Chaperone:
Real-time Locking and Loss Prevention for Smartphones

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Around 23,000 devices go missing every month, finds Kaspersky Lab

The holiday season is upon us, and that means that millions of people are getting ready for a trip abroad.

The holiday season is upon us, and that means that millions of people are getting ready for a trip abroad. And while they are on holiday, many will be taking the opportunity to capture precious memories of their time away. In fact, according to Kaspersky Lab's consumer research, one-in-five (18%) say photos and videos of their travel are the most important forms of data on their devices, with this type of data trumping all others. However, in additional research by the company, 28% said that if they lost their devices, or had them stolen, they would never be able to replace those precious holiday photos.

Uber Newsroom

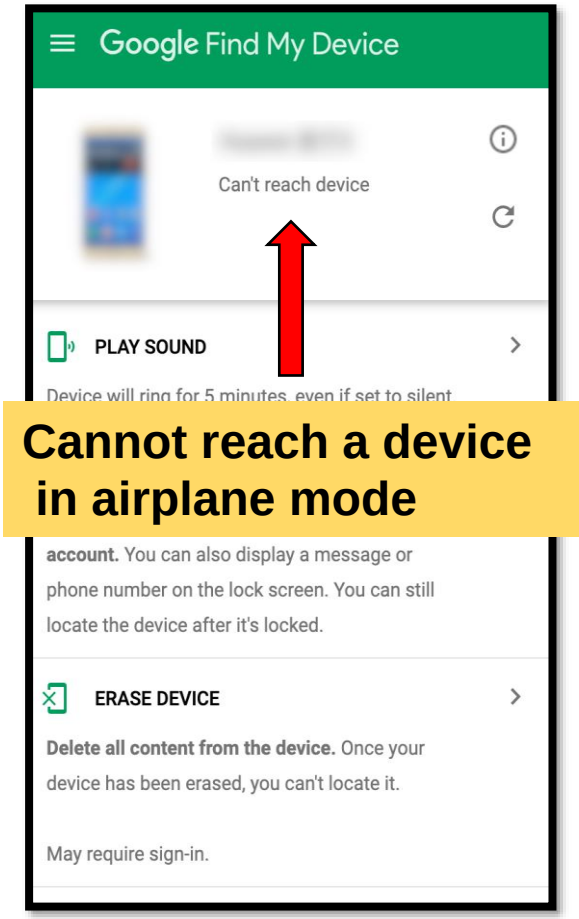
The 2020 Uber Lost & Found Index

The 10 Most Commonly Forgotten Items:

1. Phone
2. Wallet
3. Keys
4. Backpack / bag / purse
5. Headphones
6. Clothing
7. Glasses
8. Vape / e-cig
9. ID / license / passport
10. Water bottle

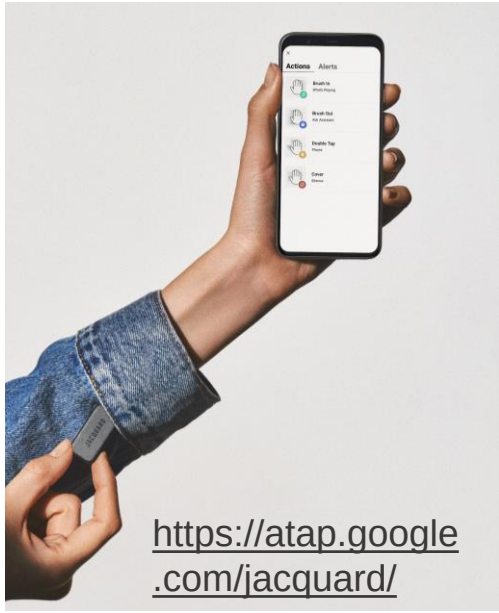
Smartphone Loss

- ×Find my device
  - Can be easily bypassed
  - Post-loss solution



Smartphone Loss

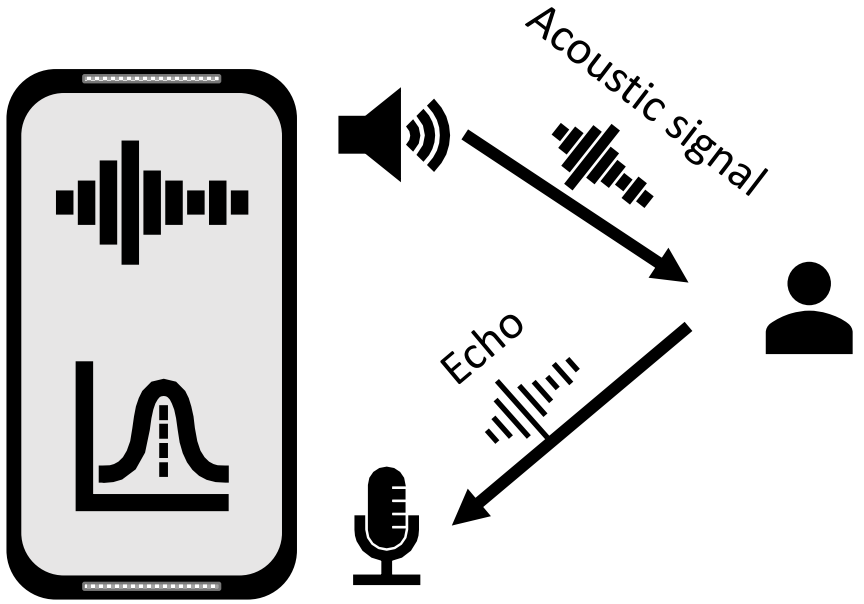
- ×Find my device
  - Can be easily bypassed
  - Post-loss solution
- ×Bluetooth/Camera-based loss prevention
  - Require additional hardware
- ✓Need a standalone loss prevention solution




Surround-See
[UIST'13]

