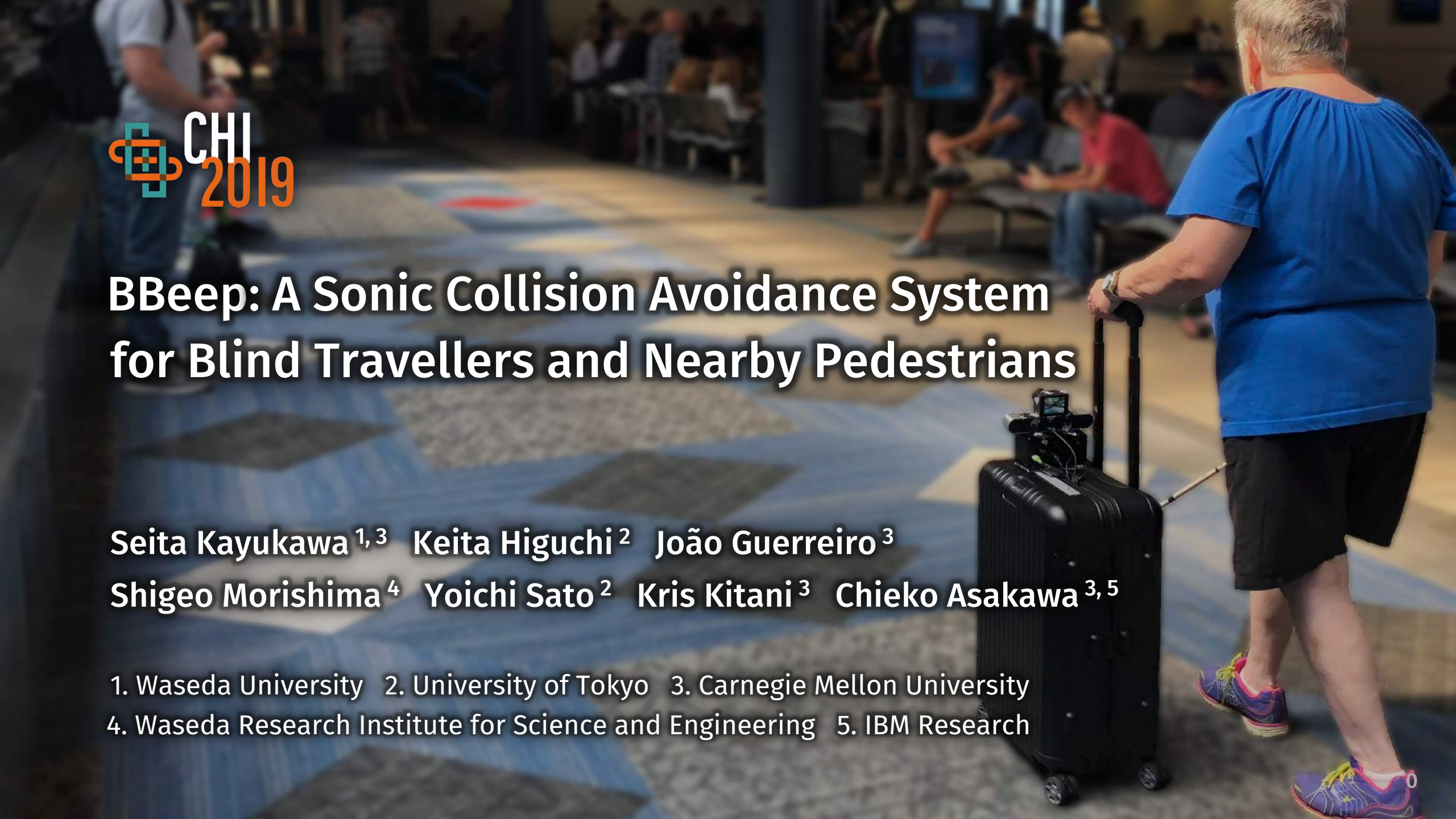


CHI 2019

BBeep: A Sonic Collision Avoidance System for Blind Travellers and Nearby Pedestrians

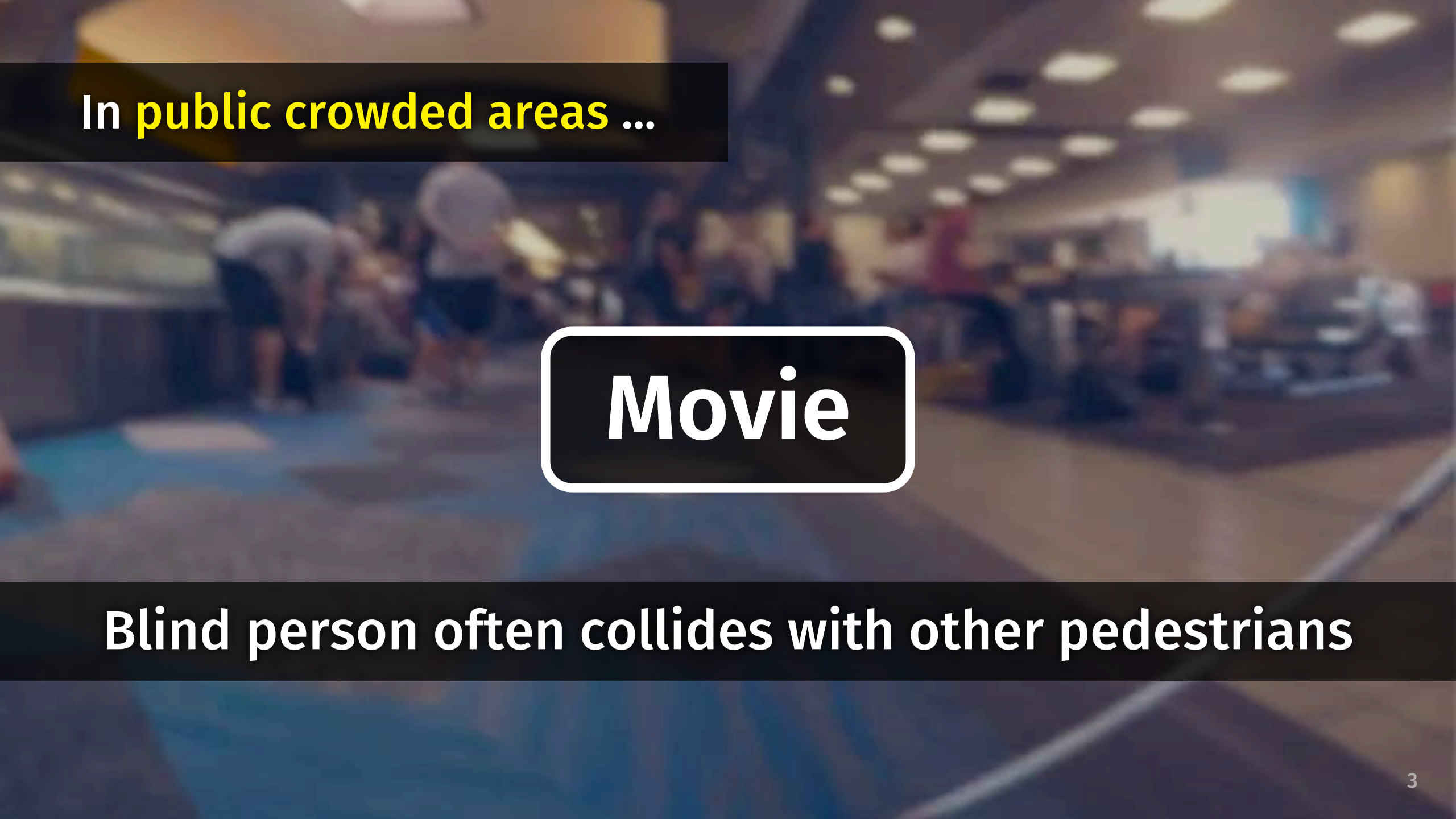
Seita Kayukawa [1, 3] Keita Higuchi [2] João Guerreiro [3]
Shigeo Morishima [4] Yoichi Sato [2] Kris Kitani [3] Chieko Asakawa [3, 5]

1. Waseda University 2. University of Tokyo 3. Carnegie Mellon University
4. Waseda Research Institute for Science and Engineering 5. IBM Research

BBeep

Collision Avoidance System for Blind People & Pedestrians


Movie


In public crowded areas ...
Movie
Blind person often collides with other pedestrians

Pedestrians who don’t see the blind person

Talking with others

Looking at a digital board

Looking at a smartphone

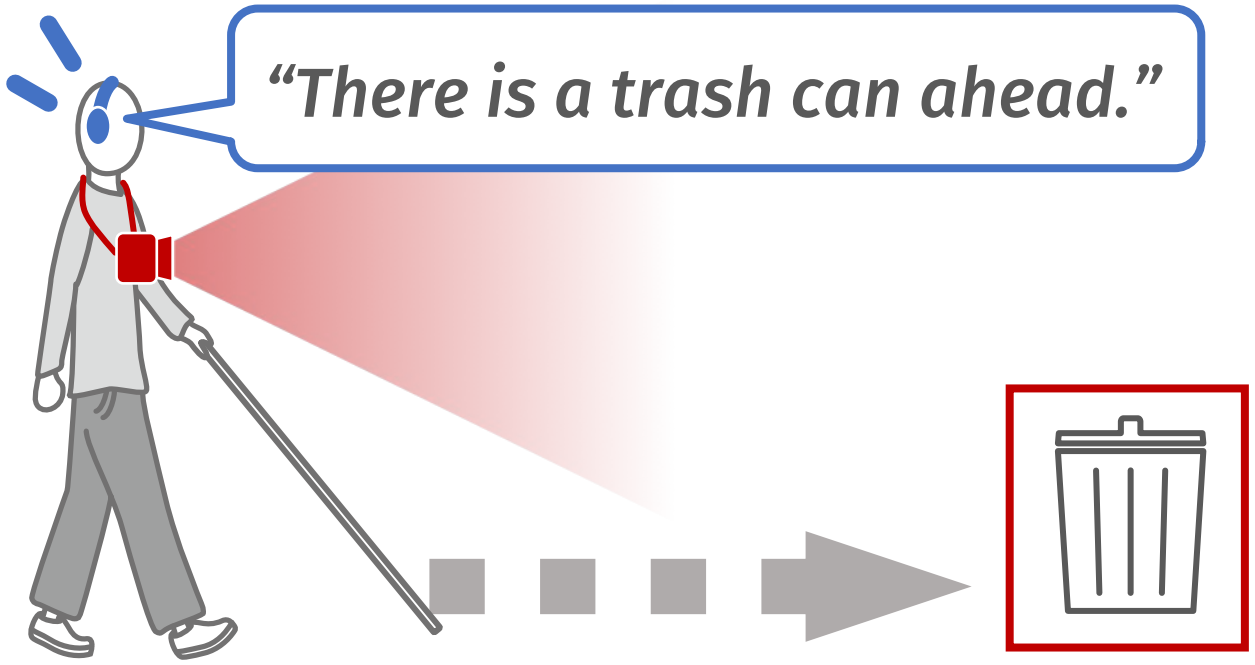
https://www.frommers.com/blogs/arthur-frommer-online/blog_posts/which-u-s-airports-are-the-most-expensive-to-fly-from-check-this-new-list

https://tech3lab.hec.ca/en/about-us/the-environnement/


In CHI2019 Reception Party...
Everyone enjoyed and concentrated on conversation
CHI
2019

