A Linear State Model for PDR+WLAN Positioning

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With support:
Outline

1. WLAN positioning
2. Pedestrian dead reckoning
3. Models for PDR
4. Results
Comparing different models for WLAN signals

Coverage area models

Fingerprinting

Pathloss models

A Linear State Model for PDR+WLAN Positioning
Inertial measurements

Inertial measurement unit

- Detects linear and angular accelerations
- Direct positioning → integration twice
Pedestrians move usually on a plane walking

Heading change

Footsteps
Comparison of traditional nonlinear model and proposed linear model

State transitions:

\[
\begin{bmatrix}
  r_{1,t} \\
  r_{2,t} \\
  \theta_t \\
  s_t
\end{bmatrix} =
\begin{bmatrix}
  r_{1,t-1} + s_{t-1} \cos \theta_{t-1} \\
  r_{2,t-1} + s_{t-1} \sin \theta_{t-1} \\
  \theta_{t-1} + \Delta \theta_t \\
  s_{t-1}
\end{bmatrix}
\]

\[
\begin{bmatrix}
  r_{1,t} \\
  r_{2,t} \\
  v_{1,t} \\
  v_{2,t}
\end{bmatrix} =
\begin{bmatrix}
  1 & 0 & 1 & 0 \\
  0 & 1 & 0 & 1 \\
  0 & 0 & \cos \Delta \theta_t & -\sin \Delta \theta_t \\
  0 & 0 & \sin \Delta \theta_t & \cos \Delta \theta_t
\end{bmatrix}
\begin{bmatrix}
  r_{1,t-1} \\
  r_{2,t-1} \\
  v_{1,t-1} \\
  v_{2,t-1}
\end{bmatrix}
\]
Estimates after steps with small uncertainty


give

Nonlinear estimate

Linearized estimate

Linear model
Estimates after steps with large uncertainty

Nonlinear estimate

Linearized estimate

Linear model
Effect of gyroscope quality

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Effect of initial angle

Effect of initial heading error

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Filtered real data

WLAN measurements

Proposed model

Nonlinear model

Nonlinear model with step lengths

100m
Smoothed real data

WLAN measurements

Proposed model

Nonlinear model

Nonlinear model with step lengths

100m
### Real data results

<table>
<thead>
<tr>
<th>Initial angle error</th>
<th>WLAN only static</th>
<th>Proposed</th>
<th>Nonlinear sensor footsteps</th>
<th>Nonlinear estimated footsteps</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>8.2m</td>
<td>6.8m</td>
<td>6.7m</td>
<td>7.4m</td>
</tr>
<tr>
<td>90°</td>
<td>8.2m</td>
<td>6.8m</td>
<td>7.4m</td>
<td>10.7m</td>
</tr>
<tr>
<td>180°</td>
<td>8.2m</td>
<td>6.8m</td>
<td>8.2m</td>
<td>12.1m</td>
</tr>
</tbody>
</table>

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</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>8.2m</td>
<td>4.6m</td>
<td>3.8m</td>
<td>4.3m</td>
</tr>
<tr>
<td>90°</td>
<td>8.2m</td>
<td>4.6m</td>
<td>5.2m</td>
<td>6.9m</td>
</tr>
<tr>
<td>180°</td>
<td>8.2m</td>
<td>4.6m</td>
<td>7.3m</td>
<td>8.0m</td>
</tr>
</tbody>
</table>
Conclusions

- Proposed model:
  - As accurate as similar models in literature when initial state known
  - Outperforms other models when initial state is not known
  - Good for smoothing
  - Can be used, for example, for initialization of a particle filter (Nurminen & al. IPIN2013)