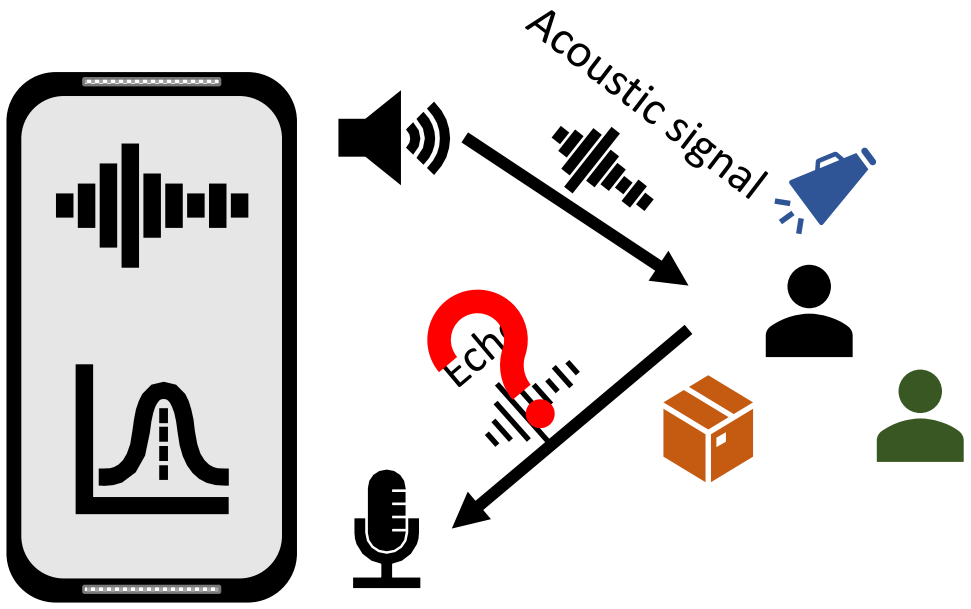
Active Acoustic Sensing

- Distance estimation based on reflected signals
- iLock [CCS'16]: a distance-based solution to auto-lock a smartphone
  - Tested in lab and library



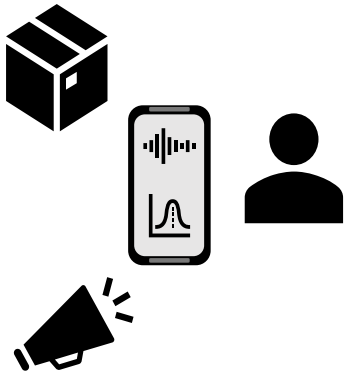
Active Acoustic Sensing

- Distance estimation based on reflected signals
- iLock [CCS'16]: a distance-based solution to auto-lock a smartphone
  - Tested in lab and library
- **Environmental factors**

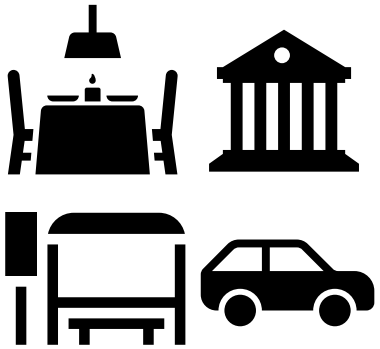


Chaperone

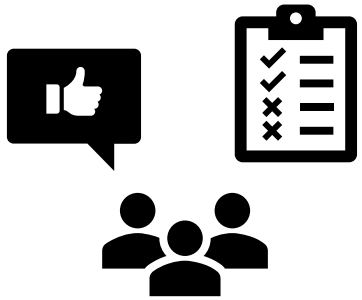
- Real-time smartphone loss prevention solution
  - Detect owner's departure from phone using active acoustic sensing



