

Autonomous Inland & Short Sea Shipping Conference
5th & 6th September 2023
Duisburg



**Information Platform Concept for
HD Inland Waterway Mapping**

Lukas Hösch, Iulian Filip, Xiangdong An,
Daniel Medina, Ralf Ziebold



Funded by:



on the basis of a decision
by the German Bundestag



Mapping of inland waterway infrastructure



<https://www.deutschlandfunk.de/hightech-fuer-fluss-und-kanal-100.html>, 09.08.23



https://izw.baw.de/publikationen/kolloquien/0/6_BAW_F&E_Projekte_LAESSI_SCIPPER_Final.pdf, 09.08.23

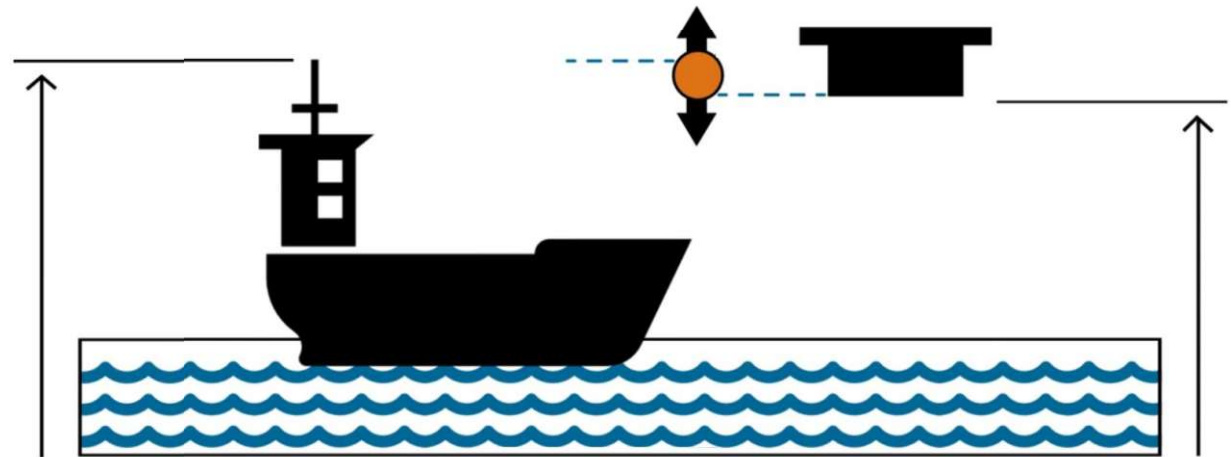
- Inland waterway transport as relevant part of modal split
- Key factor for reduction of traffic-related greenhouse gas emissions
- Bridge collision dangerous to operation

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

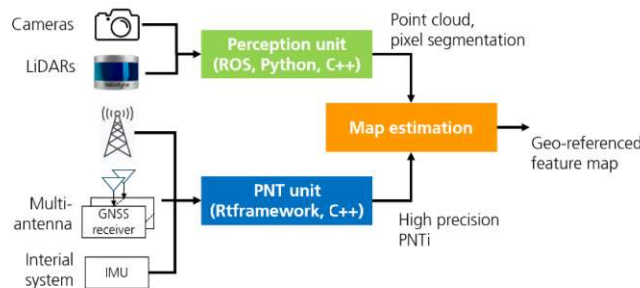
Information Platform

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



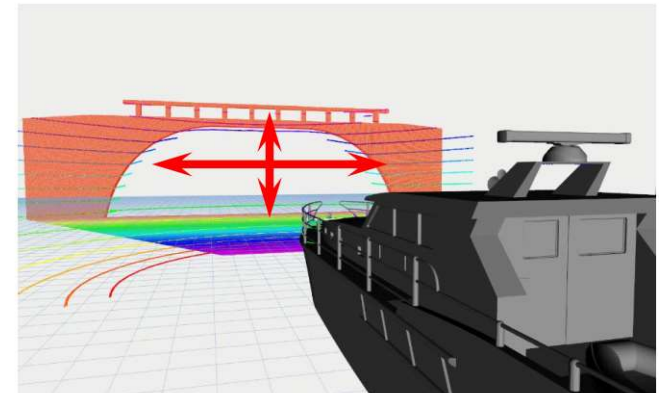
Map processing

- **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



Outline



1. Our Information Platform

2. Map Estimation

- a) Navigation Algorithm
- b) SLAM Engine

3. High Definition Mapping in Berlin

4. Outlook and Future Work

Outline



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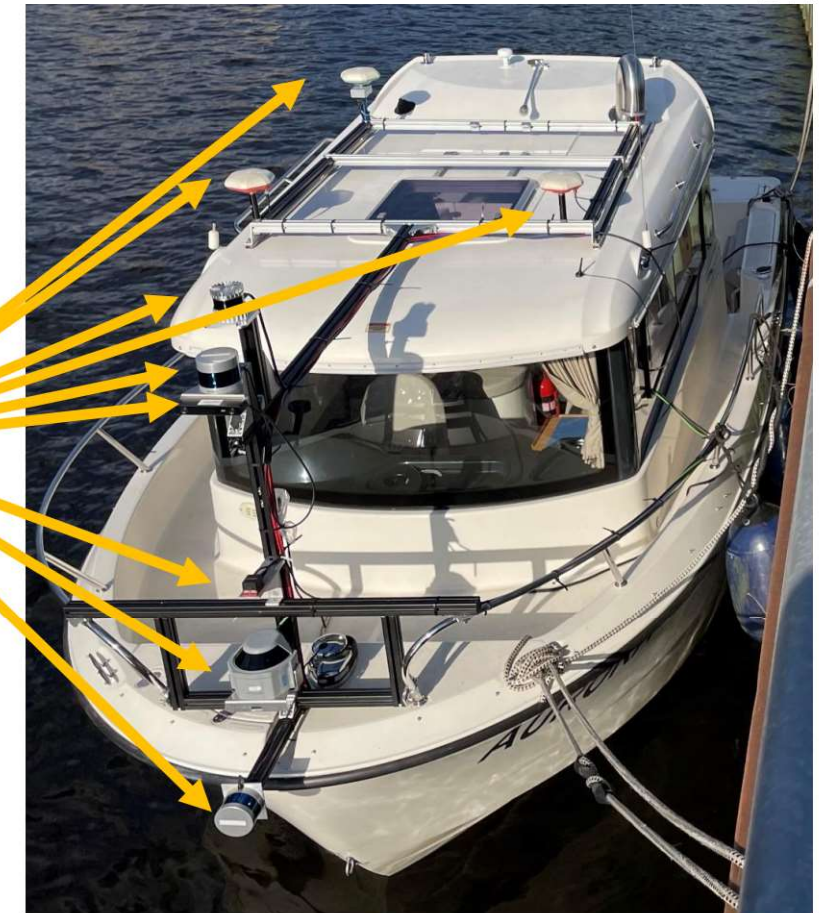
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Building an information platform



Research boat AURORA



Information platform

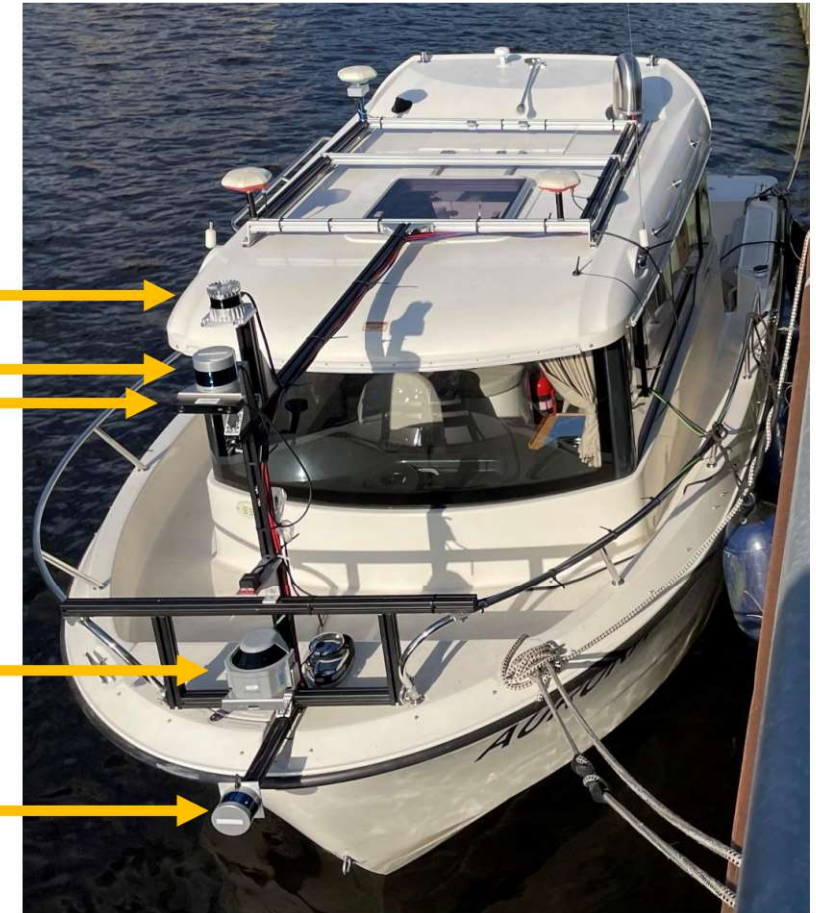
Our Information Platform sensor mounting



