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

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Information Platform Concept for HD Inland Waterway Mapping

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

AutonomSOWII

DLR

Mapping of inland waterway infrastructure

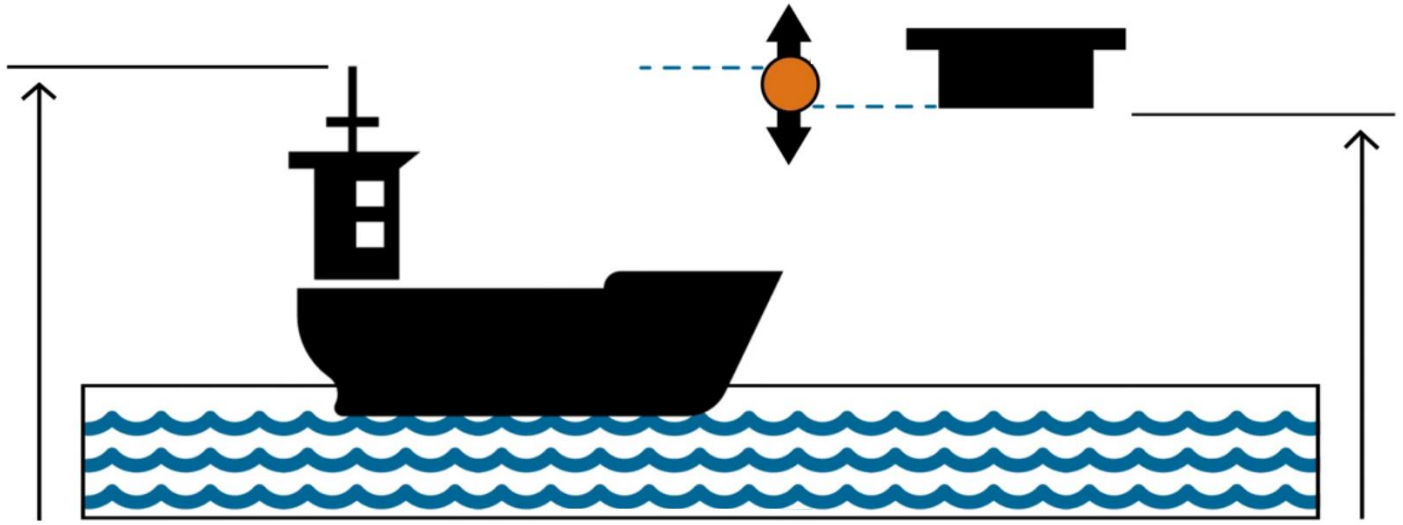
- Inland waterway transport as relevant part of modal split
- Key factor for reduction of traffic-related greenhouse gas emissions

- 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

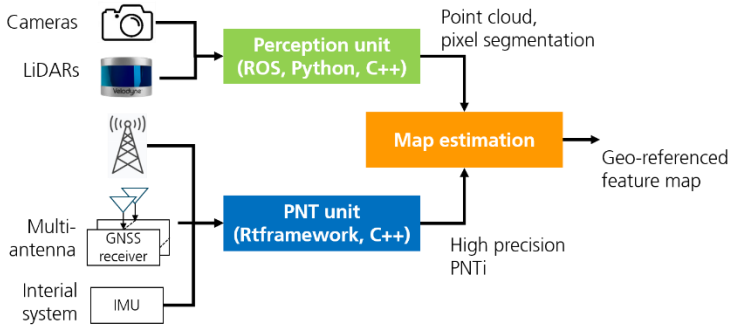
Procedure for HD Mapping

Information Platform

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

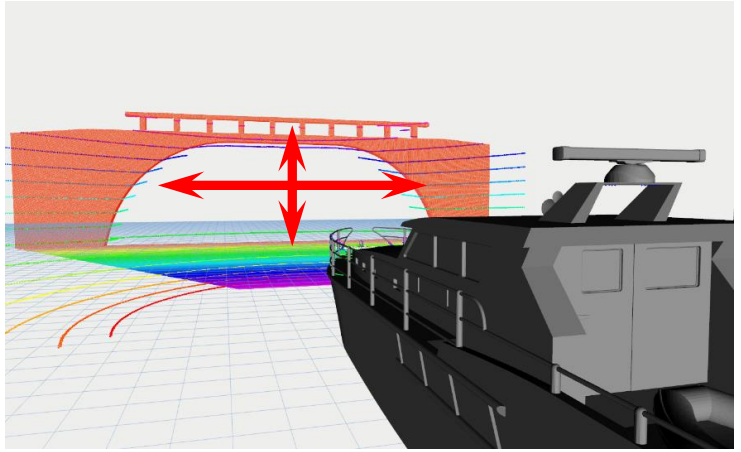
Map processing

- **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



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

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

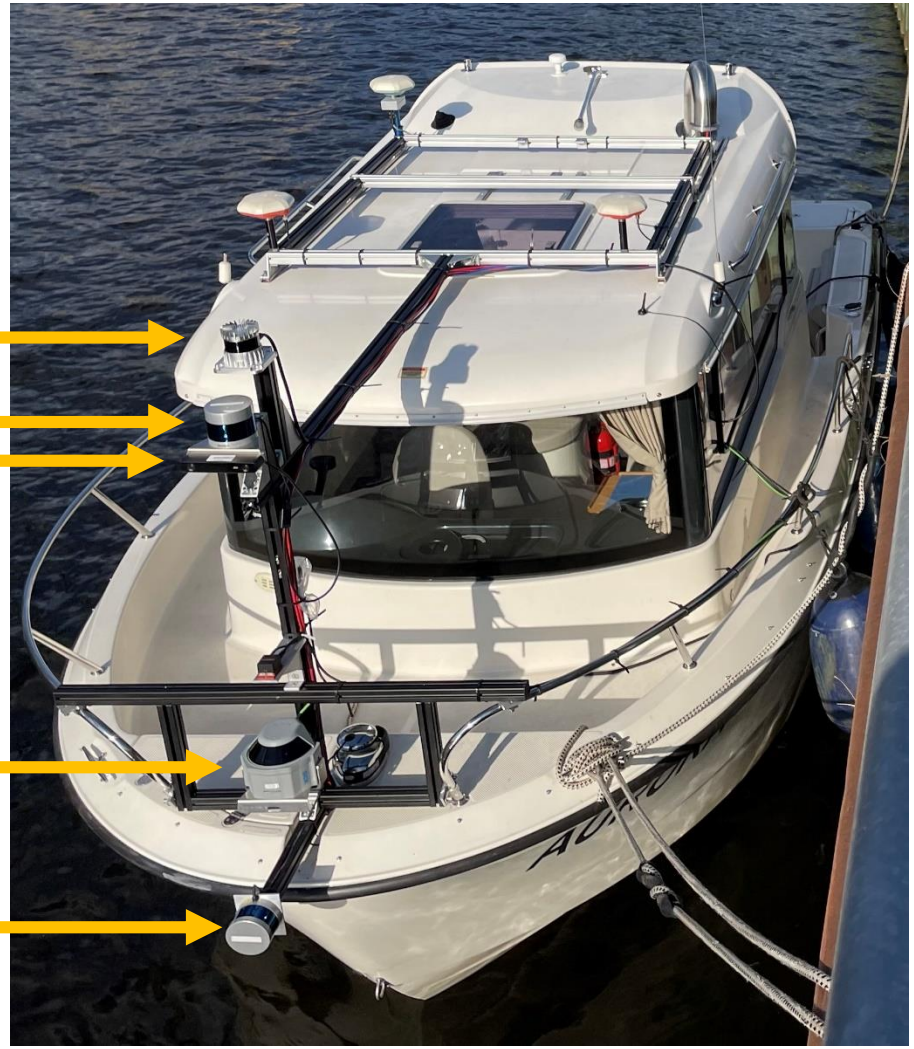
1. **Our Information Platform**
2. **Map Estimation**
   a) Navigation Algorithm
   b) SLAM Engine
3. **High Definition Mapping in Berlin**
4. **Outlook and Future Work**

