Intelligent Database Architecture for High-Integrity Urban Navigation

Fabian Ruwisch[1], Le Ren[2], Christian Skupin[3], Tobias Kersten[1], Marcus O'Connor[2], Steffen Schön[1], Temmo Wübbena[2]
[1]Institut für Erdmessung, Leibniz Universität Hannover | [2]Geo++® GmbH, Garbsen | [3]Robert Bosch GmbH, Hildesheim

Leibniz Universität Hannover

Motivation

Accuracy, integrity and availability requirements are very stringent in urban navigation and autonomous driving. The GNSS sensor is the only one that provides self-localisation in a global coordinate system.

Challenge: NLOS and multipath signal reception in urban areas.

- To meet high accuracy requirements, these large signal distortions has to be known and corrected.
- Ray tracing approaches are real-time capable but require high computation load (O'Connor et al., 2021).

KOMET vision: Correction of GNSS multipath effects for reliable autonomous localisation of highly automated vehicles in metropolitan areas.

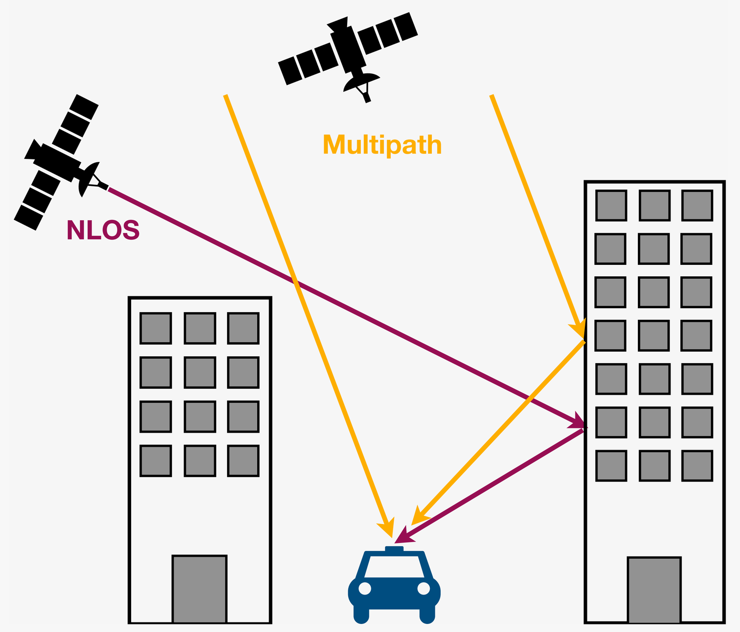
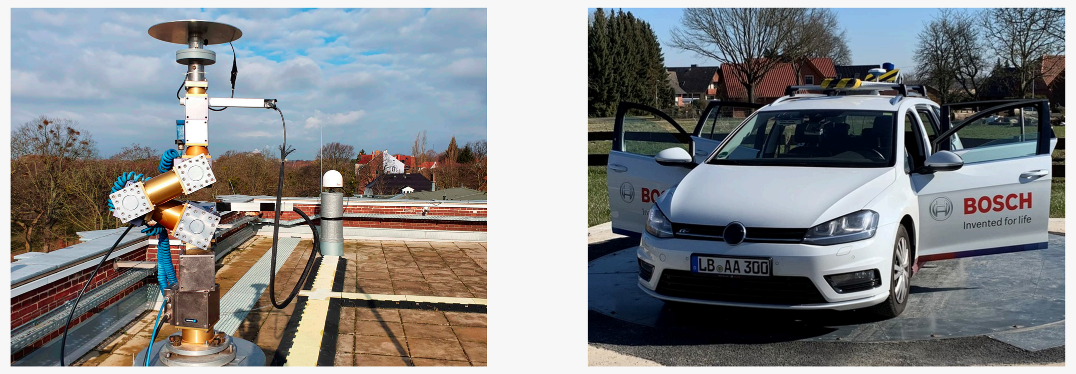


Fig. 1: Erroneous GNSS signal reception in urban environments.