Ouster OS0
Velodyne VLP32 C
ZED2i stereo camera

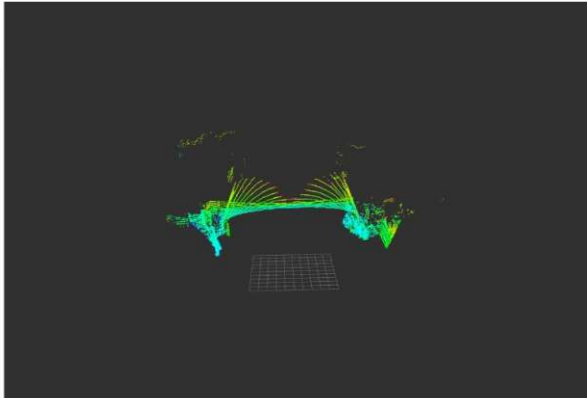
SICK MRS 6000

Velodyne VLP16



Our Information Platform

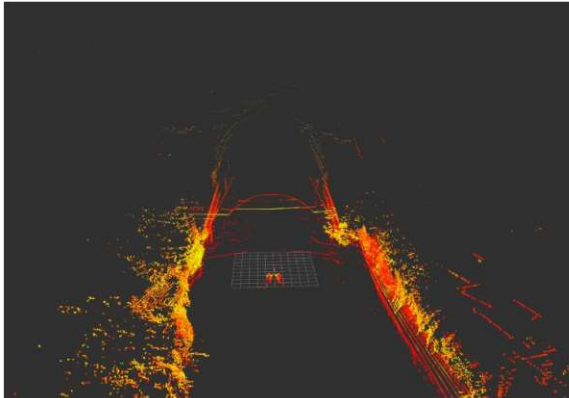
LiDAR sensors



LiDAR	FoV	Range	Resolution	Purpose
SICK MRS 6000	15° x 120°	200 m	Horizontal: 0.13° Vertical: 0.625°	Fine-grained spatial mapping

Our Information Platform

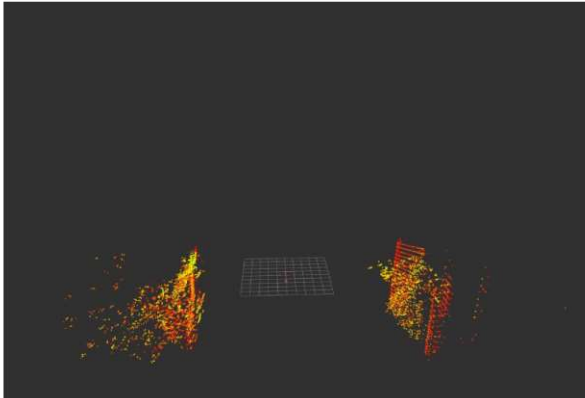
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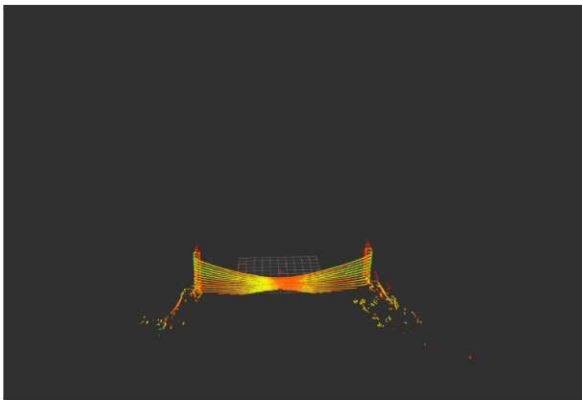
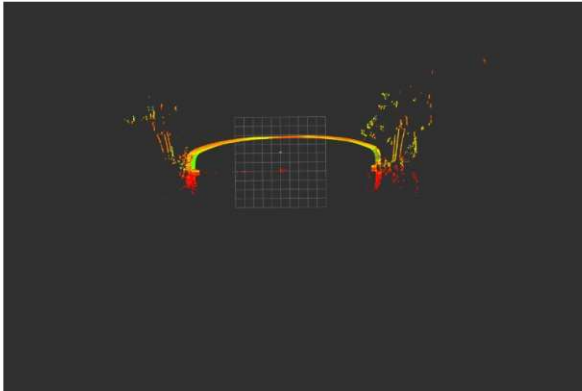
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Our Information Platform

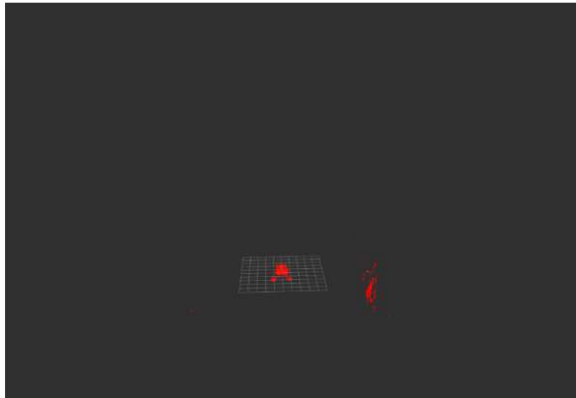
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Our Information Platform

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Ouster OS0	90° x 360°	100 m	Horizontal: 0.18°– 0.7° Vertical: 0.35° – 0.7°	Close quater spatial mapping

Our Information Platform Camera



Sensor: ZED2i stereo camera



<https://www.stereolabs.com/zed-2/>, 09.08.23

Purpose: Semantic Scene understanding

- Semantic Segmentation of camera image
- Image – point cloud alignment allows point cloud segmentation



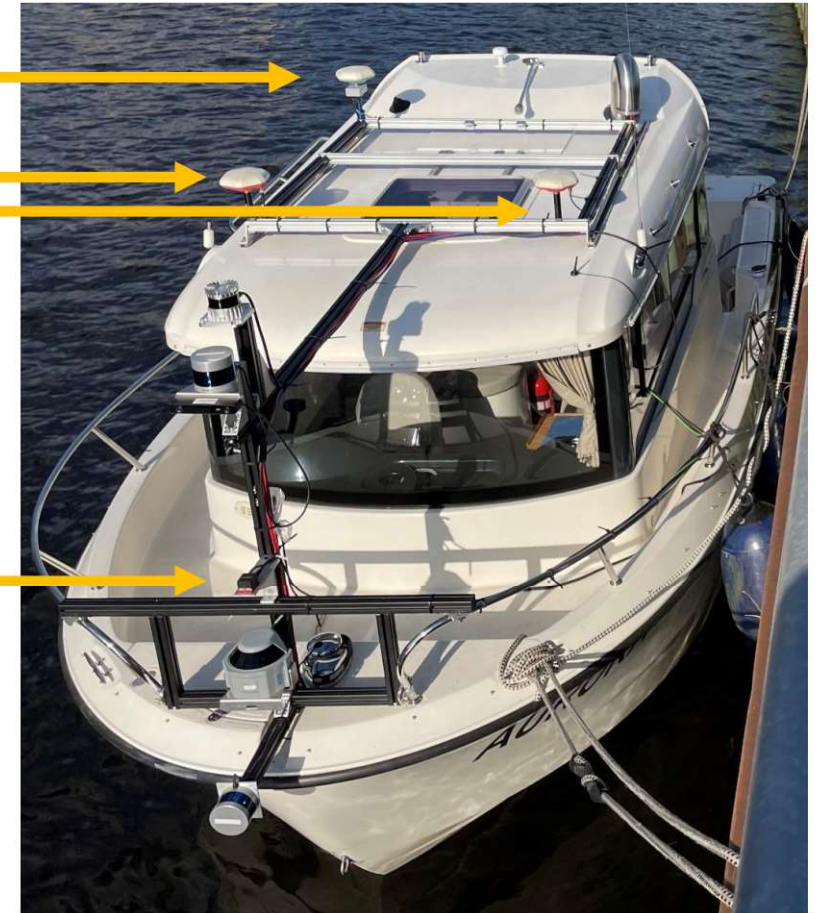
Our Information Platform sensor mounting



