

Intelligent Transport Systems Conference  
24.09. – 28.09., Bilbao



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

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



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

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

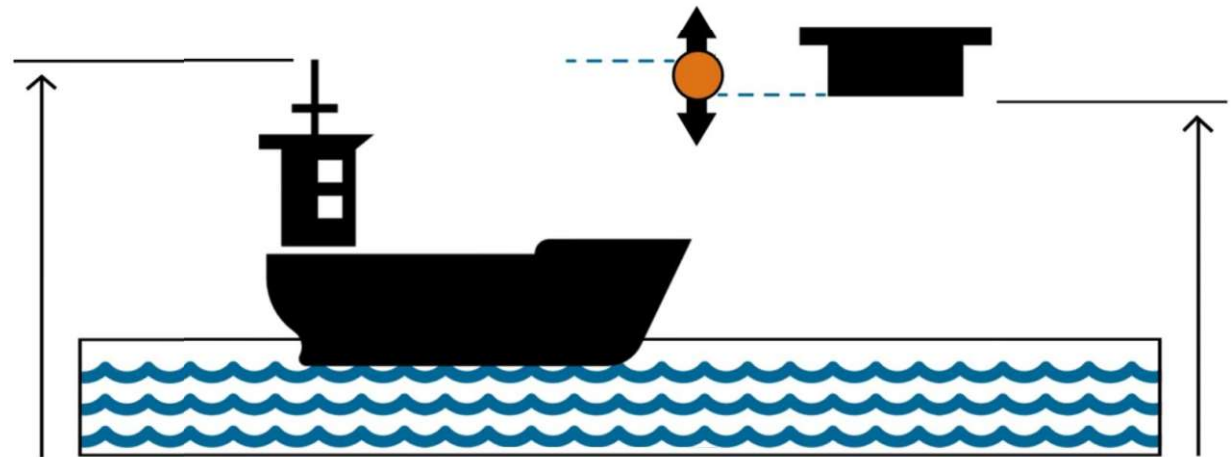


# Mapping of inland waterway infrastructure



- 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

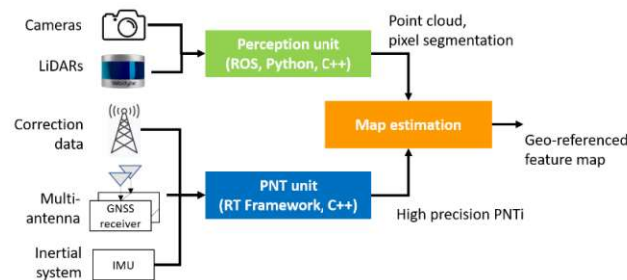
## Sensor Platform

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



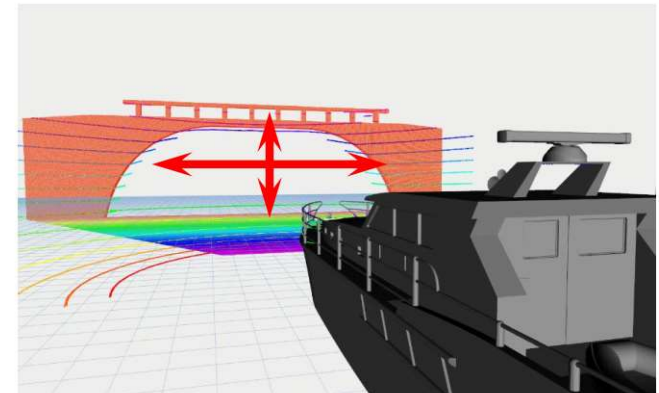
## Map processing

- **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



# 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

# Outline



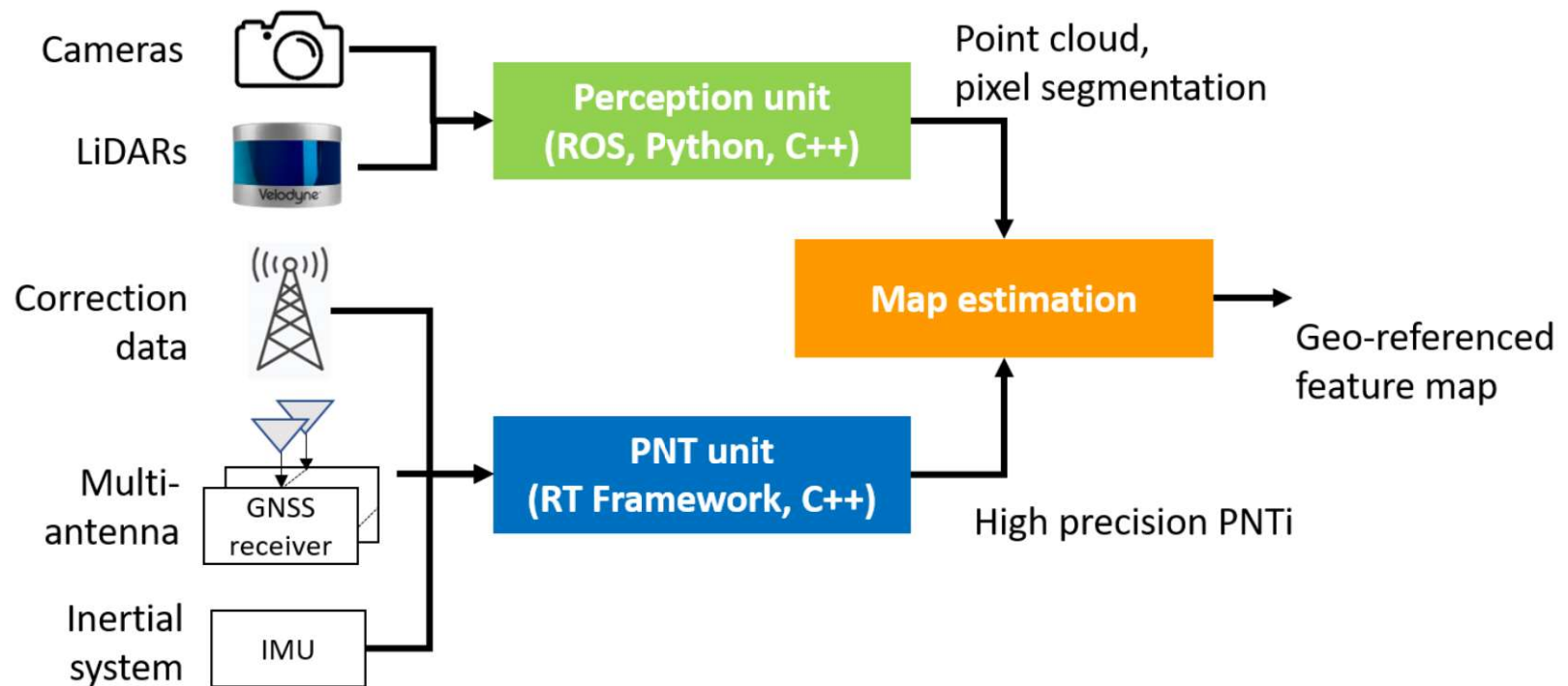
## 1. Map Estimation

- a) Geo-referenced navigation
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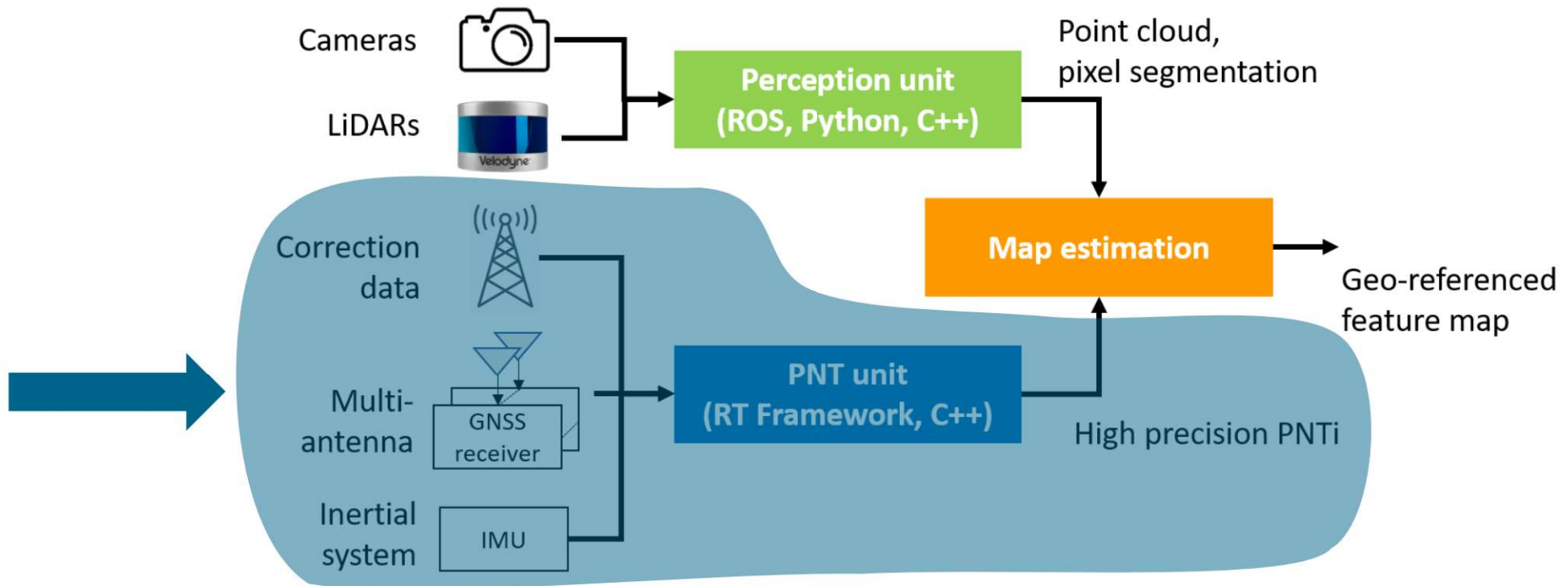
## 2. High Definition Mapping in Berlin

