

# Robotics

Erwin M. Bakker | LIACS Media Lab

4-3 2025



Universiteit  
Leiden

Bij ons leer je de wereld kennen

## Organization and Overview

### Lecturer:

Dr Erwin M. Bakker ( [erwin@liacs.nl](mailto:erwin@liacs.nl) )  
Room LIACS Media Lab (LML)  
Please email for a meeting.

**Period:** February 11<sup>th</sup> - May 13<sup>th</sup> 2025

**Time:** Tuesday 11.15 - 13.00

**Place (Rooms):** Van Steenis F1.04

**Exceptions:**

Gortaeus Building BM.1.33 on April 1st

Gortaeus Building BM.1.23 on May 20th

### Teaching assistants:

TBA

### Schedule (tentative, visit regularly):

Date	Subject
11-2	Introduction and Overview
18-2	Locomotion and Inverse Kinematics
25-2	Robotics Sensors and Image Processing
4-3	SLAM + Workshop@Home Introduction
11-3	Robotics Vision + Introduction Mobile Robot Challenge
18-3	Project Proposals I (by students)
25-3	Project Proposals II (by students)
1-4	Robotics Reinforcement Learning + RL Workshop@Home
8-4	Project Progress Reports I
15-4	Project Progress Reports II
22-4	Mobile Robot Challenge I
29-4	Mobile Robot Challenge II
6-5	TBA
13-5	Project Demos I
20-5	Project Demos II
27-5	Project Deliverables



### Grading (6 ECTS):

- Presentations and Robotics Project (60% of grade).
- Class discussions, attendance, 2 assignments (pass/no pass)
- 2 Workshops (0-10) (20% of the grade).
- Mobile Robot Challenge (0-10) (20% of the grade)
- ***It is necessary to be at every class and to complete every workshop and assignment.***

Website: <http://liacs.leidenuniv.nl/~bakkerem2/robotics/>

Universiteit Leiden. Bij ons leer je de wereld kennen

# Robotics Project Proposals Presentations

Tuesday 18-3 and 25-3 2025

Present your Robotics Project Proposal during a **5 minute (max)** talk. Clearly state the title of your project, the team members, your goals, how you will pursue them, what are the challenges and what at least can and should be delivered on the demo day on **May 13<sup>th</sup> and May 20<sup>th</sup> 2025**.

**Note: Groups of 1-5 members are allowed.**

**Please form your project group in the coming week. (Due 14-3 2025)**

The presentation should contain slides for:

1. Title and group members.
2. Goal of the project: **what is novel? Refer to at least one relevant and published research paper!**
3. How will you pursue these goals: division of work per group member
4. What are the challenges of your project.
5. What at least can and should be delivered on the demo days on **May 13<sup>th</sup> and May 20<sup>th</sup> 2025**.

The LIACS Media Lab can support your project with some materials for your project. Please clearly state any materials that you would need for your proposal. **Note that these materials are limited so project goals may need to be adjusted accordingly.**

**Each presentation will be followed by a short class discussion.**

Universiteit Leiden. Bij ons leer je de wereld kennen

Thursday 12-3 2025 at 12.00 Kaltura Project Questions Sessions

## SLAM: Simultaneous Localization And Mapping

### Mapping

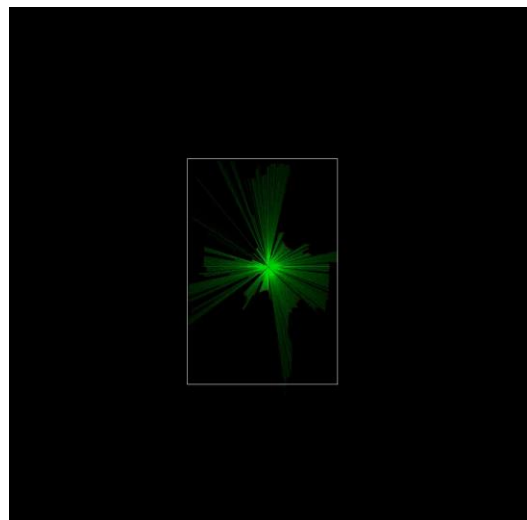
- Use sensor data: US, LIDAR, Camera, Structured Light, etc. to make a map of the environment of the robot.

### Localization

- Determine the pose of the robot relative to the map.
- Initial pose can be given: **pose tracking problem**
- No initial pose given: **global localization problem**

**SLAM:** do both **Mapping** and **Localization** at the same time.

**VSLAM:** use camera (mono, stereo, multi-, depth, etc.) to solve SLAM

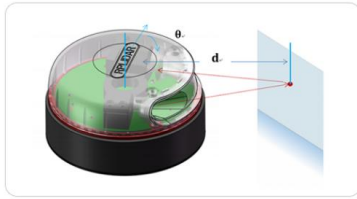


MonsterBorg SLAM by E. van der Zande

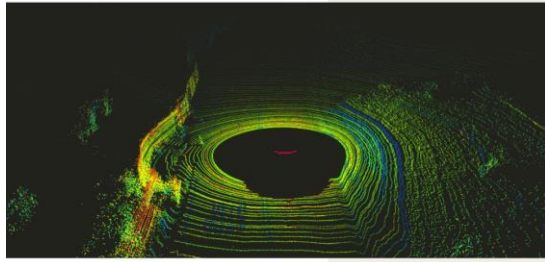
Universiteit Leiden. Bij ons leer je de wereld kennen