Building an information platform

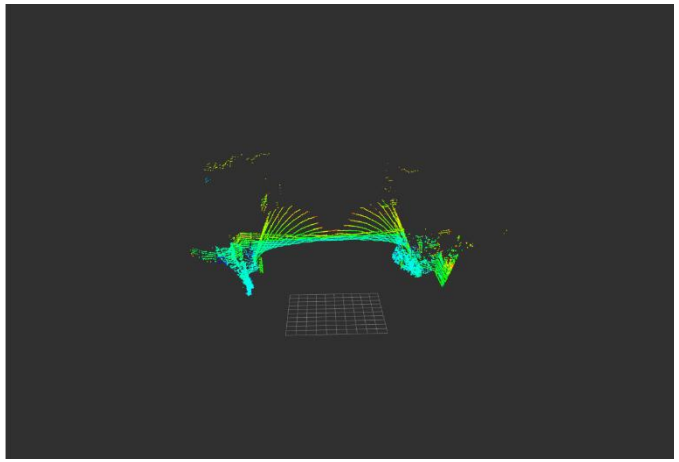
Research boat AURORA

Information platform

Our Information Platform sensor mounting

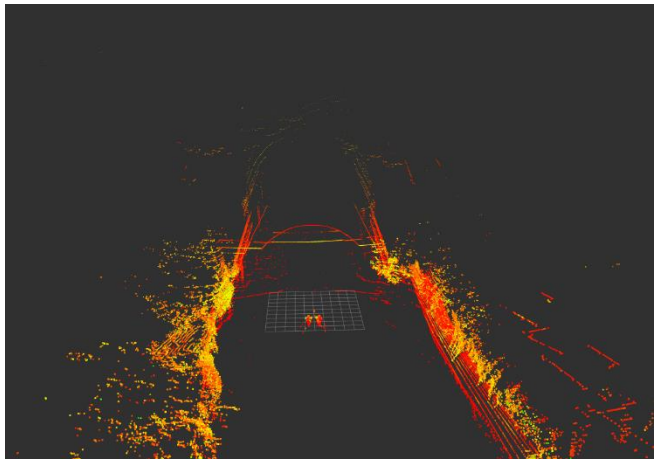


Our Information Platform
LiDAR sensors



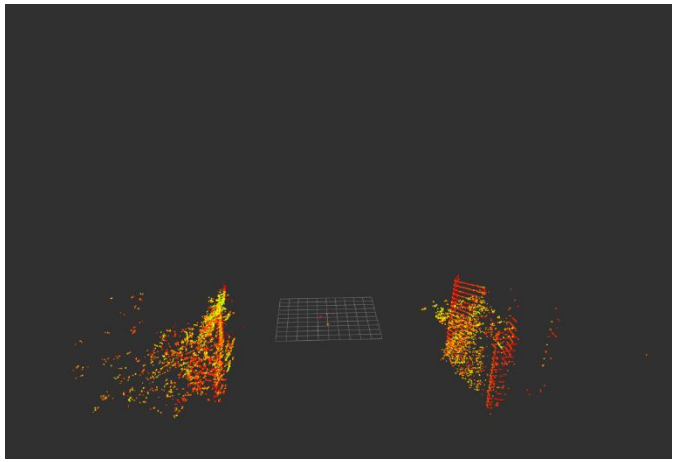
LiDAR	FoV	Range	Resolution	Purpose
SICK MRS 6000	15° x 120°	200 m	Horizontal: 0.13° Vertical: 0.625°	Fine-grained spatial mapping

Our Information Platform
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 VLP32	**40° x 360°**	**200 m**	**Horizontal: 0.1° – 0.4° Vertical: 0.33°**	**General spatial mapping**

Our Information Platform
LiDAR sensors



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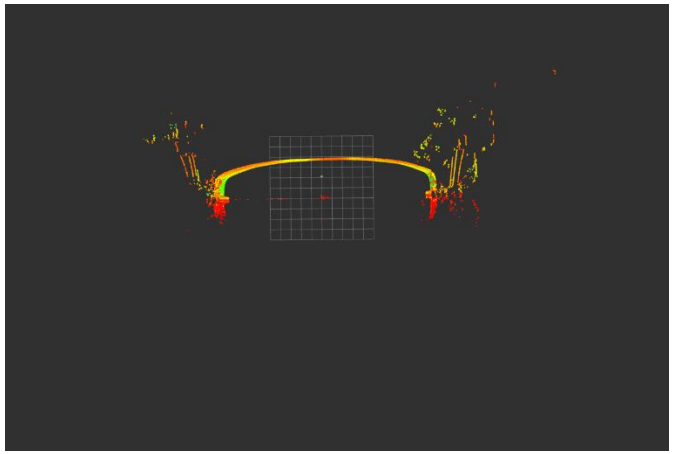
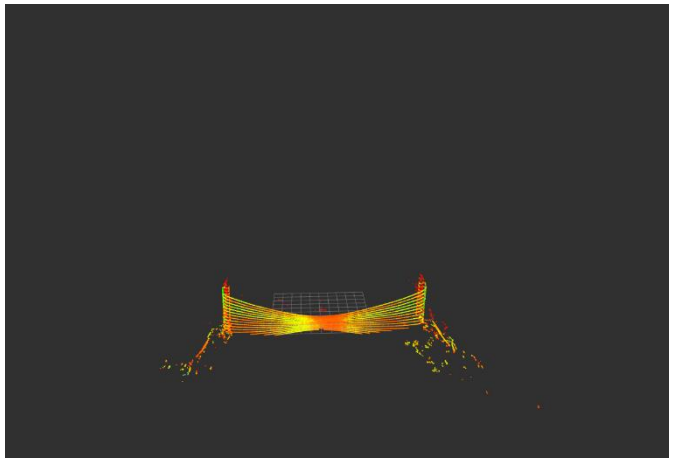
Our Information Platform
LiDAR sensors





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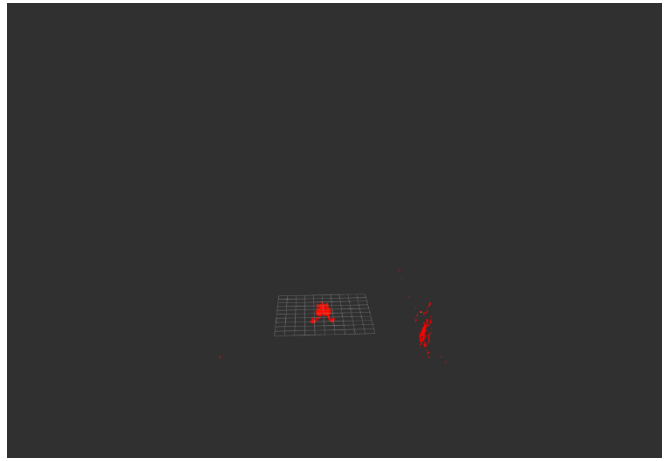
Our Information Platform
LiDAR sensors



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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 (Sensonor STIM 3000)
- GNSS data correction over GSM (Galileo HAS corrections and SSRZ from SAPOS)

Outline

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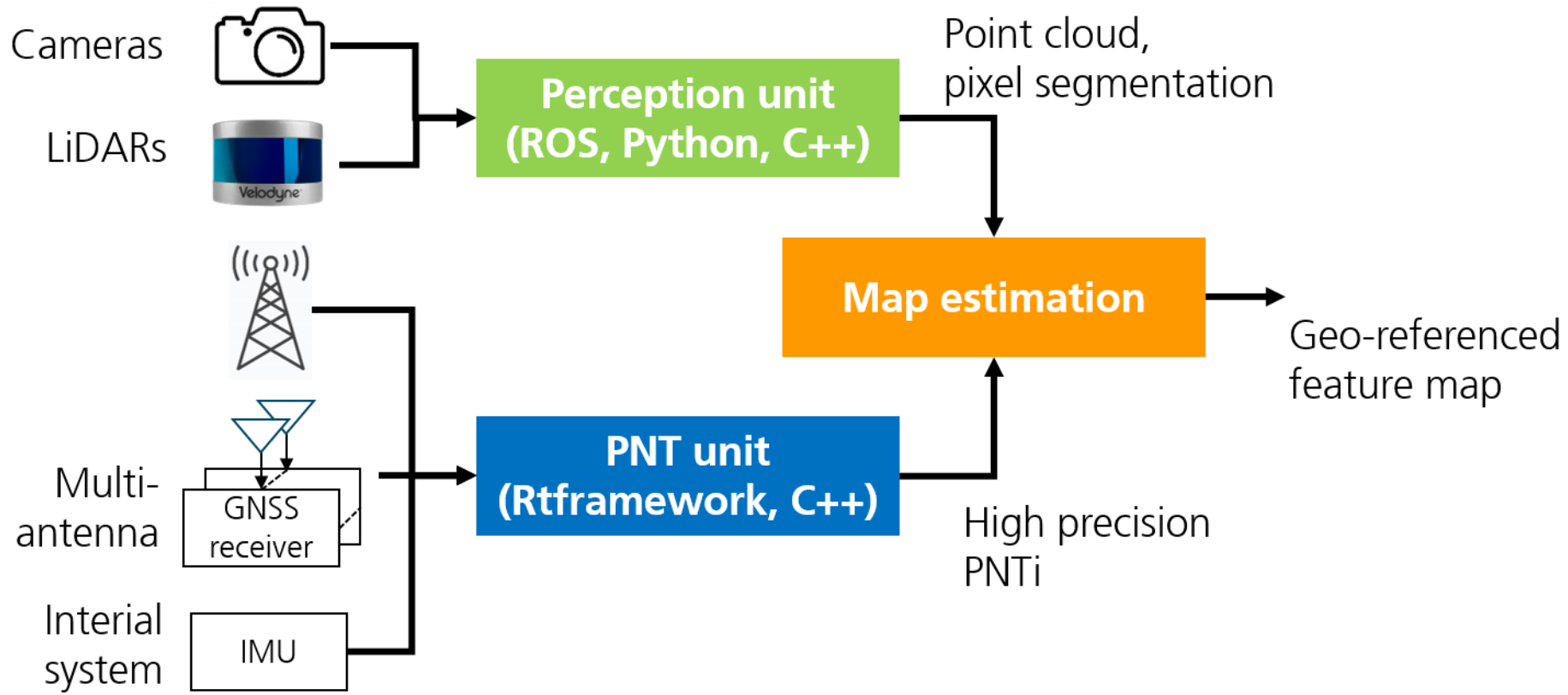
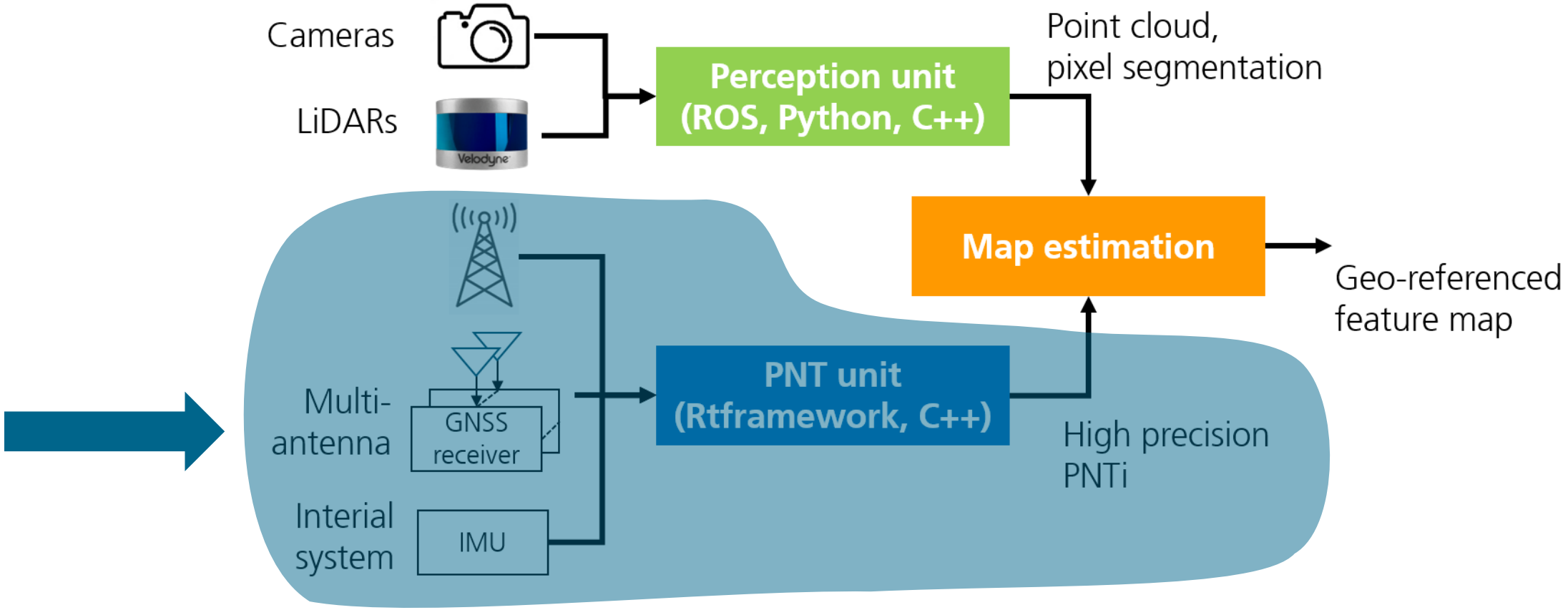
4. Outlook and Future Work

