

# Human-object Interaction Reasoning using RFID-enabled Smart Shelf

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# Motivation & Research Objectives



- Context-aware smart shelf leading to real-time events detection
- Indirect events detection only using RFID (no sensors or vision)
- High and low-level features analytics from standard UHF RFID equipment to identify interaction
- IoT technology leading to events reasoning in physical spaces

# Related Work (I)

Combining RFID with vision or sensors data



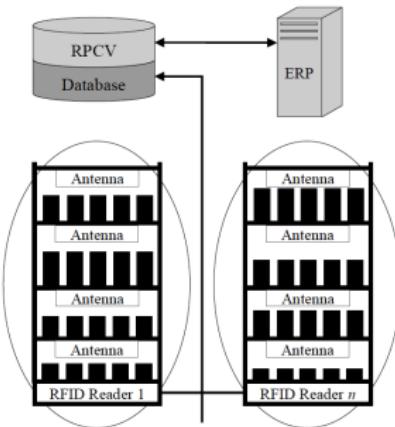
Wu et al., *A Scalable Approach to Activity Recognition based on Object Use*, 2007.



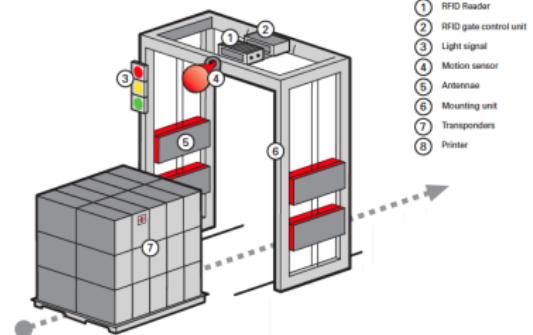
Schmitz et al., *The Digital Sommelier: Interacting with Intelligent Products*, 2008.

# Related Work (& II)

Only using RFID data



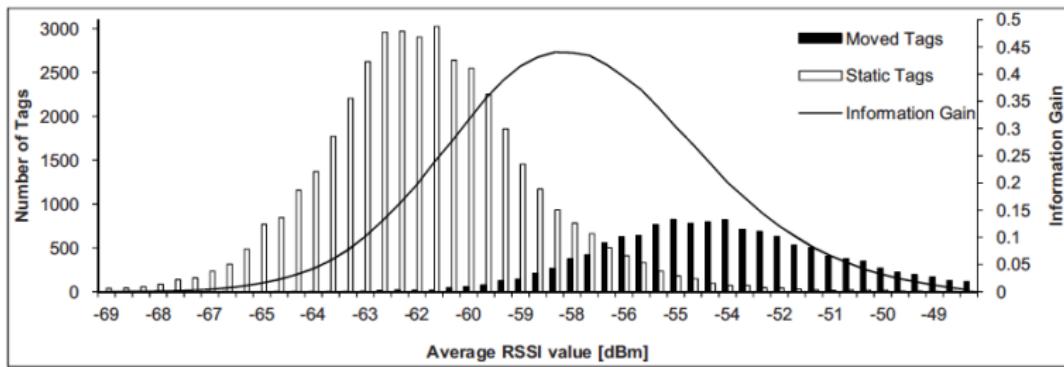
Weiss et al., *Finding Misplaced Items in Retail by Clustering RFID Data*, 2010.



Keller et al., *Using Low-Level Reader Data to Detect False-Positive RFID Tag Reads*, 2010.

## Related Work (& II)

Also using low-level RFID data



Keller et al., *Using Low-Level Reader Data to Detect False-Positive RFID Tag Reads*, 2010.