# LIDAR

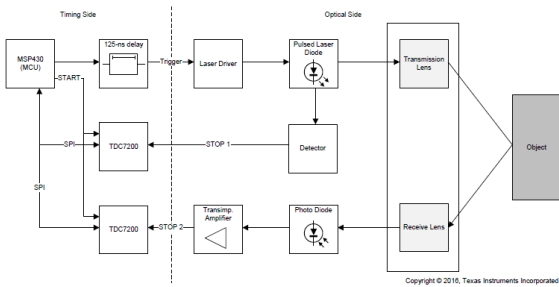
Traditional algorithm  
RPVision 3.0



<http://www.slamtec.com/en/lidar/A3>

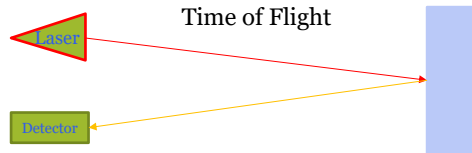


<https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff>



Copyright © 2016, Texas Instruments Incorporated

Texas Instruments LIDAR Pulsed Reference Design



- Speed of light  $\sim 3 \times 10^8$  m/s
- In 1 picosecond ( $= 10^{-12}$  sec) light travels  $\sim 3 \times 10^{-4}$  m = 0.3 mm
- During 33 picoseconds light travels  $\sim 1$ cm

Universiteit Leiden. Bij ons leer je de wereld kennen

# CES2019

BMW Self Driving Car

InnovizOne Solid-state Lidar (goal: sub \$1000 sensor)

- Angular resolution  $0.1^\circ \times 0.1^\circ$
- FOV  $120^\circ \times 25^\circ$
- 25 FPS
- Range 250m



## Perception Capabilities

- Object detection and classification
- Lane detection
- Object Tracking
- SLAM



SLAM (Simultaneous Localization And Mapping)

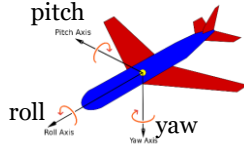


Universiteit Leiden. Bij ons leer je de wereld kennen

# IMU, or Inertial Measurement Unit

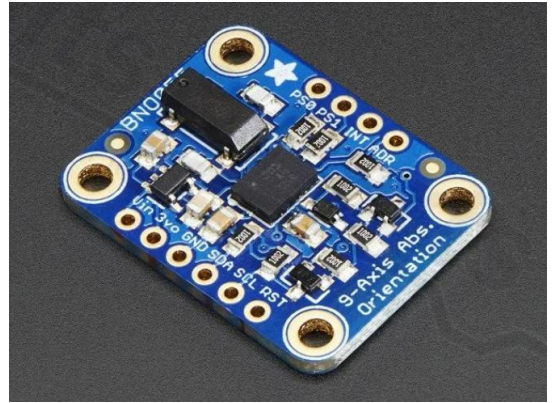
IMU consist of Sensors for

- orientation, by measuring the earths magnetic field and a gyroscope.
- acceleration,
- (angular) velocity.



In SLAM

- **Orientation** is very useful for scan matching: a good initial guess.
- **Acceleration** is calculated by subtracting the earth gravity vector from the raw accelerometer data.
- **Velocity** is calculated by time integration of the acceleration (tends to accumulate large errors)



IMU Bosch BNO055 Sampling Frequencies:

- **Accelerometer** updates: 1 KHz
- **Gyroscope** updates: 523 Hz
- **Magnetometer** updates: 30Hz

Universiteit Leiden. Bij ons leer je de wereld kennen

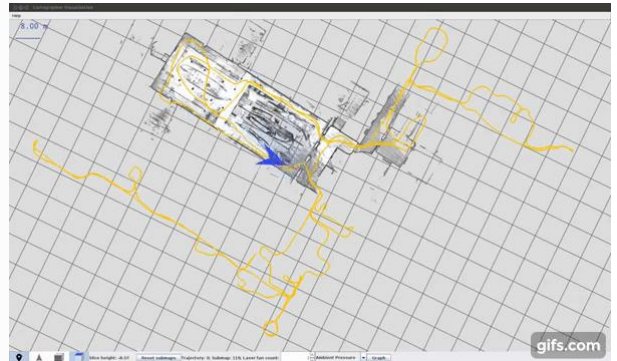
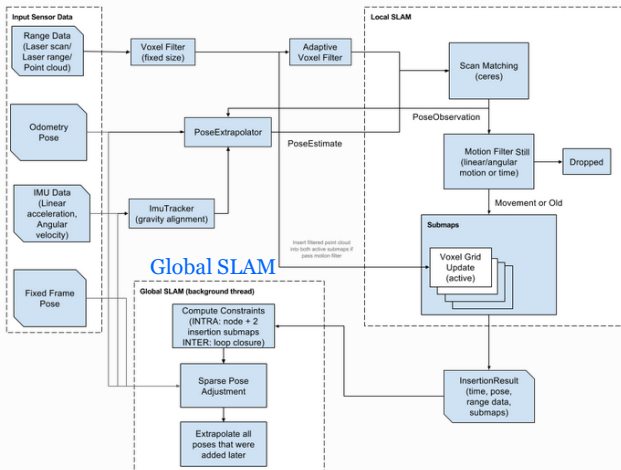
# Cartographer

<https://github.com/cartographer-project/cartographer>

- High level system overview of Cartographer

Input Sensor Data

Local SLAM



Cartographer gives real-time simultaneous localization and mapping (SLAM) in 2D and 3D.

