PathFinder: Designing a Map-less Navigation System for Blind People in Unfamiliar Buildings

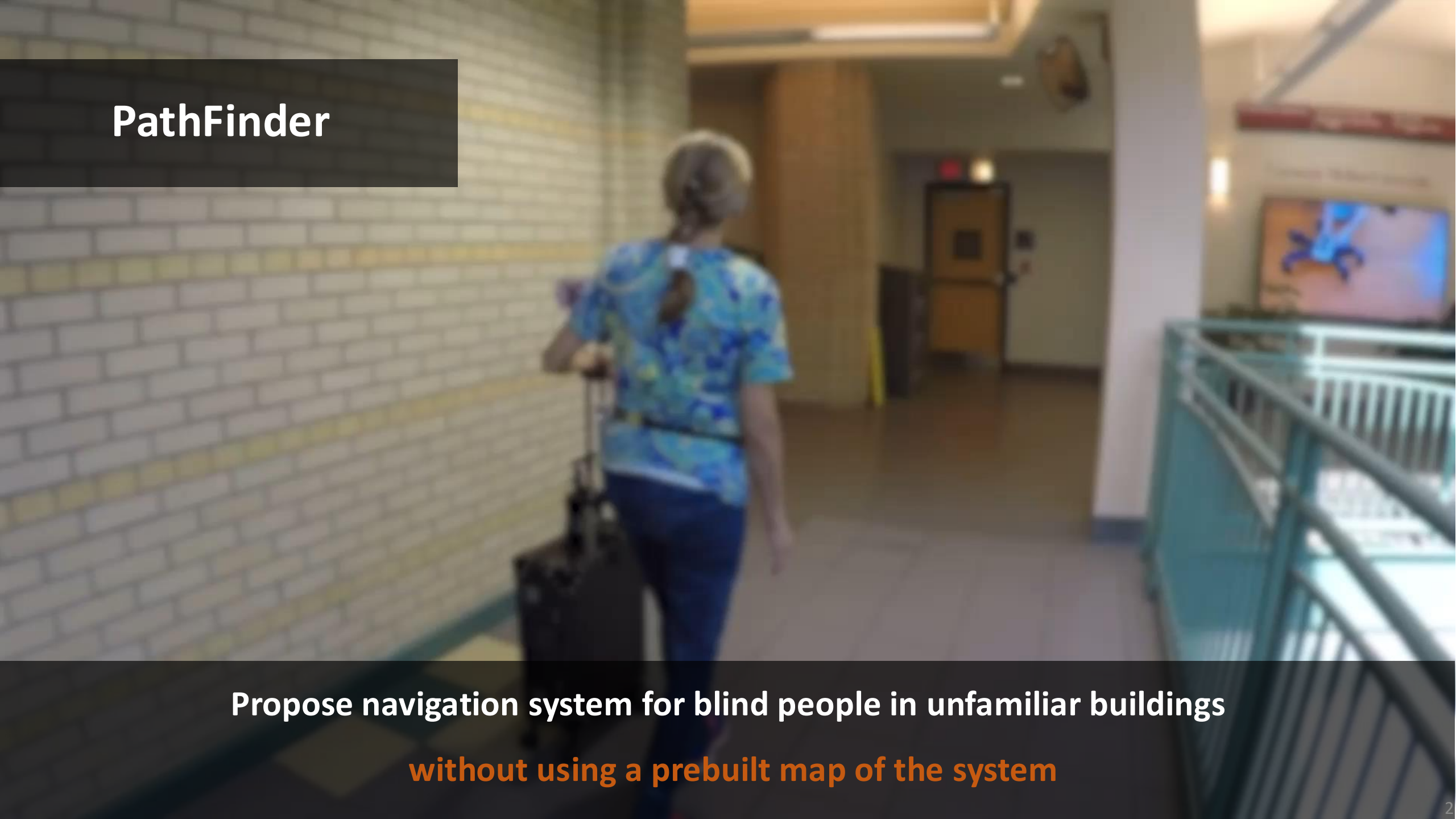
Masaki Kuribayashi[1], Tatsuya Ishihara[2], Daisuke Sato[3], Jayakorn Vonkulhbisal[2],

Karnik Ram[3], Seita Kayukawa[1], Hironobu Takagi[2], Shigeo Morishima[4], Chieko Asakawa[3,5]

[1]Waseda University, [2]IBM Research - Japan, [3]Carnegie Mellon University,

[4]Waseda Research Institute of Science and Engineering, [5]IBM Research

CHI23



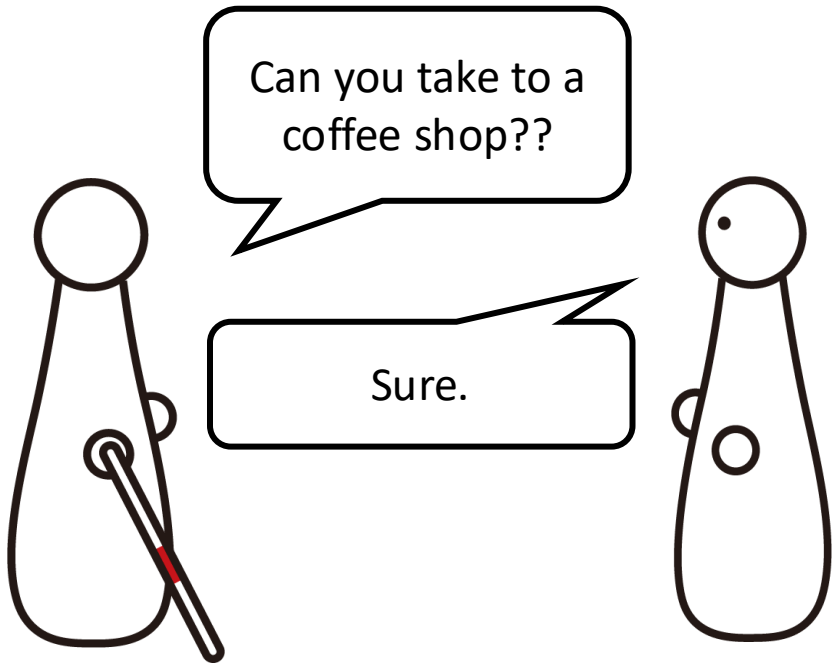
PathFinder

Propose navigation system for blind people in unfamiliar buildings

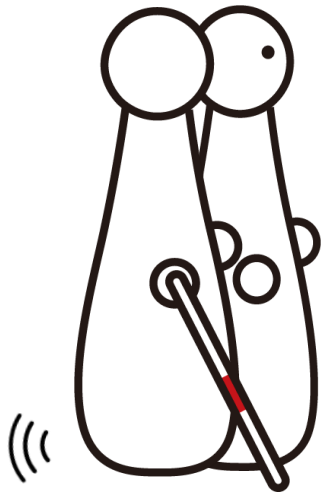
without using a prebuilt map of the system

Blind People Need Help of Sighted People in Unfamiliar Buildings[1]

Ask sighted people for help



Navigate to a destination together



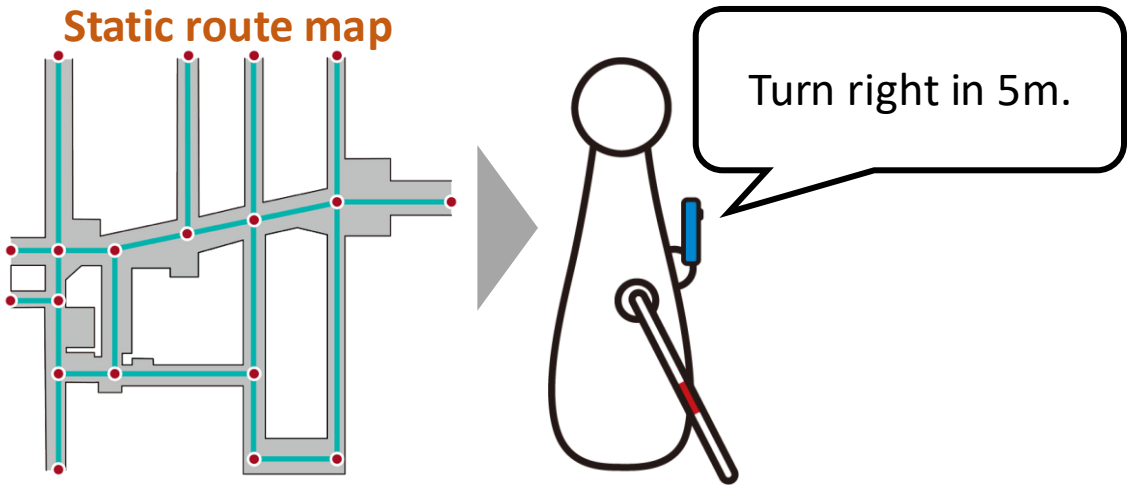
Assistants aren’t always available and its hard for blind to be independent

[1] Engel et al., “Travelling More Independently: A Requirements Analysis for Accessible Journeys to Unknown Buildings for People with Visual Impairments”

