Indoor Position and Orientation for the Blind

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Abstract. This work proposes the study and design of mobile interfaces to iden-
tify the position and orientation of blind people in closed environments.
Through this development we seek to reach a consensus on the use of a certain
technology that would allow for the identification of the position and orienta-
tion of people within a closed space (such as a school or home) with the neces-
sary infrastructure. A focus group was held in order to identify the users'
problems with the navigation. In addition we made initial and final usability
tests. The results of the usability evaluation showed that the interface designed
was highly usable for blind users and that the technology designed worked to
improve the indoor navigation of blind people.

Keywords: blind navigation, indoor navigation, orientation and mobility.

1 Introduction

For most visually disabled users the biggest obstacle to moving around is that they are
always restricted to the same navigated spaces. This is because to change their route
or branch off from the road could be dangerous and confusing, impeding them from
finding their way back. As a result, blind users are limited to taking routine journeys
and are denied from exploring new places [5]. Other obstacles for a blind person in-
clude the determination of their location in an environment, knowing which way they
are facing or the direction in which they are moving, and the lack of information
about important objects in the environment, such as the distance at which they are
located both in terms of nearby objects and those at a distance [4]. In general, in a
familiar environment a visually disabled user can enjoy a conventional degree of
navigation, because he/she knows the surroundings, or because they have adequate
aid for navigation. In a closed unfamiliar environment, the experience of navigation
can be complex and completely non-deterministic [6].

If the goal is to confront the problems that blind users face in the context of orien-
tation and mobility, the idea to use mobility-related technologies emerges. Computer
technology that aids in teaching and learning has traditionally been represented by
desktop computers to access learning resources [2]. Mobile device technology pro-
vides opportunities for new kinds of teaching and learning support. These devices are
becoming part of the personal technological resources of each student, with the
important advantage that they are available anytime and anywhere [2].

The same technology cannot be used to locate objects in indoor and outdoor spaces [1]. For outdoor spaces such as a neighborhood, a city or a back yard, the simplest mechanism to use is GPS. However, this technology is not apt for closed spaces such as parking garages, underground locations, stores or buildings. This implies seeking out alternative technology that would allow a user to obtain his/her location in places where GPS is not apt. Gill [3] proposes a hybrid method to track people's location in closed environments. This method employs different measuring devices: a digital compass, accelerometer and an infrared sensor. Each time a new step is detected, the system updates the user's position. The problem with this solution is how awkward the machine that the user must carry around is, as it implies three elements that are not comfortably mobile and only work in association with the use of a portable computer. Na [7] in his work presents BIGS, Blind Interactive Guide System, for blind people to be able to move about in a building. The BIGS system consists of two parts: a. The intelligent placement of passive RFID tags on the grid, which only transmits in ID, and b. A portable terminal embedded with an RFID device that receives the data from the passive tags and generates information about the person's location. This method also uses the previous representation of the environment and the location of the different tags on the ground. In addition to this, the system can use Wi-Fi technology so that the security personnel in the building can constantly monitor the movements and the route being taken by the user.

This work proposes the study and design of mobile interfaces to identify the position and orientation of blind people in closed environments.

2   Interface Design

From the literature it can be gathered that there are certain ways of approaching the orientation and mobility issue. There are studies that indicate the aspects to consider when designing an application in support of the orientation and mobility of blind people. For this reason it is necessary to know the opinions of the end users and their apprehensions when faced with a situation in which they are in an unknown place and have to move about.

In order to obtain this information a Focus Group was held at the start of the study in which 4 blind people between 19 and 34 years of age participated (see Table 1). The Focus Group was coordinated by 2 interface experts and 1 special education teacher specializing in visual disorders.

At the start of the Focus Group the expert proposed discussing in general terms the *"Most recurrent or most significant problems that the blind have when they want to*

Table 1. Participants of the Focus Group

Case	Age	Ophthalmologic Diagnostic	*Degree of Vision*
1	19	Retinitis Pigmentosa	Low Vision
2	34	Retinitis Pigmentosa	Totally Blind
3	20	Retinitis Pigmentosa	Low Vision
4	27	Retinal Detachment Glaucoma	Low Vision

know where they are". On this, case 1 commented: *"Places that I don't know are complicated because of people who have a different attitude. I need some help or support"*. On the same topic case 2 stated: *"The blind have the capacity to calculate spaces, it would be great to have a device that tells you if there are obstacles to prevent accidents and to know where you are"*. Case 3 proposed that the amount of attention that the blind pay to their movements is what makes locating oneself so difficult in general, in both familiar and unfamiliar spaces: *"It's hard to always pay attention, overall where there is a lot of noise. That skill has to be developed. I would say that it has to do with my attention span, my concentration"*.

