Evaluation of a Fully Train-Borne Localization Algorithm

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Motivation

Why do we deal with train-borne localization systems?

⇒ Replacement of expensive and inflexible track-side signalling systems
  + Increases capacity
  + Enables many flexibilizations
  + Saves costs

What are the challenges when developing a train-borne localization systems?

► Very high demands in the sense of accuracy and availability
Motivation

Why do we deal with train-borne localization systems?

⇒ Replacement of expensive and inflexible track-side signalling systems

⇒ Evaluation of an approach we presented earlier, but which has only been tested in simulations.

What are the challenges when developing a train-borne localization systems?

► Very high demands in the sense of accuracy and availability
Outline

► Motivation

► Basics

► Evaluation

► Concluding Remarks
Basics
Measurement Set-Up – Test Vehicle

Vehicle: *Thales test-vehicle LUCY*
- 4 axle diesel railcar (NE81)

Sensor: *iMAR iNAT-M200/STN*
- MEMS INS/GNSS navigation system
- 2 frequency GNSS antenna
- Measured quantities:
  - Position (Lat./Long./Alt.)
  - Velocity (N/E/D)
  - Accelerations (x/y/z)
  - Turn rates (roll/pitch/yaw)
Basics
Measurement Set-Up – Test Track

Investigated track-section:
- Secondary line
- Max 60 km/h
- Harsh environment

Map showing track section with cities:
- Schwarzenberg
- Markersbach
- Scheibenberg
- Schleltau
- Annaberg-Buchholz

Directions:
- Approx. 1 km
- Direction of travel

Graphical representation of track section and locations.
Basics
Localization and Mapping Filter

Based on:
**Evaluation**

Localization Performance (1/2)

Cumulative Distribution Function (cross-track direction)

⇒ Simulation results can be confirmed

<table>
<thead>
<tr>
<th>CDF</th>
<th>GNSS</th>
<th>standard</th>
<th>new</th>
</tr>
</thead>
<tbody>
<tr>
<td>along-track</td>
<td>±5m</td>
<td>31%</td>
<td>52%</td>
</tr>
<tr>
<td>cross-track</td>
<td>±1.5m</td>
<td>0%</td>
<td>6%</td>
</tr>
</tbody>
</table>
Qualitative evaluation

- Significantly smaller error ellipses with the new approach
- Performance gain especially in bad GNSS situations and in cross-track direction
- OpenStreetMap not always in line with satellite image
Evaluation
Mapping Performance (1/2)

Online identified track-geometries

Final optimized geometric track-map

Latitude in °

Longitude in °

50.550
50.545
50.540
50.535
12.860
12.880
12.900

straights

circular arcs

simple concatenated track-map

final map (straights)

final map (circular arcs)

final map (transitional arcs)
Evaluation
Mapping Performance (2/2)

Cumulative Distribution Function (error to OSM data)

► mean(|ε|) = 1.8m
► max(|ε|) = 8.7m
► CDF(|ε| < 2m) = 0.68

⇒ Simulation results can be confirmed
⇒ Real errors may be even smaller (uncertainty of OSM data not known)
Evaluation

Video Demonstration
Evaluation

Results

Conclusions

► Evaluation of a fully train-borne localization algorithm with GNSS and IMU data
► Simulation results could be confirmed on real measurement data
  ✓ Online geometry-detection and identification
  ✓ Increased positioning accuracy in cross-track direction and in bad GNSS situations
  ✓ Generation of an accurate compact geometric track-map

Future Work

► Integration of more track features into the geometry identification process
► Refine optimization procedure for map generation
► Evaluation on longer track-sections
General Implications for Train-Borne Localization Systems

Can we generalize from the presented results (for a safety prove)? → Probably not?!

► Environmental influences: weather, vegetation, buildings, tunnels, …
► Track characteristic: curviness, steepness, speed, pavement condition, electrification, …
► Vehicle characteristics: train category, driving type, suspension, …

⇒ There is a great need for more real measurement data.
⇒ We suggest an overall safety system which can deal with dynamic uncertainties.
Thank you for your attention!

„Traveling by Train is Comfort[able], Economical, Fast and Safe“

Source: Signboard, Ayutthaya Station (Thailand)