Universiteit Leiden. Bij ons leer je de wereld kennen

# Cartographer

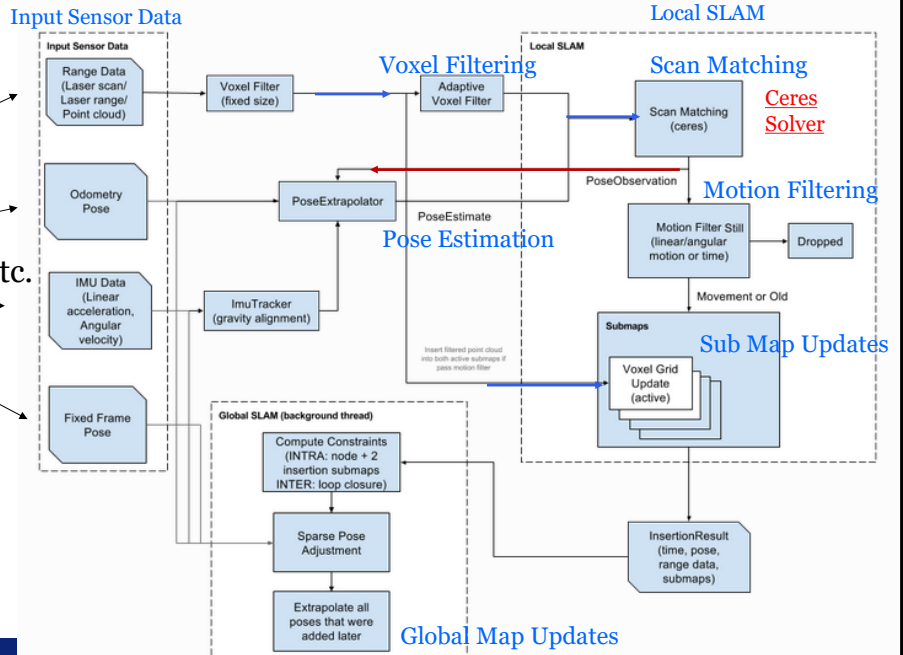
<https://github.com/cartographer-project/cartographer>

- Lidar
- Odometry
  - wheel encoders, etc.
- IMU
- Fixed Frame

Classical SLAM

Universiteit Leiden. Bij ons leer je de

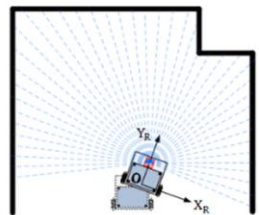
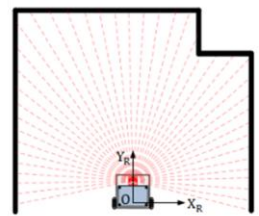
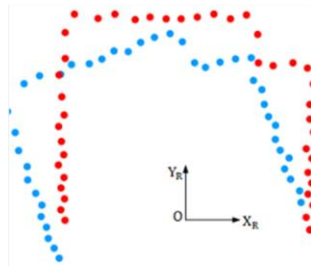
• High level system overview of Cartographer



## 2D and 3D Lidar SLAM

Front-end:

- Matching new measurements against the current belief of the environment
- Measurements:
  - typically point clouds of lidar data
  - Movement and heading data: IMU, wheel-encoders, etc.
- Filtering of the data
  - **Missing or invalid data** (zero length rays)
  - **Noisy data:** measured too far away
  - **Distorted data:** e.g., as a result of robot acceleration
- Transform
  - Scan matching tries to find a rigid body transform: **translation and rotation**
  - IMU can give heading information: more reliable than deriving it from scan matching



Riadh Dhaoui, Ruhr-Universität Bochum

Universiteit Leiden. Bij ons leer je de wereld kennen

# 2D and 3D Lidar SLAM: Scan Matching

## Point to Point Matching

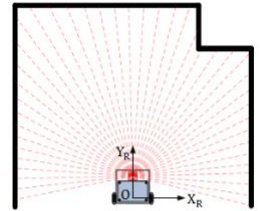
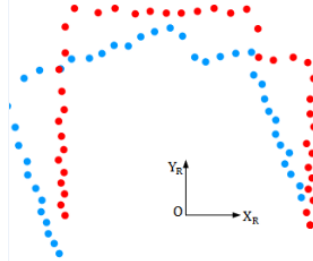
- Between the 2 scans point associations are found
- The translation from points to associated points determines a rigid body transform
- E.g found by Singular Value Decomposition (**Ceres Solver**)
- Fails in case of degenerate clouds
- Point association is difficult to obtain

## Iterative closest point (ICP) determination

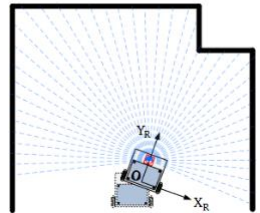
## Tangent Matching

## Point to Grid Map

- Etc.



(a) Robot scans at the first position



Riadh Dhaoui, Ruhr-Universität Bochum

Universiteit Leiden. Bij ons leer je de wereld kennen

# 2D and 3D Lidar SLAM: Scan Matching

## Point to Point Matching

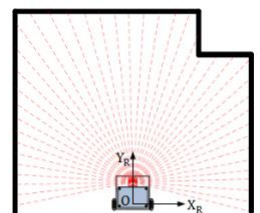
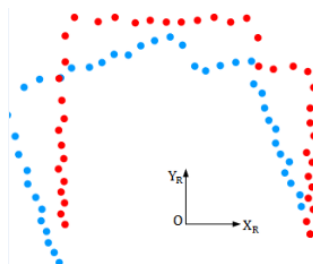
## Iterative closest point (ICP) determination

- Compute closest points
- Compute and apply the transformation
- Check if it is good enough, otherwise repeat for the new situation after the transformation
- Converges to local optimum

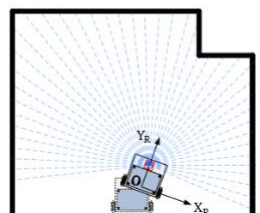
## Tangent Matching

## Point to Grid Map

- Etc.