GNSS antenna and SensorNor IMU

GNSS antennas

Xsens IMU



Our Information Platform

PNT unit



Sensor: Position Navigation Timing Unit

Purpose: accurate navigation data

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



Outline



1. Our Information Platform

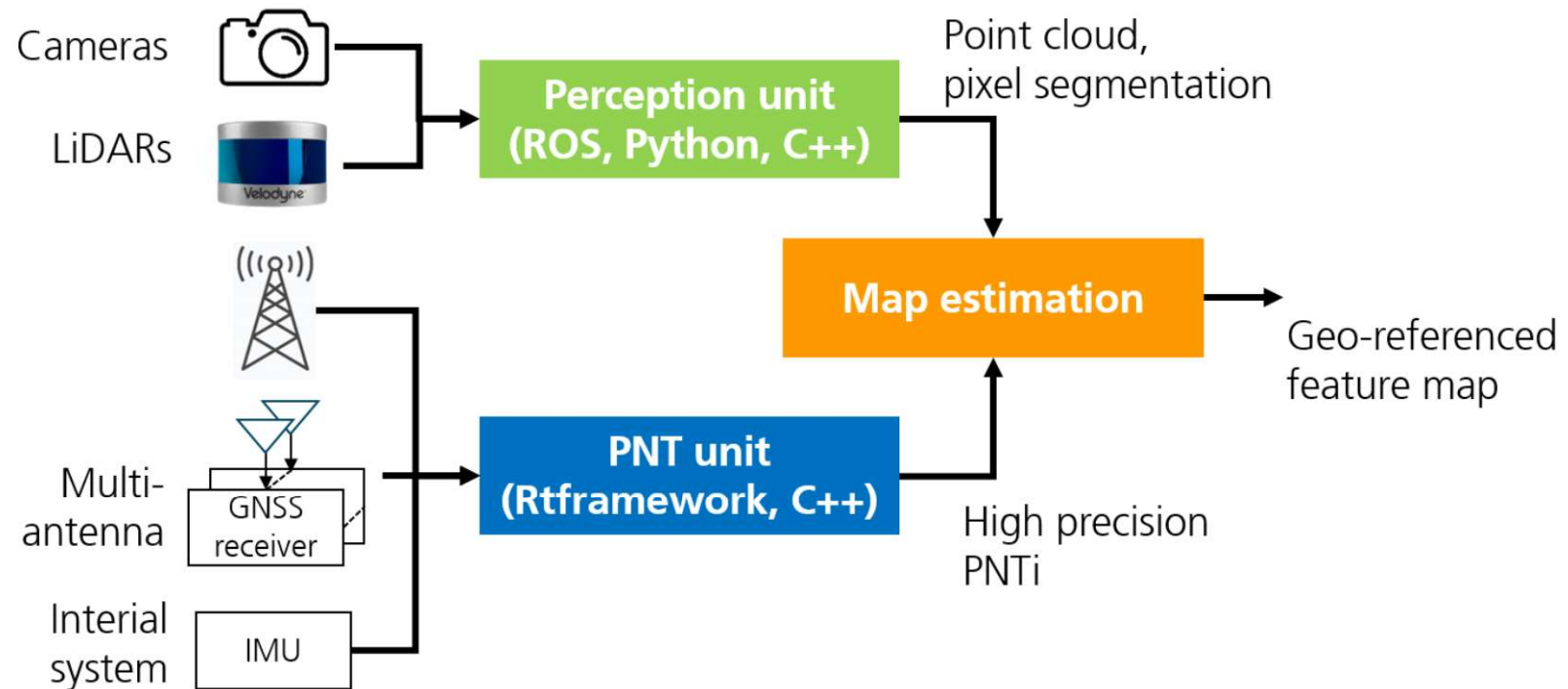
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- a) Navigation Algorithm
- b) SLAM Engine

3. High Definition Mapping in Berlin

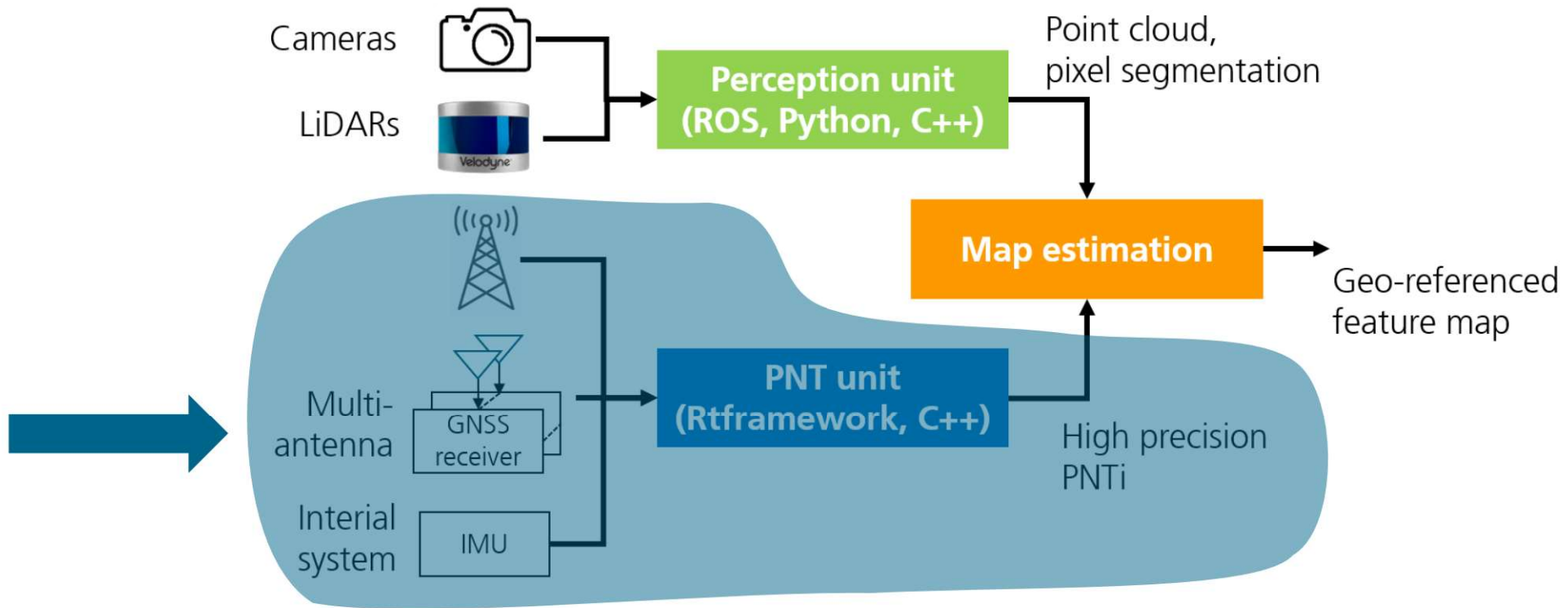
4. Outlook and Future Work

Map Estimation System architecture



Map Estimation

PNT unit

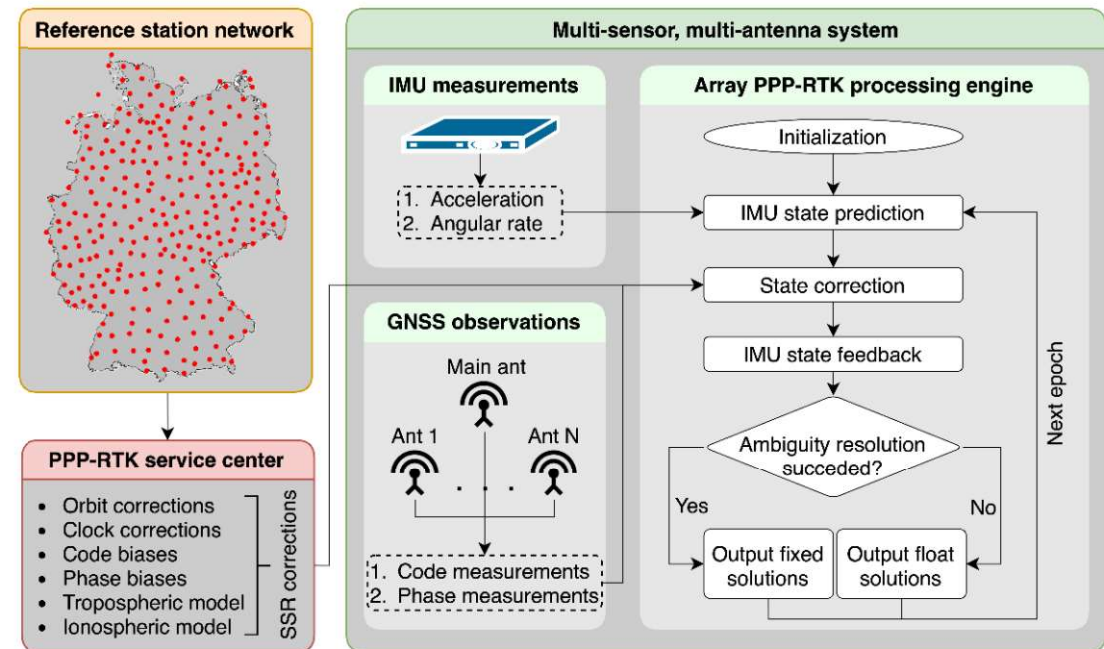
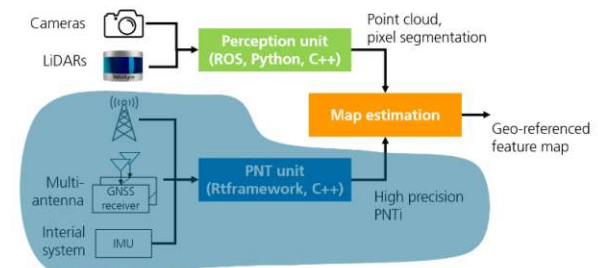


