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Quality Assessment of Various Digital Road Maps for Wrong-Way Driving Detection on the German Autobahn

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Jinyue Wang, Martin Metzner, Volker Schwieger

Institute of Engineering Geodesy (IIGS), University of Stuttgart, Germany

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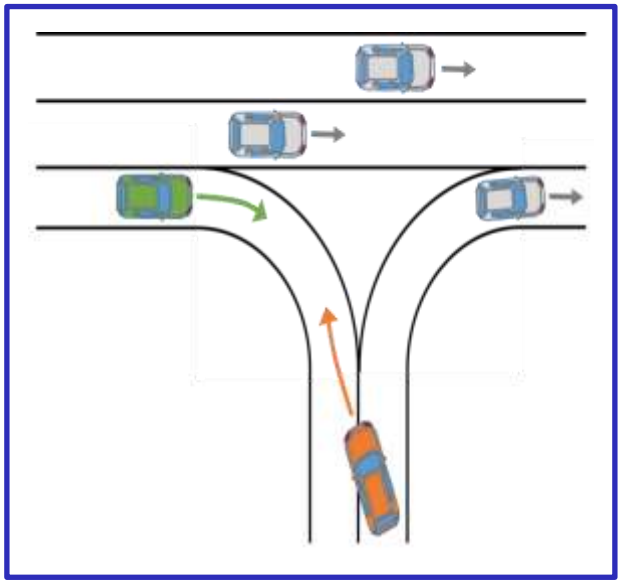
Motivation

Project Ghosthunter – a telematics system for wrong-way driver detection using GNSS, digital road maps and map-matching technology

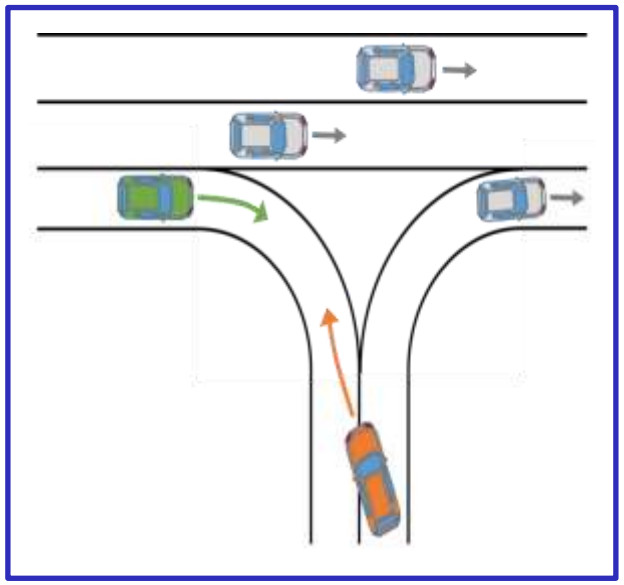
- Total number of wrong-way driver at the German Autobahn: about 1,950 per year
- The most serious traffic accidents were mostly caused by wrong-way drivers.
- Meanings and strategies to prevent such accidents:
  - Additional traffic signs or road markings
  - Induction coils on each lane
  - Laser systems on both sides of each lane
  - Video detection on bridges over the highways
  - Technical solutions based on Global Navigation Satellite System (GNSS) and digital road maps



Motivation

Project Ghosthunter – a telematics system for wrong-way driver detection using GNSS, digital road maps and map-matching technology

- Total number of wrong-way driver at the German Autobahn: about 1,950 per year
- The most serious traffic accidents were mostly caused by wrong-way drivers.
- Meanings and strategies to prevent such accidents:
  - **These would result in extremely high costs, e.g. about 25 Mio. euros for installing induction coils in Germany.**
  - Technical solutions based on Global Navigation Satellite System (GNSS) and digital road maps