(a) Robot scans at the first position



Riadh Dhaoui, Ruhr-Universität Bochum

Universiteit Leiden. Bij ons leer je de wereld kennen

# 2D and 3D Lidar SLAM: Scan Matching

## Point to Point Matching

### Iterative closest point (ICP) determination

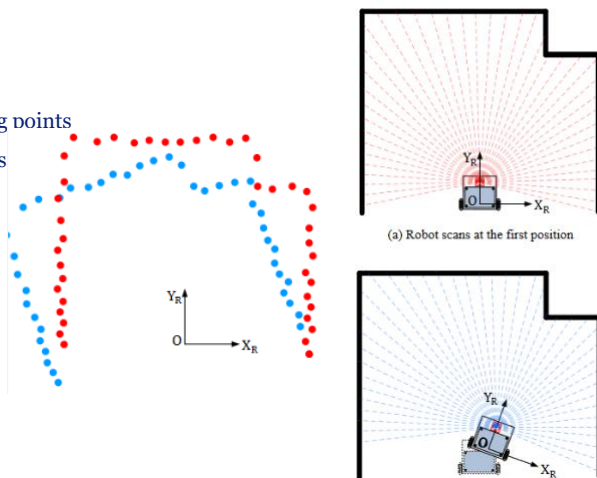
### Tangent Matching

- In each of the 2 scans find Tangent lines between neighboring points
- Instead of point matching now line matching between 2 scans
- Movement and heading data from IMU, wheel-encoders, etc. can help

### Point to Grid Map

- Map the scan points to a coarser grid map and do matching on the grid.

Etc.



Riadh Dhaoui, Ruhr-Universität Bochum

Universiteit Leiden. Bij ons leer je de wereld kennen

## SLAM: loop closing using OverlapNet

X. Chen et al. **OverlapNet**: a siamese network for computing LiDAR scan similarity with applications to loop closing and localization. Autonomous Robots, 2022.

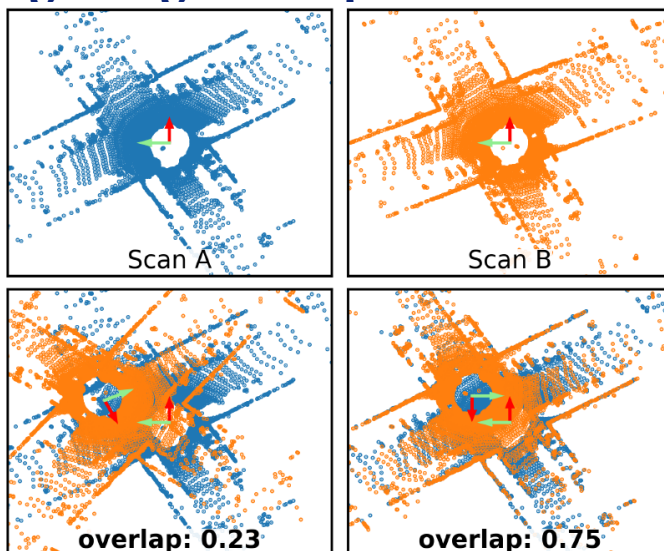
- 1) **Pose estimation relative to recent poses**: e.g. using incremental scan matching, IMU data odometry
- 2) **Loop closing**: correcting accumulated drift, maintaining consistency between measurements

### Loop closure detection:

- Estimate lidar point clouds overlap (note: also used in photogrammetry):
  - Yaw transformation estimate
  - Score, e.g., using Iterative Closest Point
- Can also be used for global scan matching.

**OverlapNet a DNN (2021)** method that does an estimate without transformation guessing, uses spherical projection of 3D Lidar data.

Performance on **Kitty-odometry dataset**.



Example: Scan A and B overlap detection: scored after transformation.

Universiteit Leiden. Bij ons leer je de wereld kennen

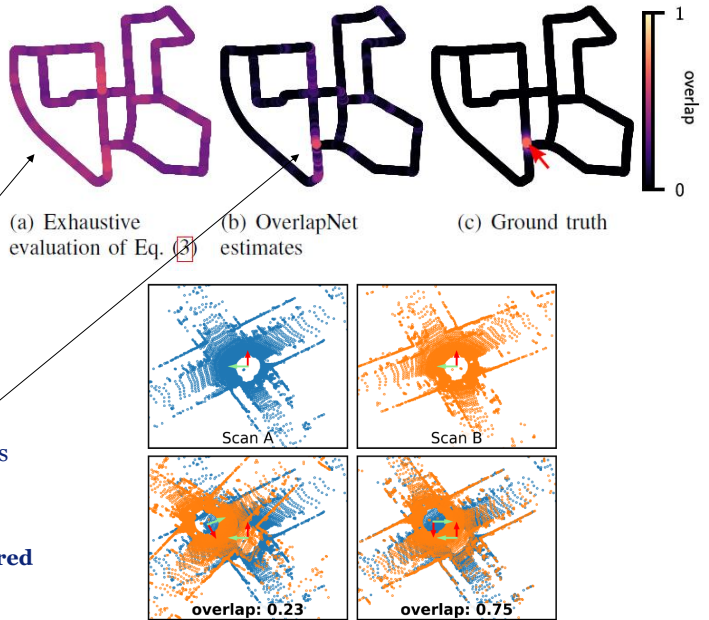
# SLAM: Loop Closing OverlapNet

- 1) **Pose estimation relative to recent poses:** incremental scan matching, odometry
- 2) **Loop closing:** correcting accumulated drift

**Loop closure detection:**

- In general **overlap scores** based on point-cloud differences (use Eq. 3 of X Chen et al., *OverlapNet ...*, *Autonomous Robots*, 2022) will be high at many locations of the map.
- OverlapNet a DNN method that does an estimate without transformation guessing, uses **spherical projection of 3D Lidar data**.

