Experiences with Performance Tradeoffs in Practical, Continuous Indoor Localization

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Introduction & Motivation

- **Indoor localization:** intensive research has focused on indoor localization
  
  *Wi-Fi fingerprinting indoor localization*

- **Motivation:**
  - Support all mobile devices,
  - Energy efficient
Research Questions & Contributions

Research Questions

• Server-based location tracking solution
• Characteristics of the indoor environment
• Performance limitations by existing commercial Wi-Fi infrastructure

Contributions

• Localization algorithms: Android and iOS
• Study the impact of building characteristics
• Reveal the performance limitations of existing controller-based solutions
## Buildings Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Mall</th>
<th>SMU</th>
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</thead>
<tbody>
<tr>
<td><strong>Number of Floors</strong></td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td><strong>Indoor/Outdoor</strong></td>
<td>Fully-Indoor</td>
<td>Mixed Indoor+ Outdoor (Floor 1&amp;2)</td>
</tr>
<tr>
<td><strong>Avg. Floor Area (sq.m)</strong></td>
<td>5000¹</td>
<td>3000</td>
</tr>
<tr>
<td><strong>Avg. Store/ Room Width (m)</strong></td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td><strong>No. of Wi-Fi APs/floor</strong></td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td><strong>Avg. AP Distance (m)</strong></td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td><strong>No. of Fingerprint Landmarks</strong></td>
<td>26 (floor 1)</td>
<td>67 (floor 2)</td>
</tr>
<tr>
<td></td>
<td>27 (floor 2)</td>
<td>76 (floor 4)</td>
</tr>
</tbody>
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Data Collection Process

- Client-based (Android):
  - Query rate: 20Hz
- Server-based (all smart-phones):
  - Query rate: 1Hz
- Data collection:
  - 6 sets of reading: 3 different times of the day on 2 different days
  - 4 orientation facing

$L_i : [\overline{RSSI}^i_{AP_1}, ..., \overline{RSSI}^i_{AP_M}]$

$L_i : [\overline{RSSI}^i_{AP_k}]$
Localization algorithm

- **Step 1:** Location estimate using RADAR
  - Wifi Scan (RADAR):
    - Controller query (iOS)
    - On phone (Android)

- **Step 2:** Path Smoothing using Viterbi
  - Sensor Sampling:
    - Accelerometer: Step counter
    - Compass: angle of movement

Dead Reckoning from $t_i$ to $t_{i+1}$
Client-based (Android) vs. Server-based (iOS)

- Client based is much better than server-based
- Dense deployment of APs in SIS: compare to Mall
  - Better server-based performance
Server-based limitations

- Stale SNR report
- Query throughput bottleneck
Issues in Practical Deployment

Occupant Density

- Impact on fingerprint data

- Higher density $\rightarrow$ larger RSSI variation

Different fingerprint map at different occupant density
Issues in Practical Deployment

Occupant Density

- Impact on indoor localization performance

- Higher occupant density $\rightarrow$ greater signal fluctuation $\rightarrow$ worse performance
Issues in Practical Deployment

Energy vs. Accuracy

<table>
<thead>
<tr>
<th></th>
<th>WI-FI</th>
<th>WI-FI + Viterbi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Consumption (mW)</td>
<td>14.538</td>
<td>251.842</td>
</tr>
<tr>
<td>Accuracy ± 1 landmark</td>
<td>77%</td>
<td>87%</td>
</tr>
</tbody>
</table>

- Inertial sensor (accelerometer and magnetometer) dominate the energy usage → attractive for intermittent sensing but can pose unacceptable energy overhead when executed continuously.
Summary and Future work

• Building a continuous indoor location tracking system:
  – Scalable: number of participant and mobile OS platforms
• Empirical experiment shows that localization accuracy depends on: building layout, density of deployed APs, occupant density in the environment
• Limitation: query controller throughput
• Dynamic fingerprint map
• Future work:
Questions?

Thank You.