ShopMiner:
Mining Customer Shopping Behavior in Physical Clothing Stores with COTS RFID Device

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Background

Shopping is something we do almost every day!

Thousands of excuses for shopping:

- ***Paper accepted,***
- ***Get promoted,***
- ***Down,***
- ***Lonely,***
- ***Angry,***
- ***Just hungry…***

People spend 150+ hours / month and 2000 hours / year on shopping!

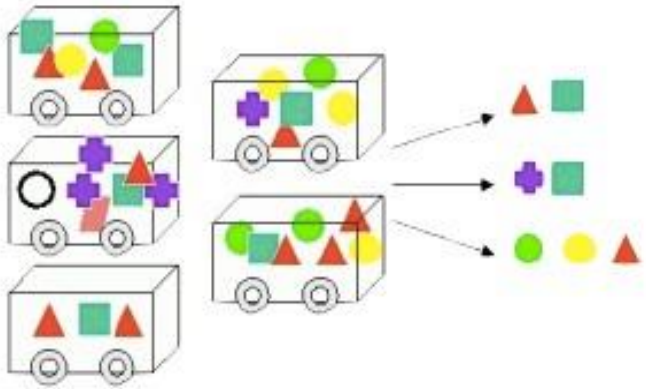
Background

Huge market → More retailers → Less profit

Trading strategy optimization!

⇩

Data collection + **Data mining**



Background

Online shopping

Cookies

Shopping cart

Massive data

Background

Online shopping

Cookies

Shopping cart

Offline shopping

Cameras

Expensive/LOS

Bills

Lack detailed info.

Focus: shopping behaviors before final purchase

Research Target

Goal:

Design an **effective, low-cost, non-intrusive** system for customer **shopping behavior** mining

Solution:

Passive Radio Frequency Identification (RFID) Technology

Target scenario

Hardware setup

Research Target

Typical shopping process:

Standing in front of items

Turning over or picking up interested items

Matching and trying on

Research Target

Typical shopping process:

Standing in front of items

Turning over or picking up interested items

Matching and trying on

Popular category

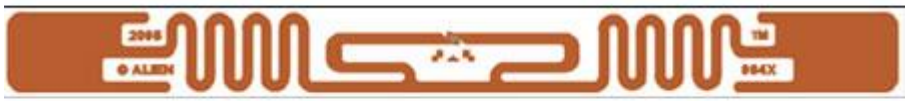
Hot items

Correlated items

Shopping behavior semantics

Research Target

Information accessible on standard APIs:

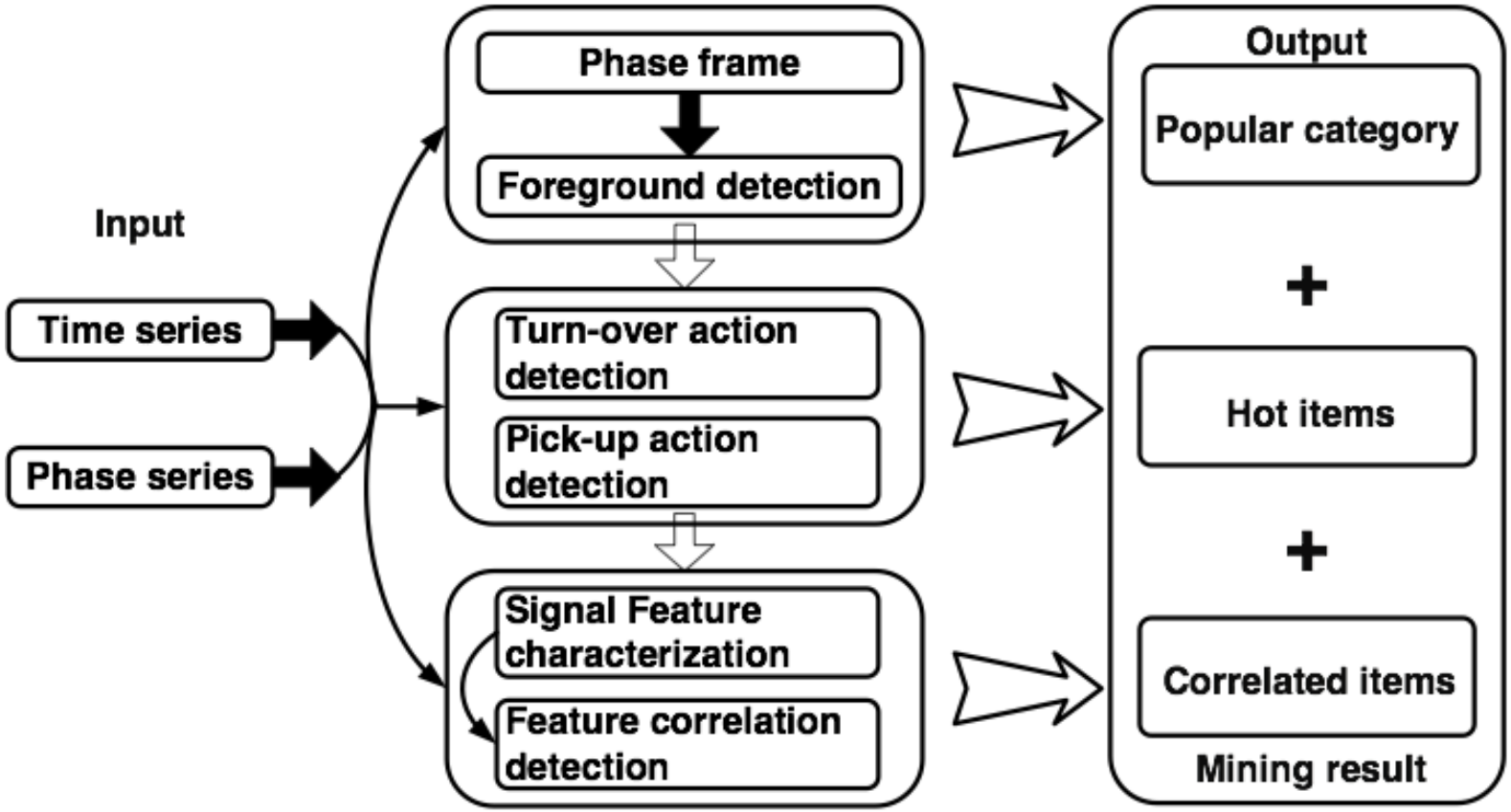


RSS	**Phase**	**Doppler**
Unstable		**Inaccurate**

Phase measurements as the only input

Han et al. [ICNP'14]

