Large-Scale Human Activity Recognition Using Ultra-Dense Sensing

Matthai Philipose
Intel Research

SHARP group members:
T. Choudhury, S. Consolvo, K. Fishkin, A. Rea, D. Haehnel, P. Powledge, J. Smith

U. Washington/CMU/MIT collaborators:
G. Borriello, D. Fox, B. Jiang, H. Kautz, A. Mamishev, D. Patterson, S. Roy, A. Sample, K. S.Rajan, E. M. Tapia, D. Wilson, D. Wyatt

Monitoring Human Physical Activity Is…

… an essential aspect of human life

e.g. care-giving, training, managing, surveillance, directing

… difficult and expensive

highly manual, tedious, intrusive

… beyond conventional computing

… at the limits of computing research

Application 1

Filling Activities of Daily Living (ADL) Forms

Activity Class	**Rating (1-5)**
Personal Appearance	
Oral Hygiene	
Toileting	
Washing up	
Appliance Use	
Use of Heating	
Care of clothes and linen	
Making a snack	
Making a drink	
Use of phone	
Leisure Activity	
Infant Care	
Medication Taking	
Housework	

shaving, brushing teeth, combing hair, flossing, gargling, applying make-up, bathing, using microwave, baking, blending, watching TV, doing laundry, mending, folding, putting away laundry, adjusting thermostat, making a sandwich, making a chocolate cake, making a martini, making a milkshake, getting a glass of water, phoning friends, phoning family, phoning caregivers, knitting, watching videos, going for a walk, walking the pet, putting grandson to bed, taking blood-pressure medication, taking vitamins, taking calcium, dusting, tidying, cleaning toilets, vacuuming, cleaning blinds, removing cobwebs, …

Application 2

Managing Best Known Methods (BKMs)

- Optimal methods confer strategic advantage
  - machine rooms, operating rooms, burger franchises
- Managing BKMs involves:
  - Identifying them
  - Training people to use them
  - Monitoring their use
- e.g. Intel maintenance, UW anesthesiology training

Application 3

Activity-Based Reminders

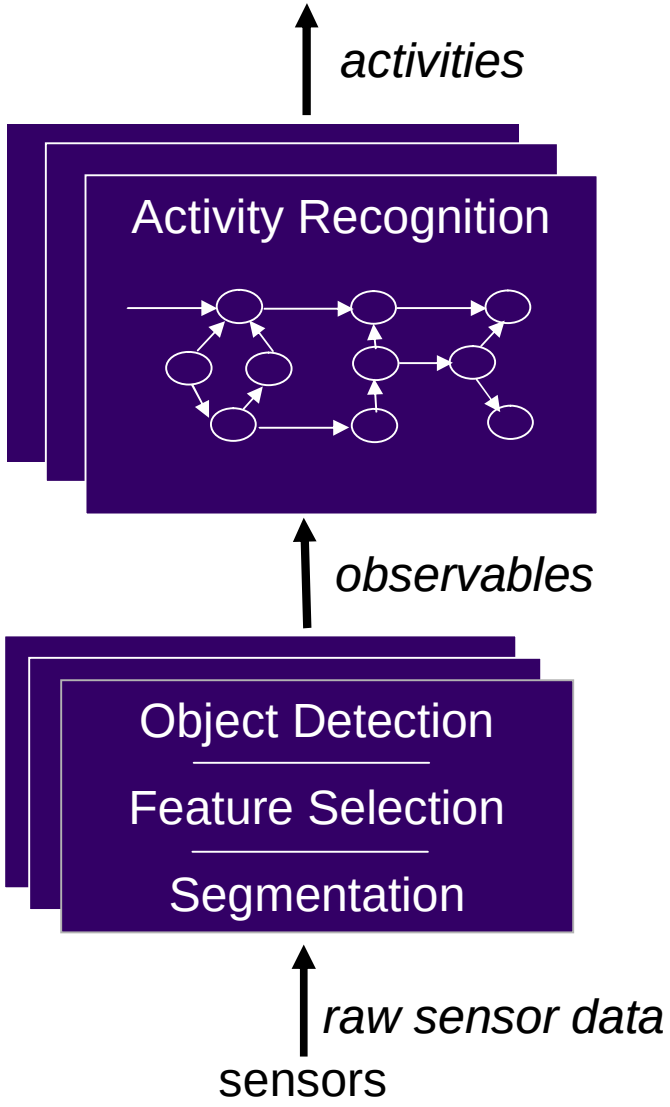
when I eat lunch **remind me to** take my pill

when I change baby's diapers **remind me to** apply cream

when I use the bathroom **remind me to** wash hands

when I use fab oven **remind me to** run debug sequence

The Traditional Architecture



Four scaling challenges:

