NAVITERIER - INDOOR NAVIGATION SYSTEM FOR VISUALLY IMPAIRED

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Abstract
This paper presents key findings gathered during development of indoor navigation system called NaviTerier [1]. This system is targeted to visually impaired users who want to navigate independently inside large buildings like hospital, library, university, etc. System is based on structured description of environment that is provided to the user by special application installed on a smartphone.

Keywords
navigation, visually impaired, smartphone, user centered design, usability testing

Introduction

Visual perception is source up to 80 percent of all information that human is gathering. Thus limitation or even full loss of vision severely influences the lives of people who suffer from visual impairment. This brings not only direct consequences like loss of ability to see but also problems with independent movement and daily self care. As visually people are dependent on help of others, loss of self confidence, negative self-concept and other problems on psychological level also occurs.

Reducing necessity to be dependent on other people during movement has positive effect on multiple problems that visually impaired person is facing to.

User research

Respecting user needs and wants

NaviTerier is being developed by means of following user centered design methodology. This means more stress during development is put on user research and usability testing then on developing of hi-tech devices enabling precise localization but then forcing users to wear them. We have also continually consulted our research with experts from organizations working with visually impaired people [2], to confirm our particular results.

Following important findings were gained from large scale, long term user research we have performed on more than 40 subjects.

Users generally do not want to change the technique of using white cane and listening to sounds of surrounding environment, they currently use for independent movement in the space. Hence new navigation equipment must not disturb or disable these techniques (for example by placing sensor in the white cane or providing user with some continuous audio feedback to the headphones)

We must bear in mind that visually impaired people are normal human beings and thus they do not like to wear some strange looking equipment (as head-mounted sensors [3]) or complicated setups.

No necessity of buying, maintaining and carrying any new device is very much appreciated by the users. Therefore NaviTerier is designed as a low cost solution and relies just on smartphones (equipped with text to speech synthesis - TTS) that visually impaired users already have to be able to communicate with the world.

Differences among visually impaired

Our user research points on large differences among needs and skills of different visually impaired people.

Factors that are influencing these differences might be seen as obvious (impairment severity, congenital or acquired blindness, etc.) but none of these dependences we were able to proof with statistical significance. On the other hand we were able to observe relations that are worth to be kept in mind during design of any navigation system for visually impaired users.

Recruitment of participants

Participants to our study were recruited mainly by invitation letters sent by email. Participants were volunteers and we motivated them by small amount of money as equivalent to their time spent by testing.

Our participants have to come to the university campus on their own and generally they were also interested in new technologies. Therefore this recruiting scheme brings us more active (better performing) users. We have not tested with people that are not able (or they are too much afraid) to navigate independently in the environment. One of constraints we put on the user is ability to navigate independently.

Distribution of performance and skills for population of visually impaired people does not seem to create Gaussian as it is for sighted people. We can rather imagine 2 peaks (one close to the minimum and the other one close to the maximum performance).

Influence of impairment length

Users with blindness acquired in later age are usually more precise and slower in navigation in comparison to congenitally blind users that are more fearless.

Normally we are very dependent on our sight and thus people who lost sight in later age had to re-start lot of thing in their lives nearly from scratch. This could lead to a fear of the unknown environment.

Congenitally blind users have never used visual perception for navigation so they have developed alternative strategies, how to navigate in the environment. They are used to practice these techniques from early childhood. On the other hand imagination of described object can be different from the reality as congenitally blind users have not the experience of vision.

Impact of impairment severity

People with low vision impairment are making more errors in navigation probably due to residual visual perception that could be partially used for orientation in space.

Let's imagine situation, where user is standing on the ramp. One stairs are in front of him and other stairs are at his back. System gives instruction like: "Turn 180 degrees and go one stairs up." Low vision user can recognize stairs in front of him and when he does not pay too much attention, he simply choose stairs that he can recognize in the front and skip the commands to turn.

On the other hand fully blind users are more patient and listen carefully to the instructions. Thus these types of errors usually do not occur by them.

Other important factor that is usually influencing performance of users is type and intensity of therapy that people receive after impairment occurs. At least in the Czech Republic there is wide difference between particular subjects.

Experience in independent orientation and movement as well as personal attitude to live with vision impairment or level of skills in controlling of electronic devices are also strongly changing the user's performance.

Personas

As a result of these findings we created two personas of visually impaired users.

Hanka is a 31 year old woman that is working as self employed translator. From her birth she has blurred vision due to Macular degeneration. Despite this impairment she is very active. Hanka has quite positive attitude to new technologies. She likes simple descriptions of environment as it is more efficient for her.

Martin (58) is fully blind by accident that happened to him in his twenties. He is big fan of modern electronic devices so he uses computer and Internet every day. Martin prefers exact and detailed description of route and he often convinces himself that he is on the correct route.