ShopMiner Architecture

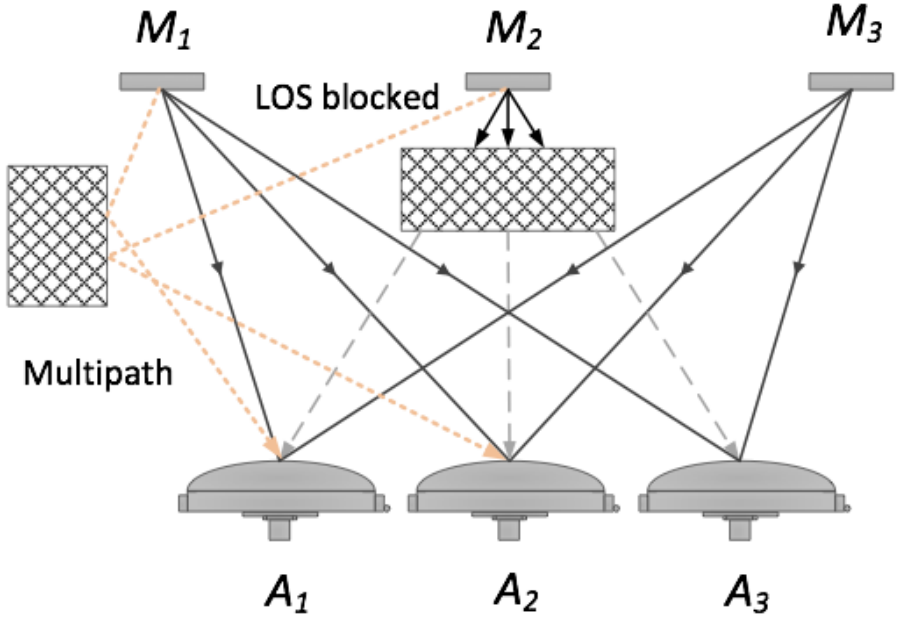


Design: Discover Popular Category

Task: **discover popular category**

Behavior: **detect customer presence in front of items**

Idea: **exploit body shadowing on RF links**



(a): LOS path blocked/multipath

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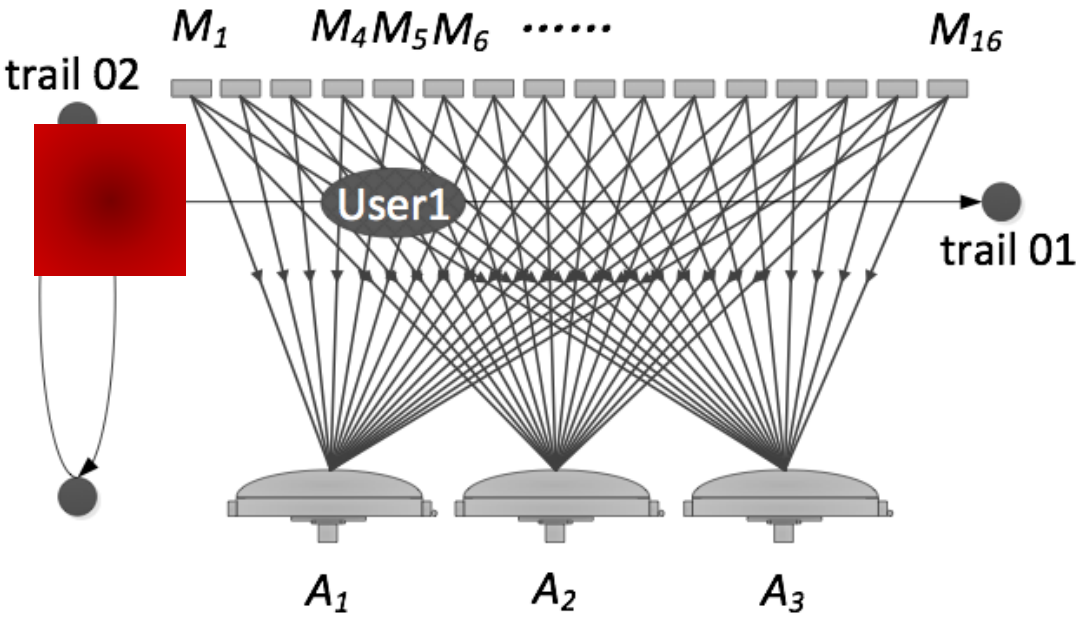

(b): moving trail of a user

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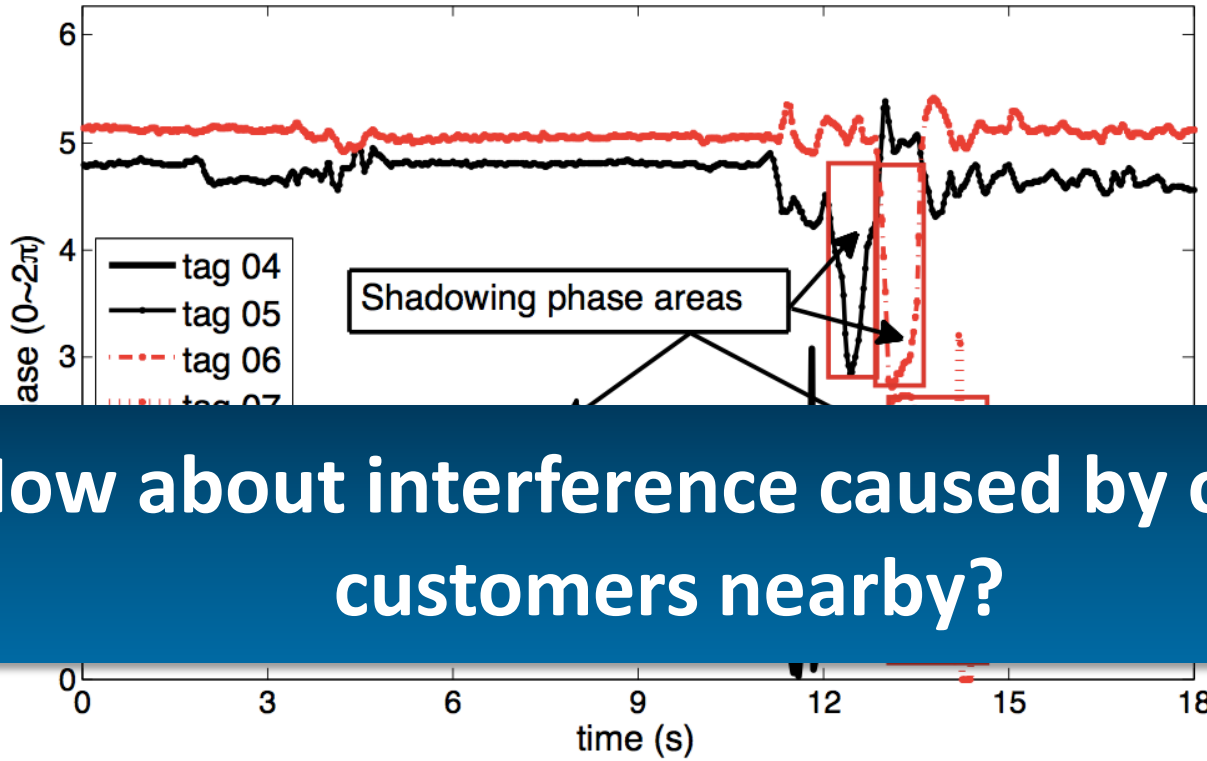

How about interference caused by other customers nearby?