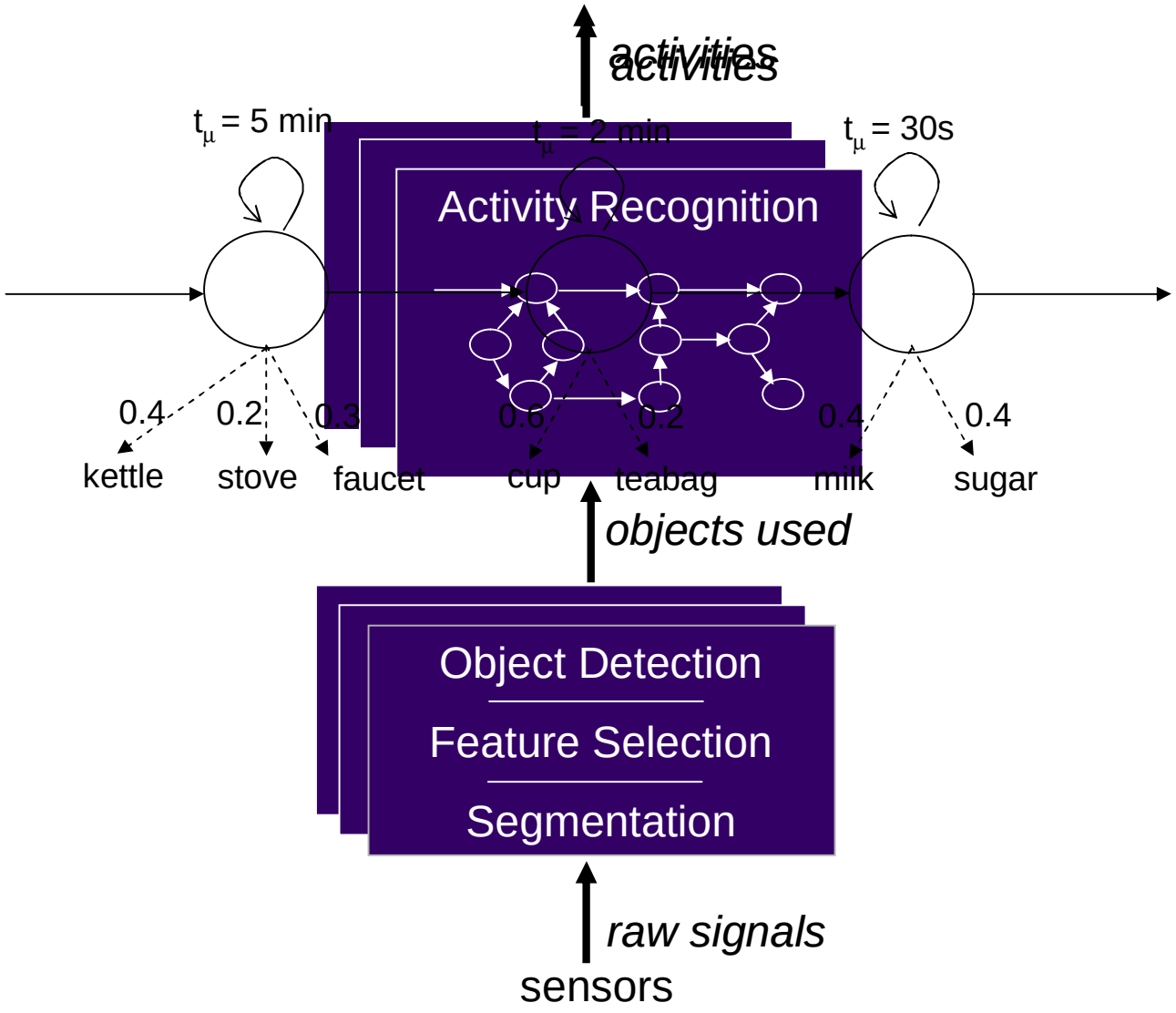
1. Designing low-level sensing
2. Designing model schema
3. Creating models
4. Pinpointing anomalies