**Example: Scan A and B overlap detection: scored after transformation.**

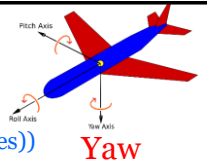


Universiteit Leiden. Bij ons leer je de wereld kennen

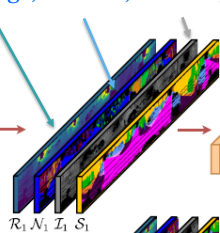
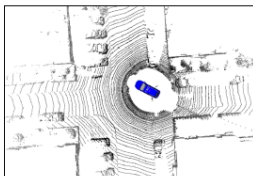
# OverlapNet

Raw scan data

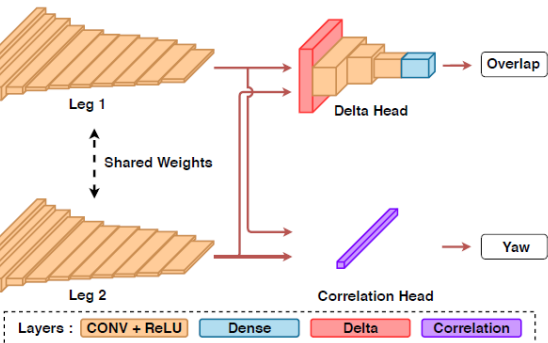
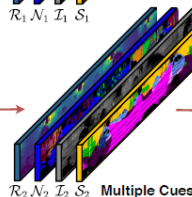
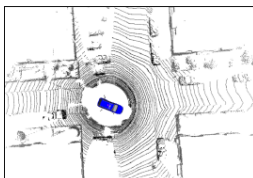
Range, Normal, Intensity, Semantic Class Probability (using RangeNet++: car, bike, etc. (20 classes))



Scan 1



Scan 2



“ Pipeline overview of our proposed approach. The left-hand side shows the preprocessing of the input data which exploits multiple cues generated from a single LiDAR scan, including range  $\mathcal{R}$ , normal  $\mathcal{N}$ , intensity  $\mathcal{I}$ , and semantic class probability  $\mathcal{S}$  information. The right-hand side shows the proposed OverlapNet which consists of two legs sharing weights and the two heads use the same pair of feature volumes generated by the two legs. The outputs are the overlap and relative yaw angle between two LiDAR scans.”

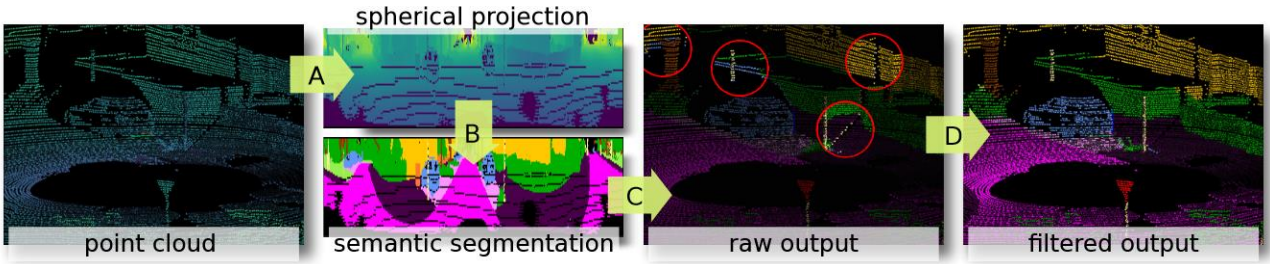
Universiteit Leiden. Bij ons leer je de wereld kennen



Milioto et al.  
**RangeNet++: Fast and Accurate Lidar Semantic Segmentation.**  
 IEEE IROS, 2019.

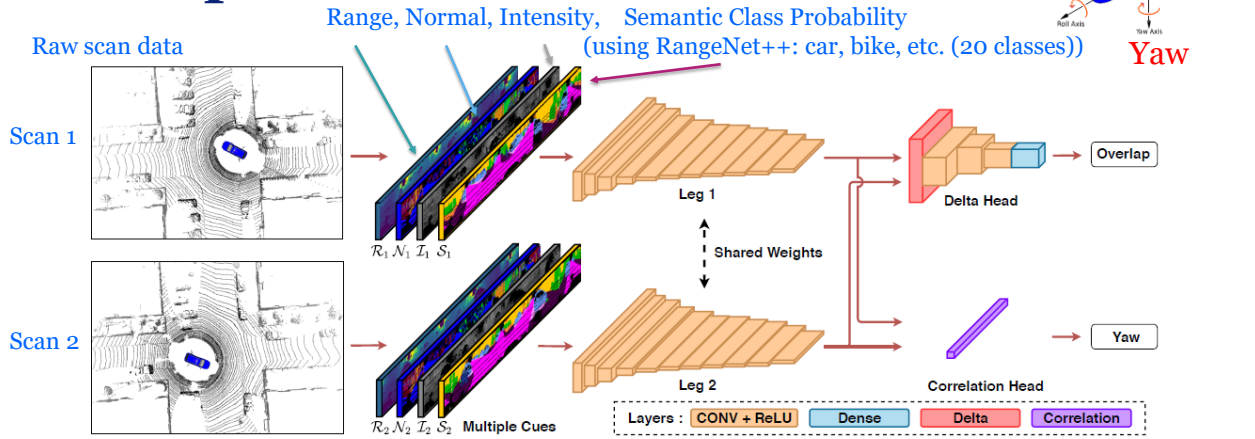
TABLE I: IoU [%] on test set (sequences 11 to 21). RangeNet21 and RangeNet53 represent the new baselines with augmented Darknet backbones (21 and 53 respectively), and the versions with (++) are treated with our fast point cloud post-processing based on range.

