BLUEEYES – EASING THE NAVIGATION AND ORIENTATION OF BLIND PEOPLE

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ABSTRACT

As reported by the World Health Organization (WHO), of the 7 billion people alive today, an estimated 253 million live with visual impairment that cannot be corrected with glasses or contact lenses. From these, 30 million blind or partially sighted persons live in Europe. Over the past years, blindness that is caused by diseases has decreased due to the success of public health actions. However, the number of blind people that are over 60 years old is increasing by 2 million per decade. Unfortunately, all these numbers are estimated to be doubled by 2020. With these facts, is necessary to bring awareness and understanding of the challenges blind people face and help to motivate research into new technology to answer those questions. This document starts to identify the challenges people with visual disabilities face in their life. The problem of navigation and orientation as well the different possibilities to deal with the locomotion situation is also addressed in this paper. It describes the traditional navigational solutions as well other which involves more sophisticated technological devices and their multimodal interfaces. The paper ends with the description of the BlueEyes project, consisting in a solution to help blind people moving in a city. The first phases of the project are described, and the actual research situations is also slightly explained.

KEYWORDS

Beacons, Internet of thinks, Human Computer Interaction, Context-aware mobile computing, Accessibility, Blind

1. INTRODUCTION

The challenges of being blind are in everyday activities like reading, cooking, shopping, going outside, using the internet, withdrawing money from an ATM, determining how much of a liquid is in a glass, handling cash, among others (Andress, 2015). According to the research, "eighty to eighty five percent of our perception learning cognition and activities are mediated through vision" (Politzer, 2015). So, all the corresponding activities represents a challenge for a person with vision disability and the difficulty to overcome it, can lead to isolation, loneliness and bring along emotional, social and financial impacts on her/his life. Within these varied challenges, it is possible to group them in two lifelong challenges: accessing the world of information and navigating through space. Society has done a far better job of opening the world of information but it has just started to identify and analyse the serious navigational limitations the blind travellers normally face. Unfortunately, these limitations are the ones that have a severe and bigger negative impact on their life development (Baldwin, 2015).

Currently, technology is a way to support some of their needs and has the potential of improving in a certain extent their life. In fact, it can be stated that today's infrastructure technology is accessible to facilitate blind people to join school, jobs and in leisure activities on a par with sighted peers. On the other hand, there is no such progress concerning blind navigation and therefore, management of mobility and orientation represents still a big and important challenge which needs to be addressed and supported by technology (Baldwin, 2015). Reduced visual capacity challenges people's spatial problem solving every day and in many ways, e.g. how to obtain, recognise, understand, and process information needed in the environment. Indeed, wayfinding can be very stressful and can cause anxiety and become a strong reason not to leave home if it is necessary to visit unfamiliar or complex places, such as shopping malls, train, metro and bus stations, among others (Saarela, 2015). It is vital that public places and community settings will be designed to be secure, as inclusive as possible and accessible for all.

2. CURRENT TOOLS TO ASSIST BLIND PEOPLE IN NAVIGATION

As mentioned before, one big challenge blind people face in everyday life, is mobility and orientation. Orientation refers to the "ability of understanding the spatial properties of an environment and being aware of one's position and his/her relationship with the surroundings"; on the other hand, mobility indicates the "capability of efficiently and safely moving in an environment (e. g. in a city by using public transport) (Giudice and Legge, 2008). In order to get an overview of the current tools which helps blind people in their navigation, these are grouped in two general categories (Baldwin, 2015):

● Currently established navigational strategies which includes independent travel (using human sensory abilities with no other aids); use of a sighted guide; use of the long cane; and use of dog guides (Baldwin, 2015). These are the simplest and the most inexpensive navigations and available tools (trained dogs and the white cane) (Baldwin, 2003). Even though these tools are very widespread, they cannot offer the blind all information and structures for safe mobility, which are accessible to people with eyesight (Shah et al., 2006).

● Electronic navigational aids - in the last few decades, many portable/wearable technological devices have been developed with the aim of improving locomotion for people with visual impairments:

○ Electronic Travel Aids (ETAs) like Mowat Sensor, Sonic Glasses, Pathsounder or Laser Cane. These are devices that gather information about the surrounding environment and transfer it to the user through sensor cameras, sonar, or laser scanners (Sánchez and Elías, 2007; Liu et al., 2010). The objective is to help the blind to avoid obstacles.

