Extending Place Lab to 3-D

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Basic concept

- Want to determine location inside a building
- Sample applications:
  - Position-aware reminders
  - Location-aware buddy list
  - Guidance for the cognitively impaired
  - Smart conference rooms
Idea
Collecting data

- Beacon readings and ground truth were collected using a GUI showing map of each floor
Intel's Place Lab

- Java codebase
- Provides basic localization functionality
  - Reading signals
    - WiFi
    - GPS
  - Particle filters
  - GUI classes
- Designed to be extended
Research issues

- How to interpret beacon readings
  - Compute centroid of APs heard
  - Use particle filter

- Place Lab extensions:
  - Beacon database includes extra information (e.g., floor)
  - Sensor model updated to include signal attenuation due to floors
  - Motion model updated to change floor variable
Evaluation—floor estimation

Particle Filter w/ floor attenuation

Mode of Beacon floors
### Evaluation – location estimation

<table>
<thead>
<tr>
<th></th>
<th>Mean 2d error</th>
<th>Median 2d error</th>
<th>Std. dev.</th>
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</thead>
<tbody>
<tr>
<td>Particle filter</td>
<td>31.4m</td>
<td>32.3</td>
<td>11.9</td>
</tr>
<tr>
<td>Centroid of APs on floor</td>
<td>12.6</td>
<td>11.2</td>
<td>9.0</td>
</tr>
</tbody>
</table>

- Particle filter uses original sensor model (based on *signal strength*), with a floor attenuation factor of 0.8
- Centroid first computes the mode of the stronger half of APs heard to determine floor, then takes the centroid of those APs
- Note: highly calibrated fingerprinting systems can get 5-10m accuracy
Improving accuracy

- **Sensor model**
  - Classify APs based on their physical properties (*model-based*)
  - Empirically learn AP properties (histogram- or fingerprint-based)

- **Binning based on response rate at different distances from APs**
  - Bin size of 10m produces mean 2d error of 17.2m, median error of 14.5m
  - Doesn't take into account effects across different floors: only gets right floor 15% of the time, within 1 floor 87% of the time

- **Binning based on distance and floor**
  - Bin size of 10m produces mean 2d error of 16.4m, median error of 16.0m
  - Gets right floor 56% of the time, within 1 floor 99% of the time
Map Based Particle Filter

- Take into account knowledge of environment
  - Walls
  - Open spaces
  - Stairwells/elevators
- Intuitively, a signal passing through several walls should be weaker
- Mobile computers shouldn't change floors unless in an elevator or stairwell
- For each particle in particle filter, use this information to decide what its likelihood is
Barometric pressure
Tradeoffs

- Can get better accuracy with
  - More extensive fingerprinting
  - Additional sensors (accel, barometric, ultrasound)

- But this comes at a price (time and money)
  - Data collection and management
  - Equipment calibration

- This limits scalability
Thanks!

Questions?