Towards a Navigation System for Blind People: A Wizard of Oz Study

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Abstract

In this paper, we present an initial study towards of an indoor navigation system for blind people. As the system itself is still in an early stage of development, we conducted a Wizard of Oz study using a generic Wizard of Oz system designed for mobile and ubiquitous studies. The goal of the study was to validate a set of audio-based navigation commands in a field study context. Further, we wanted to identify usability issues of the Wizard of Oz tool, and ensure the appropriateness of the addressed study setup. Therefore, we used eight human wizards as participants in the study. Their task was to guide two blindfolded actors through a predefined route. Such settings helped us to achieve high ecological validity of the results compared to laboratory testing. We found that the developed study setup is fully mobile and can be used in any mobile context, the voice commands chosen for navigation are almost complete, and can be used with slight modifications for the follow-up study. Additionally we identified several usability flaws of the Wizard of Oz tool. After implementing the findings, the tool and the study setup are ready for a follow-up study with blind persons in order to validate the selected voice commands in depth.

Introduction

Mobility is a fundamental part of life for every human. Human's orientation and navigation is heavily dependent on sight. Blind people, however, have to use other means for finding their way. Instead of sight, they mostly rely on the sense of touch and hearing. Reaching an unknown place is usually difficult for a blind person as he or she cannot use maps easily. This situation opens space for computer-assisted navigation systems that guide the blind person on a predefined route.

Figure 3: The pilot Wizard of Oz study with a blindfolded actor, a human wizard, and an evaluator.

The navigation task consists of two scenarios – navigation inside a building and outside. These two scenarios differ in several aspects. One of the aspects is the usage of different sensors or tracking devices. For example, most outdoor navigation systems utilize the GPS (Global Positioning System) technology, which is relatively cheap and easy to deploy as almost every smart phone contains a GPS module. Unfortunately GPS as distributed on smartphones is not working for indoor navigation without any additional hardware and thus it is not appropriate as an easily accessible technology. Another aspect is the way how the information is provided to the user of a navigation system. Regarding navigational instructions the distance between required navigational commands and thus the frequency of required commands is an essential design aspect. Distances are larger in outside navigation as the user has to e.g. pass several streets or walks to a remote place. In indoor navigation, scenarios the distances between required navigational instructions are smaller and more commands need to be issued. Floors in indoor navigation pose an additional challenge for the position acquisition as well as for navigation algorithms. Based on existing studies and systems, we identified the following hardware and software requirements for a navigation system for blind people:

- Sensors for identifying the position and rotation of the user. The sensors should be functional in indoor and outdoor scenarios.
- A map of the areas where the navigation is performed. This includes a standard outdoor map and a plan of a building for indoor navigation.
- An algorithm that computes an optimal route between the position of the user and specified destination. The algorithm should be also capable of triggering audio commands correctly.
- A set of audio commands regarding the route such as description of areas, and navigation commands.
- An interface that allows the user to control the navigation system, such as defining the route or queries on the current surroundings.

These requirements can be projected into tasks related on the one hand to technical and development aspects and on the other hand to user interface design aspects of the future navigation system. In this paper, we focus on the user interface design aspects. The selection of the possible modalities suitable for blind people inherently neglects the visual modality. This results in focus on using audio and tactile modalities to indicate the user about specific actions and situations.

One of the vital parts of a navigation system for blind people is the correct choice of voice commands. In order to evaluate such commands without having the other parts of the system required for navigation, we used the Wizard of Oz method [1]. The Wizard of Oz (WOz) method is mainly used for evaluating designs of interactive systems in their prototypical stage. In the WOz studies, a human wizard is capable of simulating unimplemented or missing parts of hardware or software of the system. The method can be applied to whole range of design stages from low-fidelity prototypes, where functionality is partly or totally replaced by the human wizard (e.g. pen and paper), to an almost fully functional system, where only specific missing functionality is simulated by the human wizard. In mobile or ubiquitous studies, the method is shifted from standard laboratory settings to the mobile environment.

In our study (see Figure 1), we used a generic WOz system [2] that supported us throughout the prototyping and the study process. A configurable Wizard of Oz tool, which is part of the WOz system, allowed us to define navigation commands that we clustered into several categories and it provided a mobile wizard application that allowed controlling the WOz prototype accordingly. It also allowed us to include the tactile modality – a vibration module in the form of a wristband that could be controlled by the wizard remotely. Based on the goals of the study, we decided not to use real blind users and to use blindfolded actors instead as the goals were focused on voice commands, usability of the tool for human wizards, and appropriateness of the study setup. WOz prototype was not elaborated in the study. The actors have been told to act according to instructions they got. The instructions were developed based on state of the art research regarding the capabilities of blind people. This helped us to tune the WOz system so that it is appropriate and ready to be used with real blind users.

The study helped us to identify guidelines regarding the definition of a set of commands and the applicability of different modalities during a WOz study. It also provided us with insights regarding the use of a WOz approach during the prototyping phase and during the study. The concrete study setup and results identified during the study are described in this paper.

Related Work

An important part of pedestrian navigation systems is the possibility to give the user information not only about the path but also about the surrounding and obstacles available in the near. Regarding outdoor navigation numerous navigation systems exist that use mostly GPS, a variety of sensors, as well as information of their surroundings that can be found in Internet based data sources. This is especially valid for blind that need information about their surroundings in order to be able to perceive the environment and navigate safely from point A to B.