Design: Discover Popular Category

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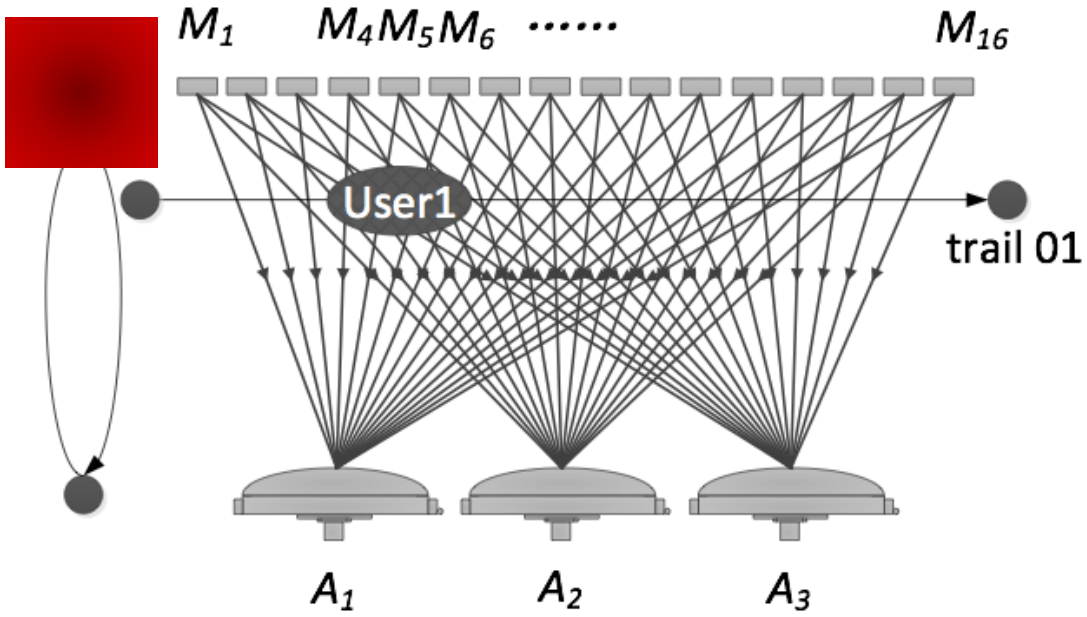

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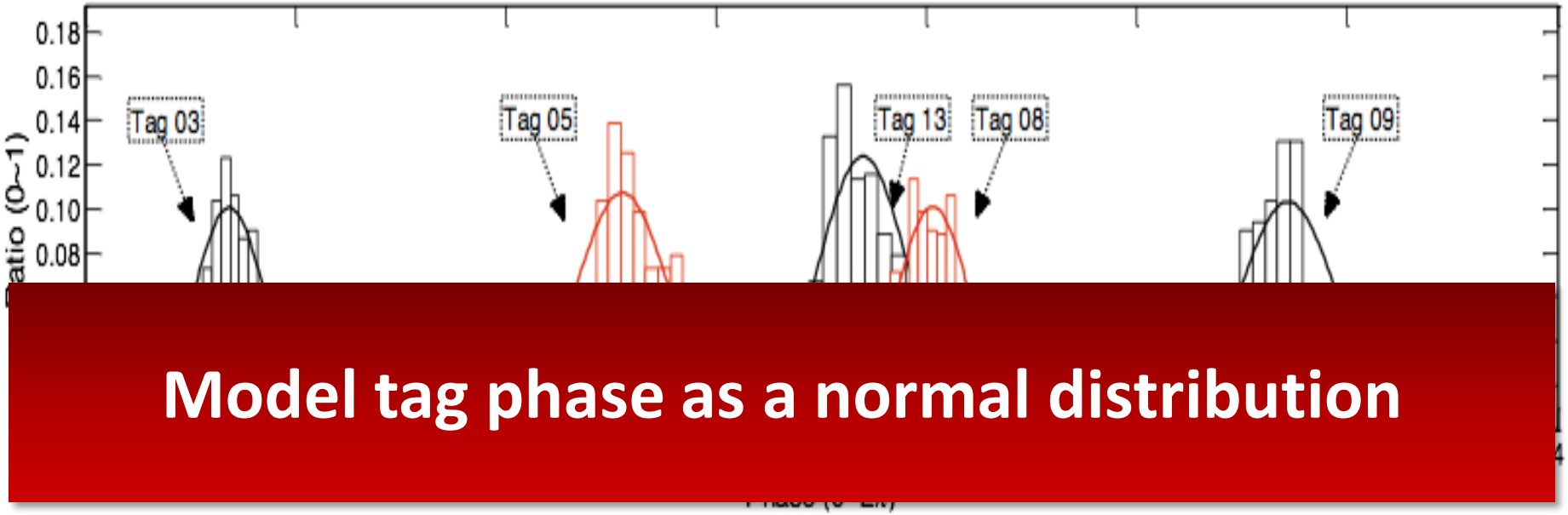
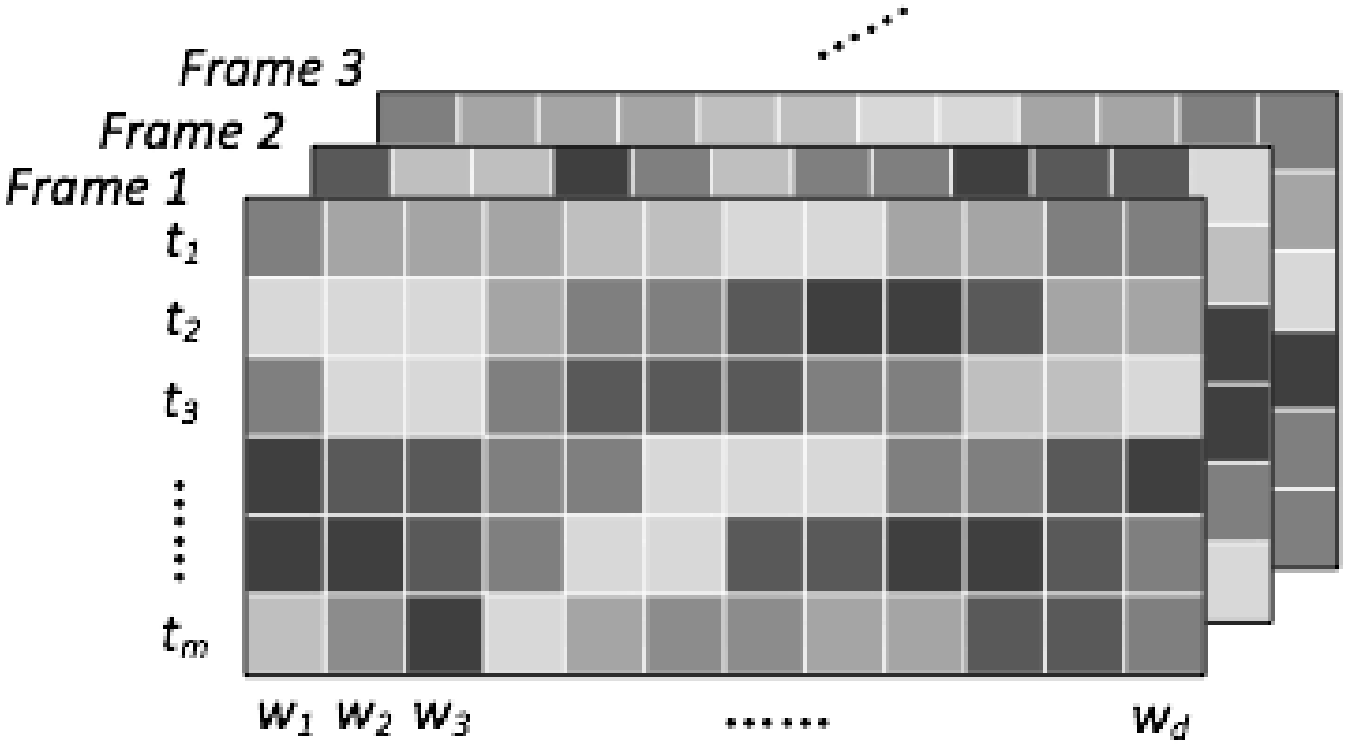