Basic Insight

What you use determines what you do

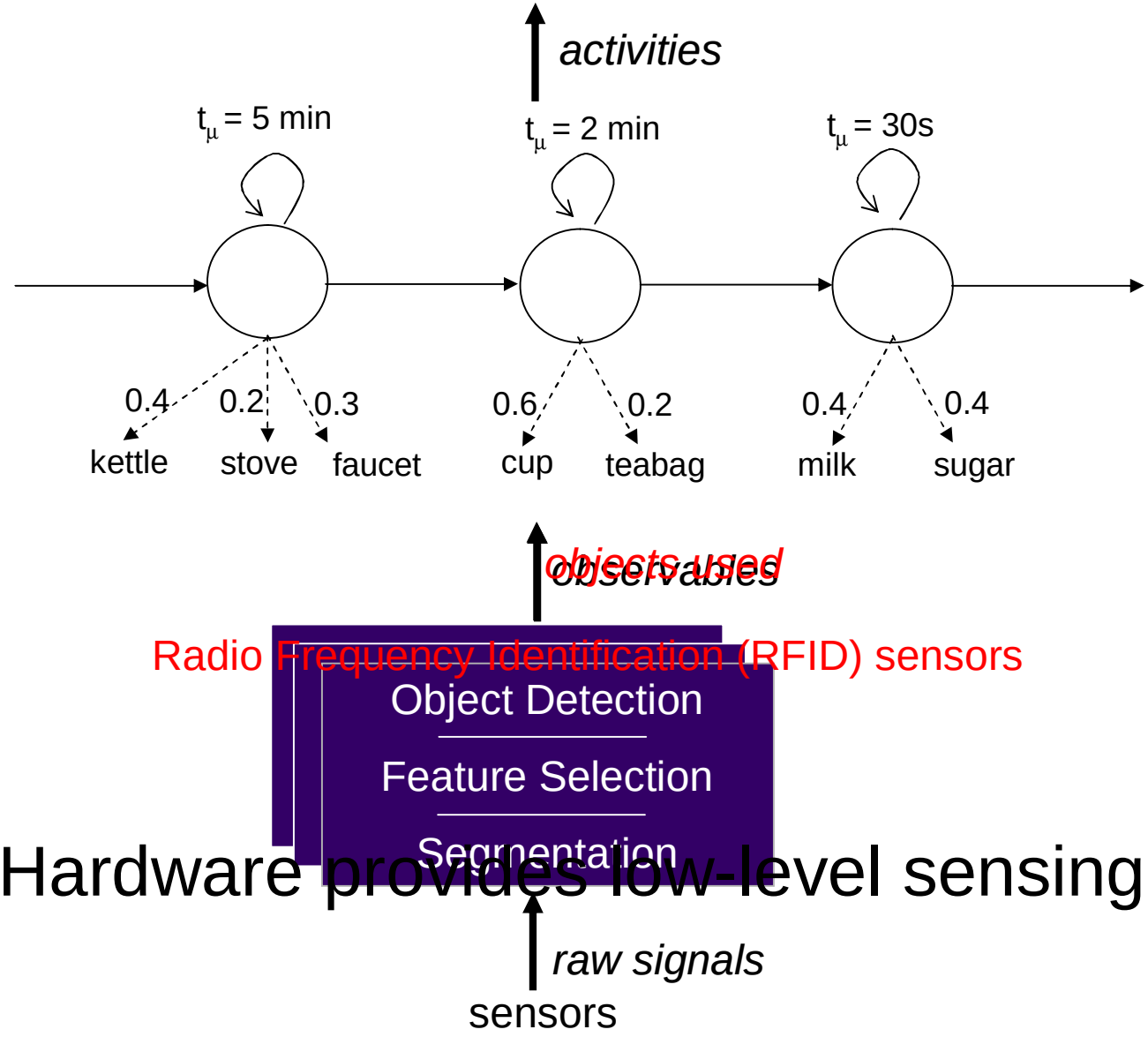
Designing Model Schema

Activities as Object-Use Patterns



Low-Level Sensing

Detecting Object Use



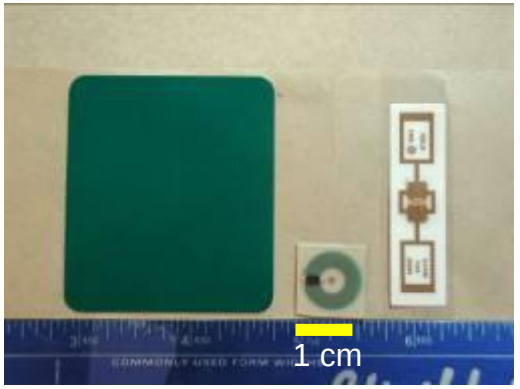
Low-Level Sensing

Radio Frequency Identification (RFID)

