

Blind User Requirements to Support Tactile Mobility

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ABSTRACT

Various innovations have been identified in assistive technology for the visually impaired. One of these innovations are systems that present feedback and information in a tactile format. These tactile systems have the potential to help the visually impaired, but there is little attention to how it can be combined with other assistive technology. In this research, we present a set of user requirements for tactile systems, focusing on the needs of the visually impaired. This is done by telephone, personal, and group interviews. As a result, we identify three themes related to the use of non-visual tactile assistive devices for blind persons: 1) context of use, 2) trust issues, and 3) user interaction. Our recommendations include focusing on a devices that solve very specific mobility problems, being transparent with users about system status such as battery life and accuracy, and limiting output to prevent overload.

Categories and Subject Descriptors

K.4.2 [Social Issues]: Assistive technologies for persons with disabilities.

General Terms

Human Factors

Keywords

Blind mobility, assistive devices, user requirements, tactile feedback

1. INTRODUCTION

Mobility is an important contributing factor to wellbeing [15]. For various persons with disabilities, having support (both social and technological) to increase their mobility can contribute to quality of life.

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Tactile and haptic information is an important source for blind persons to improve orientation and mobility [6]. Technological improvements, both non-visual communication targeted for non-disabled persons [2][3], and applications specifically introduced to support blind mobility using non-visual tactile displays [23], can offer assistance to blind persons.

Yet, the adoption of assistive devices is not always optimal, and abandonment rates can be up to 29% [12]. For example Bateni and Maki [1] note that while devices to assist mobility and balance (walkers and canes) benefit their users, persons often have problems using them. Lack of end-customer involvement has been identified as contributing factor to high abandonment [13] of such assistive devices.

This suggests that, while innovations such as tactile feedback on tablet interfaces can provide valuable improvements to the personal wellbeing of blind persons, we also need to take into account the user experience of these devices. In addition, it is important to better understand the user needs and concerns in the design and development of tactile mobility devices.

To do this, we propose a user centred design approach for the conceptualization and design of these devices. This attitude to design is *based on the active involvement of users to improve the understanding of user and task requirements, and the iteration of design and evaluation* [9]. Moreover, the context of use is also an important factor in understanding the end user [19].

In this paper, we identify relevant user requirements for the development of non-visual tactile assistive devices for blind persons. Finally, we focus specifically on the wishes for the design of a tactile feedback device, emphasizing tactile interaction.

The remainder of the paper is structured as follows: Section 2 will review related efforts to understand mobility needs of blind persons, in addition to providing a brief overview of systems that improve blind mobility. Section 3 will briefly introduce the process of developing a system to improve the mobility of the blind. Section 4 will present the method used during this study, while Section 5 will introduce the themes encountered during interviews. In Section 6 we will discuss the implications of these results, while in Section 7 we conclude and suggest future research.

2. RELATED WORK

Not being able to see can be a significant barrier to mobility [15] and for blind persons, contextual information provided as audio or tactile information can be beneficial [6][24]. As a result, systems

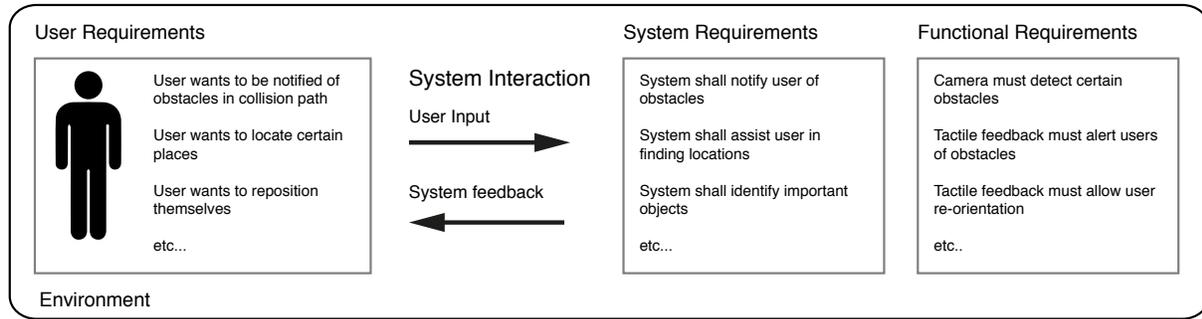


Figure 1. Depiction of the process from user requirements to system and functional requirements. For illustration purposes, some examples are included in the figure

