Intelligent Transport Systems Conference
24.09. – 28.09., Bilbao

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High Definition Mapping for Inland Waterways: Techniques, Challenges and Prospects

Lukas Hösch, Alonso Llorente, Xiangdong An,
Juan Pedro Llerena, Daniel Medina

AutonomSOWII

DLR

Mapping of inland waterway infrastructure

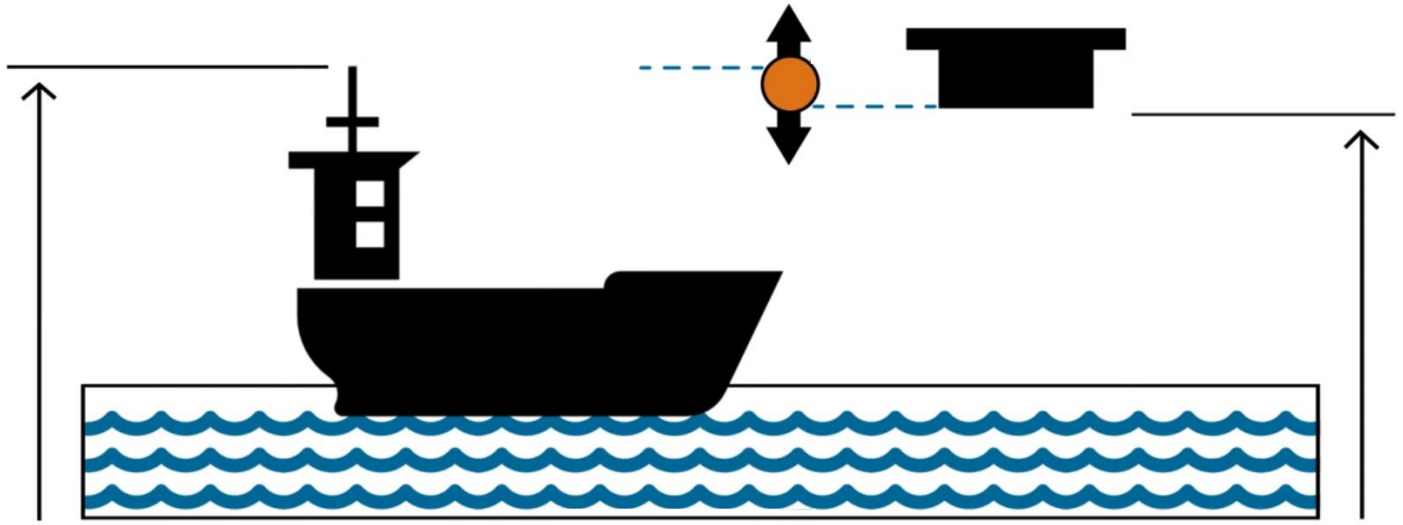
- Inland waterway transport as relevant part of modal split
- Key factor for reduction of traffic-related greenhouse gas emissions

- Bridge collision dangerous to operation

Mapping of inland waterway infrastructure

- Bridge approach assistant requires bridge **contours in geo-referenced frame**
- Sensors required anyway for autonomous operation

Solution: Inland vessel as sensor unit



Aufnahme und Abgabe von Vermessungsdaten an die Profildatenbank
GPro der LUBW – Hinweise für den Vermesser, I·S·T·W Planungsgesellschaft mbH Ludwigsburg

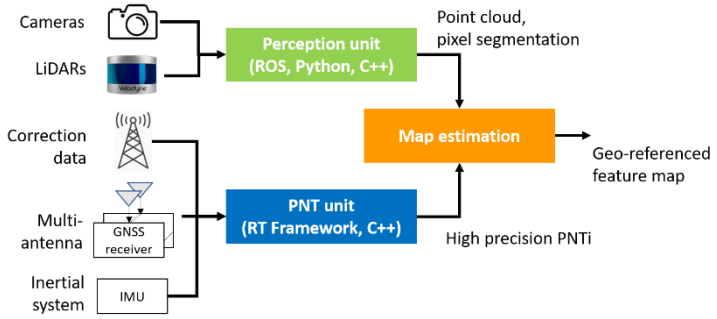
Procedure for HD Mapping

Sensor Platform

- vessel with the necessary HW
- **For geo-navigation:** GNSS, IMU, GNSS correction data
- **For perception:** LiDARs, cameras, SONAR

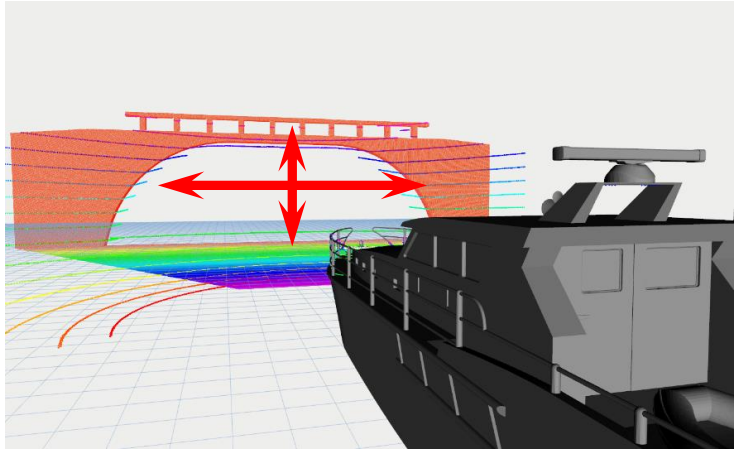
Map processing

- **Global Simultaneous Localization and Mapping (SLAM)** combines navigation & perception
- Precise positioning with multi antenna GNSS & correction data
- Representation via voxels / alphashapes
  → **geo-referenced 3D HD map**



Semantics extraction

- Feature extraction from HD map for compact information
- **Geo-referenced bridge contours**
- Traffic signs' recognition and placement



Lukas Hösch, German Aerospace Center (DLR), Department Nautical Systems

Outline

1. **Map Estimation**
   a) Geo-referenced navigation
   b) Visual Perception
   c) Global SLAM
2. **High Definition Mapping in Berlin**
3. **Outlook and Future Work**

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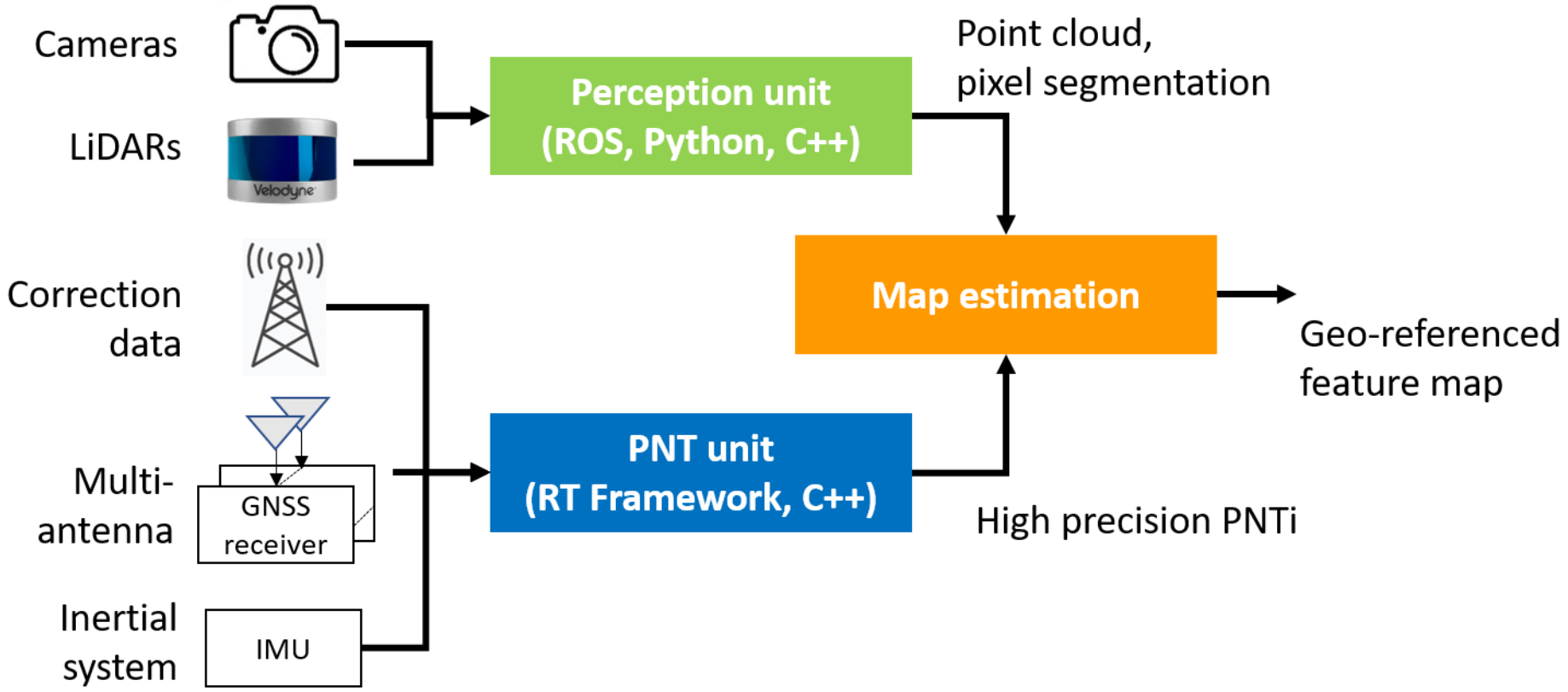
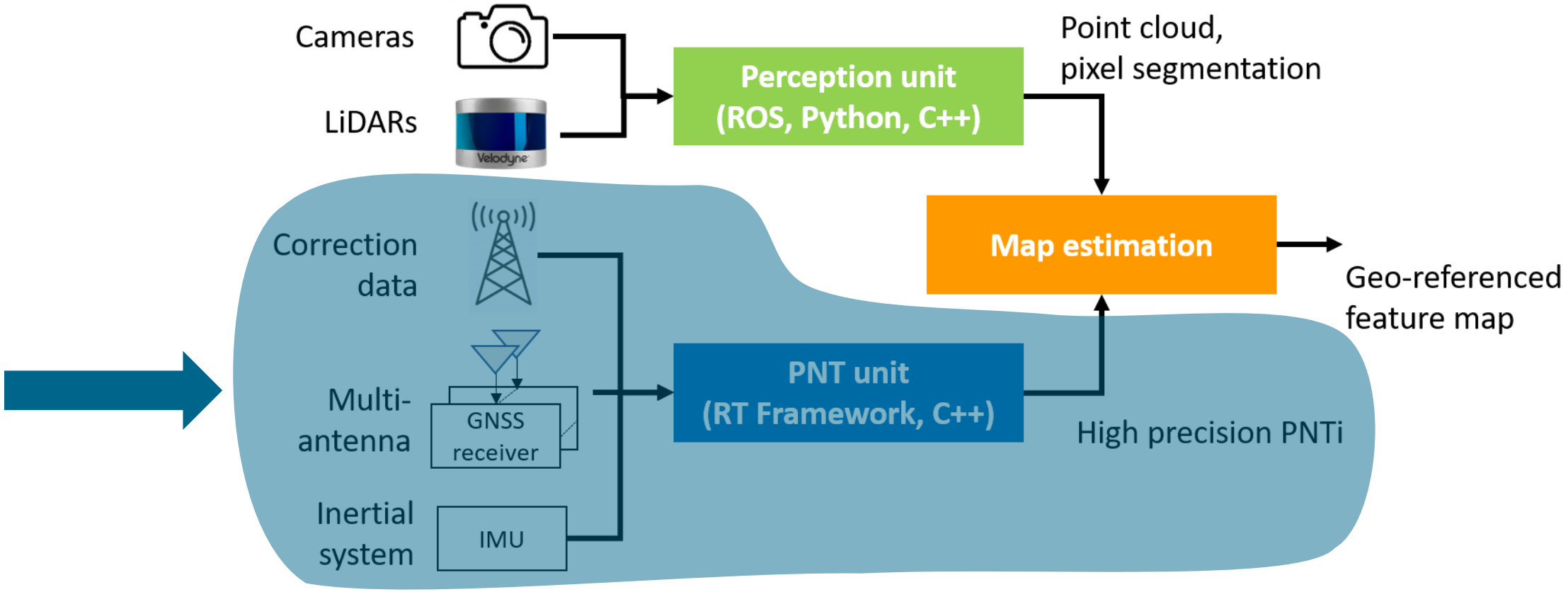
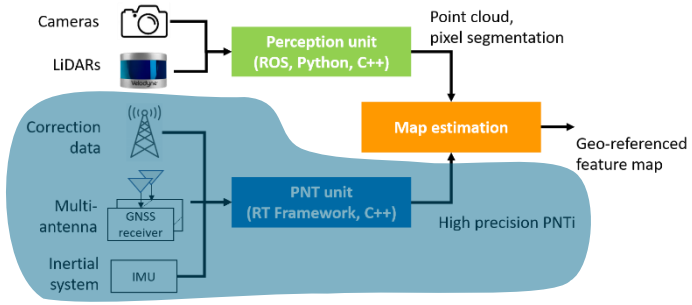
Map Estimation
System architecture