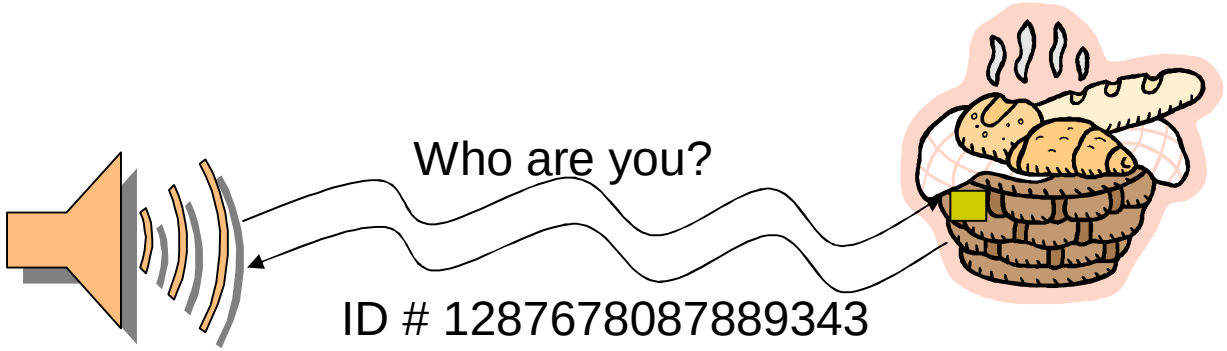
Tiny, 40-cent battery-free **tags**

+

ambient **readers**



Tags return 96-bit ID when queried by readers



<ID = e3f000e13431, desc = “bread basket”, manufacturer = “…”, … >

Low-Level Sensing

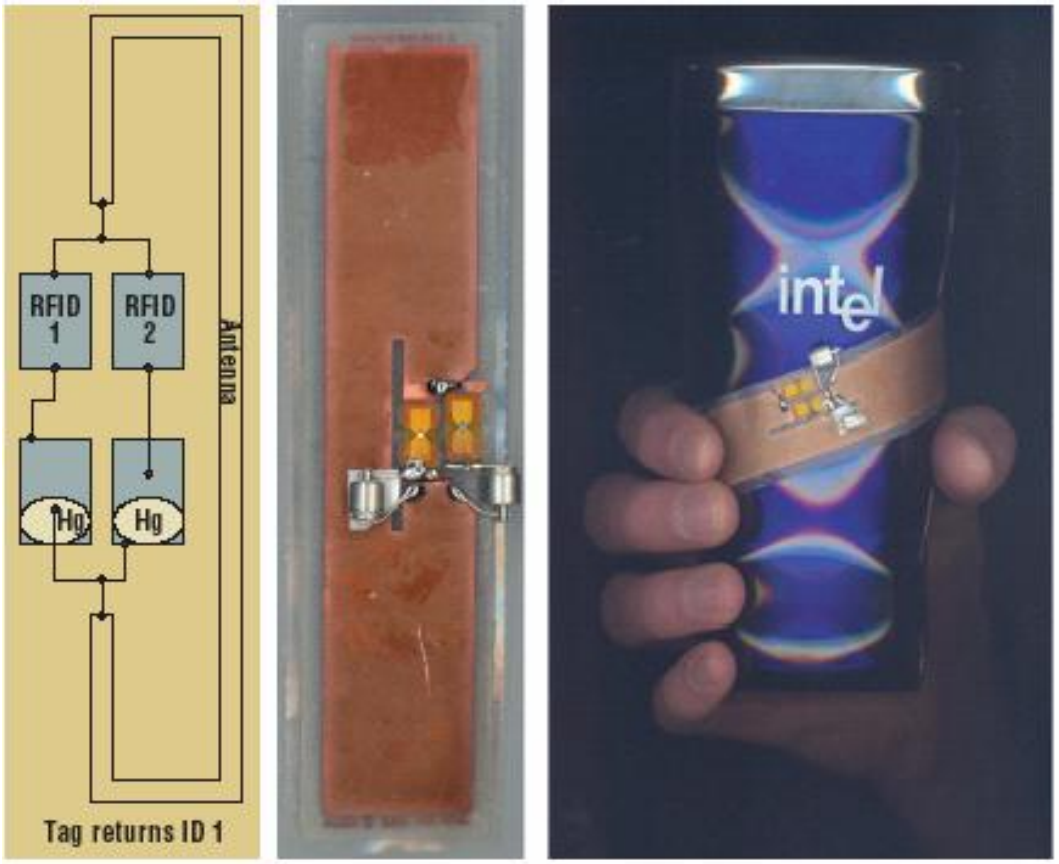
iGlove and iBracelet

13.56MHz reader, mote, power supply, antenna

Objects tagged on grasping surfaces

Low-Level Sensing

WISP: Wireless ID & Sensing Platform



Passive RFID

+

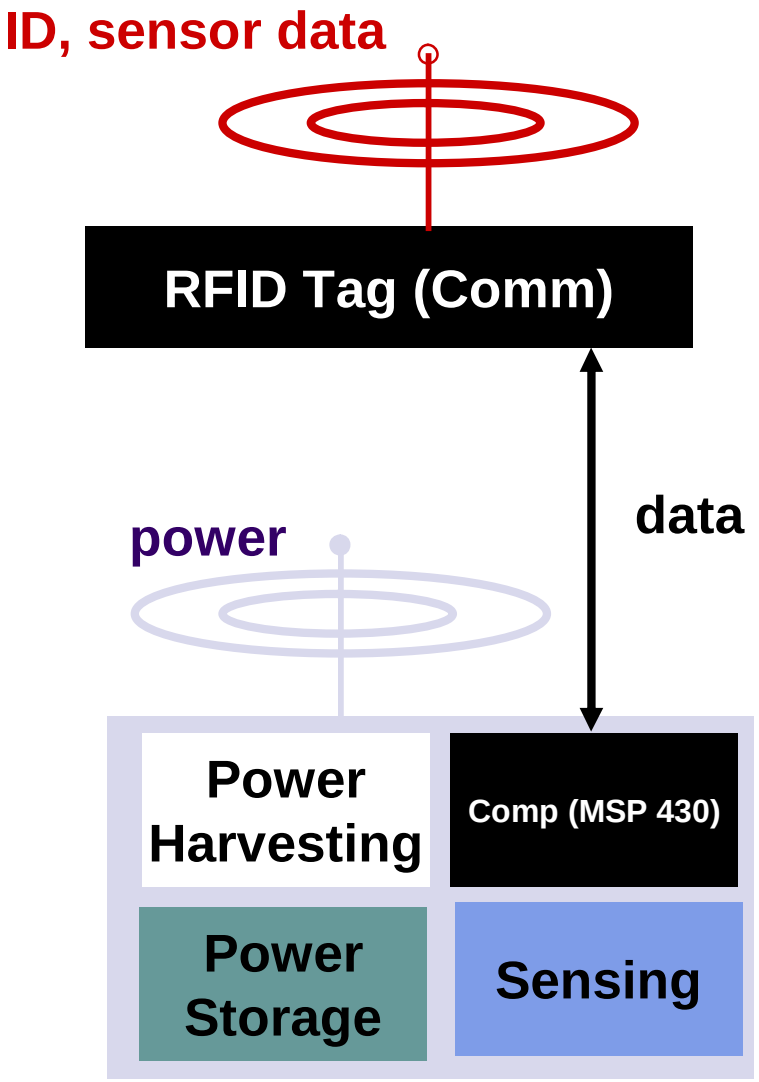
Sensors

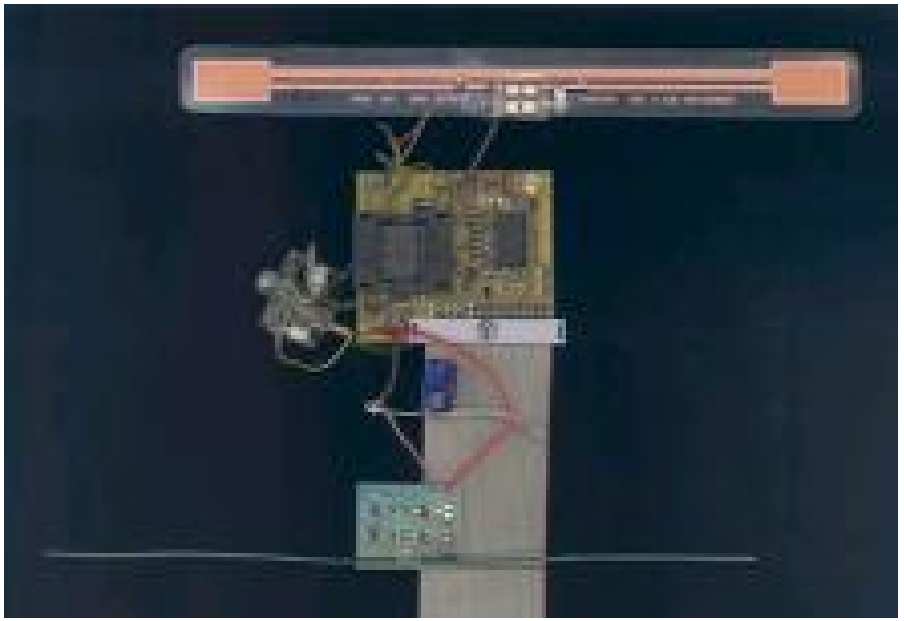
- ü small stickers
- ü battery-free
- ü room-range