Our Previous Systems That Navigate Users With Prebuilt Maps

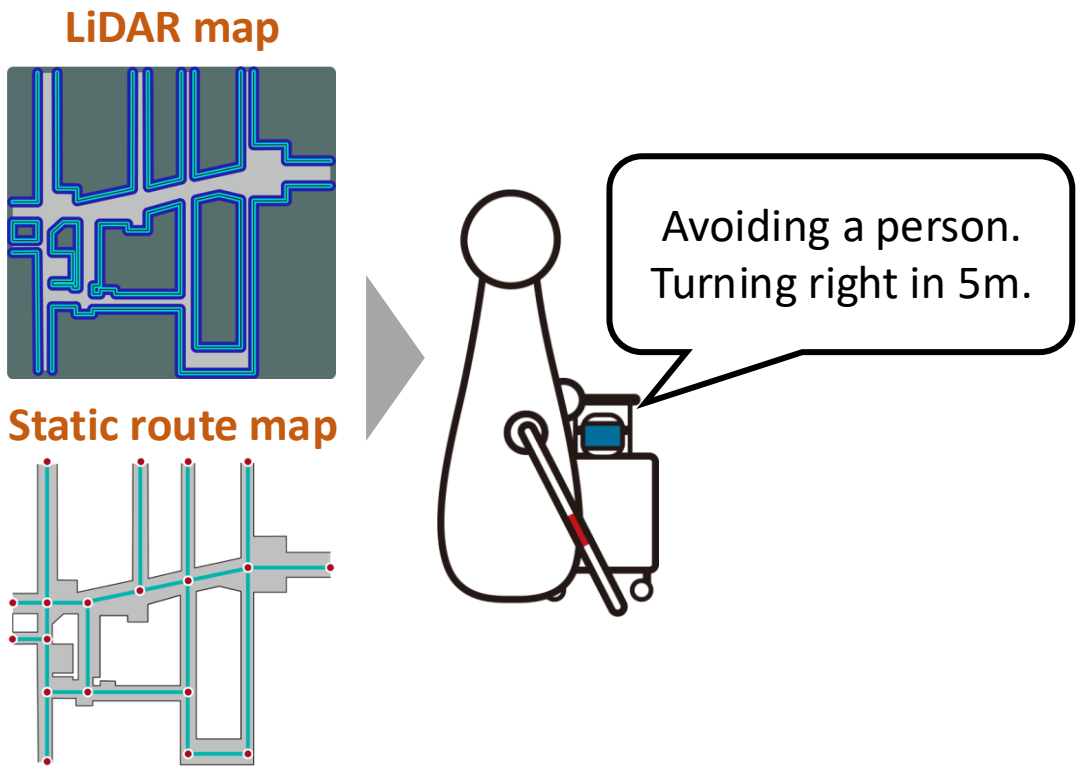
NavCog[2]

Smartphone system with static route map



CaBot[3]

Suitcase robot with additional LiDAR map



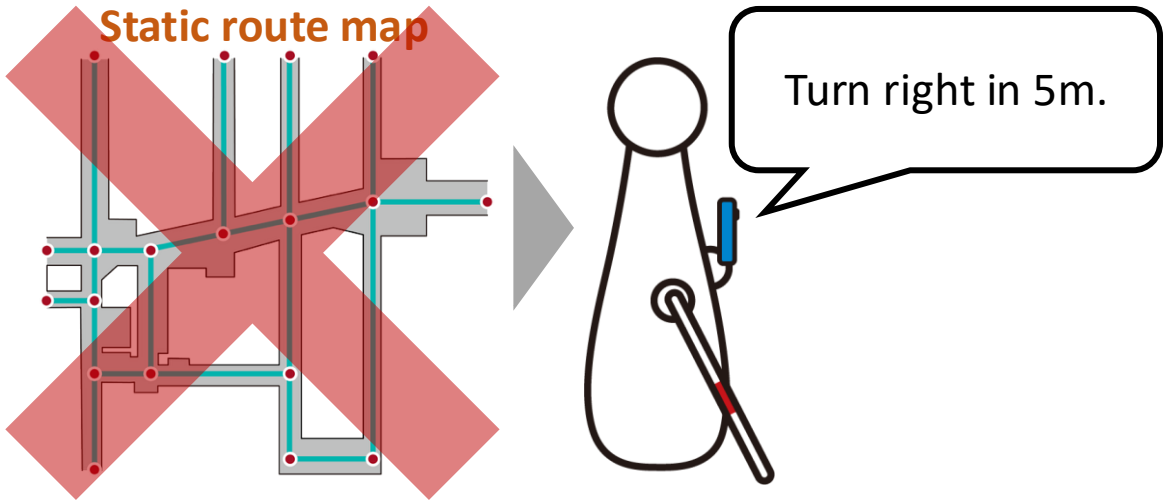
[2] Sato et al. “NavCog3 in the wild: Large-scale blind indoor navigation assistant with semantic features”

[3] Guerreiro *et al.* “CaBot: Designing and Evaluating an Autonomous Navigation Robot for Blind People”

Maps Are Costly and The System Cannot Be Used Everywhere

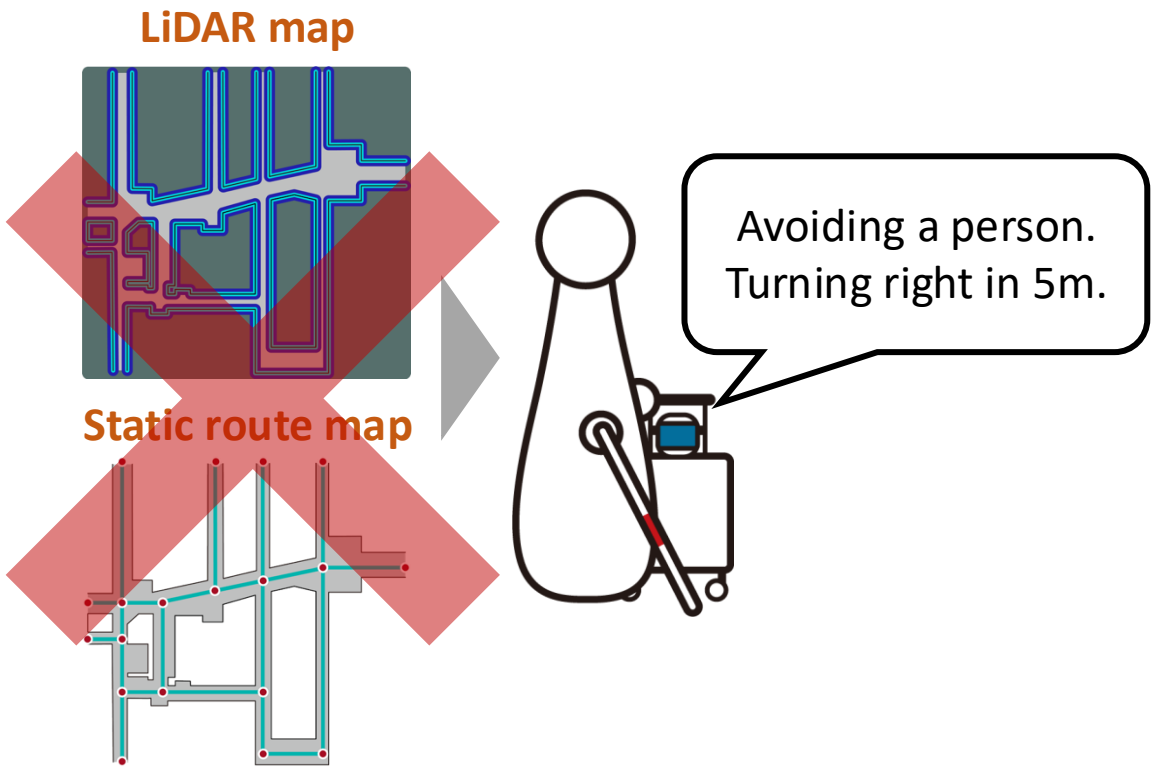
NavCog[2]

Smartphone system with static route map



CaBot[3]

Suitcase robot with additional LiDAR map



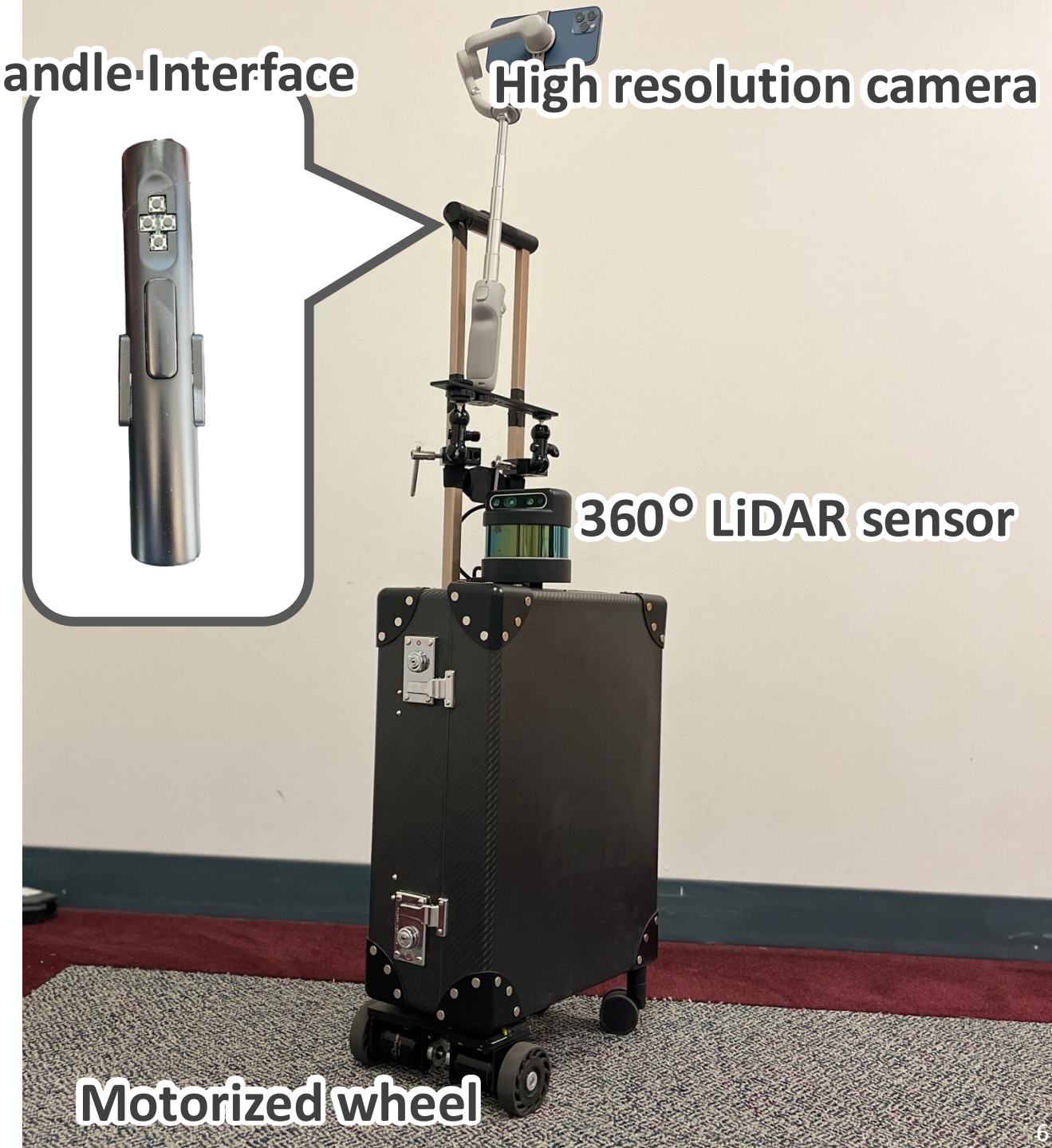
[2] Sato et al. “NavCog3 in the wild: Large-scale blind indoor navigation assistant with semantic features”

