“Turn Left After the Heater”: Landmark Navigation for Visually Impaired Users

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ABSTRACT
Indoor navigation is a challenging task for visually impaired people. Existing technologies promise to provide support for autonomous way finding; however, the accuracy of low-budget approaches is low and can lead to frustration amongst users. The presented ongoing work is based on suggestions in the literature that contextual information such as sudden changes in the surface structure or landmarks could supplement distance estimations to improve the user experience during navigation tasks. Following a user-centered design approach, a real-time interactive prototype with localization was implemented and evaluated. First results from a pilot study confirmed the hypothesis that user experience is improved by contextual information and showed that contextual information are accepted and appreciated by users.

CCS Concepts
K.4.2. Computers and society: Social issues –assistive technologies for persons with disabilities.

Keywords
Indoor navigation; visually impaired people; iBeacons.

1. INTRODUCTION
Navigation in unfamiliar environments is a difficult task for visually impaired people [7]. Current technologies such as Global Positioning System (GPS) provide real-time localization for navigation solutions and enable autonomous way finding for this user group. But GPS is limited to outdoor navigation. For indoor localization, different approaches use signals such as WiFi, Radio Frequency Identification (RFID) or Bluetooth Low Energy (BLE) to estimate the user’s current location within the building [6,9]. Several studies investigated the technical feasibility and optimization of these approaches to indoor navigation, an already proposed, but understudied approach [1]. However, these systems, are often either expensive, complex, or too inaccurate and not very reliable, which could lead to mistrust and poor user experience.

In this paper we present the human-centered development and evaluation of an indoor navigation application for visually impaired people based on iBeacons and built-in smartphone sensors. To counteract the limited accuracy in localization, we added contextual information along the navigation path [2]. We expected that the additional context information would improve the user experience during indoor navigation.

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2. DEVELOPMENT PROCESS
The prototype was developed following a user centered design process (ISO 9241-210). To understand the context of use and derive user requirements, semi-structured interviews with five visually impaired people were conducted (20 to 35 years, all male, remaining visual acuity: 2-20%, one had dyschromatopsia, one was a mobility trainer at an education center for visually impaired people). When participants already used or had used a navigation application, they demonstrated it in a short navigation task. Only observations or remarks that were stable over at least two participants were used as key requirements. For example, one re-occurring observation of normal navigation behavior was relying on familiar objects along the path. One key user requirement was therefore that navigation commands should include multimodally perceivable environment elements (e.g., landmarks such as heaters/radiators or changing surface structures; in line with e.g. [5, 8]). Also, all navigation steps should be presented in a preview mode (in line with [7]) and users should be able to individually customize the interaction with the application (e.g., distance in meters versus distance in steps). Based on the list of user requirements, we developed and evaluated a first digital Axure®-based prototype. Localization was provided through a Wizard-of-Oz setup and three students with simulated visual impairments (Cambridge Simulation glasses [3]) tested this first version.

Using insights from this first iteration, the final prototype was implemented for the Android platform (version 5.0) and used real-time iBeacon-trilateration with a localization accuracy of approximately 3m (95% of all estimations were within a 3m range of the true value). All UI-elements were labeled according to accessibility guidelines to guarantee compatibility with built-in Android accessibility features. The application allows users to turn contextual information “on” and “off”. Based on the interviews, relevant contextual elements were included (e.g., surface changes: from soft carpet to stone; smell: coffee machines; temperature: sunlight or heaters/radiators).

3. PILOT STUDY
3.1 Method
Eleven participants (age: 21-48 years; 2 female; visual acuity < 0.2) were recruited from a local education center for visually impaired people, where the experiment took place. We used a within-subject design with three conditions in randomized order. In condition “only cane”, all instructions were given before the participants started walking in form of a common description (“turn to the right in 10m”). In the condition “app without context”, our smartphone application tracked the location on the navigation path and gave auditory navigation commands (e.g., “turn to the right in 10m”) at certain waypoints. In the condition

"app with context", navigation commands were enhanced by additionally providing information on the environment and its relevant elements (e.g., "Turn to the right in 10m after the heater"). The entire path was covered with signals from eleven iBeacon emitters (8 Onyx^{TM}-beacons, 3 iPods^{TM}). After each condition, participants completed an AttrakDiff-questionnaire [4], a subjective measurement for pragmatic quality (e.g., efficiency, effectiveness) and hedonic quality (the product's ability to satisfy the users' need for stimulation and identity). The attractiveness dimension of the AttrakDiff measures the perceived global value of the product. To keep the task comparable and due to location constraints, the route was not changed between conditions.

3.2 Results

As expected, the condition "only cane" was rated highest regarding the dimension of pragmatic quality (table 1), followed by "app with context" and "app without context". For hedonic quality, "app with context" was rated highest, followed by "only cane", and "app without context" was rated lowest.