Map Estimation
System architecture



Map Estimation
Geo-referenced navigation

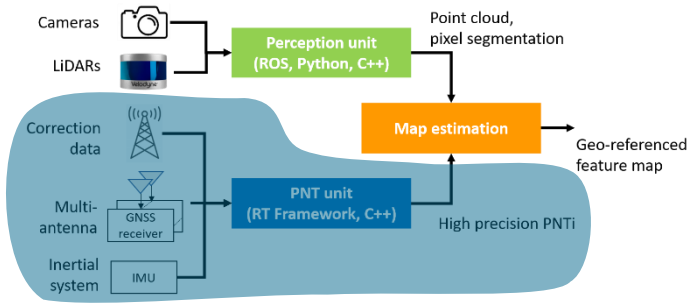


Position Navigation Timing Unit

→ accurate navigation data

- 3 GNSS receivers connected to 3 antennas
- 1x Tactical grade MEMS IMU (Sensonor STIM 3000)
- GNSS data correction over GSM (Galileo HAS corrections and SSRZ from SAPOS)

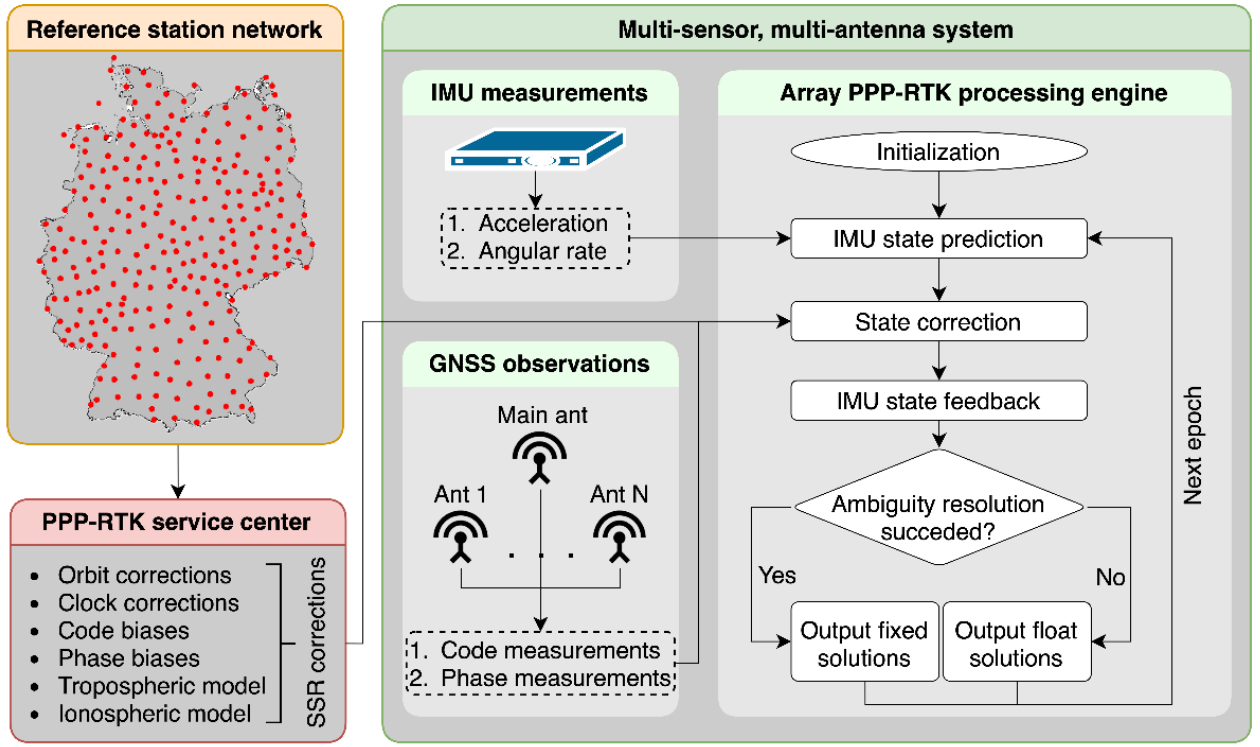
Map Estimation
Geo-referenced navigation



Multi-sensor, multi-antenna system:

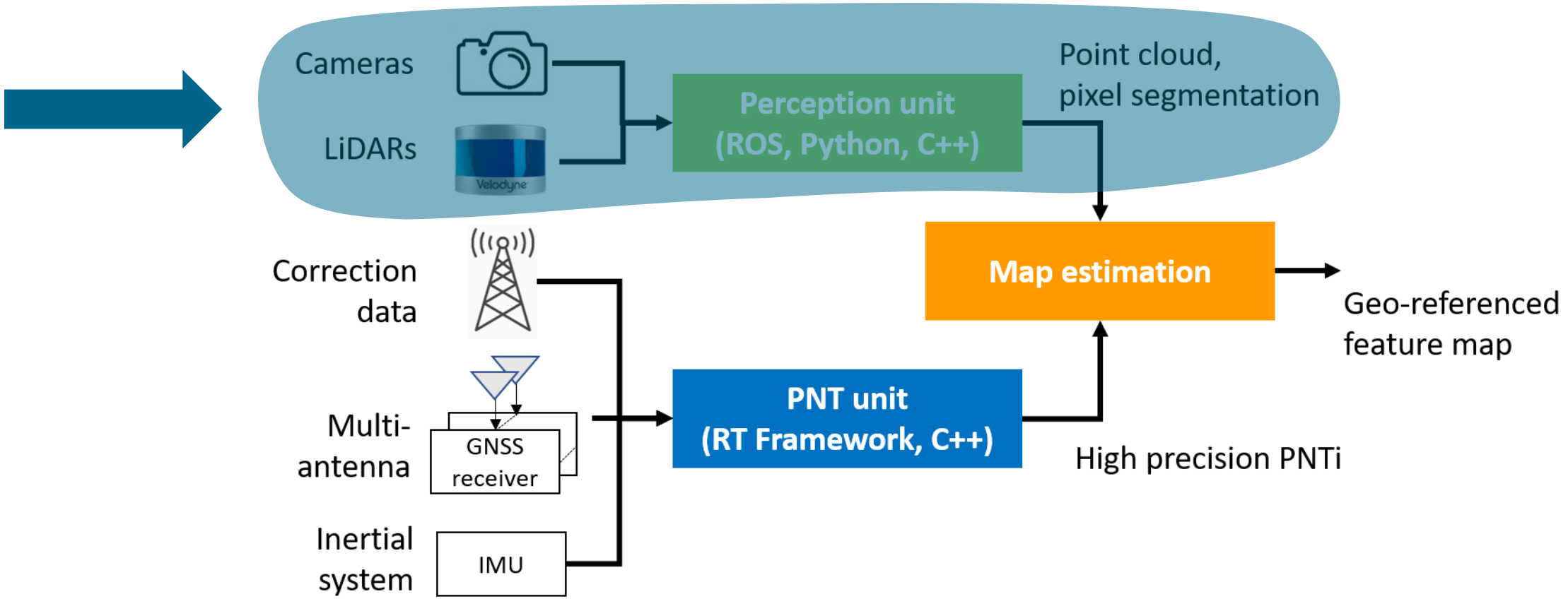
- Array PPP-RTK solution [1]
- IMU integration
- positioning in dm level, attitude estimates in sub-degree accuracy