A standalone solution that handles complicated environmental factors



1,345 experiments over different conditions and real-world scenarios

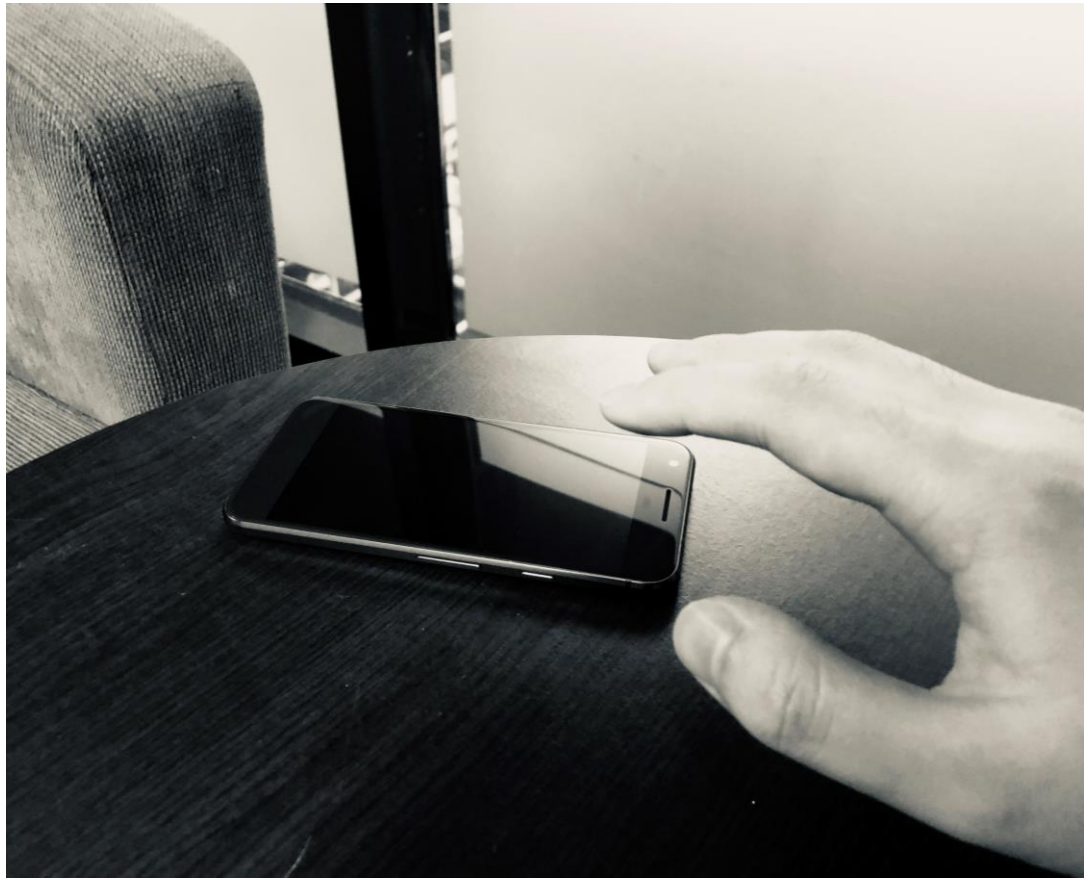


User study (n=17) for perceptional feedback and alert test

Threat Model

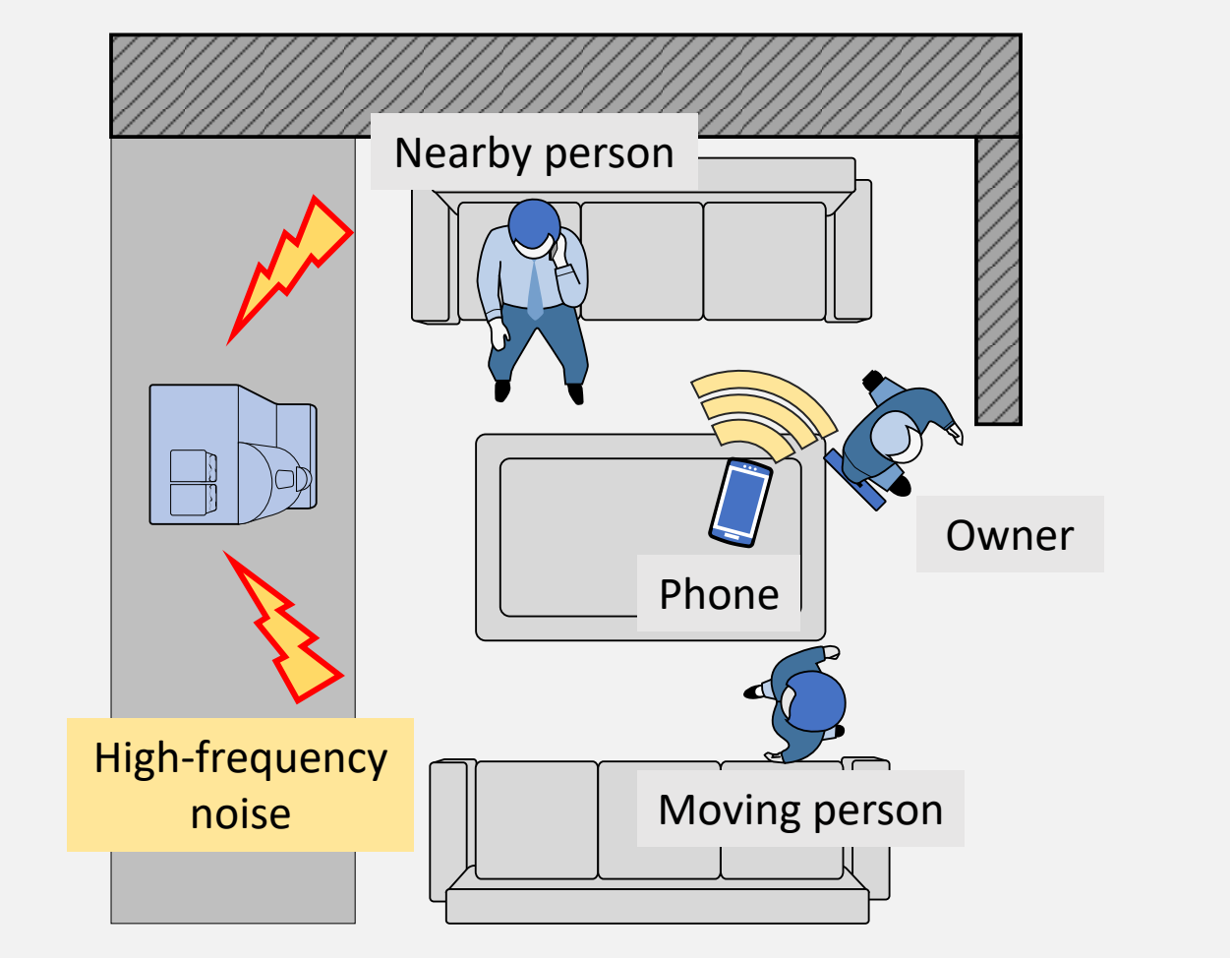
- Nearby opportunistic attackers
  - Target unattended phones*
  - Pick up a phone shortly after owner's absence
- Assumptions
  - Microphone/speaker not fully covered
  - Owner initially close to phone

*Pickpocketing and snatching are not considered.