The most of available systems focus on feasibility aspects regarding locating the blind user, defining his orientation, and providing him with navigational information usually via text-to-speech systems or tactile feedback.

Focusing on indoor navigation, Huang and Gartner [3] elaborated a survey about existing indoor navigation systems. They analysed 14 different indoor navigation systems based on their available functionality regarding indoor navigation, route communication, context-aware adaption, and other features like the platform and the required network access. They could further identify that all existing systems supporting vision-impaired users provide audio and speech as a modality to provide the users with proper navigation information. In addition, Chen et al. [4] investigated the use of multiple modalities for the particular case of non-visual information navigation. They investigated navigational as well as non-navigational commands with a focus on text input by using different modalities.

Spearcons [5] are a design methodology where spoken words are increased in speed so that they cannot be recognized as individual words anymore. The resulting sounds are used as hints and landmarks. The approach is similar to the earcons approach of Brewster et al. [6] who investigated in using position-based audio information for navigational purposes.

Wilson et al. developed “SWAN” [7], a system for wearable audio navigation. They did not rely on speech information as an interaction channel purely but used non-speech representations of navigation information. Hub et al. [8, 9] designed and prototyped a navigation and object identification system for blind users that can be attached to a white cane. They further investigated not only in the feasibility of providing information to the blind user but focused on finding out which information is important for the users.

"Drishti" [10] is one of the most mature systems developed for the navigation of blind people. It is an integrated indoor and outdoor navigation system for blind people. Drishti uses a mobile Laptop where a camera and a headset is connected. The user interface is realized using a conversational interface that allows the user to interrogate the state of the environment as well as navigational commands like "*The distance to the sofa is 5 feet*.", or "*Turn left 30 degrees and walk ahead.*" Still it requires a mobile computer that is in size and weight not suitable for using the system in an every-day scenario.

Riehle et al. [11] developed an indoor navigation system that relies on the description of the surroundings and does not provide any route guiding information. The information provided via a speech interface was similar to information that is perceivable via a white cane. In an experimental study, they compared both types of navigational information regarding the performance in a target-finding task.

"GentleGuide" is a system which uses tactile information to navigate a user. Bosman et al. [12] prototyped the GentleGuide system consisting of two vibra-enabled wristbands while the wristbands were used to indicate navigational commands. The system was used and tested with non-handicapped people.

Developing methods and systems for handicapped people has a long tradition in heavily including users already during the whole design and development process. One method that evolved in the 90s is the Wizard of Oz method. It stems from the need of simulating features that yet have not been developed where the origins can be found in the domain of speech interfaces [13].

Recently the appropriateness for using the Wizard of Oz method shifts as not only futuristic systems and functionality can be developed but also functionality that is hard to test. The range of functionality stems from low fidelity prototypes like pen and paper Wizard of Oz prototypes to high fidelity prototypes. This also requires a change in the methodology and the equipment used for conducting such studies. In the last years, experiments based on the WOz methodology are more and more used also in mobile and ubiquitous computing interaction environments with a special focus on handicapped people.

Makela et al. [14] used the WOz method for testing a design of a multimodal dialog system where the WOz methodology was used to replace an intelligent dialog system. Amores et al. [15, 16] have used the WOz methodology to develop MIMUS, a multimodal, multilingual dialog system with a focus on wheelchair users. Zachhuber et al. [2] developed and used a reusable WOz system that allows to dynamically setup WOz studies in a variety of contexts. They applied it in a factory and automotive context to simulate specific contextual situations as well as prototype functionalities.

As the WOz methodology originally stems from the area of linguistics and speech navigation, systems supported by speech are a typical area where the WOz methodology can be applied. Our approach differs in a way that we do not focus on feasibility aspects regarding the development of pedestrian navigation systems for blind people but aim to elaborate the semantics that are required for indoor navigation. We used an existing Wizard of Oz system in order to develop a prototype focusing on the elaboration and investigation in the particular navigational commands while for the particular commands two modalities, i.e. audio and the tactile modality have been used.

The Wizard of Oz prototyping system

For developing the study setup we used existing software developed by the authors of this paper called Contextual Wizard (*ConWiz*) system [17], which is a part of the Contextual Interaction Framework[6] (*CIF*) [2]. *CIF* is a software framework that provides support for engineers to rapidly develop contextual prototypes and contextual studies. The contextual prototypes and study setups either use context information or define a particular context. In the first case, information about the user, the current task, and the environment are acquired by sensors. In the latter case, the context of the study is simply defined, however, it may be altered or simulated by setting parameters of surrounding appliances like e.g. switching lights.

ConWiz System

The *ConWiz* system is implemented as a client-server architecture and it consists of following modules:

- *ConWiz Server*. The server is developed as a *CIF* plugin which allows controlling the prototype. The server is capable of storing and defining configurations of the *Mobile Wizard* interface.
- *Mobile Wizard*. The Mobile Wizard is developed as an Android client application. It provides a user interface for human wizards that is generated and rendered according to a loaded configuration and is capable of communicating with the *ConWiz* server. The human wizard can use the *Mobile Wizard* application to control the *WOz Prototype*.
- *WOz Prototype*. The prototype is a software or device which can be remotely controlled by the Mobile Wizard. In our case, it is an Android application that is capable of synthetizing voice commands for navigation, and controlling a vibra wristband used for tactile commands.