Related Work - Obstacle Avoidance System [1,2,3]

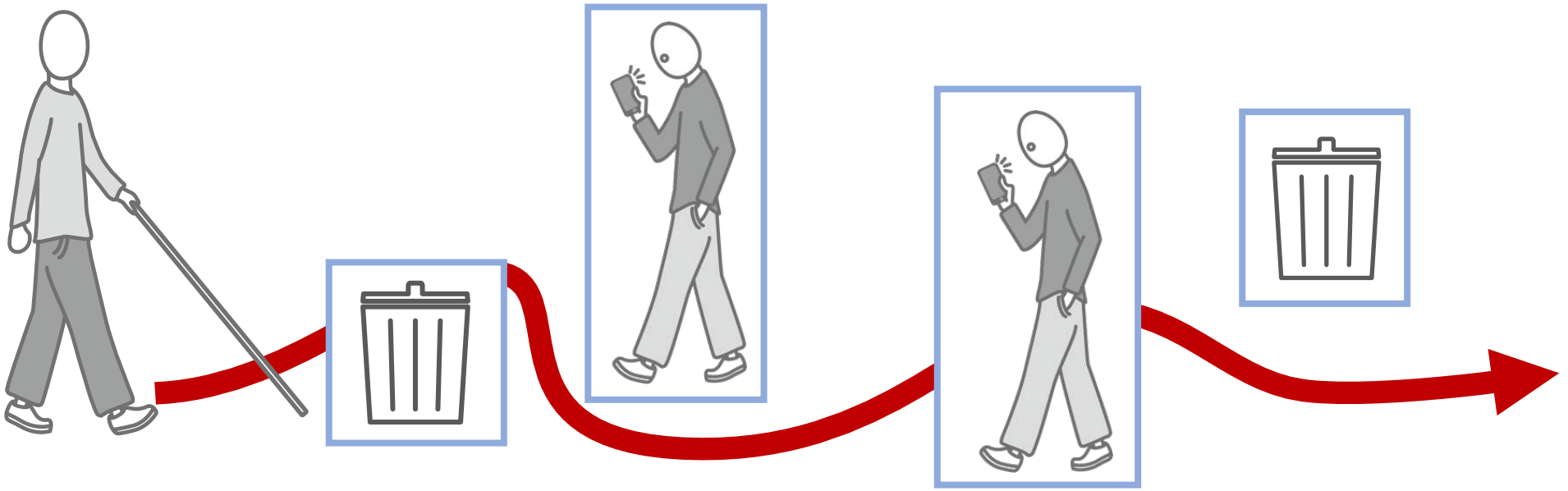
Provide **information of obstacles** via **sound or tactile feedback**



[1] Iwan Ulrich, et al. “The GuideCane-applying mobile robot technologies to assist the visually impaired”. IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans 31, 2, 2001.
[2] Bing Li, et al. "ISANA: wearable context-aware indoor assistive navigation with obstacle avoidance for the blind", ECCV’16.
[3] Limin Zeng et al. "Camera-based mobile electronic travel aids support for cognitive mapping of un-known spaces". Mobile HCI’17.

Related Work - Obstacle Avoidance System [1,2,3]

Limitation: Users have to **avoid obstacles by themselves**.



It is important **to provide a safe path** to blind users.

[1] Iwan Ulrich, et al. “The GuideCane-applying mobile robot technologies to assist the visually impaired”. IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans 31, 2, 2001.
[2] Bing Li, et al. "ISANA: wearable context-aware indoor assistive navigation with obstacle avoidance for the blind", ECCV’16.
[3] Limin Zeng et al. "Camera-based mobile electronic travel aids support for cognitive mapping of un-known spaces". Mobile HCI’17.