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# RFID in the Smart Shelf



- Electronic Product Code Class 1 Generation 2 (EPC Gen2)
- Widely used for object identification (i.e. retail)
- Used for object detection and location in smart shelves

# EPC Gen2 Antenna Multiplexing



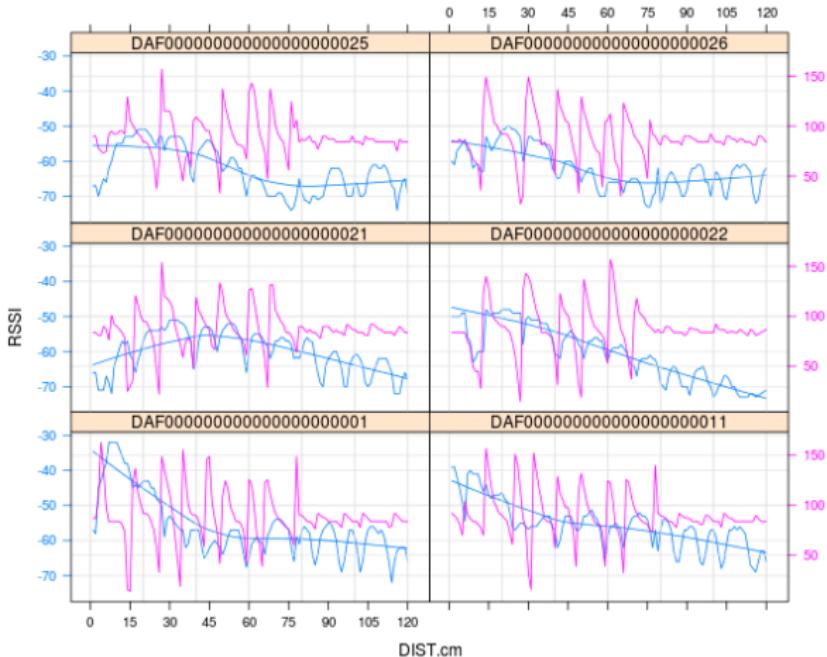
- Antenna multiplexing based on RF channel time multiplexing
- Used in retail (i.e. smart shelves) to reduce costs
- Adds temporal uncertainty for objects identification

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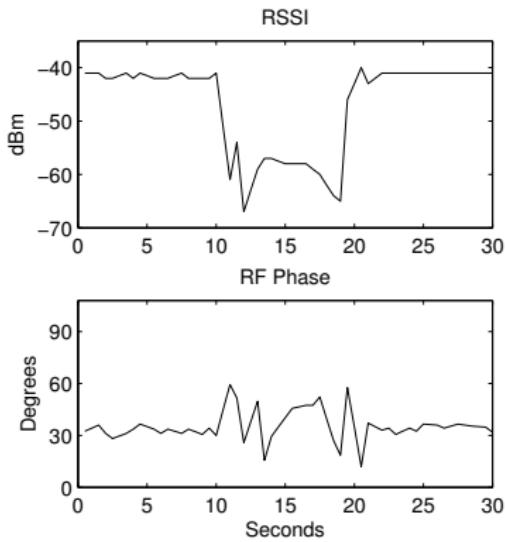


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# High & Low-level RFID Features (I)



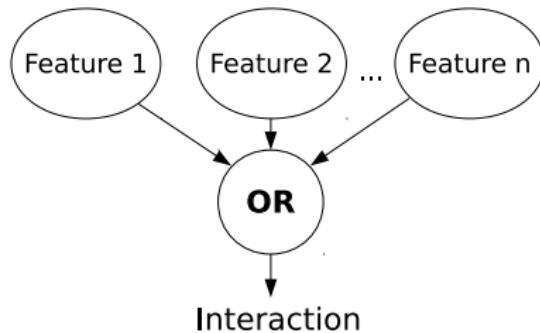
# High & Low-level RFID Features (& II)



- RSSI decreases with distance
- RF Phase varies with distance
- Antenna-based analysis provides other features to include in the model (i.e. number of antennas detecting an object)