that provide blind persons with information about their surroundings to support mobility make use of either auditory or tactile substitution [24]. These systems may receive input from one or many sensors, such as GPS [8], stereo vision cameras [22], external RFID tags [16], or online map sources [14]. The ability for touch-based tablet interfaces to provide tactile feedback thus presents the chance to contribute to user wellbeing, by providing users with information about geographical landmarks, or obstacles, without the need for sight.

MoBIC, is an example of such a system. Introduced by Strothotte et al. [18], it uses a touch enabled tablet that helps blind persons to explore a map. The system gives audio feedback about locations. KnowWhere [5] similarly projects a 2D image, while a camera translates visual map features to sounds when the blind person touches particular geographic features on the projected image. Likewise, the Talking Tactile Tablet [7] presents blind persons with audio information about visual maps.

While these systems uses tablet-like displays to translate map environments to audio, Zeng and Weber [23] introduces a system that translates geo-data to an audio haptic map that blind persons can use to find their way. The Talking TMAP [10] takes a similar approach, also offering tactile information in the form of Braille, including scale indications and street names.

Among these, we also identify solutions intended for mobile use, such as TANIA [4], which provides blind and visually impaired persons with surrounding information, using a wearable tablet that can be connected to a mobile braille display. The system relies on GPS and maps to guide the user, while the tablet display provides information about the location.

These examples show the variation of assistive devices, spanning tactile and audio feedback and relying on various input sensors to capture data. Several authors have also studied blind persons in order to understand mobility and needs associated with mobility, with the goal of user requirements for assistive devices, or to increase understanding of mobility.

For example, Strelow [17] looked at how blind people walk to develop a theory of mobility. The author notes specific skills such as a sense for the location of obstacles, the use of canes to aid mobility, or echo localization.

Völkel et al. [20] describe requirements for geographical data annotation for blind persons, with map based navigation as focus. They stress the issues of low thresholds such as curbs but also the heterogeneity of the target group. Paredes et al. [11] similarly interviewed visually impaired persons in the context of a system that provides audio based feedback to blind persons to alert them

of obstacles. Particularly notable is the distrust of technology by respondents. Finally, Williams et al. [21] interviewed 30 blind persons regarding their mobility, focusing on assistive devices in general but also including elements such as mobility training.

These examples highlight some related work on understanding blind mobility from a user perspective. Our aim in this paper is to expand on this research to include user research on blind mobility especially in the context of tactile devices,. We also taking emphasise the contextual use of current assistive devices and how comfortable people are using the system, presented as system trust.

3. USER CENTERED DESIGN APPROACH

This research is being performed within an EU project to develop a standalone prototype that detects close range obstacles and can recognize objects such as doors or stairs. Based on individual needs and with respect to context, presentation of information will be in tactile and/or audio modality. The system consists, in part, of a 3D, time-of-flight DepthSense camera by SoftKinetic, combined with a wearable tactile display developed by Elitac.

The current exploratory study is part of a general system requirements analysis that is being done to ensure a system that will be not only technically feasible, but also optimally adjusted to the users' needs. When developing personalized support systems, an iterative development process is necessary. After each cycle, the requirements the system needs to fulfil are revisited, leading to validations and refinements.

In Figure 1, the process that we will use to develop the system is depicted. Operational demands, human factor knowledge, and envisioned technology are taken into account to explicitly derive use-cases, requirements, and give a rationale for the requirements. The use cases put the requirements into context. Through interviews, where scenarios are presented and used as a basis for discussion, user requirements are determined, which are consequently translated into functional requirements and technical requirements. The user requirements form the basis of the development of the system, and deriving them should be of utmost importance and focus in the initials phase, but also during the development of the system.

In the following, it is described how the user requirements have been derived, and an overview is given over the most relevant user requirements for the proposed system.

