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Ghosthunter III – Detection of Wrong-Way Drivers

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Outline

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Introduktion

- Wrong-way drivers are a major risk of serious accidents on highways
- About 1700 wrong-way drivers on German highways every year
  - responsible for about 80 accidents and 11 deaths
- Different approaches to prevent these wrong-way driving accident
  - signs or light signals to recognize a possible wrong-way approach
  - lane claws at the off ramps
  - induction loops or cameras
- An area-wide installation infrastructure is required and is very expensive
- Ghosthunter Projects is based on an GNSS-based solutions
  - overall cost-effective system and globally availability
  - wrong-way drivers and other road users can be warned

Source: Österreichischer Rundfunk, Stiftung öffentlichen Rechts

System Design and Requirements Analysis

- Three different information inputs provided the base for the system
  - GNSS measurements
  - independent auxiliary sensors
  - digital road map data with appropriate map-matching algorithms

- False alarm rate and missed detection rate
  - false alarm rate corresponds to trust in the system → $1 \cdot 10^{-8}$
    - Equivalent to one false alarm per day for the entire German motorway network.
  - missed detection rate describes the sensitivity of the system → 0.05
    - Equivalent to 100 missed detection per year

Quality Assessment of Digital Road Map Data

- Valid, reliable and comprehensive quality assessment of digital road maps
- HERE Global B.V., TomTom N.V., OpenStreetMap, ATKIS-Basis-DLM, 3D Mapping

	HERE	TomTom	OSM	ATKIS	3D Mapping
Assessment Date	2017	2021	2017	2017	2021
Abs. positional accuracy	2.02 m	2.00 m	1.95 m	1.80 m	0.11 m
Rel. positional accuracy	4.1°	5.1°	4.2°	4.8°	0.1°
Number of traffic-related digital road map attributes	10	8	4	3	12

Map-Matching and Wrong-Way Driver Detection

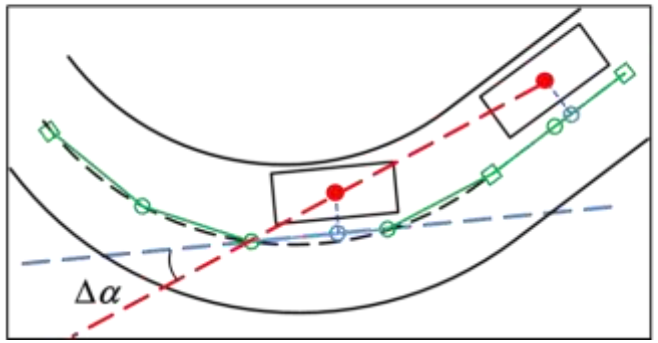
- Technique to unambiguously identify the correct road link on which a vehicle is driving

- Step 1: Multiple candidate search in the defined buffer zone (16 m x 16 m)
- Step 2: Probability computation based on three matching criteria and a weighting-function TWS
- Step 3: Statistical Decision for wrong-way drivers detection

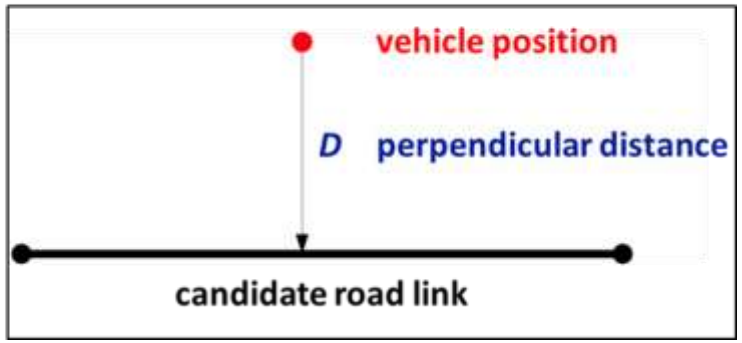
Map-Matching and Wrong-Way Driver Detection