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# Map Estimation System architecture

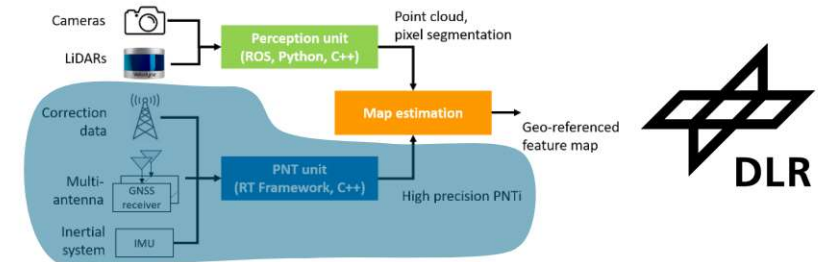


# Map Estimation System architecture





# Map Estimation Geo-referenced navigation



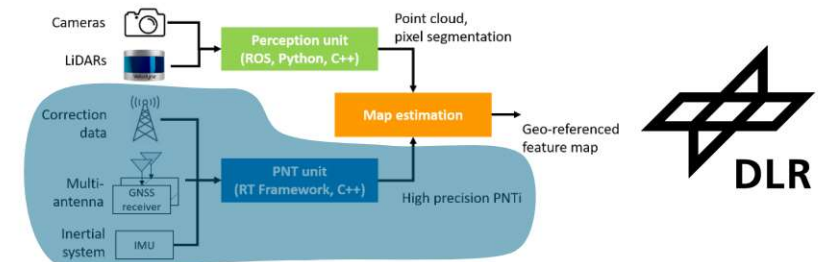
## Position Navigation Timing Unit

→ accurate navigation data

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

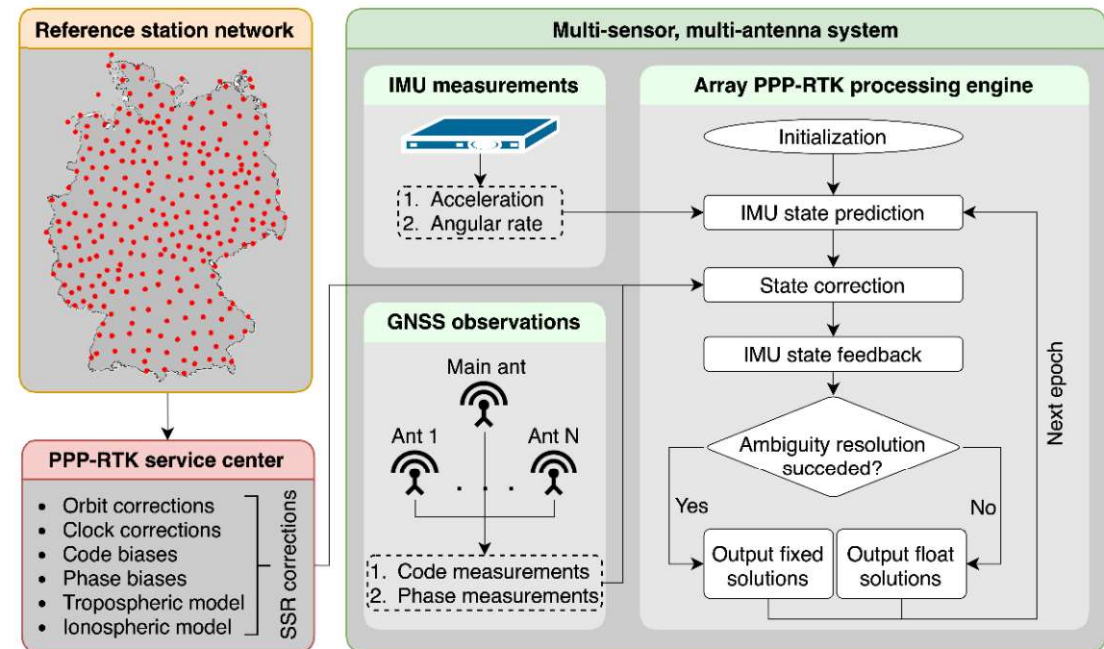


# Map Estimation Geo-referenced navigation



Multi-sensor, multi-antenna system:

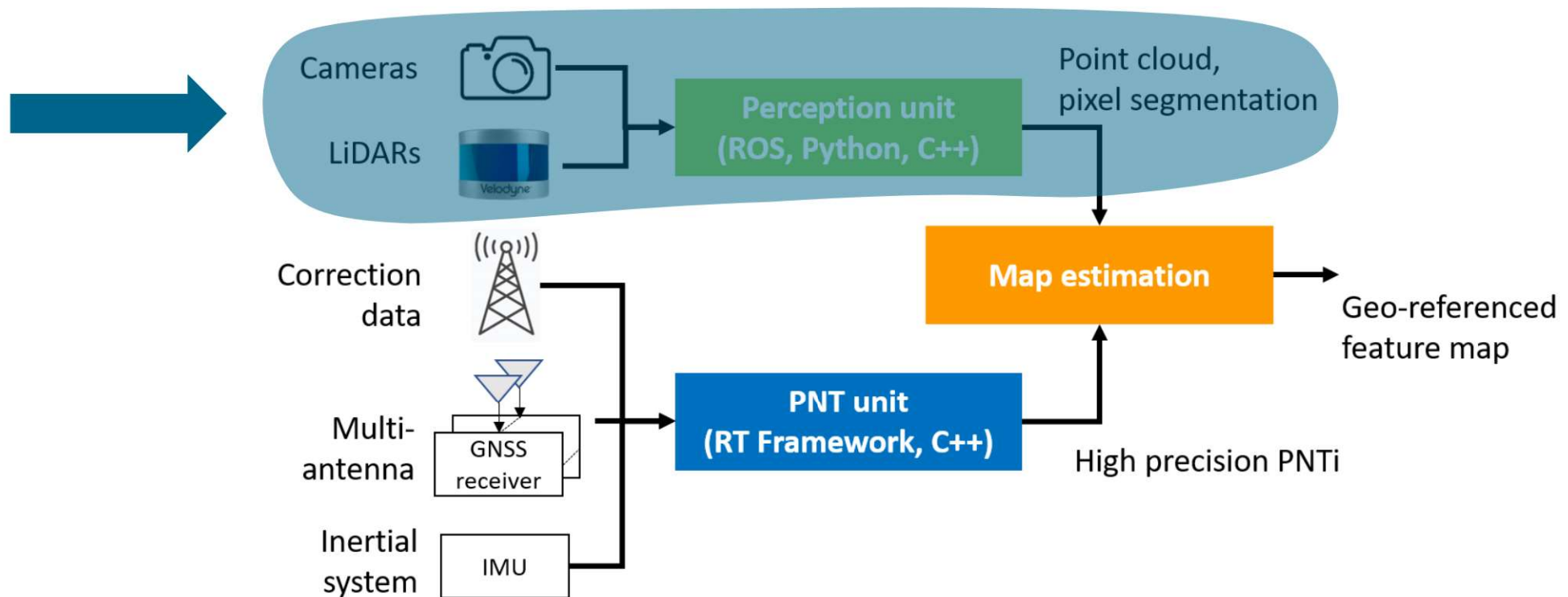
- Array PPP-RTK solution [1]
- IMU integration
- positioning in dm level, attitude estimates in sub-degree accuracy
- Real time correction via SAPOS®, in future possibly HAS (missing carrier phase biases)