4. METHOD

Our method consists of interviews, conducted during several sessions with blind persons. First, 6 interviews were held by phone (4 female, 2 male). Telephone interviews ranged from 32 minutes to 104 minutes. Interviews on location were limited to 60 minutes, while group interviews were 2 hours. Data was recorded and statements cards were made using the audio recording. These were subsequently analysed to finally arrive at the presented themes.

A loose script was followed, structured in four parts. First, general demographic data were collected such as sex, age, location, degree, and duration of blindness. Subsequently, we had a general discussion of issues related to blind mobility, using the identified scenarios as basis. Concluding this, we focused on the use of current and previous assistive devices, including dogs, but also the role of caregivers.

The use of a hypothetical tactile systems was introduced and discussed, where participants were asked to reflect on its use in contexts earlier described, such as going shopping or traveling by train. Sample questions include: “Do you often travel around?”, “Do you travel with, or without assistance?”, “How far should detection [of unknown obstacles] be necessary?”, and “How would you like to feel the information about obstacles?”.

These interviews were followed with 2 focus group discussions with blind persons. Group 1 contained 9 participants, while group 2 contained 12. Interviews were chosen because they allow for rich data to be collected, while also allowing researchers to follow-up with relevant questions.

Finally, 4 follow-up interviews were conducted with persons at home, also examining the home environment. Participants were recruited through local organisations for blind persons, digital and analogue communication platforms, and word of mouth. The ages of respondents varied, with the youngest 33 and the oldest 78, all living in Belgium. Participants were all over 18 years old and included congenital blind persons in addition to people who lost their sight as a result of illness.

The goal of the interviews described above is to gain a first idea and overview of the user requirements for the intended system. During further, the user requirements will be regularly evaluated and re-assessed to be sure that the system will be not only be acceptable by the users, but be in line of the users’ wishes.

5. THEMES

The following themes have been identified that are of importance for the end users about mobility, and which need to be taken into account when specifying user requirements (and consecutively, functional and technical requirements): (1) context of use, (2) trust issues and (3) interaction with the user.

Below we discuss these themes, focusing on the most important aspects and several themes that emerged from the interviews.

5.1 Context of Use

5.1.1 Summary of findings

Currently, the most important assistive devices are the white cane and the dog. The white cane is an important device for participants, both when used actively to assist mobility, but also as a visual and auditory signifier for blind persons, with people tapping the cane to alert passers-by of their presence. When traveling by car with someone, a different cane might be used than when traveling alone.

For our respondents the guide dog also plays a prominent role. Not only does the dog help to navigate around obstacles, but it also plays an important social function, with passers-by approaching the dog, or striking up a conversation. For some persons, the dog also acts as driving force to leave the house and go for a walk.

Participants make the distinction between primary or secondary assistance, which can change depending on the current situation, destination and route. For example, the white cane may be the primary assistive device in certain situations where the surface is uneven, while the dog may take over the primary role in indoor environments. Additionally, when accompanied by a caregiver, both the cane and the dog (if applicable) may be used only secondarily, if at all.

Devices are also used and interchanged on a contextual basis. For example, when a partner or caregiver takes the role of primary assistance, the cane (or dog) plays a less important role.

A participant’s destination and route may further impact the combination of devices used. For example, one respondent always takes a digital compass when traveling to a particular metro station where it is hard to discern direction, but leaves the compass at home when traveling somewhere else.

External factors such as rain or snow also impacts assistive device selection, such as a specific type of cane that is longer and can be used to feel the street surface through the snow. Additionally, rain may effect how accurate echo localization may be, while snow may have the same effect. An outdoor system should be usable in different (weather) conditions, not being affected by temperature or humidity.

Significantly, needs differ when discussing mobility indoors vs. outdoors. In an indoor situation, points of interest such as the location of a lift, its destination and the location of service counters are important. Information such as the length of a queue, or the current number displayed when queuing at official buildings is also of importance.

5.1.2 Recommendations

As illustrated, users rely on a variety of assistive devices that can change depending on the context. As a consequence of the above-mentioned aspects, we present some recommendations.