Fig. 1: Personas Hanka and Martin

We focused on designing the system that is able to support different categories of users by providing them different types of information. Thus NaviTerier is capable to provide descriptions in several levels of detail.

Main principle

System architecture

NaviTerier consists of standard smartphone (powerful enough to run TTS), navigation application and in advanced prepared data files with structured description of the building.

NaviTerier is based on (what we call) offline navigation principle. This means exact position of the user inside building is not tracked by any technology. Instead of technology we rely on ability of visually impaired users to follow verbal description of the environment to navigate in unknown areas. We must highlight that visually impaired people are used to it nearly on a daily basis. For successful navigation of user it is important to provide him clear and well structured instructions and description of important landmarks.

System should be designed for ad-hoc use and it is not possible to force user to learn all the route description in advance. As description of the route could be longer than what is user able to remember in short term memory, description is split to several parts called segments. Each border of segments must be easily recognizable by the user so it is situated to places like junction of the corridors, corridor turns or places where corridor is partitioned by perpendicular doors (See Fig. 2).

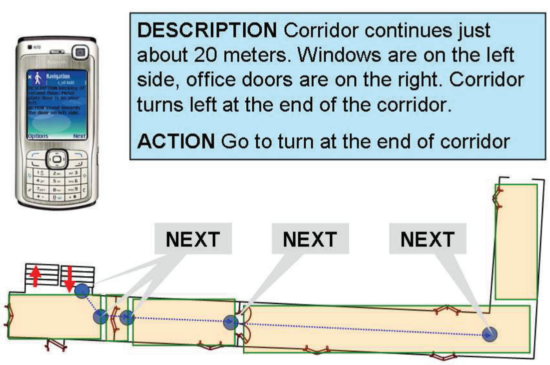

Fig. 2: Part of corridor with marked segments. Blue dots marks places where user asks system for new part of information.

When user is entering the building, system know his exact position and it is also place where navigation process starts. User receives first set of information describing the surrounding environment (opened by keyword "DESCRIPTION") and then after the keyword "ACTION" are placed instructions what user should do to reach end of the current segment. (See blue box of Fig. 2) When user reach end of the segment, he just press the Next button in the application and receives description of the next segment. Same process is repeated until the final destination is reached.

Application should also support possibility repeat instruction or to make a step back in the description to listen a description for previous segment. As users want to be fast during navigation, it is possible to repeat just the part of description that contains "ACTION" instructions.

How to overcome weak points

Potential problem is loss of synchronization between real position of the user and relative position expected by the system. Synchronization points could be added to minimize negative effect of this issue.

Fig. 3: QR code on a name plate being recognized by camera of smartphone.

Very convenient realization of these points, that can update the relative position kept by the system to the real position, can be done by installing QR codes on the nameplates that are next to nearly each doors (see Fig. 3). QR code can hold unique id of the place so when it is scanned by a camera of mobile device, the id is recognized and matched with database in the application.

Besides obstacles that are dangerous for all people, there is also specific category of objects that are very dangerous mainly for visually impaired people. These objects are literally hanging in the air so it is not possible to notice them by a white cane. If they are placed in the level of people's head, hitting such object can cause very serious injuries. NaviTerier is designed to announce these obstacles and in some cases user should be warned even one segment in advance to avoid risk of entering segment with dangerous obstacle just at its beginning.

In the Czech Republic there is no standardized vocabulary for the description of environment or objects to blind. At the beginning of the project we were facing problems with finding appropriate words for describing different sometimes strange objects. After some time of gathering proposed words we were able to internally standardize description of at least most common objects.

In scope of NaviTerier project we are also developing tool that will help with easier and faster creation of new descriptions. This editing tool will also help to keep consistency of descriptions.

Testing

During development of the system we were continually testing usability of navigation system prototypes. We have performed 7 studies with 40 independent users. Each study was carried out on a route different from the previous ones to test various combinations of landmarks and obstacles inside building.

We have been also testing possible approaches how users can be recovered in navigation after they have lost on the route. Visually impaired users are able to use camera of mobile device to scan QR code in reasonable time and with help of voice instructions recover to the correct route.

One of the important outcomes from the field tests is the finding about preferred navigation path to be used.

Some users prefer path that easier or safer for navigation. This means for example to use the side of stairs that has the handrail. On the other hand there are users that prefer to use right side of the corridor or stairs each time to avoid collisions with other people coming from opposite direction.

Conclusion

With use of NaviTerier users were able to successfully navigate in complex indoor environment previously uncommon to them.

Main advantage of the system is no additional cost for the visually impaired user and there is also no necessity to fundamental changes of way how people navigate themselves in the environment.

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