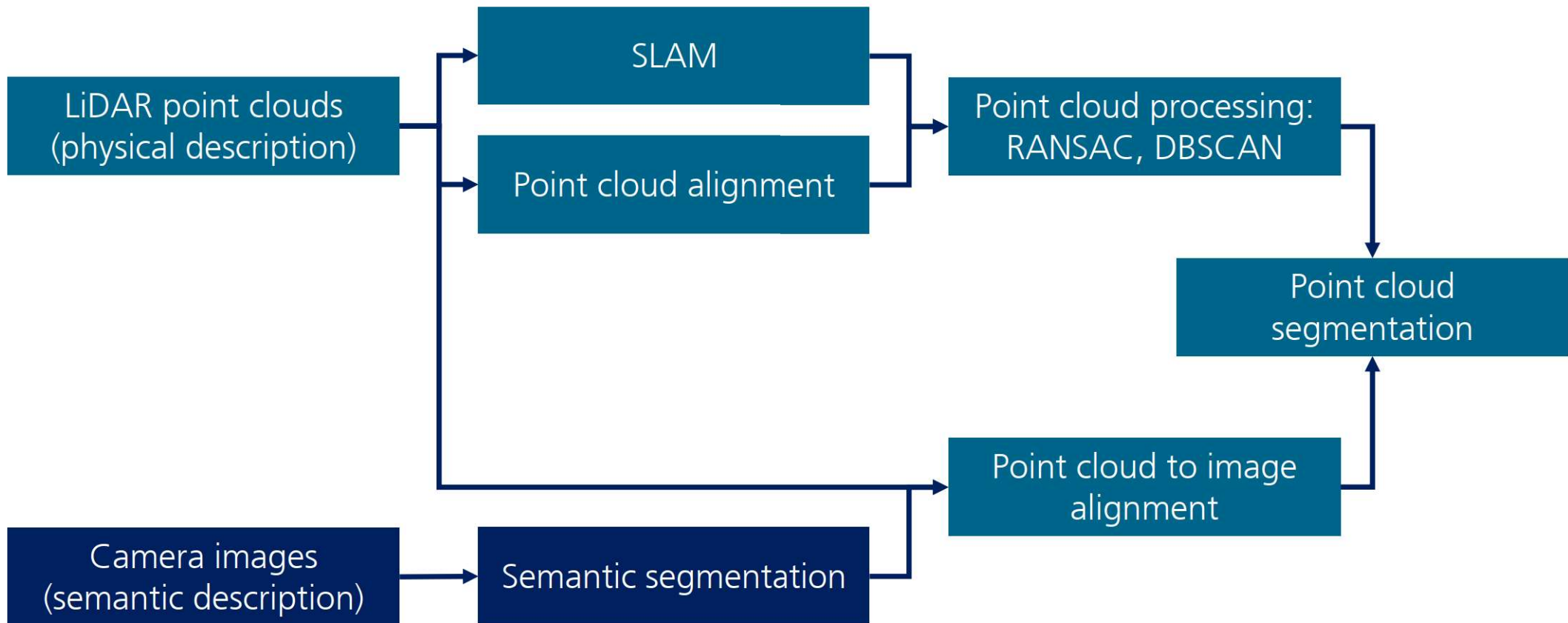
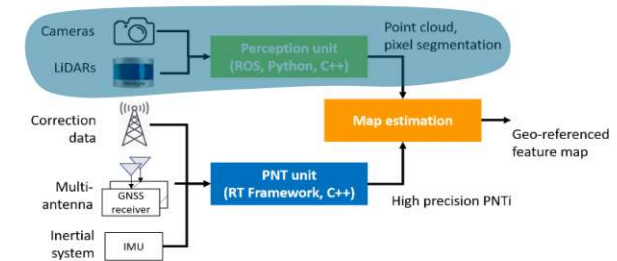
[1] submitted: Array PPP-RTK: A High Precision Pose Estimation Method for Outdoor Scenarios  
Xiangdong An, Andrea Bellés, Filippo Rizzi, Lukas Hösch, Christoph Lass, Daniel Medina  
IEEE Transactions on Intelligent Transportation Systems, 2023

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

# Map Estimation System architecture



# Map Estimation Visual Perception





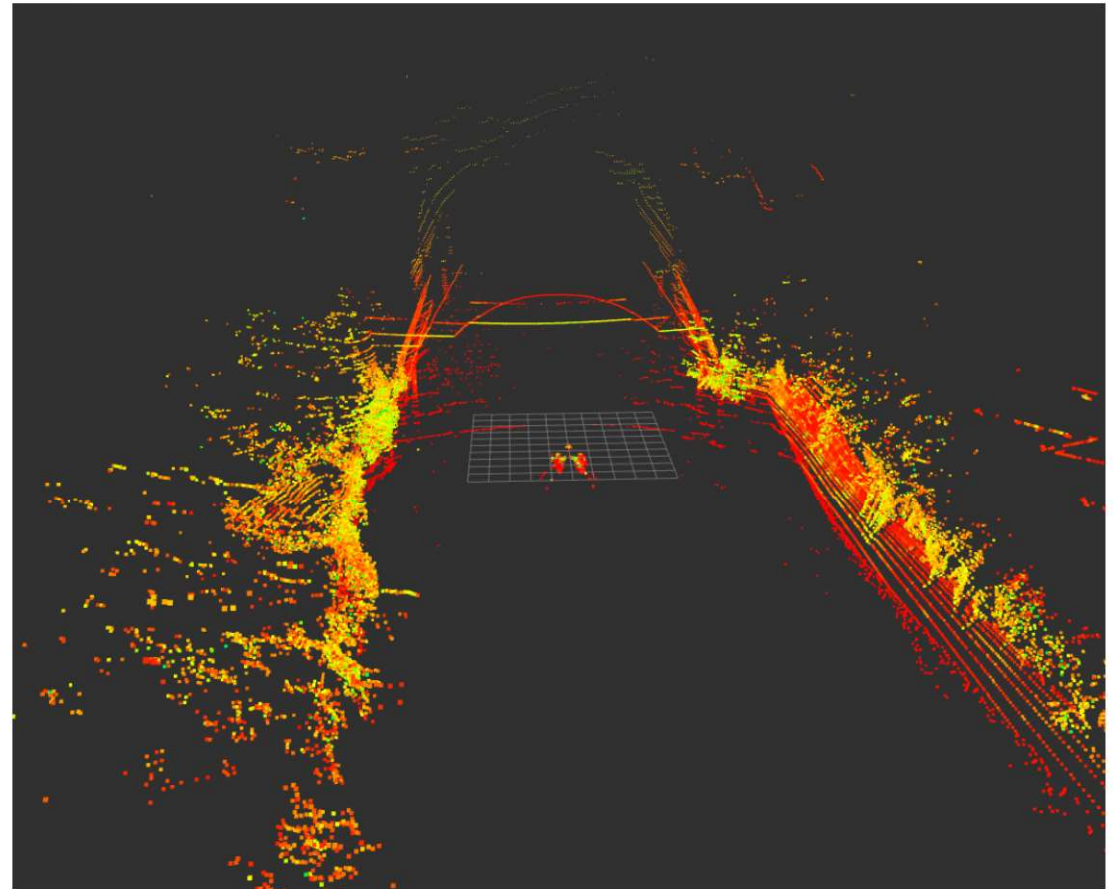
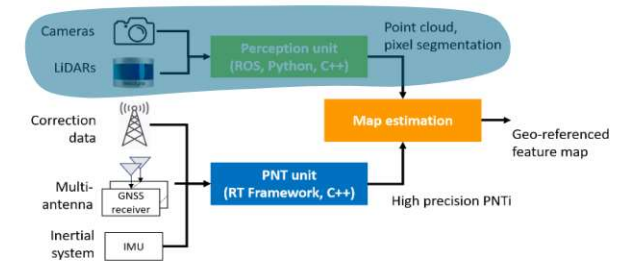
# Map Estimation