[3] Guerreiro *et al.* “CaBot: Designing and Evaluating an Autonomous Navigation Robot for Blind People”

PathFinder

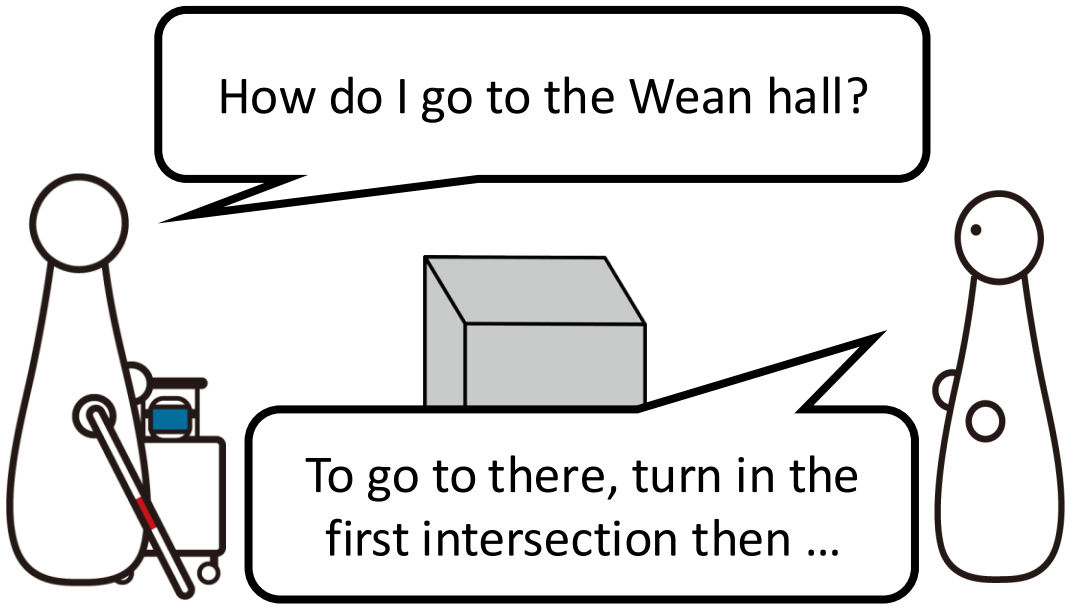
A **map-less** navigation system for

blind people in unfamiliar buildings



Situation to Use PathFinder

Unfamiliar building where a blind person have a destination and acquired route description from sighted people[1] (e.g., entrance or passersby)

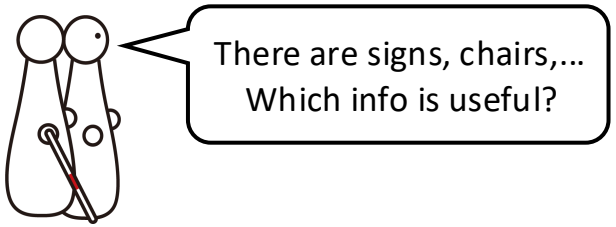


[1] Engel et al., “Travelling More Independently: A Requirements Analysis for Accessible Journeys to Unknown Buildings for People with Visual Impairments”

Design Procedure of PathFinder

Step 1: Investigation of Route Description and Useful information

Interview 10 sighted people of route description and 5 blind participants of useful information in unfamiliar building given the route description.

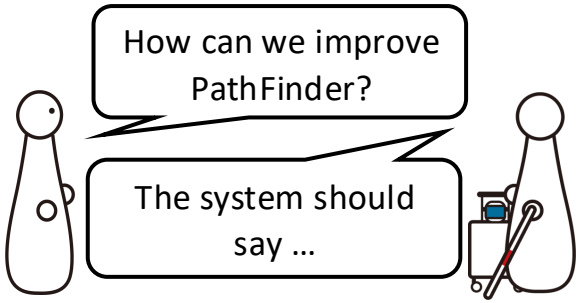


Step 2: Prototype PathFinder

Prototyped PathFinder by implementing intersection detection and sign recognition functionalities.

Step 3: Improve Interface and Functionality

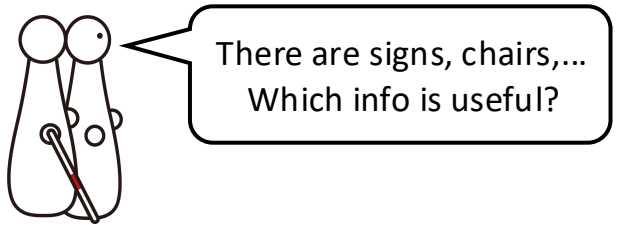
5 blind participants used the initial prototype of PathFinder and gathered comments for improvements.



Design Procedure of PathFinder

Step 1: Investigation of Route Description and Useful information

Interview 10 sighted people of route description and 5 blind participants of useful information in unfamiliar building given the route description.

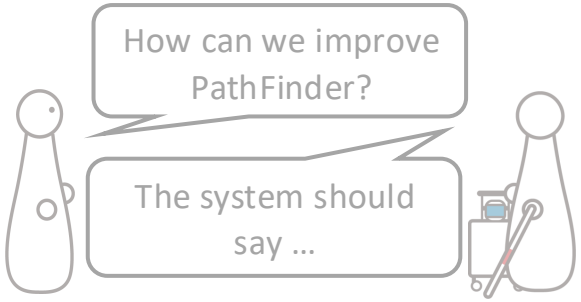


Step 2: Prototype PathFinder

Prototyped PathFinder by implementing intersection detection and sign recognition functionalities.

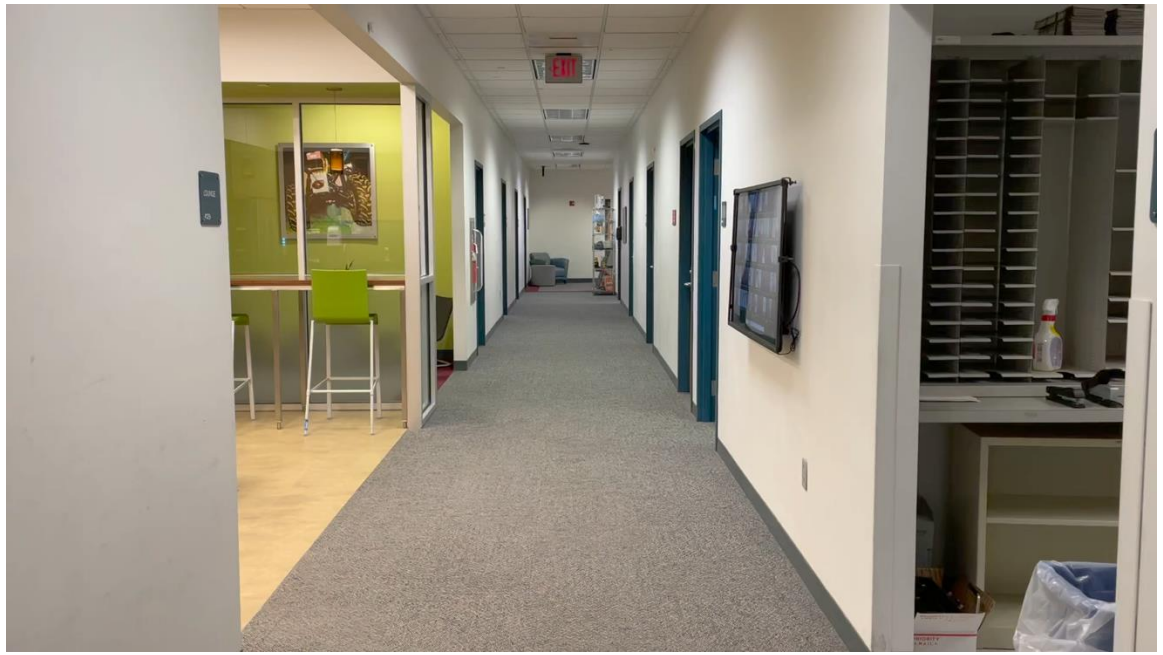
Step 3: Improve Interface and Functionality

5 blind participants used the initial prototype of PathFinder and gathered comments for improvements.