- Real time correction via SAPOS®, in future possibly HAS (missing carrier phase biases)

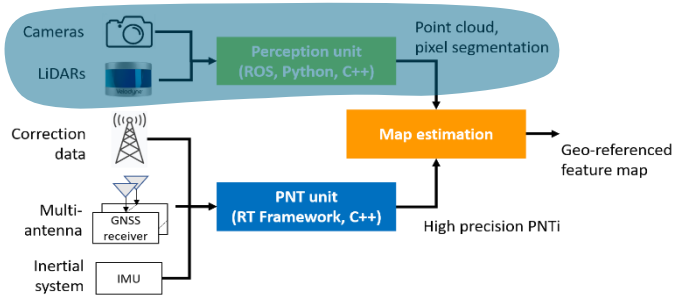


[1] submitted: Array PPP-RTK: A High Precision Pose Estimation Method for Outdoor Scenarios
Xiangdong An, Andrea Bellés, Filippo Rizzi, Lukas Hösch, Christoph Lass, Daniel Medina
IEEE Transactions on Intelligent Transportation Systems, 2023

Map Estimation
System architecture



Map Estimation Visual Perception



LiDAR point clouds (physical description)

SLAM

Point cloud alignment

Point cloud processing: RANSAC, DBSCAN

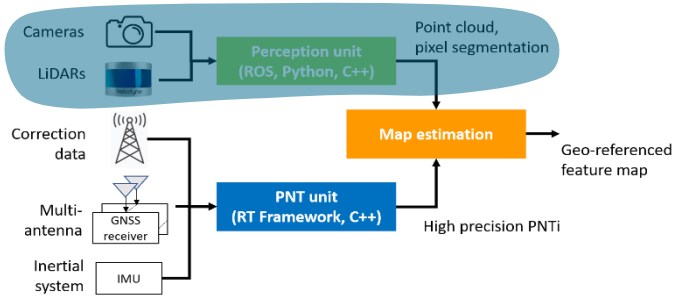
Point cloud segmentation

Point cloud to image alignment

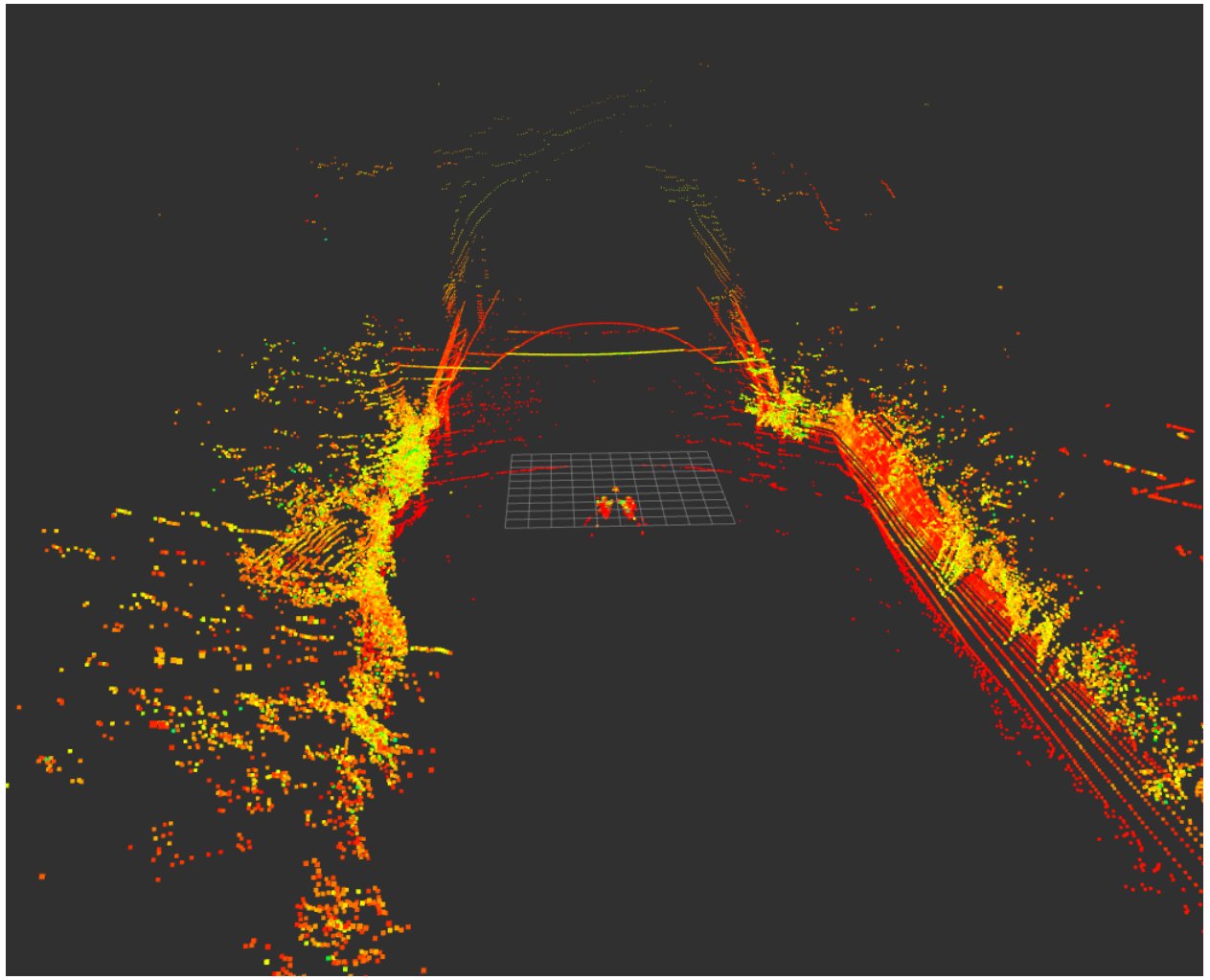
Camera images (semantic description)

Semantic segmentation

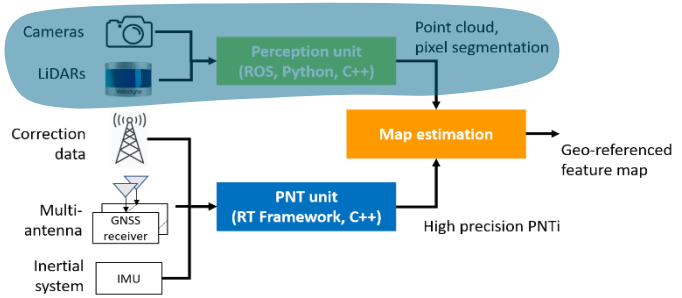
Map Estimation Physical description



- LiDAR → 3D point cloud
- Enables accurate spatial mapping
- Semantic description difficult