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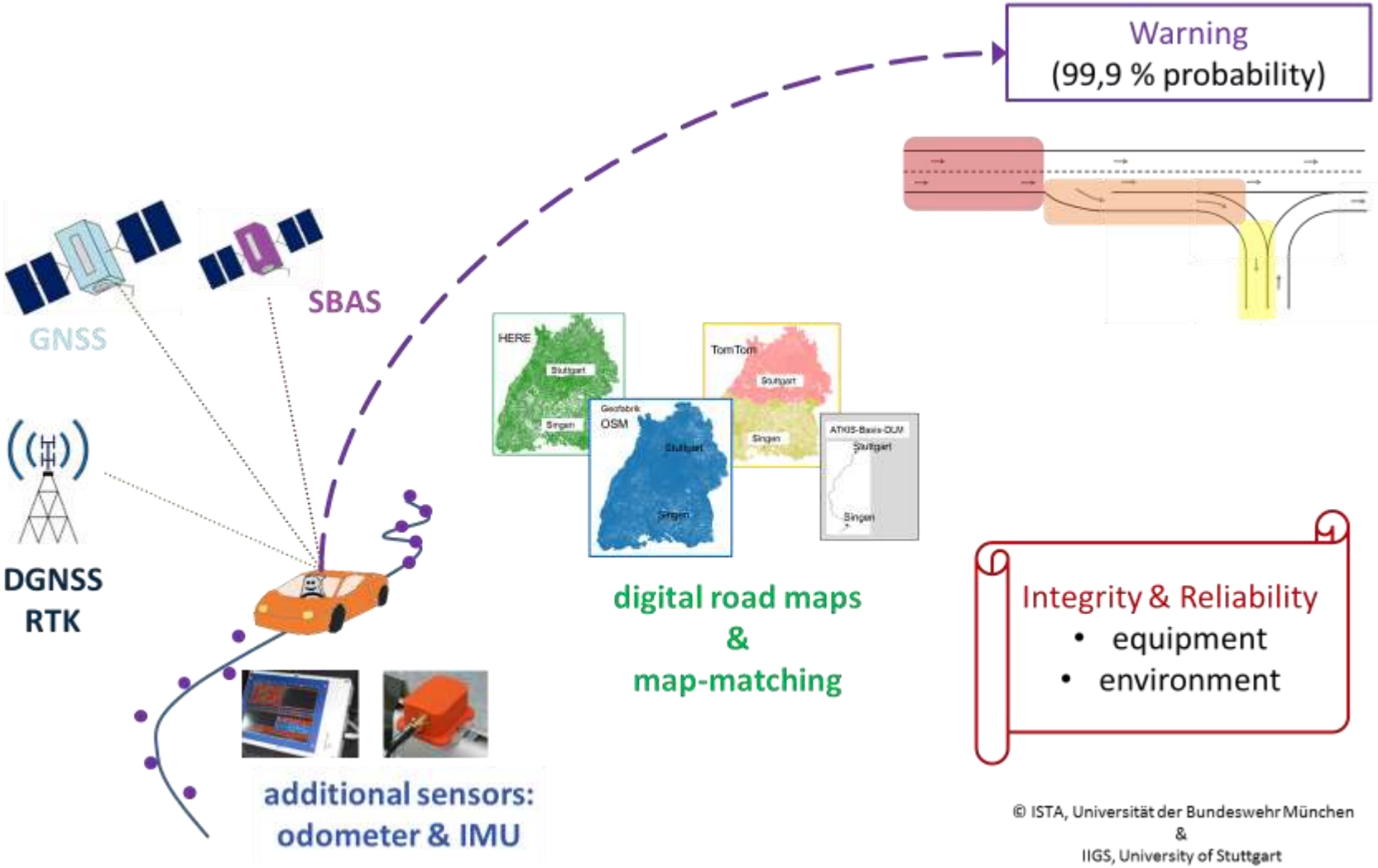
Project Ghosthunter

