An Intermodal View of the Opportunities and Challenges of GNSS as a Basic Telematics Sensor for Assisted and Automated Driving

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Agenda

1. CV, Chair and Topics of University Research
2. Definition of GPS as a basic sensor for telematics
3. GNSS in multimodal transport modes in relation to connected driving
4. Indoor solutions using pseudo GNSS backup systems
5. Conclusion and future outlook
CV Oliver Michler, University Full Professor

**Scientific and Professional Positions (since 1993)**

**1993 - 1997** Scientific Staff and PhD-Research of TU Dresden, Faculty of Electrical and Computer Engineering

**1997 – 2000** Scientific Project manager at Video-Audio-Design GmbH as a Telkom-Partner

**2000 – 2005** Scientific Staff at Fraunhofer Institute for Transportation and Infrastructure Systems Dresden (FhG-IVI)

**2005 – 2008** Professor at University of Applied Sciences Dresden in Signal Processing and Electronic Measurement Techniques

**2010 – 2017** Head of department of TUD-Research group at FhG-IVI

**2008 –** Full Professor at TU Dresden in Systems Information Technology, Faculty of Transportation and Traffic Sciences

**2017 -** Director of TU Dresden of Institute of Traffic Telematics

**2019 -** Scientific advisory board member of MRK AG, Metirionic and ISCons GmbH as a knowledge transfer research

**Research topics**

data-driven and model-based approaches, wireless mobility systems over all traffic carriers and services, autonomous driving, intelligent vehicle, next generation technologies based of communication/localization/sensing, software defined radio
University of Technology in Dresden (TUD)
The “Friedrich List” Faculty of Transport and Traffic Sciences

A unique, interdisciplinary competence center for transportation sciences

- Dresden Institute of Automobile Engineering
- Institute of Railway Vehicles and Railway Technology
- Institute of Railway Systems and Public Transport
- Institute of Logistics and Aviation
- Institute of Transport Planning and Road Traffic
- Institute of Traffic Telematics
- Institute of Transport and Economics

Technological and Market Progress in Transportation & Mobility

Changed Education in Transportation Economy and Transportation Engineering
Fields of competence (ITVS)

Communication networks
- Pico cell (ZigBee, BLE, UWB, ...)
- Micro cell (Mobil radio, WLANp, ...)
- Macro cell (DAB+, ...)

Environmental perception
- via LIDAR / Camera
- via Radar

Multi Modal Traffic Carriers
Digital Synergies

Multi-sensor data fusion (Integrity)

Precise georeferencing

Multi-GNSS-tracking (GPS, GALILEO, ...)

Communication networks
Methodological approaches with primary focus on challenges / applicability

(Driving) Operation
Road user

Cross - traffic
modal approach

Track
Road, Rail, Air, Water

Signal and data processing in relation to communication, positioning, tracking and environmental detection

Cross - technology
driven approach

Vehicle
Automobile, (Freight wagon)
Train, aircraft, ship

Research focus: Traffic carrier cross-modal vehicle environment signals

Telematics and IT - Platforms (RF, LF, Software, Protocols, Interfaces, HMI)

- Modelling, Parametrisation
- Error analysis, Integrity

Radio channel simulation (PC environment)

Signal environment generation (Lab environment)

Record/Playback Field measurements (Field-, long term tests)

- Automotive
- Rail transport
- Aviation / Aircraft cabin
- Water transport
Research focus: Digital Synergies in Projects / Industry Applications

Connected and automated driving
IVS-AMP, IVS-LOK, Fast Sign

Intelligent rail transport
AZubiG, Messstraba

Innovative air traffic
CabiNET, CANARIA & ADKT

Production 4.0
IOPS, DROPS

Inland vessel navigation 4.0
PiLoNav, DigiShip

Forestry 4.0
AutoDrone & HarvesterNavi

Overview of all current / previous projects: https://tu-dresden.de/bu/verkehr/vis/itvs/forschung/forschungsprojekte?set_language=en
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2. Definition of GPS as a basic sensor for telematics - Motivation

- Knowledge about location on earth is a central prerequisite for many applications of transport telematics.
Satellite communication and navigation basics

- Basic principle of position determination:
  - Time-of-flight measurement at the receiver leads to a distance measurement via the correlation of the speed of light (synchronisation required).

\[ D = \Delta t \cdot c \]
Satellite communication and navigation basics

- Basic principle of position determination:
  - Synchronization error of the receiver can be compensated by a second, time-synchronised transmitting station (pre-condition: distance between transmitting stations known)

\[ D = \frac{(\Delta \tau_1 - \Delta \tau_2) \cdot c + A}{2} \]
Satellite communication and navigation basics