Map Estimation
System architecture



Map Estimation
PNT unit



Map Estimation
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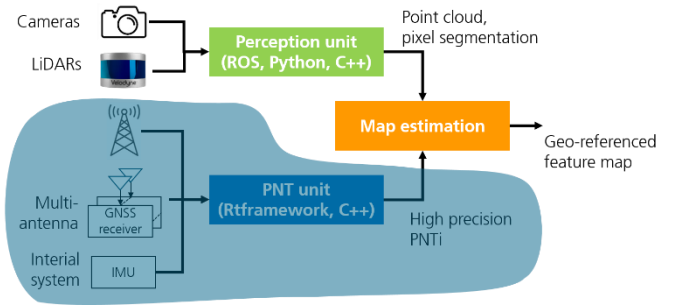
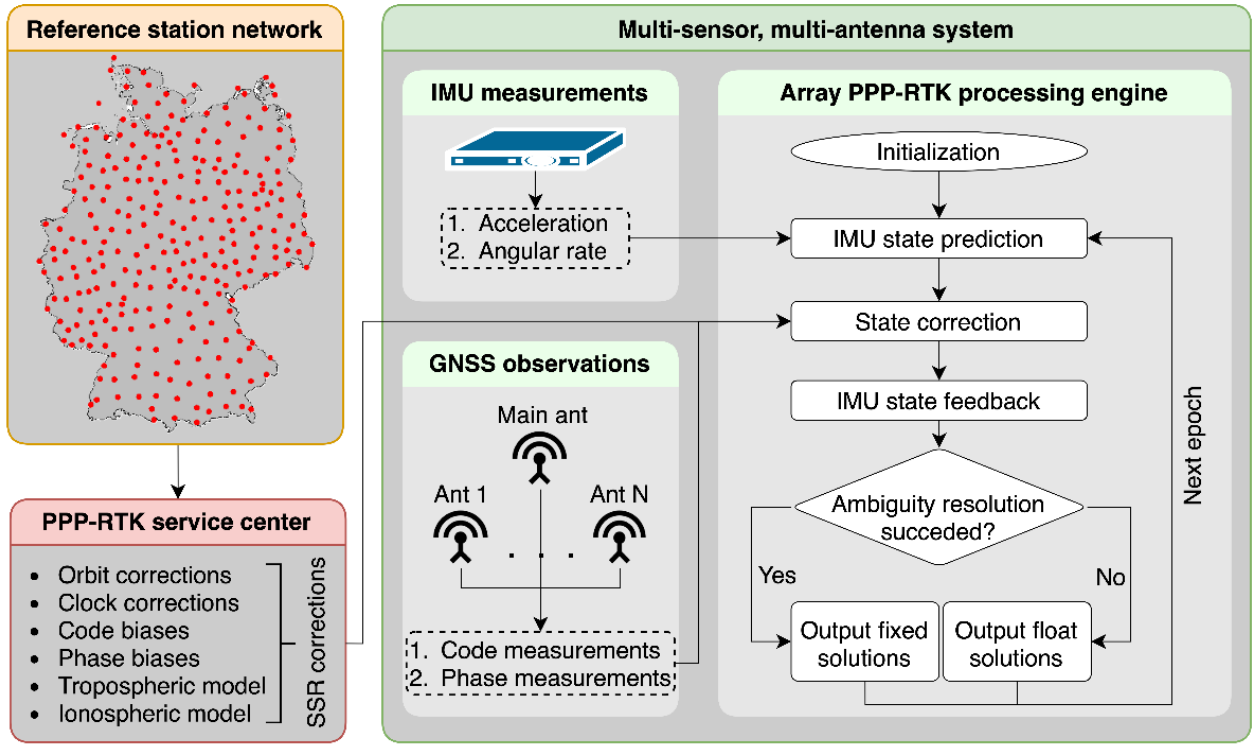


Multi-sensor, multi-antenna system:

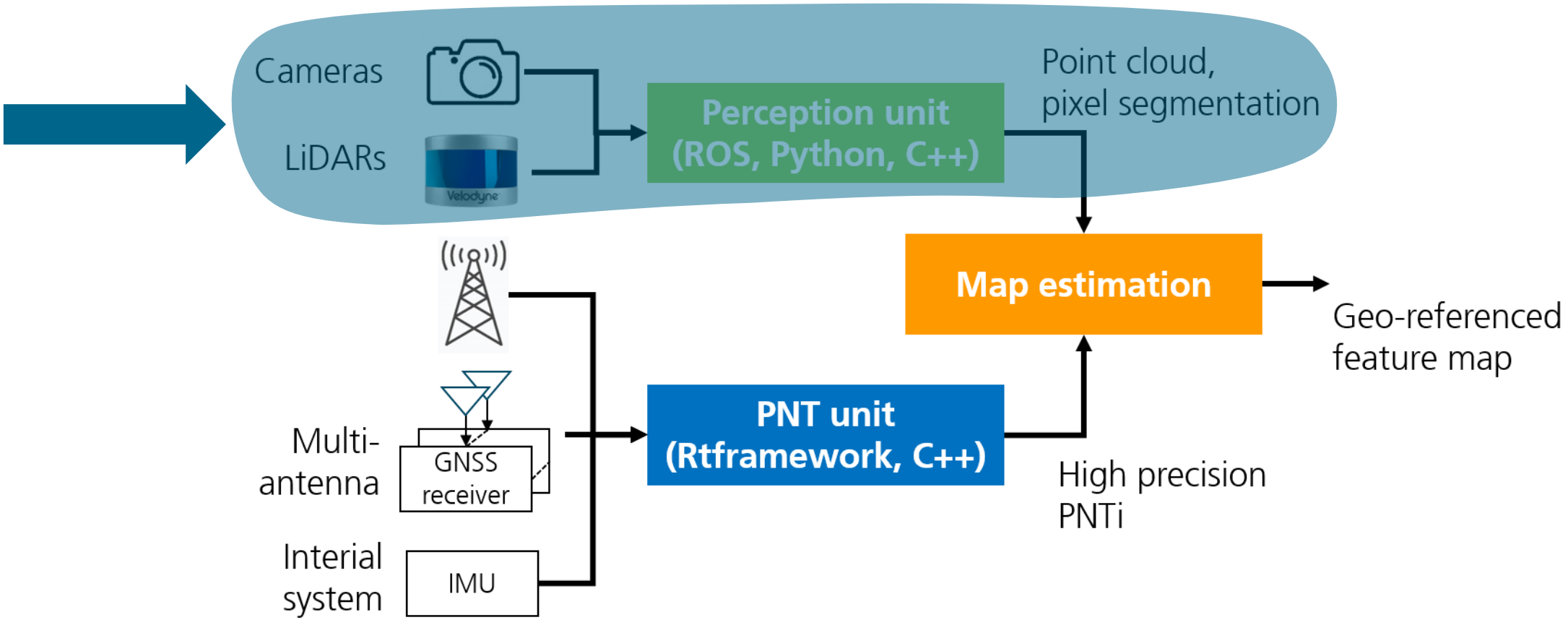
- Array PPP-RTK solution [1]
- IMU integration
- positioning in dm level, attitude estimates in sub-degree accuracy