Investigation of Routes Description Using Two Routes

Route 1

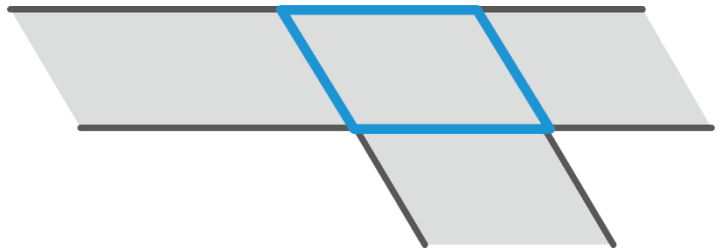


Route 2

Intersections and distance to walk were the most described information by sighted people

Three Most Useful Information For Blind People in Unfamiliar Buildings

Intersections
Help users determine when to turn



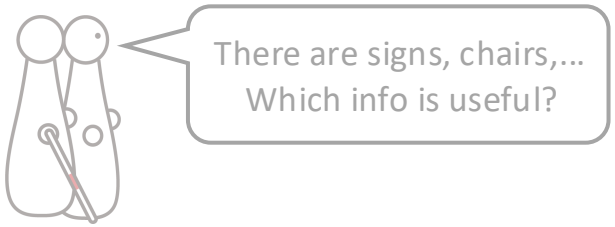
Directional Signs
Help users to be confident that they are going the correct way

Textual Signs
Helps users to know that they have reached the destination

Design Procedure of PathFinder

Step 1: Investigation of Route Description and Useful information

Interview 10 sighted people of route description and 5 blind participants of useful information in unfamiliar building given the route description.

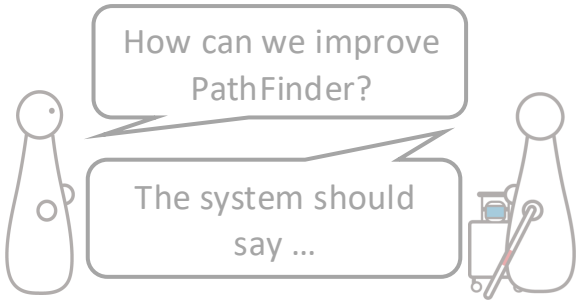


Step 2: Prototype PathFinder

Prototyped PathFinder by implementing intersection detection and sign recognition functionalities.

Step 3: Improve Interface and Functionality

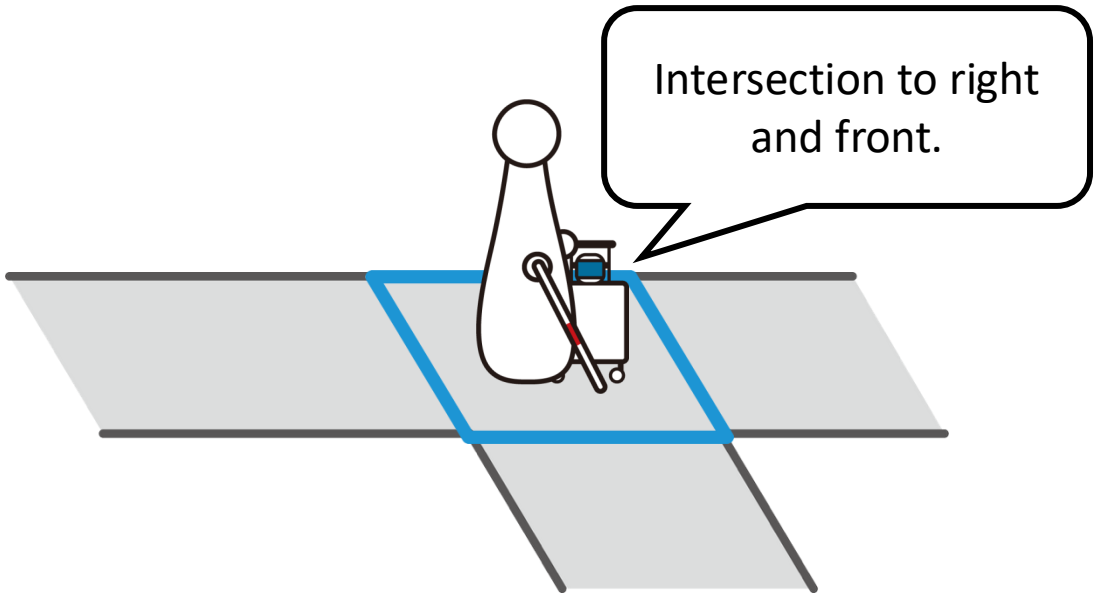
5 blind participants used the initial prototype of PathFinder and gathered comments for improvements.



System Design of PathFinder

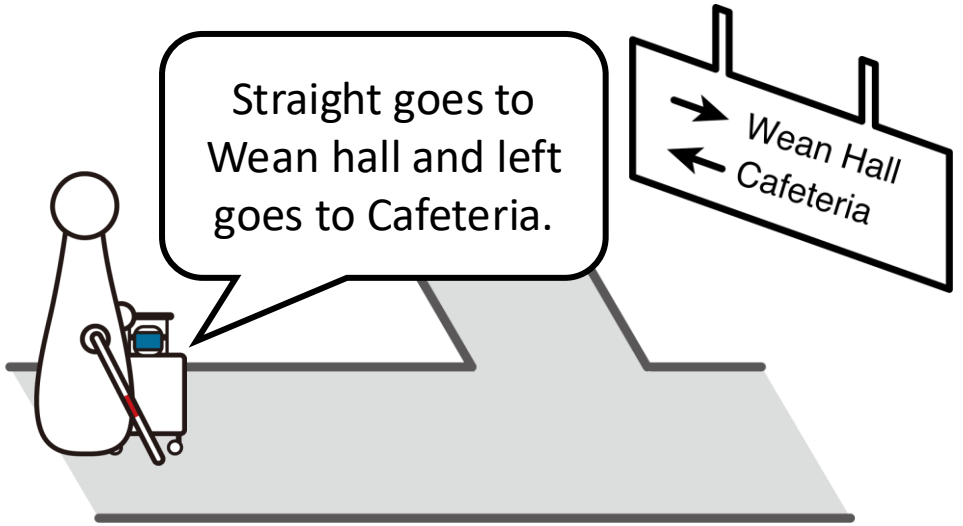
Intersection Detection[4]

Recognize location and shape of intersections



Sign Recognition

Read out textual and directional signs to help users to be more confident

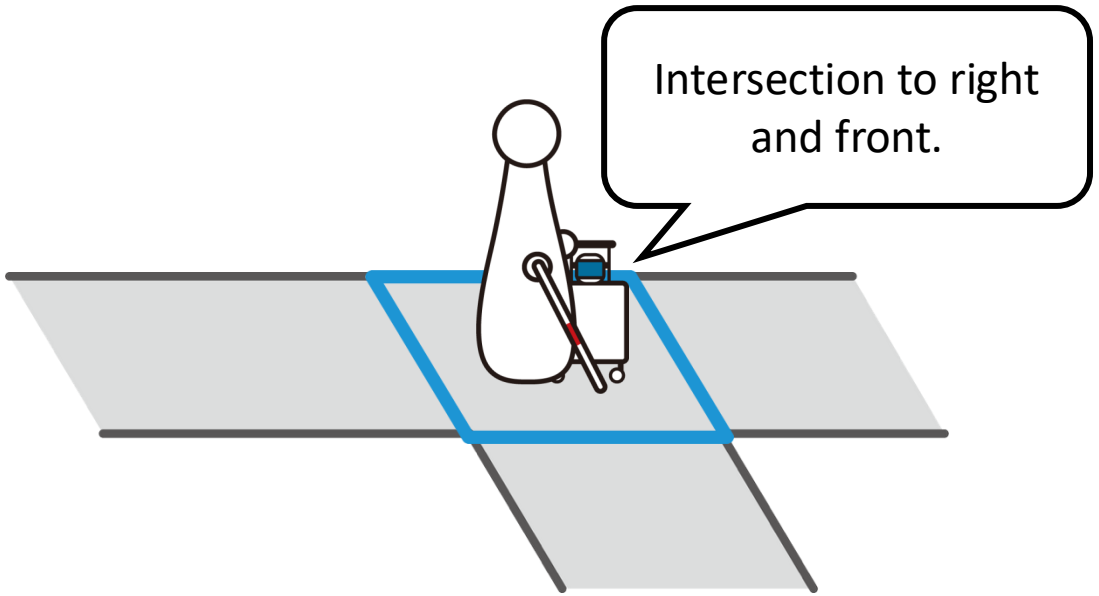


[4] Yang et al., “Graph-based topological exploration planning in large-scale 3d environment”

System Design of PathFinder

Intersection Detection[4]