- Localisation in three-dimensional space:
  - 3 satellites for positioning

- Localisation by means of signal propagation times:
  - 1 Satellite to determine the time offset

A total of 4 satellites required for positioning
Satellite structure and systems

- General GNSS structure:
  - Segments:
    - Space segment
    - User segment
    - Control segment
    - From the ground station

2. Definition of GPS as a basic sensor for telematics
GNSS Challenges in stand-alone positioning

- **Multipath:**
  - Shading and reflections because of buildings (interference of signals)

- **Jamming / Interference and HW/SW-Impacts**

- **Refractive and Synchronisation errors:**
  - Error of satellite position and satellite time (nav-data)
  - Longer path because of refraction
  - Ionosphere and plasmasphere 70…2000 km height
  - Troposphere 0 … 70 km height

2. Definition of GPS as a basic sensor for telematics
General approaches to increase accuracy of GNSS (Overview/Expertise)

2. Definition of GPS as a basic sensor for telematics
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- Transport fields of competence (ITVS) – Multi modal GNSS applications

**Multi Modal Traffic Carriers**
**Digital Synergies**

- Multi-GNSS-tracking (GPS, GALILEO, ...)

1. [Image of a car's dashboard with GPS coordinates]
2. [Image of a train and rail tracks]
3. [Image of a boat on a river]
GNSS-basics in Automotive applications (research points)

- Navigation systems / TMC application quality project (Lab based)
  - Integrated GPS constellation simulator and RDS-TMC generator
  - Black-box test of various navigation systems
  - Creation of scenarios directly from GIS data
  - Speed profile with dynamic vehicle model

![Integration of GNSS and Automotive Systems](image-url)

Quelle: ADAC
GNSS-basics in Automotive applications (research points)

- Tracing a trajectory and platooning application (Automotive test field HTW-Dresden)

<table>
<thead>
<tr>
<th>Test field highway</th>
<th>Test field area</th>
<th>Test road crossing</th>
<th>Parking garage</th>
</tr>
</thead>
</table>

Testing field highway → Test area field → Test road crossing → Parking garage

(Images of testing environment and GNSS positioning technology)

3. GNSS in multimodal transport modes
GNSS-basics in Automotive applications (research points)

- Tracing a trajectory and platooning application (Automotive test field HTW-Dresden)

3. GNSS in multimodal transport modes

Elimination / Reduction of correlated error terms
GNSS-basics in Train applications (research points)

- Assisted and automated driving of rail vehicles and freight wagons /
GNSS-basics in Train applications (research points)

- Track-selective localization through sensor data fusion

```
\[ \text{northing [m]} \]
760
750
740
730
720

\[ \text{easting [m]} \]
6240 6250 6260 6270 6280 6290 6300 6310

direction of driving

- GPS position measurement (2 switches)
- Result after fusion of data from GNSS receiver, radar and IMU and map matching
```
GNSS-basics in Shipping in applications (research points)

- Assisted and automated driving of Inland vessels and rescue systems (AIS)

Universal Automatic Identification System (AIS)

Inland Ship Lock
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- GNSS-Availability or Accuracy aren`t complied? What can we do ...

Ranging over Pseudo Satellites

Wireless Sensor Networks (WSN)

Received Signal Strength  Time of Arrival  Phase of Arrival  Angle of Arrival  Cell of Origin

RSS  ToA  PoA  AoA  CoO
Transport fields of competence (ITVS) – Multi modal GNSS applications

- Positioning Process in Wireless Sensor Networks

- $X_A$... anchor node (known position)
- $X_M$... mobile node (unknown position)
- $d_{ij}$... ranging (distance measurement)

$$d_{ij}^2 = (x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2$$

Set of Equations

4. Indoor solutions using pseudo GNSS backup systems
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- GNSS is the basic sensor in multimodal traffic telematics for outdoor environments
- Location errors can be minimized through signal processing and data fusion
- WSN can solve indoor positioning tasks as pseudo GNSS

- **Future:** High precision universal position sensor for hybrid vehicles (cross-modal)

> „If I had asked the people what they wanted, they would have said faster horses.“
> (Henry Ford / 1863-1947)

Source: [www.duden.de](http://www.duden.de)
Source: [www.edle-oldtimer.de/ford-t-modell](http://www.edle-oldtimer.de/ford-t-modell)
Source: [https://youtu.be/wHJTZ7k0BXU](https://youtu.be/wHJTZ7k0BXU)
Thank you for your attention!

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