Map Estimation
Semantic description

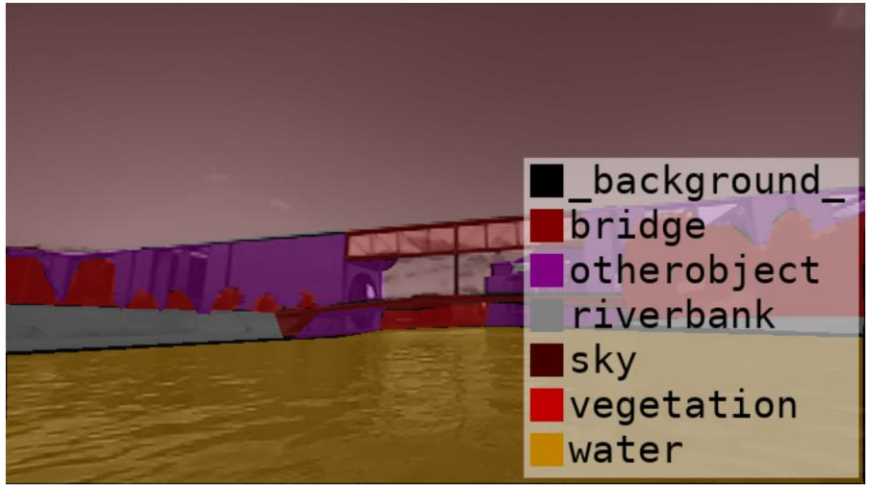


Semantic Scene understanding

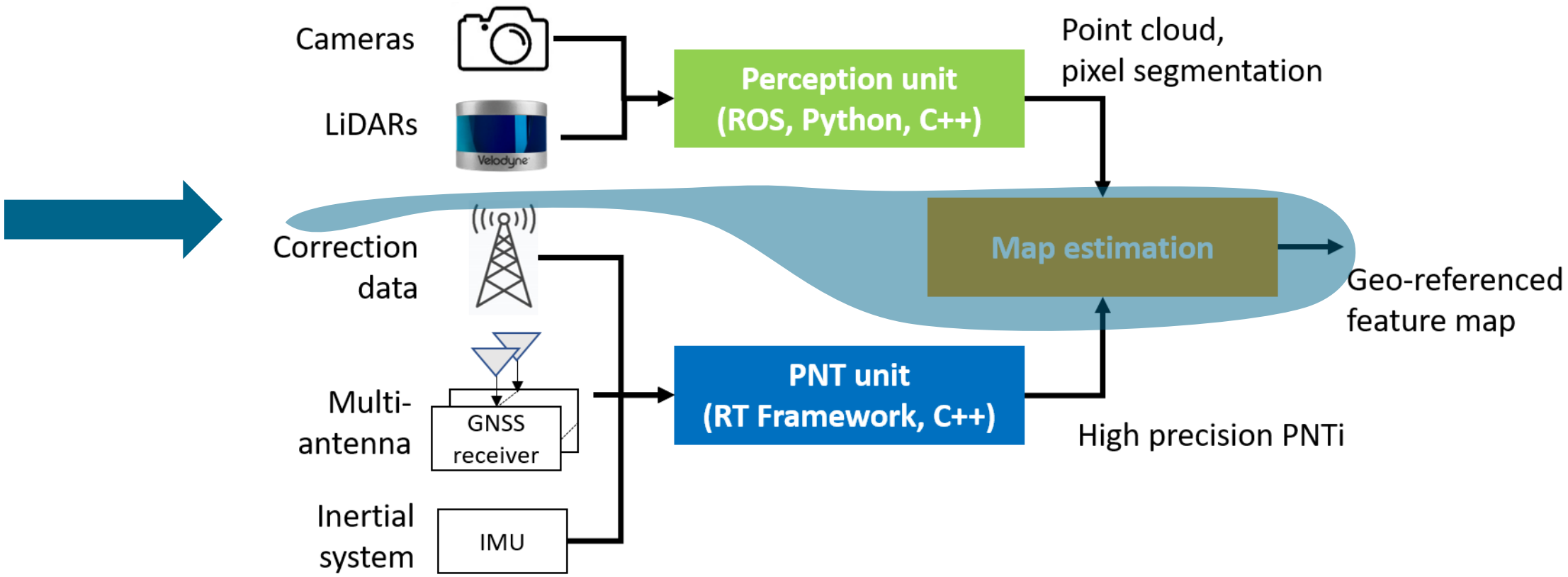
- Semantic Segmentation of camera image

- ML application → data hungry
- Development of our own dataset

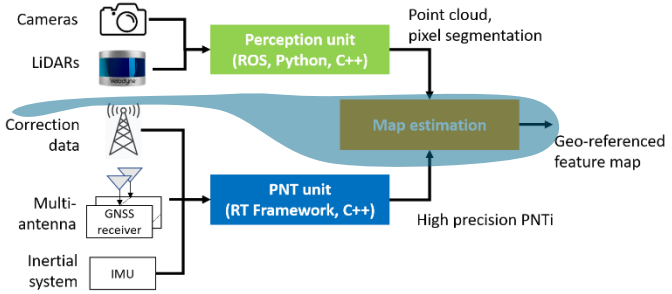
- Image – point cloud alignment allows point cloud segmentation



Map Estimation
System architecture

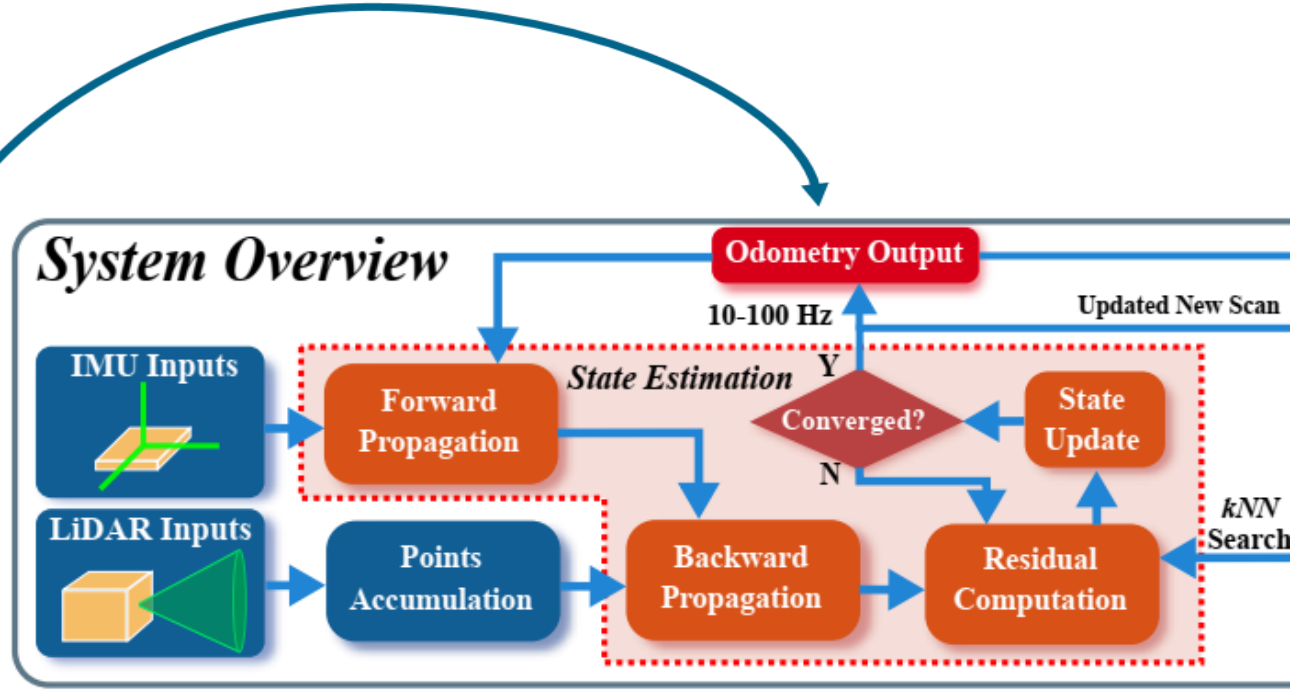


Map estimation Global SLAM



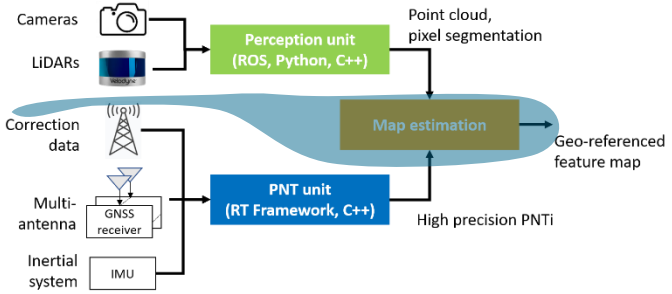
Adaption of FastLIO2 algorithm

- Original: Odometry information used for positioning
- Adaption: apply GNSS as navigation information to KF



[2] Xu, W., Cai, Y., He, D., Lin, J., & Zhang, F. (2022).
Fast-lio2: Fast direct lidar-inertial odometry. *IEEE Transactions on Robotics*, *38*(4), 2053-2073.