All communication between the *ConWiz* Server and the mobile tool is handled using the developed *ConWiz* protocol, which is a generic protocol to control wide range of prototypes. The protocol can define generic Wizard Objects with specific parameters. Those Wizard Objects can be set within the *Mobile Wizard* and sent to the *ConWiz* server which manages the communication with the prototype. The protocol specifies the exact grammar of possible parameters of a Wizard Objects, the selection of studies, and the corresponding scenarios. An example of a possible scenario for using such a system could be a living room with two Wizard Objects (*WzObj*). A *WzObj* is a sensor or actuator that can provide specific information or can be controlled by the Mobile Wizard. Examples for such are a virtual digital photo frame whose content can be changed or a real-world switchable light that can be switched or dimmed by the wizard.

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[6] Contextual Interaction Framework – CIF (http://cif.icts.sbg.ac.at)

A typical workflow of a human wizard starts with the selection of a scenario and requesting its Wizard Objects. These requests are handled by the *ConWiz* server accessing data within the *CIF* as well as from external applications such as the study prototype. After obtaining a list of available Wizard Objects each parameter of a particular Wizard Objects is visualized on the *Mobile Wizard* which provides functionality to modify the *WzObjs* while the activity related to the parameters is reflected in the simulated context. An example for this is that by switching a state of a *WzObj* "Lamp" it can be turned on or off.

The configuration of a Wizard of Oz study is done from within the *CIF*. When starting the *ConWiz* server, the configured files are loaded and the study setups made available to the Mobile Wizard. A configuration contains the required study scenarios that define the particular Wizard Objects controllable by the *ConWiz* system. After loading a particular configuration, the *Mobile Wizard* automatically generates a user interface based on the configured objects while the definition of the particular user interface elements is based on the type of configured wizard object.

Voice Commands

Before conducting the study, we analyzed several indoor routes which were used for identifying necessary voice commands for the navigation task. The routes consisted of walking through corridors inside a university building, through a small courtyard, going up and down spiral and normal stairs, using an elevator, and entering several doors.

Table 1: Voice commands selected for the prototype. Direction commands can be combined with distance and object suffix. Command parts shown in brackets are variants of more command, e.g. "go (left | right)" stands for two commands "go left" and "go right".

Category	Command	Suffix distance	Suffix object
Directions	go ahead go (left | right) go light (left | right) go to the next corner and then (left | right) turn around Stop	1 m 2 m 3 m 5 m 10 m	door elevator stairs
Door	enter door enter (1st | 2nd) door on (left | right) side		
Stairs and Elevator	go (upstairs | downstairs) enter elevator exit elevator go to the (ground | 1st | 2nd | 3rd | 4th) floor you are on the (ground | 1st | 2nd | 3rd | 4th) floor		

Based on these routes we identified a required set of commands and we clustered them as shown in Table 1. We found three main categories:

- "*Directions*". This category contains commands for going ahead, left, and right, etc. The commands can be combined with two suffixes to indicate either distance to walk or an object to reach. In case of distance, the resulting command would be e.g. "*Go ahead for 5 meters*." When using object, a command would be e.g. "*Go ahead until stairs*." Both suffixes can be combined together to compose commands such as "*Go ahead for 5 meters until stairs*."
- The category "*Door*" contains simple navigational commands related with doors.
- "*Stairs and Elevator*" contains commands for going upstairs, downstairs, commands for going to a particular floor, and informative commands for telling the user on which floor he or she is.

Mobile Wizard

The interface for human wizards is called *Mobile Wizard* application and the application capable of synthetizing voice commands and playing them to the blindfolded actor is further referred to as the WOz Prototype. The communication between these applications is depicted in Figure 2. This section describes only the user interface of the Mobile Wizard application as the WOz Prototype is rather simple in current stage of development and does not provide any controllable user interface.

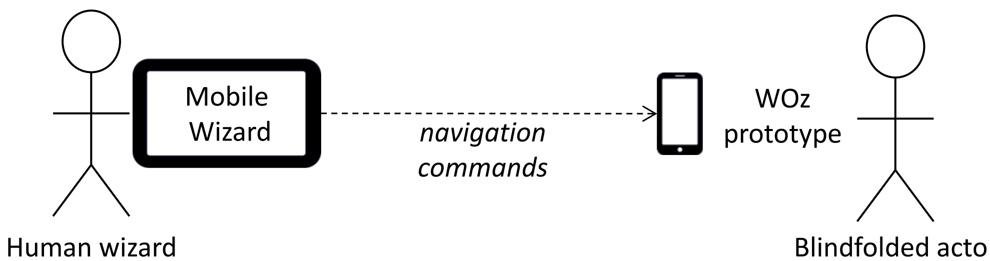

Figure 4: Usage of Mobile Wizard and WOz prototype.

A human wizard holds and uses the *Mobile Wizard* which is an application running on an Android tablet and moves freely in the study context. The human wizard observes the user interacting with the WOz Prototype by means of the *Mobile Wizard* as well as through observations and is able to react to the user's actions and to the actual context. The generic *Mobile Wizard* application was configured to enable sending navigational commands to the WOz Prototype carried by the actor. The WOz prototype is capable of synthetizing these textual commands to speech. In addition, the *Mobile Wizard* application controls vibration commands and to provides additional note-taking functionality that allows the human wizard to log important events.

