A MOBILE SOLUTION TO HELP VISUALLY IMPAIRED PEOPLE IN PUBLIC TRANSPORTS AND IN PEDESTRIAN WALKS

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ABSTRACT
Promoting social inclusion is a field of active research and an emergent topic that relates to blind and visually impaired people. They face plenty of problems in their daily routines and solutions to increase their independence are important. Among the difficulties they face, we discuss two that aim to help them in the use of public transport and the carrying out of walking routes between strategic points such as the City Hall, Finances, Health Center, etc. While the first task can be easier to accomplish, the later relies on GPS and as there are places with week signal, there are some additional difficulties. In this paper, we present a case study, developed in the Historical Center of Viana do Castelo, a city on the north of Portugal, which had the collaboration of a Visually Impaired Association that helped us along the process of the mobile application development and field tests. We present the objectives, developed prototypes, performed tests and evaluation of the system.
Keywords: mobile solutions, navigation system, pedestrian walks, public transport, visually impaired people

1 INTRODUCTION

Social inclusion is an emerging issue of undeniable importance today. Access to the same opportunities and benefits by all citizens is a concern shared by more and more people. Although inclusion is for everyone, there are people who feel more excluded because they have some type of disability such as visual or motor. The work we present relates to promoting social inclusion to those with a specific type of disability – visual – using mobile applications with the purpose of promoting their autonomy and independence. Mobile solutions are commonly used today for several purposes and domains. The growing number of mobile reserchers and developers, the technology and processing power improvements, the increasing number of supported sensors and functionalities of mobile phones allow the development of a large range of different applications targeting different domains such as tourism, health and care, businesses, transportations, etc. While some people may raise privacy issues, there are many everyday situations where mobile applications can be useful to us. Our focus goes to use mobile technology to help promote social inclusion, namely working with visually impaired people (VIP). The limitations these people have prevents them, plenty of times, from walking alone in the streets as most of the times, they can only go to places they previously learned. Getting lost is a huge problem and asking for help can sometimes be the only solution. Another limitation VIP feel and that we address has to do with public urban transportation, a service most cities provide to their citizens to allow them to reach a given part of the city without using their own car. This service is also very relevant for VIP but using these transportations is not always easy and problems come up such as knowing where they are along the way and when to leave the bus. Again, the solution most of the times is to ask someone who is on the bus. Some of the most adequate technologies to systems to help solve these issues are GPS or RFID, but there are definitely some trade-offs in both. GPS cannot guarantee an accurate precision and can fail in routes between high buildings. On the other hand, a mobile solution can be relatively cheap when comparing to a RFID

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based-system that requires the streets to be prepared with tags in the sidewalks. The benefit of this solution is that centimeters precision can be achieved.

In this paper, we present the INCLUSO platform, that represents an evolution of our first prototype [1], that have been tested in the field and allowed us to have feedback from real users to improve it. INCLUSO is now available in the Play Store and is already serving citizens of Viana do Castelo. We start this paper by presenting some state of the art regarding the thematic of platforms for disabled people. Next we present a summary of the results of our previous work and main challenges that lead us to the development of INCLUSO, which we present in detail in section 4. Here we present the architecture, backend and the two modules of mobile solution: the bus module and the pedestrian module. Before conclusions we present the evaluation of the solution and the positive contribution it currently has on citizens.