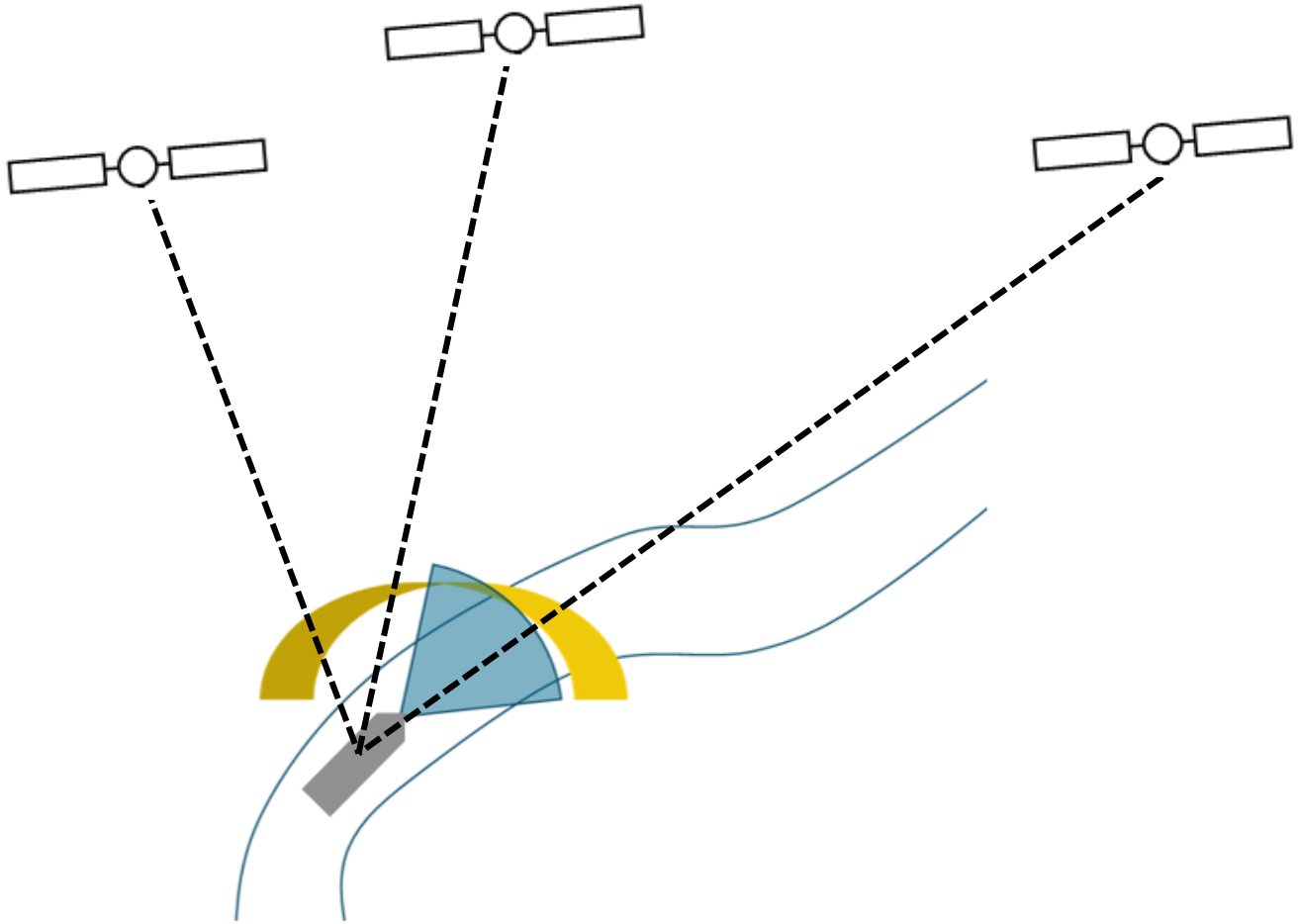
Map estimation Global SLAM



Global, feature-based SLAM solution

- Perception unit derives features
- PNT unit determines position & orientation

- Precise global registration of features



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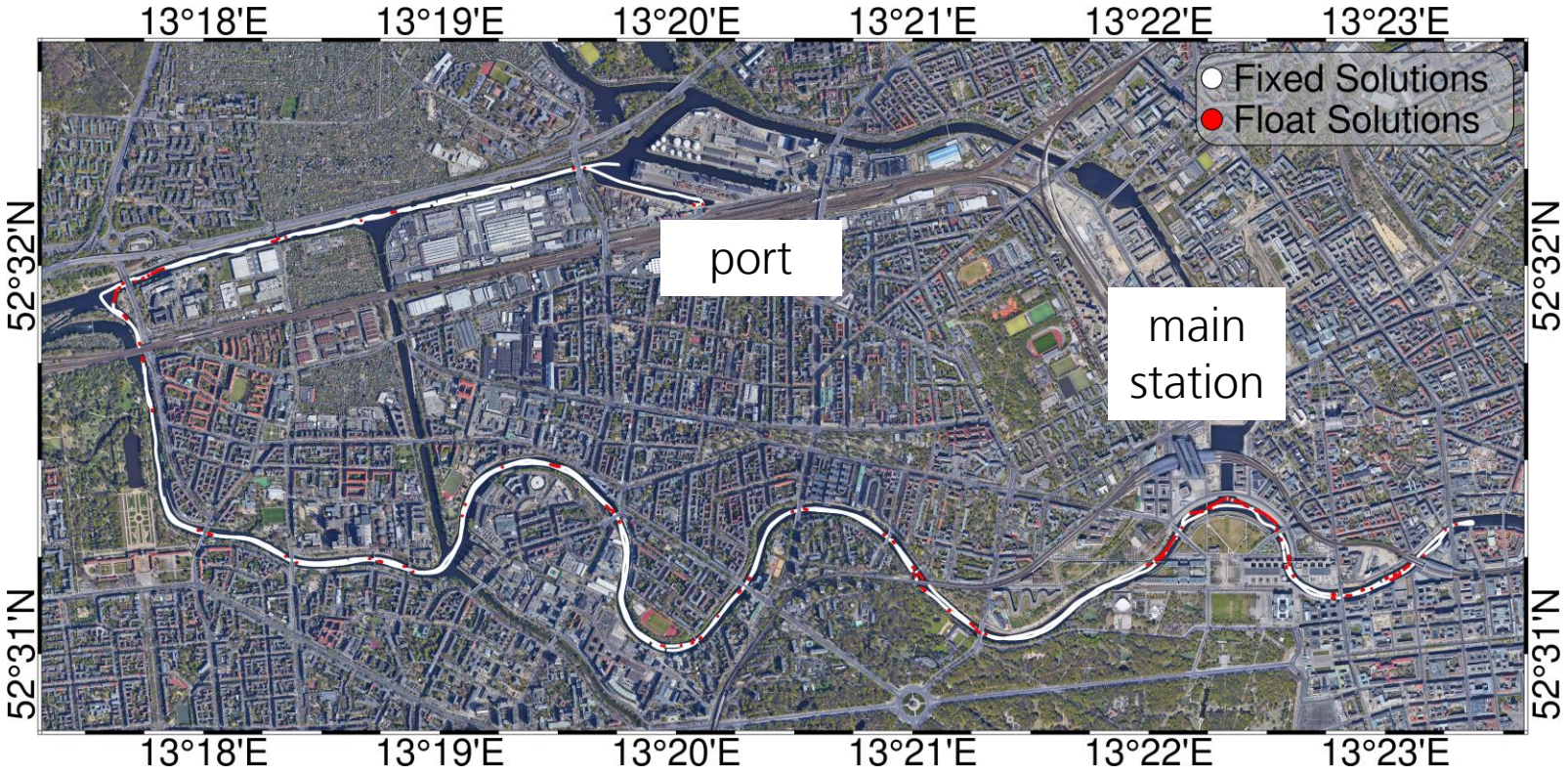
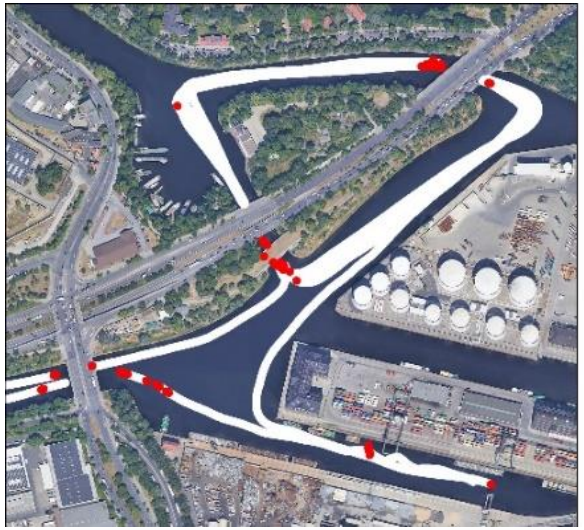
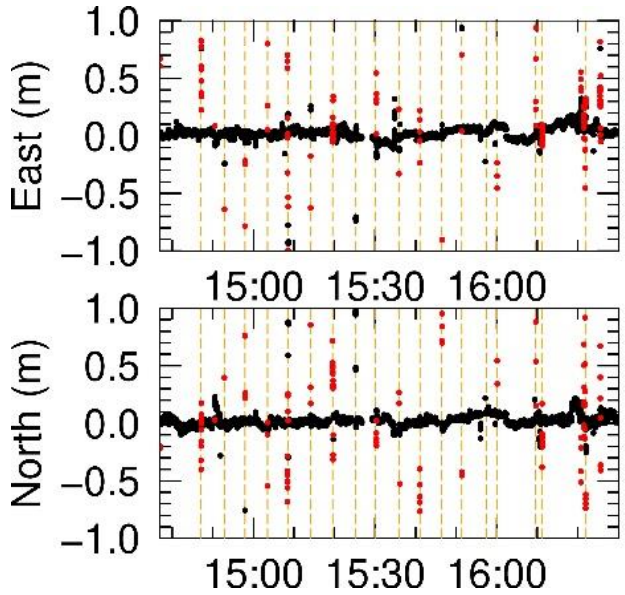
High Definition Mapping in Berlin Navigation