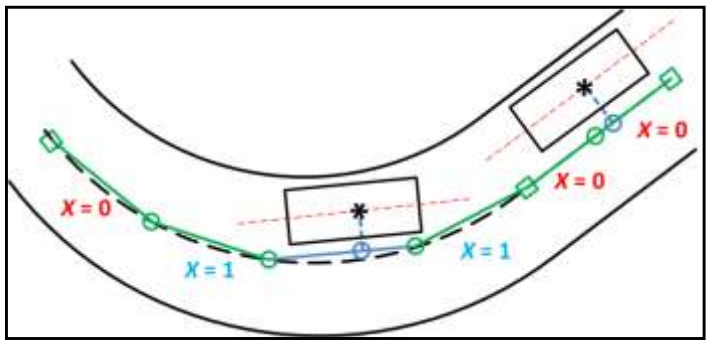
- Probability computation based on three matching criteria

(1) heading criterion: $\Delta\alpha$



(2) proximity (closeness) criterion: *D*



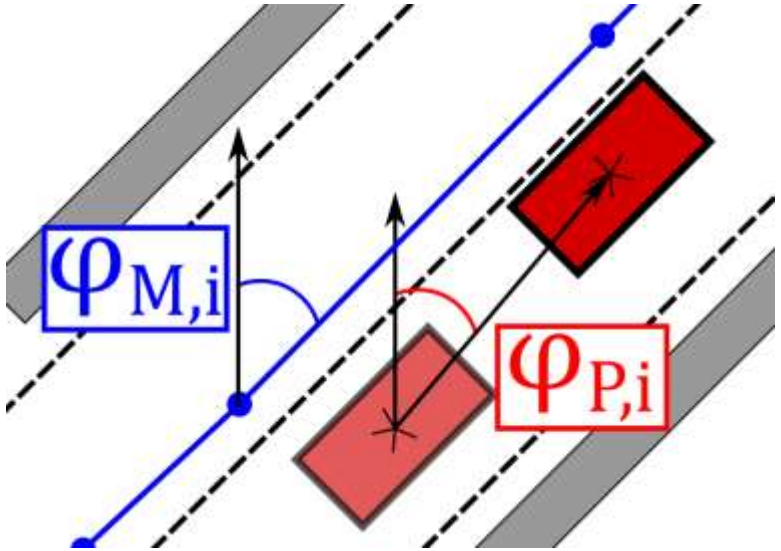


(3) link connectivity criterion: *X*

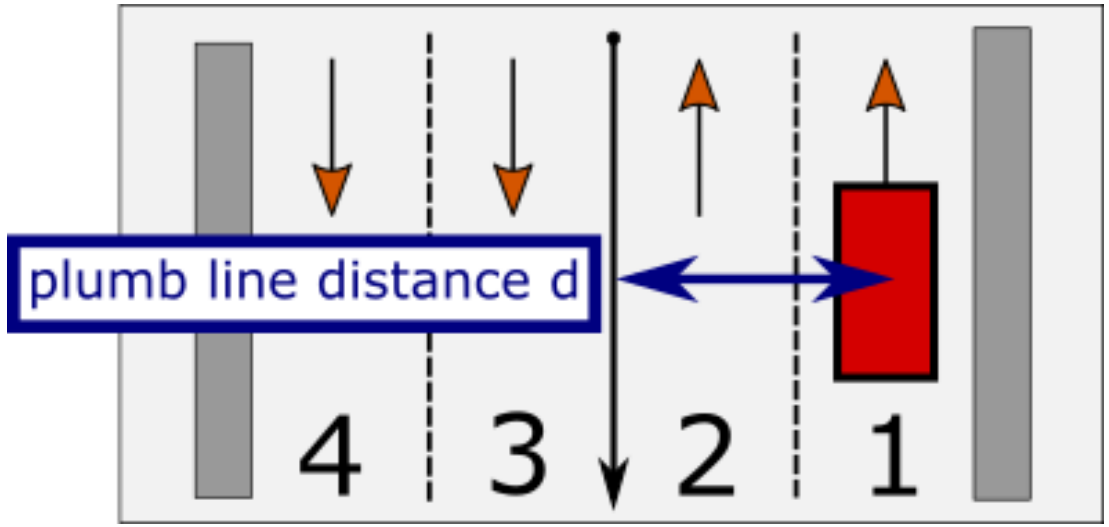
$$TWS = \frac{1}{3}\cos(\Delta\alpha) + \frac{1}{3}\left(\frac{\sqrt{2}b - D}{\sqrt{2}b}\right) + \frac{1}{3}X$$