Table 1. Mean and [Standard Deviation] of the AttrakDiff questionnaire. PQ: pragmatic quality, HQ: hedonic quality, GA: global attractiveness (scales range from -3 to +3).

Condition	PQ	HQ	GA
Only Cane	1.30 [0.94]	0.35 [0.40]	1.08 [0.97]
App without context	0.10 [1.33]	0.23 [1.44]	0.25 [1.75]
App with context	0.73 [0.94]	0.81 [0.83]	0.75 [1.00]

Statistical analysis was conducted using a repeated-measures ANOVA with planned Helmert contrasts (level 1: "only cane", level 2: "app without context", level 3: "app with context") for the dimensions pragmatic quality and hedonic quality, and a Difference contrast for the dimension global attractiveness. Regarding the pragmatic quality, the condition "only cane" was rated significantly higher compared to both versions of the application, $F(1, 10) = 5.45$, $p = .042$, but no significant difference could be found between both applications. On the dimension of hedonic quality, "only cane" did not differ significantly from both applications, but "app with context" was rated significantly higher than "app without context", $F(1, 10) = 5.15$, $p = .047$. None of the planned contrasts for global attractiveness was significant.

Since the main purpose of this pilot study was to test the new application, interviews focused on its functionality, accuracy, usability, and accessibility. 10 out of 11 participants stated that they were satisfied with the functionality of both versions (with and without context information) and would trust the navigation commands. The accuracy was described by half of the participants as accurate enough that it could be helpful in daily use. Participants did not encounter major problems while interacting with the application. Seven of the 11 participants report that they would prefer the version with context information, the remaining 4 would switch it permanently off. Participants stated that they worried about an overstimulation with contextual information in complex environments. It is therefore important to be able to customize the application regarding the quantity and quality of the information given.

4. DISCUSSION

Following a human-centered design process, we developed and tested an interactive prototype making use of contextual information for indoor navigation. First results indicate that adding contextual information to the navigation commands could lead to a better user experience compared to a version without landmarks. Still, both versions are rated lower in terms of pragmatic qualities compared to a condition, where participants used only their cane. One interesting implication of this finding is that the negative effect of an inaccurate localization on the user experience could at least partially be reverted by adding context information to navigation commands. Several methodological drawbacks narrow the generalizability of these findings. The rather simple navigation task, the small sample size, the within-participant design of the study, and a lack of performance data are certainly limitations. Despite these limitations, we gained first promising insights into context-supported, low-budget indoor navigation. The next iteration will include further improvements of the usability of the application and the main evaluation will overcome the aforementioned limitations.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Corna, A., Fontana, L., Nacci, A.A., and Sciuto, D. 2015. Occupancy detection via iBeacon on Android devices for smart building management. In *DATE '15*. EDA Consortium, San Jose, CA, USA, 629-632.

[2] El-Shimy, D., Grond, F., Olmos, A., and Cooperstock, J.R. 2012. Eyes-free environmental awareness for navigation. *Journal on Multimodal User Interfaces*, *5*(3-4), 131-141.

[3] Engineering Design Centre: Inclusive Design Tools. In: Inclusive Design Toolkit, Retrieved January 11, 2016 from http://www.inclusivedesigntoolkit.com/betterdesign2/inclusivetools/inclusivedesigntools.html

[4] Hassenzahl, M., Burmester, M., and Koller, F. 2003. AttrakDiff: A questionnaire to measure perceived hedonic and pragmatic quality. In *Mensch & Computer 2003*. Vieweg+ Teubner Verlag, 187-196.

[5] Chen, H.-E., Lin, Y.-Y., Chen, C.-H., and Wang, I.-F. 2015. BlindNavi: A Navigation App for the Visually Impaired Smartphone User. In *CHI '15 Extended Abstracts*. ACM, New York, NY, USA, 19-24.

[6] Fallah, N., Apostolopoulos, I., Bekris, K., and Folmer, E. (2013). Indoor human navigation systems: A survey. *Interacting with Computers, 25*(1), 21-33.

[7] Miao, M., Spindler, M., and Weber, G. 2011. Requirements of indoor navigation system from blind users. In *Proceedings of the 7th Conference of the Workgroup HCI and Usability Engineering of the Austrian Computer Society 2011*. Springer, Berlin Heidelberg, Germany, 673-679.

[8] Quinones, P.-A., Greene, Tammy, Yang, R., and Newman, M. 2011. Supporting visually impaired navigation: a needs-finding study. In *CHI '11 Extended Abstracts*. ACM, New York, NY, USA, 1645-1650.

[9] Ruffa, J.A. 2015. *Assessing iBeacons as an Assistive Tool for Blind People in Denmark.* Doctoral Thesis. Worcester Polytechnic Institute, Worcester.