Recognize location and shape of intersections



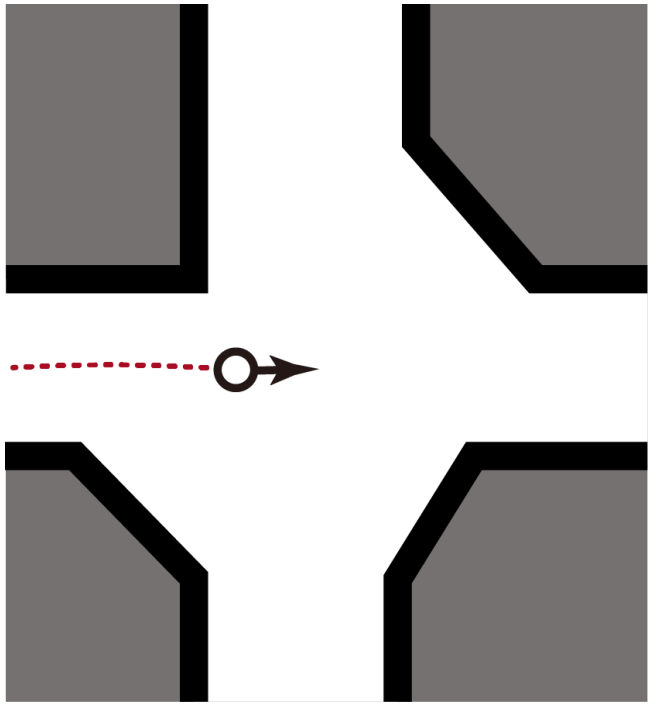
Sign Recognition

Read out textual and directional signs to help users to be more confident

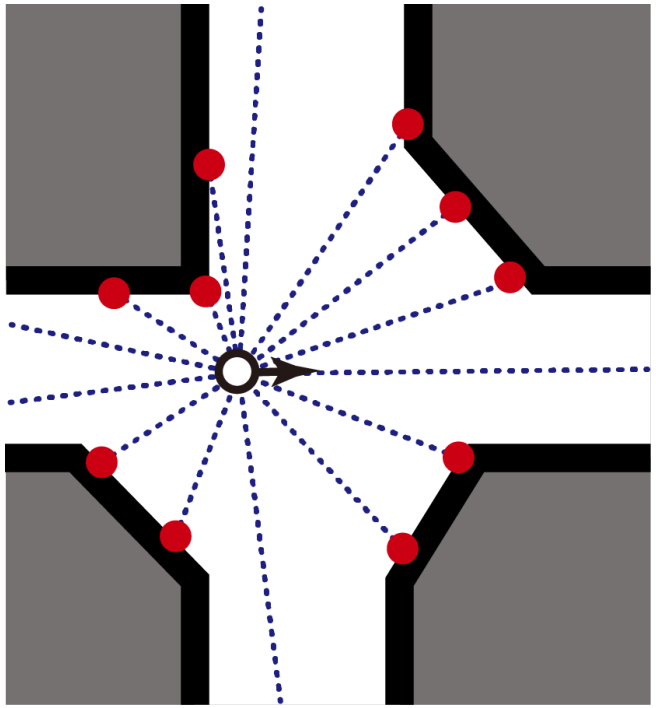
[4] Yang et al., “Graph-based topological exploration planning in large-scale 3d environment”

Intersection Detection from 360° LiDAR Sensor of PathFinder[4]

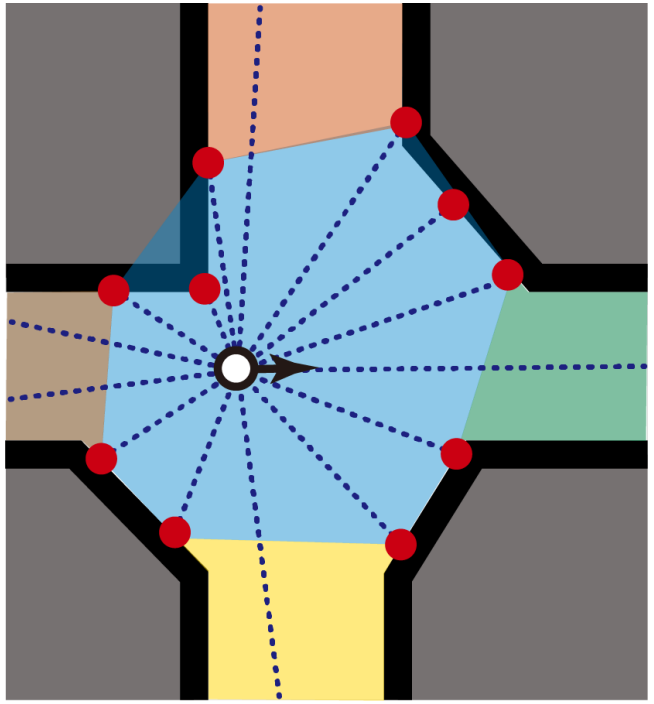
1. Map environment using SLAM algorithm



2. Sample points by casting rays to each direction



3. Compute convex hull of the points and find paths

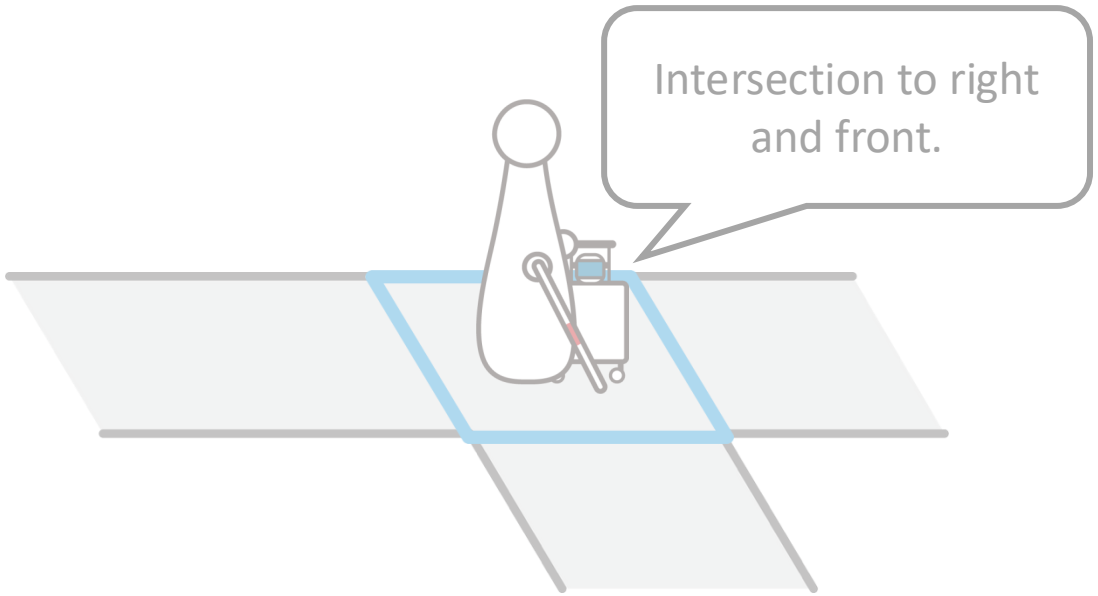


[4] Yang et al., "Graph-based topological exploration planning in large-scale 3d environment"

System Design of PathFinder

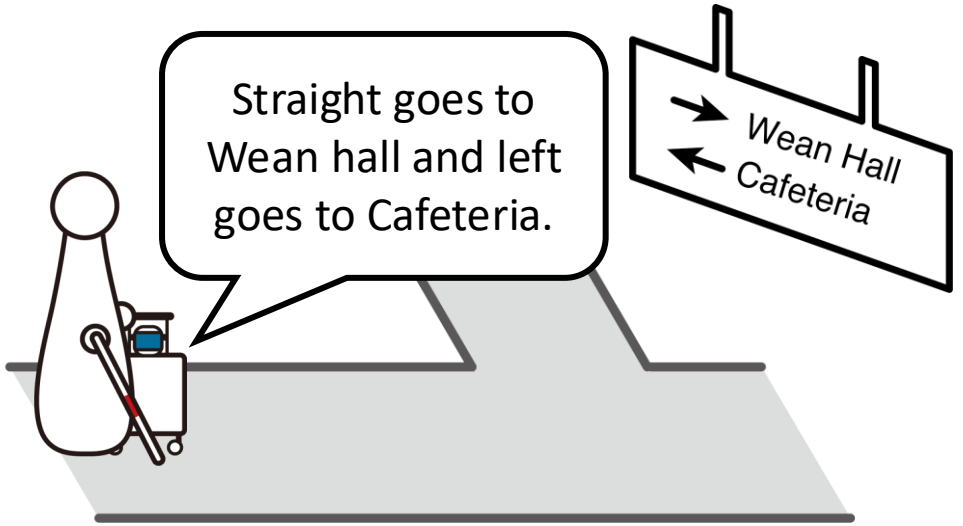
Intersection Detection[4]

Recognize location and shape of intersections



Sign Recognition

Read out textual and directional signs to help users to be more confident



[4] Yang et al., “Graph-based topological exploration planning in large-scale 3d environment”

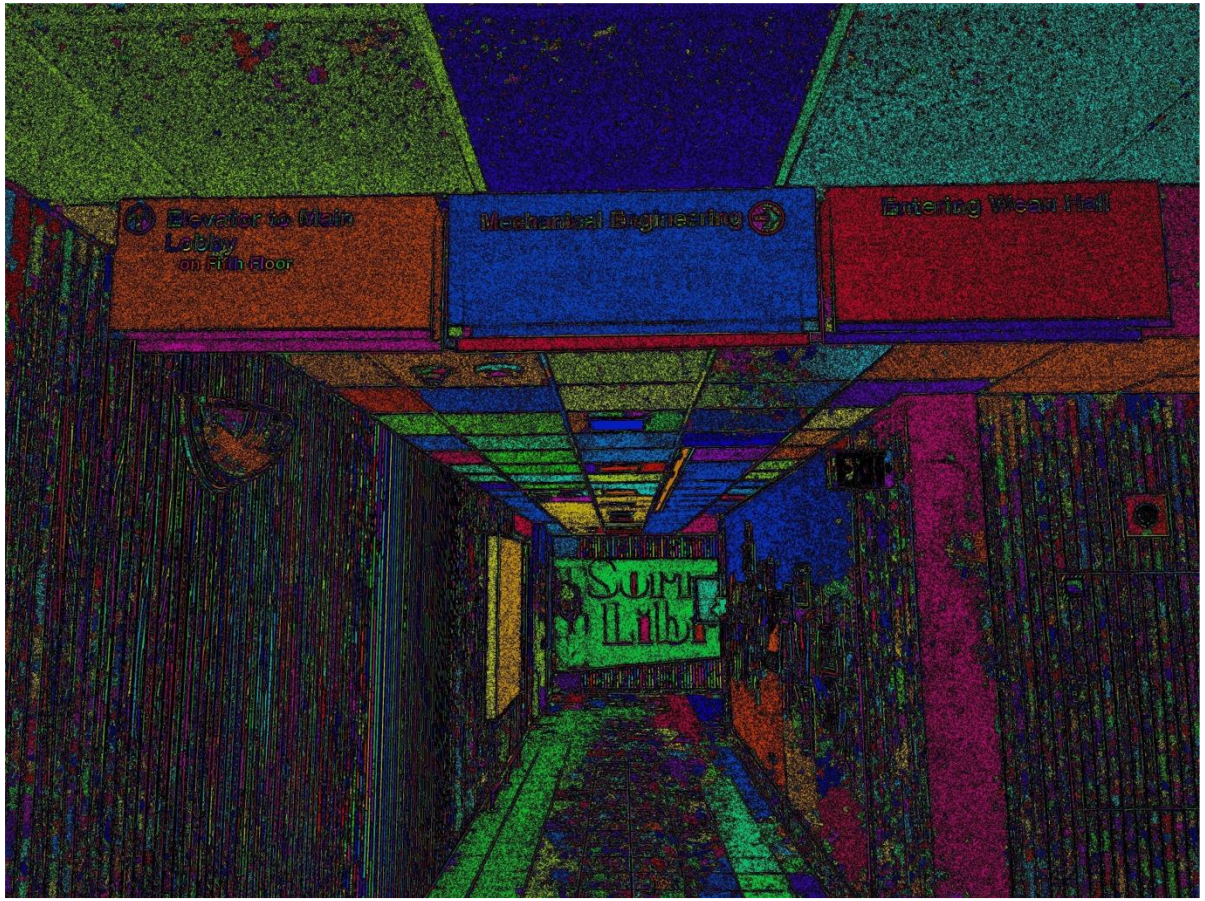
Sign Recognition from RGB camera of PathFinder