2 STATE OF THE ART

Because of the growing research and development for disabled people, several platforms and systems have emerged in the last few years. One of such systems is detailed in Ref. [2] where the authors present a novel prototype application of a system supporting street navigation and independent, outdoor movement of the blind. The system can find the route from the indicated source to chosen destination, using dedicated digital map and a set of various sensors. Subsequently, the system supports the movement of the blind along the found route. The user's position is obtained with the use of DGPS receiver. To further improve accuracy, particle filtering method is used. The system operates on a casual smartphone and communicates with the blind by the touch screen and by the voice messages generated by speech synthesizer. Nandish *et al*. [3] presented a research of a navigation system for blind people to provide more precise location information. To identify the position and orientation and location of the blind person the authors rely on Global Positioning System (GPS) technology, TTS (Text-to-Speech) program and Google Maps APIs to provide navigation with voices. Another solution of a navigation scheme has been proposed in Ref. [4], where the authors materialized a solution for the blind and low-vision people to provide precise location information using Android smartphone. The navigation scheme uses TTS for blindness to offer a navigation service through voice and Floyd-Warshall algorithm for suggesting the shortest paths. Also, it uses Google map API to show the route information. The proposed scheme, as an independent program, is cheap and it is possible to install onto Android-based smart phone in an easy manner which allows blind and low-vision people to access the program interactively. Another solution, which is presented by Dornhofer *et al.* [5], is motivated by the fact that affordable technologies are not accurate enough to navigate blind persons on a safe trip. The authors defend positioning should be improved by telling the user the surrounding environment. They present a comparison between three different tools to route people (PgRouting, OpenTripPlanner and OpenSourceRoutingMachine).

Finally, they present a prototype for Android to route blind people to a given destination with the following functionalities: allow the user to explore the whole trip on the screen, provide turn instruction by turn instruction, periodically speak the distance to the next crossing point. Yet another proposal is discussed in Ref. [6], where the authors introduce a system that provides indoor navigation by using Radio Frequency Identifier (RFID), outdoor navigation by using Global Position System (GPS) as well as obstacle detection by using ultrasonic sensor. User will give the starting and ending location then this system will give voice instruction to reach at destination by detecting obstacle also. This system can specially use in big campus like industries, big institutes where it will act as guiding map.

3 OUR PREVIOUS WORK

In this section, we describe with some detail the scenario we had in hands. When we first approached the Visually Impaired Association, they referred two main problems their associates feel in their daily routines: using public transports and performing pedestrian walks. We made a first approach to each of the situations. Viana do Castelo has a bus, as shown in Figure 1, which runs throughout the historic center and stops at any place provided the user rings a bell. The problem VIP have is that they lose track of where they are so they asked us for an application that would inform them of where they are so they can ring the bell in an autonomous way. We developed a first prototype, as shown in Figures 2 and 3, which shows a map with

Figure 1: Bus that runs throughout the historic center of Viana do Castelo.

Figure 2: First layouts developed for informing the user where he is along the bus route, showing one reference point.

Figure 3: First layouts developed for informing the user where he is along the bus route, with several reference points.

Figure 4: Route drawn in a backend to support mobile applications.

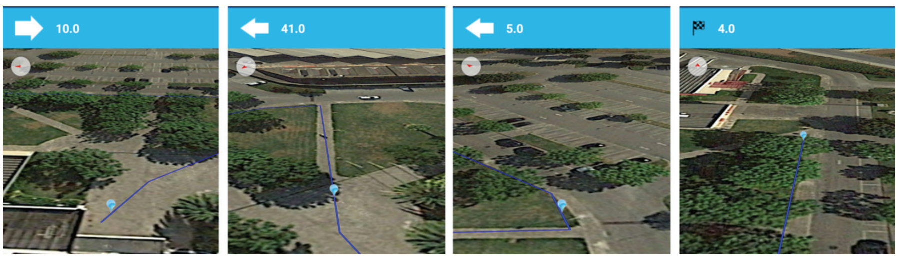

Figure 5: First layouts developed for the navigation system for guiding VIP.

the next reference points that can be relevant to the user and supports TalkBack and VoiceOver as this is fundamental for VIP. At a given moment the user is informed of the reference points he will find in a space of 150 meters.

The main drawbacks we had in this version were the reference points that sometimes were not the most relevant and the type and content of the message presented to the user. These are the main aspects we solve in the solution we will present in the next section.

Regarding the pedestrian walks, the first approach was to draw a route in a backend, as shown in Figure 4, and design a navigation algorithm to lead the VIP through that route. We present in Figure 5 the first interface.

The main problems we realized in the field tests were the lack of GPS cover in some streets, the turns are difficult to inform to VIP and the need to draw the route in a very detailed way. Based on the knowledge gathered from this first prototype, we advanced to a much mature and useful solution, which we present in the next section.