Due to the context-based interchange-ability of devices, systems could focus on solving a very specific problem, while universal solutions may prove too complex. An example may be the ability to retrace steps to a previously specified location, or indications of where building exits are.

The presence of existing assistance also influences the types of goals and functionalities desired by participants. For example, persons with dogs may be less in need of large obstacle detection and notification, but may rather desire notification of uneven surfaces. In the case of devices that - through tactile feedback - provide blind persons with contextual information about their surroundings, the most important information that needs to be communicated is information that cannot be detected by the current accompanying assistive devices. For example, for participants with a cane and a dog, there was a strong need to be notified of uneven floor surfaces such as loose street tiles, puddles or other small holes, or the location of objects that cannot be detected accurately by a dog.

Designers of new assistive systems should be aware of the various weather conditions in which devices could be used. For example, for tactile feedback outdoor, cold conditions may prevent proper

feedback. Simultaneously, it is important to provide functions for the various goals that may not be met by current devices.

The current assistive devices assume that a person has at least one hand available for using the white cane or controlling the dog. This excludes (or at least makes it more difficult for) people with a walking impairment, e.g., when sitting in a wheelchair.

5.2 Trust Issues

5.2.1 Summary of findings

A recurring theme during the interviews when electronic assistive devices were discussed relates broadly to issues of trust. One participant insisted on waiting for a device to become popular before using it to ensure sufficient training and support.

Lack of training for devices was also noted as a reason why some assistive devices did not get used extensively. While training might be given initially, the use of the particular device is too complicated and users stated that due to the complexity, they have forgotten how to use it and do not want to rely on using the system in critical situations.

These issues are augmented with general fears about the failing of technology. Anxiety about power running out at unfortunate locations, or the accurateness of the system, impacts buying decisions. For a blind person, attempting something as potentially life threatening as crossing the street while relying solely on a technological device may seem daunting.

One of the participants biggest stated fears were feeling lost in a new environment. While aides such as GPS systems might offer help in such contexts, participants were afraid to rely on them, stating that they are often made without consideration for blind persons.

This fear is heightened in situations where there are no bystanders that can assist blind persons to find their way again. While dogs might be trained in mobility around familiar locations, when arriving in an entirely new situation, they are not always capable of assistance. Subsequent failure of devices in such unknown environments impacts the willingness to try them.

5.2.2 Recommendations

As illustrated, safety and trust in the system is a very important aspect. The following user requirement can be identified:

Systems should reliably provide relevant information when needed, while also considering information accuracy. Designers should also consider providing critical features such as re-location or re-positioning, to allow users to find their way back.

Furthermore, users should be provided with system status information that is critical to use. This may include battery status or current system accuracy. Additionally, devices that are used outdoor may need easy ways of recharging batteries, or make use of external batteries.

System complexity should also be avoided, to prevent long training times. This is especially important because devices may only be used incidentally to solve a specific problem. Finally, it should not interfere with other safety relevant interaction mechanisms.

5.3 Interaction with User

5.3.1 Summary of findings

While audio based feedback devices are interesting for blind persons, participants remained reluctant to rely heavily on audio feedback outdoor because of the current strong dependence on

hearing for echo localization and ambient sounds. None of the participants wears earphones on both ears while traveling (even incidentally) with the only exception being earphones that hang down from the ear and still allow ambient sounds to be heard. As a consequence, a system to support them should not rely on communicating important or vital information via audio only.

A large emphasis is placed on giving tactile feedback about unexpected obstacles. Given that participants worried about impulse overload, the tactile actuators need to be positioned in a way that it is not burdensome to experience, not irritating, and not in a sensitive place. In addition, the signals should not be continuous to prevent overload. Also, it was mentioned that not all information should be presented: a filter is needed.

As a result, the desired distance detection remained short. However, in certain cases, longer distances might be preferred, such as being able to scan a new, unknown path. While memory of a station might be good, having an unexpected new obstacle is troublesome. This is especially possible in locations such as public transport halls, i.e.: before or after taking the train. This also applies to situations where the stairs are slightly higher, or stop abruptly. Given this, the distance might not be as relevant, but rather the ability to reveal only unexpected obstacles. A significant concern for some participants was the presence of cyclists. While cars can be heard, when crossing a road, cyclists are not easily detected.