α-wisp (motion sensor wisp)

Low-Level Sensing

The WISP Computer





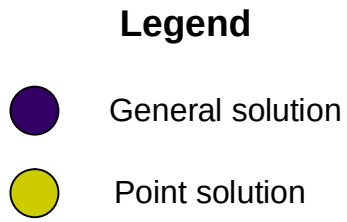
- ü multiplexing, aggregation
- ü > 1 min power storage
- ü light sensor

End-to-End Evaluation: ADL Form Filling

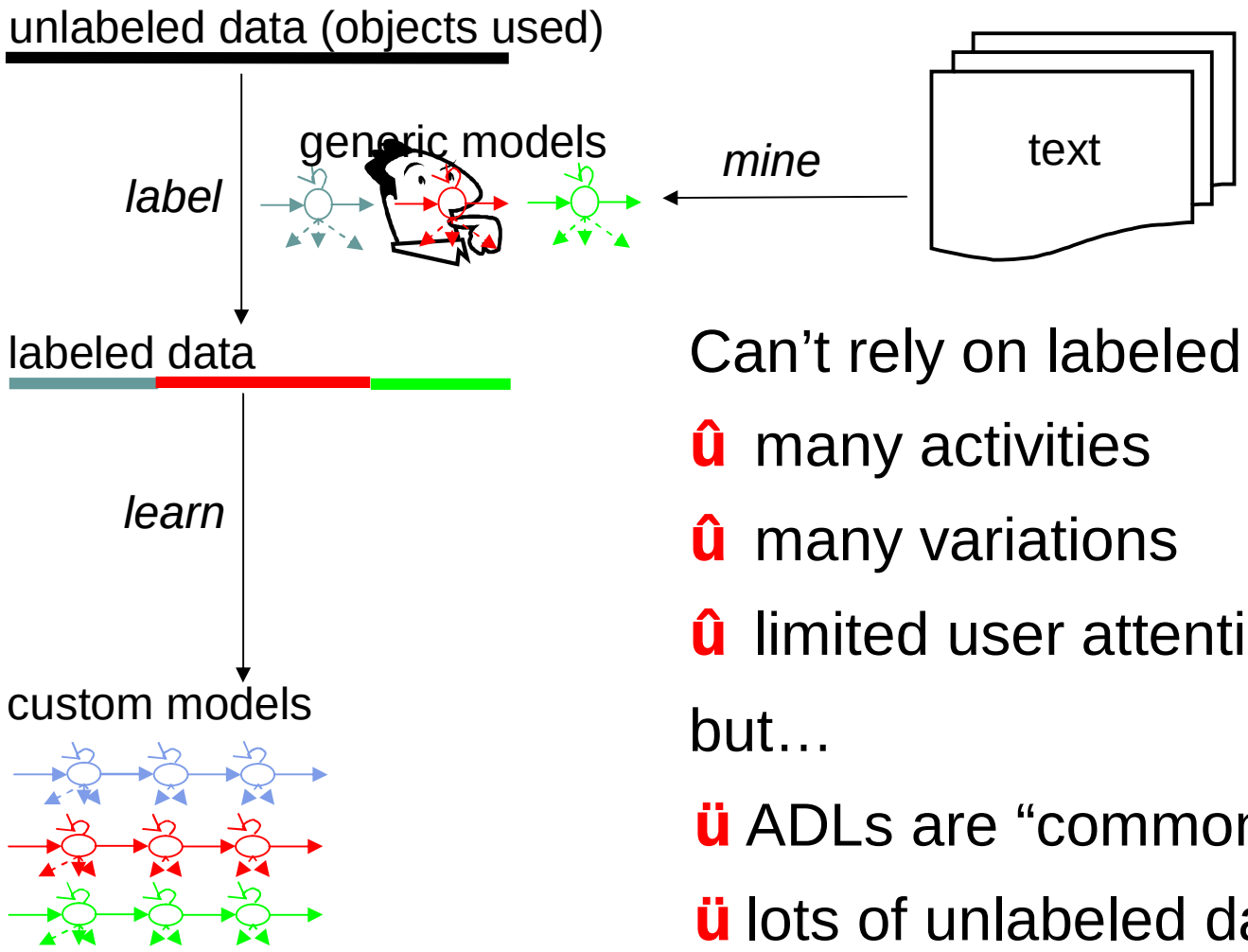
- Tagged real home with 108 tags
- **14 subjects** each did **12 of 14 ADL (65 instances)** in arbitrary order
- Subjects wore gloves, recorded activities
- **Given objects touched, infer activities**

Simple Models Suffice

Activity	Prior Work	SHARP (precision/recall)
Personal Appearance		92/92
Oral Hygiene		70/78
Toileting		73/73
Washing up	95/84	100/33
Appliance Use		100/75
Use of Heating		84/78
Care of clothes and linen		100/73
Making a snack		100/78
Making a drink		75/60
Use of phone		64/64
Leisure Activity		100/79
Infant Care		100/58
Medication Taking		100/93
Housework		100/82