Figure 3 shows a screenshot of the Mobile Wizard. The user interface is divided into two columns. The left column contains menus that correspond to categories of the voice commands (Directions, Door, and Stairs and Elevator) and it also contains additional menu for tactile commands (Contextual Environment), note-taking functionality (Notes) and study control settings (Study Control). The right column contains controllable objects and their parameters.

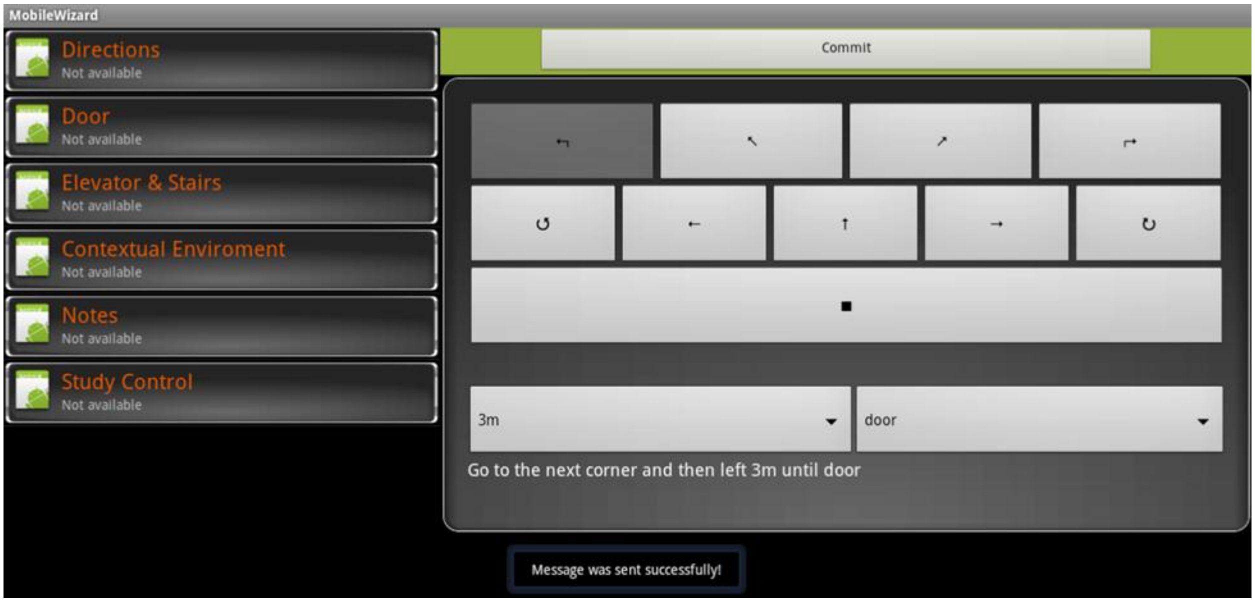

Figure 5: Mobile Wizard interface – Menu is located in the left part of the user interface. Right side contains commands for Directions. The feedback informing the user about sending the voice command is located in the bottom part of the interface.