Model tag phase as a normal distribution

Design: Discover Popular Category

Detection scheme: similar to object tracking in CV

Step 1: Composing phase frames



Design: Discover Popular Category

Detection scheme: similar to object tracking in CV

Step 2: Foreground detection

$$\begin{cases} H_0 : r_{i,j} \notin \left(\mu_i \pm \frac{\sigma_i}{\sqrt{k_i}} \cdot z_{\alpha/2}\right) \\ H_1 : r_{i,j} \in \left(\mu_i \pm \frac{\sigma_i}{\sqrt{k_i}} \cdot z_{\alpha/2}\right) \end{cases}$$

Phase reading of the i-th tag collected within the j-th window

Design: Discover Popular Category

Detection scheme: similar to object tracking in CV

Step 3: Popular category discovery

$$\begin{cases} H_0 : s_i \geq \theta \\ H_1 : s_i < \theta \end{cases}$$

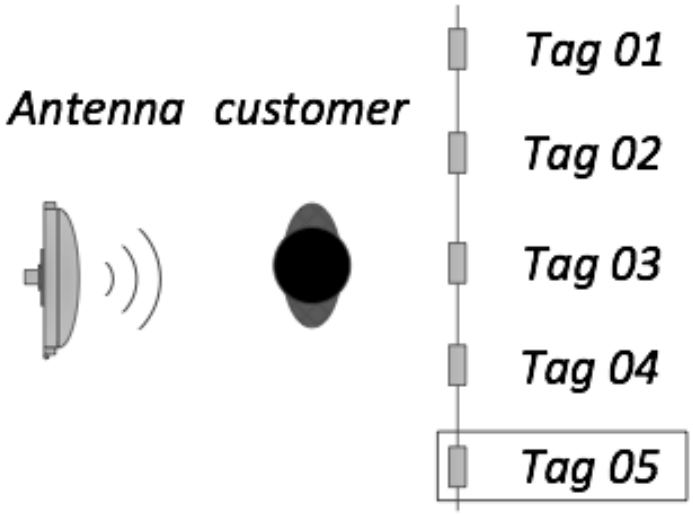
# of consecutive frames that the links of the i-th tag are blocked

Design: Identify Hot Items

Task: **identify hot items**

Behavior: **detect turn-over / pick-up actions**

Idea: **exploit phase trends among nearby tags**

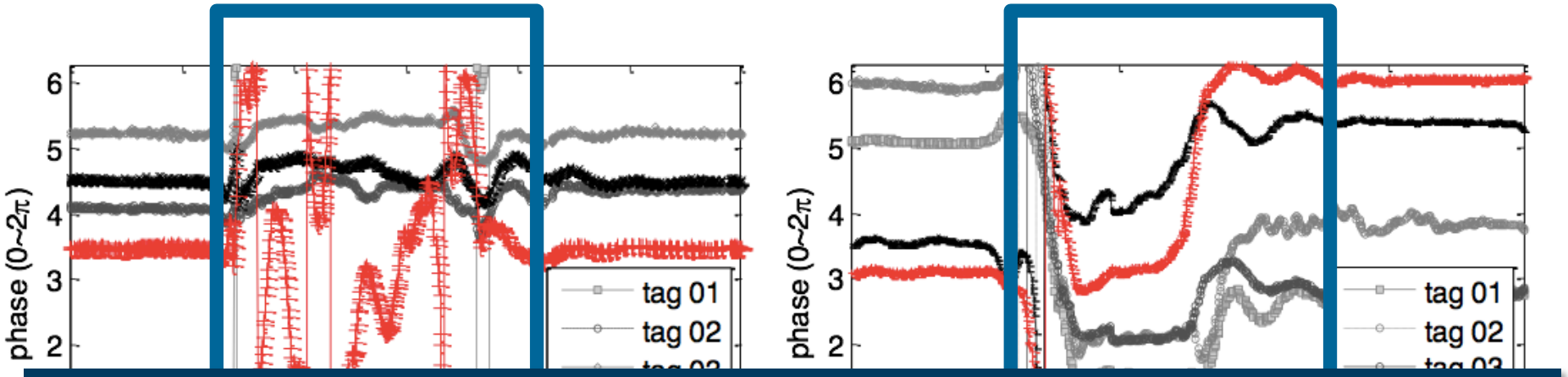


Design: Identify Hot Items

Task: **identify hot items**

Behavior: **detect turn-over / pick-up actions**

Idea: **exploit similarity of pick-up and turn-over**



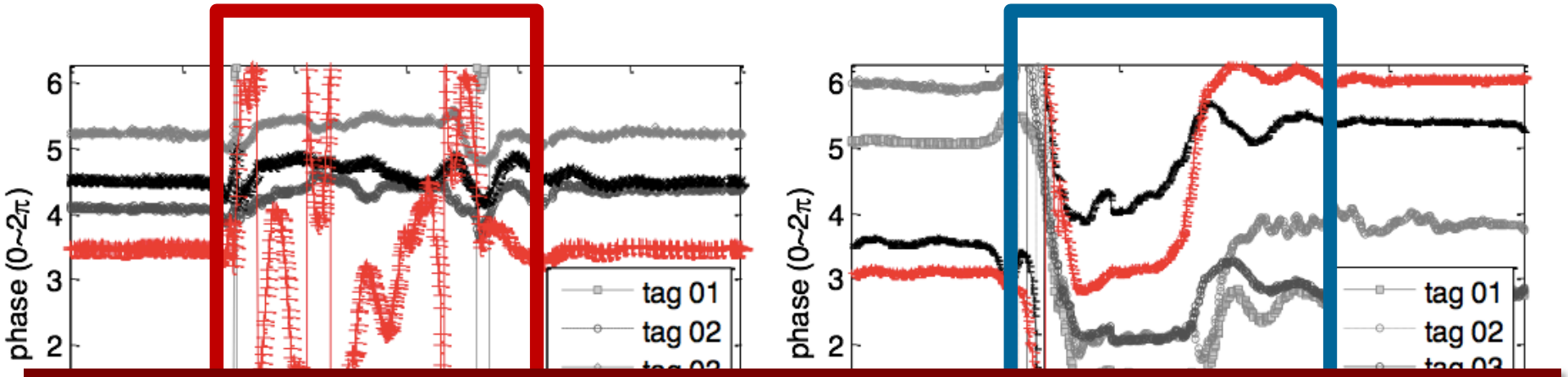
Dramatic phase changes
for both pick-up and turn-over

