Ü. G., Kale, A., and Yazıcı, A. 2015. "Indoor Mobile Navigation Software for Blind People," *Signal Processing and Communications Applications Conference (SIU), 2015 23th*: IEEE, pp. 666-669.

Copyright