4 THE INCLUSO PLATFORM

The solution we came up with is built on a platform we named INCLUSO (after social inclusion). The platform is composed of a mobile solution and a backend. The backend allows to insert all information that the mobile solution needs. At this point, the mobile solution has two main functionalities: to help users use public transports and to help them in pedestrian walks.

4.1 The architecture

The architecture of the solution is shown in Figure 6. The solution is composed of several components: final users with mobile devices, a backend, a web services layer, a central database and the GPS satellite. The users of this solution can be the general citizen as the application has information that is not only relevant for visually impaired people. Every people can benefit from having information about the nearby locations when using the bus or getting directions to a reference point of the city. The requirement is that the user must have an android smartphone with GPS connectivity and, preferably, internet connection also, to have access to all functionalities. We are aware that with GPS we will not always provide the desired accuracy, and it depends on several aspects such as the hardware of the equipment or weather conditions, but the main choice to use GPS was based on the need to build a low-cost solution. For the mobile application to have the necessary information, a backend was also developed and is part of this solution. In the backend, developed using PHP language, it is possible to manage all information of routes (bus or pedestrian), include reference points and crosswalks, persisted in a MYSQL database. This information is accessed and used by the mobile application, via a web services layer, which includes services to obtain and/or update the available routes for buses or pedestrian walks, reference points and crosswalks when the user opens the app.

4.2 The backend

The backend supports the insertion of reference points, both for the bus module and the pedestrian one and an area to visualize all points. The backend also allows to define the clockwise and counter-clockwise messages for the pedestrian module, as both directions are supported to calculate the shortest route given an origin and destination. The backend uses a MYSQL database and a web interface build using PHP language. Some images of the backend are shown in Figures 7 and 8.

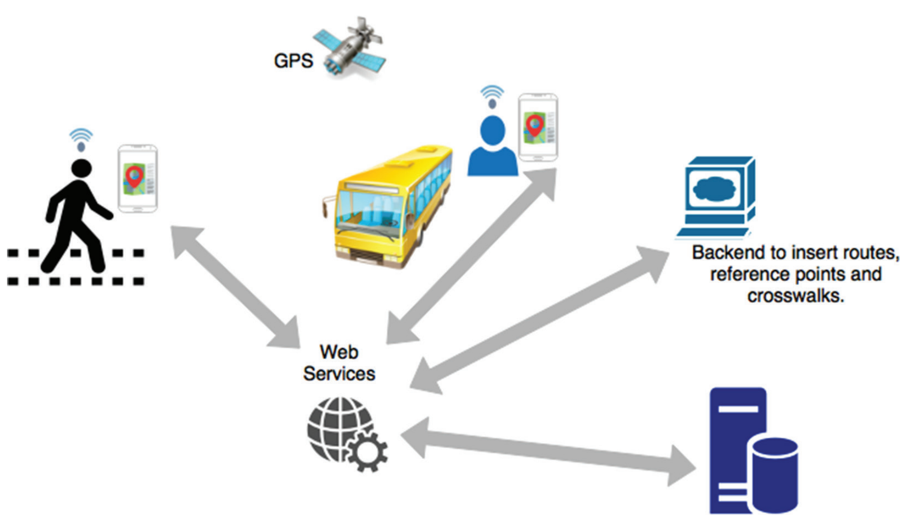

Figure 6: Architecture and components for the INCLUSO platform.

Figure 7: Backend functionality to add bus and pedestrian reference points.

Figure 8: Backend functionality to reference points information.

The mobile application, as afore mentioned, has two main functionalities and each one will be described in the next sections.

4.3 The mobile application – Urban transport module

Considering the previous work developed, described in section 3, and the feedback from the field tests with associates, the major change we had to do on this functionality was to improve the messages provided so they become more accurate and useful for end users and adjust the place the messages are sent.

After performing the entire route with the associates, we gathered all information regarding the coordinates of all places (Figure 9 represents some of the points annotated along the route) where they needed a specific information that can be of several types: 'You are entering Avenue X', 'A crosswalk exists in 100 meters', 'The museum Y will appear at your right in approximately 150 meters'. More than 30 points were inserted in the central database regarding the bus route. The final UX of the bus module is shown in Figure 10. The interface

Figure 9: Gathered points along bus route where associates said they needed to receive feedback from the mobile application.