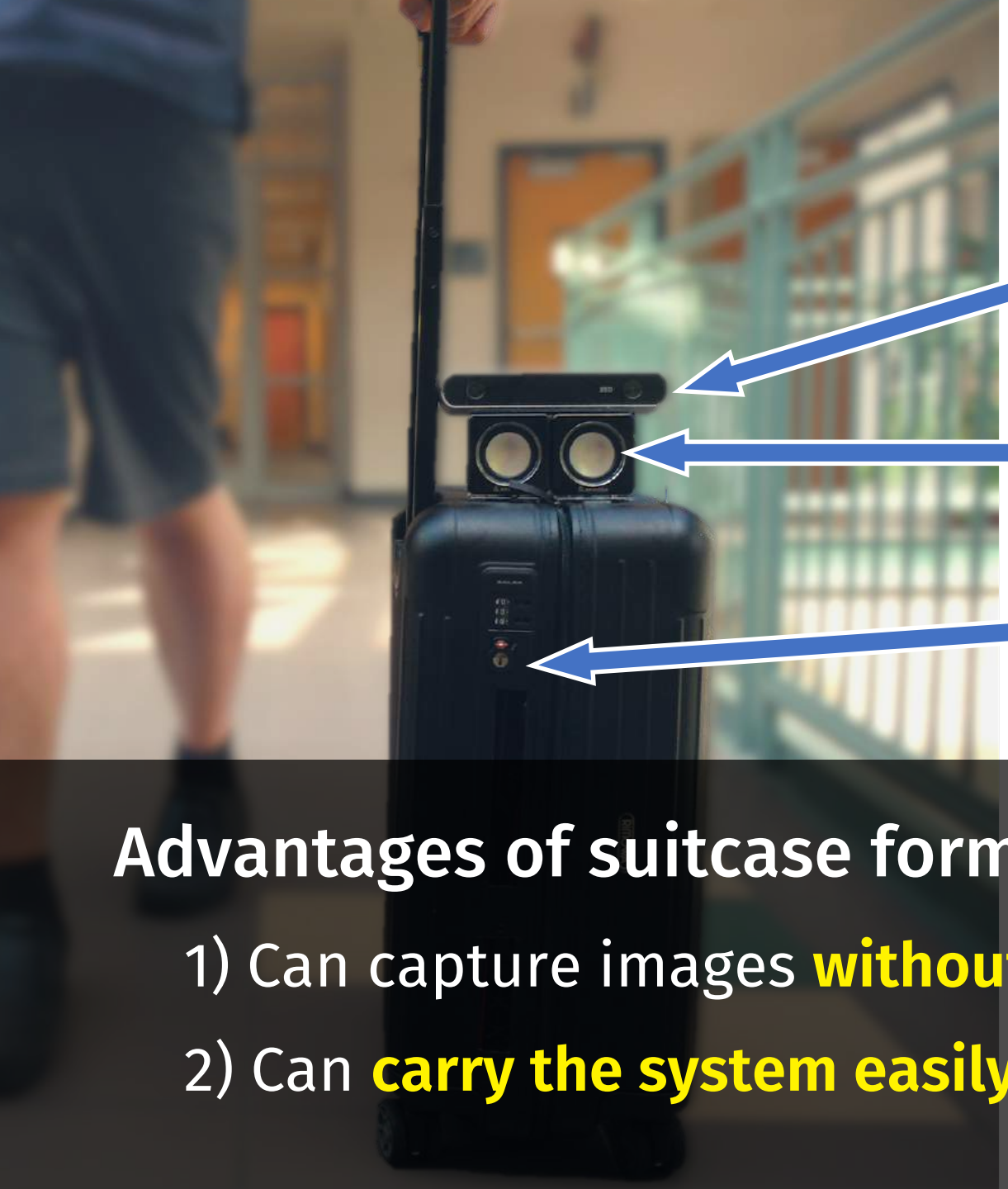
BBeep

Collision Avoidance System for Blind People & Pedestrians

Stereo Camera

Speaker

Laptop



Advantages of suitcase form factor

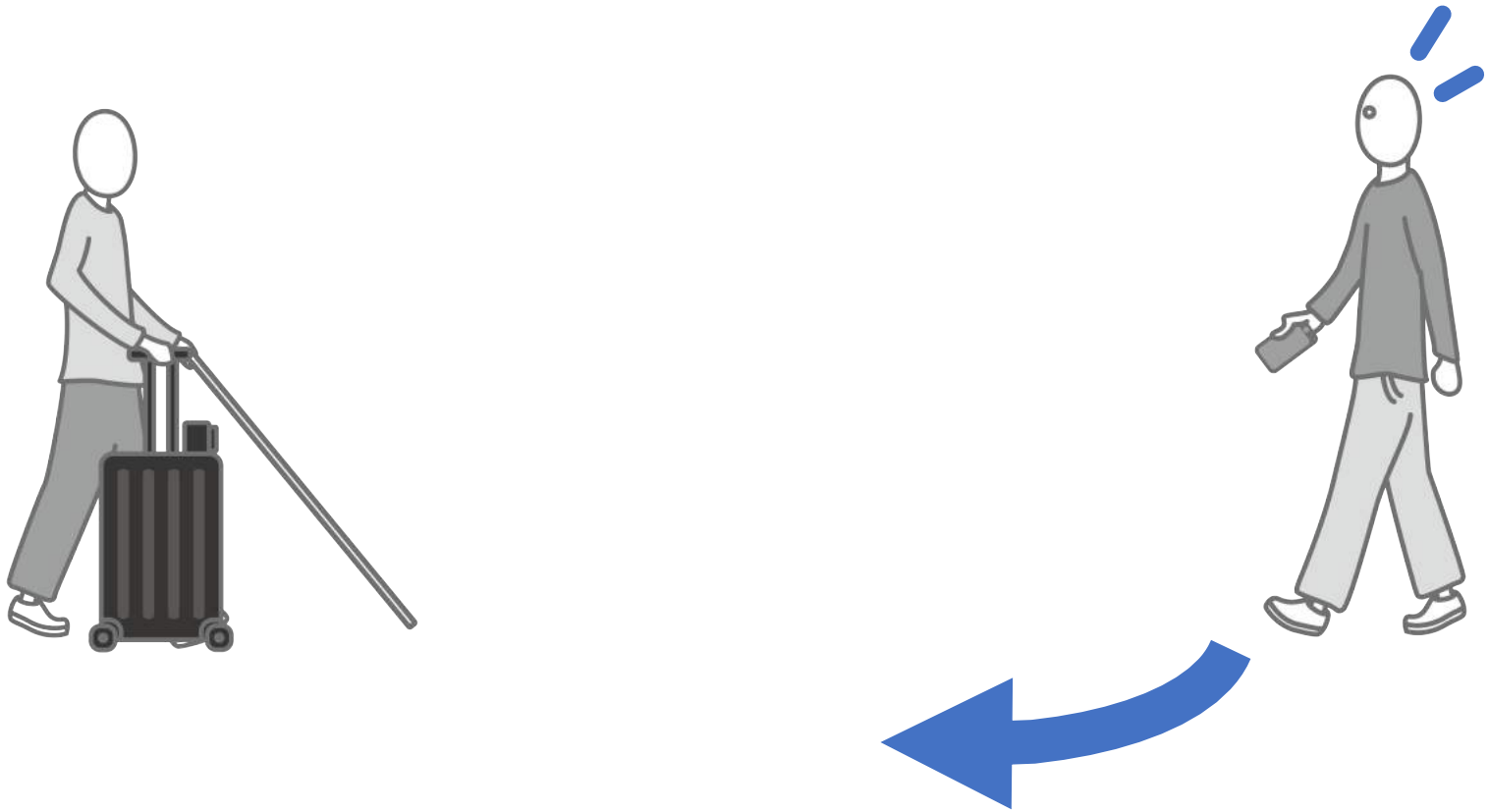
1) Can capture images **without significant motion-induced blur**

2) Can **carry the system easily** on flat spaces

Key Idea: Sound Notifications for Users and Pedestrians

Alert both the blind user & pedestrians about the risk of collision

Key Idea: Sound Notifications for Users and Pedestrians



Prompt nearby pedestrians to **clear the path for blind users**

Key Idea: Sound Notifications for Users and Pedestrians

Problem

Frequent emission of alarm can be **socially disruptive**

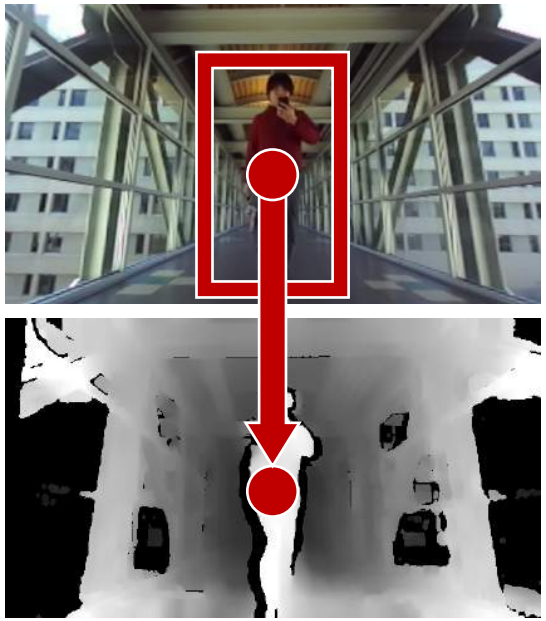
We present an adaptive sonic warning system

that **only emits sounds when needed**.

Collision Prediction to Reduce Sound Emissions

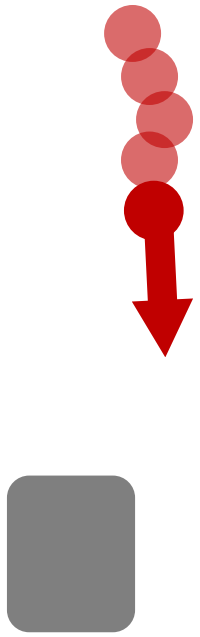
Step 1

Pedestrian Detection



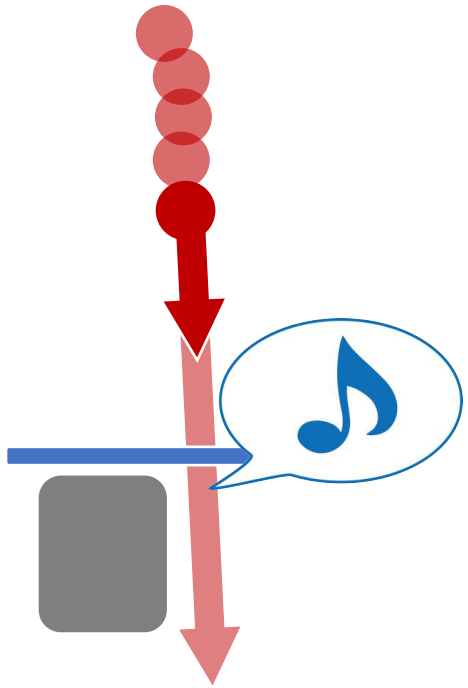
Step 2

Pedestrian Tracking



Step 3

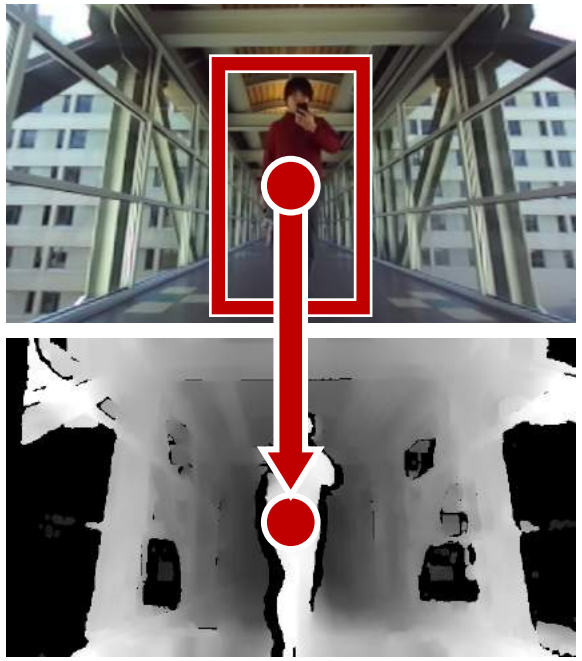
Collision Prediction

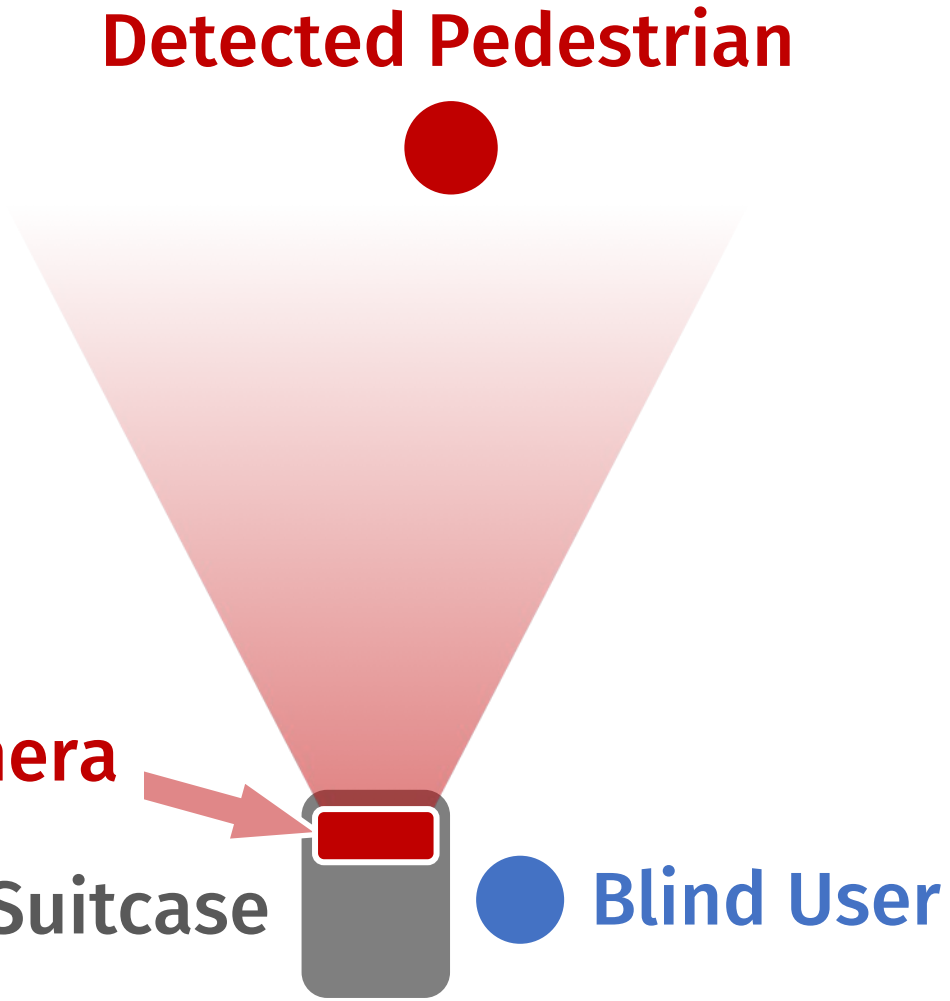


Step 1　Pedestrian Detection

Detect the position of pedestrians
in the camera coordinate system

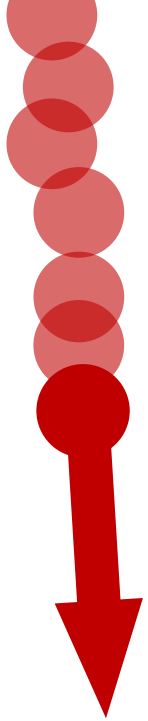
YOLO v2[1] -Based Detection





[1] J. Redmon, et al. " YOLO9000: Better, Faster, Stronger ” CVPR ’17.