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

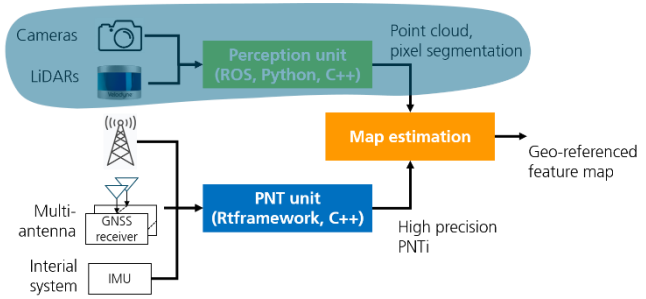


[1] Array PPP-RTK: A High Precision Pose Estimation Method for Outdoor Scenarios
Xiangdong An, Andrea Bellés, Filippo Rizzi, Lukas Hösch, Christoph Lass, Daniel Medina
IEEE Transactions on Intelligent Transportation Systems, 2023

Map Estimation Perception Unit



Map Estimation Perception Unit



LiDAR point clouds

SLAM

Point cloud alignment

Point cloud processing: RANSAC, DBSCAN

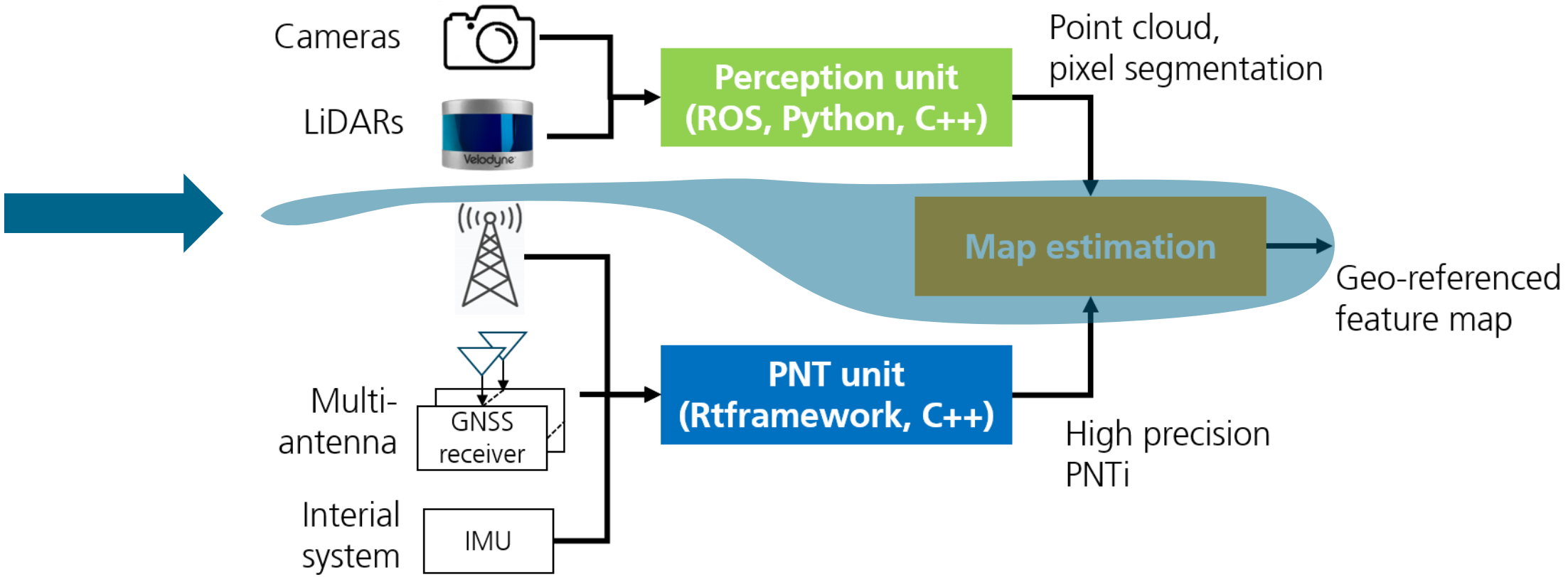
Point cloud segmentation

Point cloud to image alignment

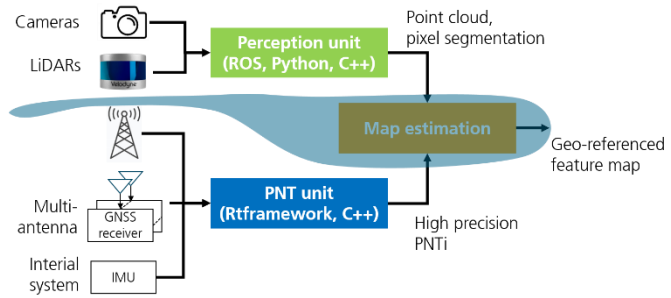
Camera images

Semantic segmentation

Map estimation
SLAM engine

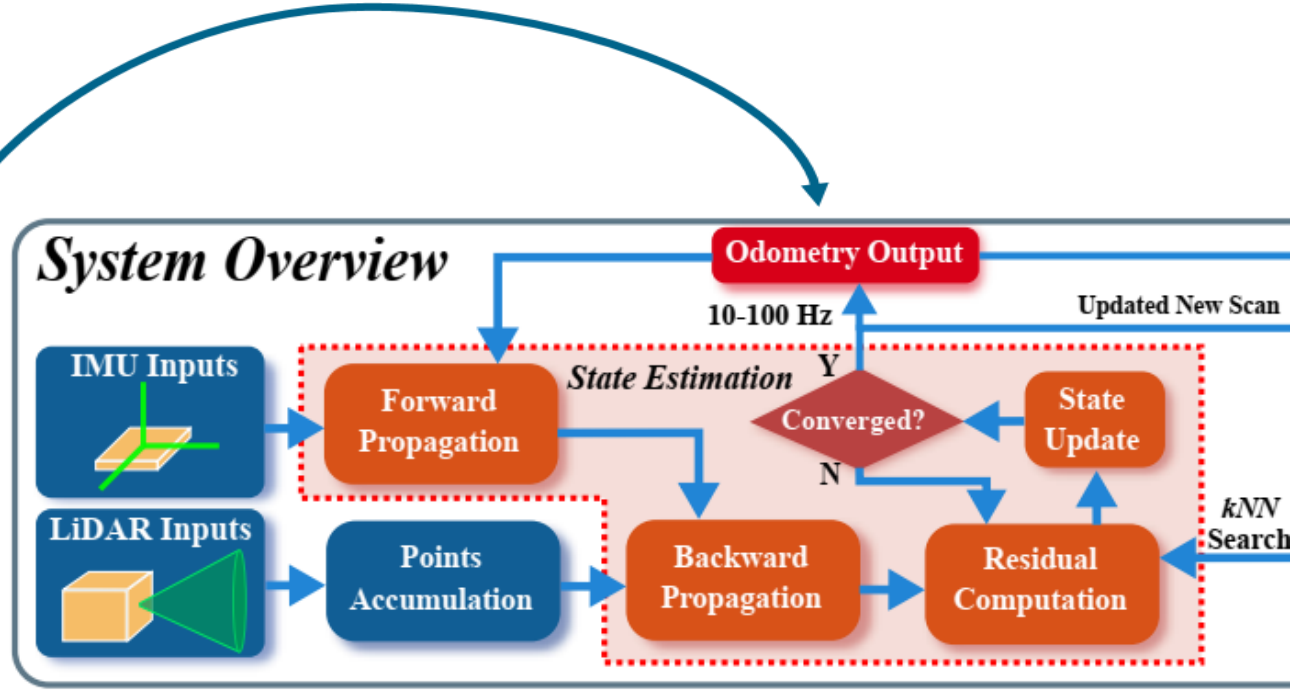


Map estimation SLAM engine



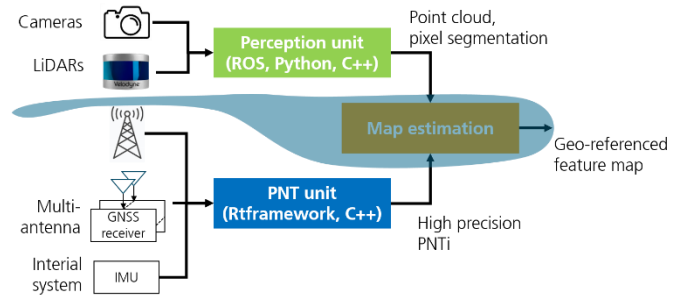
Adaption of FastLIO2 algorithm

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



[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.