## Physical description

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



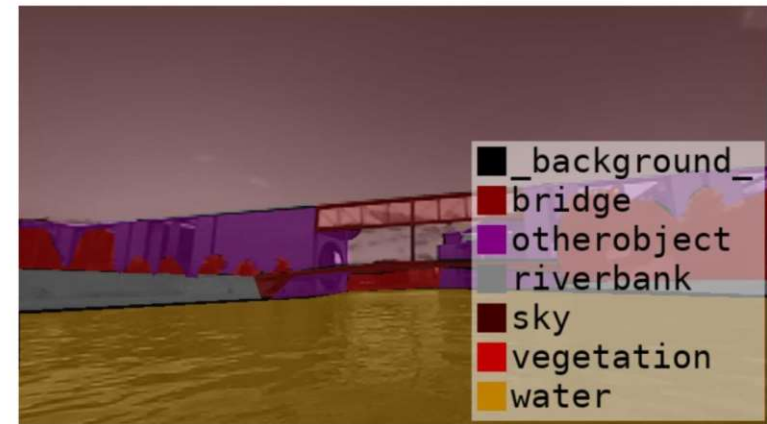
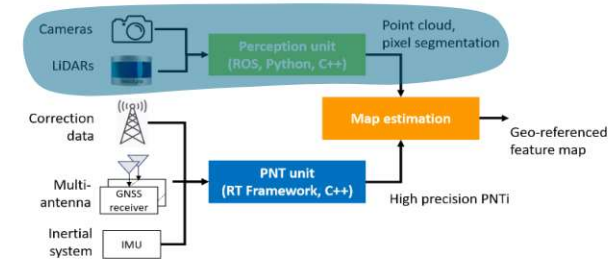
Lukas Hösch, German Aerospace Center (DLR), Department Nautical Systems



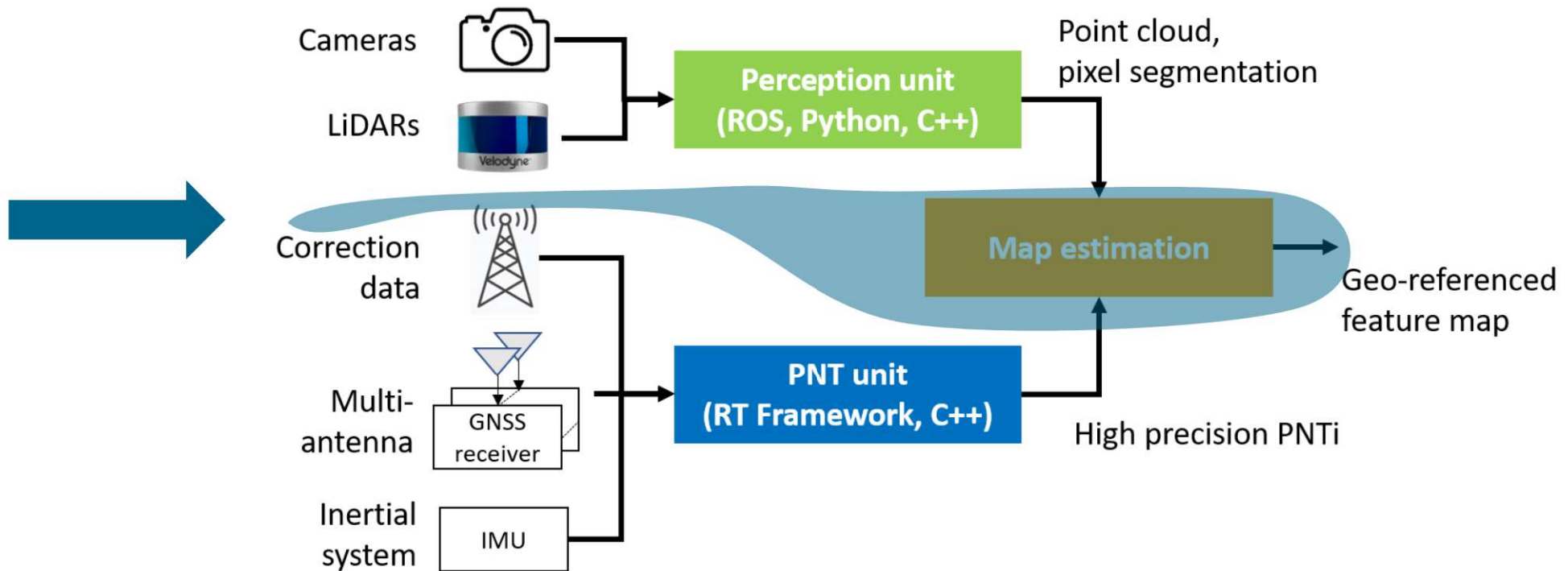
# Map Estimation Semantic description

## Semantic Scene understanding

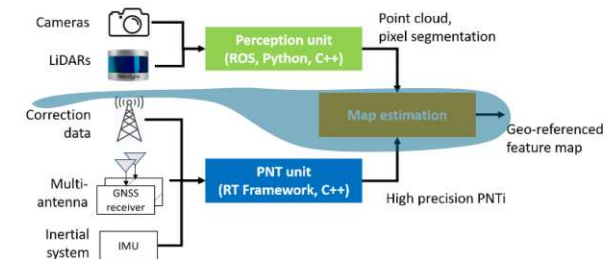
- Semantic Segmentation of camera image
- ML application → data hungry
- Development of our own dataset
- Image – point cloud alignment allows point cloud segmentation



# Map Estimation System architecture

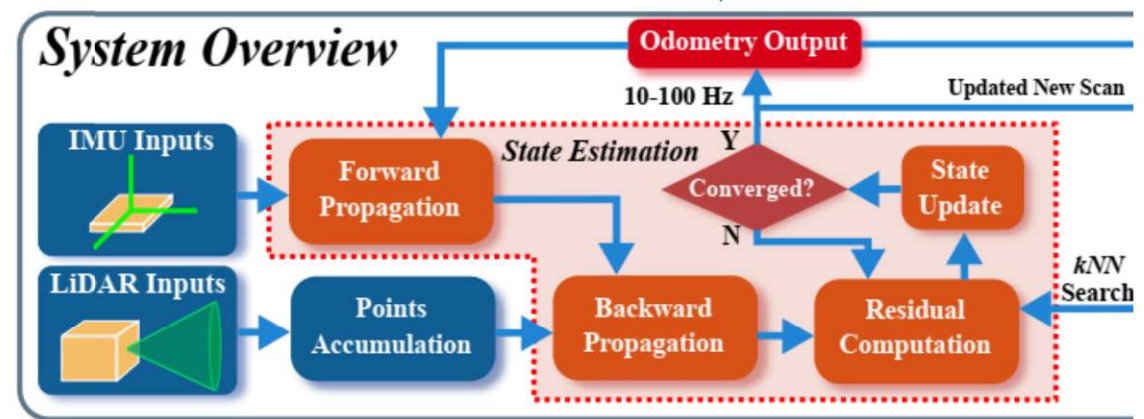


# Map estimation Global SLAM



## 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).

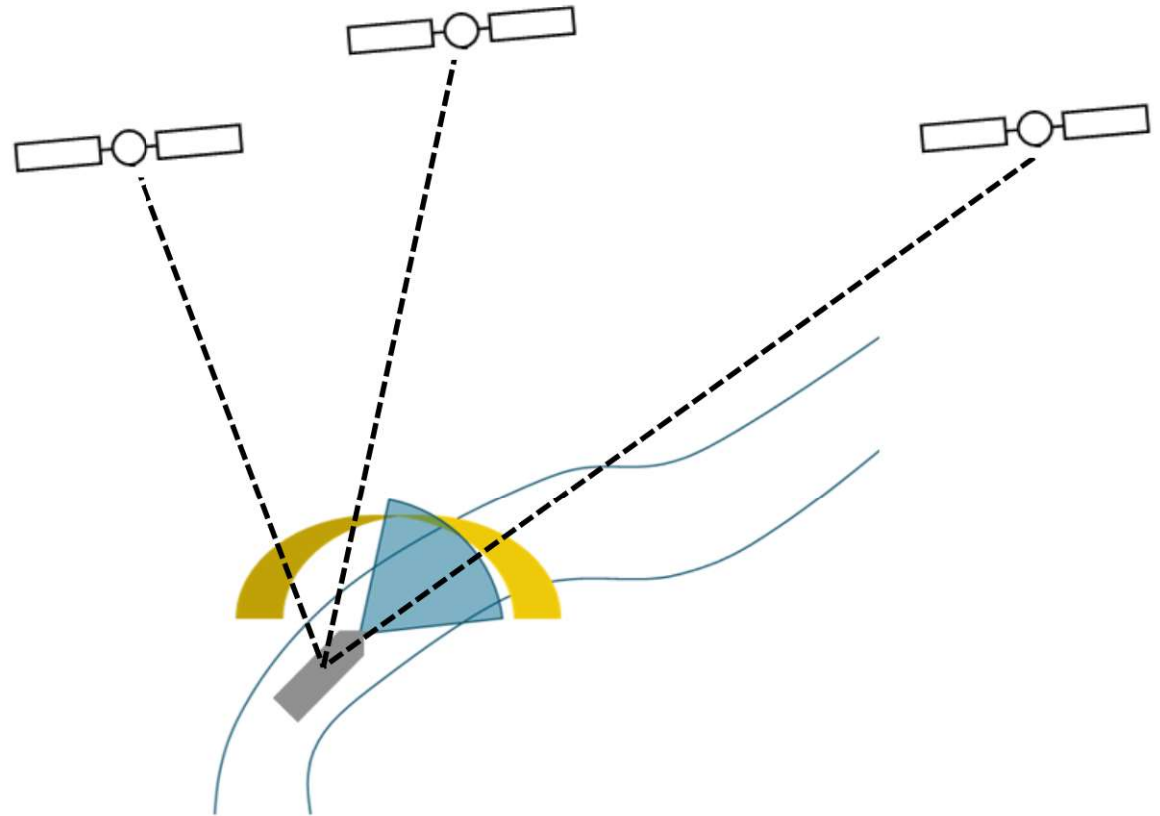
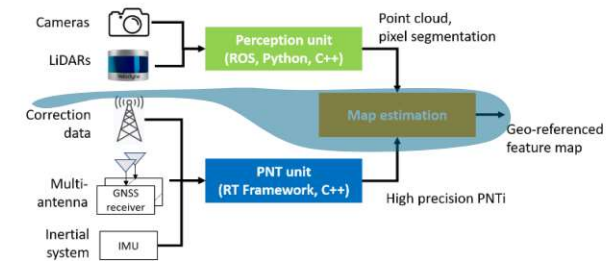
Fast-lío2: Fast direct lidar-inertial odometry. *IEEE Transactions on Robotics*, 38(4), 2053-2073.