Supported by:
Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

- Project partners:
  - Institute of Space Technology and Space Applications (ISTA), Universität der Bundeswehr München,
  - Institute of Engineering Geodesy (IIGS), University of Stuttgart,
  - Navcert GmbH in Braunschweig, Germany.
- Granted and funded by
  - the German Federal Ministry for Economic Affairs and Energy (BMWi)
  - the German Aerospace Centre (DLR)
- Objective: wrong-way driving detection on the German autobahn to prevent ghost driver incidents and thus to enhance the road safety, particularly by entering and exiting an autobahn

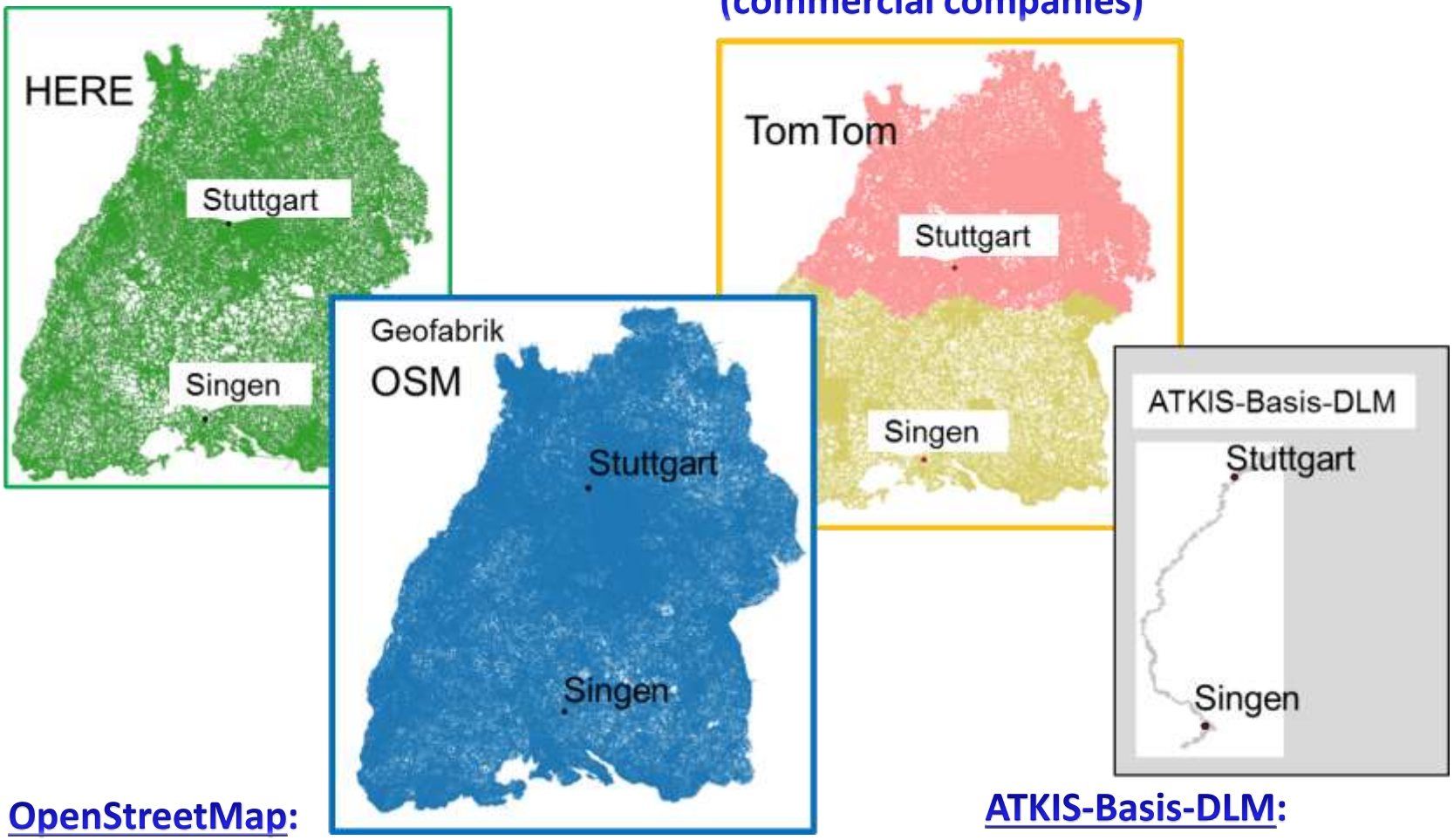
Project Ghosthunter

Principle of operation: a telematics system for wrong-way driver detection using GNSS, digital road maps and map-matching technology