Figure 10: Final UX of the bus module of INCLUSO solution.

is simple but this functionality does not require a more complex layout to serve its purposes.

4.4 The mobile application – Pedestrian module

General overview

The development of this module is very challenging as the accuracy of the position is very important to the success of the entire application. So, the first step to developing this module was to define the main reference points in the historic center that were more relevant and used by the associates. The association defined six major points: the library, the Association Headquarters, the Health Center, the Finances, The Post Offices and the Interface (place where buses are taken), as shown in Figure 11. Next step was to draw a route that goes through all those places, that is safe and that uses roads with at least medium GPS coverage. To draw this route, we travelled the course with the associates and the technicians of the Association. The associates perspective is fundamental as they provide us with real information of what messages they need to hear along the way and in what exact point. Along the route, the associates identified 43 places where they need information such as: 'Cross the street through the crosswalk that is in front of you.', 'Possible passage of cars on your right. Be careful when you pass the street.', 'Turn left and continue 6 meters.'. They also told us that it would be good to know, some meters before the place, of what is going to happen, so we defined what we called an anticipated message that sends information such as: 'Walkway without sound warning to 5 meters.', 'Careful, at 5 meters there may be obstacles on the sidewalk.', 'Water source at 5 meters.'.

Despite there is only one route, we must consider two directions: clockwise and counterclockwise as the messages are different in both cases. We need to consider both directions because when the user wants to go to a given destination, we need to know which direction has the shortest path to the destination. Figure 11 shows the information of all gathered points that were identified by the associates as being important and usually correspond to a place where a turn or an obstacle exist that they should know about. Figure 12 shows the route drawn to pass by identified points. Before each point there is also a marker showing the place where the anticipated message is presented. The anticipated message is a message that warns the user of

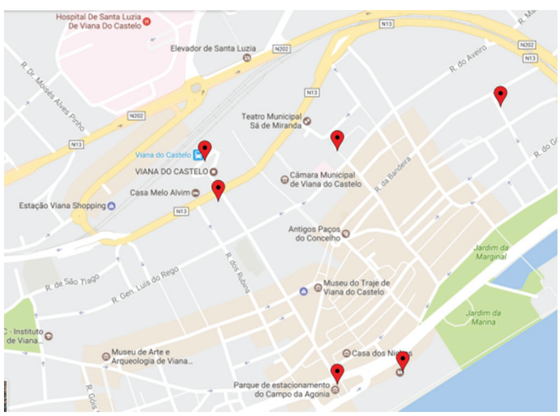

Figure 11: Map with the six places identified as more relevant for the associates in the historic center.

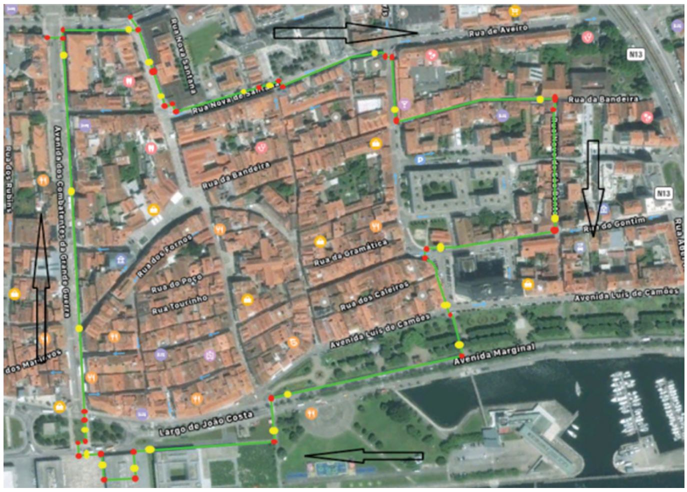

Figure 12: Route that goes through identified places annotated with all points where a message should be given to the user (counter-clockwise).

what is going to happen in 2 or 3 meters' distance. This was the methodology chosen to provide the user with enough information to successfully walk the route in an autonomous way.