Creating Models
Using Web-Mined Common Sense



Can't rely on labeled data

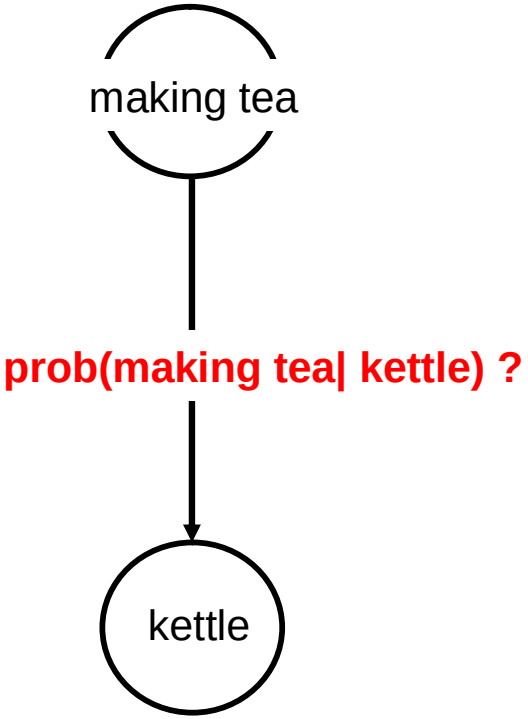
- û many activities
- û many variations
- û limited user attention

but…

- ü ADLs are "commonsense"
- ü lots of unlabeled data

Creating Models

Shallow, Large-Scale Web Mining



Google(“making tea”) = 194,000

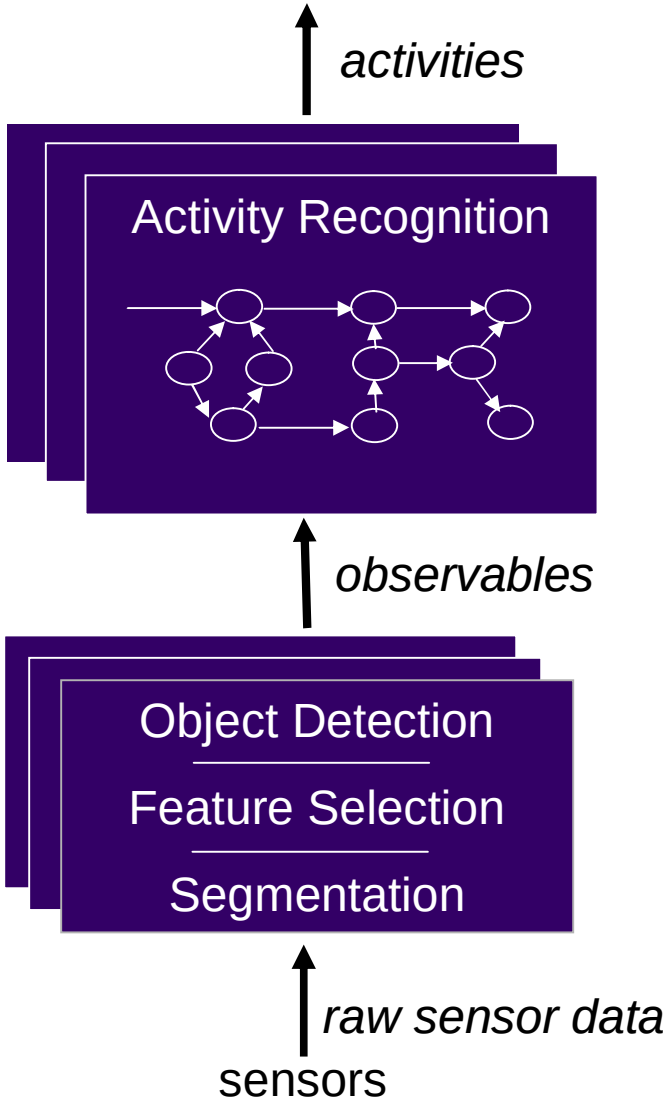
Google(kettle “making tea”) = 30,100

prob = 30,100/194,000 = 15.5%

Performance quite good in practice

40,000 activities modeled in 5 weeks

The Challenges Revisited



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Ultra-Dense Sensing: The Road Ahead

Applications

Physiological monitoring

Structural integrity monitoring

Resource usage monitoring

Quantitative Sociology

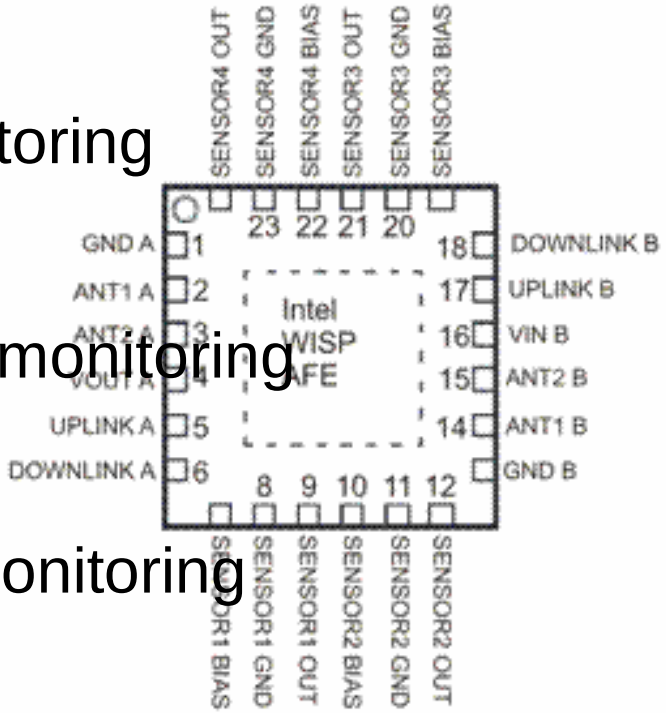
Challenges

ıngе, power

ıd manufacturing

ıg model

Privacy, public acceptance



Ultra-Dense Sensing and Privacy

Variants of privacy

- Share no data
- Avoid sharing data with non-authorized parties
- Share data but control inferences