# Map estimation Global SLAM

Global, feature-based SLAM solution

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



[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



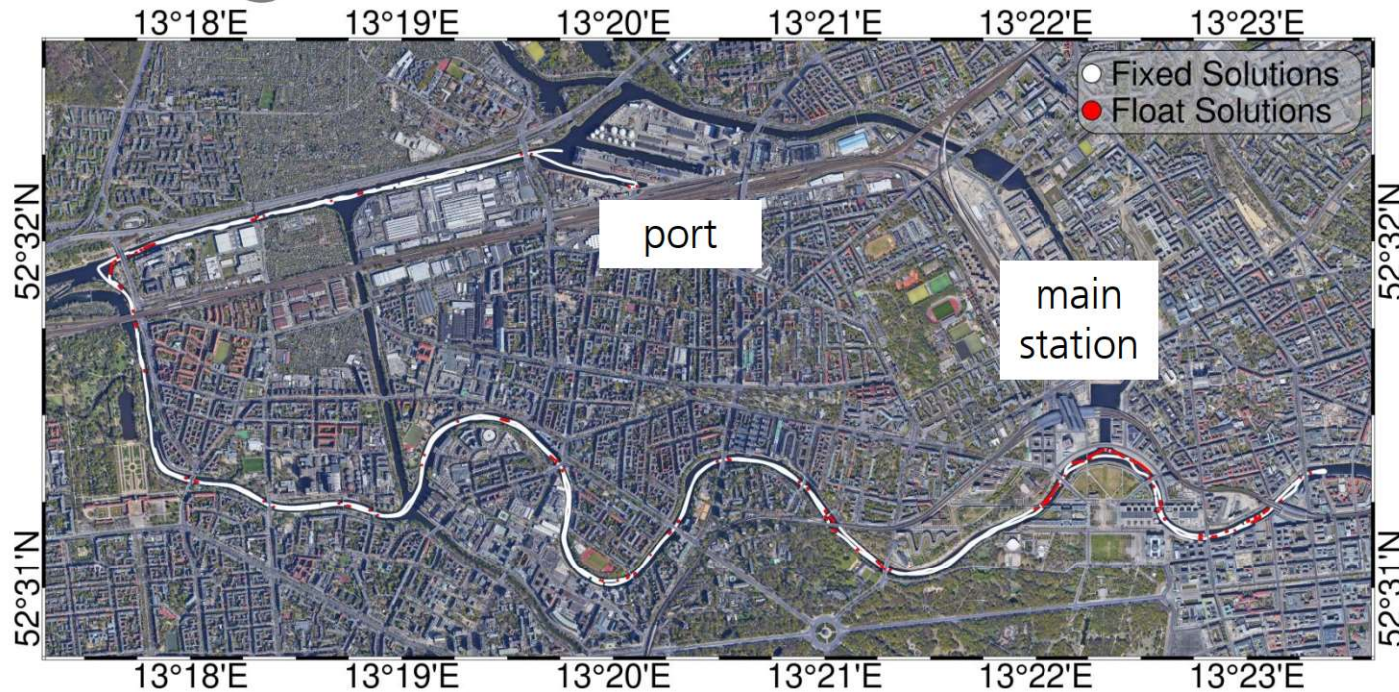
## 1. Map Estimation

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- b) Visual Perception
- c) Global SLAM

## 2. High Definition Mapping in Berlin

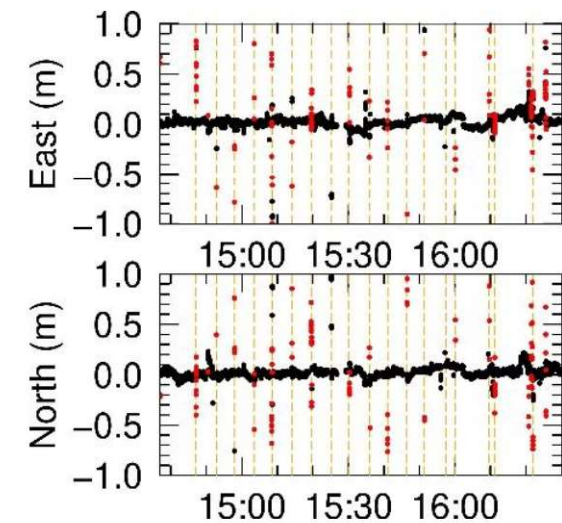
## 3. Outlook and Future Work

# High Definition Mapping in Berlin Navigation



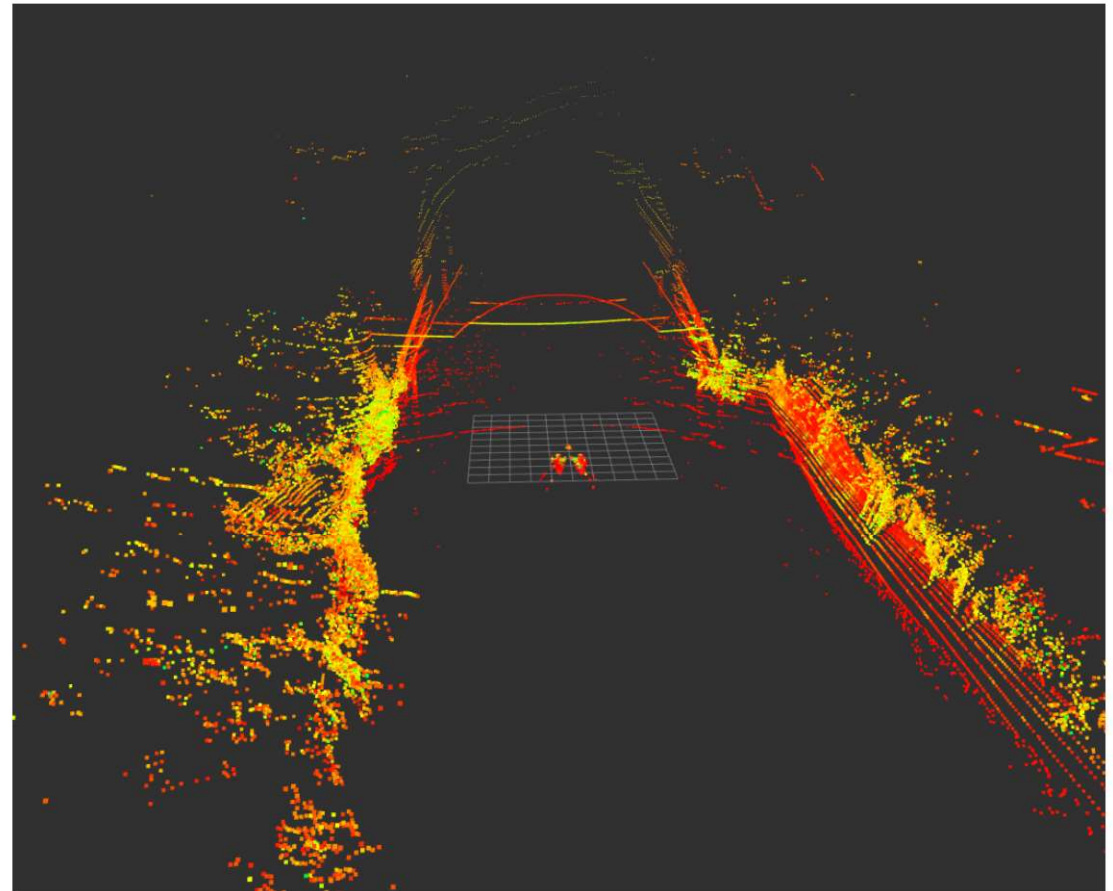
## Results from measurement campaign June 2022