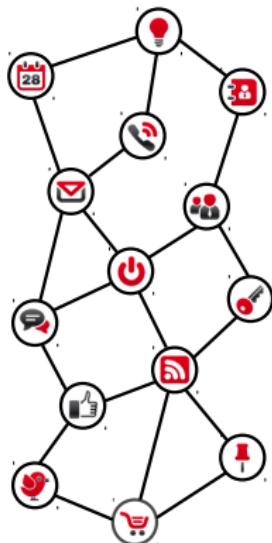
# Interaction Modeling & Reasoning

Noisy-OR model:



$$P(y|X'_i) = 1 - \left[ (1 - \lambda_0) \prod_{i=1}^z (1 - \lambda_i) \right]$$

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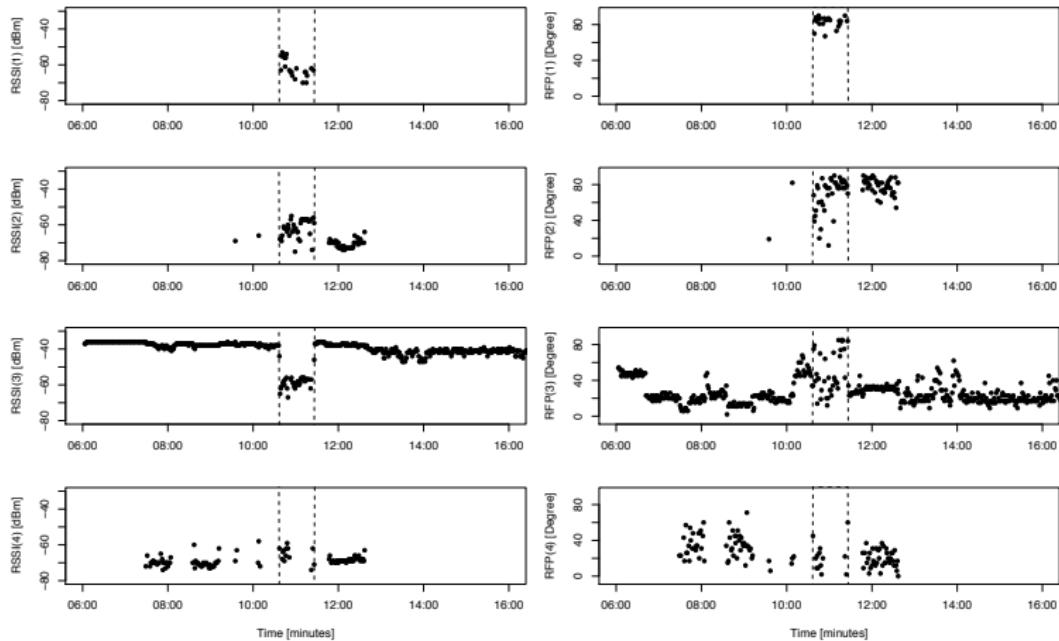
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# Experimental Setup (I)



- EPC Gen2 Reader:
  - ThingMagic M6e (ETSI)
  - Tx power: 31.5 dBm
  - Sensitivity: -80 dBm
  - Read time: 200ms + 50ms processing
  - Q value: Dynamic
- 4 antennas:
  - Directivity: ~100 Degree
  - Gain: 3.2 dBi
- Tags: AK UHF tags