Antenna Calibration

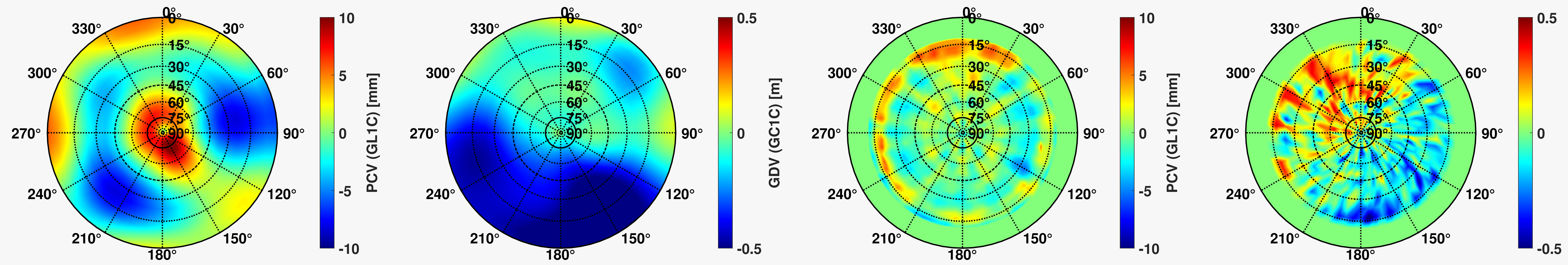
- Group Delay Variation (GDV) and Phase Center Variations (PCV) to correct for antenna effects.
- Installations on car roofs affect the antenna near field.
- Accurate multipath error determination requires elimination of these effects.

Needs: Antenna calibration including the test vehicle.



(a) (b)

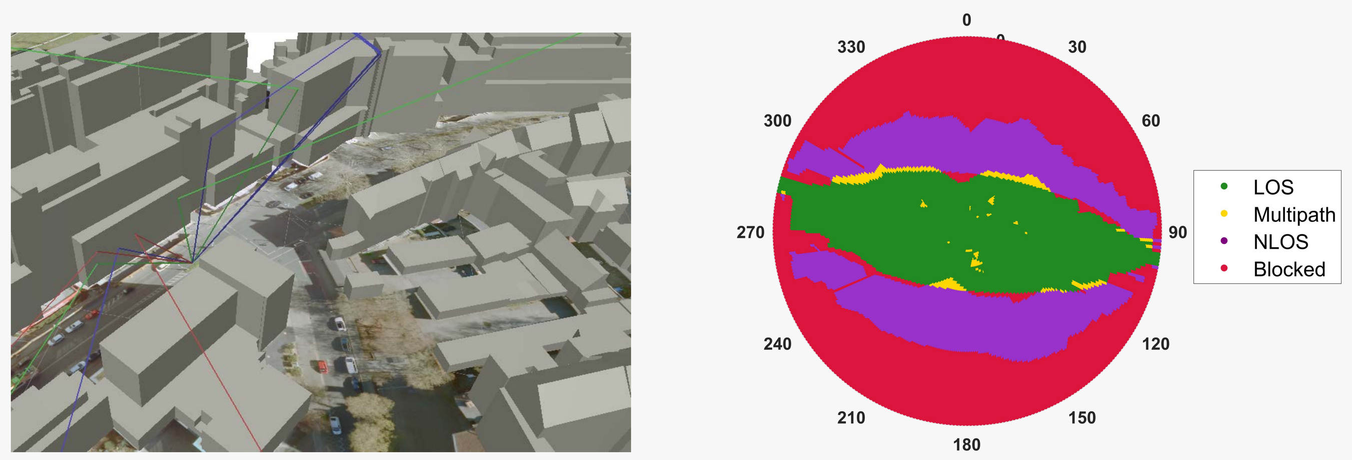
Fig. 2: Calibration setup on a robot (a) and on the moving platform (b).



