

## Abstract

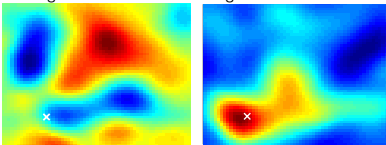
For smart buildings, in-home elder care, smart authorization, and emergency response, we need *human context awareness* based on probabilistic data. We enable this using inference on (1) *radio tomography* measurements made by a deployed static wireless network which locate but do not id people; and (2) RFID measurements which locate & identify. We develop (a) multi-channel methods, (b) space-time and probabilistic data representations to merge IDed and non-IDed data. We develop *probabilistic middleware* which uses this sometimes ambiguous, unlabeled data, and integrates user feedback from applications to provide human context awareness.

## Improvements to Radio Tomographic Imaging (RTI)

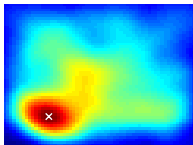
RTI can be dramatically improved:

- **Kernel distance:** Single metric to quantify change in RSS distribution [4]
- **Multi-channel measurements:** Frequency diversity increases localization information [5]
- **Multi-scale modeling:** Spatial impact area differs by fade level [7]

Through-wall RTI estimates using:



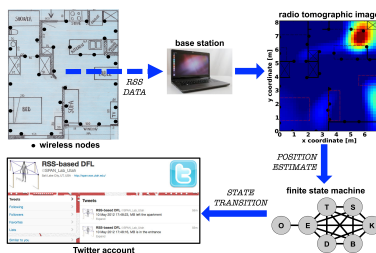
(a) single channel (b) multi-channel [6]



(c) multi-channel multi-scale RTI [7]

	Single Channel	Multi-Channel [6]	Multi-Scale [7]
RMSE	1.57 m	0.70 m	0.30 m
% Reduction		55%	81%

## In-Home Elder Care



RTI for assisted living applications:

- A **non-invasive** location sensing technology: don't need to remember to wear a tag
- Can **improve activity recognition** from 75% to 90%
- Can **adapt to changes** in an apartment environment for long-term monitoring [5]

Our CPS team participated in the 2012 *Evaluating AAL Systems through Competitive Benchmarking (EvaAL)* international competition.

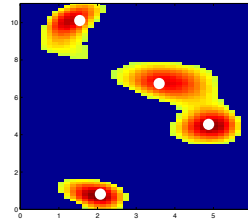
**We won 1st place (out of 8) in the Indoor Localization and Tracking for AAL competition.**



## Real-time Multi-target Tracking

Machine vision algs developed for RTI images [1]:

- To track multiple targets in **real-time**
- To track a **varying number of targets** having **intersecting trajectories**



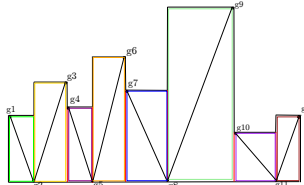
## RSS-based Localization Security

- **Power attack:** Falsifying TX or RX power to fool localization
- Results: TX [10] and RX [9] attacks reliably detected
- Compensating TX power enables **location eavesdropping**. Future work: prevent such attacks.

## Guard Coverage for RTI Deployment

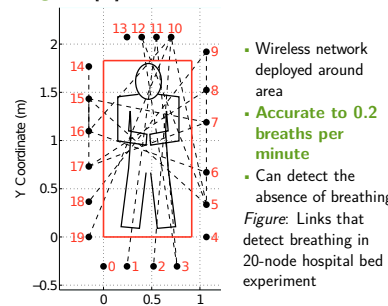
Q: **How do you place RF sensors to cover the area?** Results:

- **Optimal # is w/in small constant factor of optimal # of covering rectangles**
- NP-hard, upper & lower bounds on sensors
- Future work: Cover an area with "holes"



## Breathing Monitoring from RSS

Reliable breathing detection & rate estimation using RSS [14]:



- Wireless network deployed around area
  - **Accurate to 0.2 breaths per minute**
  - Can detect the absence of breathing
- Figure: Links that detect breathing in 20-node hospital bed experiment

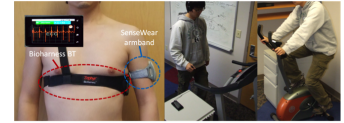
## Dissemination and Education

Major outputs from grant work:

- *Applications of Fading Channels:* Created a **new graduate class** on RSS-based DFL technologies
  - Impact for applications using unlabelled, noisy data -> increased safety, security in buildings, homes
  - Dissemination via competitive benchmarking: **EvAAL**
- Breathing monitoring news in popular press:



## Ubiware: Context-Awareness During Physical Activity



We have developed a [2]:

- Real-time activity recognition system
- Combines wearable sensors and device-free localization
- Recognizes physical activities: walking, biking, standing, etc.
- Used in **EvAAL 2012 activity recognition track** [3]



## Other Current Directions

- Merging breathing monitoring with device-free localization
- Detecting of falls in domestic environments
- Improved algorithms for merging active/passive loc. data
- Improved protocols for large-scale (300 node) deployments

## Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. #1035565. Contacts: maurizio.bocca@utah.edu, anind@cs.cmu.edu, npatwari@ece.utah.edu, {kaspera, suresh}@cs.utah.edu

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