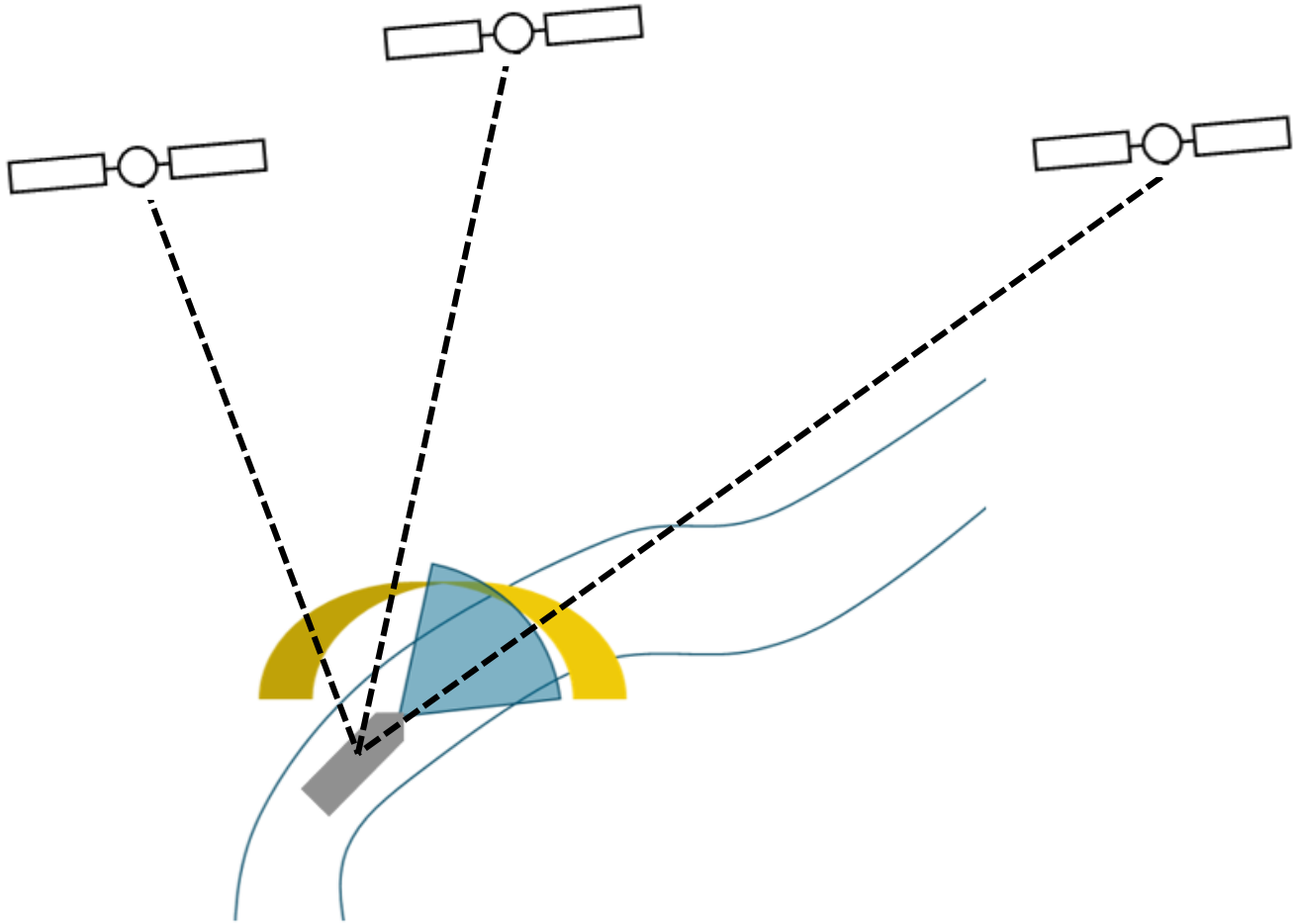
Map estimation SLAM engine



Global, feature-based SLAM solution

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

- Precise global registration of features



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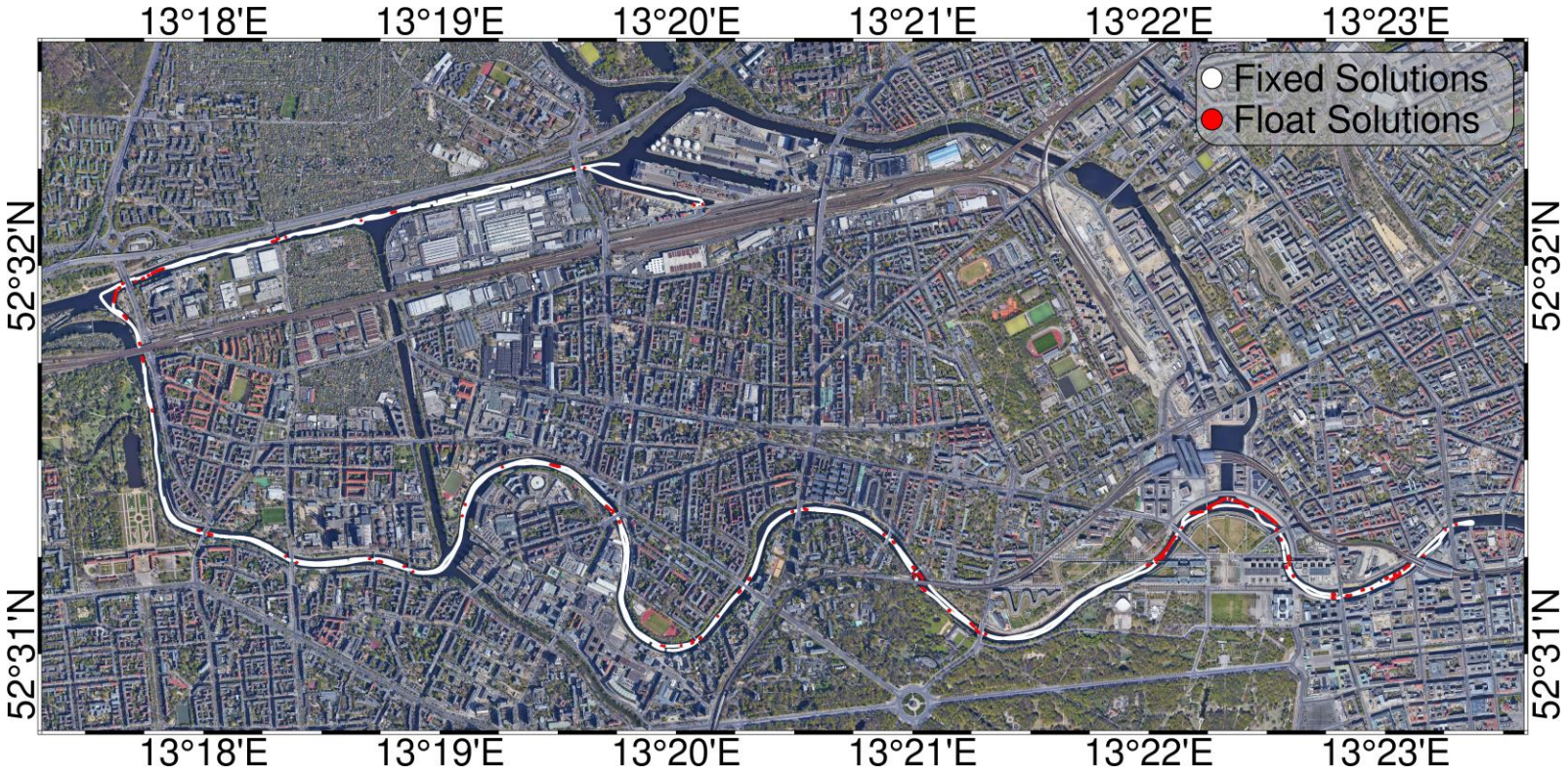
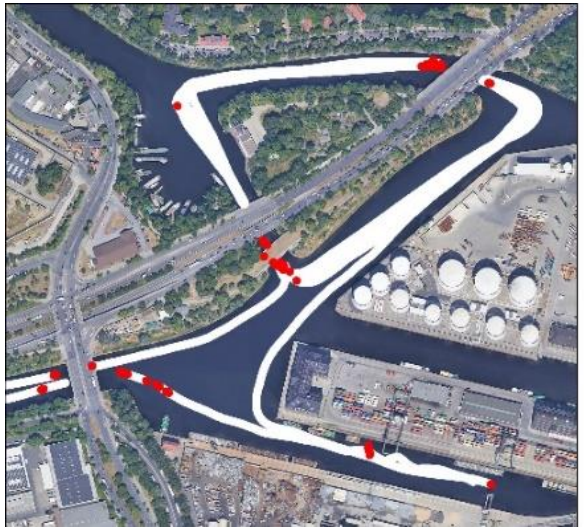
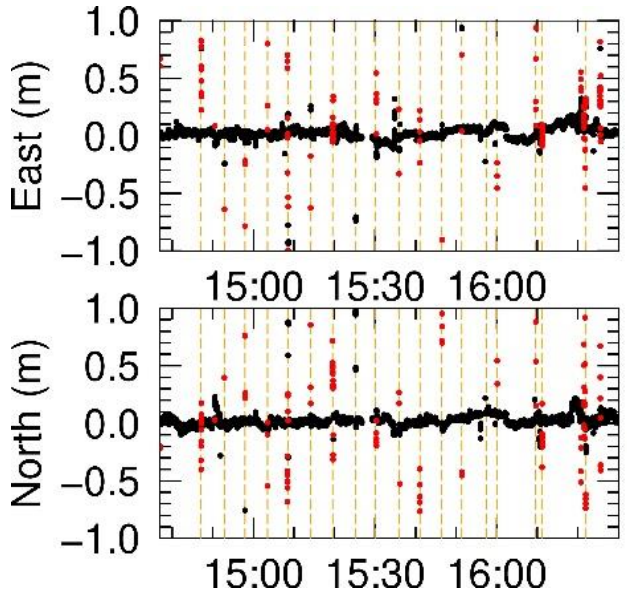
High Definition Mapping in Berlin Navigation