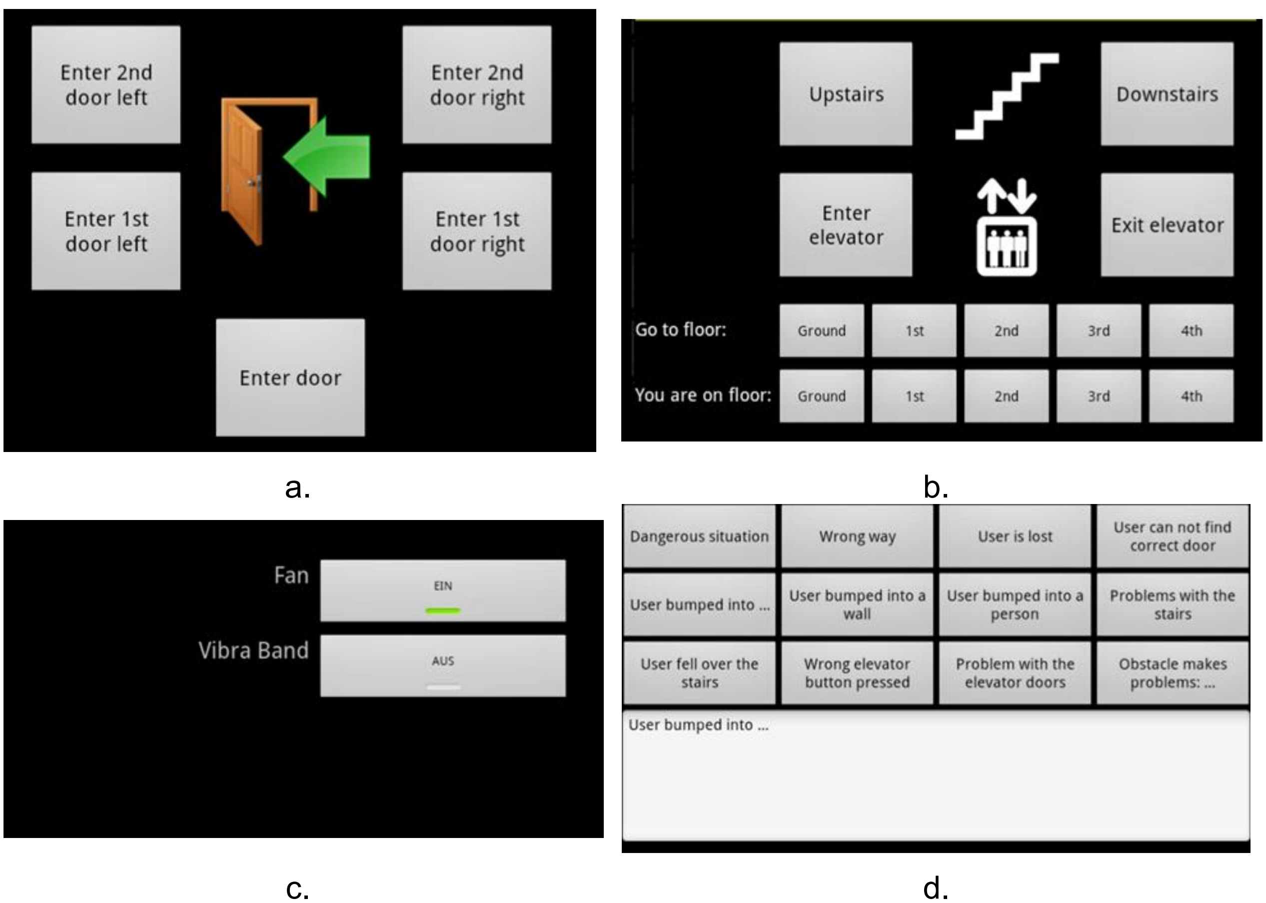

Figure 6: Mobile Wizard interface, (a) commands for door, (b) commands for stairs and elevator, (c) contextual environment commands, (d) note-taking functionality

In the Directions menu (depicted in Figure 3), the navigation commands can be composed in up to three steps using a direction, a distance and an object. The direction is selected from a D-pad (buttons with arrow icons), the distance is selected from the left bottom list, and the object is selected from the right bottom list. Once the command is composed, it can be sent to the navigation prototype by pressing the Commit button located on the top of the screen. The final command is also shown in the bottom part of the screen. The order of selecting the direction, the distance and the object does not matter. Specification of the distance and the object is optional, and only direction is required.

The user interface for door commands is shown in Figure 4a, and for stairs and elevator in Figure 4b. Contextual Environment menu (see Figure 4c) is capable of turning on and off vibra wristband and a contextual object (fan) located along the route. In the Notes menu (see Figure 4d) the wizard can note a problem that occurred during the navigation. There are twelve predefined buttons with corresponding labels. The wizard can also edit the note after pressing the button in a text field or enter a new note. The note is logged after pressing the Commit button.

Pilot Study

The goal of the study was to validate a set of audio-based navigation commands in a field study context. Further goals were to identify usability issues of the *Mobile Wizard*, and ensure the appropriateness of the addressed study setup. All three aspects are needed for future studies with blind people. The study resulted in an updated command set and an improved interface of the *Mobile Wizard* tool that is ready to be used in following studies of a navigation system for blind people.

Based on past WOz studies found in literature, in common mobile WOz study setup a human wizard and an evaluator accompany a participant who interacts with a mobile tool. As one aspect of the study was the evaluation of the user interface of the Mobile Wizard, we needed a corresponding study setup that enabled evaluating the interface through multiple test runs conducted by multiple human wizards. In our study, human wizards observed a blindfolded user of the audio-based navigation application (the WOz prototype).

Roles of study participants

Three different roles of people involved in the study can be identified: blindfolded actors, human wizards and evaluators.

Blindfolded actors. The blindfolded users were actors that have been instructed to follow the commands obtained via the prototyped navigation system. The advantage of using actors is in reducing total number of participants required for the study. For example, having two blindfolded users for each of eight human wizards results in total number of 24 participant (i.e. 2*8 blindfolded users + 8 wizards). By using trained actors, we are able to reduce the number to only 12 participants as we used 4 blindfolded actors (i.e. 4 actors + 8 wizards). Each actor was instructed where to simulate problems during the route in order to enforce the human wizard to take notes of these problematic parts where the actors were struggling. The instructions were based on navigational problems encountered during the pilot runs such as, "*Go with the elevator to a wrong floor*" or "*Struggle finding doors to courtyard*".

Human wizards. Human wizards themselves used the *Mobile Wizard* that allows controlling the prototyped navigation system. The wizards were instructed to use vibration commands in dangerous situations or in situations that required increased attention. In addition, human wizards were asked to use the note-taking feature on the *Mobile Wizard* during the evaluation.

Evaluators. Evaluators focused on observing the human wizards when interacting with the *ConWiz* system and took notes during the evaluation to record problems that occurred during the usage of the *Mobile Wizard* tool. The wizards were instructed to use thinking aloud.