(a) (b) (c) (d)

Fig. 3: GDV and PCV pattern of the Tallysman TW7972 antenna: calibrated on a robot ((a) and (b)) with 0° is geographical north and on the moving platform ((c) and (d)) with 0° is driving direction. Note, that the colour-axes are different for visualisation purposes.

Ray Tracing Using 3D Building Model



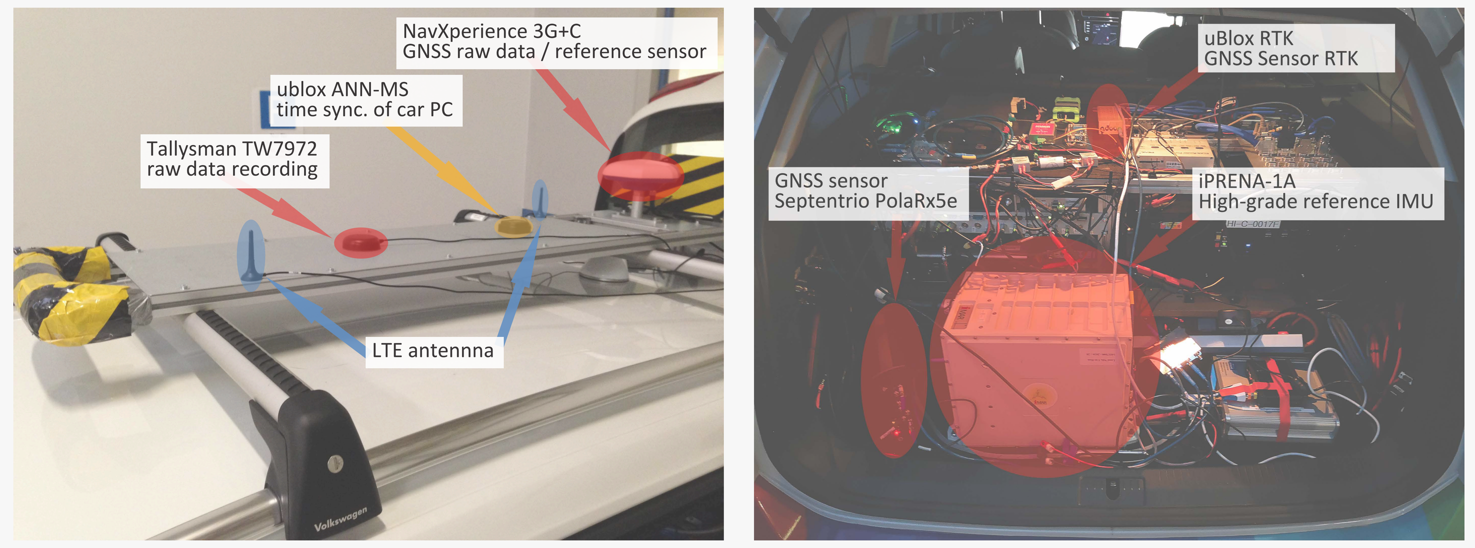
(a) (b)

Fig. 4: 3D Visualisation of ray tracing computation for an exemplary situation in the city of Hannover (a) and 360° × 90° simulation results for a specific location visualised in a skyplot (b).

- 3D Mapping-Aided GNSS is a common method to mitigate and correct GNSS errors in urban areas (Ruwisch and Schön, 2022).
- Characterisation of error magnitude dependent on user location and satellite position.
- Determination of NLOS and multipath signal reception areas.