Step 2　Pedestrian Tracking

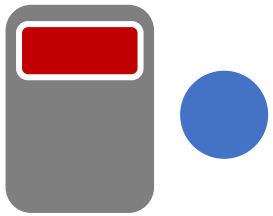


Trajectory

Velocity

Track pedestrians based on the detection results

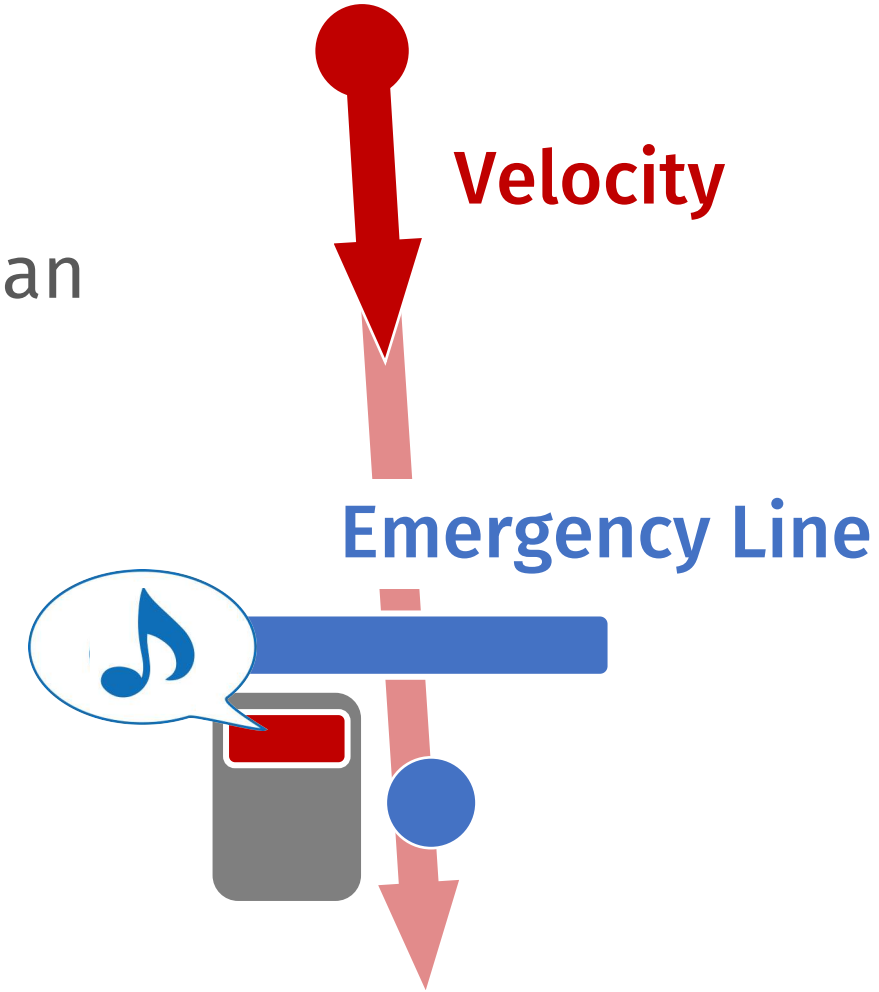
From the position for 30 frames,
calculate the relative velocity of the pedestrian

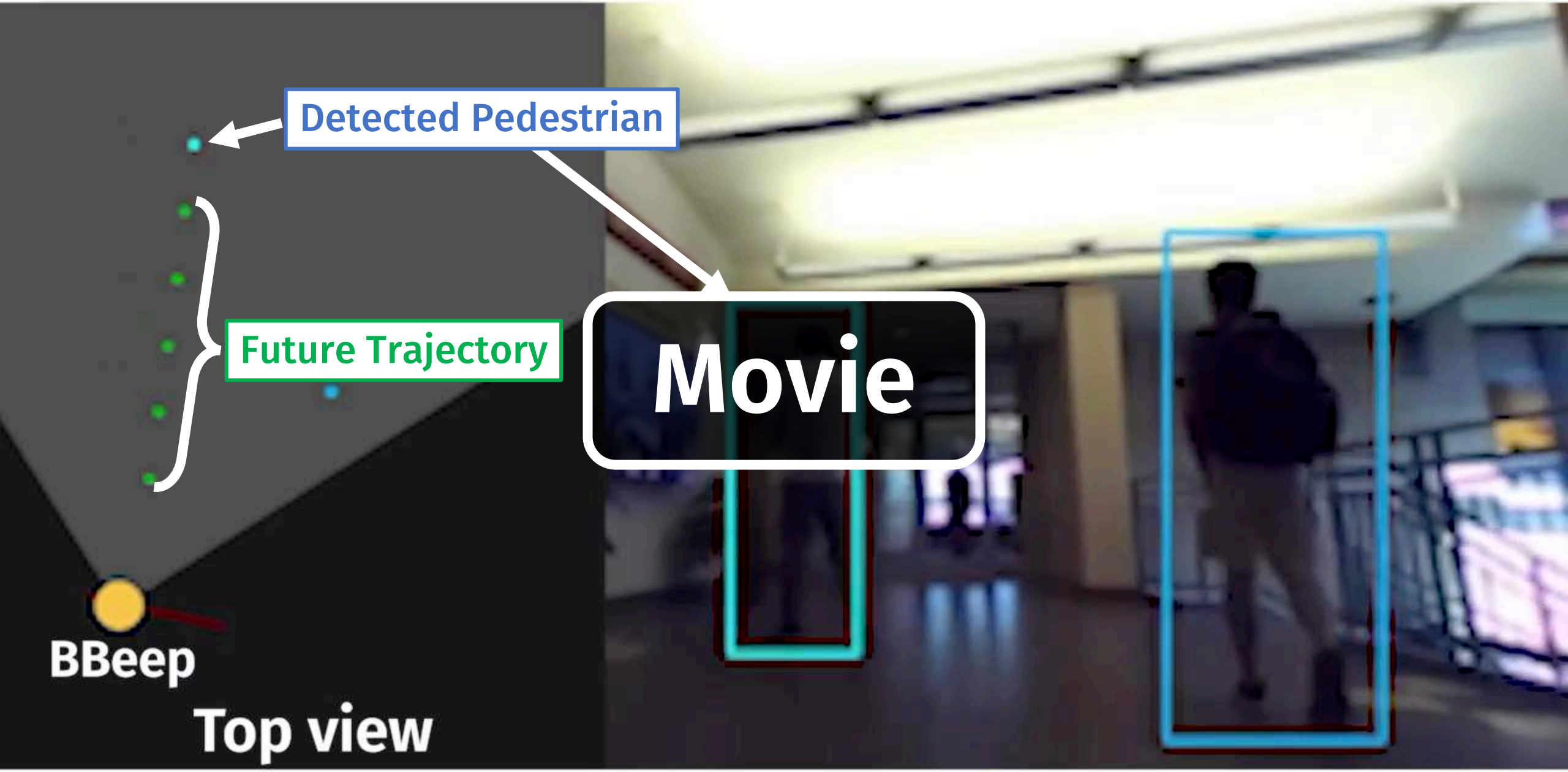


Step 3　Collision Prediction

Predict the future trajectory of the pedestrian

Emit sound alerts
if the trajectory **intersects Emergency Line**.




Detected Pedestrian
Future Trajectory
Movie
BBeep
Top view

Key Idea - Sonic Collision Warning System

Alert both the blind user and pedestrians about a risk of collision

Research Question

There is no knowledge about

how a pedestrian reacts to an audible signal.

We investigated **what types of sound** are **effective** for **collision avoidance.**

Beep Sound: Popular Alert Sound

Airport carts

Large Trucks

Beep sounds have been used to **clear the path for moving vehicles**

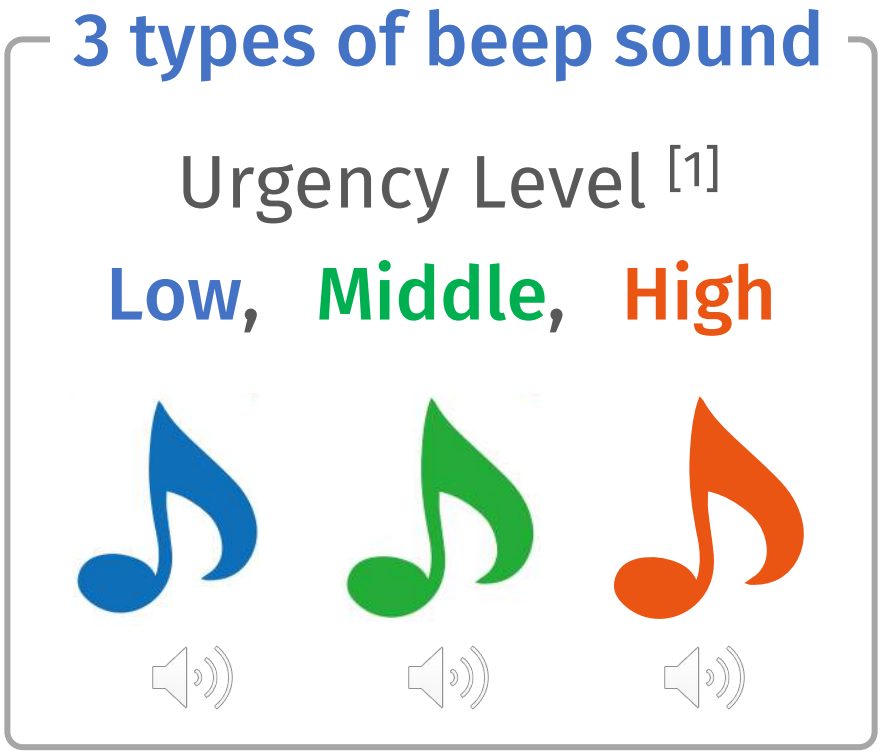
https://www.schoolphotoproject.com/_picture-of-cars-motorbikes/car-boxtruck-photo-l.jpg