○ Electronic Orientation Aids (EOAs) - these are devices that provide pedestrians with directions in unfamiliar places (Kammoun et al., 2011), and support on finding out the route for the best path, providing mobility instructions and path signs to guide the user and develop her/his brain about the environment. It means it aids the blind in finding their way in an unknown environment. EOA is only for occasional use in unknown environments or for very difficult routes that are not used frequently.

○ Position Locator Devices (PLD) - these are devices that define the exact position of its holder such as devices that use GPS technology (Gaggi, 2016).

The navigational technologies are classified according to their sensor characteristics: sonar-based devices (using sonic sensors), vision-based (using cameras or lasers), infrared (IR) or GPS devices (Nicholas, 2008). Sonar-based devices detect and localize objects in order to offer those people a sense of the external environment using sensors. The sensors also aid the user with the mobility task based on the determination of dimensions, range and height of the objects. Camera or laser-based devices use a technology that converts images from a camera into patterns of vibrations delivered through an array of vibrotactile stimulators on the tongue. Infrared signage are systems consisting of infrared transmitters and a handheld IR receiver. Usually the transmitters are placed in strategic locations in the environment. Each sign sends short audio messages, via a constantly emitted IR beam, which can be decoded and spoken when picked up by the receiver. GPS devices enables the user to know his/her position when navigating outdoors, due to the location's information provided by satellite.

However, these systems present some drawbacks. Sonar-based devices have some limitations. They are not very effective in crowded environments because the signal is prone to reflection errors and the technology is also expensive. Camera-based devices need a high bandwidth. Even though GPS technology has made tremendous advances on outdoor navigating systems, methods for tracking position and orientation in indoor environments are still not reliable. Next, some considerations on the technology currently accepted and used by blind population is made.

2.1. White Canes and Guide Dogs

White canes are principally used to scan user's environment for obstacles or orientation landmarks, but they are also useful for other people to identify the user as blind and take the necessary precautions. The latter is the reason for the cane's famous white colour, which in many jurisdictions is mandatory. Used in combination with normal sensory monitoring (and often with a sighted guide), the long cane allows for travel in both familiar and unfamiliar areas. It is cheap, light, portable, needs little maintenance, and it is easy to use (Baldwin, 2015). There are three types of white canes, depending on a person’s visual impairment, age, height and specific needs: Identification Canes, White Support Canes and Long Canes. Identification Canes: lightweight, can collapse to fit in a pocket or briefcase are used by the person to indicate to others that they are blind or visually impaired; they can be used to assist with depth perception on stairs or curbs. White Support Canes: collapsible, or rigid are designed to support a person’s weight and to help him or her walk. Long Canes are used as bumpers and probes, mainly for independent travel in the home or unfamiliar places requiring specialized training from an orientation and mobility instructor (FFB, 2018).

The main disadvantage of the white cane is its incomplete resolution. It is a near space tool and it does not recognize spatial position or objects. It doesn´t bring blind travellers closer to the abilities obtainable by sight (Baldwin, 2015). The guide dog is also a "mobility aid" that can assist blind people so they can travel safely. They can guide people around obstacles and through crowds, stop at curbs and stairs, and sometimes even be trained to find a limited number of objects that are within sight when given orders. The guide dog user can also train the dog to find frequently used landmarks, such as a bus stop pole or a mailbox (Noriega, 2018). But it is necessary to be aware that guide dogs are expensive as well their maintenance and care. Also, people misinterpret their use: the person who is blind or has low vision directs the dog; the function and purpose of the dog is to merely guide the person around obstacles and indicate the location of steps and curbs. For example, a guide dog cannot know when to cross a street since it is colour blind.

Studies relating different mobility aids (Whitmarsh, 2001) highpoint the diverse purposes, advantages and disadvantages of guide dogs and other aids, such as long canes. For example, guide dogs mobility are more likely to be considered more relaxing than long cane mobility, since the previous implicates obstacle prevention and the latter obstacle detection. A guide dog also offers more advantages than long canes in unfamiliar surroundings or in unknown routes. On the other hand, long canes do not need the care and domestic space of a guide dog (Miner, 2001). Still, the cane and guide dog have similar limitations. “They are most effective for detection of proximal cues, are limited in detecting overhanging or non-ground-level obstructions and do not provide much in the way of orientation information about the user’s position (Giudice, 2008).