# Experimental Setup (& II)

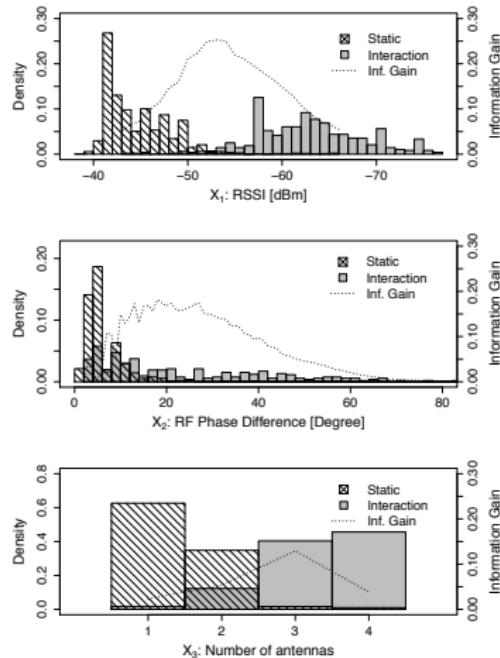


# Experimental Results (I)

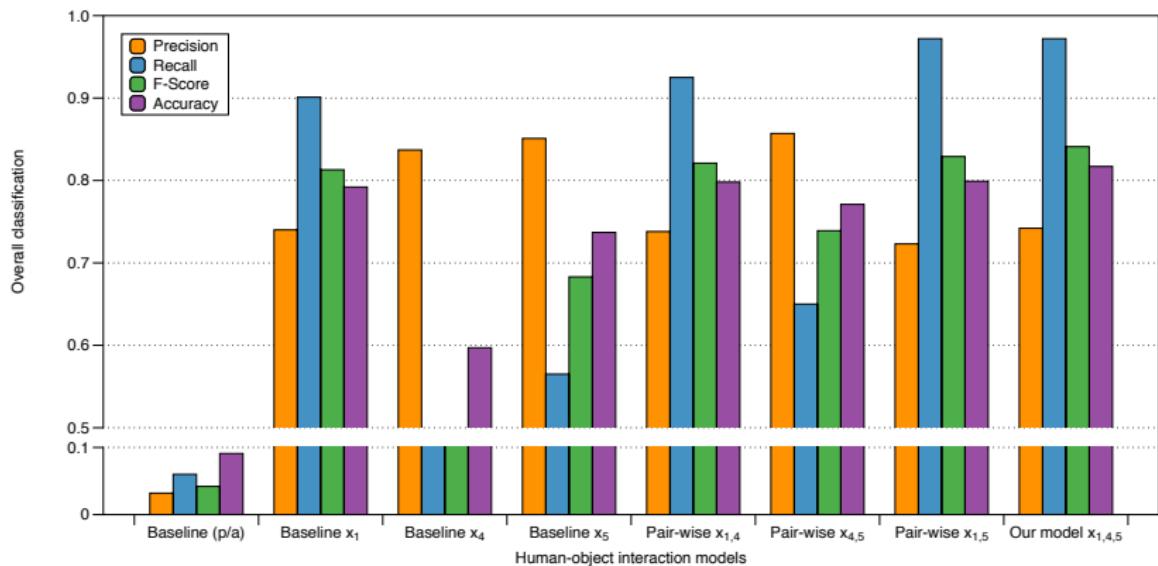
Summary of Information Gain analysis  
from Smart Shelf data:

Parameter	Range	Threshold	max(IG)	$\lambda_i$
$x_1$ : RSSI	-76:-36	-54	<b>0.26</b>	0.78
$x_2$ : $ \Delta \text{RSSI} $	0:27	9	0.03	0.43
$x_3$ : RFP	0:177	168	0.04	0.50
$x_4$ : $ \Delta \text{RFP} $	0:84	18	<b>0.14</b>	0.64
$x_5$ : #Ant	1:4	3	<b>0.13</b>	0.74

RSSI unit is dBm and RFP unit is Deg.