Observation Study in a Corridor

Record pedestrians' reactions and trajectories

7 Sound Patterns

- Baseline pattern (without sound)
- Six sound emission pattern



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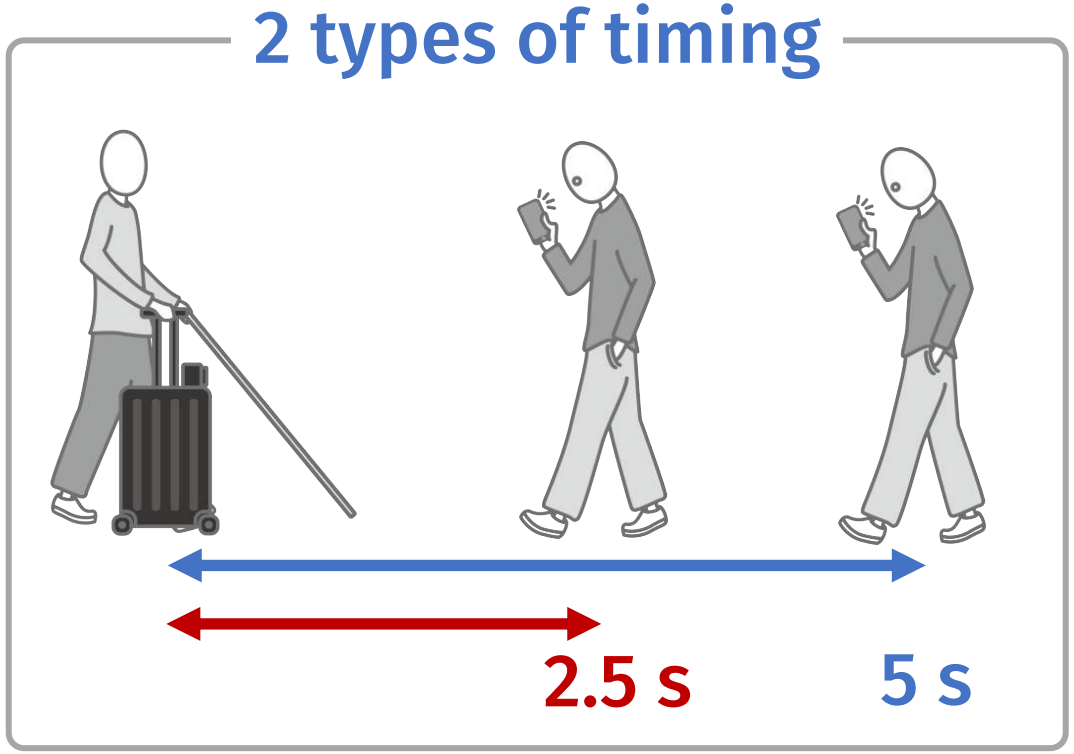


[1] J. Edworthy, et al. "Improving auditory warning design: Relationship between warning sound parameters and perceived urgency" 1991.

Analyzed 399 trajectories in total

Result - 3 Findings

1 **Sound warning** influenced pedestrians walking **away from the system**.

2 **The timing of sound emissions** also **affected pedestrians' trajectories**.

3 **The type of sound emissions** was **not significant factor**.

Design of the Sound-Emission Policy

Previous Study [1,2]

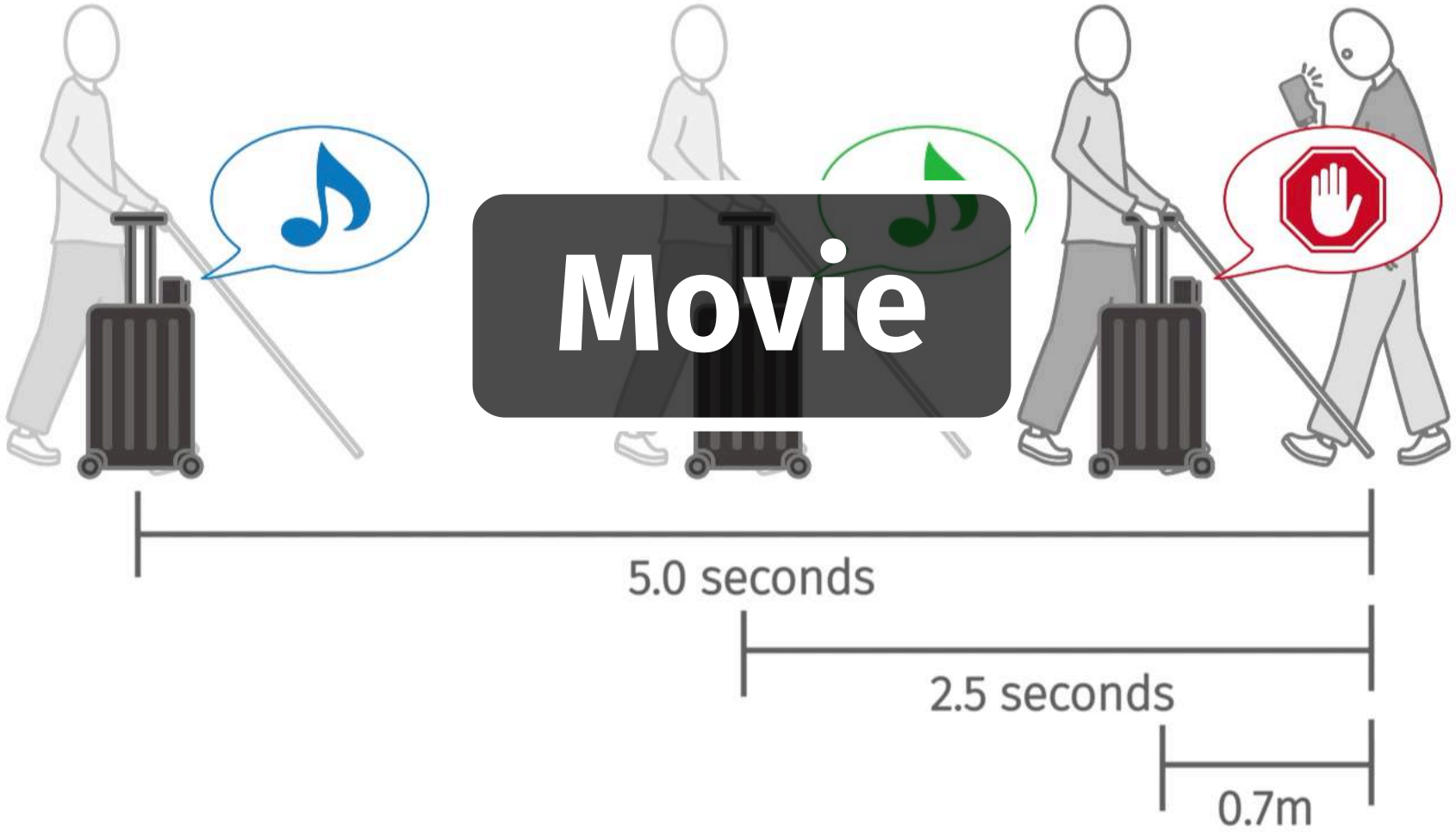
The **higher the urgency level** of the signal,

the greater the annoyance rating.

We used two sound alerts with **lower urgency and annoyance** levels.

[1] J. Edworthy, et al. "Improving auditory warning design: Relationship between warning sound parameters and perceived urgency" 1991.
[2] D. C. Marshall, et al. "Alerts for in-vehicle information systems: Annoyance, urgency, and appropriateness" 2007.

Design of the Sound-Emission Policy



Real-world User Study at an Airport

Six blind participants walked in front of a crowded gate

Conditions

	Speaker (BBeep)	Bone-conducting Headset	No sound
Interface			
Target	**User & Pedestrians**	**Only User**	**None**
Total trial number	**2 × 6 users**	**2 × 6 users**	**1 × 6 users**