From iPhone camera,

detect arrows and words

Sign Recognition from RGB camera of PathFinder

Cluster regions based on similarity of its color



Sign Recognition from RGB camera of PathFinder

Group arrows and words based on the clustering result

Sign Recognition from RGB camera of PathFinder

Result Feedback

“There is a sign saying,

Front leads to Elevator to main lobby,

right leads to mechanical engineering.

Also, there is one sign saying **Entering Wean Hall**”

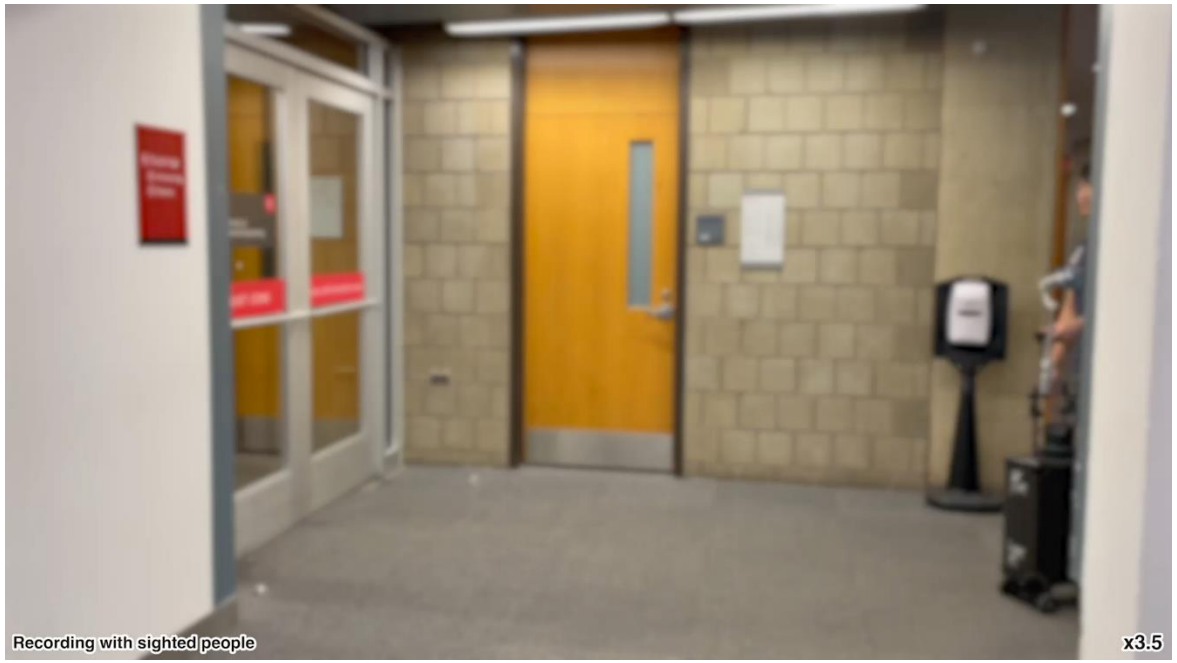
Interface of PathFinder

Intersection Detection[4]

User can press front button to go to next intersection and left/right button to specify direction to go

Sign Recognition

User can press back button to instruct the robot to perform sign recognition

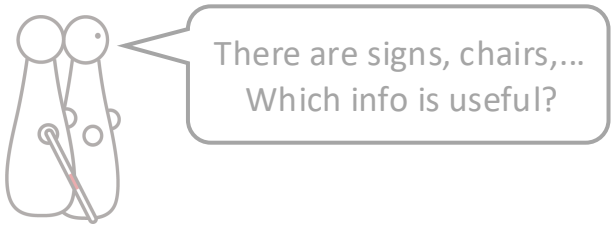


[4] Yang et al., “Graph-based topological exploration planning in large-scale 3d environment”

Design Procedure of PathFinder

Step 1: Investigation of Route Description and Useful information

Interview 10 sighted people of route description and 5 blind participants of useful information in unfamiliar building given the route description.

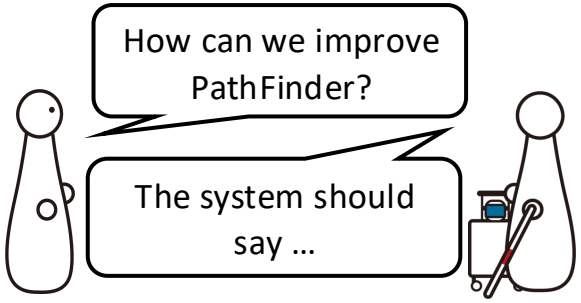


Step 2: Prototype PathFinder

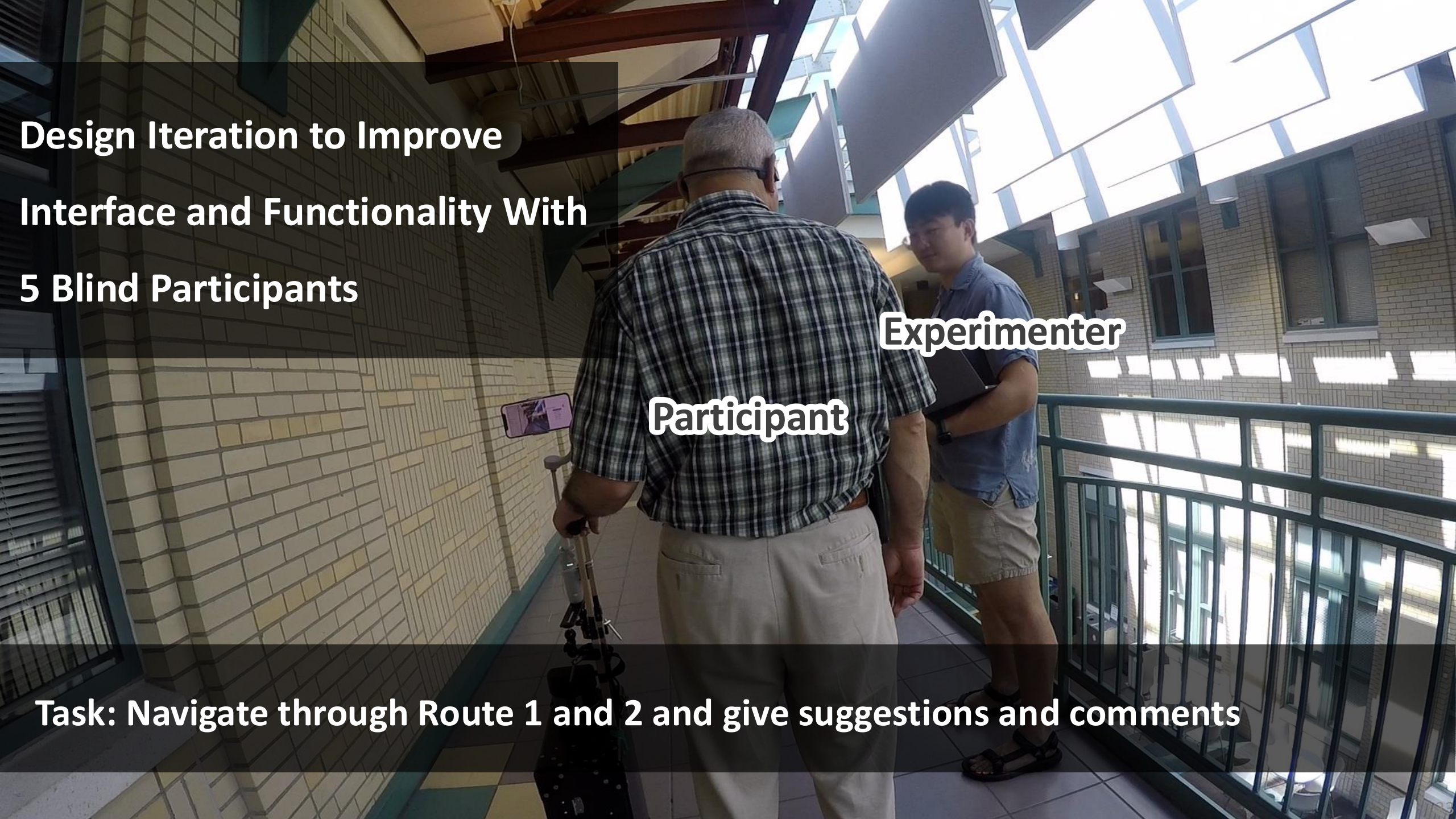
Prototyped PathFinder by implementing intersection detection and sign recognition functionalities.