Map-Matching and Wrong-Way Driver Detection

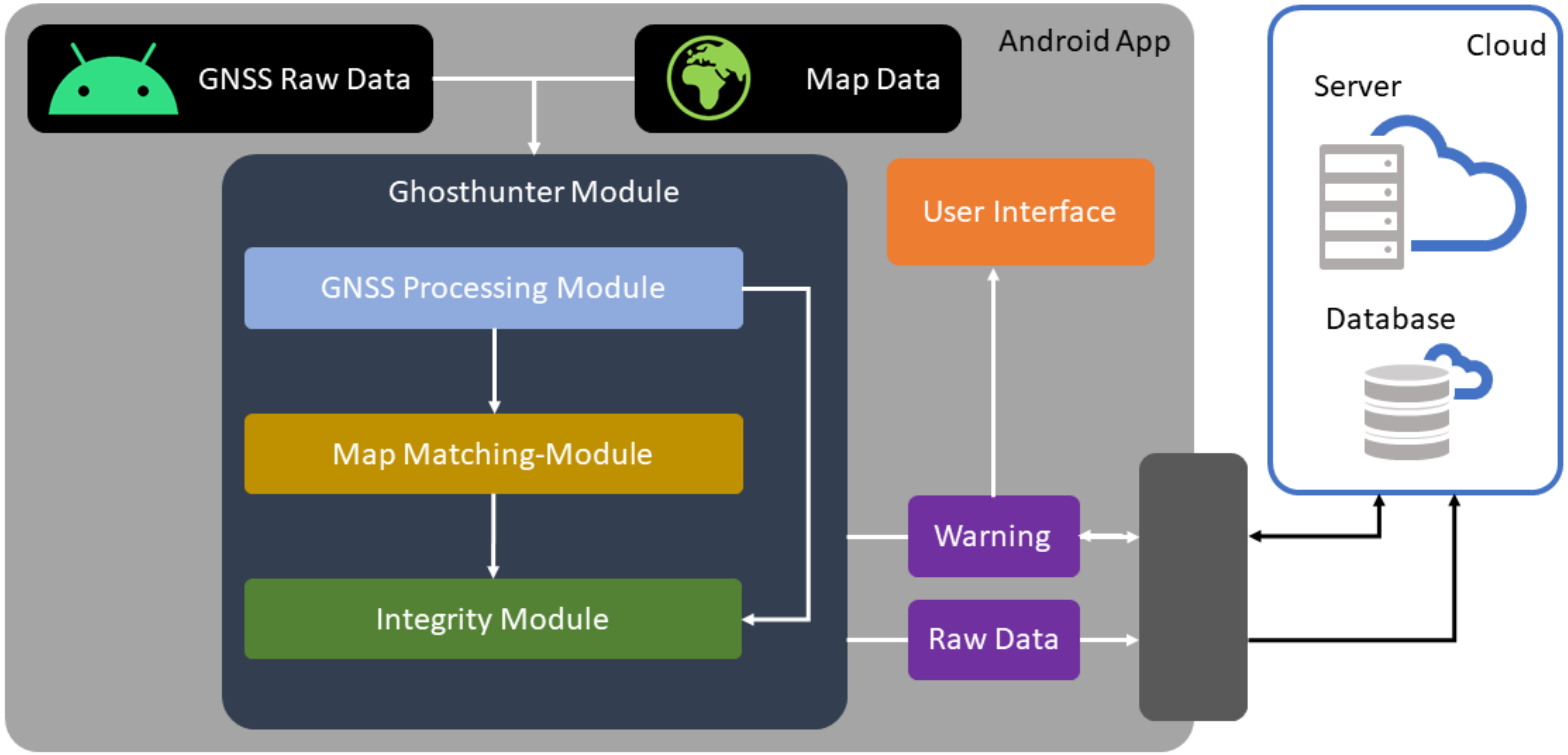
- One way attribute (comparision of angle of road segment and trajectory)



- Two way attribute (position of the vehicle (left or right of the centerline))



Demonstrator



Evaluation of Wrong-Way Driver Detection

- Evaluation based on real trajectories and simulated data with Maps from TomTom and 3D Mapping
- Confusion matrix of wrong-way driver detection with real trajectories
  - H_0: Vehicle driving in the wrong direction
  - H_1: Vehicle driving in the right direction