Results from measurement campaign June 2022

Submitted: Array PPP-RTK: A High Precision Pose Estimation Method for Outdoor Scenarios
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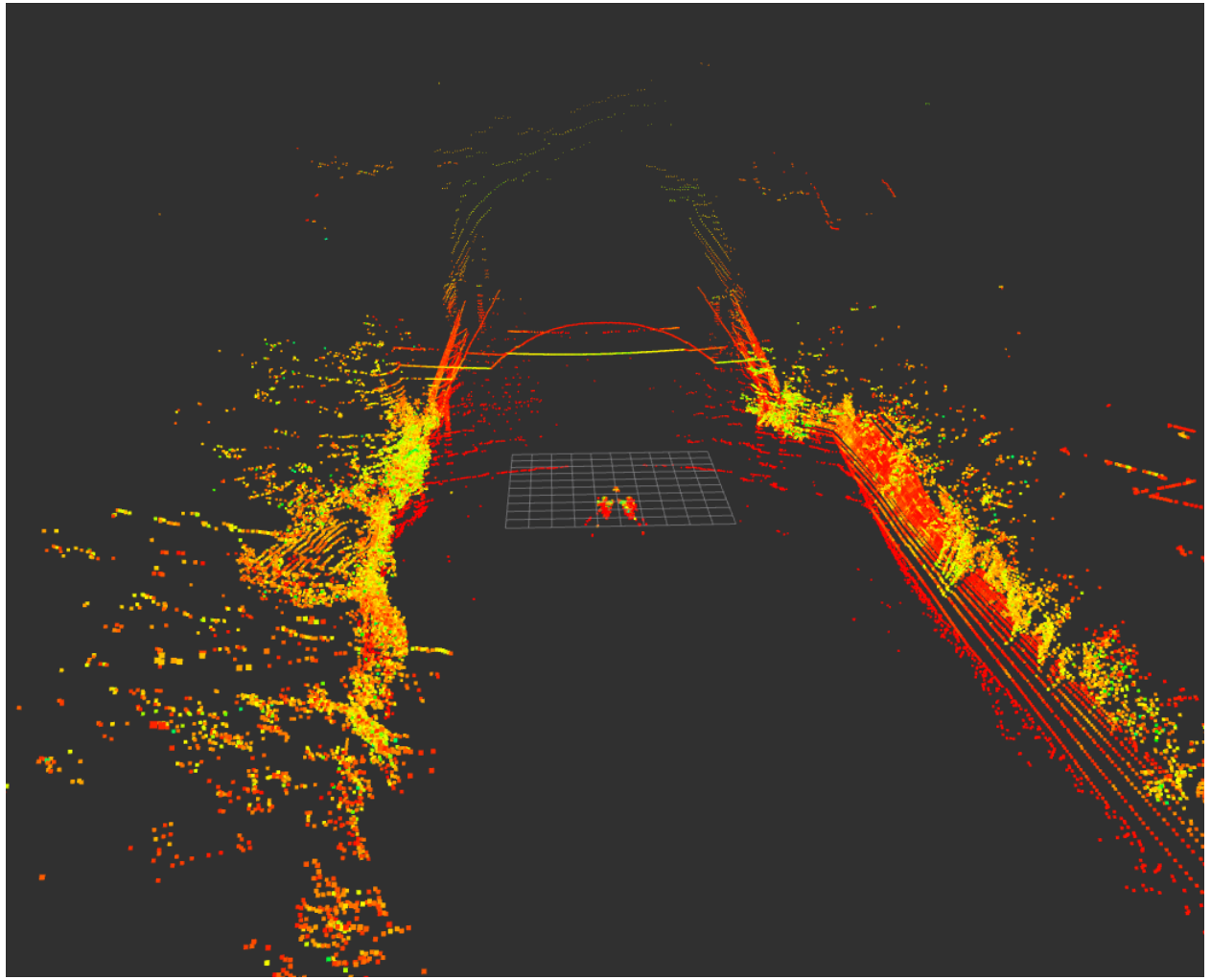
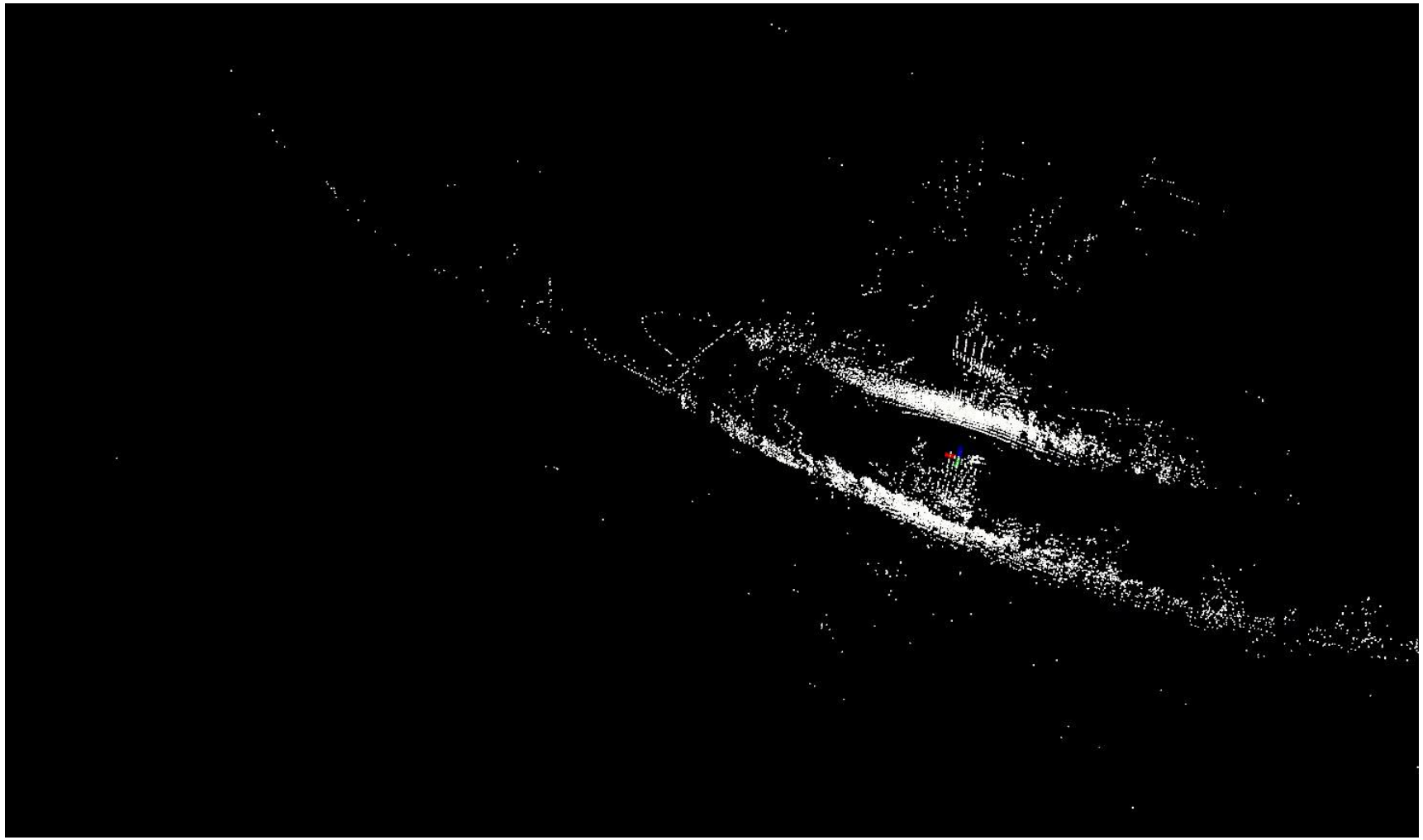
High Definition Mapping in Berlin Perception