Map Estimation PNT unit

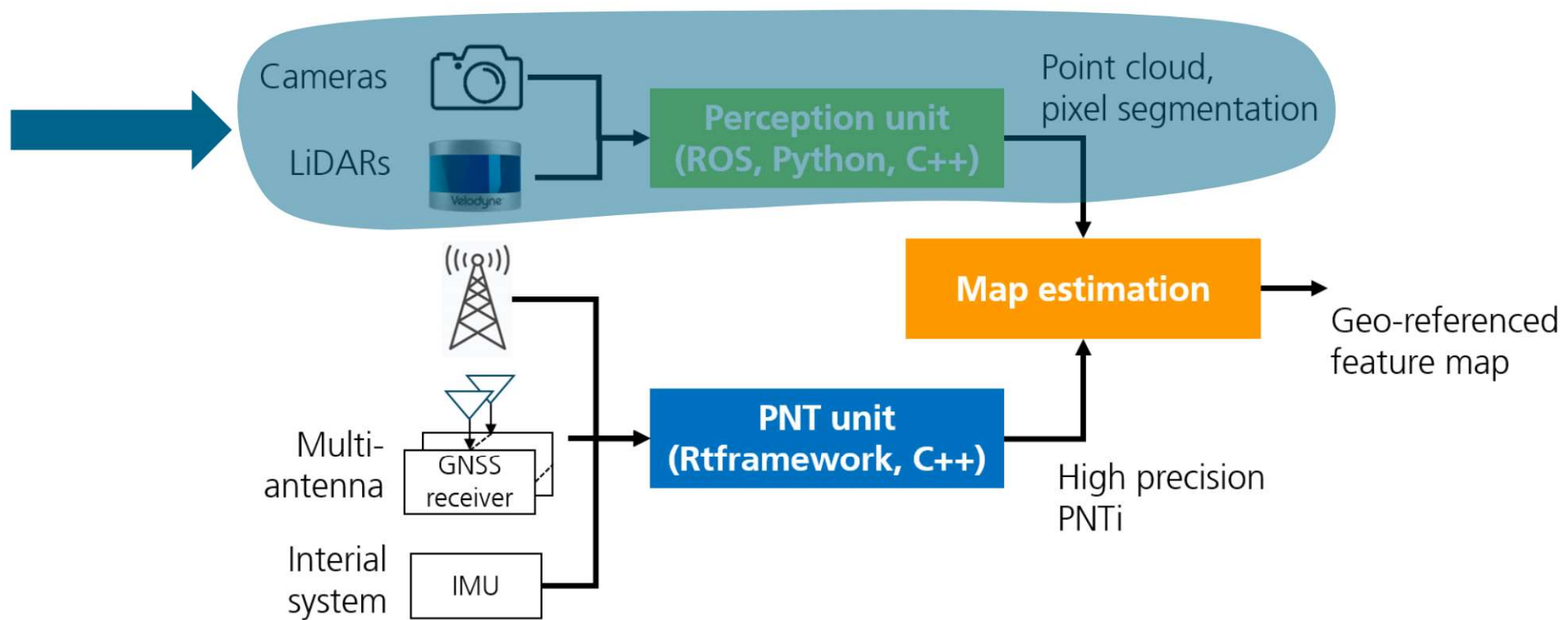
- Multi-sensor, multi-antenna system:
- Array PPP-RTK solution [1]
 - IMU integration
 - positioning in dm level, attitude estimates in sub-degree accuracy
 - Real time correction via SAPOS®, in future possibly HAS (missing carrier phase biases)

[1] 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

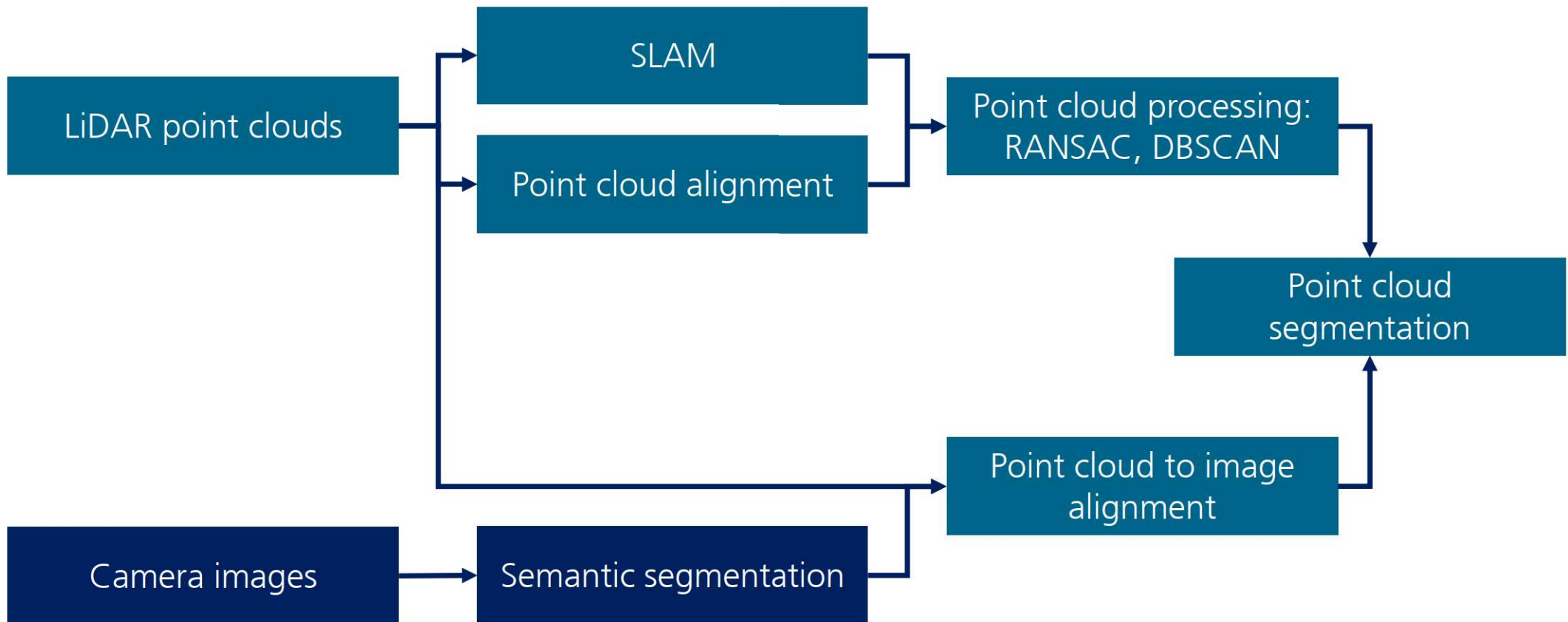
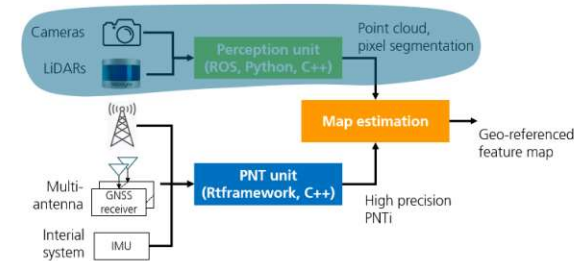
Lukas Hösch, German Aerospace Center (DLR), Department Nautical Systems