When speaking with the associates, we understood we don´t need to guide them in every detail of the route because they can do some things on their own, as they developed capacities other people don´t have, such as an improved sense of orientation. For example, if we give a direction 'move ahead for 30 meters along the wall', they can autonomously do it because with the walking stick they can sense the wall and move along it even if some small turns exist. Figure 13 presents some of these situations. On the first situation, we use the grass to tell the user that he should move forward along the grass which is simple for him to detect because of the walking stick. In the second situation, we warn the user of a bench that will appear at the front in 10 meters and that he should turn left after the bench. On the third scenario, we told the user a crosswalk was approaching and that he should cross it and then turn left. Again, with the walking stick, these instructions are enough for the user. In the fourth situation, we warn the user of some obstacles on his front and that he should detect and avoid them. Finally, in the last scenario, we use the wall to guide the user, telling him to move forward always close to the wall.

The algorithm

To achieve the above behavior, we defined an algorithm, as shown in Figure 14, which is applied when the user chooses the destination where he wants to go to. There are two main phases: in the first we gather and compare all information we need to decide which route will be the best; in the second phase, we handle each point of the route till the destination and present the messages to the user based on his location.

We initiate the process by getting the user location and the destination location, which is the user selection in the mobile application. After that, we obtain the nearest point to the user to locate him on the route, which represents the start point to calculate the distance to the destination. After that we execute a query to a local database, previously populated with data obtained from Web Services, to retrieve all points between start and destination which allows