Results from measurement campaign June 2022

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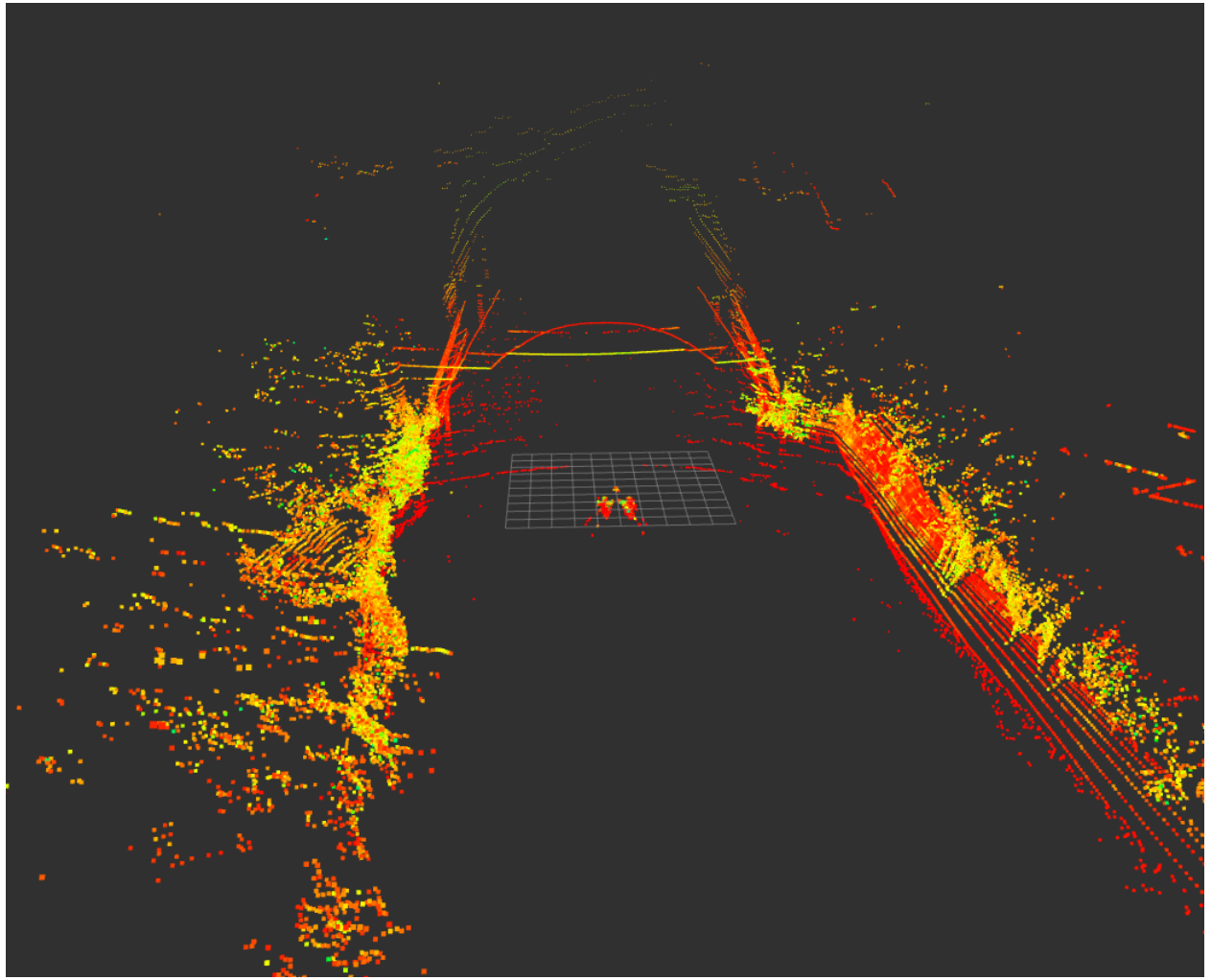
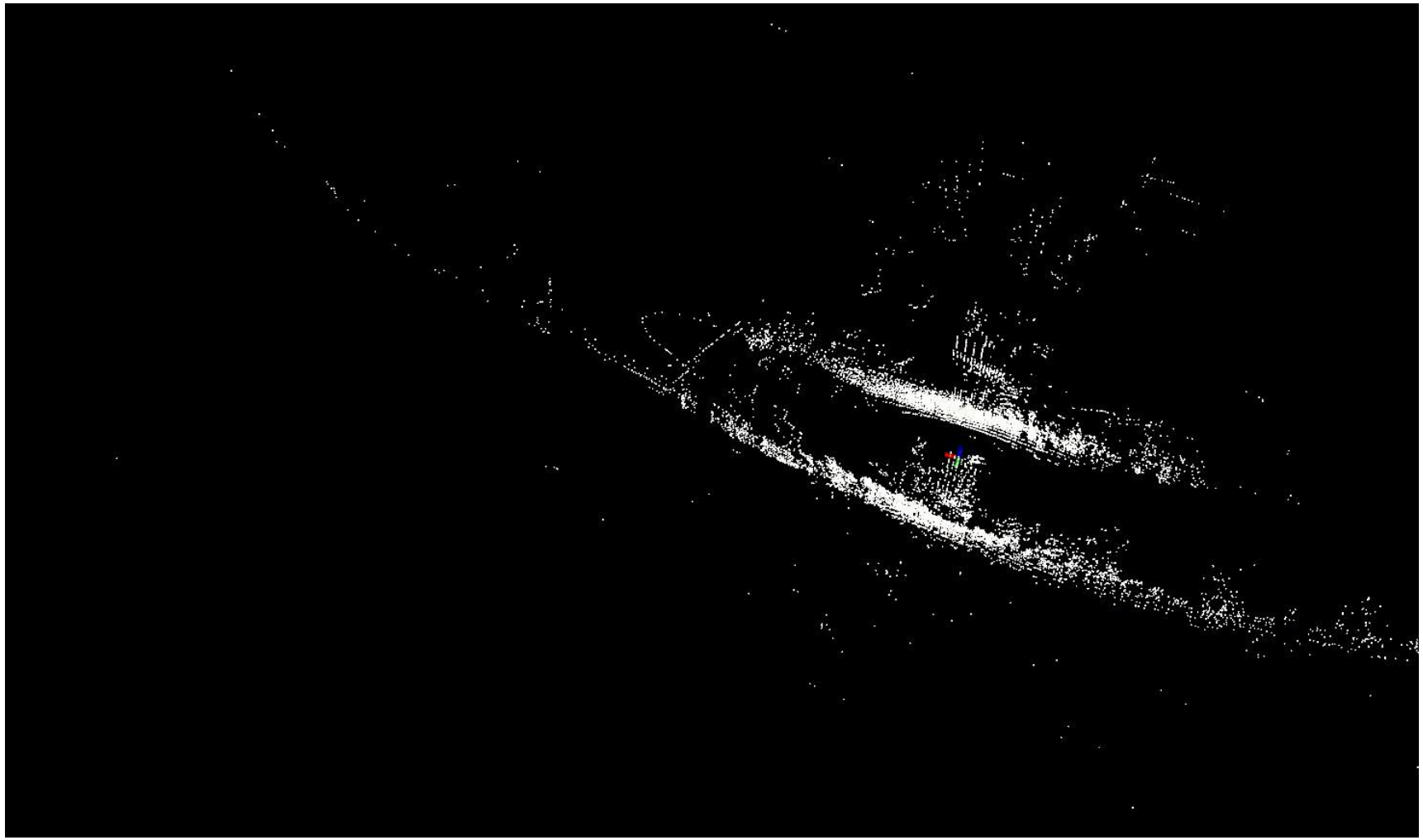
High Definition Mapping in Berlin Perception