Study organization

The study was conducted with 8 human wizards (3 women, 5 men, mean age = 29.6, stdev = 3.20) from local university staff. All of them were familiar with the WOz method and 4 of them already participated in other WOz studies either as wizards, evaluators, or both. All of them have experience with using tablet computers. The actors (blindfolded users of the prototyped navigation system) were trained to use the navigation system. We used a number of four actors (all men, mean age = 30.3, stdev = 7.9) to take part in the study. The training of actors comprised of handing and explaining the instructions, showing the path, blindfolding them and going through the path. The training lasted approximately 30 minutes. The organization of one session with a human wizard was as follows:

1. *Instructions*. After initial warm-up and briefing (greetings, explaining the study, filling informed consent and non-disclosure agreement), the wizard was shown the route and instructed which navigation commands should be used in different parts of the route. The instruction phase took approximately 20 minutes. The wizards were told to simulate a mobile audio-based navigation system which was realized as a mobile WOz prototype. The simulation should take into account that the navigation system shall be aware of the map of the building and surrounding areas and which can sense a user's position and rotation. The instruction included an explanation of the *Mobile Wizard* and allowed the wizard to get familiar with the configured study setup.
2. *Navigation task*. The navigation task was performed twice. Each wizard had to simulate the navigation system with two different actors while each study task included the indoor navigation scenario as described in Section Voice Commands. Performing the study tasks took approximately one hour. The wizards were asked to use the think-aloud protocol as in standard usability testing [18]. To avoid an influence of the think-aloud protocol on the actors, they were instructed to react only on commands they obtained through the prototyped navigation system only, not on the wizard's speech.
3. *Debriefing*. The wizard was debriefed by means of a semi-structured interview and was asked to fill out the USE [19] and TAM [20] questionnaires.

Hardware and software setup

The hardware and software setup used in the study is depicted in Figure 5. The *Mobile Wizard* runs on an Android tablet and is carried by the human wizard. We used two tablets – Samsung Galaxy Tab with 7” screen and a Lenovo IdeaPad K1 with 10.1” screen. The navigation prototype, which is responsible for synthetizing the navigation commands to speech, runs on an Android phone (Galaxy Nexus) and is carried by the blindfolded actor. The *ConWiz* server is running together with the Contextual Interaction Framework (*CIF*) on a laptop computer (Lenovo ThinkPad with MS Windows 7) carried in a backpack of the evaluator. An XBee[7] radio antenna is connected to the laptop in order to control vibrations of the wristband. The phone, the tablet, and the computer are connected to a wireless network provided by another Android device (Galaxy Nexus) in order to enable communication among all parts of the *ConWiz* system. The device is carried in the evaluator's pocket.

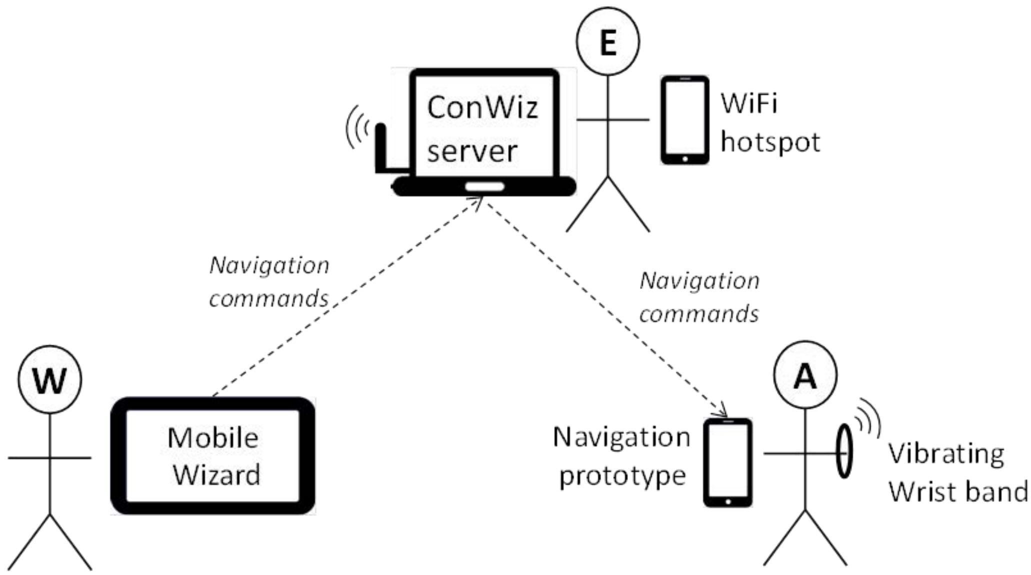

Figure 7: Hardware and software setup depicting communication among the devices and distribution of the devices to the evaluator (E), the human wizard (W) and the blindfolded actor (A).

Results

During the study runs we collected qualitative and quantitative data. The qualitative data stems from interviews, evaluator notes, and observations, while the quantitative data has been collected by logging all interactions with the *Mobile Wizard*. In addition, we collected quantitative data by means of the USE and TAM questionnaires that have been filled out by the wizards after each study run. We analyzed the findings and categorized them into categories described below.

Voice commands

The voice commands were described as complete by three wizards. Other five wizards missed some commands. They suggested additional navigation commands, mainly descriptive commands and commands expressing or explaining possible threats. The suggested commands are listed in Table 2. The commands related to navigation can be easily added to the supported command set. On the other hand, commands expressing warnings or describing the situation would need additional devices capable of sensing the current context (e.g. camera and corresponding computer vision

[7] http://www.digi.com/xbee/

algorithm). Therefore, we decided not to include those commands in the supported command set.

Meaning of commands "*go (left | right)*" and "*go light (left | right)*" were interpreted differently by most wizards. One wizard also mentioned that they were interpreted differently even by the actors. The possibility of expressing exact direction (e.g. "*go 45 degree left*") is a potential for future study to find out commands that better fit indoor navigation systems.