Reference Trajectory

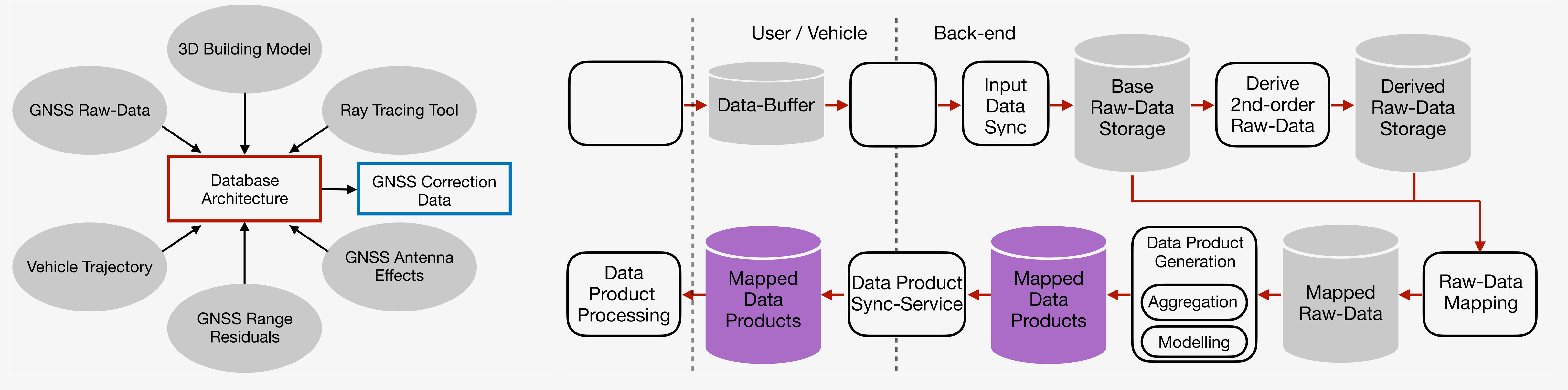
- Accurate reference trajectory for precise range residuals.
- Accurate positioning system with redundant RTK systems, fibre-optical ADMA-IMU, 360° LiDAR sensor and additional precise orthophotos.
- Ensuring precise and accurate trajectories, each location, all times.
- Validation by tightly coupled IMU/GNSS post-processing with ring-laser IMU/INS.



(a) (b)

Fig. 5: Multi-sensor system platform for the development of high-precision reference trajectories with dedicates sensors on roof top (a) and inside the car (b) for the drives in Hannover city.

Intelligent Database Architecture



(a) (b)

Fig. 6: General database setup diagram (a) and detailed architecture description (b) with defined input and output values.

Vehicle domain

- Data-logging: GNSS raw measurements, reference trajectory, metadata.
- Data-buffer: Storage of logged data for further processing in various files.
- Process mapped data products for improved GNSS-based positioning.

Back-end domain

- Time-sync. GNSS observations, location data, meta-data and derived raw-data based on post-processing.
- Crowd-sourced raw-data stored in a specific format serves as backbone for generation of data products.
- Mapped raw-data is processed in order to derive aggregated data products represented in a multi-dimensional map.

Conclusions and Future Work

- Development of a work flow to precisely determine GNSS NLOS and multipath errors.
- Intelligent database architecture to aggregate observations, antenna locations and to derive data products.
- Collected raw-data will be used for derivation of NLOS and multipath correction data for improved urban navigation.

References

O'Connor, Marcus et al. (Sept. 2021). "Low-latency GNSS multipath simulator for real-time applications in autonomous driving". In: *2021 IEEE/ACM 25th International Symposium on Distributed Simulation and Real Time Applications (DS-RT)*. IEEE, pp. 1–9. DOI: 10.1109/ds-rt52167.2021.9576146.
Ruwisch, Fabian and Steffen Schön (2022). "GNSS Feature Map: Representation of Signal Propagation-related Features in Urban Trenches". In: *Proceedings of the 2022 International Technical Meeting of The Institute of Navigation*, pp. 701–711. DOI: 10.33012/2022.18171.

Acknowledgement

This project is funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK) based on a resolution of the German Bundestag and supervised by TÜV-Rheinland (PT-TÜV) under the grant 19A20002C.