The expert asked about the factors that could be determinant for attention. To this question, case 2 stated that when he talks to someone he loses his concentration on the space and is not able to focus on the two things at once. Case 3 mentioned that she always follows a group of people, but that she gets confused if there are too many people: *"It happens to me when there are a lot of people, my route is established. People confuse me; it is difficult to know where I am. I always follow the group"*. Case 1 stated that the level of attention is not all that necessary because in the city of Santiago people help the blind with their navigation more than in the provinces.

Orientation was discussed, and the participants were asked about the strategies they used and the problems they encountered. Case 3 pointed out that it is always important to know the point from which the trip started, because in not knowing this they would be completely disoriented on the return trip. Case 2 mentioned his specific situation in the Metro, in which he was certain that he had no difficulties because he knows the coordinates of his destination well. Despite this he states that he gets disoriented in complex stations. The way they have to solve the problem of disorientation is by asking for help. On this the expert proposed discussing what basic information is necessary to get to a destination. On this, Case 3 stated: *"First, what direction I have to go (straight, to the right, etc), where I have to get to and how to follow the route"*. Case 2 described the necessary information in detail: *"…which hall, to take a right or a left, approximate distance, is there a wall, what will I find in my path, and that's enough. I have a defined route and I look for the reference points that the (Metro) guard gives me"*. What they need to move about are reference points that allow them to locate themselves in space.

From these results the PYOM software interfaces and the ServerPYOM were designed. Also, thanks to the software usability evaluation we were able to improve the interfaces, which is reflected in the end user evaluation.

3   Software

3.1   ServerPYOM

The ServerPYOM application contains all the necessary information to provide a user with his/her orientation and location when requested through interaction with the PocketPC device.

In an initial version of the ServerPYOM software the user's orientation was provided through laterality. The user was found to be to the right of, left of, in front of or behind certain objects. This mode of orientation was not sufficient for the users, and they needed more precise and concrete information. According to the results obtained
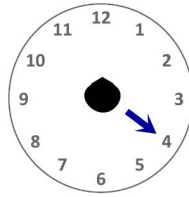
Fig. 1. Clock metaphor to spatially orient the user

from the initial usability evaluation, it was found that the best method for providing the user with his/her orientation was by means of the clock metaphor.

In this metaphor the user is always facing 12:00, being the center of the clock [9]. The directions that the system provides regarding the location of different objects or places correspond to the respective hours on the clock. The information is exact when it corresponds to an hour and is approximate if it corresponds to an intermediate direction between two hours. Figure 1 represents an example of the direction in which an object is located, at 4:00.

The ServerPYOM interface had two designs. The first was developed based on the results obtained from the Focus Group, and although it responded to the users' requirements it was not able to provide answers for all the information they needed (Fig. 1A). In the first usability evaluation it was found that the information provided by the software was not sufficient, and the user had to be provided with more precise and detailed information. Thanks to this, the interface was redesigned to provide the user with the necessary information (Fig. 1B).

Every time a PocketPC connects to the network the server detects it and is ready to communicate with the device. The connected devices appear listed on the upper portion the screen and the facilitator must select the device to which the information will be sent.

When the user asks for his/her position or orientation, a request message appears on the interface, to which the facilitator must respond by sending the requested information. In the case of position, the facilitator must provide this information by selecting the place in which the user is located and the specific sector in which he/she is within this place. In the example provided in figure 2A the user is in the parking garage. The user's orientation is provided according to the key points within the room
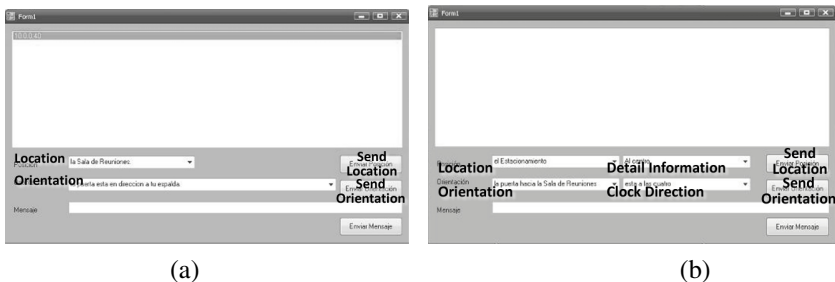