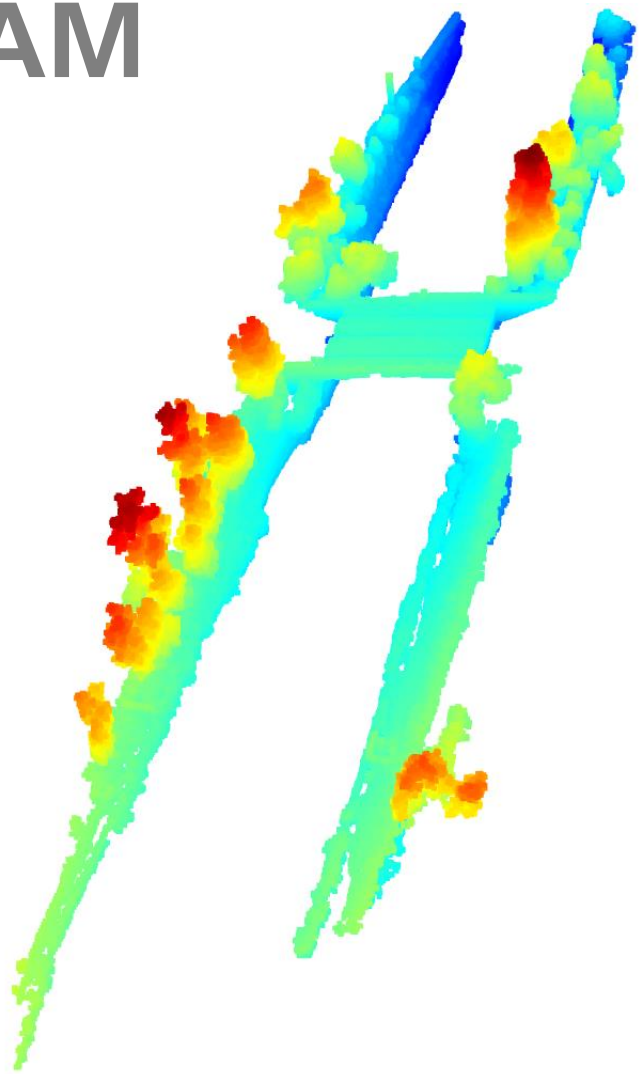


Lukas Hösch, German Aerospace Center (DLR), Department Nautical Systems

High Definition Mapping in Berlin Perception



High Definition Mapping in Berlin local SLAM



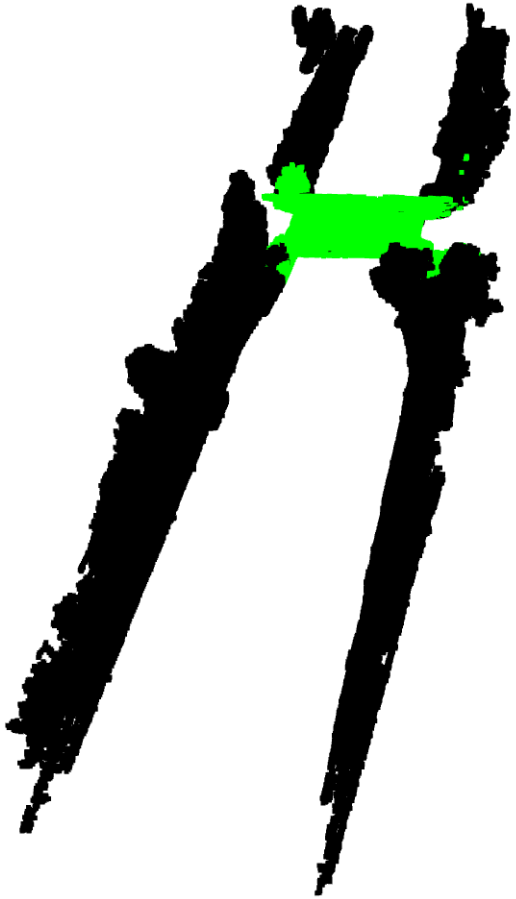
FastLIO2 [2] SLAM solution

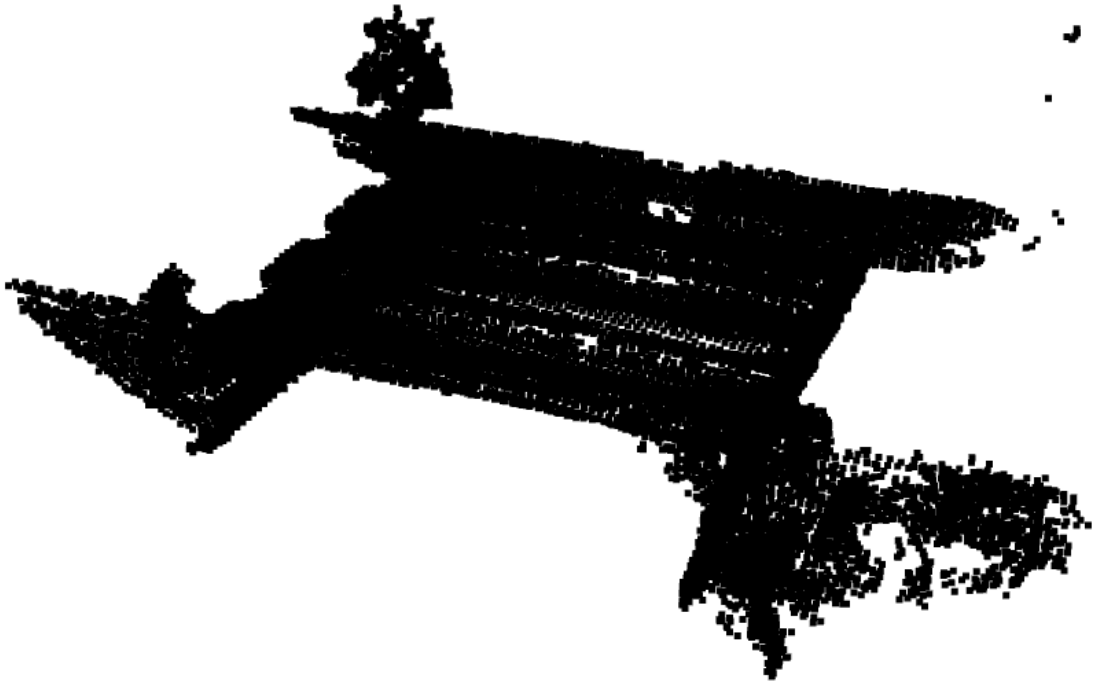
Corresponding alphashape

Lukas Hösch, German Aerospace Center (DLR), Department Nautical Systems

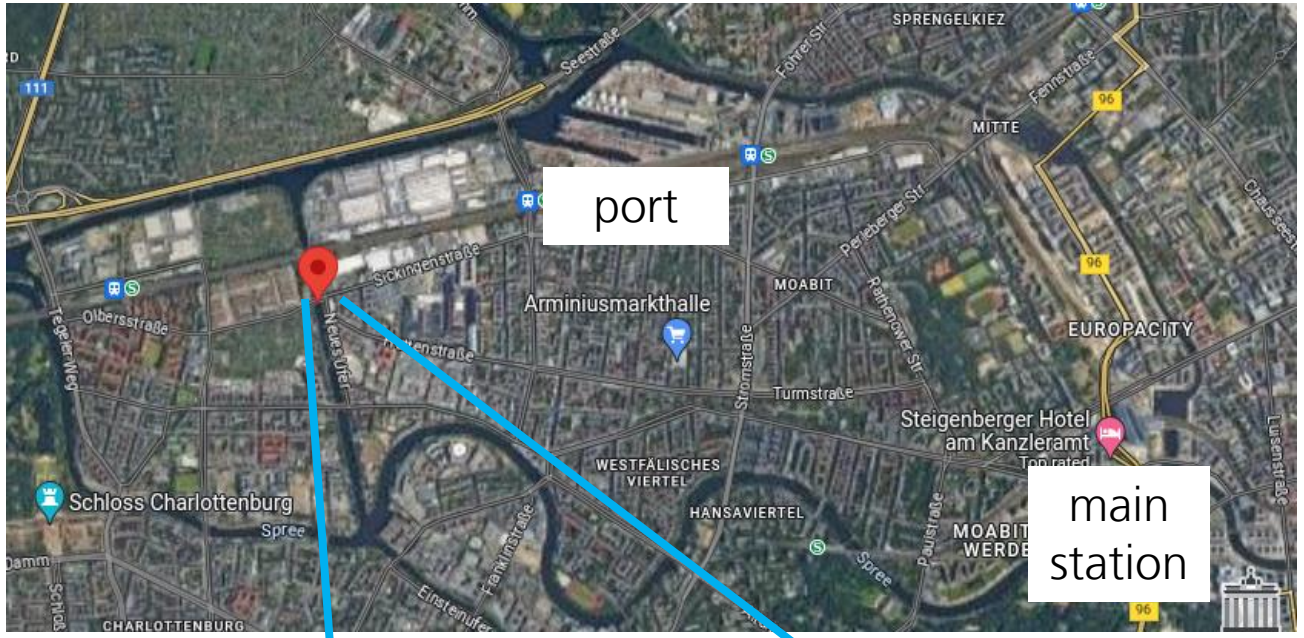
[2] Xu, W., Cai, Y., He, D., Lin, J., & Zhang, F. (2022).
Fast-lio2: Fast direct lidar-inertial odometry. *IEEE Transactions on Robotics*, *38*(4), 2053-2073.

High Definition Mapping in Berlin
local SLAM: bridge segmentation





High Definition Mapping in Berlin global SLAM



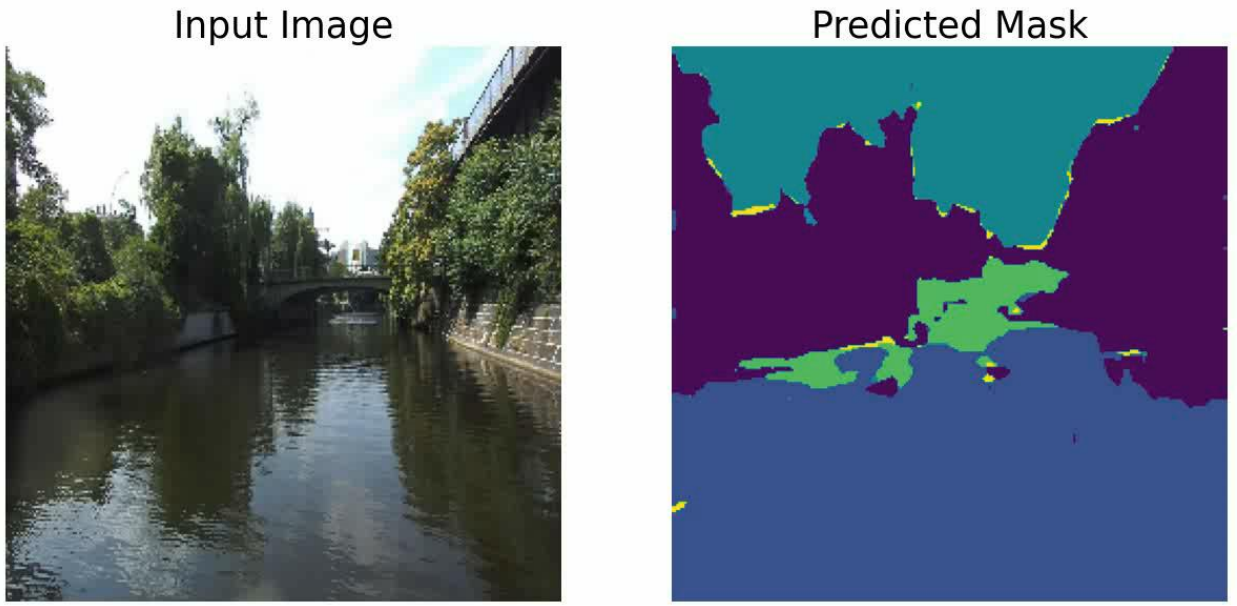
Submitted: GNSS LiDAR-Intertial Odometry and Mapping: A Solution for HD Mapping in Inland Waterway Scenarios
Iulian Filip, Alonso Llorente, Lukas Hösch, Austin Li, Christoph Lass, Daniel Medina
IEEE International Conference on Robotics and Automation (ICRA) 2024

High Definition Mapping in Berlin Semantic Segmentation

Semantic Segmentation on RGB images

- Machine Learning problem
- Good performance on known data
- Data hungry application

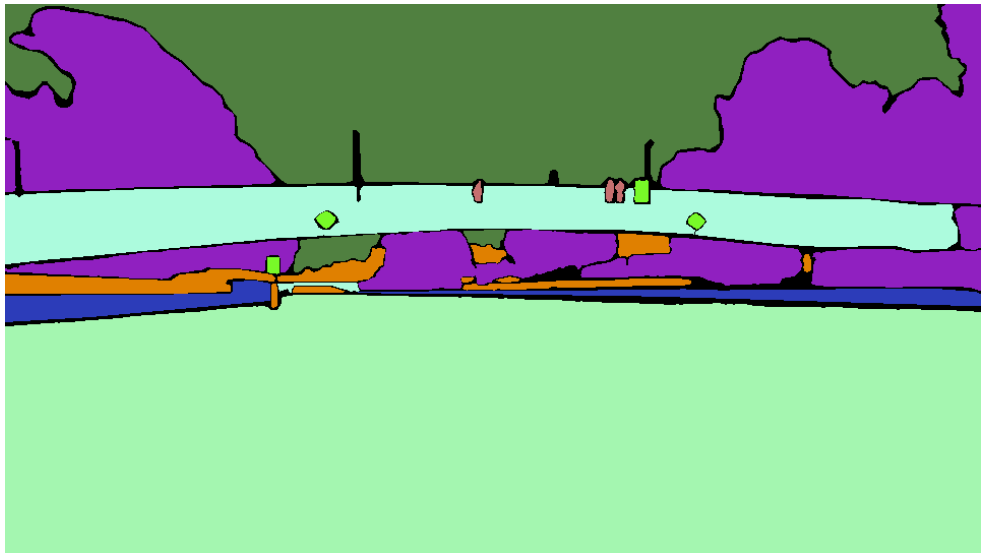
- Expandable performance on unknown data
- Image / point cloud alignment pending



High Definition Mapping in Berlin
Semantic Segmentation

Semantic Segmentation on RGB images

- New labelled examples from own developed dataset
- Labelling process ongoing
- Image to point cloud alignment ongoing



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Conclusion

- Geo-referenced bridge contours needed for warning system
- Architecture for 3D HD inland waterway chart

→ **Step towards higher autonomy levels**

Future Work

Next steps:

- Generating geo-referenced bridge contours
- Extraction of semantic information and bridge clearances
- Development of own, compact sensor box

Further interests:

- DigitalSOW: extraction of quay edge for automatic docking
- RadarSOW: application of automotive radar and comparison

