Designing a Robot Guide for Blind People in Indoor Environments

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ABSTRACT
Navigating indoors is challenging for blind people and they often rely on assistance from sighted people. We propose a solution for indoor navigation involving multi-purpose robots that will likely reside in many buildings in the future. In this report, we present a design for how robots can guide blind people to an indoor destination in an effective and socially-acceptable way. We used participatory design, creating a design team with three designers and five non-designers. All but one member of the team had a visual impairment. Our resulting design specifies how the robot and the user initially meet, how the robot guides the user through hallways and around obstacles, and how the robot and user conclude their session.

Categories and Subject Descriptors
H.1.2 User/Machine Systems

Keywords
Robots, indoor navigation, blind, participatory design.

1. INTRODUCTION
While GPS-based systems have become effective for outdoor navigation, indoor navigation remains an open problem. Sighted people rely on visual cues to get to destinations in large buildings such as doctors' offices, shopping malls, and airports, but for blind people, indoor navigation is a major challenge.

We believe that robots that will reside in buildings in the future to serve various functions can also serve as effective guides for blind people who need assistance with indoor navigation. Robots offer an appealing solution for two reasons. First, robots can be programmed to interact with blind people like sighted human assistants, which would require no special training from end users. Second, when robots become widely available, blind people will be able to use mainstream robots instead of specialized assistive devices to solve an accessibility problem. Robots that can autonomously navigate around their building environments will be able to simply download software that enables them to help blind people in addition to completing their other tasks.

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In this report, we present the design of a robot guide for blind people in indoor environments. We used *participatory design*, a method where the end users of the system participate in the design process. We form a team of designers and non-designers with a range of vision abilities to design the robot interactions through group and individual sessions. The team designed specifications for how the robot should initiate contact with a blind user, guide the user to a destination, and end the help session.

2. RELATED WORK
There has been much prior work on using robots to assist blind people with navigation. Kulyukin *et al*. [3] developed a robot guide for indoor environments that assisted with wayfinding. The robot learned about its environment through posted RFID tags in a building. Unlike our work, Kulyukin *et al.* focus on the technical aspects of the system (*e.g.*, the path-finding algorithm, the speech recognition accuracy). There is no discussion of the robot's behavior or how the user and robot should begin or end a session. There's also no mention of "sighted guide" technique.

Several projects have explored the use of robots to replace blind people's personal mobility aids. For example, Borenstein *et al.* presented the handheld device GuideCan [2], and Lacey and Dawson-Bowe presented a robotic walker for older blind people with mobility challenges [4]. These devices aim to replace white canes or guide dogs and can detect and avoid obstacles. They do not assist with wayfinding. Unlike these systems, our approach focuses on leveraging mainstream robots in buildings so they can help blind people find a destination in a building.

3. METHOD
We used participatory design (PD) [5], a methodology where the users of the system have power over its design. We created a design team made up of three designers (*i.e.*, people with a background in technology research and design), and five non-designers with varying visual abilities. The designers' areas of expertise were human-computer interaction and human-robot interaction. Two of the designers had vision impairments (one with no functional vision and one with low-vision) and one was sighted. Among the five non-designers (2 females and 3 males, average age of 39), three had no functional vision and two had low-vision. All were professionals who used mobile devices, computers, and various assistive technologies on a regular basis. Five of the seven team members used a white cane while two members who had some functional vision did not use a mobility aid. Unfortunately, we were unable to recruit a guide dog user.

The design was formulated over three sessions with each participant: a 30-minute interview, a 90-minute group workshop, and an individual 60-minute session. During the interview, we asked participants about navigation challenges in indoor environments and robot design suggestions. During the group session, participants discussed how the robot would interact with the human from the initial contact to the final conclusion of the interaction. The researchers facilitated the discussion by asking questions, taking notes, and clarifying participant responses.