Headset

Notify **only the blind user**

BBeep

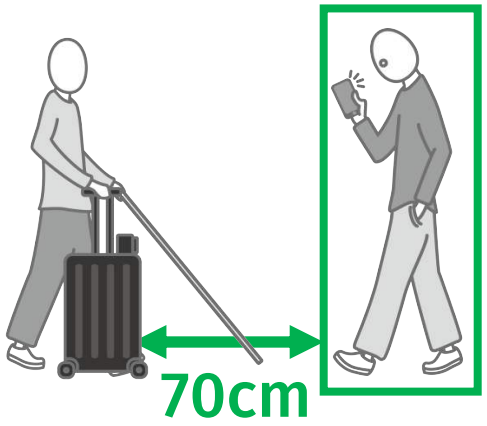
Notify pedestrians & the blind user

Evaluation Measurements

Risk Continuity Ratio = Imminent Collision Frequency / Collision Risk Frequency

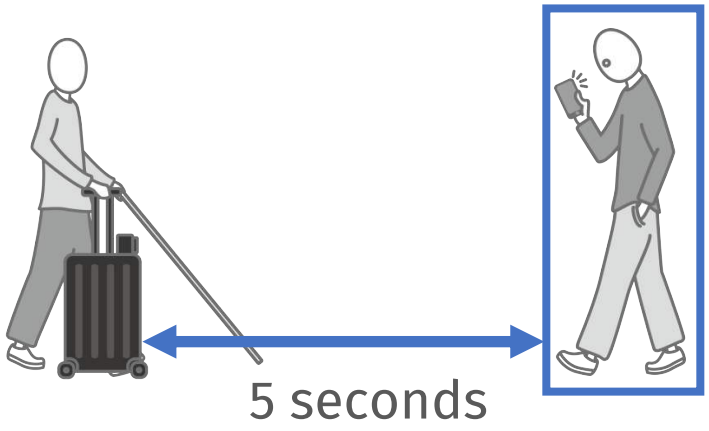
Imminent Collision Frequency

The number of pedestrians within 70 cm



Collision Risk Frequency

The number of pedestrians who had a risk of collision within 5 seconds



Evaluation Measurements

Risk Continuity Ratio = Imminent Collision Frequency / Collision Risk Frequency

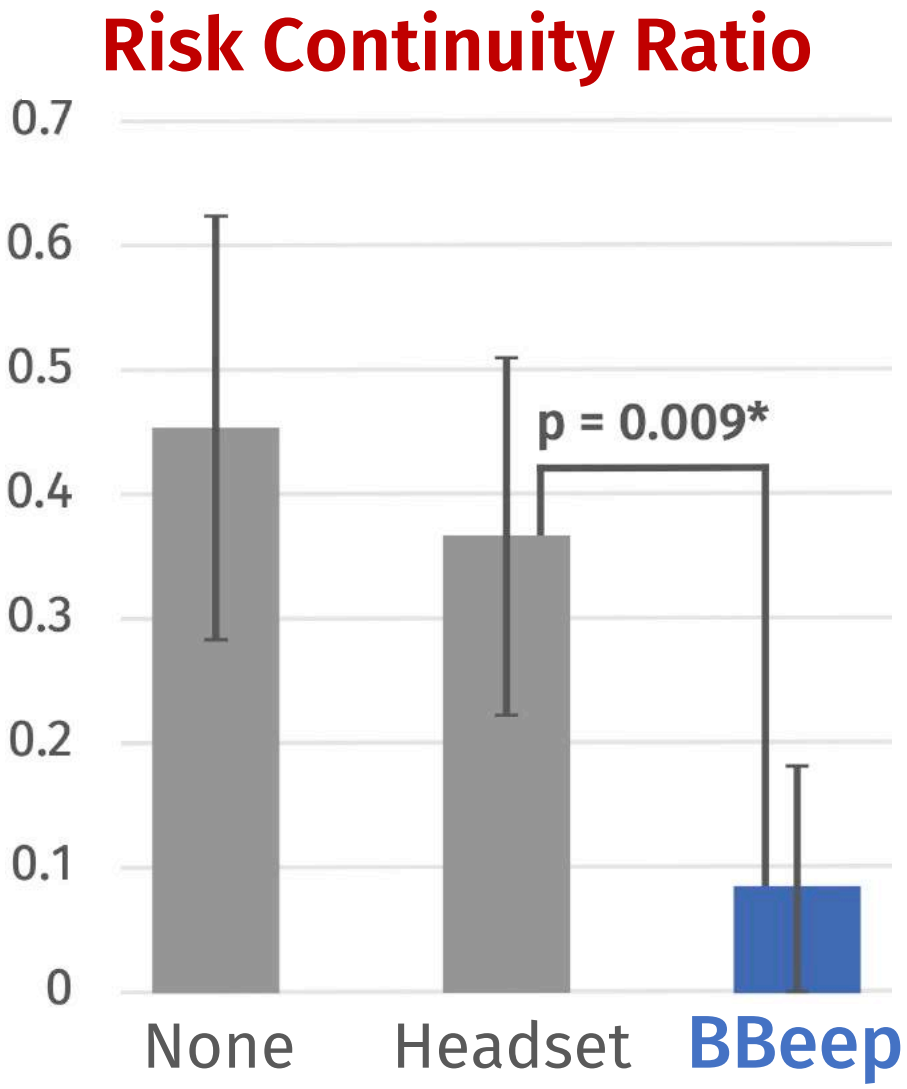
A Smaller Risk Continuity Ratio

II

The System **reduces the risk of collision**

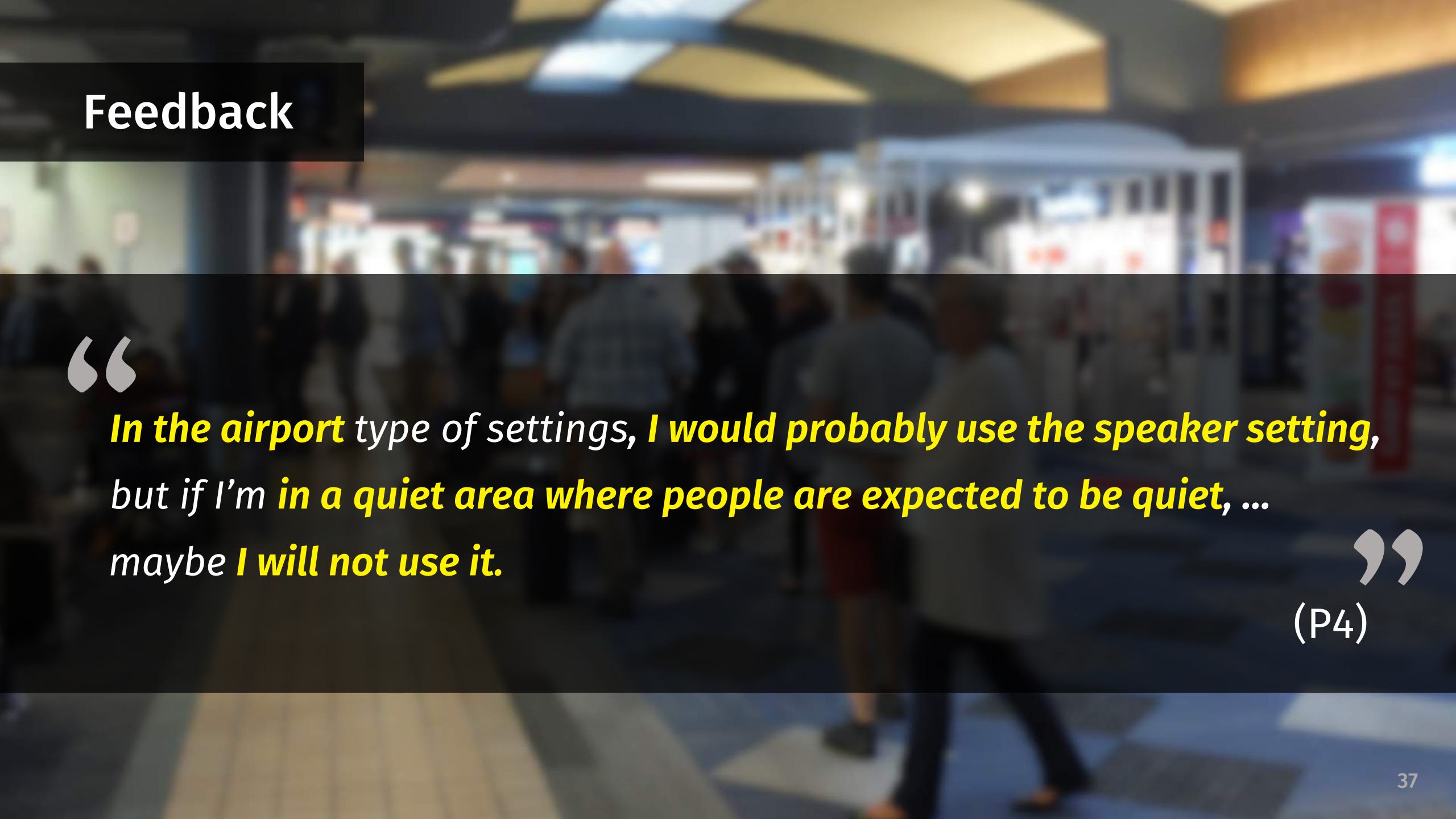
between the blind user and pedestrians

Results



BBeep significantly **reduced the Risk Continuity Ratio**.

Feedback



“*In the airport type of settings, I would probably use the speaker setting, but if I’m in a quiet area where people are expected to be quiet, … maybe I will not use it.*”

(P4)

Using BBeep in quieter environments

Idea

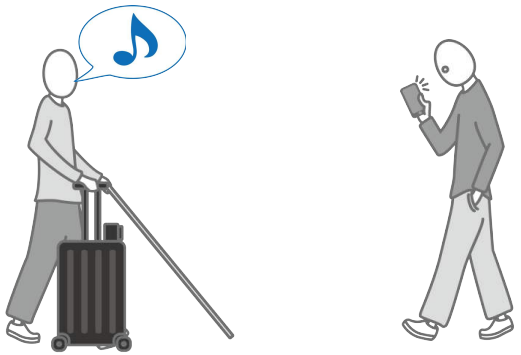
Change the parameters of beep sound **considering the environment**