Practical approach: public policy + education

- Strong legal recourse
- Maximize perceived cost vs. benefit

Conclusions

Monitoring human activity a “disruptive” capability

Mix of enabling technologies within grasp

- Very high density sensing is key

Ultra-dense sensing has implications beyond activity monitoring

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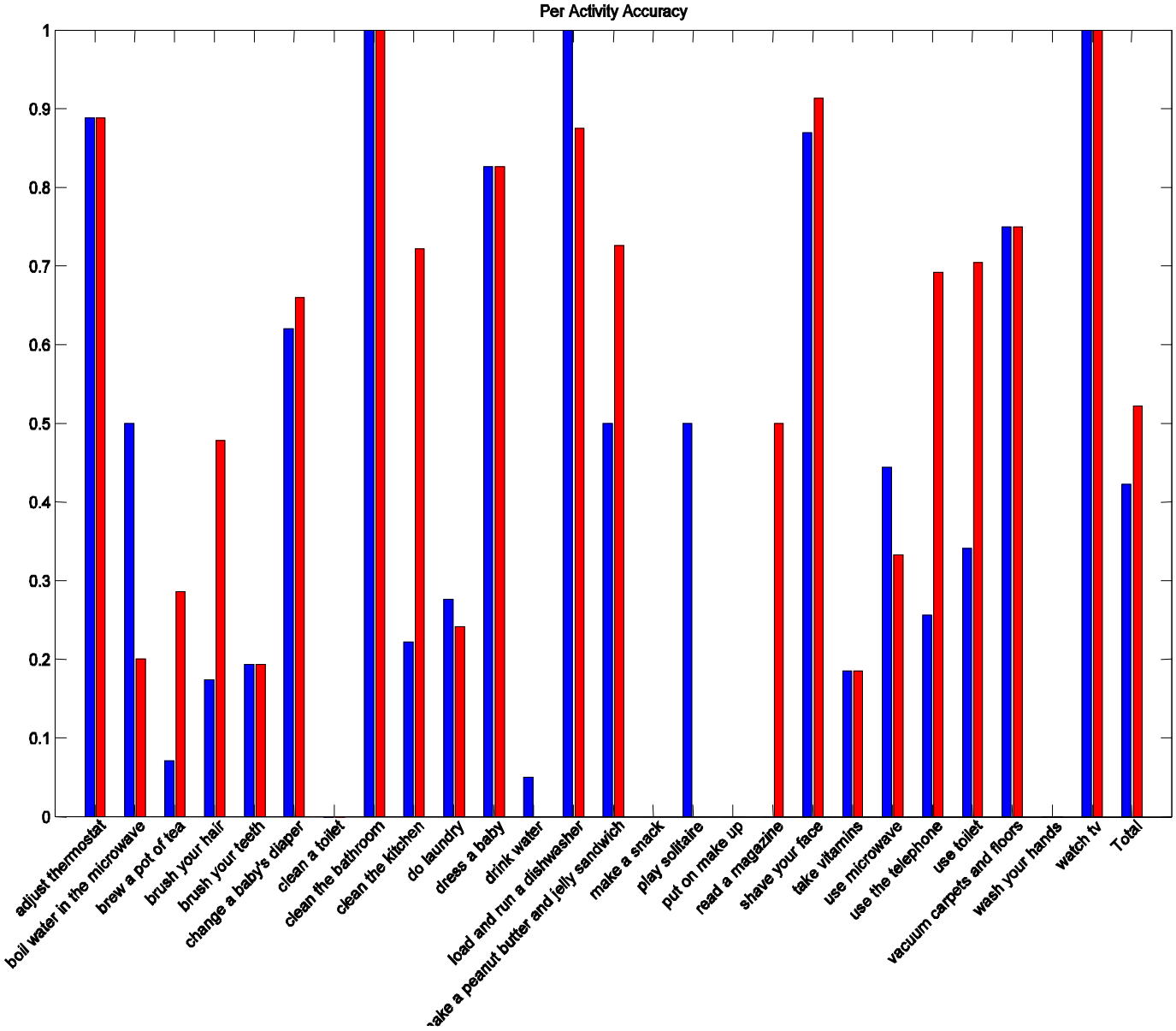
Requirements

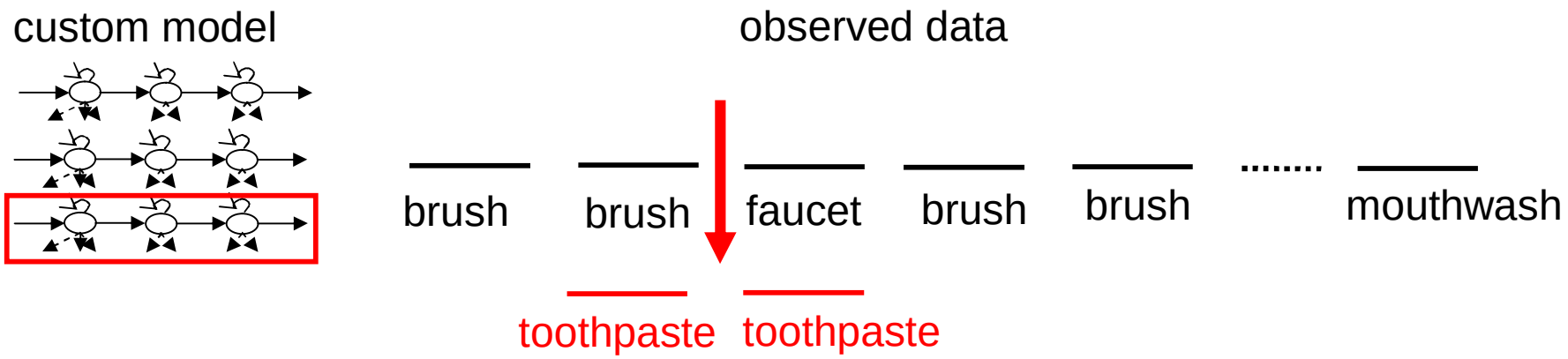
functionality	logging, rating, prompting
scope	thousands of activities
timescale	seconds to hours
speed	interactive time
accuracy	moderate to high (>>50%)
resolution	detect individual “steps”