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



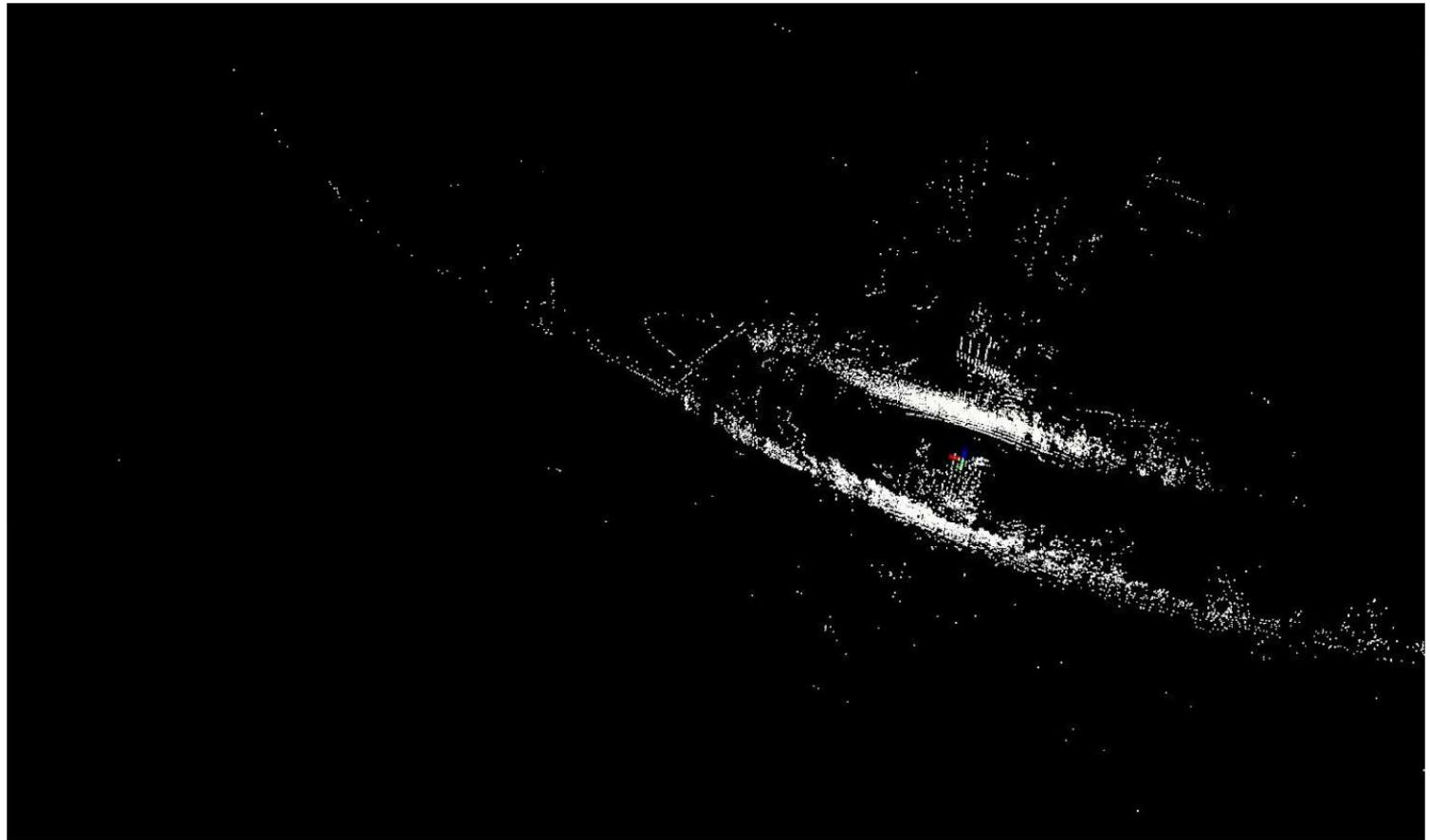


# High Definition Mapping in Berlin Perception

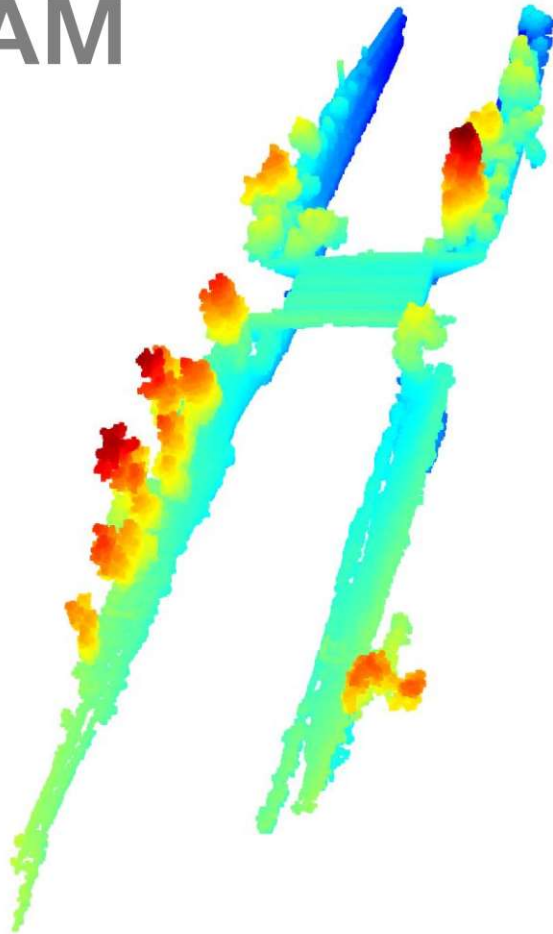




# High Definition Mapping in Berlin Perception



# High Definition Mapping in Berlin local SLAM



FastLIO2 [2] SLAM solution

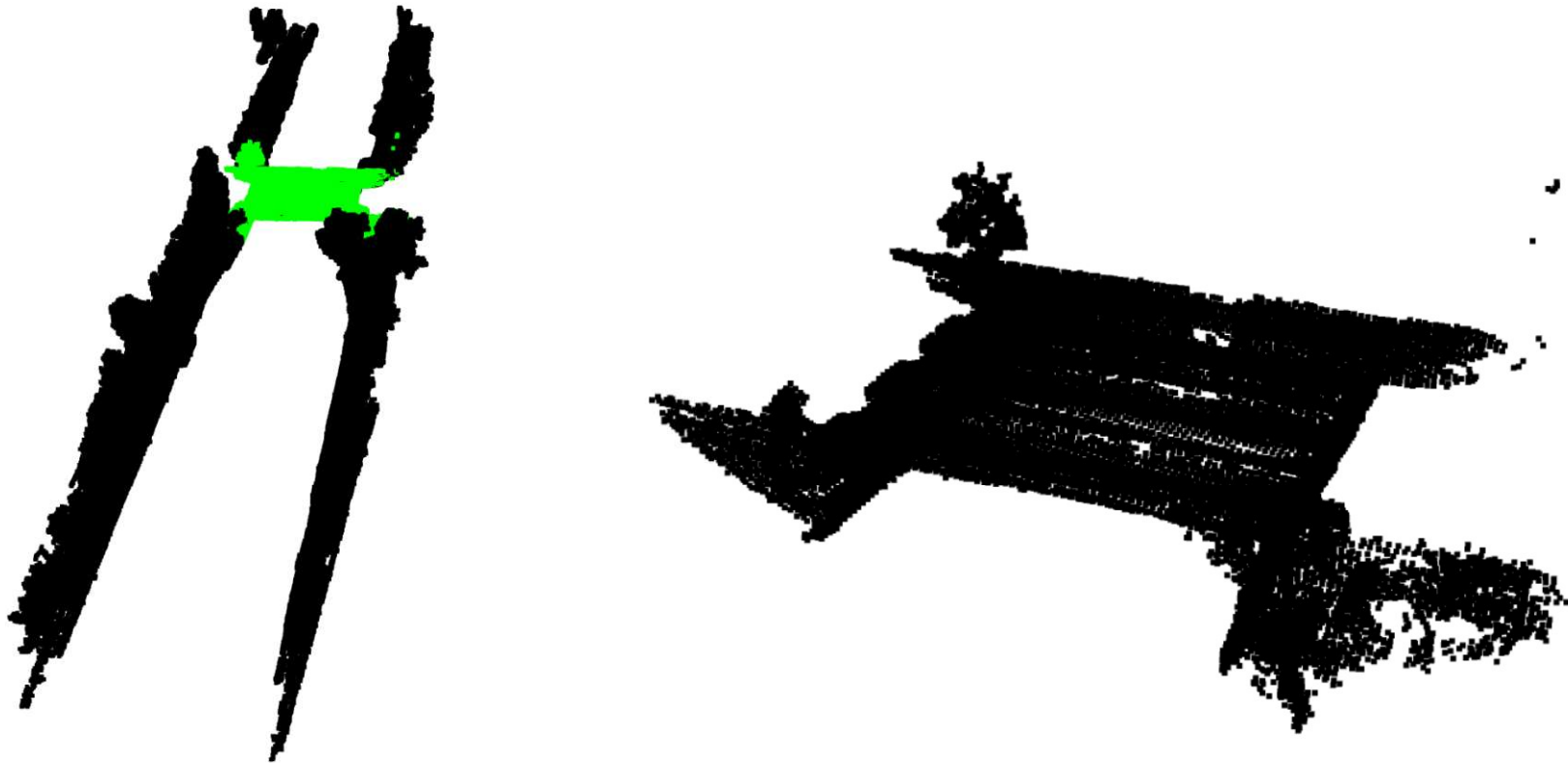


Corresponding alphashape

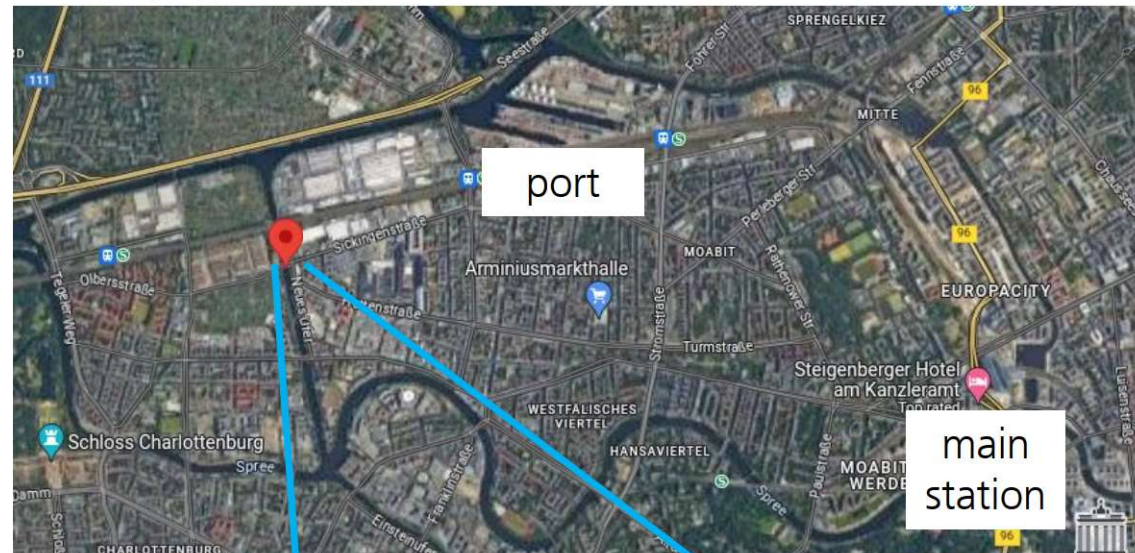
[2] Xu, W., Cai, Y., He, D., Lin, J., & Zhang, F. (2022).  
Fast-lío2: Fast direct lidar-inertial odometry. *IEEE Transactions on Robotics*, 38(4), 2053-2073.

# High Definition Mapping in Berlin

## local SLAM: bridge segmentation



# High Definition Mapping in Berlin global SLAM



Submitted: GNSS LiDAR-Inertial Odometry and Mapping: A Solution for HD Mapping in Inland Waterway Scenarios

Julian Filip, Alonso Llorente, Lukas Hösch, Austin Li, Christoph Lass, Daniel Medina  