2.2. Accessible Pedestrian Signals - APS

As mentioned, blind people encounter several difficulties when walking and crossing roads, especially in big cities where traffic jams are more intense. APS support blind pedestrians by using a device that communicates information about pedestrian timing in non-visual format such as audible tones, verbal messages, and/or vibrating surfaces (Harkey et. al., 2007). There are different types of APS´s within different countries which provide different information (audible and vibrotactile signals). It can be about the existence and location of the push button that activates a “Walk” signal; the beginning of the walk interval; the direction of the crosswalk and the location of the destination curb; intersection street names in braille, raised print, or speech messages, intersection signalization with a speech message, and intersection geometry through tactile maps and diagrams or through speech messages (Harkey et. al., 2007).

2.3. Global Positioning System – GPS

As within APSs the orientation on crossing streets is very helpful for blind pedestrians, but still they are not aware of the street name or their position in order to reach a certain destination. With the support of a global positioning system (GPS), the user is able to know his position when navigating outdoors, due to the location's information provided by satellite. This information is displayed on various smartphone applications, for instance Google Maps or dedicated GPS devices (Ruffa et al., 2015). "GPS-based navigation systems are a true orientation aid, as the satellites constantly provide updated position information whether or not the pedestrian is moving" (Giudice, 2008).

There are several GPS-based navigation systems available on the market which use visual display (and some that even provide coarse speech output for in-car route navigation), but they cannot be used fully by blind navigators. Examples of available GPS devices for blind people are the Wayfinder system (Wayfinder, 2005), the Trekker system and the GPS Braille note (Denham et al., 2004).

The information provided by a GPS is "expected to greatly improve blind orientation performance and increase user confidence in promoting safe and independent travel. No other technology can provide the range of orientation information that GPS-based systems make available" (Giudice, 2008). There are nevertheless certain limitations on this technology: although the accessible software is not expensive, the indispensable software is quite costly. Additionally, the user needs to periodically buy new maps and databases of commercial posts of interest. But the most significant disadvantage of GPS is that it cannot be used indoors and is also unable to tell a user about the presence of drop-offs, obstacles, or moving objects in the environment, such as cars or other pedestrians (Hersh, 2006).

3. IBEACON TECHNOLOGY

As stated before, indoor navigation technology still needs further development. There are several devices for specific daily needs, but it is missing a stable accepted technology that provides information about the user's immediate surroundings. This can be in a shopping-mall, a grocery store, airport, train station etc. So, the path of technology development on mobility and orientation tools for visual disabled people should be towards the enhancement of the potential for smarter interaction and accessibility, by adding multisensory features into environments, and by developing multisensory way-finding solutions.

iBeacon can be used as a possible solution, because it is a technology which its potential can be exploited for multisensory and mobility in order to facilitate the tracking, routing and mapping solutions. An iBeacon is a small-scale network transmitter that instead of using latitude and longitude to define the location uses a Bluetooth low energy signal, which iOS devices detect (Gilchrist, 2014). In other words, it's a tiny device with low power consumption that can be placed in a wall or another part of a building. It transmits constantly an identification number via Bluetooth to enable devices which are around and use the corresponding application. BLE beacons-based indoor navigation apps can help visually-impaired and blind people understand the surrounding world in a similar way as GPS technology already does. BLE Beacons (also called Bluetooth Smart or Version 4.0+ of the Bluetooth specification) is the power and application-friendly version of Bluetooth that was built for the Internet of Things (IoT) (Apple, 2018).

One example of a project that builds up a smart environment was developed in Helsinki in a Shopping Mall. The environment was tagged with iBeacons that communicated with blind people's smartphone and BlindSquare App. iBeacons were set on locations that had landmark recognized by blind or visually impaired people (Saarela, 2015). Another project from Indoo.rs whose target was to develop a solution for Terminal 2 at Los Angeles Airport and designed as a mobile app with a voice assistant that helps visually-challenged travellers find their way to any location at the terminal. Another project is an indoor navigation solution for the London tube called Wayfindr. It has been designed by the "ustwo studio in close collaboration with the Royal London Society for Blind People. The developers successfully tested the new system in the Pimlico station in the spring of 2015. They launched Wayfindr as the first open navigation standard for blind people in October 2015" (Suddia, 2018).