(a)   (b)

Fig. 2. ServerPYOM interfaces (a) Initial ServerPYOM interface (b) Final ServerPYOM interface

that identify the direction in which this point is located. In the example given in figure 2B, orientation is provided by the door to the meeting room, which is located at 4:00.

3.2   PYOM

PYOM, or Mobile Position and Orientation System, is the name given to the entire system and the user application. Totally oriented for use by blind users, all the information output is provided by audio. The PYOM software was developed with Microsoft Visual Studio .Net in C# language for PocketPC devices. This software can be executed on computers with Windows Mobile 5.0.

The application's opening interface uses the buttons on the PocketPC device as well as the touch screen. Of the 4 buttons on the PocketPC only two are used, located at the extremes so that it is easy to find them. The left button is used to request help; in pressing this button the user comes to know how to interact with the application. In starting up PYOM, the user is provided with instructions about the buttons used in the device. The right button is used to quit and shut down the application.

The screen is divided into two vertical parts. In each vertical part of the touch screen (left and right) the user can interact by using his/her fingers to execute the corresponding command. In the left rectangle the user can ask for information about his/her position in space, while in the right section the user can request information about his/her orientation. For the device to recognize the user's instructions, it is necessary for the user to trace his/her finger upwards from below, not necessarily in a straight line but as straight as possible (Fig. 3).

The output interface for blind users uses synthesized spoken text, thus achieving the total transfer of the information directly, or through the use of headphones connected to the PocketPC. This synthesized text is achieved through the use of a Text-to-Speech engine from the Acapella group, for which reason the information delivered is dynamic and can vary without presenting any problems or additional recording costs.

There were two phases for working on the PYOM software. The first phase consisted of getting to know the real needs of the users for a position and location system. The second phase consisted of using the system in a real application.

Phase 1. In this phase we worked under a client-server architecture in which the PocketPC had the client application and the server application (ServerPYOM) was run from a laptop. The server application contains all the information necessary to provide the user with his/her orientation and location when he/she requests it through interaction with the PocketPC device.
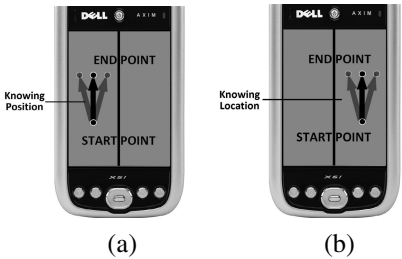

(a)   (b)

Fig. 3. PYOM input interface. (A) Form of use in order to request Position. (B) Form of use in order to request Orientation.
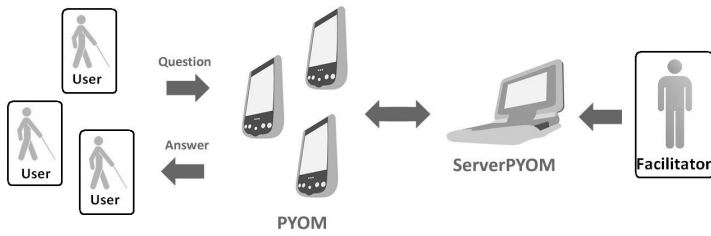
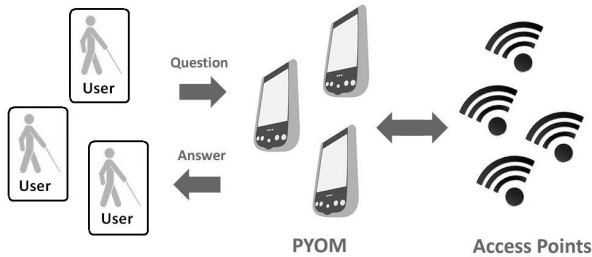**Fig. 4.** Diagram of communication with the PYOM system in phase 1

Fig. 5. Diagram of communication with the PYOM system in phase 2

Through an ad-hoc network both applications communicate with each other. The user can request position or orientation information by sending a message to the server, and then the server returns the requested information to the device (Fig. 4).

