Indoor Positioning via Three Different RF Technologies

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Outline

- Introduction
- Positioning methods based on
  - RFID
  - Bluetooth
  - WLAN
- Experiments (incl. video)
- Conclusion
Introduction

- Positioning: Position estimation in a given environment by means of sensor information
- Position information highly relevant for context-aware services and tracking purposes
- Potential scenarios
  - Patient and asset tracking
  - Product localization
  - Warehousing and logistics
  - Positioning for mobile systems, e.g. transport containers, autonomous vehicles, persons with laptops
- GPS fails indoors ⇒ requirement for alternatives
- Desirable: reuse of existing, inexpensive infrastructure
Expected coexistence of common RF technologies:

**Passive UHF RFID** (EPC Class 1 Gen. 2)
- 868 MHz
- Range: up to 7 m
- Measurable: detection rates

**Bluetooth** (IEEE 802.15)
- 2.4 GHz
- Range: class 2 typ. 15 m
- Measurable: RSSI

**WLAN** (IEEE 802.11)
- 2.4 GHz
- Range: up to 100 m
- Measurable: time of arrival
Positioning – General Idea
Particle Filtering

- Estimation of the state of a dynamic system
  Here: location of a mobile system

- **Bayesian filtering** technique, probability density function (PDF) over state space

- Discrete approximation of the PDF by set of **weighted samples**

- **Robust and accurate**, applicable to virtually any sensor

- Iterations of prediction, correction, normalization, and resampling

![Diagram showing particle filtering process](image)
1. Positioning via Passive UHF RFID

- Near future: palettes, cartons, and products RFID tagged
- Mobile system carries RFID reader
  - one reader only, lots of inexpensive tags
- Usual positioning method: proximity to tag of known position determines cell-based location
- Shortcomings:
  - Position resolved to coarse area only
  - Well-known problems of passive tags: false negatives, reflections, …
- Our goal: accurate, metric localization
Positioning via Passive UHF RFID – cont’d

- Idea: Exploitation of the fact that tag detection rates depend on relative position between RFID tag and RFID antenna
- Detection rate model (see figure) is used in particle filtering ⇒ probabilistic position refinement over time
- See (Hähnel et al. 2004, Vorst et al. 2008)
2. Positioning via Bluetooth

- Variety of mobile devices equipped with Bluetooth radio transceivers
- Received **signal strength** (RSSI) can be measured
- RSSI values decrease with distance between sender and receiver ⇒ **distance estimation**
Positioning via Bluetooth – continued

- Each RSSI value can be assigned a **PDF over possible distances**
- Observation: **noise**, low resolution for small RSSI values
- Positioning: multilateration (e.g., MMSE), particle filtering
- PDF used for particle reweighting in correction step
3. Positioning via Wireless LAN

- Usual positioning approach with WLAN: usage of RSSI values
- Alternative: **time of arrival** (TOA)
- Idea: Position has impact on the time of flight of WLAN packages between sender and receiver
- Advantage: TOA measurements scale **linearly** with open-air propagation distances
- Challenge: **low clock resolution** of off-the-shelf hardware (1μs ~ 300 m)
Positioning via WLAN – continued

- Novel four-way TOA: TOA measurements conforming to IEEE 802.11 protocol using 4 transmission steps
- Improvement by averaging over 500-2000 packets
- Open-source software Goodtry provided freely
- See (Hoene et al. 2008)
Experimental Setup

Mobile service robot (RWI B21)
- UHF RFID reader (ALR-8780)
- 2 Bluetooth USB sticks
- 2 WLAN PCI cards + antennas (for pings and TOA measurements)
- 240° laser scanner (reference positioning)
Experimental Setup – Environment

Laboratory with landmarks of known positions

- 24 RFID tags (Alien Techn. „Squiggle“)
- 7 Bluetooth nodes (BTnodes, ETH Zürich)
- 6 WLAN access points

Additionally: 400 RFID-labeled products of unknown positions in a supermarket shelf (metal)
Experimental Results

- Data: 11+4 sample trajectories with RFID/BT+WLAN recordings plus accurate laser reference positions, > 5 min.
- Particle filter with 300 samples using odometry
- Investigation: Tracking, i.e., coarse initial pose estimate provided; mean absolute positioning errors over time

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean ± Std. dev.</th>
<th>Median</th>
<th>90th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID (model)</td>
<td>0.432 m ± 0.095 m</td>
<td>0.435 m</td>
<td>0.527 m</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>0.494 m ± 0.149 m</td>
<td>0.474 m</td>
<td>0.678 m</td>
</tr>
<tr>
<td>WLAN</td>
<td>3.315 m ± 0.738 m</td>
<td>3.545 m</td>
<td>4.274 m</td>
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</tbody>
</table>
Video

[ play video ]
Conclusion

- Presented: Three RF-based positioning techniques
  - RFID tag detection rates
  - Bluetooth signal strength
  - WLAN time-of-arrival measurements
- Accuracies obtained in tracking a mobile robot:
  - \( \approx 0.5 \) m for RFID, Bluetooth
  - \( \approx 3-4 \) m for WLAN
- Low-cost, off-the-shelf hardware used in common RF infrastructures
- Future work:
  - Fusion of the techniques \( \Rightarrow \) easily possible due to particle filters
  - Refinements of methods and experiments in larger environments
Thank you for your interest!

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- www.AmbiSense.org

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References


Picture Credits

- RFID Tag (slides 2,4,5,23) from Alien Technology (http://www.alientechnology.com/tags/index.php)
- BTnode (slides 4,6) from ETH Zürich (http://www.btnode.ethz.ch/Main/Purchase)
- PDA (slides 2,4) from PIXmania (http://www.pixmania.lu/lu/de/554386/art/htc/pda-mit-telefonfunktion-t.html)
- WLAN router (slides 2,4,11) from Litec Computer (http://www.litec-computer.de/popup_image.php?pID=9611/imgID=0)
- Other pictures: courtesy of the corresponding AmbiSense subprojects
Extra slides
Positioning via RFID Snapshots

- Further possibility: **fingerprinting**
- **Prior training**: learning of a database of RFID measurements for different positions
- **Positioning** phase: Comparison of current list of detected tags with trained database
- Again: particle filtering to increase robustness
Experimental Results

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<td>0.527 m</td>
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<tr>
<td>RFID (snapshots)</td>
<td>0.264 m ± 0.047 m</td>
<td>0.267 m</td>
<td></td>
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<tr>
<td>Bluetooth</td>
<td>0.494 m ± 0.149 m</td>
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(higher tag density)