Table 2. Suggested voice commands by the human wizards.

Suggested Command	Command Class
1. turn (left | right)	navigation
2. go backwards	navigation
3. keep yourself (left | right)	navigation
4. there is a (person | stairs | ...) ahead you	warning
5. the door is (closed | open)	description

Table 3. The aggregated usage of voice commands during the study.

Command	Suffix	Usage
go ahead		11.58%
	distance	5.84%
	object	0.56%
	distance and object	1.04%
go (left|right)		12.64%
	distance	1.22%
	object	0.19%
	distance and object	0.47%
go light (left|right)		12.52%
	distance	1.13%
	object	0.28%
	distance and object	1.32%
go to the next corner and then (left|right)		4.90%
turn around		4.99%
Stop		15.25%
enter door		7.25%
enter (1st| 2nd) door on (left|right) side		2.07%
go (upstairs|downstairs)		8.19%
(enter | exit) elevator		2.07%
go to the (ground 1st, 2nd, 3rd, 4th) floor		4.24%
you are on the (ground 1st, 2nd, 3rd, 4th) floor		2.26%

As already mentioned, the directions menu was capable of sending complex commands with a distance or an object suffix (e.g. "*Go straight ahead 3 meter until* *door*"). Five wizards stated that the complex commands were rather difficult and slow to enter while one wizard really liked the possibility to compose the navigational commands. One wizard did not use complex commands at all, two wizards used them only one to five times, one wizard used them almost all time, and the rest (4 wizards) used them in 30%-70% of the cases. Wizards, who used complex commands, preferred distances to objects.

The usage of voice commands in percent is shown in Table 3. The values stated in the table correspond to the navigation scenario used in the study setup. However, we may see a trend of the usage of the different types of commands invoked using the Mobile Wizard. As would be expected, most commands were used for direction commands such as "*go ahead*", "*go left*", etc. In the table, we can observe that the wizard rarely used object and combination of distance and object as a suffix, but they rather used distance. An interesting point is the high frequency of the "*stop*" command. An analysis of the evaluator logs showed that the wizards used it to indicate a dangerous situation to the actors or simply to gain more time for entering the next command, which negatively influences the study scenarios.

Usability Issues of the Mobile Wizard

The mixed-method approach that we applied in the study provides us with a big variety of usability-related findings regarding the *Mobile Wizard* interface. The general impression of the human wizards about the *Mobile Wizard* that could be extracted from the interviews states that seven out of eight wizards liked the structure of the user interface and the workflow implemented within the tool. Three of eight wizards made positive comments about the intuitiveness and usefulness of the Mobile Wizard. The most relevant problems that could have been identified are as follows.

Commit button. In order to be able to compose more complex commands for the navigation tool we used a commit button to also send the audio commands to the actor. The commit button was problematic for seven out of eight wizards. They often forgot to press it, or they complained that it is an additional step in sending command that can be avoided. Only one wizard appreciated the commit button as it helped preventing him from sending wrong commands. A related problem was insufficient feedback after sending a command as the default Android toast notification was used. The toast is a text message that appears on the screen for a moment in order to inform the user about results of a particular action. The default toast always appears in the lower part of the screen, which is usually occluded by user's fingers and thus the toast was left unnoticed by the user many times.

Stairs and Elevator. Three wizards complained about the position of downstairs and upstairs buttons and suggested positioning them other way round. The workflow in elevator was difficult to identify for two wizards, which resulted in sending wrong commands to the actor.

Menus. Three participants did not like the need for menu switching as additional step is needed for entering a command. However, introducing a structure is necessary as we supported 26 basic commands and nearly 100 different complex commands. Another issue mentioned by the wizards was a lack of a symbol or an icon for each menu item next to the item name as it would be easier to locate the correct menu item. Two participants expressed a need to define their own menu structure, which was supported by our tool but was not matter of the study.

Vibra wristband. Seven wizards suggested making the vibration command faster accessible as the selection takes too long. According to two wizards, the actor already passed dangerous situations before they could send the command. Two other wizards stated that they used the stop command instead as it was more reachable in the Directions' menu. One wizard expressed that using vibration is a good idea as it is an additional input channel that can convey specific information.

Questionnaire results

The results acquired by the USE questionnaire [19] are shown in Figure 6. The USE questionnaire contains 30 statements aimed at perceived usefulness (8 questions), ease of use (11), ease of learning (4) and satisfaction (7). Wizards were asked to rate agreement with the statements on a seven-point Likert scale (1 - strongly disagree … 4 – neutral … 7 - strongly agree). The results show a positive attitude of the wizards regarding the usability of the *Mobile Wizard* while they perceive the tool as useful (median = 5.0), easy to use (median = 5.0), easy to learn (median = 5.75), and satisfactory (median = 5.0).