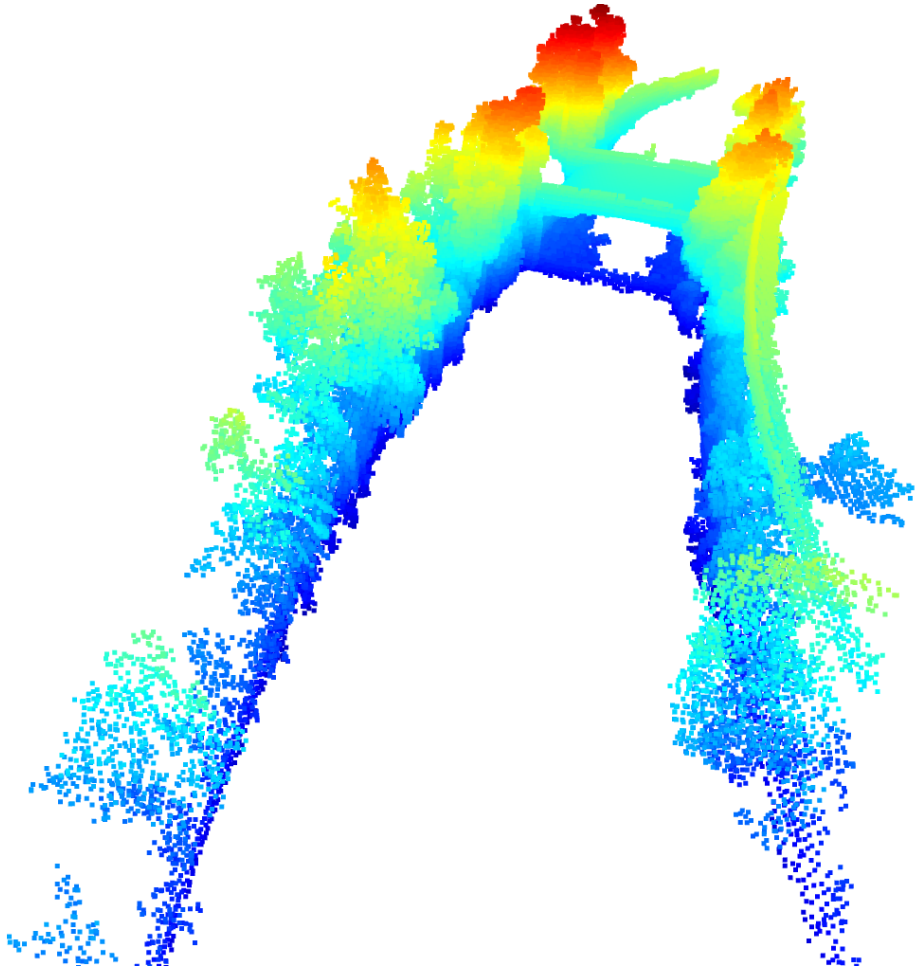
Lukas Hösch, German Aerospace Center (DLR), Department Nautical Systems

High Definition Mapping in Berlin Perception



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

High Definition Mapping in Berlin SLAM



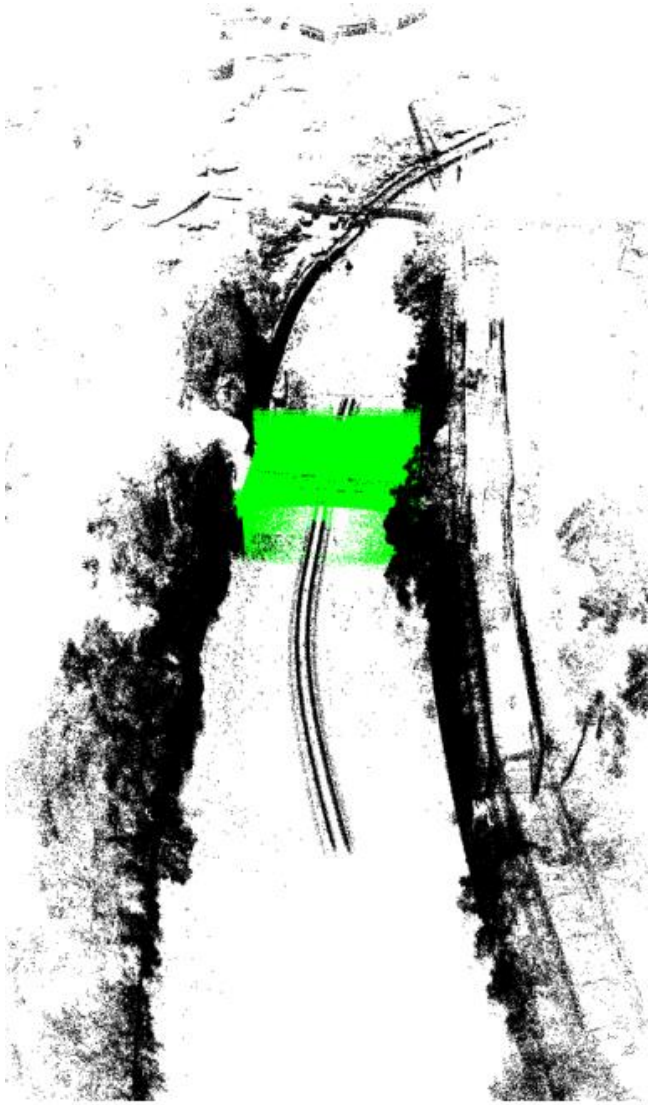
FastLIO2 [2] SLAM solution

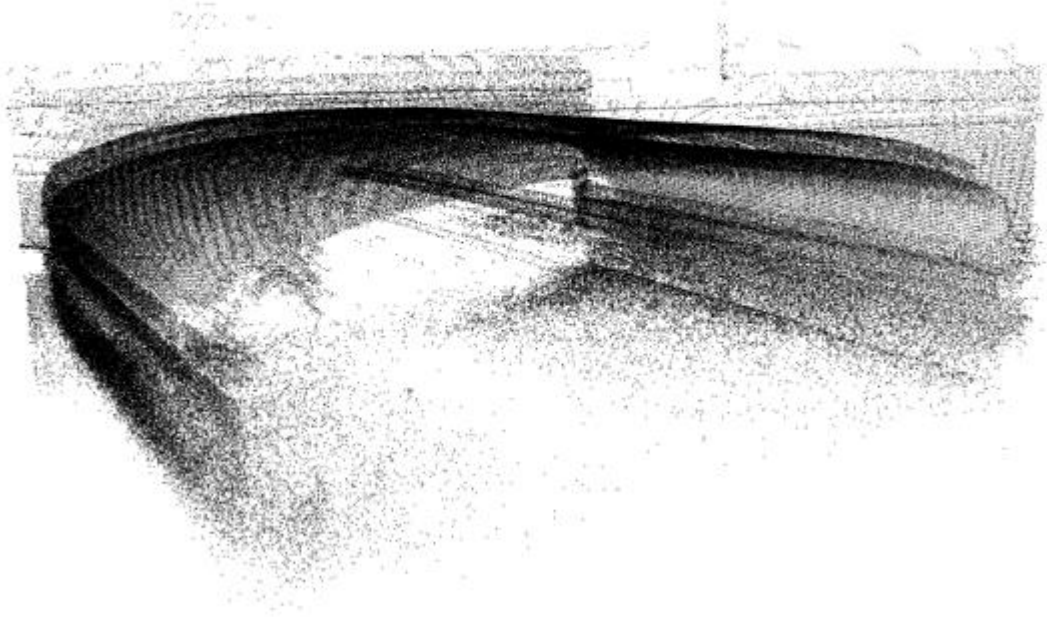
Corresponding alphashape

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
SLAM



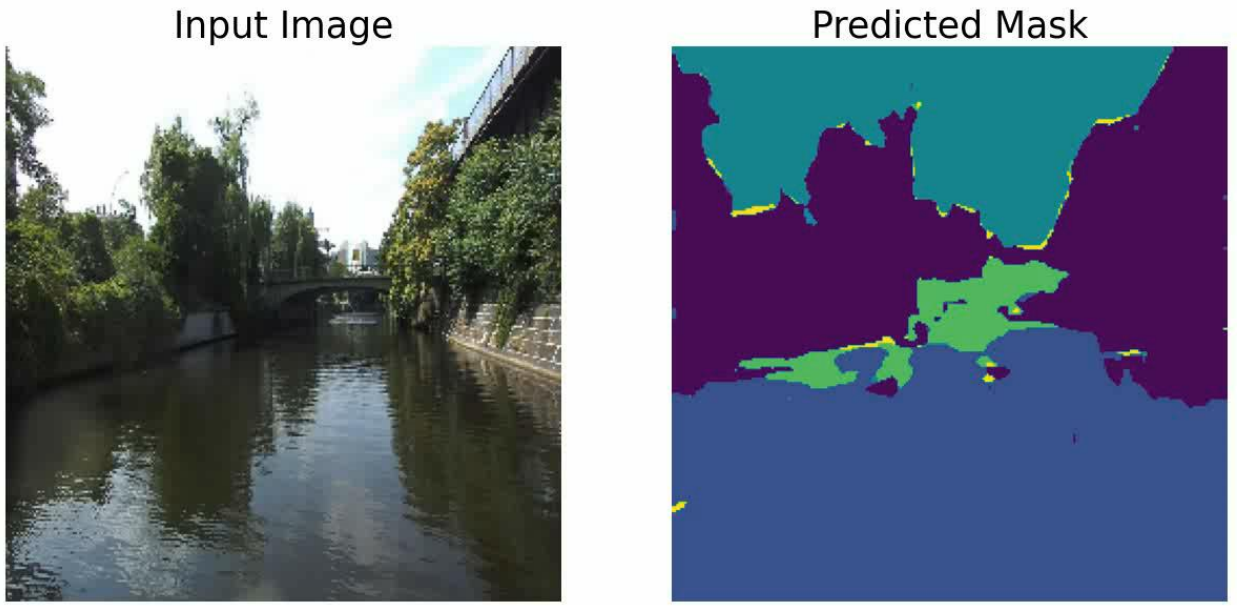


High Definition Mapping in Berlin Semantic Segmentation

Semantic Segmentation on RGB images

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

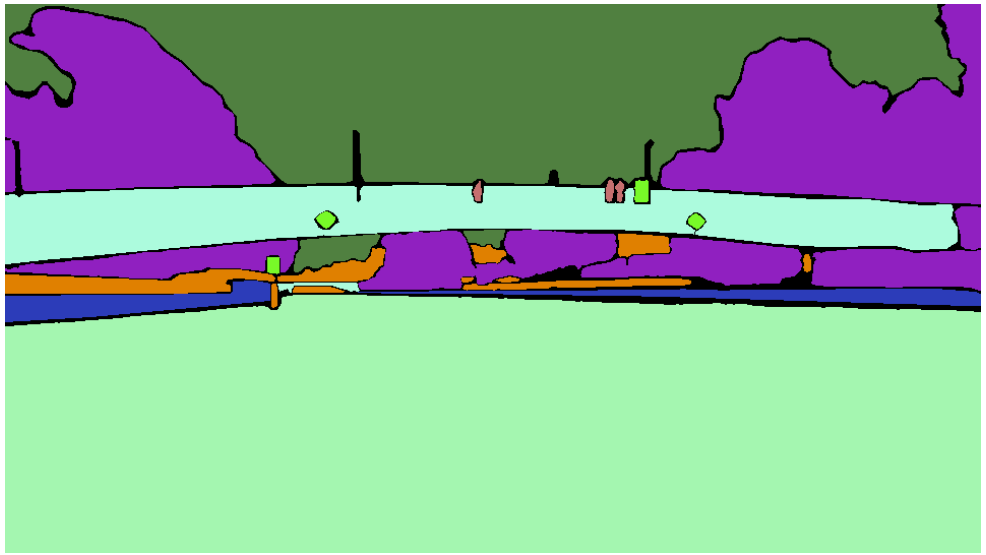
- Expandable performance on unknown data
- Image / point cloud alignment pending