AutonomSOW final demonstration
29.11., Behala (Berlin)

Thanks for your attention

Lukas Hösch, German Aerospace Center (DLR), Department Nautical Systems

DLR

Our Information Platform
LiDAR sensors

LiDAR	FoV	Range	Resolution?	Purpose
SICK MRS 6000	15° x 120°	200 m	Horizontal: 0.13° Vertical: 0.625°	Fine-grained spatial mapping
Velodyne VLP16	30° x 360°	100 m	Horizontal: 0.1° – 0.4° Vertical: 2.0°	Vertical spatial mapping
Velodyne VLP32	40° x 360°	200 m	Horizontal: 0.1° – 0.4° Vertical: 0.33°	General spatial mapping
Ouster OS0	90° x 360°	100 m	Horizontal: 0.18°– 0.7° Vertical: 0.35° – 0.7°	Close quater spatial mapping

Our Information Platform

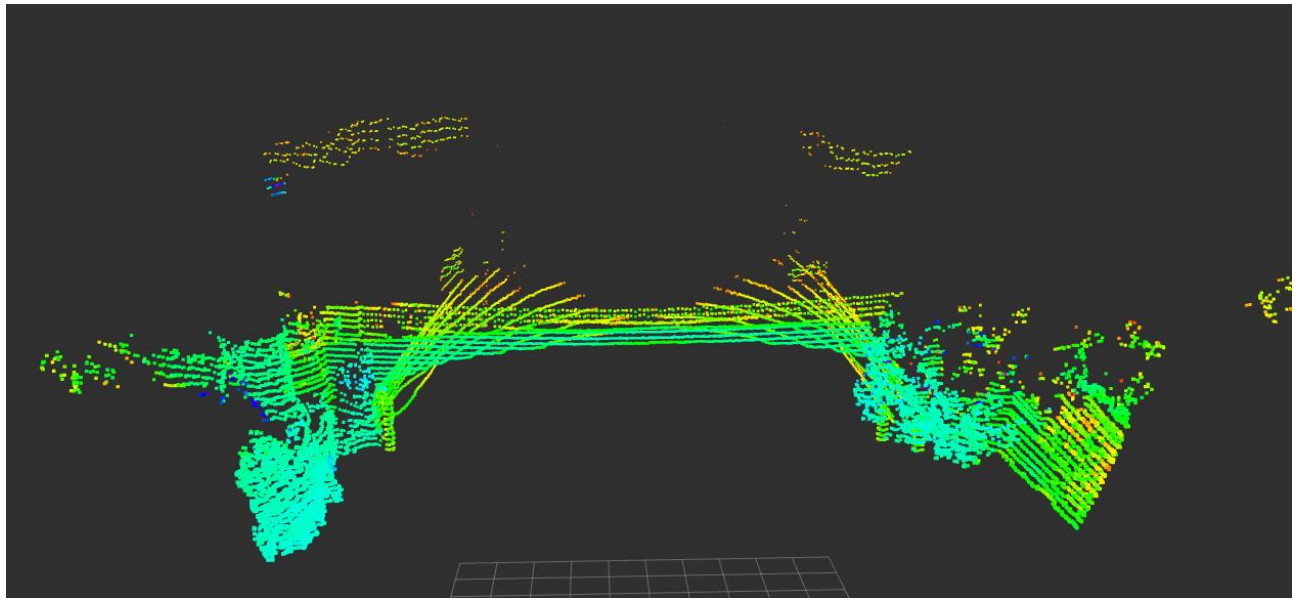
Our Information Platform – Sensor characteristics

Sensor: SICK MRS 6000

- Horizontal FoV: 120°
- Vertical FoV: 15°
- Range: 200 m

Purpose: spatial mapping

https://cdn.sick.com/media/895/3/33/333/IM0071333.png , 09.08.23



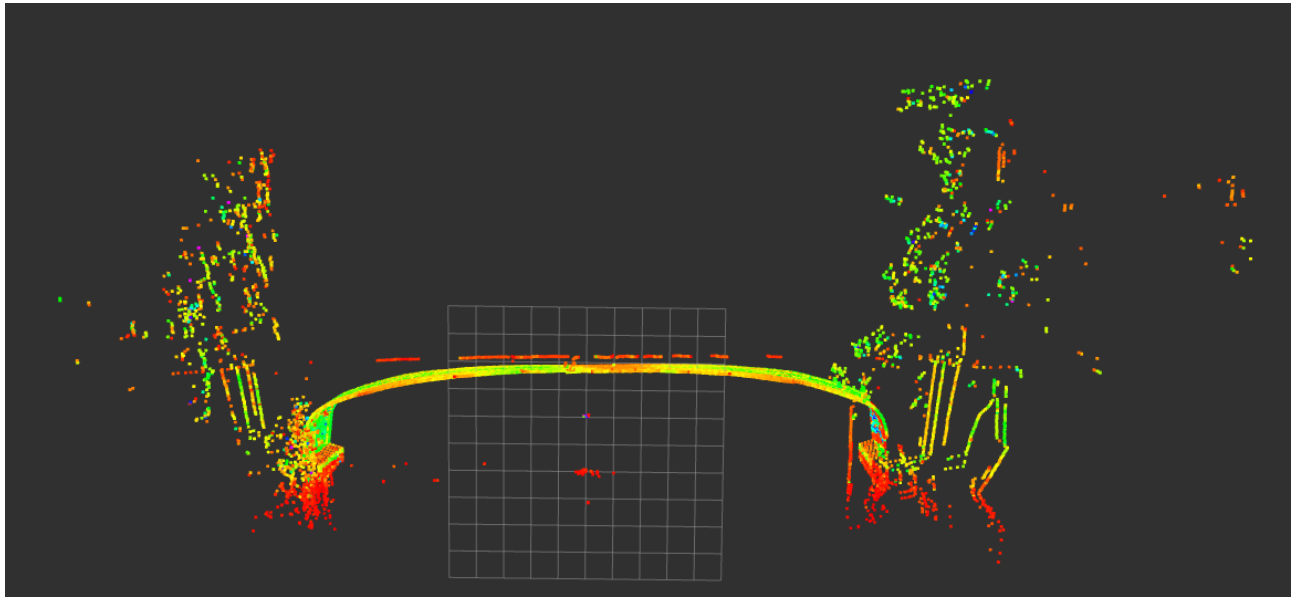
Our Information Platform – Sensor characteristics

https://airsupply.com/wp-content/uploads/2019/07/puck_lite.png, 09.08.23

Sensor: Velodyne VLP 16 (PUCK)

- **Horizontal FoV: 360°**
- **Vertical FoV: 30°**
- **Range: 100 m**

Purpose: spatial mapping



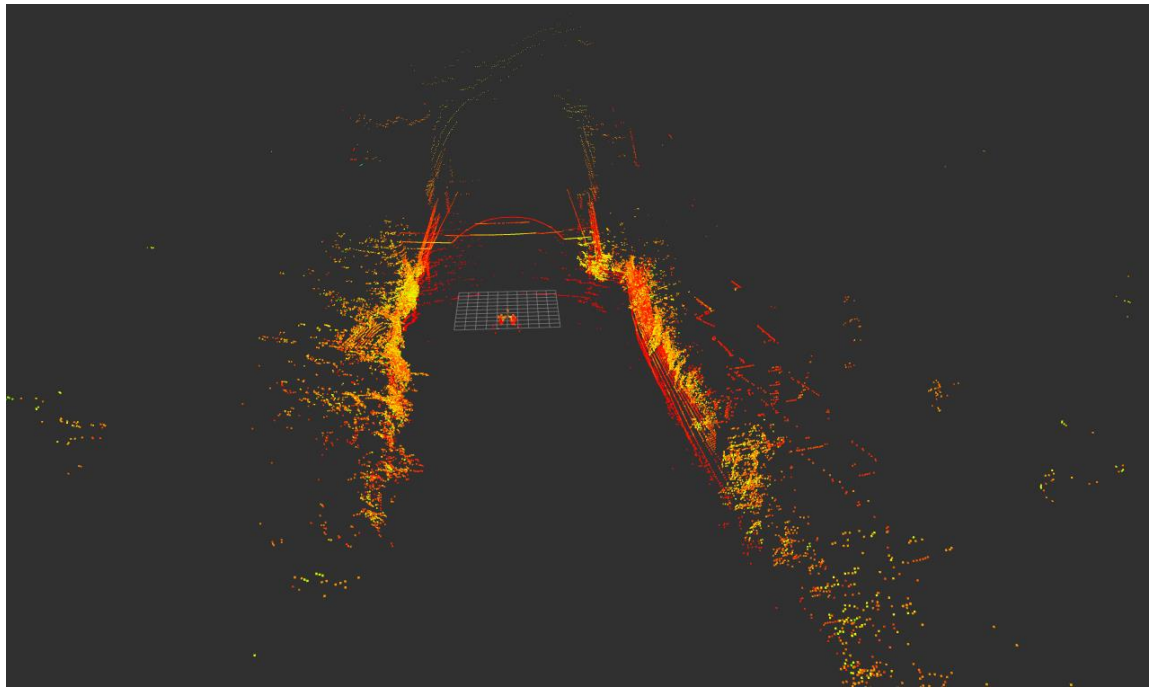
Our Information Platform – Sensor characteristics

https://levelfivesupplies.com/wp-content/uploads/2019/10/VLP-32C_Product_Image001_New-e1585836320757.png, 09.08.23

Sensor: Velodyne VLP 32 C (ultraPUCK)

- Horizontal FoV: 360°
- Vertical FoV: 40°
- Range: 200 m

Purpose: spatial mapping



Our Information Platform – Sensor characteristics

https://cdn-reichelt.de/bilder/web/artikel_ws/C300/MBS-SES-119-01-1.jpg, 09.08.23

Sensor: Ouster OS0

- **Horizontal FoV: 360°**
- **Vertical FoV: 90°**
- **Range: 100 m**

Purpose: spatial mapping