Digital Road Maps

HERE and TomTom:
two of the major digital map-makers (commercial companies)



OpenStreetMap:
volunteered geographic information

ATKIS-Basis-DLM:
the German official topological-cartographic information system

Digital Road Maps

Investigation of the geometric accuracy and completeness of traffic-related attributes of four different datasets of digital road map using

- GNSS-based precise kinematic reference trajectories
- well-founded quality criteria in terms of **absolute positional** and **shape accuracy** of digital road segments

with the aim to

- verify whether the investigated map data satisfy the level of accuracy specified in the current literature
- study the potential use of these map data for the preparation and development of an intelligent and reliable wrong-way driving detection system

Generation of Reference Trajectories

kinematic GNSS measurements at several well-selected typical autobahn junctions

precise reference trajectories generated using the GNSS Baseline Processing Engine Wa2 (co. Wasoft) with $\sigma \leq 1$ dm

GNSS raw data in Leica binary format

GNSS measurement data in RINEX format

+

SAPOS virtual reference stations (VRS) in RINEX format

+

antenna correction files in ATX format

Wa2

UTM coordinates und standard deviation of the measured vehicle position

Quality Criteria

Evaluation of the absolute positional accuracy (2D)

- **the perpendicular distance between a circle arc and a point**
- **achieved more realistic assessment results**

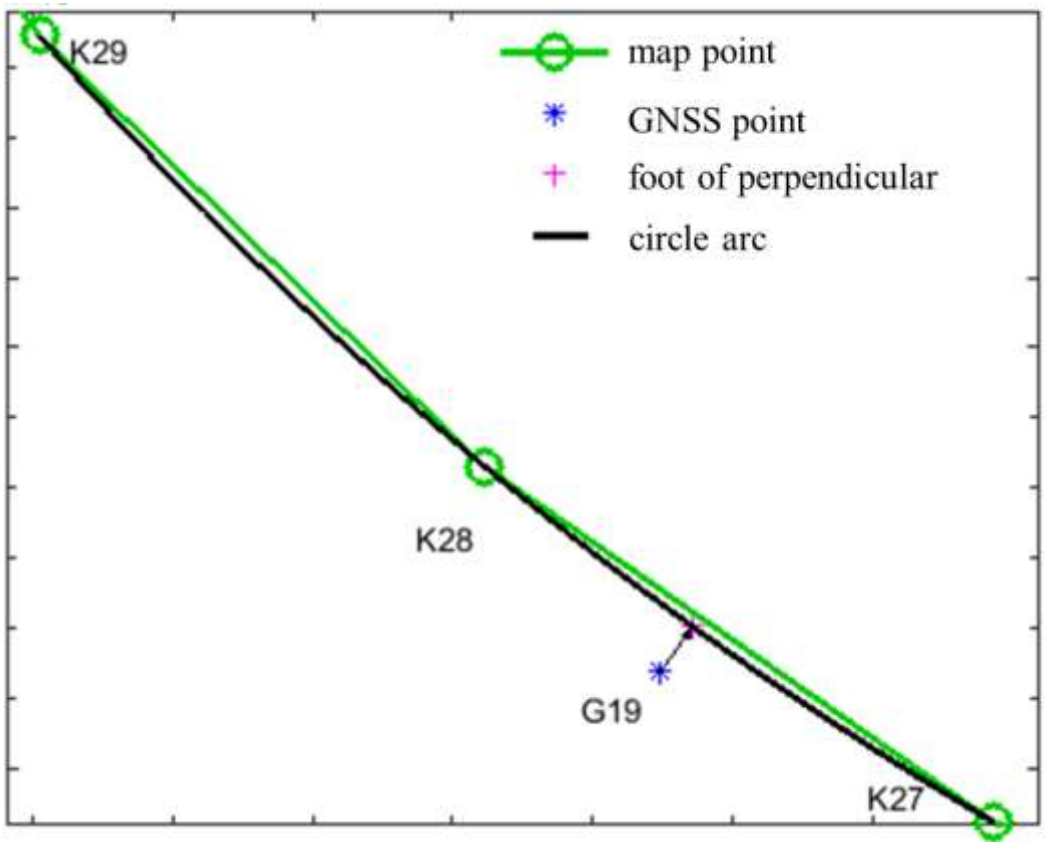
$$dx_i = x_{\text{gnss},i} - x_{\text{map},i}$$
$$dy_i = y_{\text{gnss},i} - y_{\text{map},i}$$