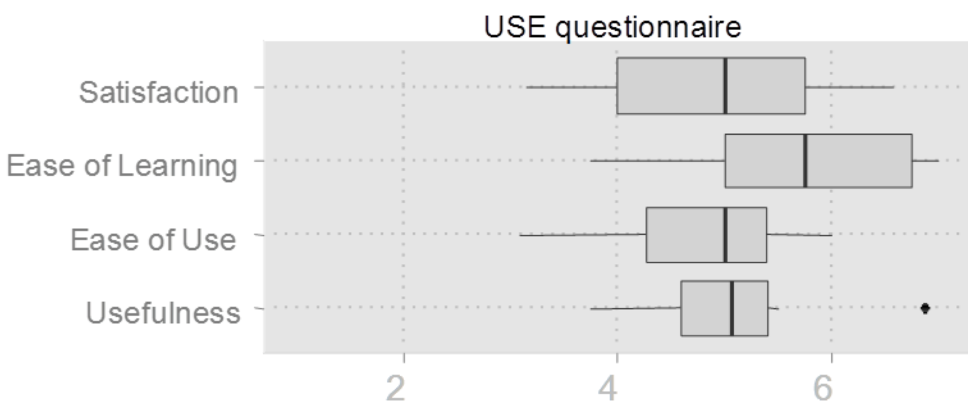

Figure 8: Boxplots showing median, upper and lower quartile, and minimum and maximum of the aggregated results of the USE questionnaire

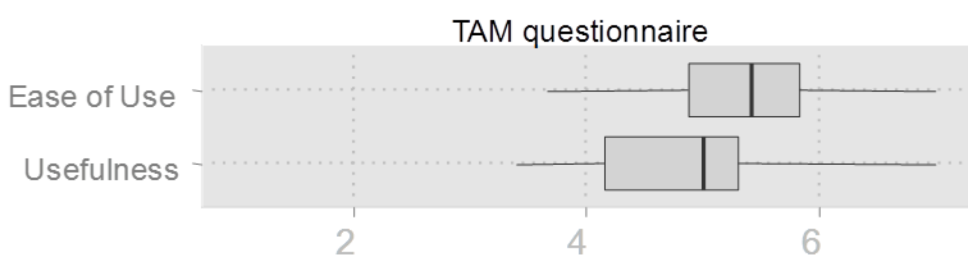

Figure 9: Boxplots showing median, upper and lower quartile, and minimum and maximum of the aggregated results of the TAM questionnaire.

The results were validated in the TAM questionnaire [20] (see Figure 7) that contains five statements regarding perceived usefulness and other six regarding ease of use. Similarly to the USE questionnaire, the wizards were asked to express agreement or disagreement with statements on a seven-point Likert scale. However, the labels were different ranging from one to seven (1 – extremely unlikely, 4 – neutral, 7 - extremely likely). Again, the results show a positive attitude of the wizards as they perceived the *Mobile Wizard* as useful (median = 5.0) and easy to use (median = 5.4).

Practical considerations

The utilized hardware and software setup enables the study to be fully mobile, not bound to one particular place or particular wireless network, and it does not even require Internet access. However, three issues were identified that have to be kept in mind when conducting such a study.

Battery life. As the setup is fully mobile there is no permanent power source and the batteries can be drained in several hours. The devices should be therefore plugged while not needed (i.e. during briefing and interviews) and backup devices should be ready in case of empty batteries. In our case, the most problematic device was the tablet as its screen had to be switched on during almost whole test run. Therefore, we had to use two tablet devices and swap them in consecutive study runs.

Connection losses. The blindfolded actor, the human wizard, and the evaluator should keep together in order to prevent connection losses. The distance should not be more than 10 meters, depending on the device used. Even though the *ConWiz* system is capable of handling connection interruptions, reestablishing connections causes unpleasant time lags.

Tablet device. As already mentioned, two tablet devices with different screen sizes were used. The disadvantage of the bigger device (Lenovo tablet) was the too large screen size and the higher weight. The wizards were holding the device in both hands and tried to reach the buttons with their thumbs. On the Lenovo tablet, however, they were not able to cover the whole screen space. One female wizard also commented that the device is too heavy to hold it for a longer time. One wizard suggested using another, more specialized, device such as game pad for entering the direction commands.

Conclusion

The goals of the study described in this paper were performing an initial validation of voice commands selected for the navigation in the context, finding possible usability issues of the *Mobile Wizard* tool for human wizards, and ensuring appropriateness of the study setup. The voice commands were found almost complete for the selected scenario, only a few additional navigation commands should be added. We also measured the usage of voice commands and identified that the complex commands were used only rarely due to high workload of the human wizard.

The *Mobile Wizard* is a part of the *ConWiz* system which is a flexible tool for conducting Wizard of Oz studies with a focus on simulating contextual scenarios. The usability of the interface of the *Mobile Wizard* could be evaluated in a standard usability test in a laboratory. However, with a laboratory setup context-related problems that appear during the usage of the tool cannot be studied. Putting the *Mobile Wizard* into context thus significantly increases the ecological validity of the results regarding the applicability and appropriateness of the *Mobile Wizard*.

Although we collected positive feedback about the usability of the *Mobile Wizard*, we identified several improvement potentials regarding the structure of the tool (especially with the menu-based approach). During the study we also experienced usual problems with mobile devices such as connection losses, battery drain, interrupts through a system's notification system, varying screen sizes, weight of the devices, etc.

The study described in this paper is a first step towards the development of a navigation system for blind people. The immediate follow-up will be a study with blind people to conduct an in-depth evaluation of the selected commands for navigation. The future work includes solving other aspects of navigation for blind, such as incorporating sensors for position and rotation acquisition, an algorithm for route computation and an interface allowing the user to control the navigation system.

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