		Actual condition	
		H_0	H_1
Predicted condition	H_0	99.982 %	-
	H_1	0.018 %	-

Evaluation of Wrong-Way Driver Detection

- Confusion matrix of wrong-way driver detection with simulated trajectories ($\Delta_Q < 2\ m$)
  - Δ_Q is the GNSS position accuracy

TomTom

		Actual condition	
		H_0	H_1
Predicted condition	H_0	99.99 %	2.11 %
	H_1	$8 \cdot 10^{-3}$ %	97.89 %

3D Mapping

		Actual condition	
		H_0	H_1
Predicted condition	H_0	99.99 %	1.68 %
	H_1	$7 \cdot 10^{-4}$ %	98.32 %

Conclusion

- Main Goals of the projects
  - Development of a wrong-way driver detection system based on GNSS positions and a digital map including a warning system for other road users
- The basic system design was specified and then the target variables that the system has to meet in terms of robustness, maximum detection probability and minimum probability of false alarms were defined
- Demonstrator in the form of an Android app and a cloud infrastructure was developed
- Test of the current system with regard to the target values
  - Target values could not be fully achieved at this stage of development

Recent and Future Work

Positioning and OSM Map Data

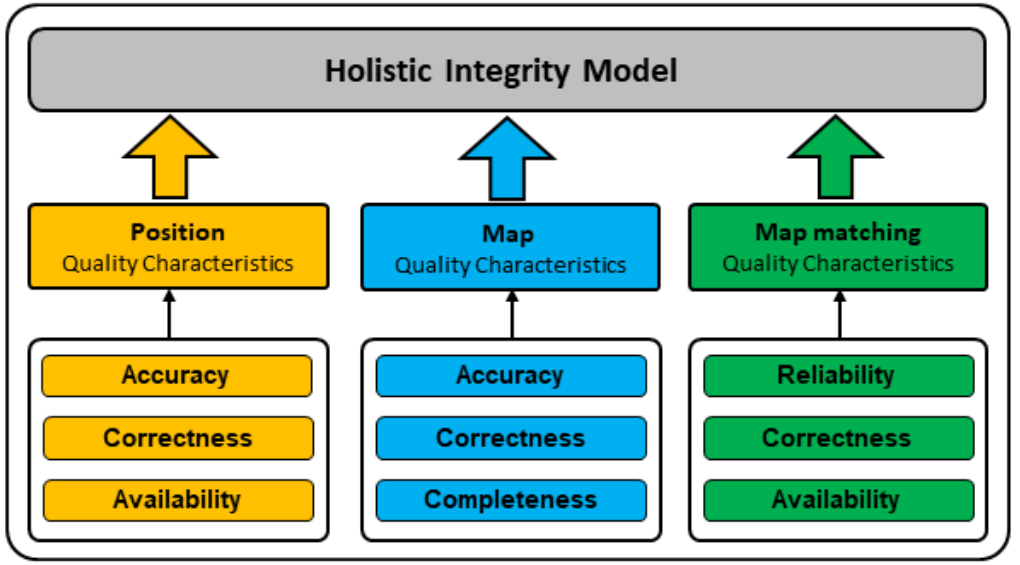
- Devellopement and further optimizations of positioning module that provides the required accuracy and integrity

- To provide large-scale distribution, a freely available digital road map should be used
  - OSM as digital Map
  - Algorithms have to be adapted

Source aerial photo: Google

Recent and Future Work

Integrity



- Ensuring the integrity of the overall system
- Individual analyzing of position, digital road maps and map matching

Integrity

  - Position integrity → filters for monitoring the integrity features
  - Map integrity → methods and algorithms to automatically check and evaluate the OSM map
  - Map matching → further development of existing algorithms
    → algorithms to detect changed lane alignments (e.g. due to road works)
- Development of a holistic integrity model
  - Combines the individual integrities to an overall model

Recent and Future Work

Certification

- Certification of the Ghosthunter app is one of the main goals
- Prototypical certification
  - Creation of a certification scheme
  - Definition of a measurement evaluation process
  - Execution of a measurement uncertainty analysis
  - Creation of a standard operating procedure (SOP)
  - Development of the detailed test plan
  - Validation of SOP and test plan through independent product specialists

→ Certification body decides whether to grant the certificate based on the results of the prototypical certification

→ Handover of the app to a partner who will take care of the system's operation in the future

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