Creating Models

Mined Models Can Bootstrap Learning



Anomaly Localization as Error Correction

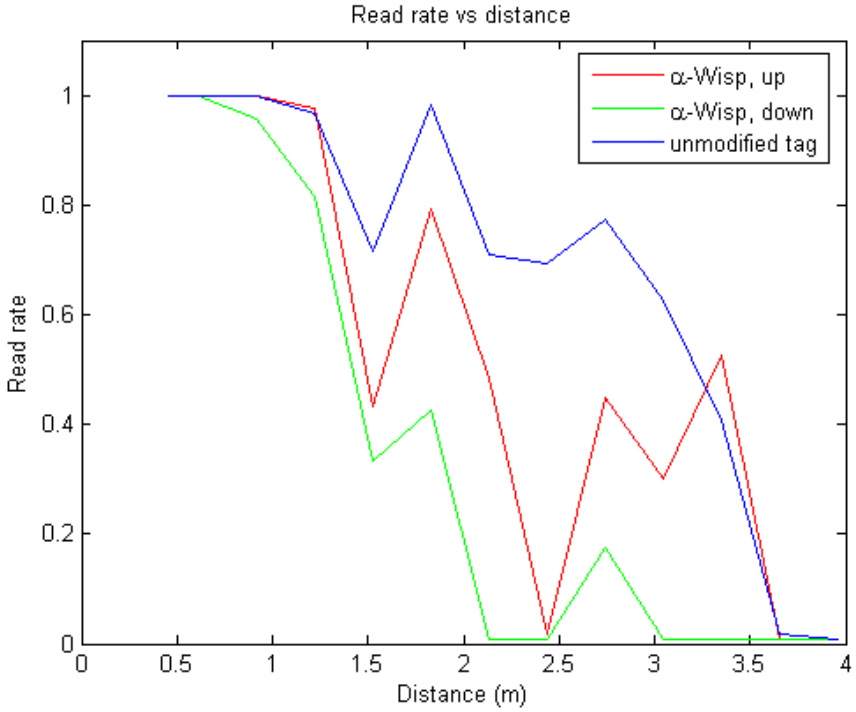


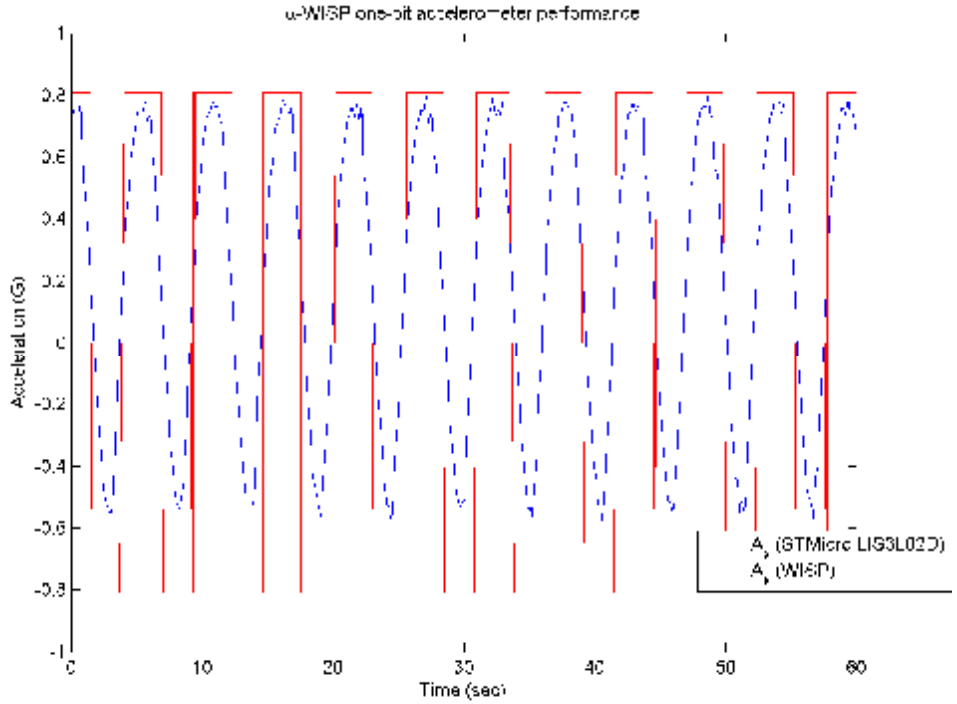
"Error Correcting Viterbi Parsing"

New algorithms fast even without explicit error models

Low-Level Sensing

α-wisp: Read-Range and Response





1-bit accelerometer accurate @ 1-10 feet

new tags @ 10-20 feet