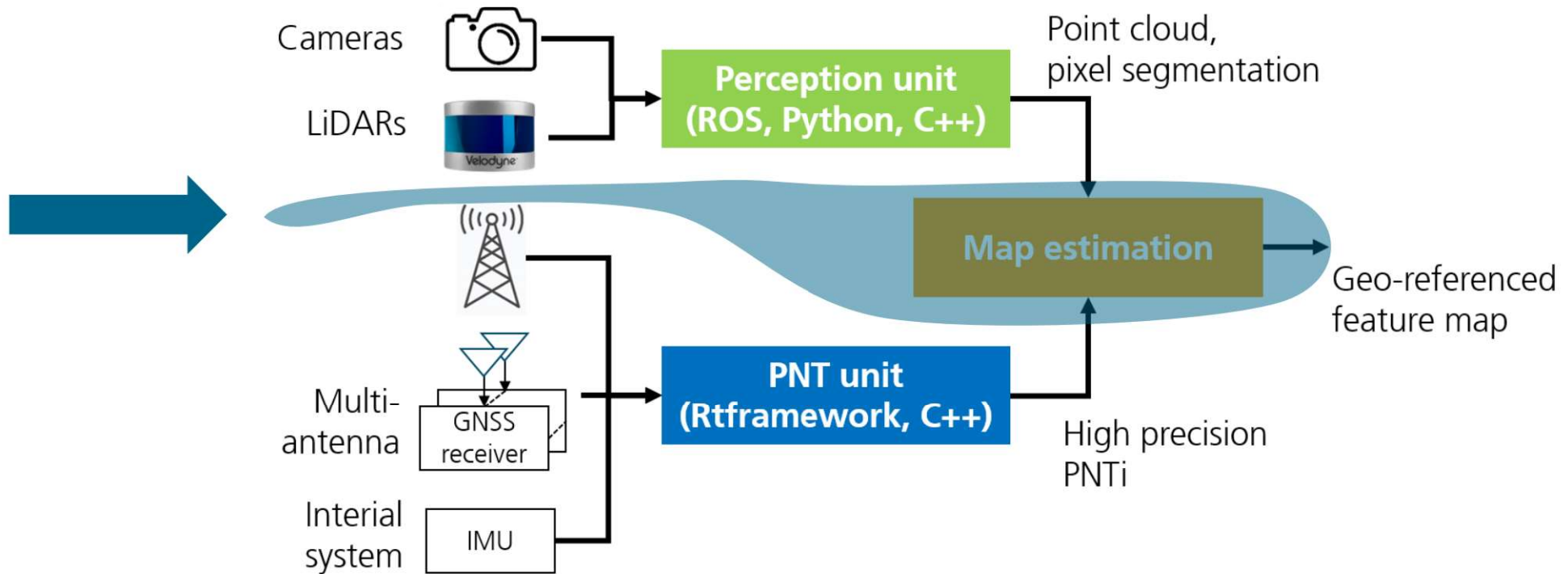
Map Estimation Perception Unit



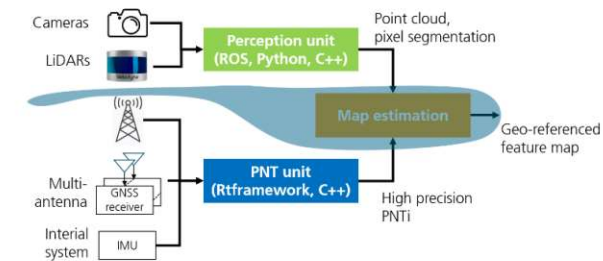
Map Estimation Perception Unit



Map estimation SLAM engine

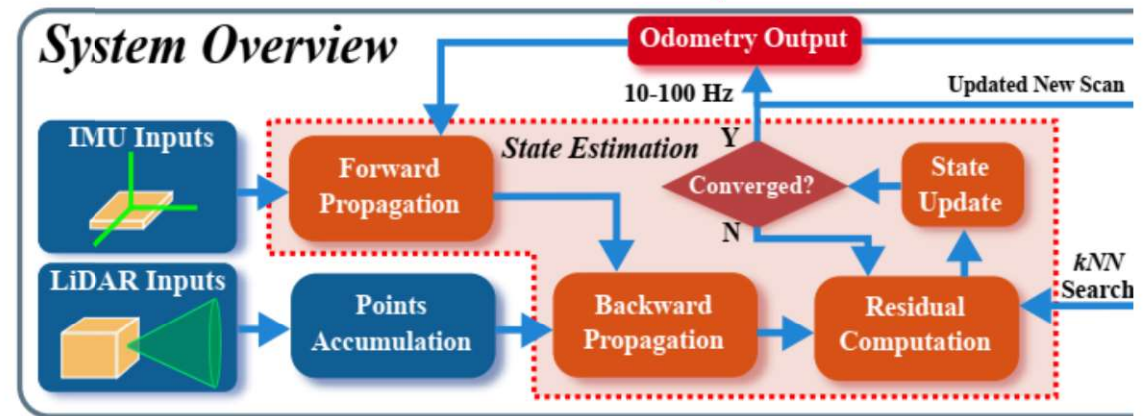


Map estimation SLAM engine



Adaption of FastLIO2 algorithm

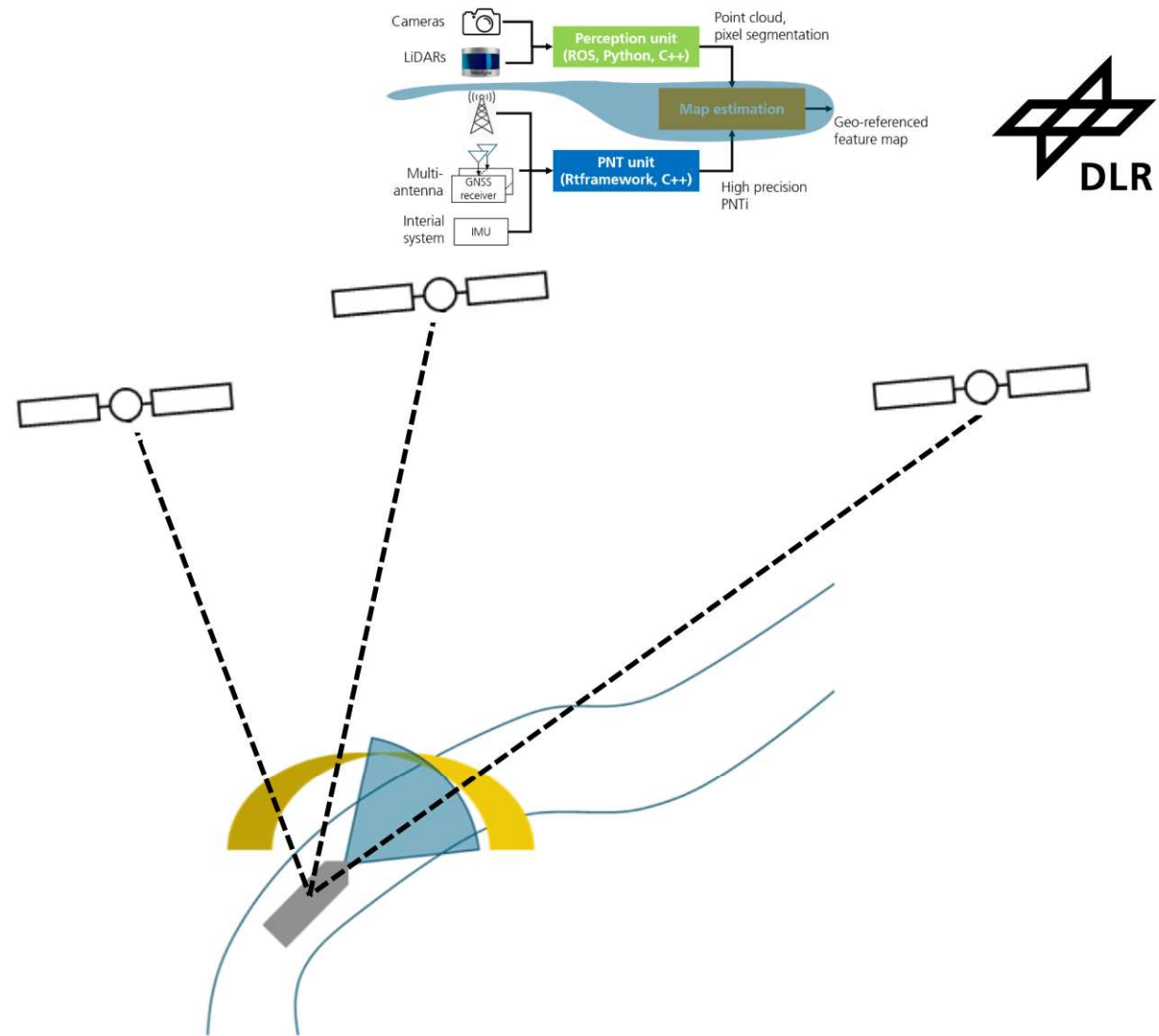
- Original: Odometry information used for positioning
- Adaption: feed GNSS as odometry information to KF



Map estimation SLAM engine

Global, feature-based SLAM solution

- Perception unit derives features
- PNT unit determines position & orientation
- Precise global registration of features



[2] Xu, W., Cai, Y., He, D., Lin, J., & Zhang, F. (2022). Fast-lid2: Fast direct lidar-inertial odometry. *IEEE Transactions on Robotics*, 38(4), 2053-2073.

Outline



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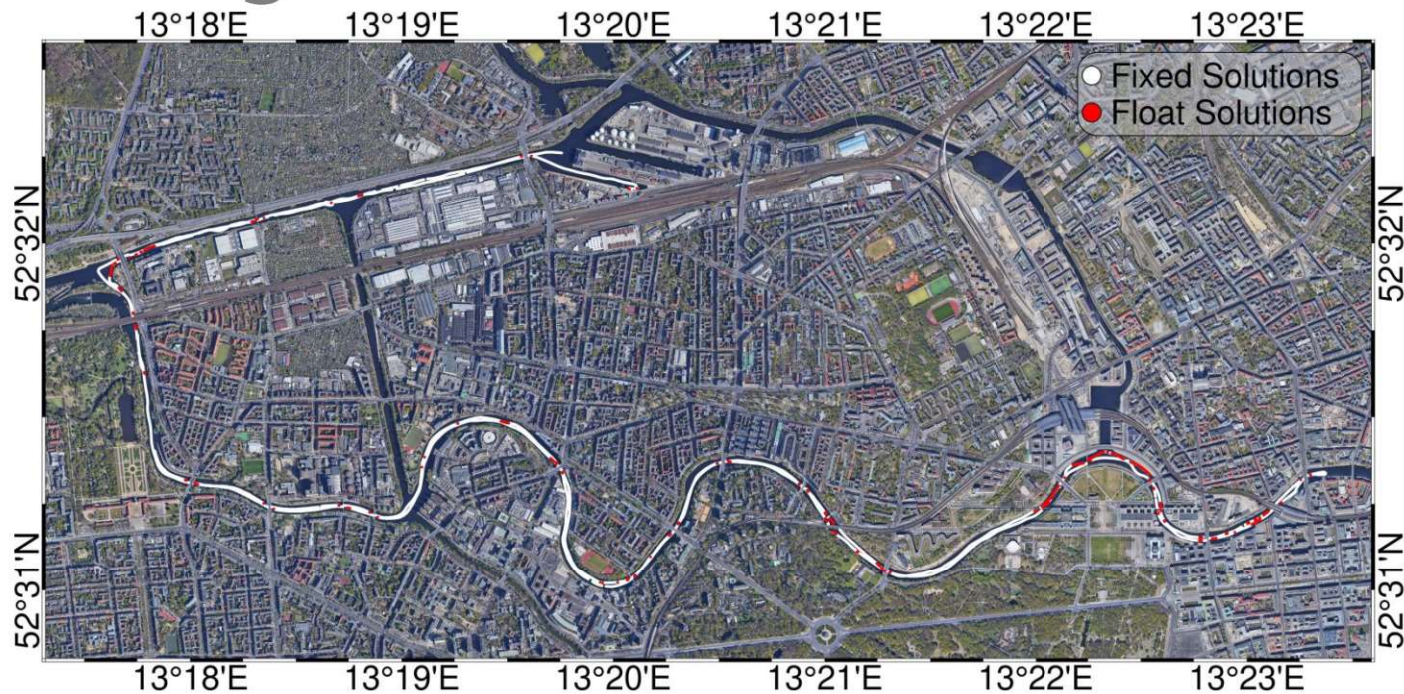
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3. High Definition Mapping in Berlin