Challenges

- **High-frequency noise**
- Nearby people
- Layout & obstacles



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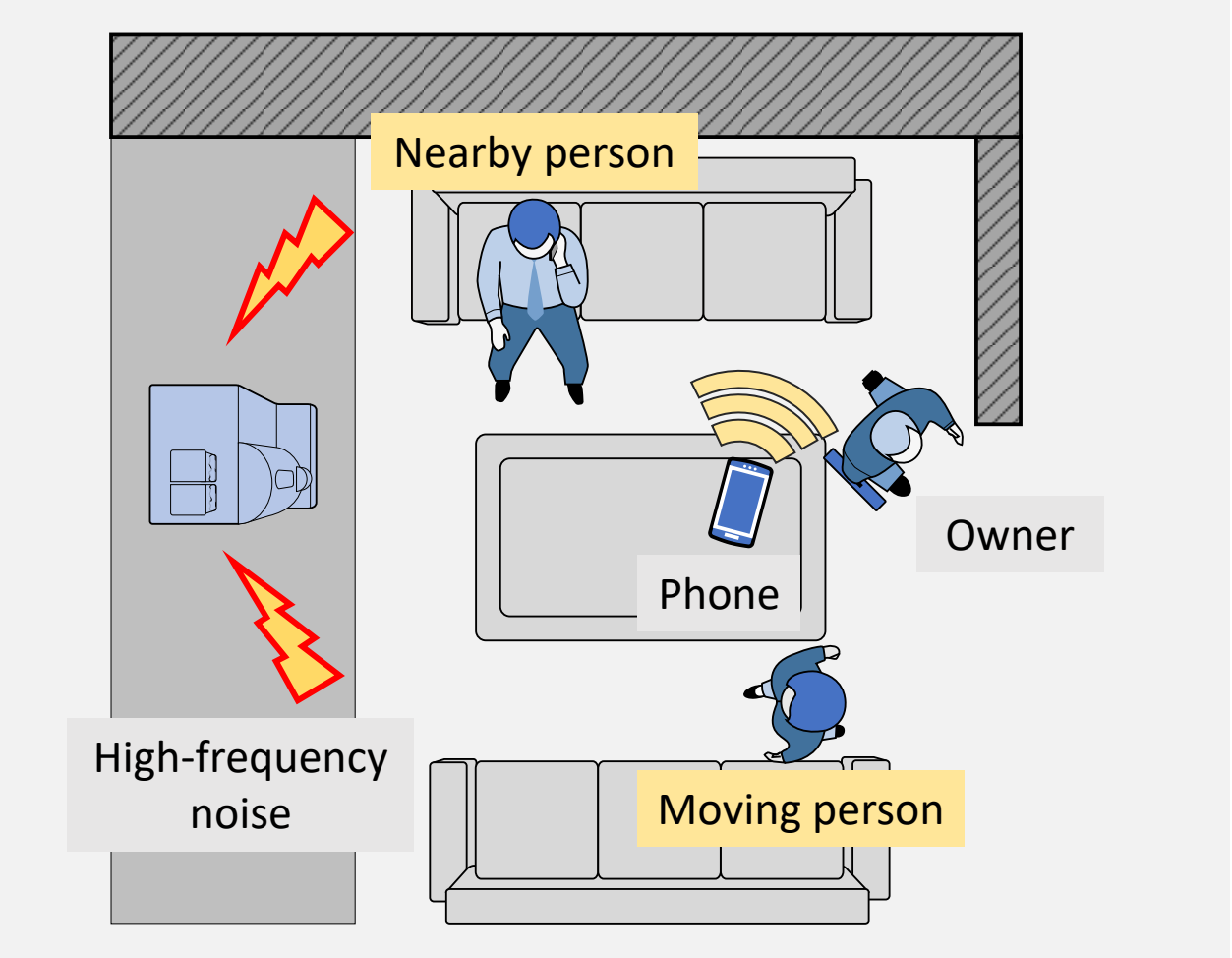

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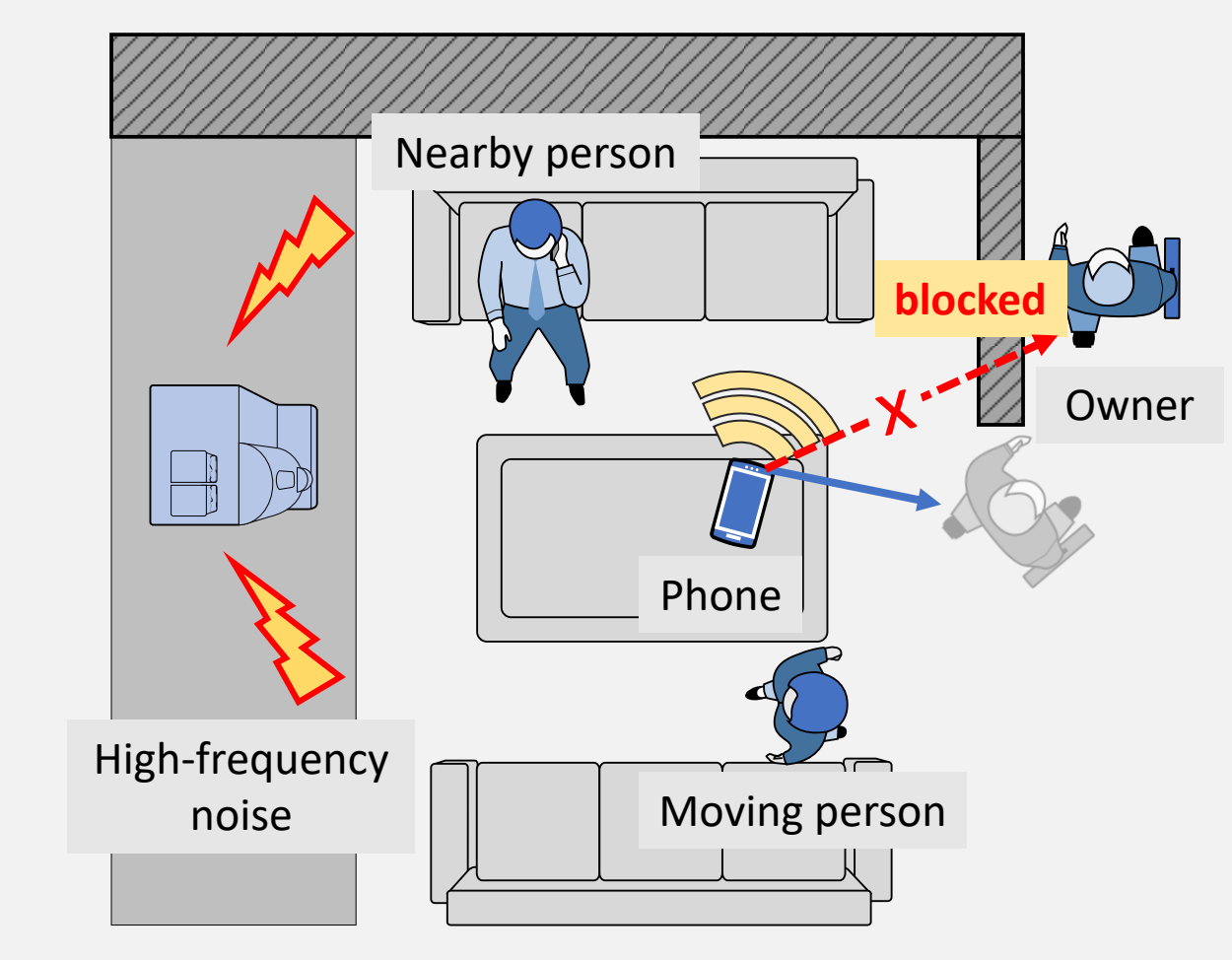
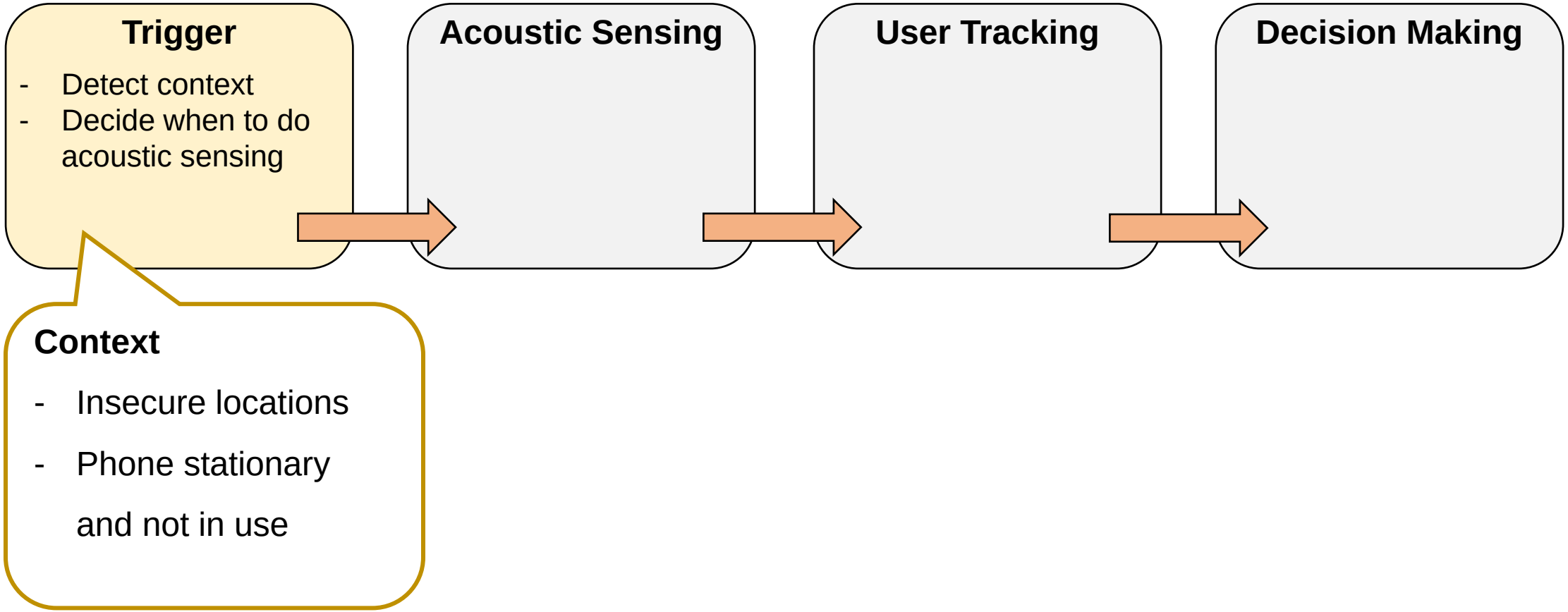