Step 3: Improve Interface and Functionality

5 blind participants used the initial prototype of PathFinder and gathered comments for improvements.



Design Iteration to Improve Interface and Functionality With 5 Blind Participants

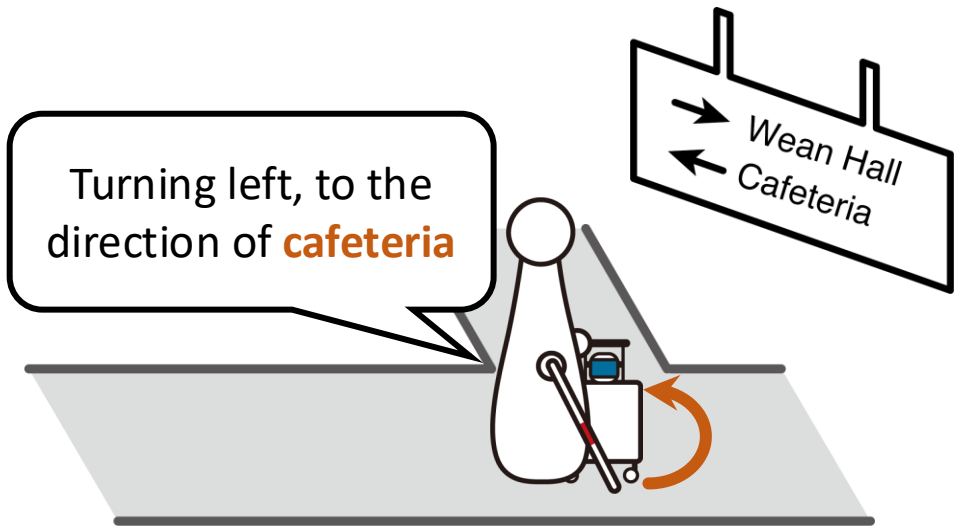


Task: Navigate through Route 1 and 2 and give suggestions and comments

Examples of Improvement of Interface and Functionality

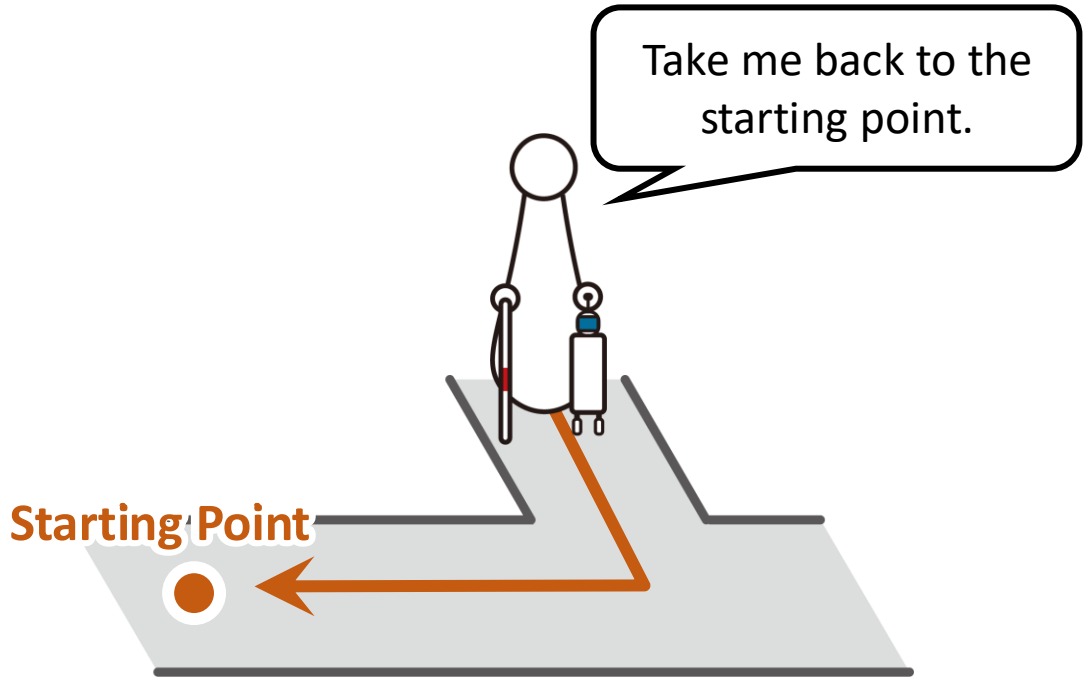
Refer to Signs When Turing

One participant wanted the system to refer to signs while turning when they are available



Additional "Take-Me-Back" Functionality

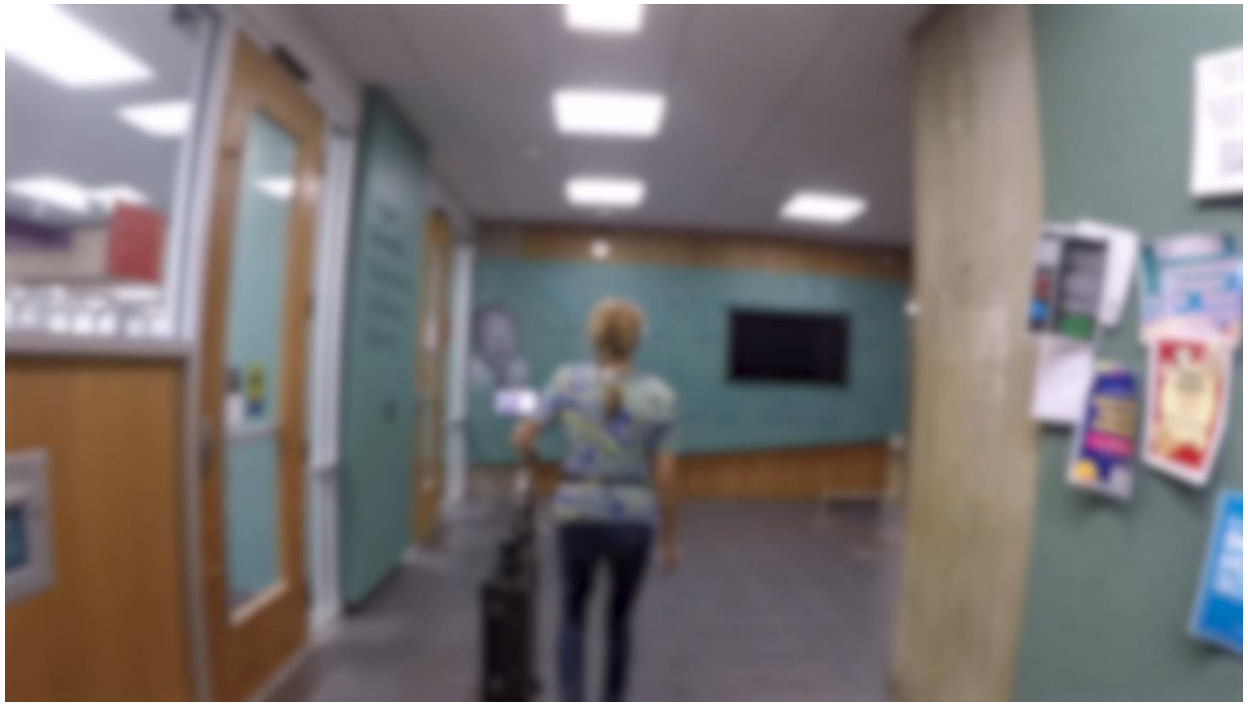
One participant requested for a functionality to go back to where they started



User Study with 7 Blind Participants

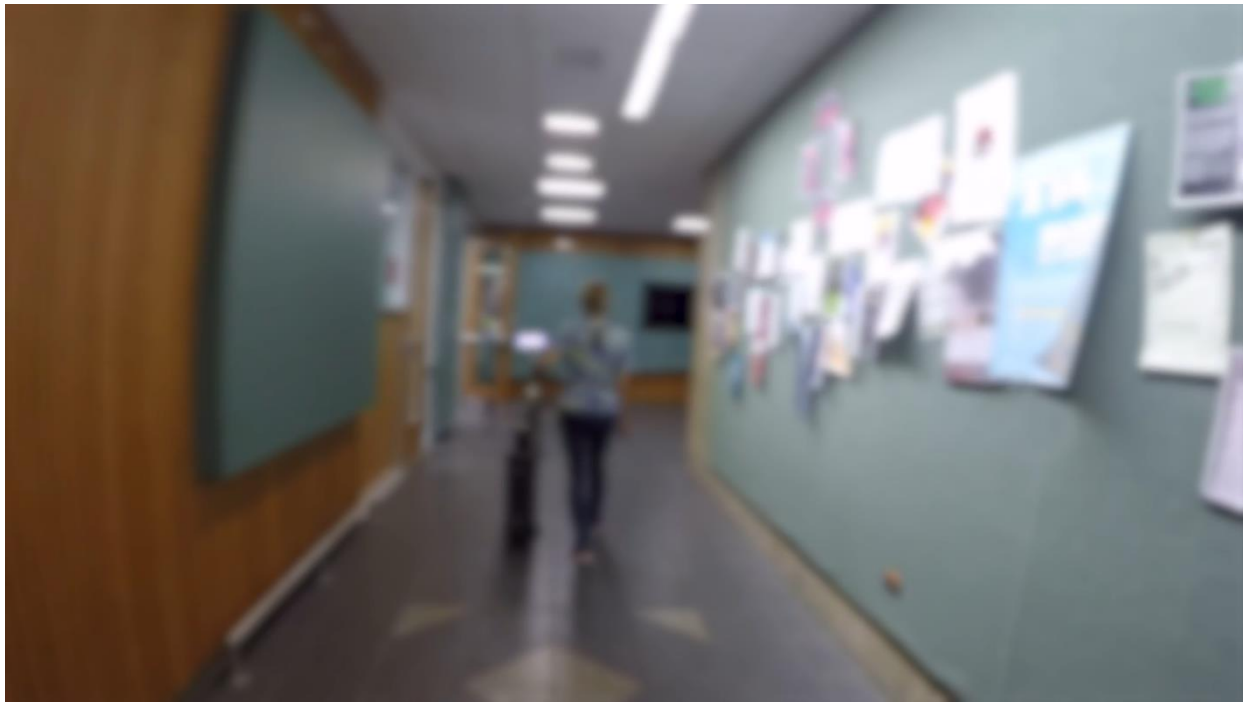
PathFinder

A navigation robot **without prebuilt map**



CaBot[3]