Design: Identify Hot Items

Task: **identify hot items**

Behavior: **detect turn-over / pick-up actions**

Idea: **exploit dissimilarity of pick-up and turn-over**

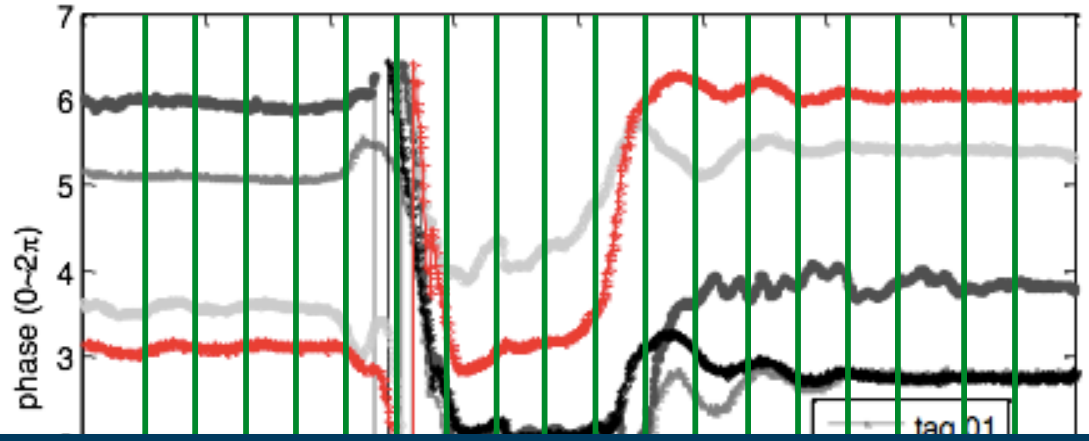


Turn-over leads to similar phase changes among nearby tags

Design: Identify Hot Items

Detection scheme

Step 1: Segmentation (sliding window + KL divergence)

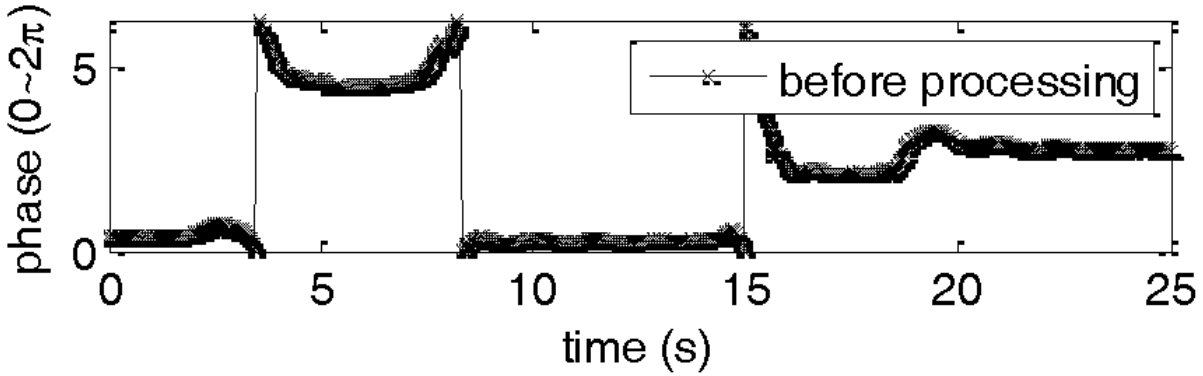


Filter out silent periods (no pick-up or turn-over actions)

Design: Identify Hot Items

Detection scheme

Step 2: Calibration (de-periodicity)

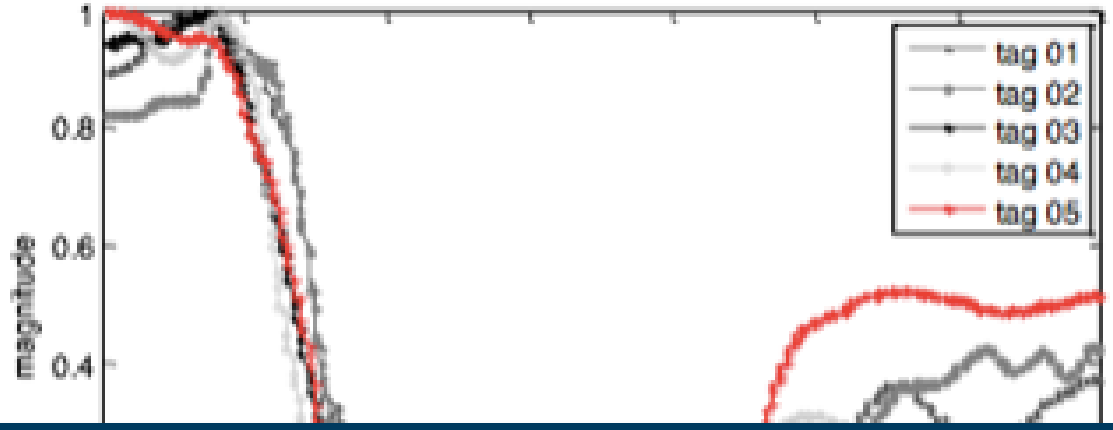


Eliminate abrupt phase jumps

Design: Identify Hot Items

Detection scheme

Step 2: Calibration (normalization)



Keep the changing trend only

Design: Identify Hot Items

Detection scheme

Step 3: Auto-correlation

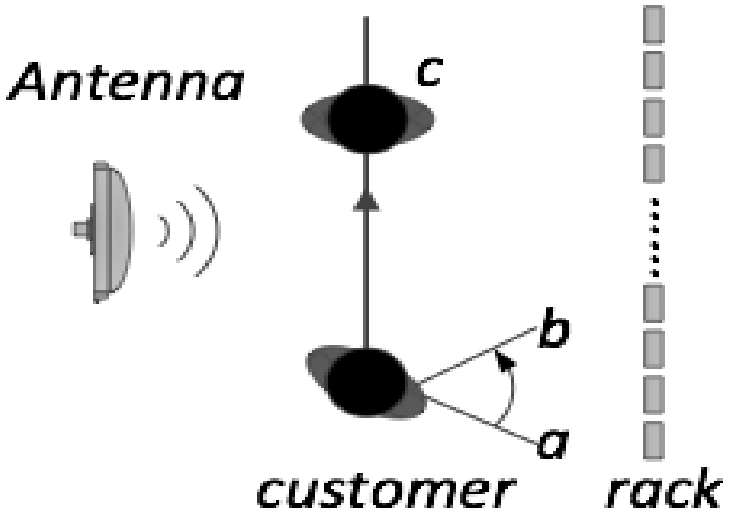
$$\chi(m,\tau) = \frac{\sum_{k=0}^{k=\tau-1}[s_{m+k} - \mu(m,\tau)][s_{m+k+\tau} - \mu(m+\tau,\tau)]}{\tau \cdot \sigma(m,\tau) \cdot \sigma(m+\tau,\tau)}$$