Approach	Size	car	bicycle	motorcycle	truck	other-vehicle	person	bicyclist	motorcyclist	road	parking	sidewalk	other-ground	building	fence	vegetation	trunk	terrain	pole	traffic-sign	mean IoU	Scans/sec
Pointnet [14]	50000pts	46.3	1.3	0.3	0.1	0.8	0.2	0.2	0.0	61.6	15.8	35.7	1.4	41.4	12.9	31.0	4.6	17.6	2.4	3.7	14.6	2
Pointnet++ [15]		53.7	1.9	0.2	0.9	0.2	0.9	1.0	0.0	72.0	18.7	41.8	5.6	62.3	16.9	46.5	13.8	30.0	6.0	8.9	20.1	0.1
SPLGraph [10]		68.3	0.9	4.5	0.9	0.8	1.0	6.0	0.0	49.5	1.7	24.2	0.3	68.2	22.5	59.2	27.2	17.0	18.3	10.5	20.0	0.2
SPLATNet [19]		66.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.4	0.8	41.5	0.0	68.7	27.8	72.3	35.9	35.8	13.8	0.0	22.8	1
TangentConv [20]		86.8	1.3	12.7	11.6	10.2	17.1	20.2	0.5	82.9	15.2	61.7	9.0	82.8	44.2	75.5	42.5	55.5	30.2	22.2	35.9	0.3
SqueezeSeg [21]	64 × 2048 px	68.8	16.0	4.1	3.3	3.6	12.9	13.1	0.9	85.4	26.9	54.3	4.5	57.4	29.0	60.0	24.3	53.7	17.5	24.5	29.5	66
SqueezeSeg-CRF [21]		68.3	18.1	5.1	4.1	4.8	16.5	17.3	1.2	84.9	28.4	54.7	0.4	61.5	29.2	59.6	25.5	54.7	11.2	36.3	30.8	55
SqueezeSegV2 [22]		81.8	18.5	17.9	13.4	14.0	20.1	25.1	3.9	88.6	45.8	67.6	17.7	73.7	41.1	71.8	35.8	60.2	20.2	36.3	39.7	50
SqueezeSegV2-CRF [22]		82.7	21.0	22.6	14.5	15.9	20.2	24.3	2.9	88.5	42.4	65.5	18.7	73.8	41.0	68.5	36.9	58.9	12.9	41.0	39.6	40
RangeNet21 [Ours]		85.4	26.2	26.5	18.6	15.6	31.8	33.6	4.0	91.4	57.0	74.0	26.4	81.9	52.3	77.6	48.4	63.6	36.0	50.0	47.4	20
RangeNet53 [Ours]	64 × 2048 px	86.4	24.5	32.7	25.5	22.6	36.2	33.6	4.7	91.8	64.8	74.6	27.9	84.1	55.0	78.3	50.1	64.0	38.9	52.2	49.9	13
	64 × 1024 px	84.6	20.0	25.3	24.8	17.3	27.5	27.7	7.1	90.4	51.8	72.1	22.8	80.4	50.0	75.1	46.0	62.7	33.4	43.4	45.4	25
	64 × 512 px	81.0	9.9	11.7	19.3	7.9	16.8	25.8	2.5	90.1	49.9	69.4	2.0	76.0	45.5	74.2	38.8	62.7	25.5	38.1	39.3	52
RangeNet53++ [Ours+kNN]	64 × 2048 px	91.4	25.7	34.4	25.7	23.0	38.3	38.8	4.8	91.8	65.0	75.2	27.8	87.4	58.6	80.5	55.1	64.6	47.9	55.9	52.2	12
	64 × 1024 px	90.3	20.6	27.1	25.2	17.6	29.6	34.2	7.1	90.4	52.3	72.7	22.8	83.9	53.3	77.7	52.5	63.7	43.8	47.2	48.0	21
	64 × 512 px	87.4	9.9	12.4	19.6	7.9	18.1	29.5	2.5	90.0	50.0	70.0	2.0	80.2	48.9	77.1	45.7	64.1	37.1	42.0	41.9	38



Universiteit Leiden. Bij ons leer je de wereld kennen

# OverlapNet



“ Pipeline overview of our proposed approach. The left-hand side shows the preprocessing of the input data which exploits multiple cues generated from a single LiDAR scan, including range  $\mathcal{R}$ , normal  $\mathcal{N}$ , intensity  $\mathcal{I}$ , and semantic class probability  $\mathcal{S}$  information. The right-hand side shows the proposed OverlapNet which consists of two legs sharing weights and the two heads use the same pair of feature volumes generated by the two legs. The outputs are the overlap and relative yaw angle between two LiDAR scans.”

Universiteit Leiden. Bij ons leer je de wereld kennen

# OverlapNet

X. Chen et al. OverlapNet: a siamese network for computing LiDAR scan similarity with applications to loop closing and localization. Autonomous Robots, 2022.

TABLE II: Comparison with state of the art.

Dataset	Approach	AUC	F1 score
KITTI	Histogram [26]	0.83	0.83
	M2DP [14]	0.83	0.87
	SuMa [2]	-	0.85
	Ours (AllChannel, TwoHeads)	<b>0.87</b>	<b>0.88</b>
Ford Campus	Histogram [26]	0.84	0.83
	M2DP [14]	0.84	<b>0.85</b>
	SuMa [2]	-	0.33
	Ours (GeoOnly)	<b>0.85</b>	0.84

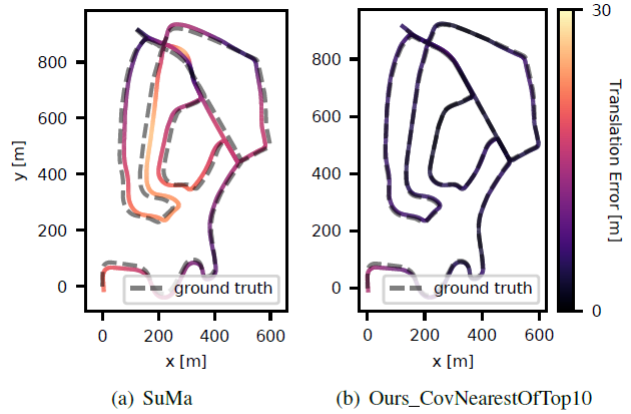


Fig. 6: Qualitative result on KITTI sequence 02.

