A New Method for Improving Wi-Fi Based In-door Positioning Accuracy

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LBS 2014
11th Symposium on Location-Based Services
Vienna, 26-28 November 2014

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Outline

• Background
• Techniques for location tracking and positioning
• Common algorithms for location fingerprinting
• A new algorithm
• Test result
• Conclusion
Location-based service (LBS) technologies have become an essential part of our daily lives:

- Global revenue of LBS will generate up to US$127b by the end of 2014 (the report of Juniper Networks)
- LBS output of China in 2013 yielded RMB ¥ 70b

LBS technologies for outdoor free space are mature, e.g., usage of GPS, but for indoor environments or city canyons are problematic.

Increasing needs arise to locate and find people and objects in buildings/indoor-like environments.

Algorithm development for increasing the positioning accuracy is still desirable.
## Wide Application Areas

<table>
<thead>
<tr>
<th>Agriculture &amp; forestry</th>
<th>Entertainment</th>
<th>Packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airports &amp; aviation</td>
<td>Environmental protection</td>
<td>Public Services</td>
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<td>Automotive &amp; parts</td>
<td>Finance &amp; banking</td>
<td>Publishing &amp; printing</td>
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<tr>
<td>Business services</td>
<td>Food &amp; drinking</td>
<td>Real estate</td>
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<td>Chemicals industry</td>
<td>Governance</td>
<td>Retail &amp; wholesale</td>
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<td>Construction</td>
<td>Healthcare &amp; medication</td>
<td>Security</td>
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<td>Consumer goods</td>
<td>Information technology</td>
<td>Stock raising</td>
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<td>Defence</td>
<td>Logistics</td>
<td>Telecommunications</td>
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<td>Education</td>
<td>Manufacturing</td>
<td>Transportation</td>
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<td>Energy &amp; utilities</td>
<td>Media</td>
<td>Travel &amp; leisure</td>
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Techniques for Positioning/Location Tracking

- **Measurement types**
  - Time of arrival (ToA)
  - Time difference of arrival (TDoA)
  - Angle of arrival (AoA)
  - Received signal strength indicator (RSSI)

- **Location estimation methods**
  - Cell of origin (CoO)
  - Distance-based
    - e.g., trilateration
  - Fingerprinting
    - pattern recognition
Common Algorithms for Fingerprinting

- **Probabilistic, e.g.,**
  - Bayesian

\[
p(l_x|o_x) = \frac{p(l_x) \cdot p(o_x|l_x)}{\sum_{i=1}^{m} p(l_i) \cdot p(o_x|l_i)}
\]

- **Deterministic, e.g.,**
  - Nearest Neighbor (NN)
  - K-NN
  - Weighted KNN

- **Our new algorithm**
Our Algorithm for Fingerprinting

• Based on the NN algorithm
• For improving location accuracy on fingerprinting
• Findings used for our algorithm
  ➢ A former test (test environment: 56 x 18.2 x 3.3 m³ space, 11 access points (APs) and 30 test points)
  ➢ Findings: stronger signals presented more stability and more consistency. Therefore, our algorithm started from the surrounding APs with the strongest RSSI values observed, named the initial AP (AP_init)
Distance Calculated from RSSI Observations (Cisco™)

\[
d = 10^{\frac{TX_{PWR} - RX_{PWR} - LOSS_{TX} - LOSS_{RX} + GAIN_{TX} + GAIN_{RX} - PL_{1\text{METER}} - s}{10n}}
\]

where,

- \( d \): distance between the user and the associated AP in metres;
- \( RX_{PWR} \): detected RSSI value from the user’s smartphone in dB;
- \( TX_{PWR} \): transmitter output power in dB;
- \( LOSS_{TX} \): sum of all transmitter-side cable and connector losses in dB;
- \( GAIN_{TX} \): transmitter-side antenna gain in dBi;
- \( LOSS_{RX} \): sum of all user-side cable and connector losses in dB;
- \( GAIN_{RX} \): user-side antenna gain in dBi;
- \( PL_{1\text{METER}} \): reference path loss for the distance of 1 meter and for the desired frequency, in dB;
- \( n \): path loss exponent for the environment;
- \( s \): standard deviation associated with the degree of shadow fading present in the environment.
Principle of the New Algorithm (1)
Averaging a few observations for each reference point (RP):

$$\bar{S}_{RP_k} = \left( \overline{RSSI}_{RP_k}^{AP_1}, \overline{RSSI}_{RP_k}^{AP_2}, \ldots, \overline{RSSI}_{RP_k}^{AP_n} \right)$$

User’s $P_{\text{init}}$ is determined by the RP with the minimum $\delta_k$:

$$\delta_k = \sqrt{\sum_{i=1}^{n} \left( RSSI_{USR}^{API_i} - \overline{RSSI}_{RP_k}^{AP_i} \right)^2}$$
Principle of the New Algorithm (3)

Calculate the differences:
\[ \Delta d_1 = d_{1\text{est}} - \overline{d_{1\text{est}}} \]
\[ \Delta d_2 = d_{2\text{est}} - \overline{d_{2\text{est}}} \]

\[
\begin{align*}
  r_1 &= D_1 + \Delta d_1 \\
  r_2 &= D_2 + \Delta d_2
\end{align*}
\]

User's location: \( P(x, y) \)

Proper geometry configuration

<table>
<thead>
<tr>
<th>True distance</th>
<th>Estimated distance</th>
<th>Estimated distance</th>
<th>( \Delta d = d - \overline{d} )</th>
<th>( r = D + \Delta d )</th>
<th>Final ( P(x, y) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D_1 = 3.15 )</td>
<td>( \overline{d_1} = 1.50 )</td>
<td>( d_1 = 1.25 )</td>
<td>( \Delta d_1 = -0.25 )</td>
<td>( r_1 = 2.90 )</td>
<td>The nearer intersection point of the circles (( r_1 &amp; r_2 ))</td>
</tr>
<tr>
<td>( D_2 = 5.68 )</td>
<td>( \overline{d_2} = 1.64 )</td>
<td>( d_2 = 1.37 )</td>
<td>( \Delta d_2 = -0.28 )</td>
<td>( r_2 = 5.40 )</td>
<td></td>
</tr>
</tbody>
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12/7/2014

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Analysis of the Test Results

Statistics results of 30 test points calculated by:

$$\delta_{RMS} = \sqrt{\frac{1}{m} \sum_{k=1}^{m} [(x_k - x_{ek})^2 + (y_k - y_{ek})^2]}$$
A new method for indoor positioning is proposed

The new method is based on the NN algorithm with an improvement on location accuracy of half a meter

The differential approach provides a new way for systematic error elimination to improve position estimates

Future work:
- 3D implementation
- Investigation of the variation of RSSI observations from a particular AP at different times
- Accuracy comparison between KNN, Weited-KNNS
Thank you!

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