A navigation robot **with prebuilt map**



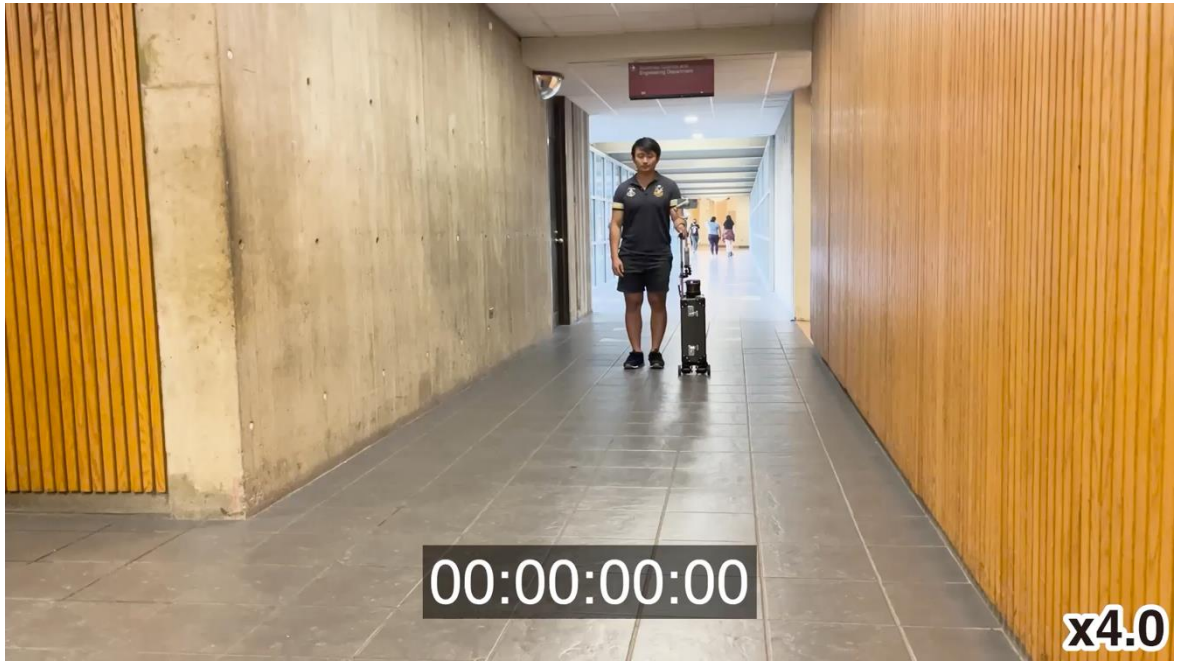
Task: Navigate through the Routes and go back using “Take-me-back” functionality

[3] Guerreiro et al. “CaBot: Designing and Evaluating an Autonomous Navigation Robot for Blind People”

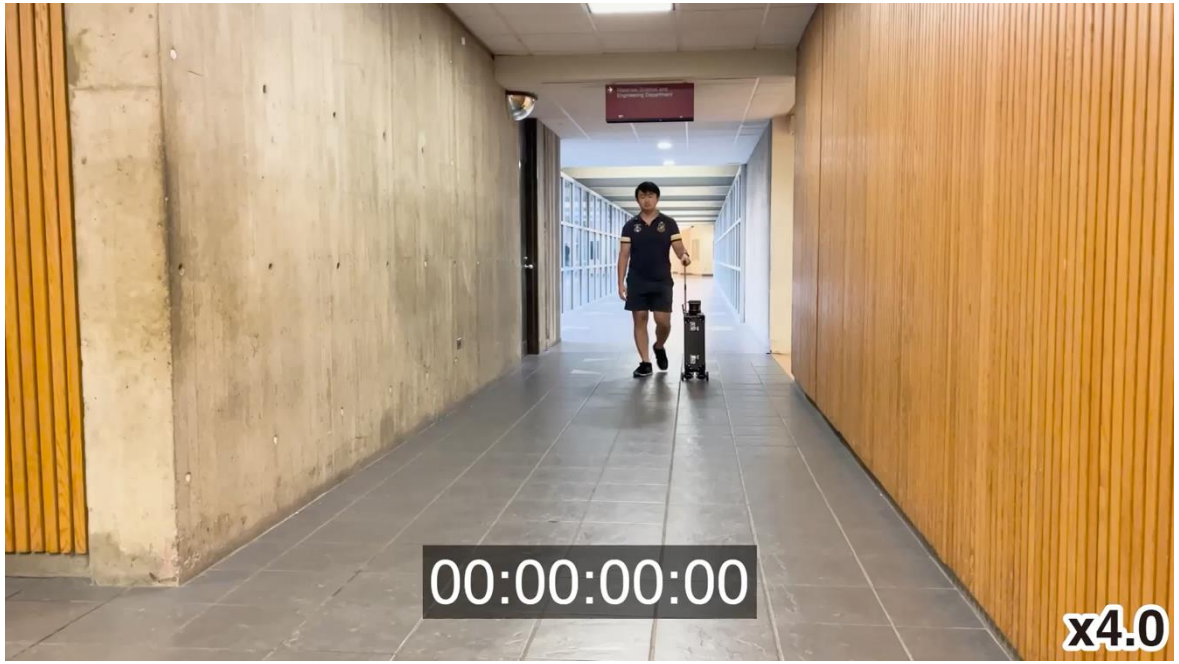
Task Completion Time Increased When Using PathFinder

Users needed to instruct PathFinder which way to go at every intersection

PathFinder

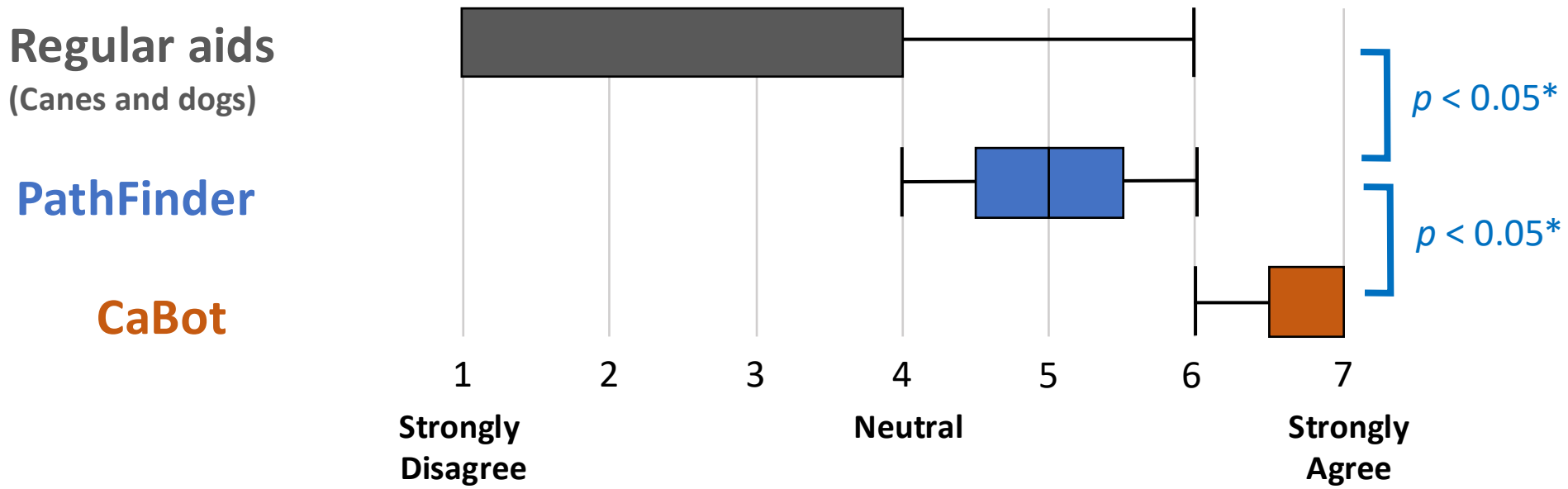


CaBot



Confidence when Navigating Unfamiliar Buildings

Q. I can navigate in an unfamiliar building with confidence



PathFinder was rated in between CaBot and regular aids

*Used Wilcoxon Signed Rank test for statical analysis

A Comment Appreciating Map-less Aspect of PathFinder

All participants appreciated that PathFinder could be used in various places

"If maps are available, it is definetely the most useful. But maps are not available every where. However, ***even without map information, the robot is very useful because it reads out information around me and lets me find my way****."*

Comments Comparing of Pathfinder and Guide Dogs

A guide dog user P12 described pros and cons of the system compared to guide dogs

P12

"The guide dog doesn't always know how to go back. ***With the robot, I would just have to hit the button, and it would take me back.***"

"I think ***once I learn the layout of a building, I will be able to navigate much faster with my guide dog*** *than with the robot."*

PathFinder: Designing a Map-less Navigation System for Blind People in Unfamiliar Buildings

- We tackled the situation where blind people navigate in unfamiliar buildings where navigation system has no prebuilt maps.

- We designed a map-less system called PathFinder with blind people and verified that they could navigate unfamiliar building with increased confidence.

- For future work, we aim to investigate how we can navigate blind users with PathFinder multi floor routes