For successful navigation, users need at least a "smartphone with BLE (Bluetooth Low Energy) onboard (iOS 7, Android 4.3 or later) and a pre-installed app. The app contains maps of the facility and it guides people via voice directions. This might not be comfortable for other people so the users need bone-conduct earbuds or Google Glass. This will make the directions inaudible for others, but the app's users will still hear what is going on outside. Another option is a smart watch which receives directions from a smartphone application and transmits them as tactile signals” (Suddia, 2018).

4. BLUEYES PROPOSAL

The aim of this project is to help the blind to be aware of the environment in which they live, where navigation and way finding is crucial to guarantee their mobility and to improve their quality of life. We also know that people with visual disabilities in new environments usually feel totally disoriented and isolated. It is not easy for blind people to move independently, therefore it is urgent to ensure easy mobility for them. According to the World Health Organization, nowadays, there are 285 million people with visual impairment, of which 39 million are completely blind and 246 million have low visibility disabilities. Therefore the aim is to improve the social inclusion of these citizens, with novel mobility solution to assist the visually impaired in their daily journey, using a smartphone, without the need for any special hardware, and Bluetooth Low Energy (BLE) technology. Thus, a practical scientific research is proposed supported by three Beacon’s Living Labs, in Coimbra, Caldas da Rainha and Tábua.

Another aim is to determine a good architectural model for context-aware mobile apps that leverage Beacons and determine their strengths and limitations for context-awareness for real-world settings. These applications will act like a city guide with accurate tracking and micro-location context-aware on a mobile device with BLE. Each Living Lab network contains iBeacons (Apple) and Eddystone (Google) beacons.

In the city of Coimbra the living lab will be at SMTUC line 5 (25 bus stops and 5 buses) to support the mobility of blind citizens in the city of Coimbra. The system will assist the visually impaired to the proximity of a stop and inform the number of buses and their route. Additionally, it can calculate the best route for their destination. In the event of routine alterations, customers will be informed. Blind customers can interact and determine decisions of SMTUC (a Portuguese acronym for "Municipal Transport Services of Coimbra) services, especially those that are intended to function. Inside the bus, the blind may have access to more usable audio information from these stops, the current stop, as well as additional information to support route and the following, such as route change to move to the desired destination.

In the city of Caldas da Rainha the living lab will be at the Bordaliana Route, to support the mobility of blind citizens. This is a cultural route dedicated to Rafael Bordallo Pinheiro, with his giant works of art to integrate a urban street art project. Designed for walking, Bordaliana Route offers a longer route, which approximately takes two hours to be completed, to see unique toponymic parts, human scale and read about episodes of Rafael Bordallo Pinheiro's life and a bit of history of the city.

In the city of Tábua the living lab will be at the centre of the town, to help the pedestrian movement of visually impaired people to access services at public buildings.

The first phase of the project is ready. A survey for an exact number of beacons for each Living Lab network with iBeacons (Apple) and Eddystone beacons (Google), the study of the points of their placement and the acquisition of beacons from different manufacturers was already made. Its facilities, tests and validation are already in working mode. Also underway is the creation of a public web site with georeferenced information of the location of each beacon and technical information inherent in the operation and the maintenance plan.

Understanding our Users and their HCI needs is a crucial aspect of BueEyes project. Our primary users are blind people. UX projects typically consist of three main phases, a research phase, a design phase and a further research phase, designed to test and validate the designs, including the prototypes. The target audience will be distributed in the 3 aforementioned cities. UX studies will be developed in the context of usability lab IPC (Polytechnic Institute of Coimbra)-ESEC(Coimbra Higher Education School), with Masters students in HCI and bachelor’s in communication and Multimedia Design. All case studies, creation of personas, wireframes and prototypes involve the blind citizens of the towns of living labs and their association (ACAPO - a Portuguese acronym for Association of the Blind and of Portugal). Now, we are starting to define a set of procedures to start interviewing and observing blind people in their day to day, studying and researching multimodal interactions that should have a crucial role in this project. Therefore, some considerations are described in the following section.

5. MULTIMODAL INTERACTION DESIGN

When it comes to building interfaces for blind people, it is necessary to explore multimodal interfaces. How is it to navigate without seeing? Finding such Human Computer Interface (HCI) concepts from augmentative and alternative communication can serve designers, engineers or educators in various ways in order to reduce social disability.