The goal of the third session was to develop low-level specifications for how the robot should behave when walking with a blind person. Using contextual inquiry, we asked participants to walk with a research assistant as a guide, as we observed the interaction and asked about preferred guidance techniques and feedback. Participants walked with the guide down a hallway, took an elevator, circumvented obstacles, *etc*. We then created a Wizard of Oz prototype for a robot guide by controlling a PR2 robot with a joystick. We guided the non-designers down a hall and around obstacles with our prototype and sought their feedback.

To analyze our findings, we audio-recorded all sessions and took notes. We reviewed the notes and recordings and noted strong preferences, common patterns, and themes.

4. RESULTS

The team members felt that the robot would be most useful in buildings such as offices, shopping malls, airports, and conference centers. They designed the robot to act as a *sighted guide*, a technique where a sighted person guides a blind person by walking one step ahead and beside the blind person as the blind person touches the sighted person's elbow.

To initiate a guidance session, the design team suggested that users summon a robot when entering a building through a mobile device application. A user should then be able to treat the robot as a "friendly receptionist" by asking it for assistance. The robot should tell the user where to hold it and ensure that the user is facing the correct direction. With the PR2, participants found it easiest to hold the robot's shoulder rather than its elbow, as seen in Fig. 1. As the robot and user walk through a building, the robot should stop if the user loses contact with it and wait for the user to resume contact. The robot should notify the user when changes in the path occur by saying, for example, "turning left" or "veering left around an obstacle." Doorways and ramps should also be announced. Most team members did not want the robot to pause or slow down before veering around obstacles or turning, saying that verbal feedback was sufficient. When moving through narrow passages, the robot should rotate sideways so that the user knows to walk directly behind the robot. This simulates the sighted guide technique, where the sighted person moves her elbow backwards to signal the blind person to follow her in single-file. When taking an elevator, the robot should guide the user to the front of the elevator button panel and tell the user which buttons to push.

In addition to the sighted guide method, participants wanted the robot to provide assistance as an *escort* and *information kiosk*. Two team members who had functional vision preferred that the robot walk slightly in front of them as an escort rather than a traditional sighted guide. Some participants wanted the robot act like a person in an information kiosk and give them specific and quantitative directions to their destination (*e.g.*, "walk up two flights of stairs and enter the third door on the left"). This information kiosk would be more appropriate for users who are somewhat familiar with the building. If needed, participants wanted the robot to give detailed descriptions of the space when walking through it. This would help them learn about the building and navigate more independently in the future.

When the robot guide and the user reach a destination, the robot should leave the user at the door or guide her to a seat. The user should be able to ask the robot to return to the current location in some amount of time. For example, users could instruct the robot to "come back in an hour" when their meeting is over.

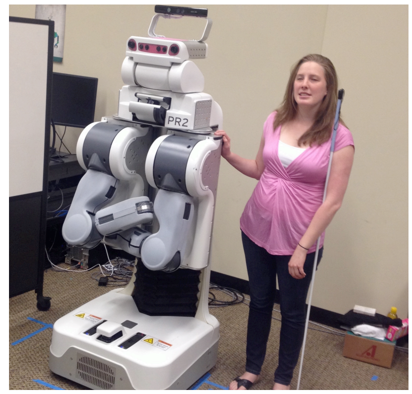

Figure 1. A blind person prepares to walk with the robot as a "sighted guide." Holding her cane, she stands to the side and slightly behind the robot, touching its "shoulder."

5. DISCUSSION

Two dominant themes emerged in our study: enabling users to (1) control the robot's behavior and (2) customize every aspect of the experience. While we initially expected Sighted Guide to be the only method of assistance, team members felt it was important to accommodate people with varying visual abilities and degrees of familiarity with the building. Blind people often value independence, especially when travelling [1], and team members felt that options and control were ways of enhancing their independence in such an assistance scenario.

6. CONCLUSION & FUTURE WORK

While there has been work on robotic tools for blind people, our work introduces the perspectives of blind and low-vision people and presents their novel design for a robot guide. In the future, we plan to build and evaluate a prototype based on our design.

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