Design of Chaperone



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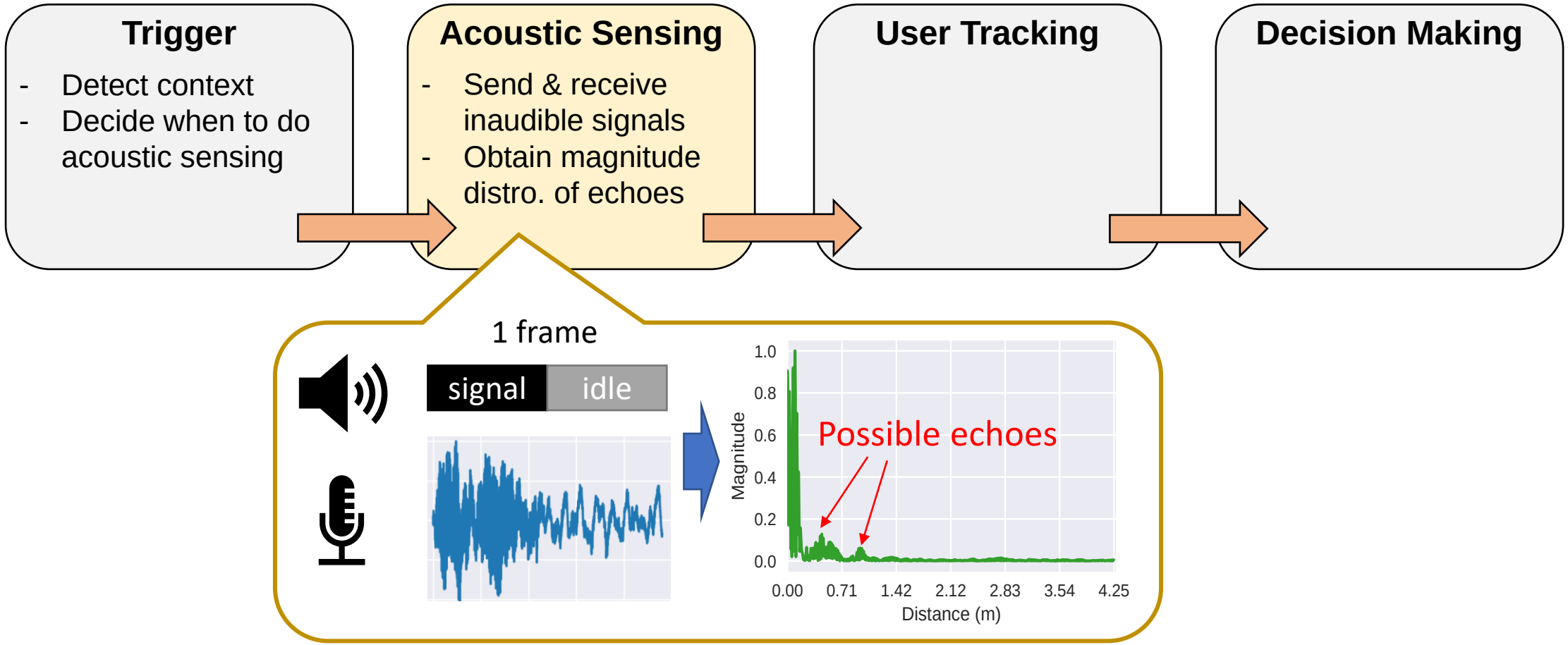


