A filtering algorithm based on peer-to-peer ad-hoc networks for GNSS-challenged environments

ICG WG-B Application SG Meeting
Location Based Services and Mass Market Applications
Session 2
Pedestrian Indoor Navigation

- Convergence of personal navigation device and mobile phone
- Use of the smart phone for outdoor location-based services:
  - Find my friends feature of iOS developed by Apple, sharing of current location with other users
  - Allowing other user to view their current location on Google Maps
- Use of such services also indoors
Pedestrian Indoor Navigation with GPS

- Attenuation of GPS signals by different materials:

<table>
<thead>
<tr>
<th>Material</th>
<th>Attenuation in L1 [dB]</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drywall</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Plywood</td>
<td>1 – 3</td>
<td>0.8 – 0.5</td>
</tr>
<tr>
<td>Glass</td>
<td>1 – 4</td>
<td>0.8 – 0.4</td>
</tr>
<tr>
<td>Toned glass</td>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>Timber</td>
<td>2 – 9</td>
<td>0.6 – 0.1</td>
</tr>
<tr>
<td>Iron</td>
<td>2 – 11</td>
<td>0.6 – 0.08</td>
</tr>
<tr>
<td>Brick</td>
<td>5 – 31</td>
<td>0.3 – 0.001</td>
</tr>
<tr>
<td>Concrete</td>
<td>12 -43</td>
<td>0.06- 0.00005</td>
</tr>
<tr>
<td>Armored concrete</td>
<td>29 – 33</td>
<td>0.001 – 0.0005</td>
</tr>
</tbody>
</table>

- GPS signals 20 to 30 dB weaker indoor than outdoor
- Navigation not possible
Pedestrian Indoor Navigation with A-GPS

- Obtaining satellite data via cellular network
- Indoor positioning partly possible but almost no navigation
Pedestrian Indoor Navigation with Inertial Sensors

- Integrated MEMS (microelectro mechanical system) today in every smartphone
- Mostly accelerometer to extend user interaction with device; additionally magnetometer and gyroscopes

- Draws: Poor measurements and integrating error
P2P Filtering Approach

- Combination of inertial navigation using integrated MEMS and peer-to-peer filtering algorithm

- Obtaining a better position solution for both peers
Position estimation in deep-indoors

• Based on the last known GPS-position performing dead reckoning:

\[
\begin{align*}
x_n &= x_{n-1} + l \cdot \sin \theta \\
y_n &= y_{n-1} + l \cdot \cos \theta
\end{align*}
\]

• Step detection and step length estimation based on accelerometer measurements

• Heading estimation based either on magnetometers or change of gyroscope based on the last known heading
Exchange of Position Data

- Via wireless ad-hoc networks:
  - Bluetooth
  - WLAN / WiFi direct
  - ZigBee
- Mutual filtering of own position with received position of another peer
- Filtering realized by extended Kalman filter algorithm using incoming position as additional noisy measurement
Demands on the P2P Kalman Filter

- Autonomous navigation using either GPS / A-GPS, a combination of inertial sensor and GPS or only inertial sensors
- Enabling navigation also in deep indoor
- No surveying of building in advance and no additional infrastructure needed
- Favoring local charge-free ad-hoc networks against regional costly server connections
Simulation Configuration for P2P filtering

- Simulation of an rectangular indoor area with reference position and varying amount of peers:

  - Variation of several variables:
    - Measurement accuracy of sensors
    - Number of peers
    - Maximum distance to other peer

We are navigation!
Results of P2P filtering approach

- Maximum distance to other peer 5m: Increasing position accuracy related to the number of peers
- Maximum distance to other peer 10m: Decreasing position accuracy
### Peer-to-Peer network standards

<table>
<thead>
<tr>
<th>Bluetooth</th>
<th>WiFi direct</th>
<th>ZigBee</th>
</tr>
</thead>
</table>
| ![Bluetooth Logo](image)  
IEEE 802.15.1 | ![WiFi CERTIFIED Logo](image)  
IEEE 802.11 | ![ZigBee Alliance Logo](image)  
IEEE 802.15.4 |
| Founded 1998 as Special Interest Group by five companies | Founded 1999 as consortium of more than 300 companies | Founded 2002 as an open non-profit association |
| Working in the 2.4 GHz ISM frequency band | Working in the 2.4 GHz ISM and the 5 GHz frequency band | Working in the 2.4 GHz ISM frequency band |
| Establishment of Piconets (~5m) or scatternets | Establishment of IBSS with a size of 100 m | Establishment of star-topology or peer-to-peer topology networks (~8m) |
Demands on the network protocol

<table>
<thead>
<tr>
<th></th>
<th>Bluetooth</th>
<th>WiFi direct</th>
<th>ZigBee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Acceptance</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Small transmission area (~5m)</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Fast network establishment</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>No user interaction required</td>
<td>-</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Estimating distance to other peer</td>
<td>-</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
Summary

- Increasing position accuracy by enabling peer-to-peer filtering
- Only possible when distance to other peers kept below a certain threshold
- Two main demands on peer-to-peer networking:
  - Easy way to estimate the distance between two peers
  - Avoiding user interaction and enabling security protocol to hide position information of other users
- Future work: Implementation of a prototype and improving of dead reckoning algorithm