$$rms_{ds} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} dx_i^2 + dy_i^2}$$

$x_{\text{gnss},i}$, $y_{\text{gnss},i}$: UTM easting and northing (grid zone 32U) of the GNSS point

$x_{\text{map},i}$, $y_{\text{map},i}$: UTM easting and northing (grid zone 32U) of the map point

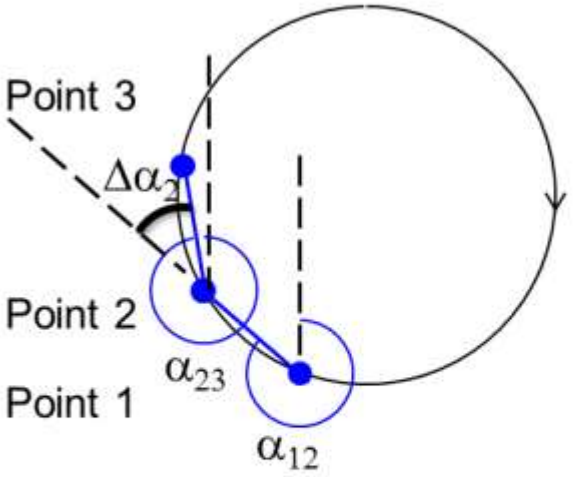
n *:* the total number of map points

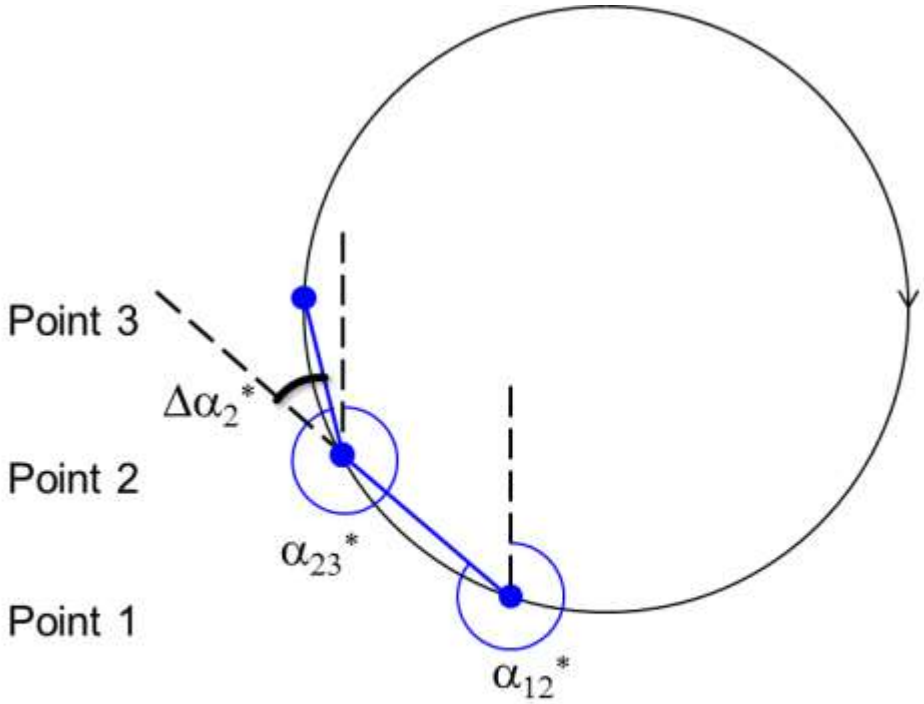


Quality Criteria

Evaluation of the shape accuracy (the relative positional accuracy, 2D)

- **orientation changes** $\Delta\alpha$
- **curvature** κ





$$\Delta\alpha_2 = \alpha_{23} - \alpha_{12}$$