Design of Chaperone

Trigger

- Detect context
- Decide when to do acoustic sensing

Acoustic Sensing

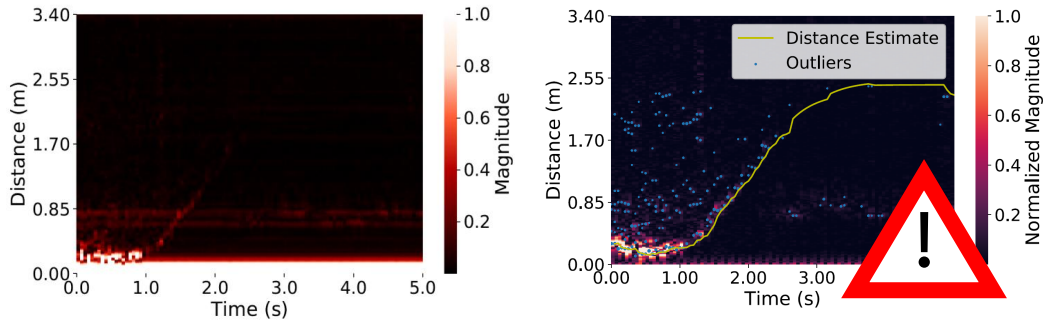
- Send & receive inaudible signals
- Obtain magnitude distro. of echoes