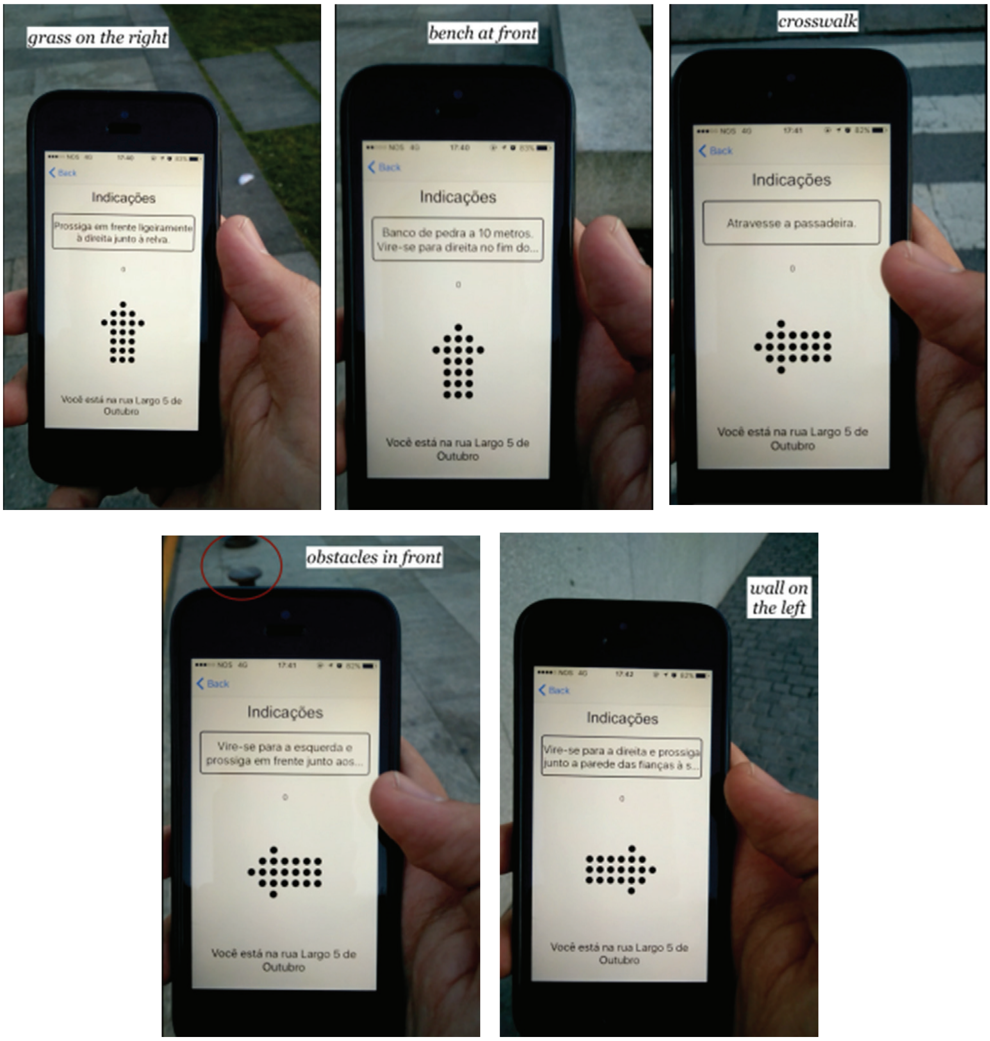

Figure 13: Some situations along the route that represent obstacles to the user and the messages we provide to help them.

us to calculate the total distance in both directions and that allows us to conclude which way we will guide the user to the destination. The second part of the algorithm now starts. With the start point (where the user is), we check if the user is aligned with the point to avoid him going in a wrong direction. After that, we get the next point where a message should be presented and, using GPS coordinates, we compare the distance to the next point. If it is less than 5 meters we present the message; if it less than 10 we present the anticipated message. The process continues until the user gets to the destination.

Vincenty Solution

In the Android implementation, the obtained location was always deviated to north and with a five to ten meters' distance, which for this case is a lot. This was confirmed with different