in noisy area

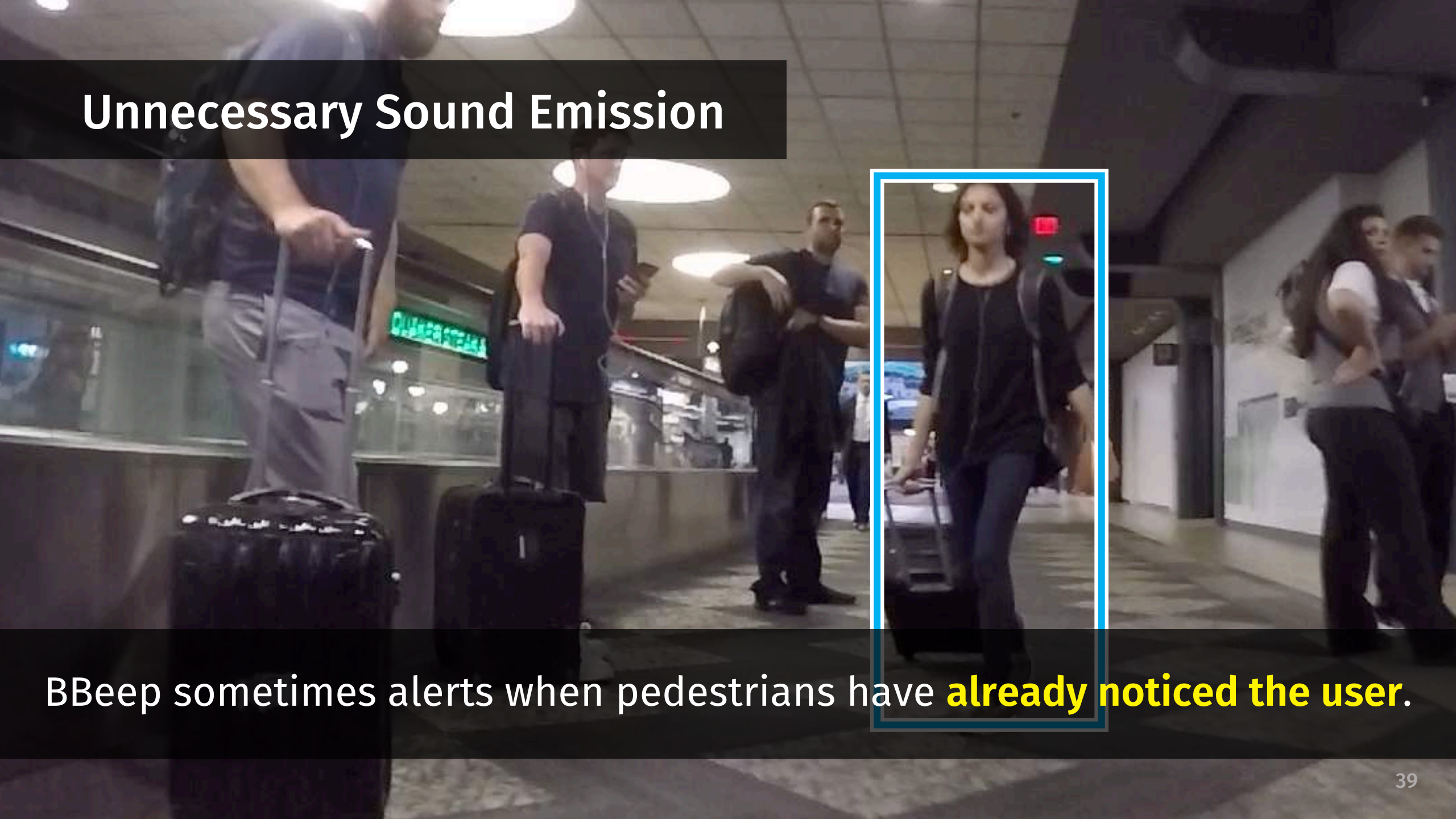
High urgency & **high volume**

in quiet area

Low urgency & **lower volume**
or **notify only the user**

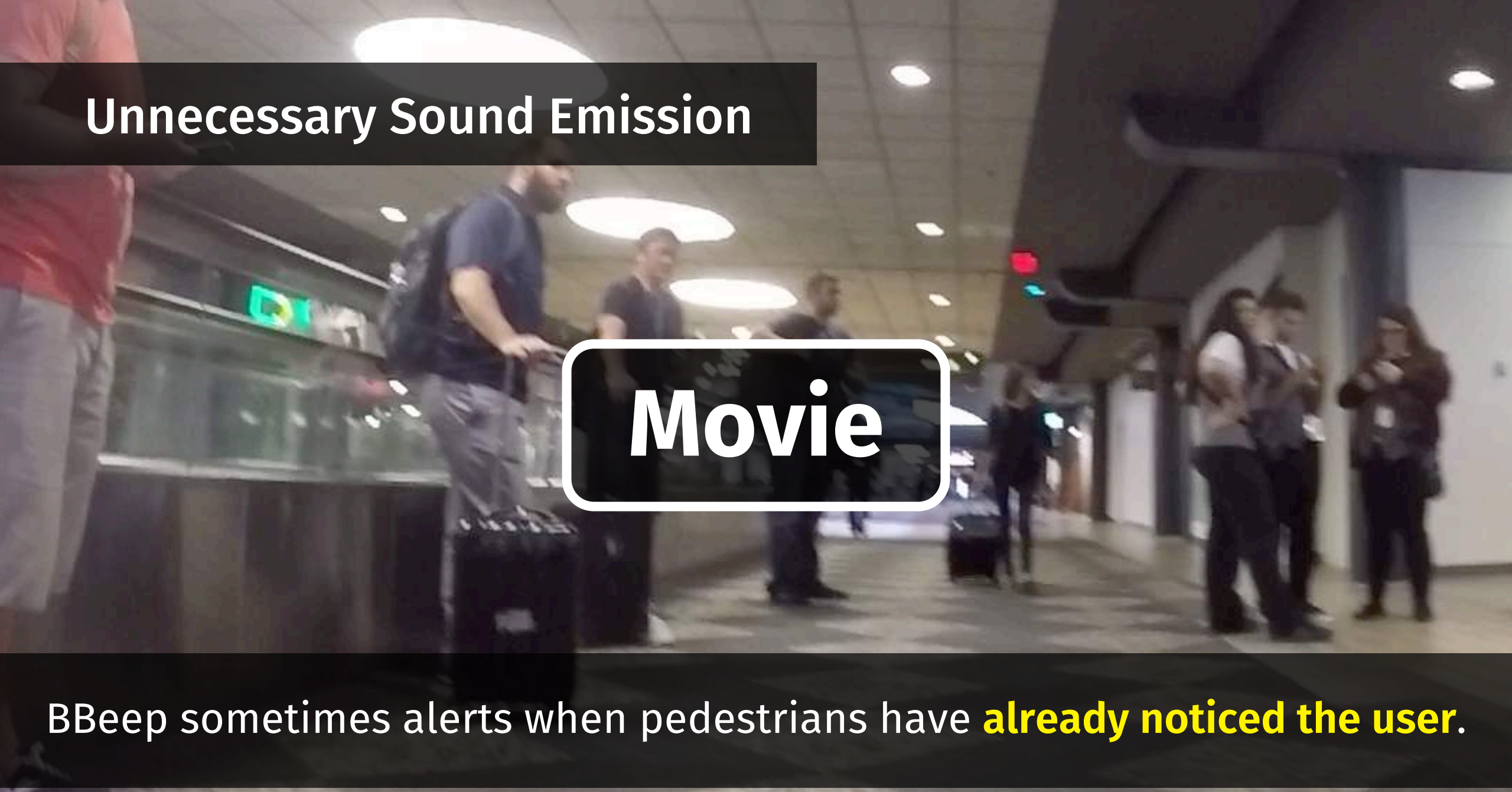


Unnecessary Sound Emission



BBeep sometimes alerts when pedestrians have **already noticed the user**.

Unnecessary Sound Emission



BBeep sometimes alerts when pedestrians have **already noticed the user**.

Unnecessary Sound Emission

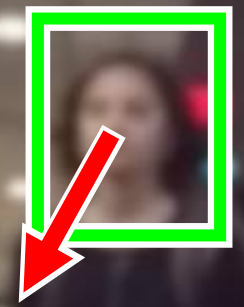
Cause:

BBeep Predicts future collision by using **only the position of pedestrians.**

Unnecessary Sound Emission

Cause:

BBeep Predicts future collision by using **only the position of pedestrians.**



Improvement of Collision Prediction:

Use **face tracking** or **gaze estimation** techniques[1] to assess whether pedestrians are **aware of the blind user.**

[1] Z. Zhang, et al. "MPIIGaze: Real-World Dataset and Deep Appearance-Based Gaze Estimation" 2017.

BBeep: A Sonic Collision Avoidance System for Blind Travellers and Nearby Pedestrians

We present an assistive suitcase system, **BBeep**, for supporting **blind people** when walking **through crowded environments**.

Our **user study at an airport** revealed that BBeep significantly **reduces the number of imminent collisions**.

Appendix

The reason we used beep sounds as a sound alert

Emitting beep sound is a common approach to notify users of urgent situation.

Beep sound is easy to set sound parameters.

Prior research showed relationships between annoyance and the parameter.

[1] J. Edworthy, et al. "Improving auditory warning design: Relationship between warning sound parameters and perceived urgency" 1991.
[2] D. C. Marshall, et al. "Alerts for in-vehicle information systems: Annoyance, urgency, and appropriateness" 2007.

BBeep Acceptability by Sighted Pedestrians.

We did not recruit sighted people beforehand because it would not enable us to effectively evaluate BBeep’s ability to clear the path for blind people

We agree that collecting the impressions of pedestrians is relevant to assess the acceptability of BBeep.

About IRB

We carefully designed our IRB approved study.

A researcher were walking behind participants to guarantee their safety.

Convey more informative feedback

We have a plan to combine BBeep and a system that can **explain the surrounding environment**.

We want to use BBeep when users walk through **a very crowded area** or **a group of pedestrians are block the entire route** of a blind user.

Headset: describe the environment to **users**

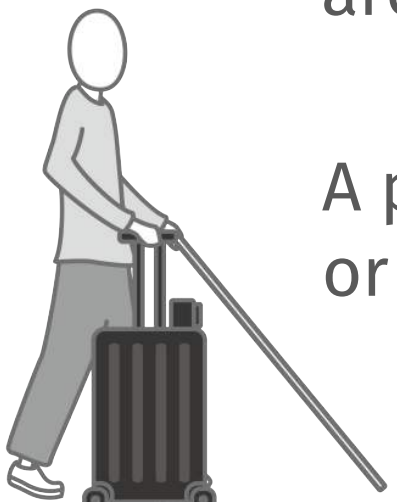
Speaker: Alert **pedestrians** about risks of collision

Will the tracking algorithm fails to work when the suitcase is accidentally turned by the user

Our system uses the 3D odometry API of the ZED camera
to remove the influence of suitcase rotation.

When users turn the suitcase widely and the tracked pedestrians
are framed-out, the pedestrian tracking algorithm fails.

A possible solution is to mount multiple stereo cameras
or a 360-degree camera on the suitcase to expand the sensing range.



Encoding distance information could be a better option

We designed our system with 3 different sounds in order to ease users' perception of the urgency levels of collision with pedestrians.

We agree that encoding distance information is more informative and an interesting approach to explore in the future.

The user study is too simple

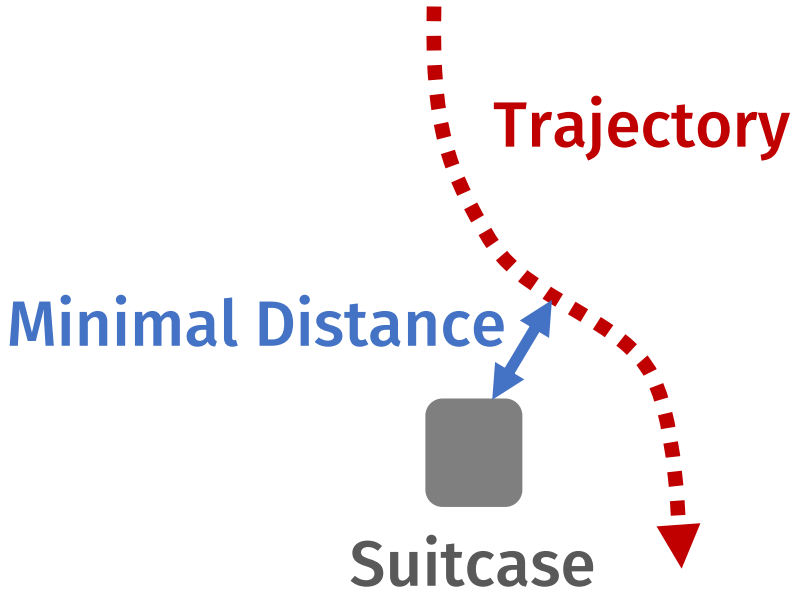
The main purpose of our user study is to evaluate the effectiveness of BBeep for preventing collisions with pedestrians in busy public environments.