IEEE International Conference on Robotics and Automation (ICRA) 2024

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



# High Definition Mapping in Berlin Semantic Segmentation



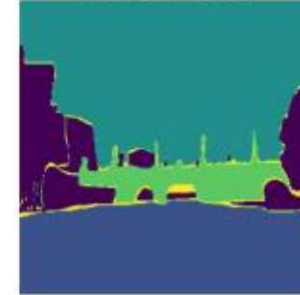
Semantic Segmentation on RGB images

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

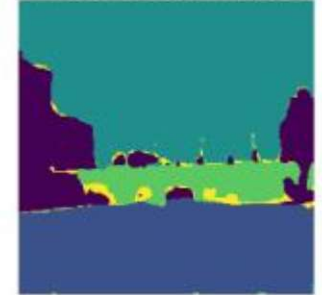
Input Image



True Mask



Predicted Mask



Input Image



Predicted Mask



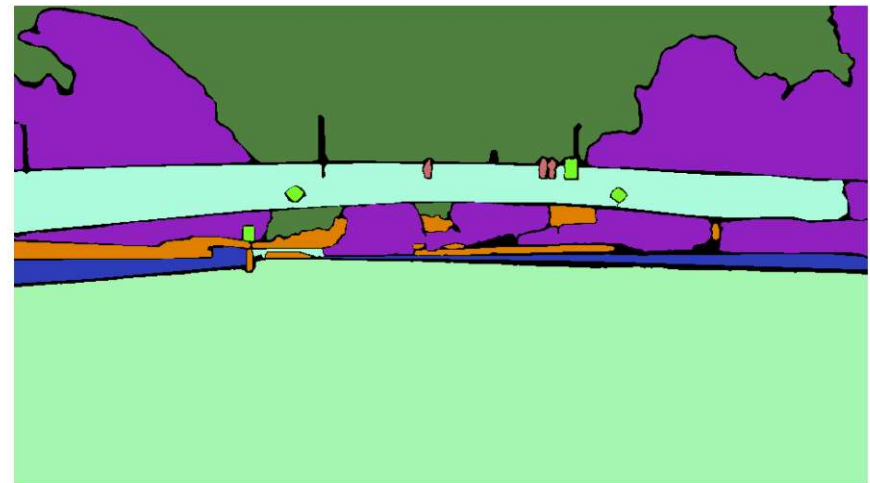
# High Definition Mapping in Berlin

## Semantic Segmentation



Semantic Segmentation on RGB images

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



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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**



[https://izw.baw.de/publikationen/kolloquien/0/6\\_BAW\\_F&E\\_Projekte\\_LAESSI\\_SCIPPER\\_Final.pdf](https://izw.baw.de/publikationen/kolloquien/0/6_BAW_F&E_Projekte_LAESSI_SCIPPER_Final.pdf),