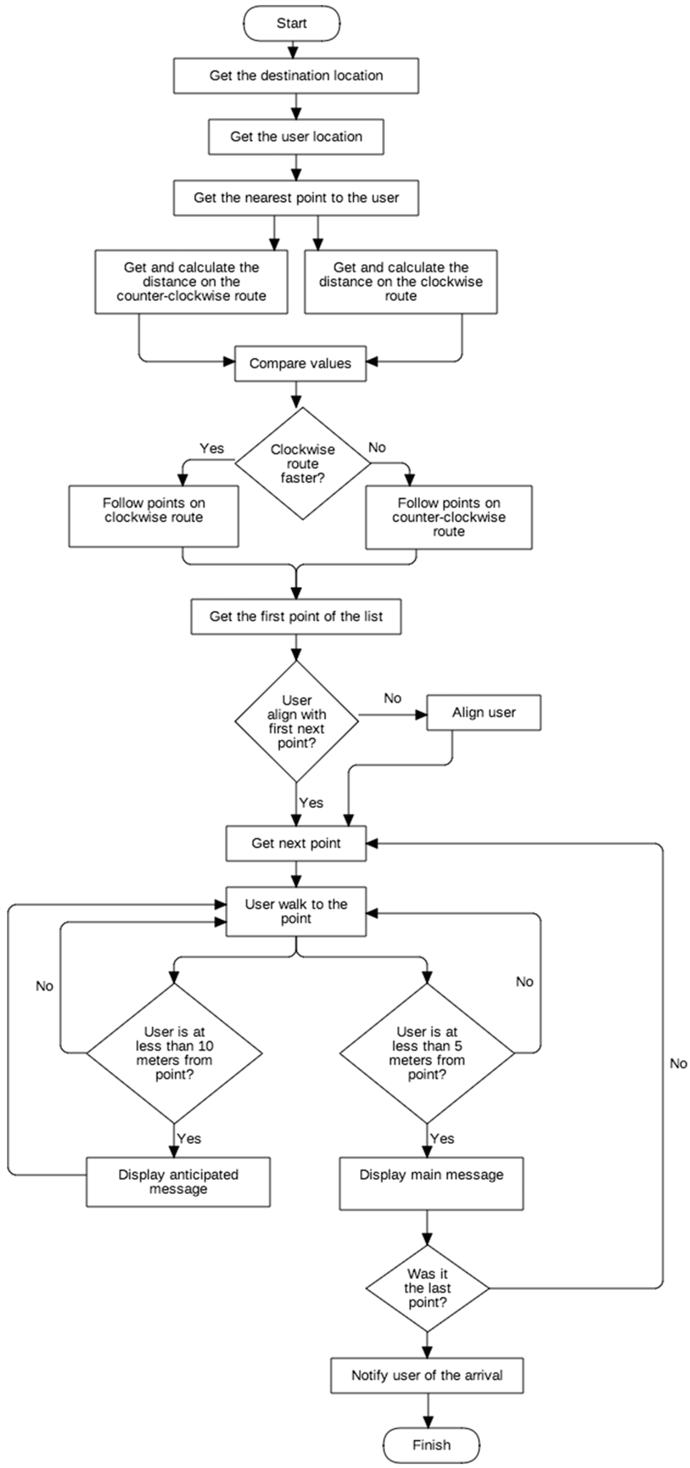

Figure 14: Algorithm applied in mobile applications after user select destination: best route is chosen and messages are presented to the user.

Android smartphones. To correct this deviation, we used one formula from the Vincenty Solution. The Vincenty Solution proposes a set of formulas to calculate distances, bearings and coordinates on ellipsoidal earth accurate within 0.5 mm for large and small distances. The formula we used is a formula to calculate new coordinates given initial coordinates, bearing and distance. The initial coordinates will be the location given by the smartphone, the distance will be the accuracy of the location divided by two to minimize errors, and the bearing will be the bearing from a point on north. The location calculated this way is significantly enhanced and more precise.

5 EVALUATION

INCLUSO solution is now available at the Play Store and currently available for all citizens and visitors of Viana do Castelo. The application has been tested with several visually impaired people, each with different eye diseases. The success of this study and developed application is majorly concluded by its practical and qualitative results that we gathered from the feedback and real usage of the application in a real scenario and in a daily basis. Nowadays, and one of the major important aspects of INCLUSO, is the fact that it is helping visually impaired people to be autonomous when using the public bus in the historic center of Viana do Castelo. The messages we defined and that are presented to the users along the bus route are very concrete and have the purpose to provide them with useful information such as locating the user near a bank, a garden or the cemetery, so he knows where to stop. With the use of the application, visually impaired people no longer need to ask someone where they are or when they should ring the bell for the driver to stop. Another important information we are also providing is related to the proximity of the crosswalks so the user can leave the bus and cross the street safety. Regarding the pedestrian module, it has been made a significant improvement since the first version and the methodology being used is in fact working for the VIP. We stopped trying to provide accurate information of every turn and started relying on the orientation sense that VIP have and defined, for a specific route that goes through some major points of the city, adequate messages that allows them to safely and independently perform the route. They are now able to go to some of the most important reference points of the city, guided by the mobile application.

Summing up, the evaluation of this application is mostly qualitative and transmitted to us by the associates after some months using the application.

6 CONCLUSIONS

In this paper, we presented INCLUSO, a mobile solution to promote social inclusion in the city of Viana do Castelo, in the north of Portugal. At this moment, the solution is mostly focused on visually impaired people and on how to help them when using public transportation and when performing pedestrian walks. We have developed and tested in the field a first prototype that allowed us to develop INCLUSO, an application that is currently published in Play Store and helping the citizens of Viana do Castelo.

The main advantage of this solution is that it had the collaboration of VIP associates who helped in the definition of all messages they needed to have to become more autonomous in some of their daily tasks. Regarding the bus module, the purpose of the app is to inform the user where he is at along the way so he can ring the bell by his own and avoid asking for help, which eventually happens without the app as the user easily lose track of where he is. We also provide instructions of nearby crosswalks so the user can leave the bus in a place where a crosswalk is near so he can safely cross the street.

Regarding the pedestrian walk, to increase the success and usefulness of the application, we defined a route with the major reference points in the historical center of the city, and gathered all necessary information that VIP needed along the way. We also incorporated in the methodology the assumption that VIP has a strong sense of orientation and that the app does not have to inform the user of all turns because he can perform some things on his own using the walking stick.

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