Requirements of rail safety specification to satellite based localization systems

- Motivation
- GNSS certification in transport
- Terminology for certification
- GNSS certification for railways
- Outlook

Dipl.-Ing. Hansjörg Manz
Motivation
Overview of worldwide GNSS

- **Galileo**
  - EGNOS Open Service available
  - 2016: 30 satellites in orbit

- **Beidou/Compass**
  - 30 satellites planned for 2020,
  - coverage of Asia-Pacific region in 2012

- **GLONASS**
  - Global coverage planned for December 2010 with 24 satellites

- **GPS**
  - Third civil signal L5 will be available in 2018 with 24 satellites
  - GBAS approaches are certified in USA for CAT I
Unified certification of GNSS receivers
Base for various safety-critical applications in transport

- Railways
  - Flexible train control and protection
  - Trackman warning
  - Control of train integrity

- Automotive
  - More efficient and safe traffic flow
  - Automatic lane changing
  - Congestion/road work warning

- Aviation
  - Direct flight and approach

- Maritime
  - Precise docking
<table>
<thead>
<tr>
<th>Disadvantages of track side equipment</th>
<th>Advantages of satellite based localization</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High total costs of ownership</td>
<td>• Reduces cost of ownership</td>
</tr>
<tr>
<td>• Exposed to environment</td>
<td>• Increases capacity</td>
</tr>
<tr>
<td>• Constitutes a state of development</td>
<td>• Enables precise safety relevant localization</td>
</tr>
<tr>
<td>• Causes compatibility problems</td>
<td>(e.g. positioning of the rear end of the train autonomously)</td>
</tr>
<tr>
<td>• Allows only discrete but not</td>
<td>• Has to be produced in serial production in future as well</td>
</tr>
<tr>
<td>continuous localization</td>
<td></td>
</tr>
</tbody>
</table>
• Today
  • Certification process is different for each transport domain
  • Localization device/receiver built separately for each domain
• Future
  • Common receiver
  • Reached by common certification process & terminology
Terminology for certification
Motivation for Terminological work

• Domain-specificity
  • Satellite based localization systems are specified using aerospace terminology
  • Intermodal applications require interdisciplinary understanding of terminology
  • Harmonized terminology currently not available

• Inconsistency
  • Different definitions do not match

• Vagueness
  • Even within individual domains definitions remain unclear
A lexeme comprises three constituent parts:

1. **Lemma**: Denomination – a sequence of sounds or letters

2. **Definition**: Description of the mental unit by natural language

3. **Variety**: The subject field, or rather the special language context in which the lexeme is used
Terminology for certification
iglos – semiotic model: problems

• Language related problems that must be solved...

Polysemy

Homonymy

Synonymy

Equivalence of phrases

Imprecise definitions

Dependence on context

Transterminologisation
Terminology for certification
iglos – semiotic model: problems & benefits

• Definition of one lexeme may vary within one variety
• Different lexeme may have one lemma but different varieties and definitions
• The trilateral, variety-based semiotic model can map the variations of the single constituents of lexemes precisely.
Terminology for certification
Advantages of iglos

- Allows for semi-automatic conclusions regarding the connections within the terminological system
- Potential sources of misunderstandings can be tracked in time
- The user can be made aware of these potential sources of misunderstandings
- A team requires approved awareness of terminological issues
Terminology for certification

iglos at iVA

• iglos tool at iVA to find common definition for one term in all domains of transport
• Compare and combine terminologies of different domains as base for application of GNSS in transport
• Convert characteristic values for common standards
• iglos implementation into databases under development
• Sponsored by DIN and GAUSS
• Terms are verified and approved
• Specific responsibilities ensure quality
• Term “safety”: not existing in GNSS-terminology
• Systems used in train control need quantified safety level
• “Safety” has to be embedded into GNSS system
• GNSS as part of the railway system
• Localization components built modular
• Certification of components necessary
• SIL level of GNSS as localization technique in railways needs to be calculated
• Unified safety-certified components can be used for localization in other modes of transport
• System certification in railways according to EN 50129
  • Tolerable hazard rate (THR) for system function to be determined
  • System-THR to be divided into THR for partial systems
  • If physical autonomy is given:
    Failure rate for devices to be calculated
• Approach has to be adopted for GNSS system
• GNSS does already exist and shall be used as partial system for railways
• THR calculation needs to be done vice versa
• Measurement system
  • Satellites and according receivers: calculate position
• Diagnosis system
  • Integrity monitoring: control correct function of position calculation
Motivation

- GNSS certification for railways

Values

- tolerable hazard rate (?)
- safe down rate (?)
- safe down time (?)
- alarm rate
- response time
- response rate
- failure rate (?)
- time to alarm

Failure

- latent fault
- fault detection
- detected fault
- negation
- safe state

Values

- failure rate
- fault detection time
- fault detection rate
- negation time
- negation rate
- tolerable hazard rate
- safe down time
- safe down rate

Technische Universität Braunschweig
Institute for Traffic Safety and Automation Engineering iVA

26.-27.05.2010, EURO - Žel 2010, Slide 14
## GNSS certification for railways

### Calculation of THR

<table>
<thead>
<tr>
<th>Measurement System</th>
<th>Diagnosis System</th>
</tr>
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<tbody>
<tr>
<td><strong>Failure Rate (FR)</strong></td>
<td>FR(_A) = 2.3 \times 10^{-4} \quad</td>
</tr>
<tr>
<td><strong>Safe Down Rate (SDR)</strong></td>
<td>SDR(_A) = 4.6 \times 10^{-5} \quad</td>
</tr>
</tbody>
</table>

\[
THR_S \approx \frac{FR_A}{SDR_A} \times \frac{FR_B}{SDR_B} \times (SDR_A + SDR_B)
\]

\[
THR_S \approx \frac{8.4 \times 10^{-5}}{1h}
\]

- EN 50129 allows adoption of GNSS as localization system to railway terminology
- Satellite based localization: SIL 1
- GNSS can fulfill localization tasks with low safety relevance
- Additive localization equipment is necessary
GNSS certification for railways
SIL classification of applications

- SIL 0
  - Trackman warning
  - Dispatching
  - Tracking and Tracing
  - Infrastructure inspection (track, catenary wire)
  - Passenger information
- SIL 1
  - Energy saving
- SIL 2
  - Train integrity
  - Tilting activation, deactivation
  - Standstill detection
- SIL 3
  - Train protection
- SIL 4
  - Temporal availability: 99,99%
  - 99,8%
  - 99,6%
  - 99,4%
  - 99,2%
  - 99,0%

GNSS: time to alarm
Railways: fault detection time
< 1 s
1 s < Alarm < 10 s
> 10 s
10 km 1 km 100 m 10 m 1 m 10 cm 1 cm
horizontal/vertical accuracy
SIL classification of applications:
- Spatial availability: Discrete
- Spatial availability: Continuous
• Safety relevant usage of satellite based localization systems in railways is possible
• For functions with high safety needs further localization devices are needed
• Quantities not known in GNSS-specifications needs to be specified by according authorities
• Terminological framework of GNSS and all transport domains need to be established according to a single concept
• Common terminological framework will enable qualification of GNSS-receivers for all transport domains
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