# Experimental Results (& II)



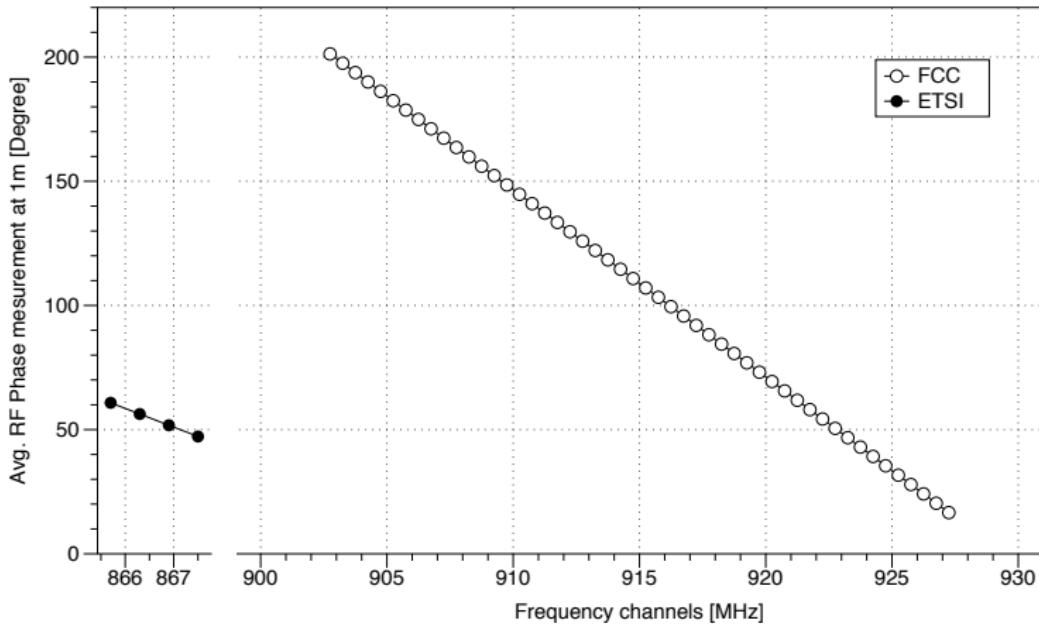
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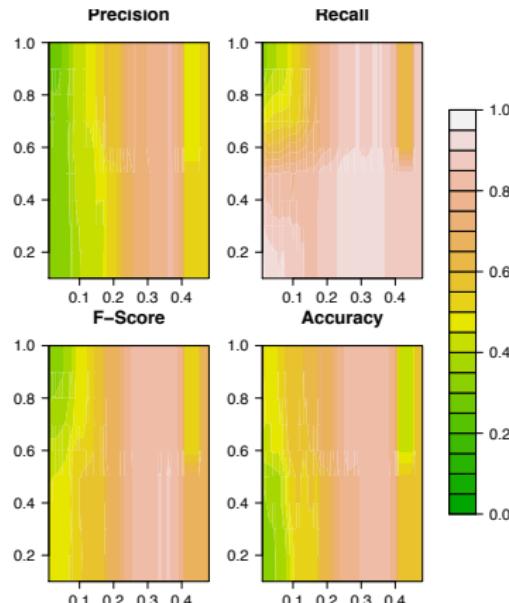
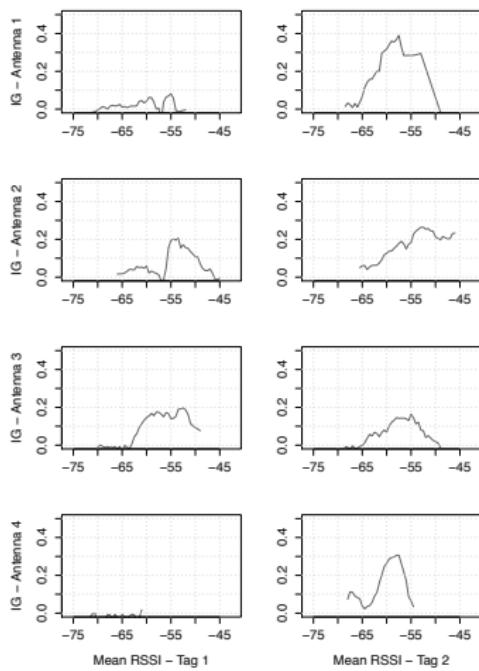
# Future Work (I)

ETSI vs. FCC frequency-hop effect on phase measurement



# Future Work (& II)

## Antenna and object-wise Information Gain analysis



# Conclusion & Research Contributions

- Reliably reasoning human-object interactions based on standard RFID technology, leading to digital events in physical scenarios
- High and low-level RFID features to model interactions using machine learning classification
- Enabling IoT in real environments: empirical results return 84.1% accuracy in classifying interactions
- Future work towards features and modeling improvement

# Human-object Interaction Reasoning using RFID-enabled Smart Shelf



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