Universiteit Leiden. Bij ons leer je de wereld kennen

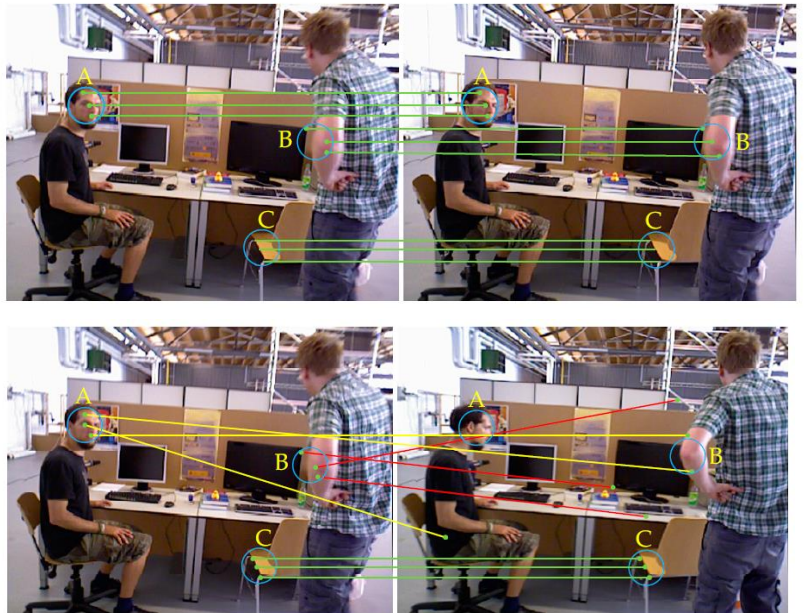
# Visual SLAM

VSLAM: use camera (mono, stereo, multi-, depth, etc.) to solve SLAM

- Readily available on mobile platforms: drones, cars, mobile phones, AR/VR Glasses
- DMS-SLAM (2019), OpenVSLAM (2019)
- ORBSLAM (2015) (5979 citations in 2023, 7330 in 2024, 8674 in 2025), feature based (ORB) monocular SLAM system

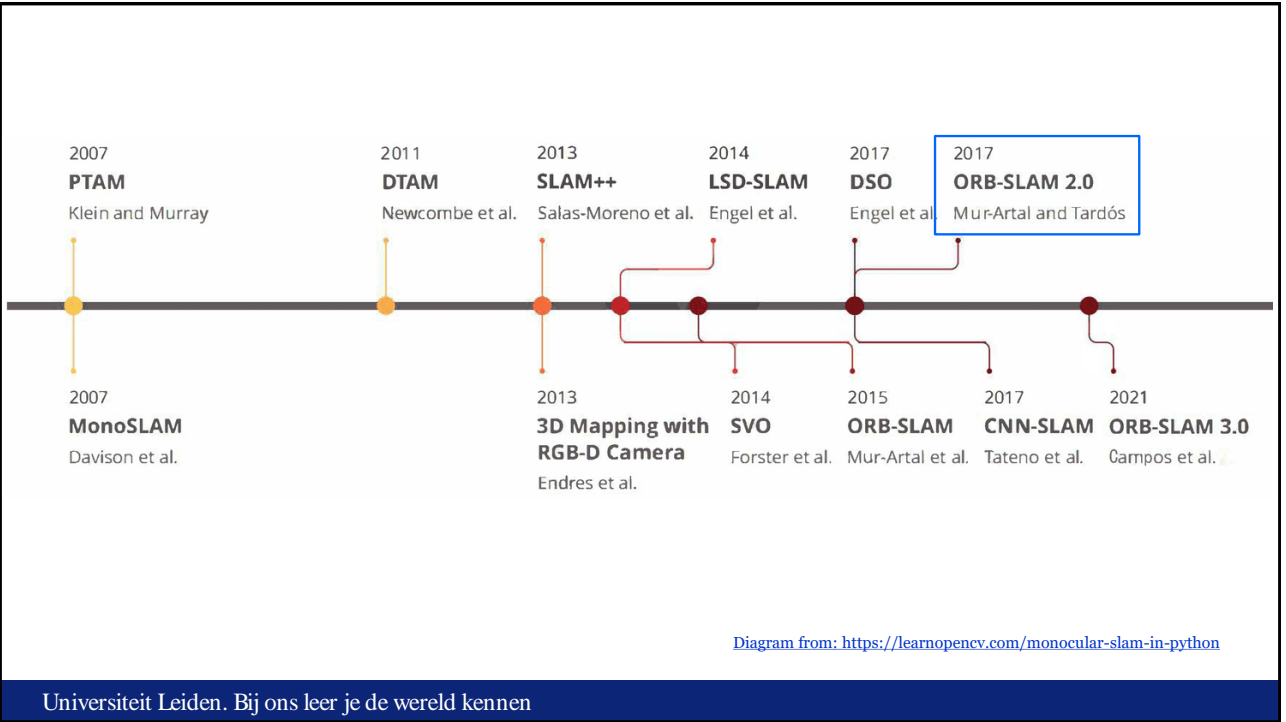
DMS-SLAM [2]:  $\longrightarrow$

- pose tracking, closed-loop detection and re-localization based on static 3D map points of the local map
- supports monocular, stereo and RGB-D visual sensors in dynamic scenes.



A and B partial Motion, C static => A and B matching errors, C still correct.