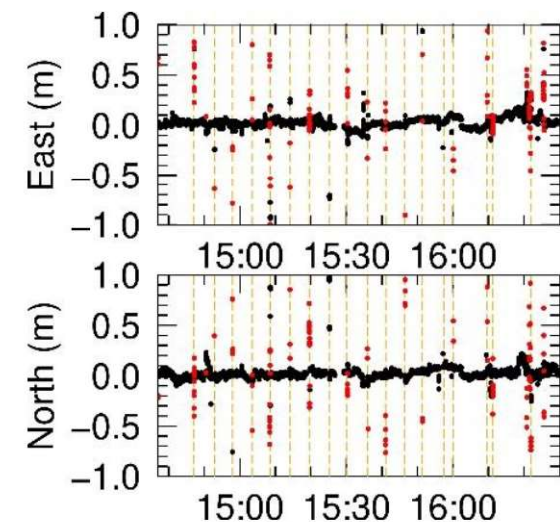
4. Outlook and Future Work

High Definition Mapping in Berlin Navigation

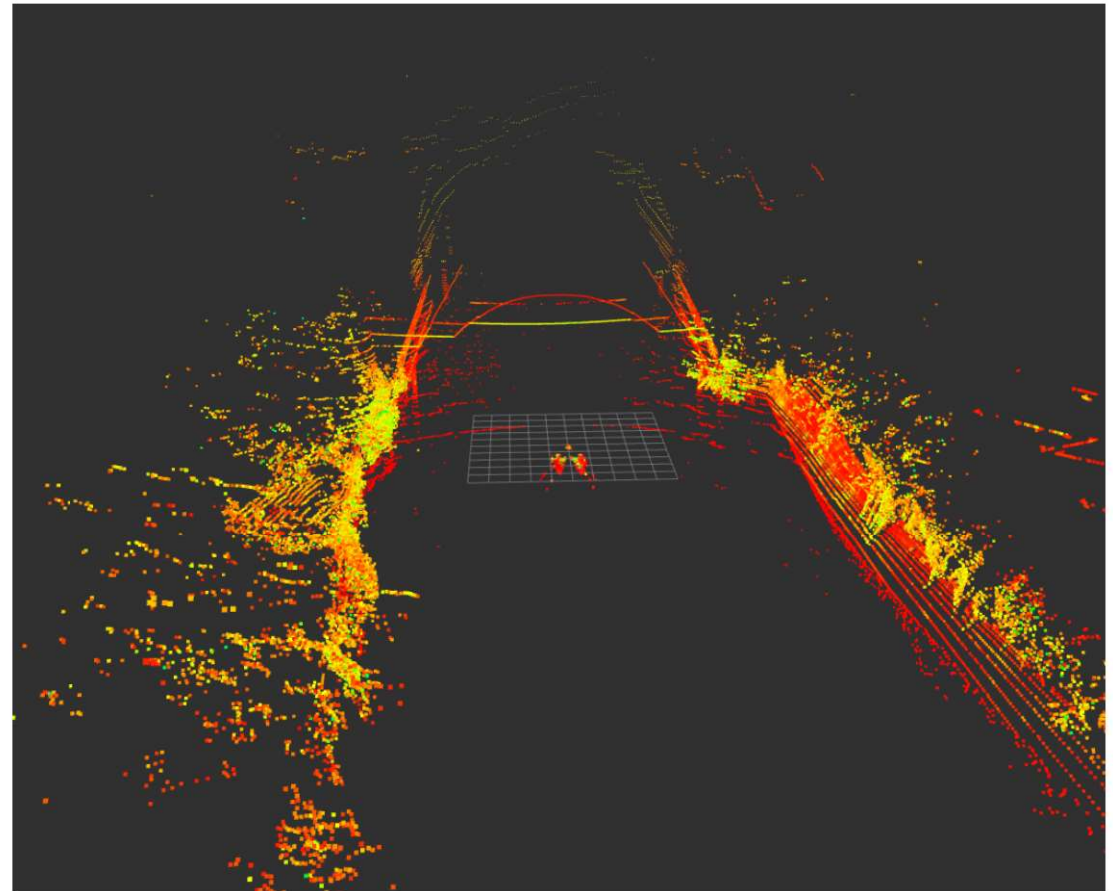


Results from measurement campaign June 2022

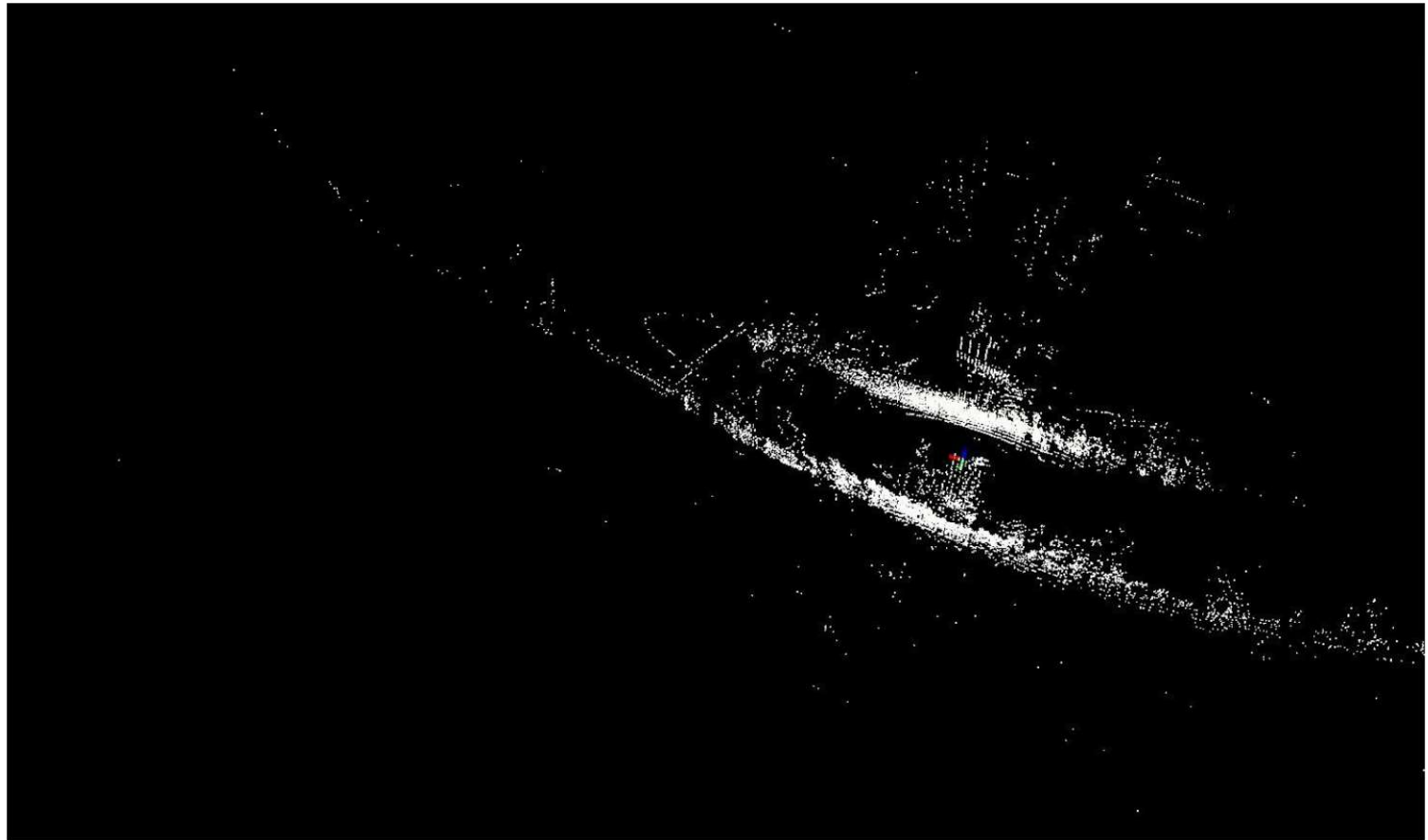
Array PPP-RTK: A High Precision Pose Estimation Method for Outdoor Scenarios
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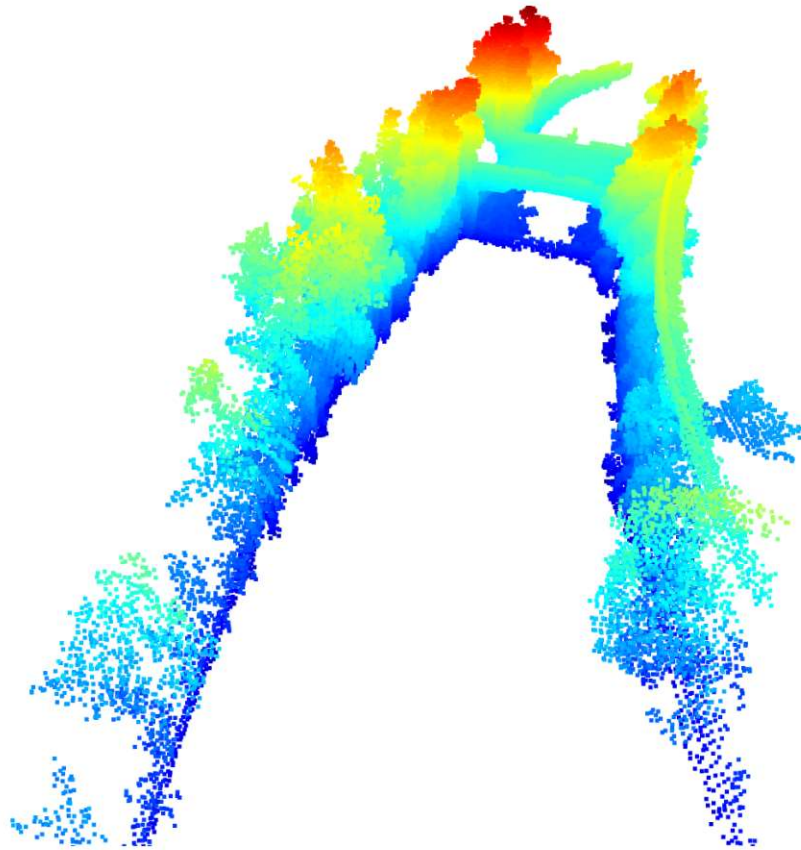
High Definition Mapping in Berlin Perception