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 infrastucture
2. Our Information Platform
    1. System architecture
    2. Sensor characterisitcs
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**

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

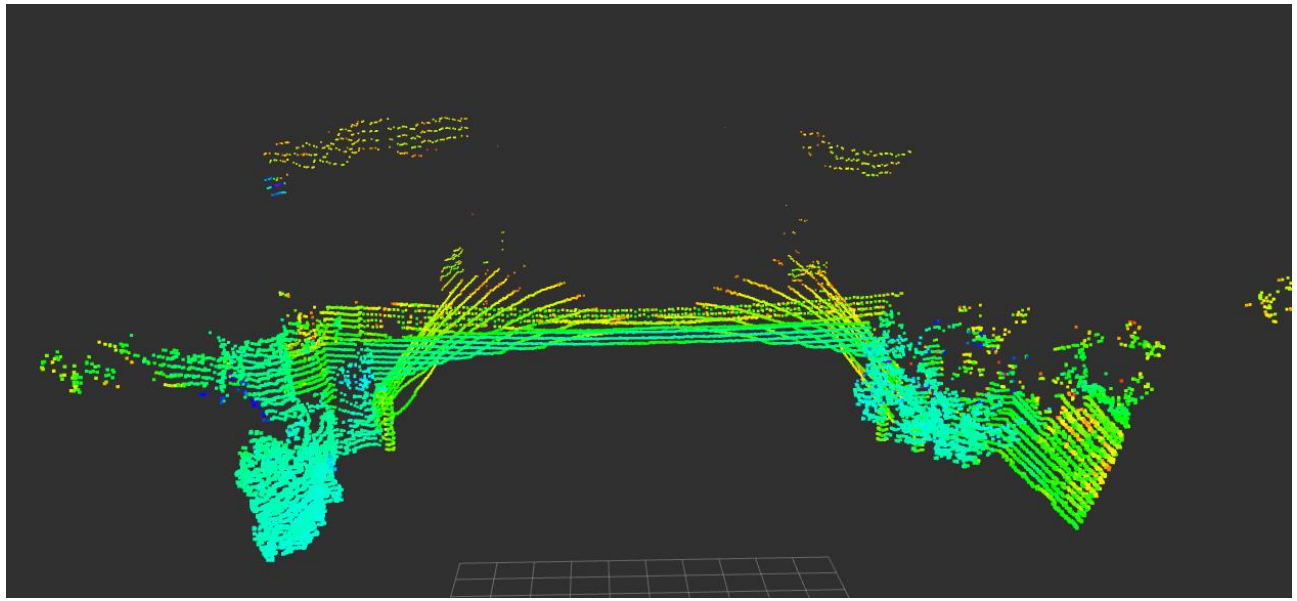
Our Information Platform – Sensor characteristics

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



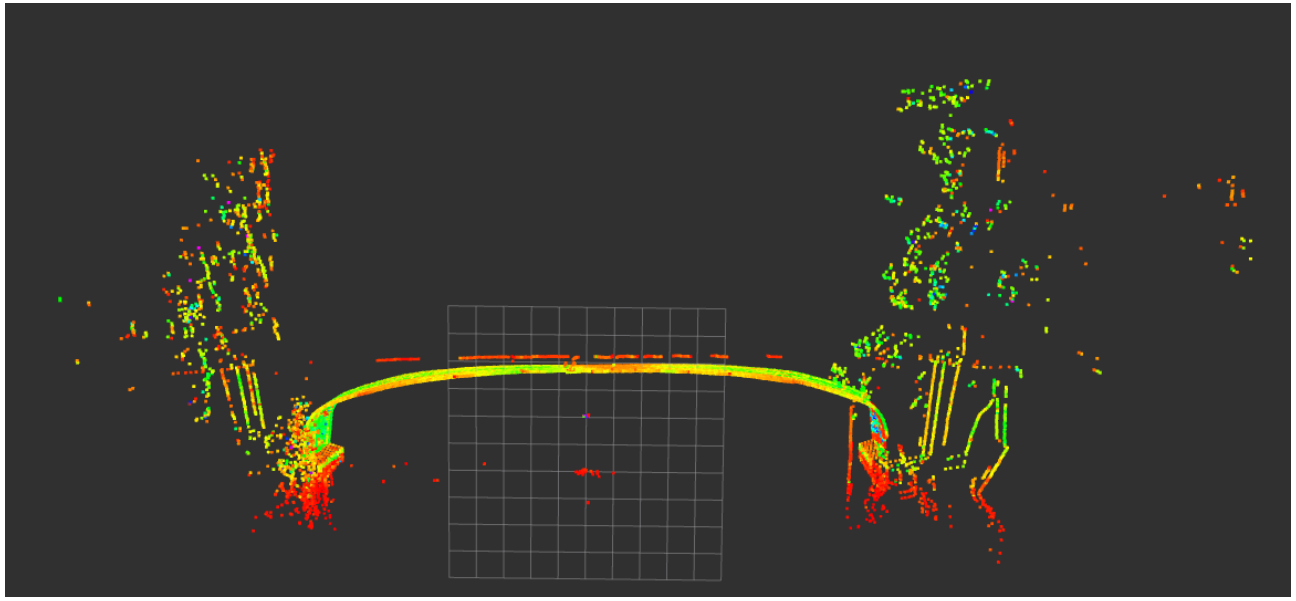
Our Information Platform – Sensor characteristics

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



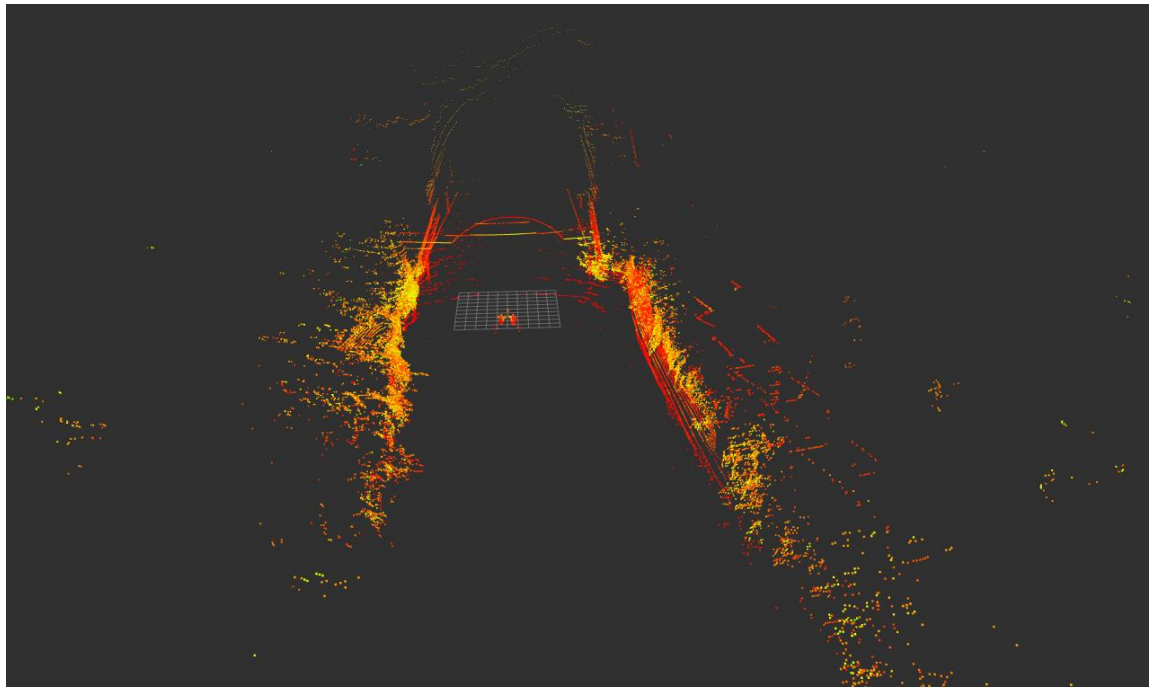
Our Information Platform – Sensor characteristics

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

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