Multimodal human-computer interaction refers to "interaction with the virtual and physical environment through natural modes of communication"[48]. Multimodal systems can offer a flexible, efficient and usable environment allowing users to interact through input modalities, such as speech, vibration or hand gesture, and to receive information from the system through output modalities, such as speech synthesis, smart graphics and other modalities, opportunely combined. Voice message is a speech channel used either through an input or output modality generally considered self-sufficient, carrying most of the informational content in a multimodal interface. There are significant advantages such as:

● "Creates a time-efficient interaction. Just as we try to limit the number of clicks a user must make to complete an action, limit the amount of voice interaction needed.

● Keep messages short and allow interruptions. Don't force a user to listen to long messages or lists of choices without a way to continue forward.

● Let users control the speech rate. "Many blind users of screen readers can listen to text as exceedingly fast speeds." Designers should recognize this enhanced skill and design accordingly.

● Make it discoverable. Consider how the ability to speak with a device is conveyed. If it is expected that a user speaks to a device, make sure that user knows it exists and can open a dialog" (Campbell, 2018).

Unfortunately, speech input typically uses a limited vocabulary, forcing the user to recall a particular command syntax. Ambiguities can appear as a result of recognition errors as well as erroneous language constructs (Campbell, 2018).

Voice Vision substitution is similar to vision enhancement, yet the result constitutes non-visual display, which can be vibration, auditory or both, based on the hearing and touch senses that can be easily controlled and felt by the blind user. For example, a smart cane uses a special vibrator glove which has a specific vibration for each finger, and each one has a specific meaning (Elmannai, 2017). Another example is the "Path Force Feedback belt" to help blind people navigate outside. It uses three components: "the main unit (the process) with two dual video cameras, power supply which is packed into a pocket and the belt to be worn around the user's waist. The belt has a number of cells that gives feedback to the user" (Oliveira, 2013). The corresponding cells will vibrate around the belt and show the user the right path. The system is designed such that each feature has its own signature use of the vibration pattern. So, each vibration frequency differentiates a specific feature or obstacle, e.g., the sidewalk's border marked in some way.

Hand gesture was extensively studied as an efficient input modality. Gesture languages with different levels of complexity (starting from grasp-release commands to Sign Language) were proposed for various applications (Popescu et al., 2002). In addition to input modalities, emerging technologies such as indirect sensing of neural activity (e.g., brain–computer interfaces) may become practical components of multimodal interaction systems in the near future (Turk, 2013). As shown, there are different possibilities of multimodal interfaces that describe interactive systems that seek to leverage natural human capabilities to communicate via speech, gesture, touch, facial expression, and other modalities, bringing more sophisticated pattern recognition and classification methods to human–computer interaction. While these are unlikely to fully displace traditional desktop and GUI-based interfaces, multimodal interfaces are growing in importance due to advances in hardware and software, the benefits that they can provide to users, and the natural fit with the increasingly ubiquitous computing environment (Cutugno, 2012).

Multimodal interfaces can increase task efficiency, and Humans may process information faster and better when it is presented in multiple modalities (Turk, 2013).

6. CONCLUSION

This paper provides information related to problems blind people are facing, starting from the challenges that are beyond their daily life and then emphasises one of the most complex and important challenge, that is navigation and orientation in indoor and outdoor environments. Specially, mobility challenges in large complex buildings concerns almost everyone. It is critical that public places and community settings will be designed to be safe, as inclusive as possible and accessible for all. There are several technologies in development with multimodal human-computer interaction that can turn these indoor locations into smart environments. The future of new solutions, brings us to the world of the artificial intelligence and intelligent machines through smaller and cheaper solutions. These navigational tools will be personalized, prescribed appliances, designed to satisfy individual tastes as well as needs. These tools will be part of clothing, unseen, but probably not unheard. The device will be linked to the internet, to a powerful server computer specifically tailored to the blind traveller. In the age of technology, people with disabilities have certainly new hope coming in waves year after year, like never before in history.

In this paper we described the idea underlying the BlueEyes project, consisting in a useful system for the orientation and navigation of blind people. The project is being implemented in 3 Portuguese cities with different needs and realities.

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