- if $\chi(m,\tau) \geq \delta$, then *action* = *turn-over*;
- if $\chi(m,\tau) < \delta$, then *action* = *pick-up*;

Design: Extract Correlated Items

Task: **extract correlated items**

Idea: **correlated items have similar spatial-temporal correlation of signal trend due to similar moving trail**



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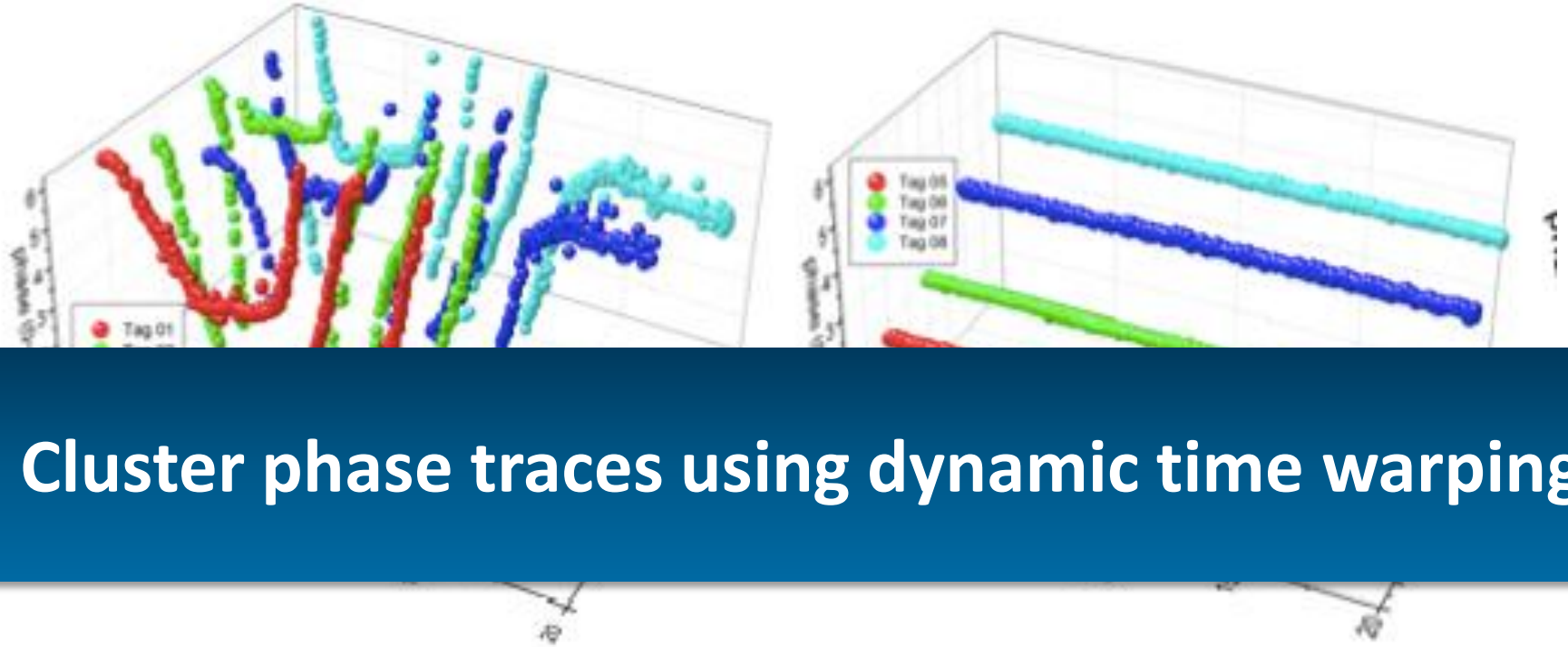