Phase 2. In this phase it is no longer necessary to use the server application. The architecture consists of an ad-hoc network with several access points in the room. The PYOM software detects the user's location and orientation according to the data received from the intensity of the signals coming from the different access points in the room. The signal from the access points is collected and analyzed beforehand by the PYOMDatos software, and is then analyzed with the PYOMAnalyses software, which produces an XML file with all the necessary information to be compared with the data obtained by PYOM (Fig. 5).

4   Evaluation

4.1   Sample

The sample was made up of 5 users between 14 and 34 years of age, including 2 women and 3 men, 3 totally blind users and 2 with partial vision (according to ophthalmologic diagnoses). Of all the 5 users, 3 participated in two evaluations and the other 2 in the final evaluation. These last two were not familiar with the testing center.

An engineer who is an expert in interfaces, as well as a special-education teacher specializing in visual disabilities guided the evaluations.

4.2   Instruments

For the end-user evaluation Sanchez's Software Usability Questionnaire for Blind Children [8] was used. This guideline consists of 18 statements for which the users must define to what degree each of them was fulfilled, on a scale from 'A Little' to 'A Lot', with quantitative values from 1 (a little) to 10 (a lot). The sentences were: "I like the software", "The software is useful", "The software makes me active", "I would use the software again", "I would recommend this software to other children/young people", "I learned through this software", "I felt I could control the software's situations", "The software is interactive", "The software is easy to use", "The software is motivating", "The software adapts to my rhythm", "The software allowed me to understand new things", "I like the sounds in the software", "The sounds in the software are clearly identifiable", and "The sounds in the software provide me with information". In addition to this, an Evaluation Questionnaire with Open Questions containing 10 questions regarding the use of the software and its applicability was also used. The following questions, among others, were included: "Is the information that the software provides enough to know what to do and what is happening? What did you think about the sounds in the game? Would you add more sounds?" Finally, a PYOM Evaluation Questionnaire especially designed for this software including 3 open questions focusing on the problems directly related to the use of the software was used: "When using the software, what problems did you have with location? What problems did you have with orientation? Was the software useful for you?"

4.3   Procedure

The evaluation was carried out in the facilities of the C5 Research Center of the Computer Science Department at the University of Chile. The end-user usability evaluation was administered for the system's main application, PYOM.

The end-user evaluation was carried out during two sessions. The first session was held for 2 hours. In this session the users executed the task of arriving at a specific point within the C5 building. This route was taken without the help of a cane and without any kind of assistance beyond that provided by the PYOM software. The starting point was the center's meeting room, and the users had to get to the front hall (Fig. 6).

The second session also took place in the C5 center, and lasted 3 hours. In this session the users arrived to a point in the building where they had never been before, for which reason the route and its location were totally unknown. The route in questions consisted of going from the meeting room to the center's research and development office (Fig. 6).

As we sought to test the mode of using and operating the interface, in both usability tests the PYOM software worked together with the ServerPYOM software, which provided the user with the position and orientation information as described in the ServerPYOM sub-section of the Design section in this paper.

The evaluation was performed individually with each of the users, in which they had to get to the previously defined destination at their own pace. Once the users had finished the route, the Software Usability Questionnaire for Blind Children, the Evaluation Questionnaire with Open Questions and the PYOM Evaluation Questionnaire were administered.
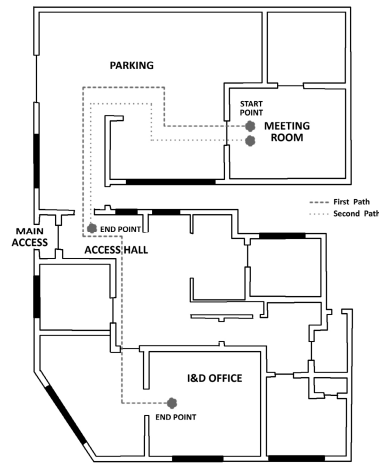
Fig. 6. Routes taken during the evaluation sessions. The First path is the route that the users took during the first session, and the Second path is the route taken in the second session.
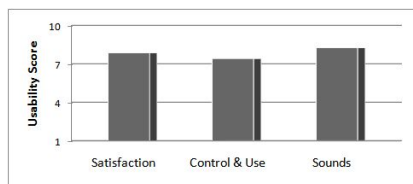
4.4 Results

For the analysis of the End-User Usability Questionnaire, the statements were grouped into three categories: Satisfaction, Control & Use, and Sounds. For each of these categories an average score from the values provided by the users in the sample was obtained, achieving a detailed evaluation of different aspects of the software.