User Tracking

- Exclude noise & static objects
- Obtain owner's motion state

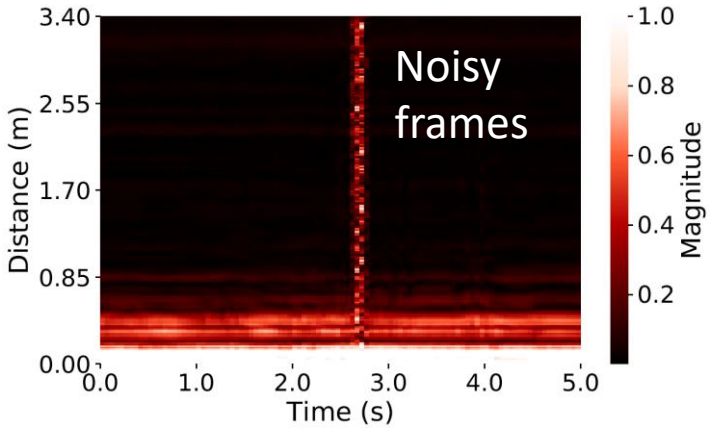
Decision Making

- Detect departure pattern
- Raise alert



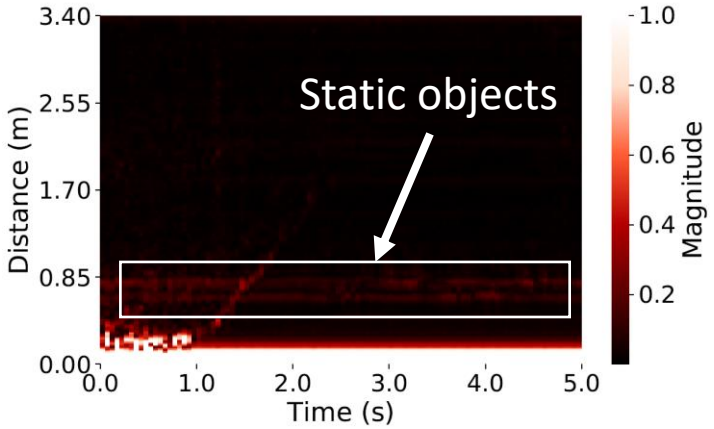
User Tracking Module

- Preprocessing

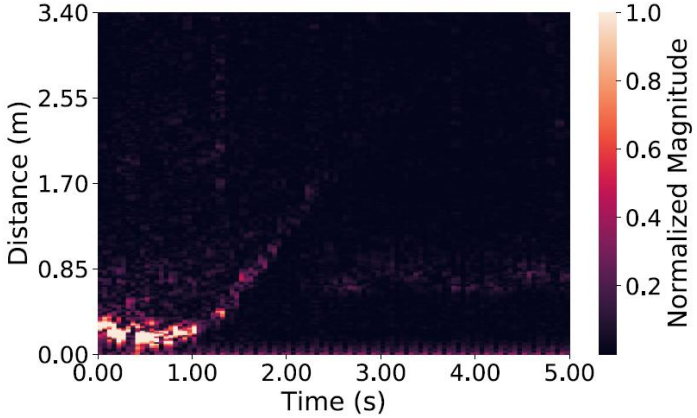


High-frequency noise detection

Raw magnitude heatmap



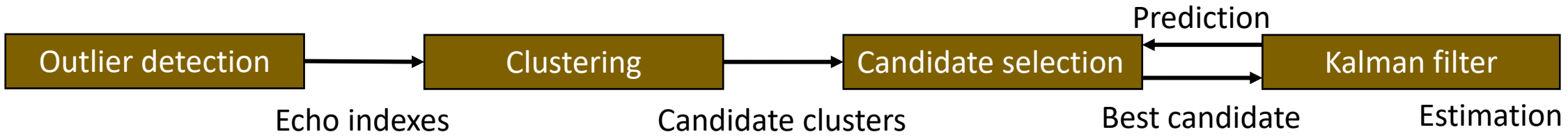
Differential magnitude heatmap



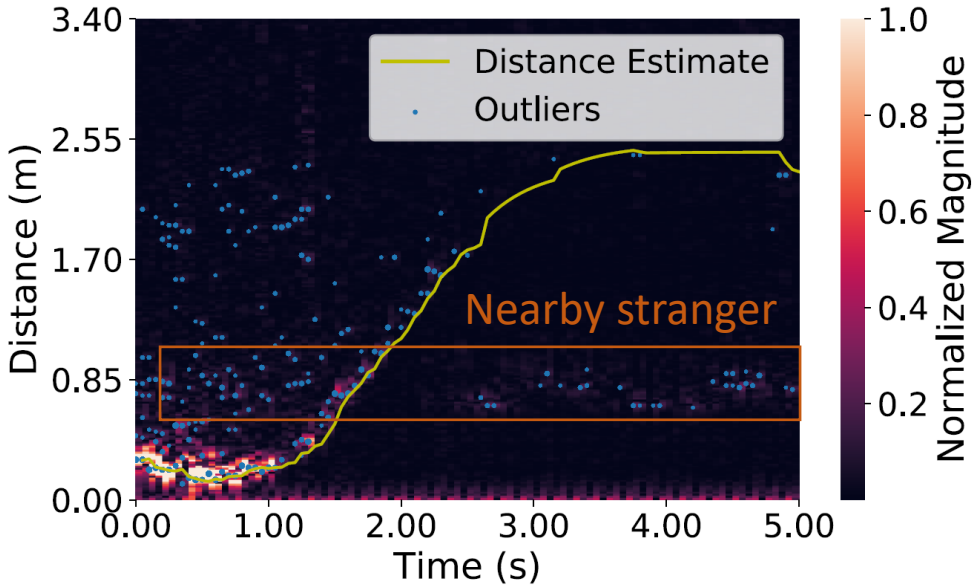
Static object exclusion

User Tracking Module

- Extract owner's motion state

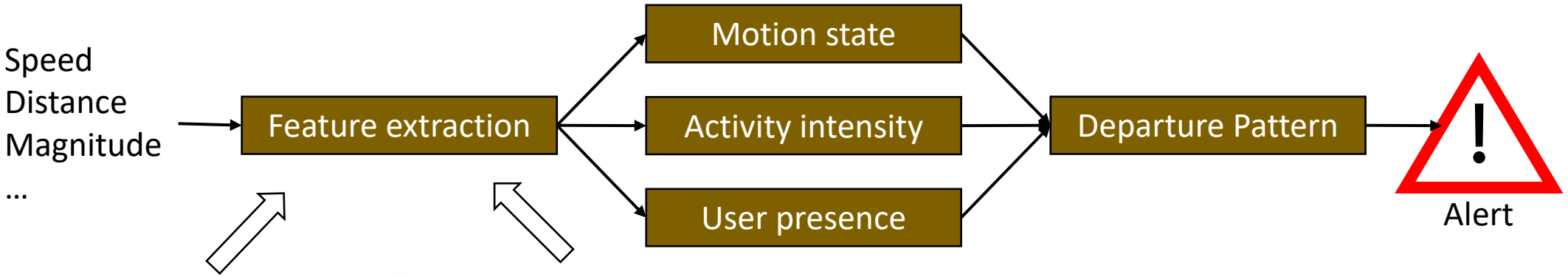


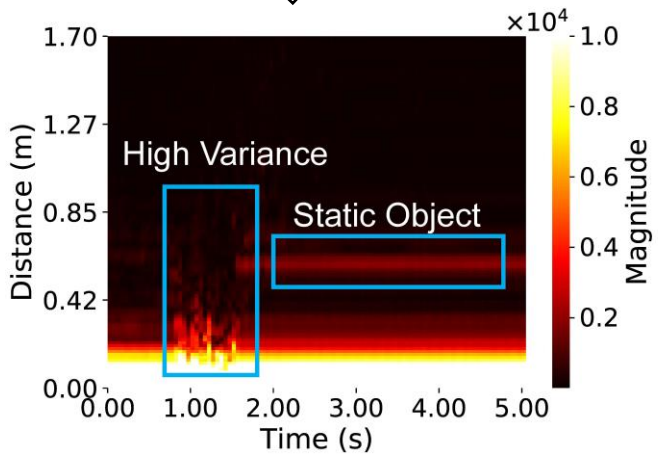
- Find all possible echoes
- Cluster echoes from same person
- Distinguish owner from nearby people
  - Motion consistency
  - Prediction + Magnitude
- Compensate noisy frames



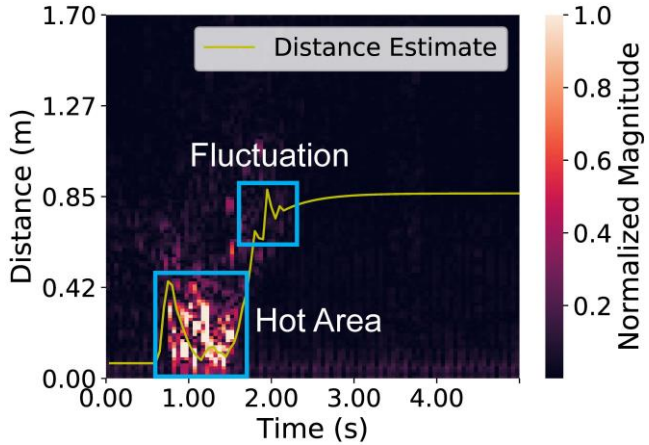
Decision Making Module

- Address limited detection range caused by layout and obstacles



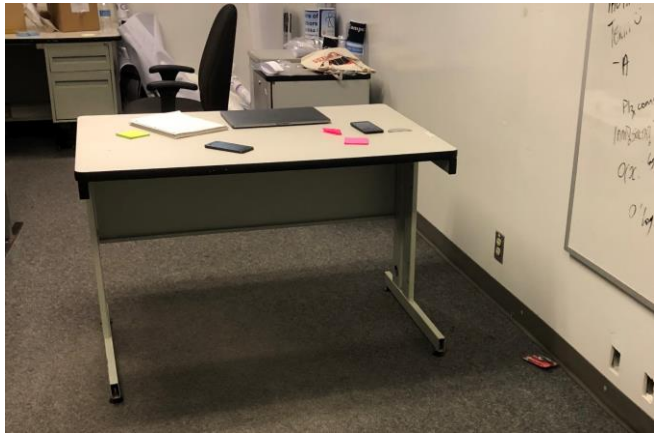


Raw magnitude



Differential magnitude

Evaluation

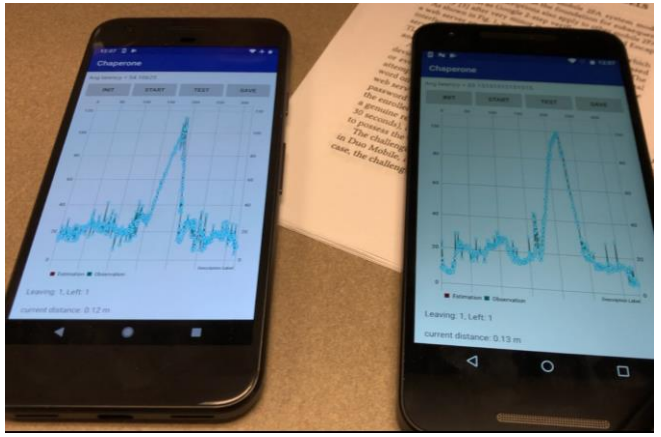


Lab experiments

- Controlled experiments
- Phone orientation angles
- Departing speeds
- Nearby stranger