Cluster phase traces using dynamic time warping

Implementation

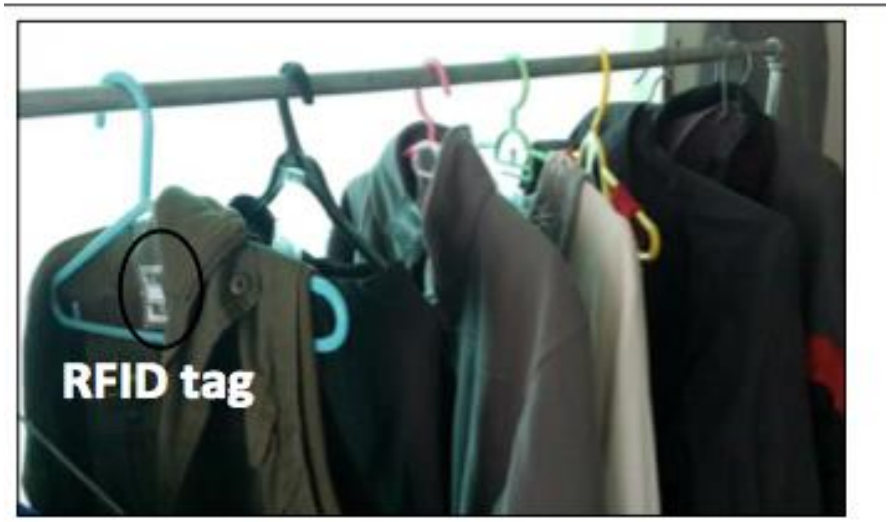
Antenna Yeon YAP-100CP antenna

Reader ImpinJ R240 reader

Tags Alien AZ-9634 passive tags

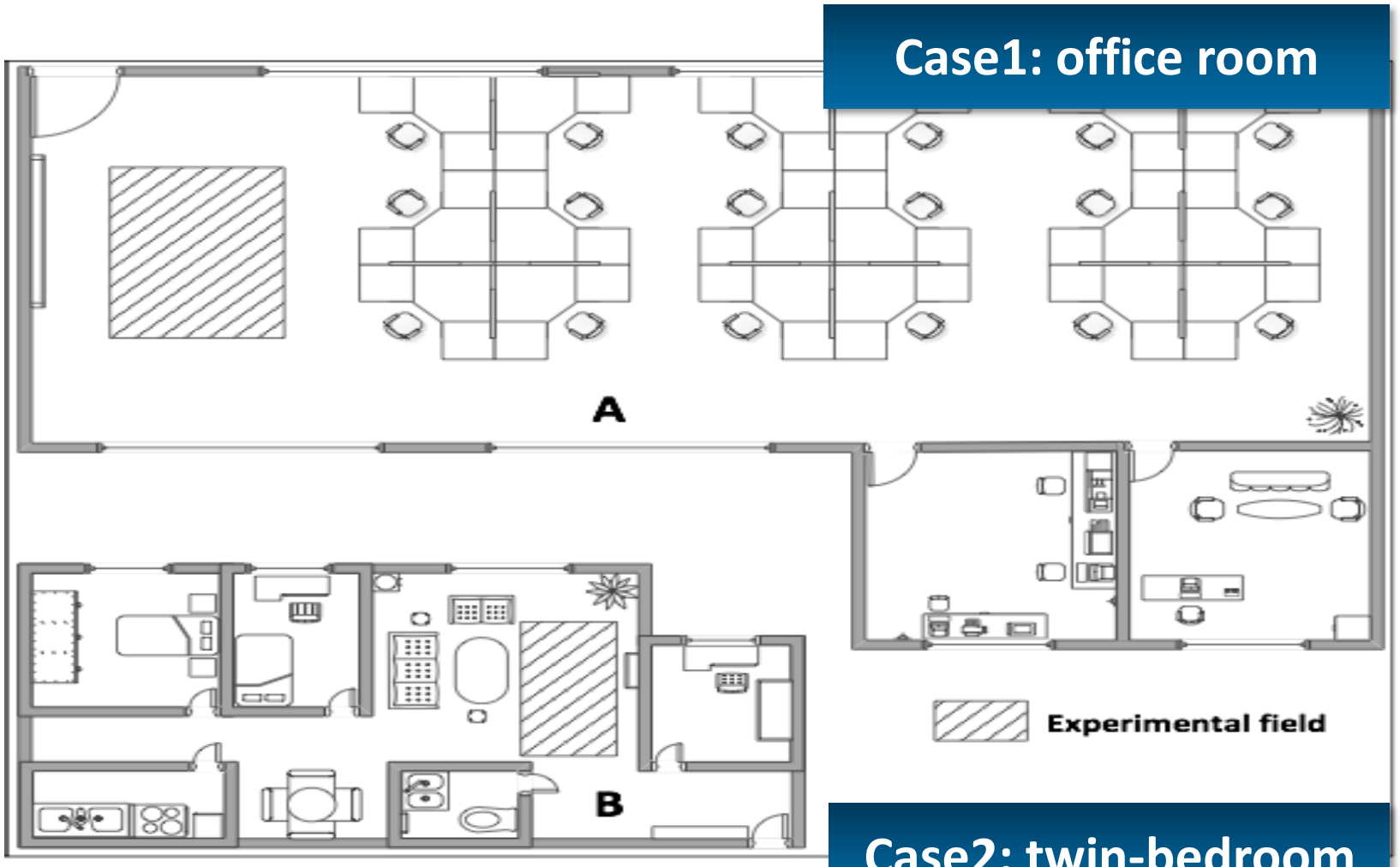
All commercial off-the-shelf devices!