A focus on the interaction with any tactile feedback device that is intended for use outside the home is also important, given that the users hands may already be occupied with the white cane, or possibly the dog. Additionally, the cane might go from the left to the right hand, depending on the current situation. In this case, input devices must be useable and accessible with both hands. Despite their hands being already occupied, participants nonetheless stated a preference for a physical input device that can be operated by hand. Voice commands were mentioned by some, but were accompanied by reservations about inference of background noise. A notable preference was also given to cabled solutions: this prevents losing the input device.

Given that participants rely heavily on backpacks to carry personal belongings, any mobile system must take into account that persons are already carrying something on their back. Any newly introduced system should not interfere with the interaction with other assistive devices or necessary resources.

Additionally, there was a stated need for two-dimensional information, in the sense that participants wanted to be able to discern between obstacles that are higher, such as at chest level, or those on floor.

Directional information is also importance. For example, when actively searching for a particular object or location, such as a lift, doors, or stairs, being given information about their location relative to the direction that the blind person is facing is valuable.

In a system where the sensor device such as a camera or infrared sensor must be place on the body, initial insights illustrate that some adjustability of the wearing location is deemed valuable. For example, the wearing location for a sensing device on top of summer clothing might be different to a winter coat. While the head as sensor location may arguably provide good results due to its height, is a reluctance to wear any sensing device on the head.

However, as one respondent suggested, applications such as Google Glass may be interesting in this context, as the relative size of the device is small and the attention it might attract is less, than when a large device is worn on the head.

5.3.2 Recommendations

From the interviews various requirements are identified related to user input. First, audio should not be the main mode of feedback, especially in situations where users rely heavily on sound to locate and orientate themselves. Alternatives to in-ear earphones may be considered, but critical system information is best communicated via alternative means.

The types of obstacles that are communicated to the user should be restricted to those that are unexpected. This is especially important to limit information overload and reduce system complexity.

Furthermore, different contexts may require different types of user interaction. Environments with many obstacles may require different types of notifications (i.e.: more frequent, closer in range).

Finally, a balance between the wearing location of both the input sensors and the tactile feedback is needed to ensure the best user experience, while also providing the best results.

6. DISCUSSION

As shown in the interviews, the current assistive device configuration determines what people are willing to try and how they will use it. For example, persons with dogs have many of their needs met already, but might want the ability to get directions for longer distances, or the ability to detect obstacles or objects that are not apparent to the dog. When deciding the functionality of any (tactile) feedback device, this remains a crucial consideration.

An insight is also the interchange-ability of devices. As the context changes, so does the configuration of device types used. For example, conditions such as snow, traveling by car, or being accompanied by a partner may result in using a different white cane, or combinations of assistive devices. Given this, a tactile tablet interface that provides map based information may only be used in situations where users are not accompanied by partner, or when the location known.

Benefits of assistive devices seem to be in small features that solve a particular pressing problem, such as being able to keep a bearing (i.e.: walk straight) when following directions, or when making a turn, while the compass can be useful in a very specific context, such as metro travel, where the layout of the building is not sufficiently clear. In one instance, the ability to use distance detection of 0.5m in front greatly improved mobility.

Even though the interviewed participants were reluctant to place full trust into assistive systems, a new system must be reliable and work in all necessary situations. Blind users need to be able to rely on the information that is given at any possible moment.

7. FUTURE WORK

The current work provides an insight into assistive device use, with an emphasis on exploring tactile feedback. However, while such an overview may prove valuable to give initial insights into device design and use, further efforts are needed to better understand detailed use. For example, if tactile patterns are used to display information to blind persons about the location of doors, stairs or entrances to lifts, how might this be presented? In addition, it needs to be evaluated which information needs to be communicated to the user in which situation. How do the context and the environment influence the needs of the user? And how does it influence the way the user wants the information, e.g., via audio or tactilely?

As next step, the user requirements will be translated into functional and technical requirements. Based on these, a prototype will be built and evaluated with visually impaired participants. The exploratory study of this paper will be the basis on which the practicability and usefulness of the prototype will be evaluated.

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