High Definition Mapping in Berlin Perception



High Definition Mapping in Berlin SLAM

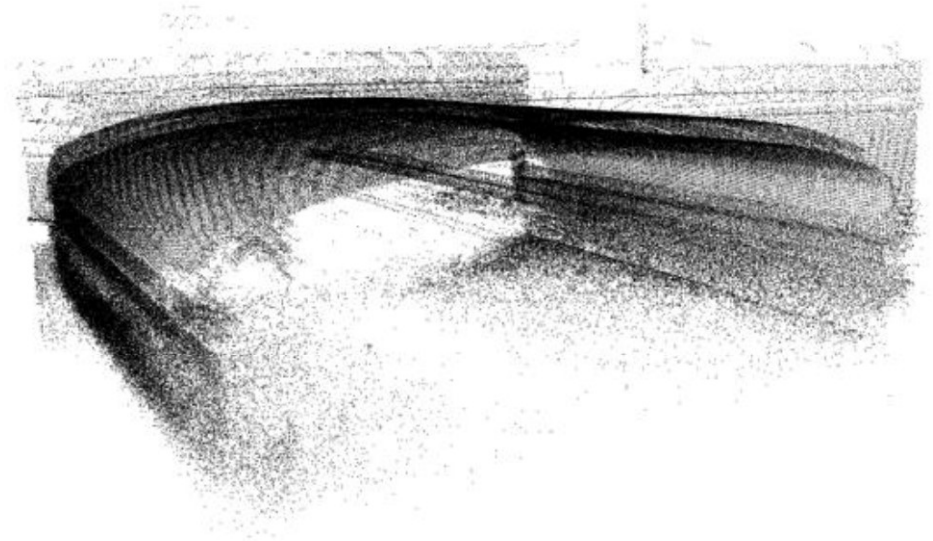
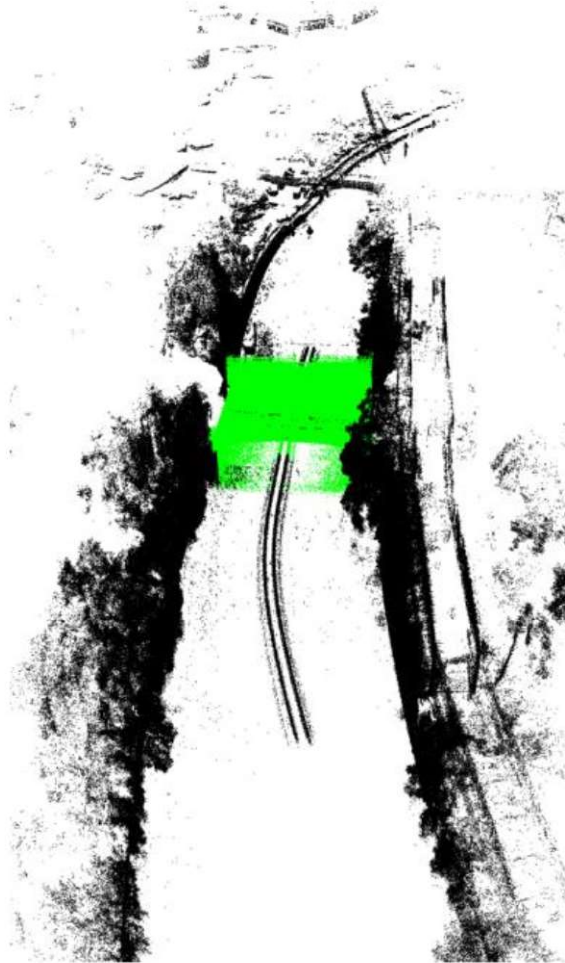


FastLIO2 [2] SLAM solution



Corresponding alphashape

High Definition Mapping in Berlin SLAM



High Definition Mapping in Berlin Semantic Segmentation



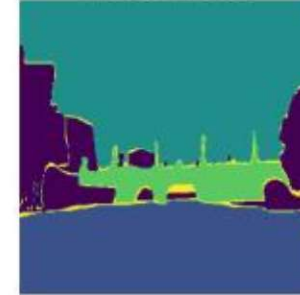
Semantic Segmentation on RGB images

- Machine Learning problem
- Good performance on known data
- Data hungry application
- Expandable performance on unknown data
- Image / point cloud alignment pending

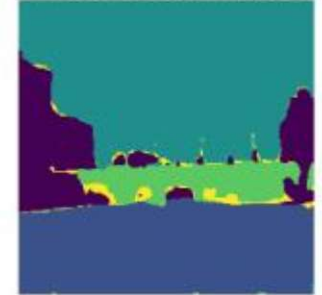
Input Image



True Mask



Predicted Mask



Input Image



Predicted Mask



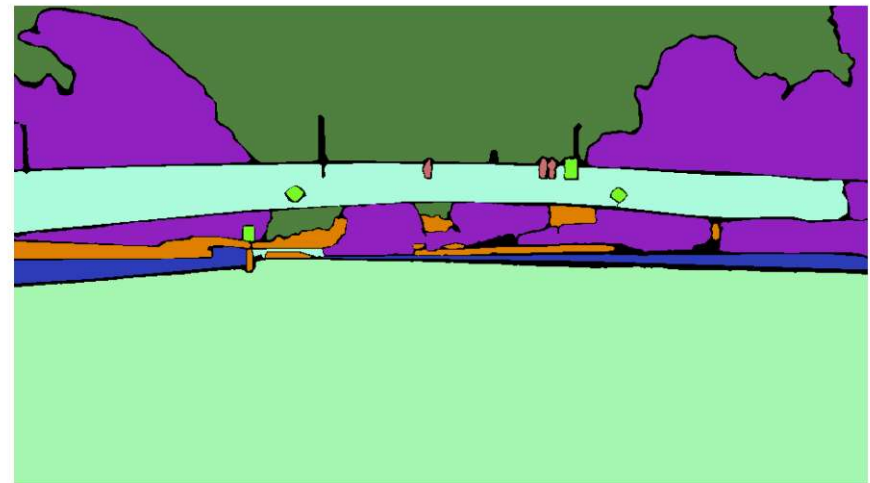
High Definition Mapping in Berlin

Semantic Segmentation



Semantic Segmentation on RGB images

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



Outline



1. Mapping of inland waterway infrastructure

2. Our Information Platform

1. System architecture
2. Sensor characteristics

3. Intermediate Results

1. Navigation solution
2. Perception

4. Conclusion and future work

Conclusion

- Geo-referenced bridge contours needed for warning system
- Information platform for spatial mapping data

→ **Step towards higher autonomy levels**



https://izw.baw.de/publikationen/kolloquien/0/6_BAW_F&E_Projekte_LAESSI_SCIPPER_Final.pdf, 09.08.23