Real-world experiments

- Eight experimenters at eight real-world scenarios
- **366** departure events and **391** everyday activities
- Simulate smartphone loss with different settings



Interference factors

- Close object
- Concurrent sensing

Lab experiments

- Combination of departing speeds and phone orientation angles
  - Departing speeds: slow, normal, fast
  - Phone orientations: 0 (vertical), 45˚, 90˚ (horizontal)
  - 15 times for each combination (135 departure events)
  - **Only 2 false negatives for (fast, 90˚)**

Real-world Experiments

- Eight locations
  - Library, office, restaurant, coffee shop, lounge, bus stop, in-vehicle and academic venue
- Use lab experiment data for classifier training
- Overall precision: **93%**, recall **96%**
- In 95% of successful cases, Chaperone can detect a potential device loss **within 500ms**







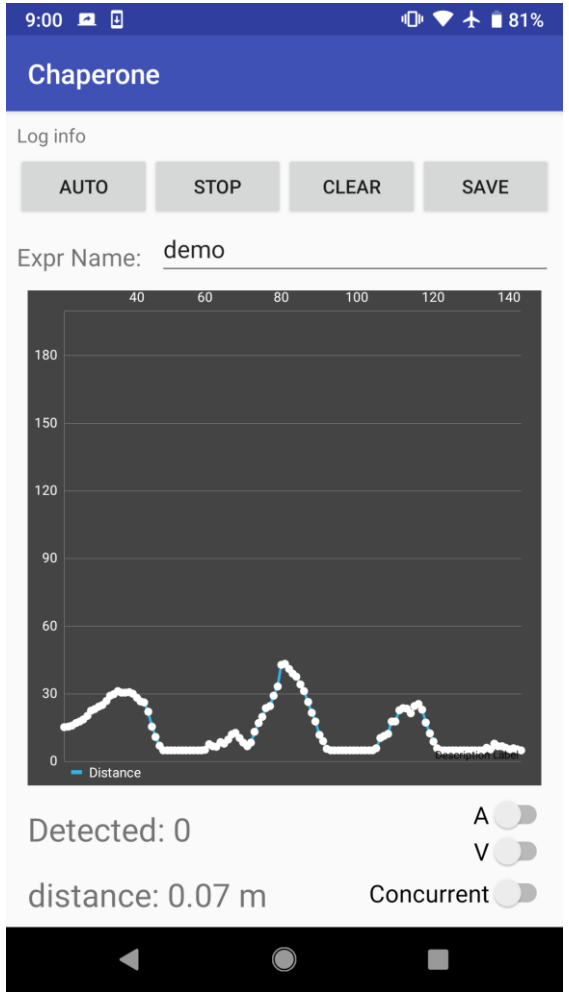

Example: Bus Stop

- A small glass-enclosed waiting area and an open-air bench
- Noise from passing vehicles
- Several people waiting or passing by

- **92%** precision with no false negatives

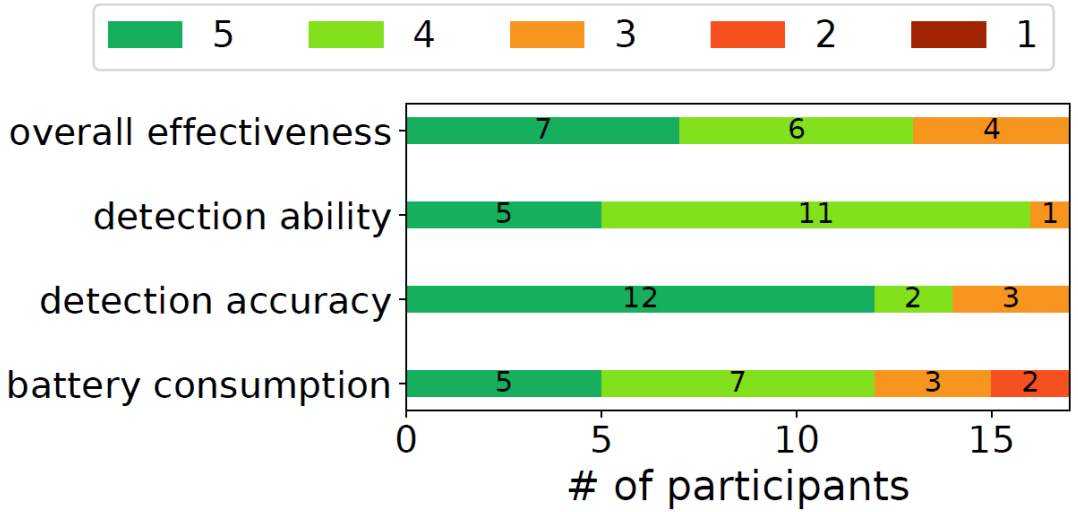
User Study

- Semi-structured interview with demo session
  - 17 participants
  - Restaurant scenario
  - A demo of Chaperone with real-time trace display
- Learn about
  - Smartphone loss experience
  - Perception of Chaperone
  - Effectiveness of ringtone alerts



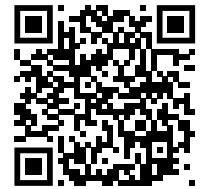
User Study Results

- Perception of Chaperone
  - **13/17** participants are satisfied with overall effectiveness of Chaperone
- Effectiveness of ringtone alert
  - Simulate a smartphone loss without knowing the ringtone
  - **16/17** Participants noticed the ringtone
  - Participants expect different alert methods for different scenarios



Conclusion

- Summary
  - Proposed a standalone real-time smartphone loss prevention solution
  - Conducted extensive experiments to evaluate the detection performance
  - Conducted a user study to obtain perceptional results and study alert methods
- Future work
  - Systematic study on specific environmental factors
  - Long-term user study
  - Adaptive alert schemes
- Source code & dataset: https://github.com/cryspuwaterloo/chaperone
- Email: jiayi.chen@uwaterloo.ca
- Thank you!



Chaperone