$$\Delta\alpha_2^* = \alpha_{23}^* - \alpha_{12}^*$$

$$\Delta\alpha_2 = \Delta\alpha_2^*,\ \kappa \neq \kappa^*$$

Quality Criteria

Evaluation of the shape accuracy (the relative positional accuracy, 2D)

- **the difference of $\Delta\alpha$**

$$\Delta\Delta\alpha_i = \Delta\alpha_{\text{gnss},i} - \Delta\alpha_{\text{map},i}$$

$$rms_{\Delta\Delta\alpha} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\Delta\Delta\alpha_i^2}$$

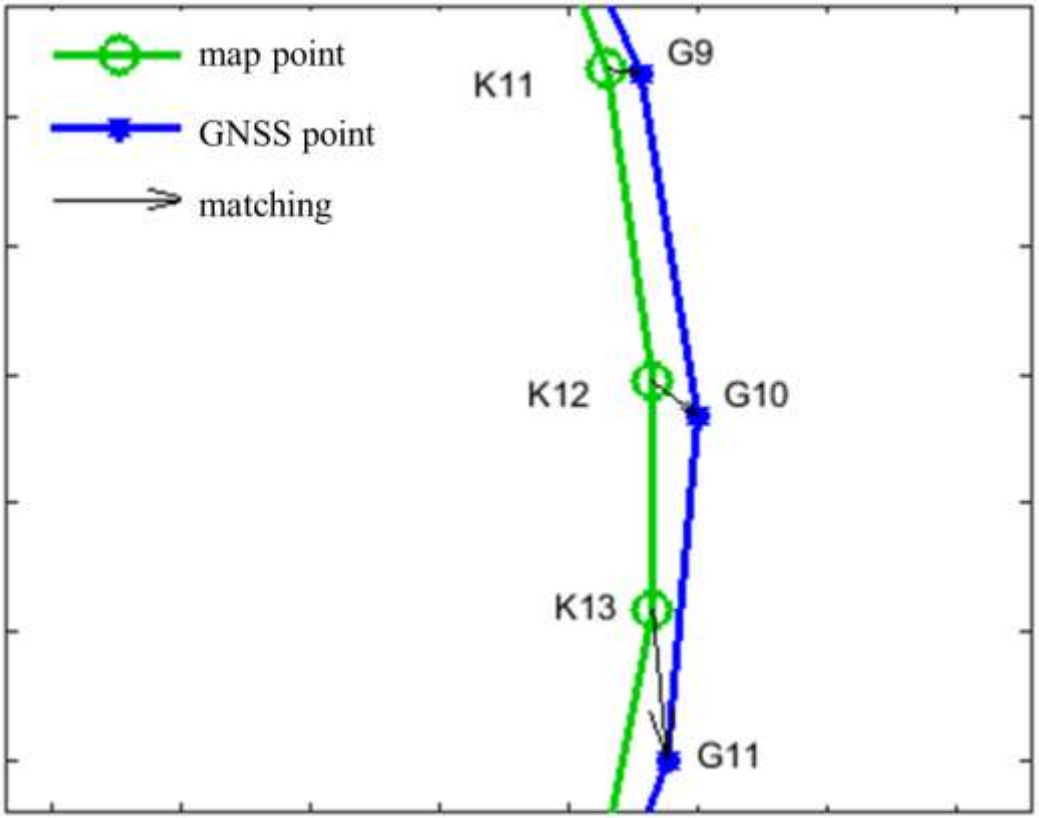
$$rms_{\Delta\Delta\alpha^*} = rms_{\Delta\Delta\alpha}\cdot\frac{\pi}{180}\cdot\Delta l$$