# 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





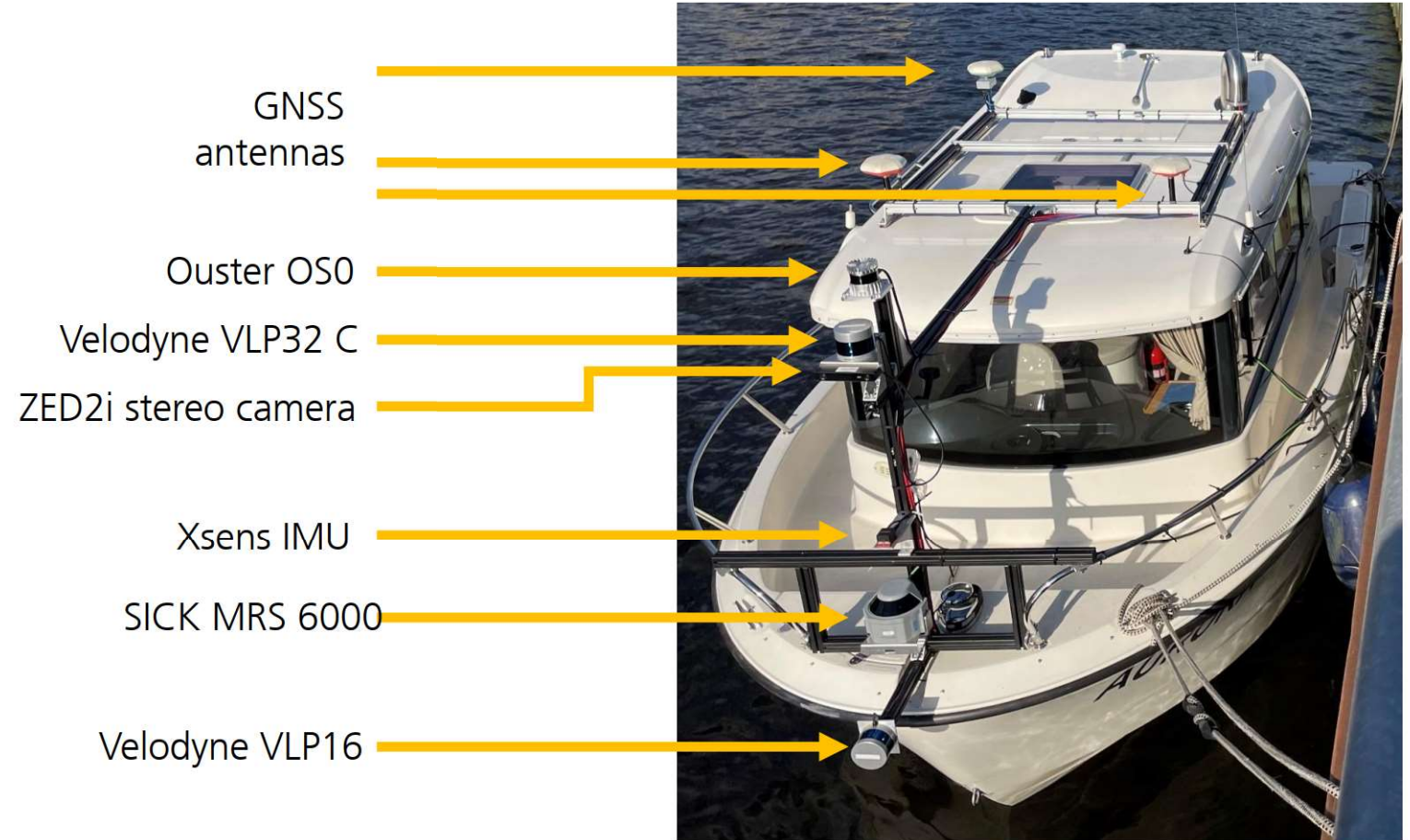
# Our Information Platform

## LiDAR sensors



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

# Our Information Platform





# Our Information Platform – Sensor characteristics



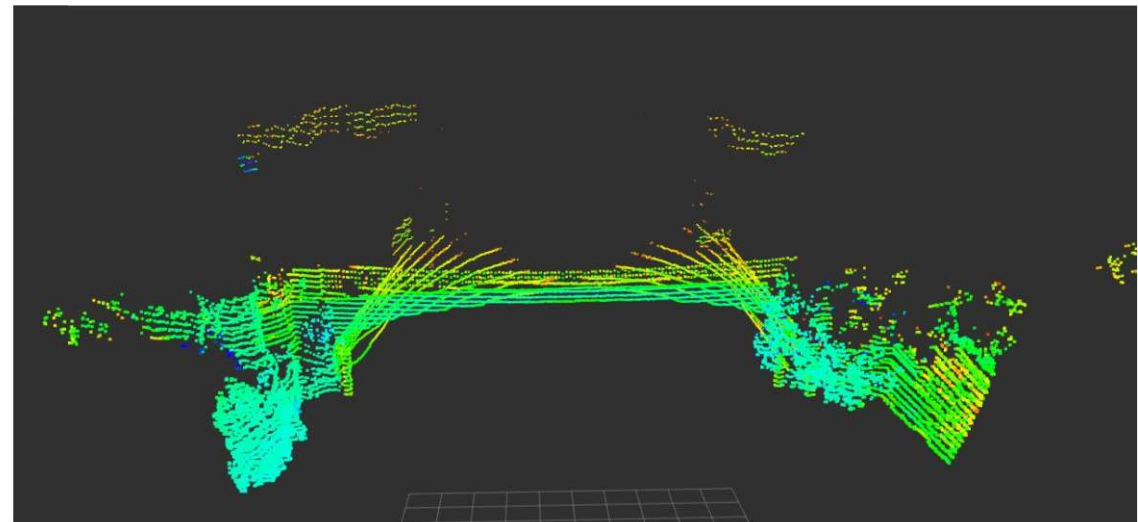
Sensor: **SICK** MRS 6000

- 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



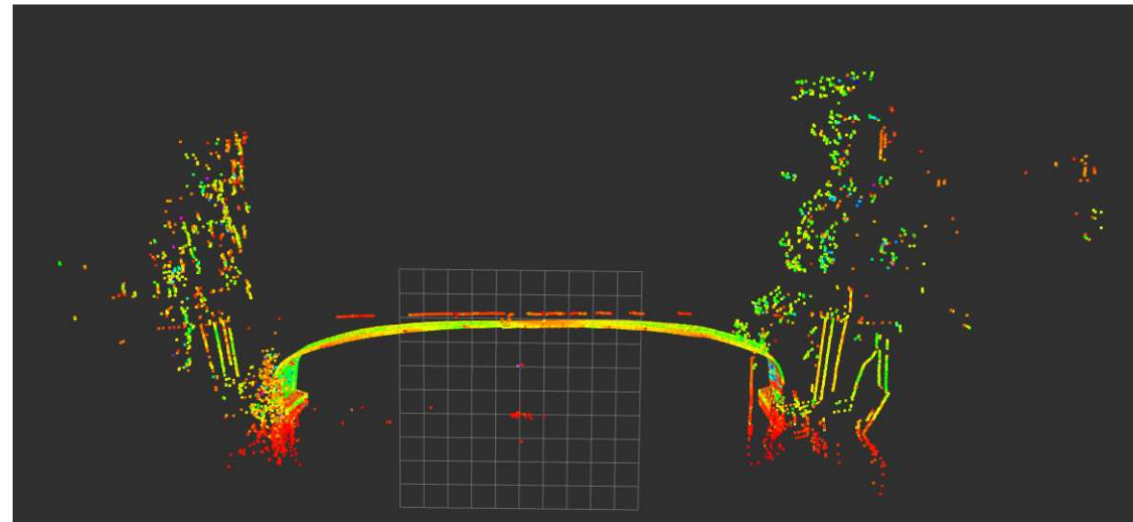
Sensor: Velodyne VLP 16 (PUCK)

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

Purpose: spatial mapping



[https://airsupply.com/wp-content/uploads/2019/07/puck\\_lite.png](https://airsupply.com/wp-content/uploads/2019/07/puck_lite.png),  
09.08.23



# Our Information Platform – Sensor characteristics

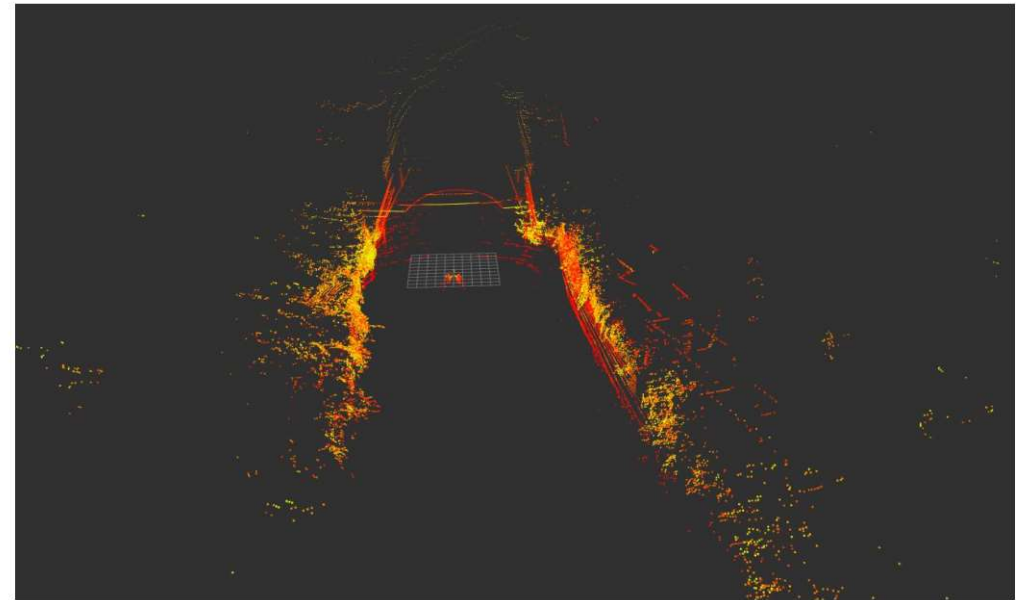


**Sensor: Velodyne VLP 32 C (ultraPUCK)**

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

[https://levelfivesupplies.com/wp-content/uploads/2019/10/VLP-32C\\_Product\\_Image001\\_New-e1585836320757.png](https://levelfivesupplies.com/wp-content/uploads/2019/10/VLP-32C_Product_Image001_New-e1585836320757.png), 09.08.23

**Purpose: spatial mapping**





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