Of the maximum total of 10 points that each category could receive, the results of the first usability test were rated in the middle. The satisfaction and control & use categories obtained the lowest score, both with 5.3 points, while the sounds category was rated slightly higher with 6.2 points (Fig. 7A).

Despite these general results, particular statements in each category show relevant results. The sensation of controlling all the software's actions was positively evaluated (7.6 points), as well as that which stated that the software is easy to use (9.3 points). The fact that the sounds transmit information was a very highly evaluated point with an average of 9.3 points. The lowest-evaluated statements were: "The software adapts to my rhythm" (3.3 points), "I like the sounds in the software" and "The software is motivating", these last two obtaining 4.3 points.
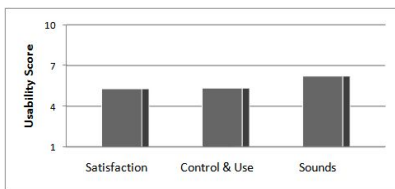
(a)   (b)

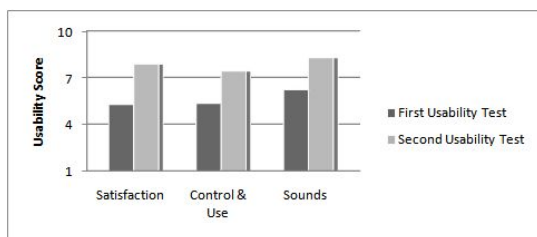**Fig. 7.** (a) Results of the first usability test (b) Result of the second usability test

Fig. 8. Comparative results between the first usability test and the second usability test of the PYOM software

"The software is easy to use" and "The sounds provide me with information" were the two statements that obtained the highest evaluations, with 9.8 points and 9.6 points respectively. "The software adapts to my rhythm" was still the statement with the lowest evaluation, receiving a score of 3.6. This is explained by the fact that the software provides information on position and orientation according to what the user requests, and the process and information are the same whether the user is a novice or more experienced.

Although there were no statistically significant differences (t=-1.756, p>0.05), the scores for the second usability test were higher than the first, and there was a considerable improvement expected for the changes made to the software based on the results of the first evaluation. The category that obtained the highest evaluation was still that regarding the sounds, with 8.3 points, followed by satisfaction with 7.9 points and finally control & use with 7.4 points (Fig. 7B).

The final test received a higher evaluation than the first, but without statistically significant differences, reaching 2.6 points more in satisfaction (t=-1.015, p>0.05; pretest= 5.3 points, posttest=7.9 points), 2.1 points difference in control & use (t=-1.973, p>0.05; pretest=5.3 points, posttest=7.4 points), and 2.1 points difference in sounds (t=-2.113, p<0.05; pretest=6.2 points, posttest=8.3 points) (Fig. 8).

5   Conclusions

This work proposes the study and design of mobile interfaces to identify the position and orientation of blind people in closed environments.

From the usability evaluation we were able to obtain the relevant information that blind users need in order to locate and orient themselves spatially in a certain place. Also, the way in which the information is provided is a critical point that was identified in this study. The users worked correctly with the clock system for orientation, achieving clarity as far as where they had to go in the environment, thus being able to arrive to their destination independently.

Although there were no significant differences in the usability evaluations for both tests, including differences by gender, the PYOM software was highly evaluated, achieving high scores in the Software Usability Questionnaire for Blind Children and the Evaluation Questionnaire with Open Questions. The final usability evaluation achieved the highest results of all three aspects evaluated, which were user satisfaction, control & use and sound quality. This implies an improvement in the system's interface both in the way it presents data and in the data itself.

The entire process of the design and development was carried out with a user-centered methodology, for which reason the results were usable by and accessible to the end-users. The main application, PYOM, has a touch screen and audio interface that allows for simple use by blind users, which is demonstrated by the results of the usability evaluations.

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