$$\text{with } \Delta l = 13 \text{ m}$$

- **the difference of κ**

$$\Delta\kappa_i = \kappa_{\text{gnss},i} - \kappa_{\text{map},i}$$

$$rms_{\Delta\kappa} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\Delta\kappa_i^2}$$



Results

For the map quality investigation in this work:

- **8** exemplary autobahn junctions
- including **35** (highway ramp): **18** entrance ramps and **17** exit ramps

→ This limited sample size may have an influence on the result.

Empirical map accuracy with respect to the GNSS-based trajectory

Accuracy	ATKIS	HERE	TomTom	OSM
$rms_{\text{absolute, } ds}$	1,80 m	2,02 m	2,00 m	1,95 m
$rms_{\text{relative, } \Delta\Delta\alpha}$	4,8°	4,1°	5,1°	4,2°
$rms_{\text{relative, } \Delta\Delta\alpha^*}$	1,09 m	0,93 m	1,17 m	0,95 m
$rms_{\text{relative, } \Delta\kappa}$	0,0087 m^{-1}	0,0053 m^{-1}	0,0079 m^{-1}	0,0055 m^{-1}

Accuracy specification according to the mapmakers

Accuracy	ATKIS	HERE	TomTom	OSM
σ_{absolute}	3 m	5 m*	5 m**	-
σ_{relative}	-	1 m*	1 m**	-

* HERE: Enhanced_Geometry = Y, with optimized street geometry

** TomTom: ADA = 1, ADA (Advanced Driver Assistance) Compliancy Flag

Results

ATKIS: 26 attributes
HERE: more than 200 attributes
TomTom: more than 200 attributes
OSM: 8 attributes

Completeness of traffic-related attributes

Attribute	HERE	TomTom	OSM	ATKIS
Road name	yes	yes	yes	yes
Road width	no	no	no	yes
Road length	yes	yes	no	no
Road type	yes	yes	yes	no
Travel direction	yes	yes	no	no
Travel time	no	yes	no	no
Number of lanes	yes	yes	no	yes
Speed category	yes	yes	no	no
Speed max.	yes	yes	yes	no
Accuracy level of position	yes	yes	no	no
Curvature	yes	yes*	no	no
Heading angle	yes	yes*	no	no
Angle of slope	yes	yes*	no	no
Attributes in total	11	9	3	3

Conclusion

- Conclusion:
  - absolute positional accuracy of 2 m
  - shape accuracy of 1 m
  - empirical map accuracy based on GNSS-based reference trajectory higher than the specification according to the map data providers
  - HERE and TomTom: higher completeness of telematics-related attributes

    → more compliant with road safety applications than ATKIS and OSM
- Future work / Later phases of the project:
  - Map-matching algorithms
  - related paper:

    Wang, J., Metzner, M. and Schwieger, V., 2017. Weighting-function based map-matching algorithm for a reliable wrong-way driving detection, accepted by 12th ITS European Congress, 19-22 June 2017, Strasbourg, France.

Thank you for your attention!

Contact:

Prof. Dr.-Ing. Volker Schwieger, Dr.-Ing. Martin Metzner, M.Sc. Jinyue Wang

Institute of Engineering Geodesy (IIGS)

University of Stuttgart
Geschwister-Scholl-Str. 24D
70174 Stuttgart, Germany

Phone: +49-711-685 84060
Fax: +49-711-685 84044
E-Mail: jinyue.Wang@ingeo.uni-stuttgart.de