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



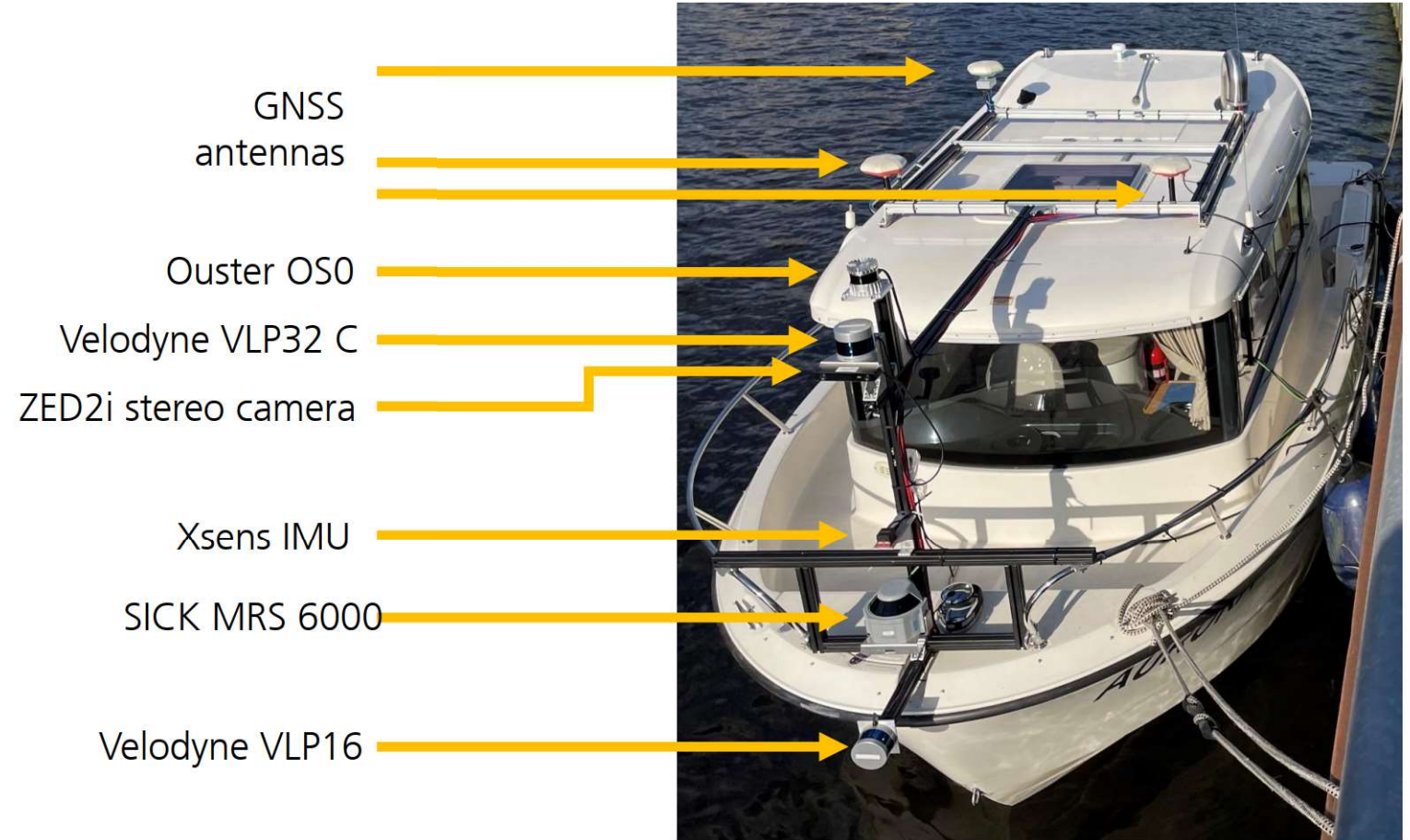
Our Information Platform

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Ouster OS0	90° x 360°	100 m	Horizontal: 0.18°– 0.7° Vertical: 0.35° – 0.7°	Close quarter spatial mapping

Our Information Platform



Our Information Platform – Sensor characteristics



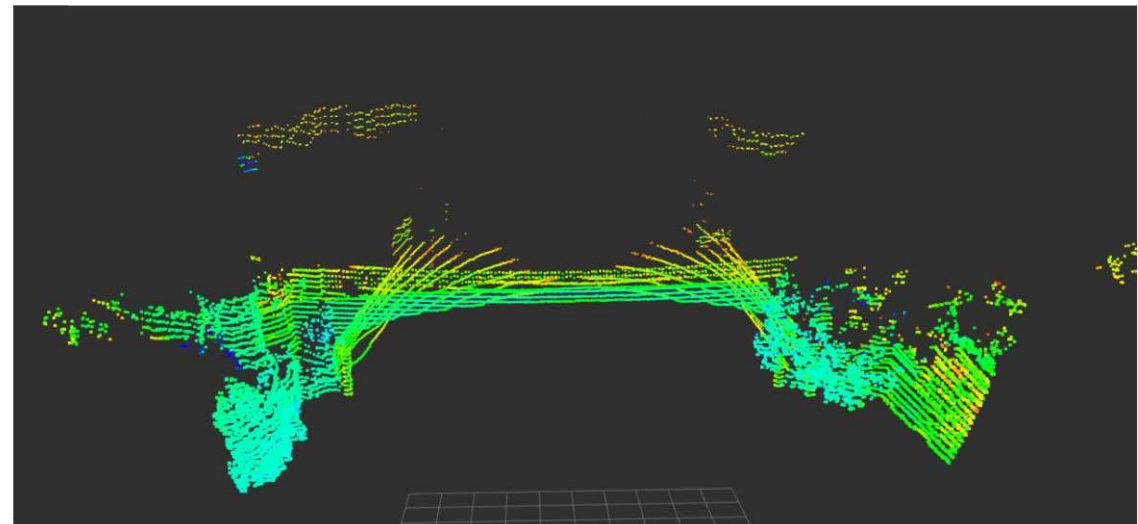
Sensor: **SICK** MRS 6000

- 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



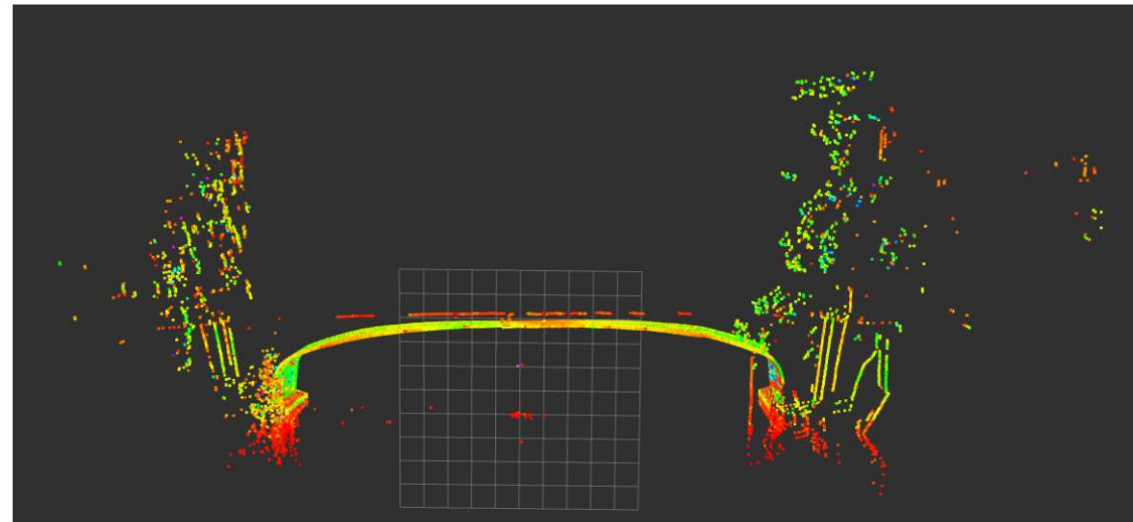
Sensor: Velodyne VLP 16 (PUCK)

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

Purpose: spatial mapping



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



Our Information Platform – Sensor characteristics



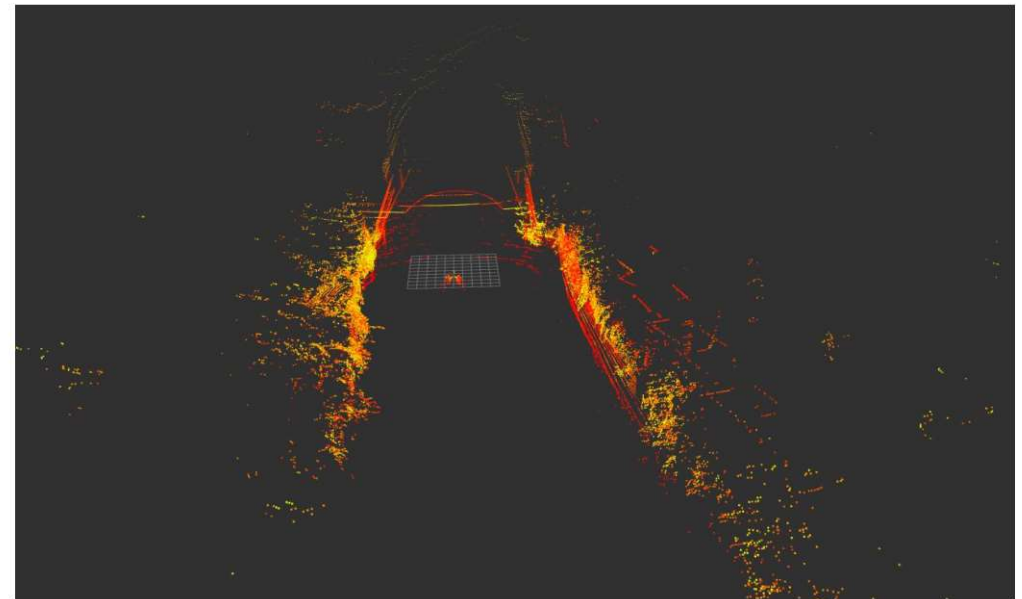
Sensor: Velodyne VLP 32 C (ultraPUCK)

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

Purpose: spatial mapping



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



Our Information Platform – Sensor characteristics



Sensor: Ouster OS0

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

Purpose: spatial mapping



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