Evaluation

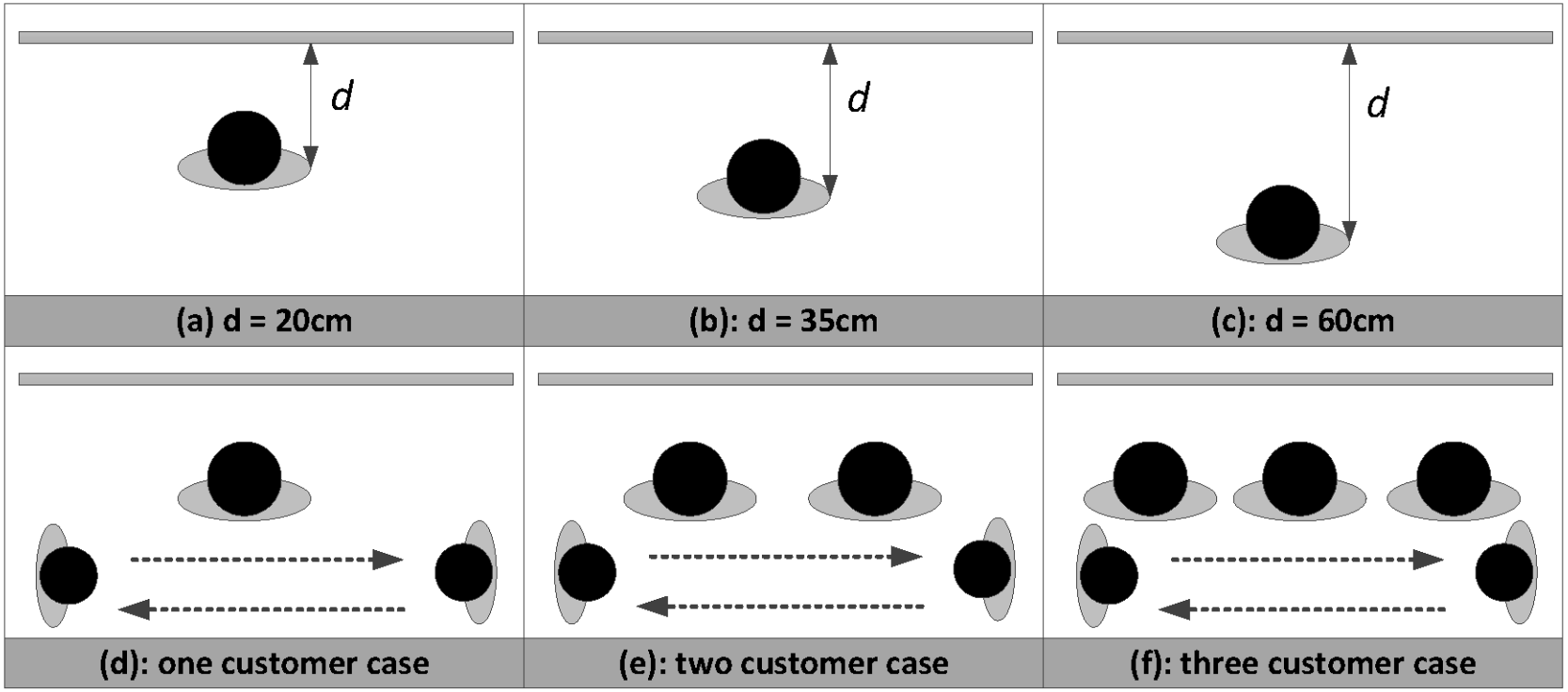


20 items per rack, adjacent space 5cm

Evaluation

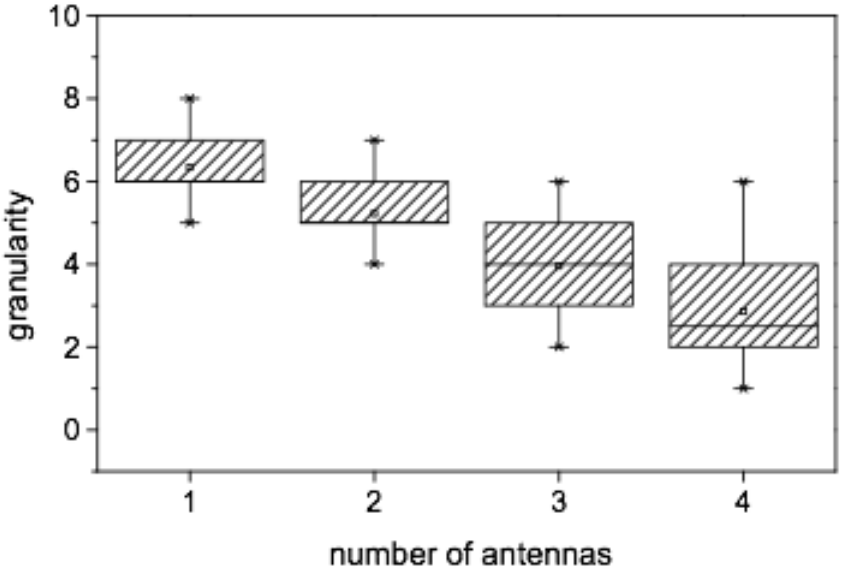

Case1: office room
A
B
Experimental field
Case2: twin-bedroom

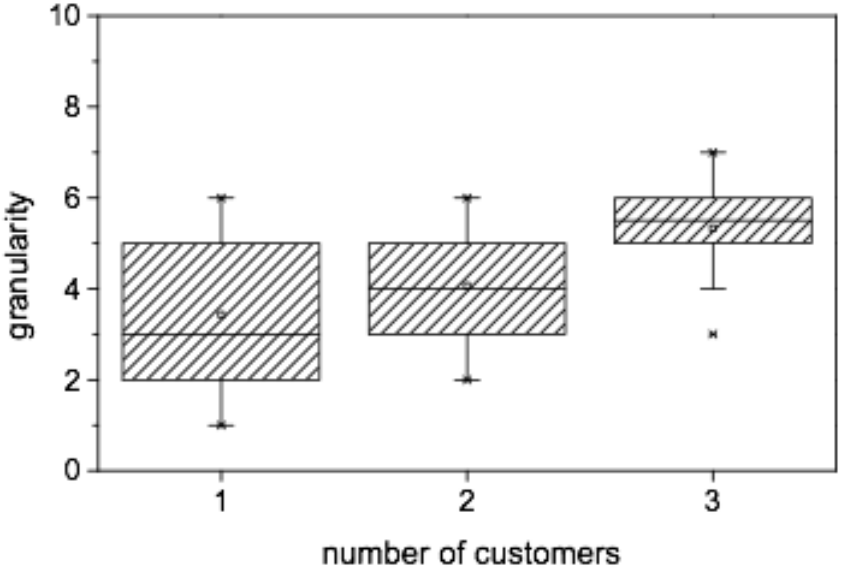
Evaluation



3 different item-customer distances
1 to 3 customers with nearby interferences

Performance: Popular Category





Granularity vs. # antennas

Granularity vs. # nearby users

More antennas bring higher accuracy
Relatively robust to interference from nearby users

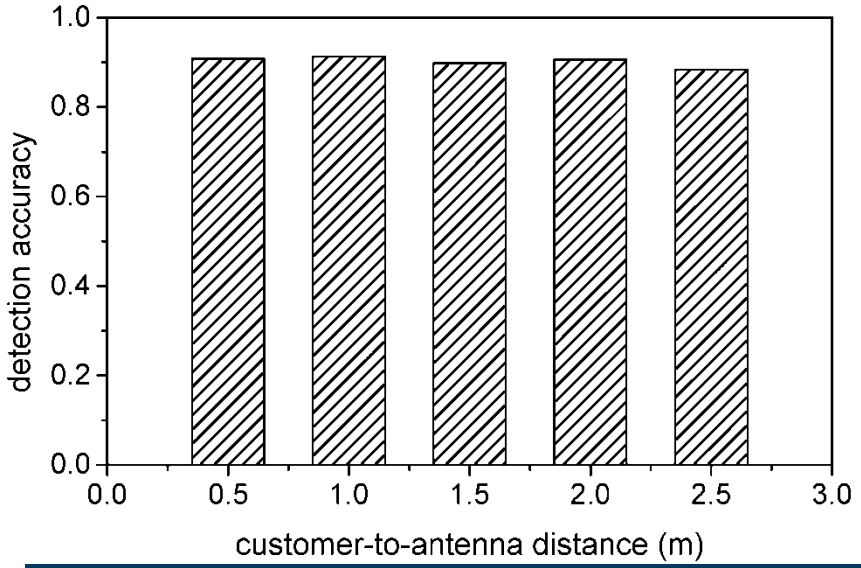
Performance: Hot Items

Ground-truth	Predicted					
	Turn over			Pick up		
	1	2	3	1	2	3
Turn over	187	184	178	13	16	22
Pick up	9	10	13	191	190	187

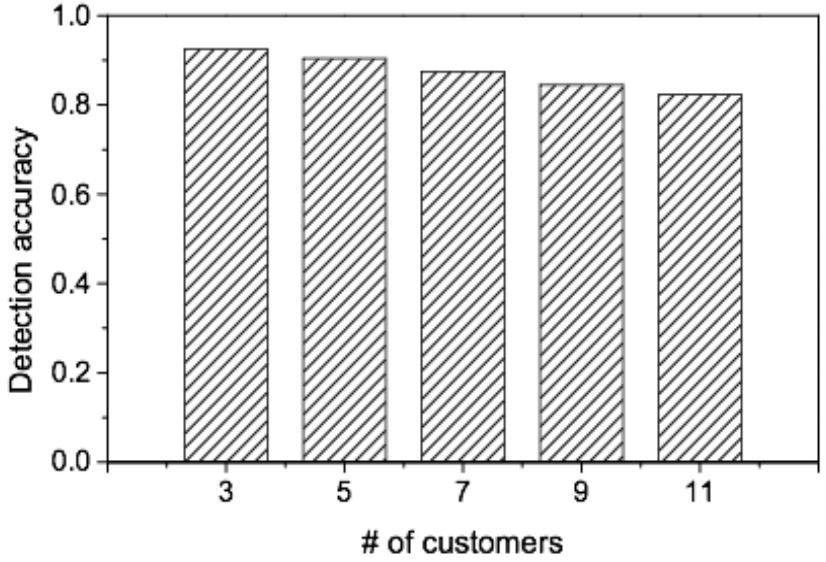
Detection accuracy: 94% (pick-up), 87% (turn-over)

Relatively insensitive to # of customers

Performance: Correlated Items



Accuracy vs. distance



Accuracy vs. # customers

Detection accuracy: 93% (1 user), 85% (6 users)
Robust to antenna-customer distance

Conclusion

Conclusion:

- **Design an RFID-based customer shopping behavior mining system for physical clothing stores.**
- **Analyze phase patterns to extract shopping semantics for three shopping behaviors**

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Limitations:

- **Deployment cost for full coverage**
- **Crowded stores**
- **Beyond clothing stores**

Q&A