For this reason, we wanted to remove additional challenges of navigation.
(e.g., knowing when to turn right/left or veering off the path)

Evaluation Metrics

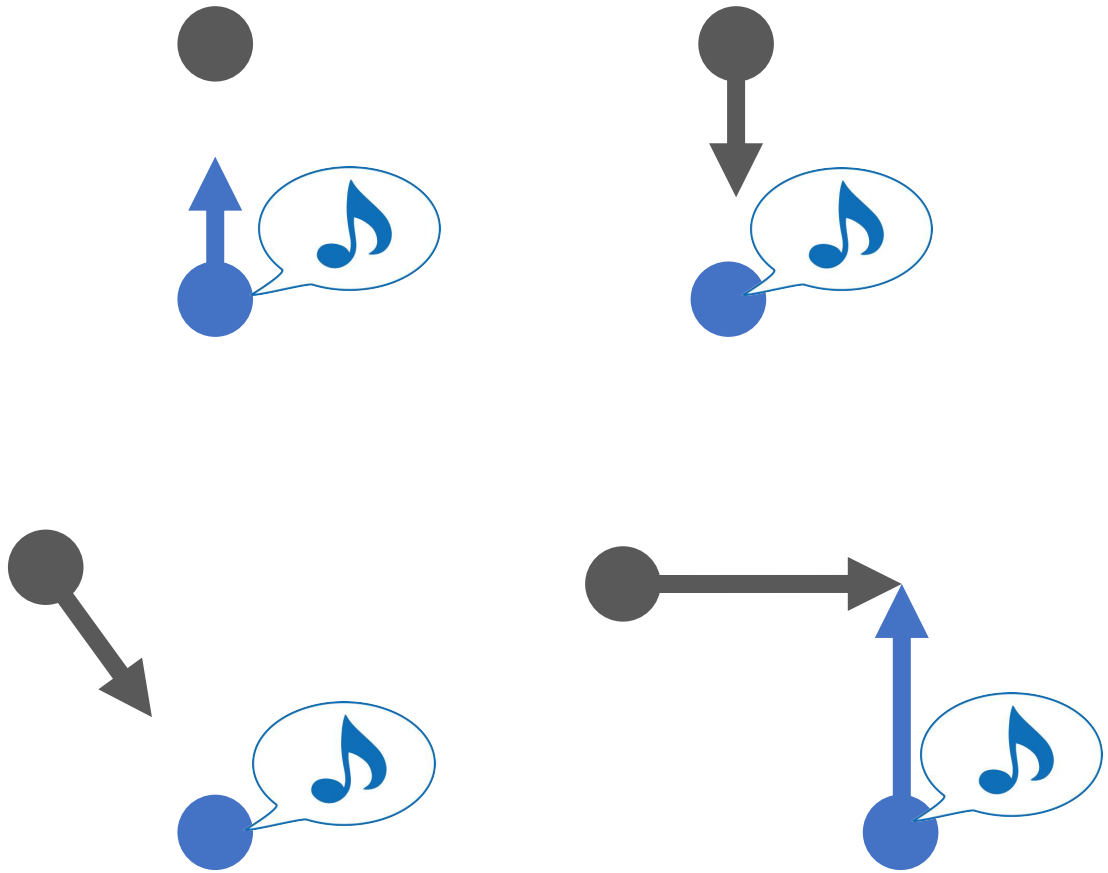
Minimal Distance

between the suitcase position and a given trajectory

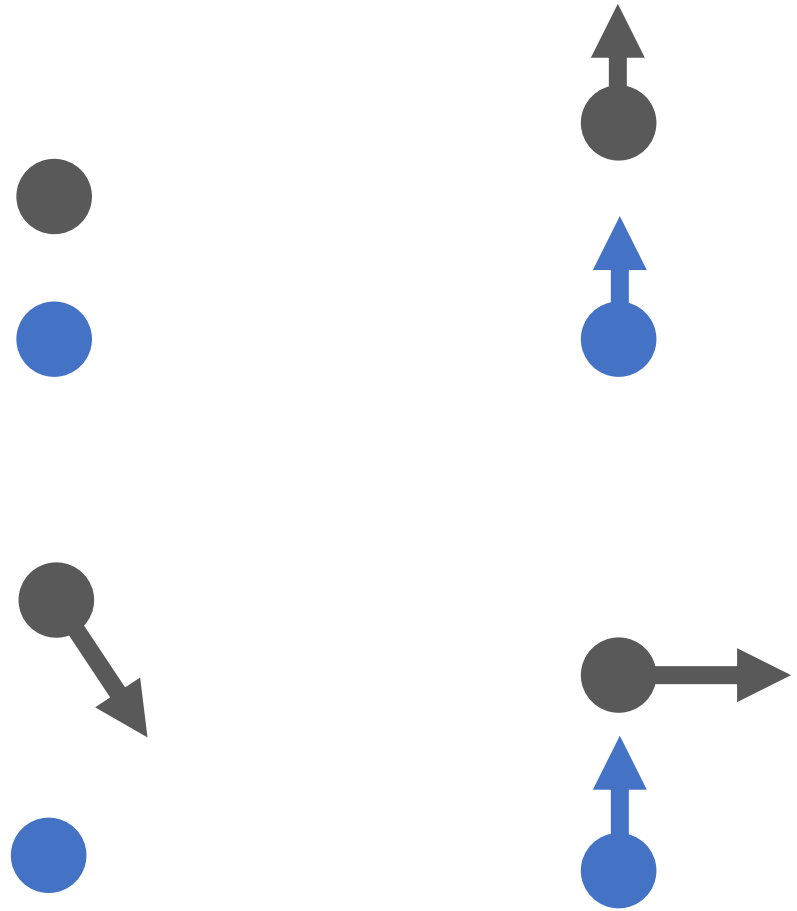


A longer minimal distance = The pedestrian has avoided the user **by a comfortable margin**

There is a risk of collision

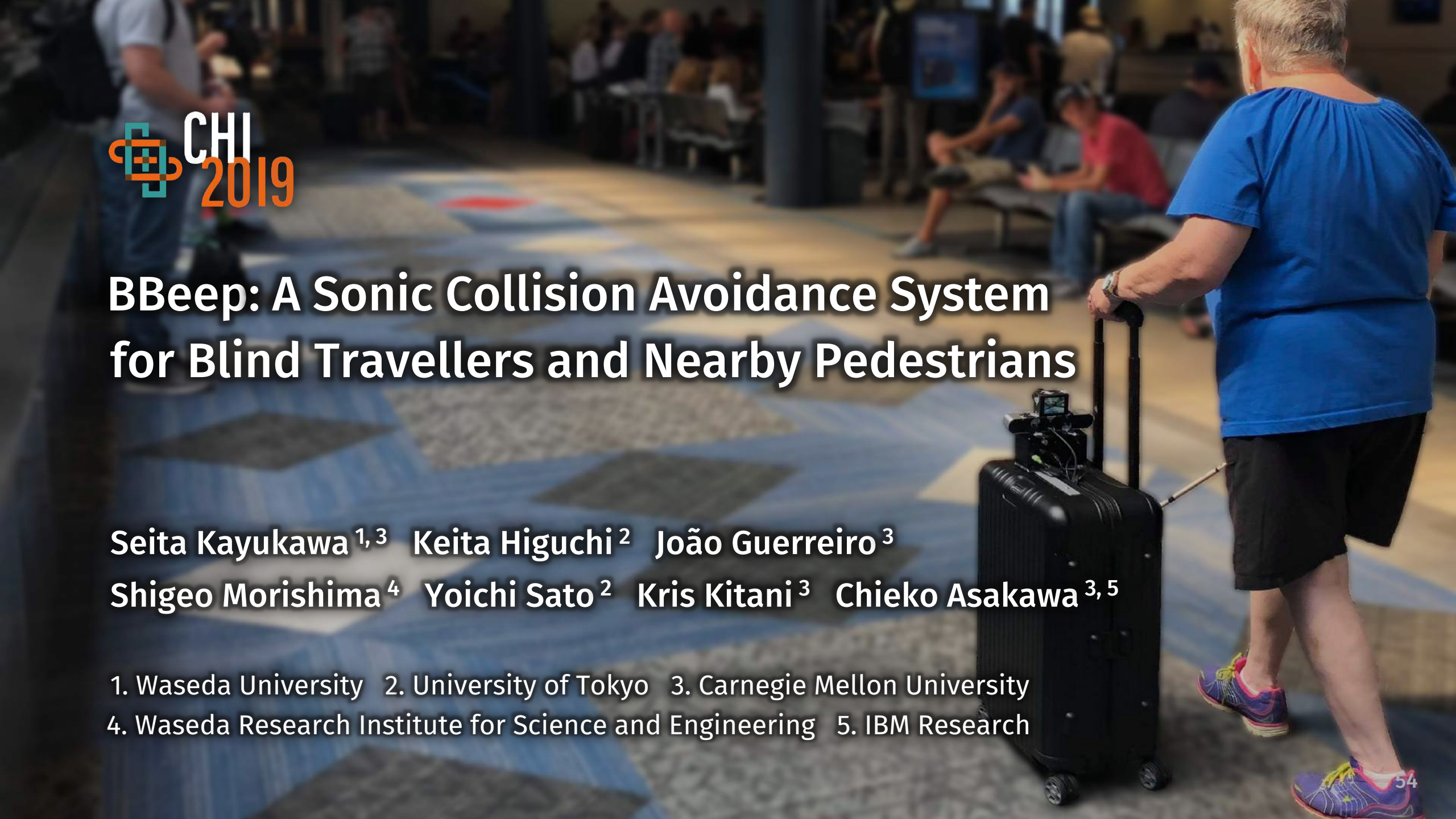


No risk of collision



BBeep

Pedestrian



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