Universiteit Leiden. Bij ons leer je de wereld kennen



# Visual SLAM

VSLAM: use camera (mono, stereo, multi-, depth, etc.) to solve SLAM

- Readily available on mobile platforms: drones, cars, mobile phones, AR/VR Glasses
- DMS-SLAM (2019), OpenVSLAM (2019)
- ORBSLAM (2015) (5979 citations in 2023, 7330 in 2024, 8674 in 2025), feature based (ORB) monocular SLAM system

**DMS-SLAM [2]:**

- pose tracking, closed-loop detection and re-localization based on static 3D map points of the local map
- supports monocular, stereo and RGB-D visual sensors in dynamic scenes.

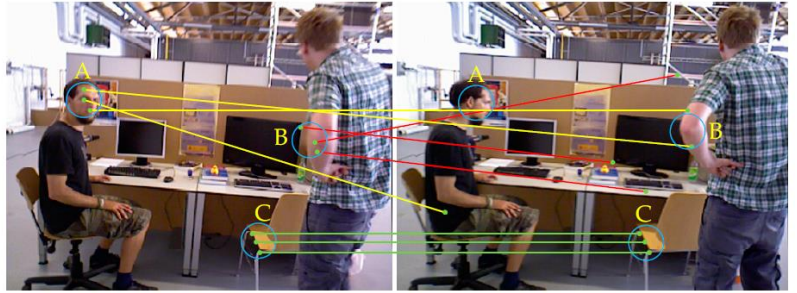
A and B partial Motion, C static => A and B matching errors, C still correct.

Universiteit Leiden. Bij ons leer je de wereld kennen

# DMS-SLAM

## VSLAM

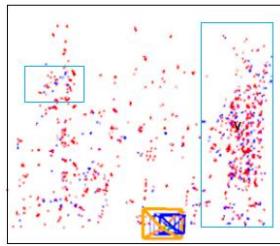
- use camera (mono, stereo, multi-cam, depth, etc.) to solve SLAM
- **DMS-SLAM [2]**, OpenVSLAM, ORBSLAM



A and B partial Motion, C static => A and B matching errors, C still correct.



**ORB-SLAM2**



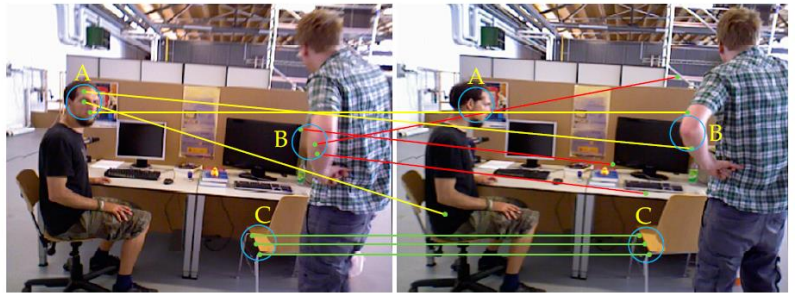
**DMS-SLAM**

RGB-D Initialization: DMS-SLAM produces a relatively static initial map

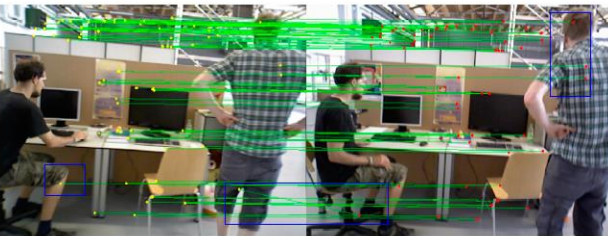
# DMS-SLAM

VSLAM: use camera (mono, stereo, multi-, depth, etc.) to solve SLAM

- **DMS-SLAM [2]**, OpenVSLAM, ORBSLAM



A and B partial Motion, C static => A and B matching errors, C still correct.



(a) ORB-SLAM2



(b) DMS-SLAM

Blue-boxes wrong feature matching point pairs.

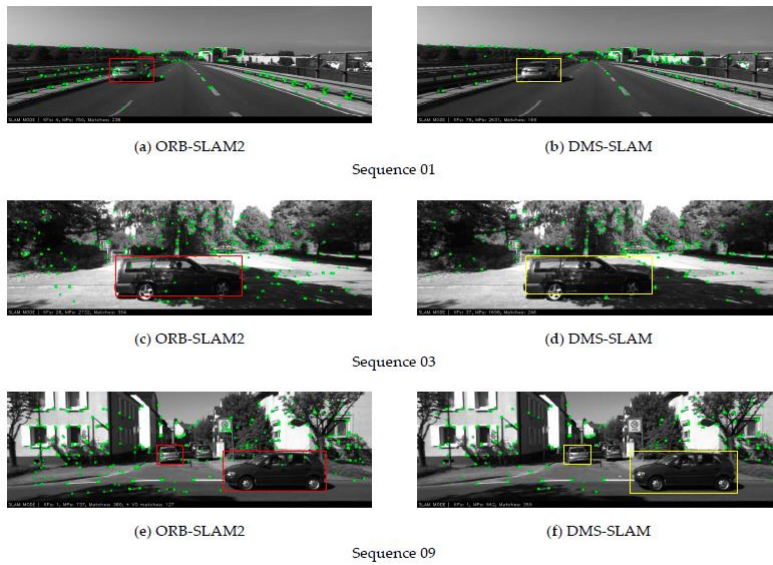


Figure 15. The pose tracking experiments of ORB-SLAM2 and DMS-SLAM on the 01, 03, 09 sequences in the KITTI dataset. The rectangular box represents the moving object in the scene, and the others are static areas.

Note: DMS-SLAM does not track feature points on dynamic objects during camera pose estimation.

# OpenVSLAM [3]

A Versatile Visual SLAM Framework. (S. Sumikura et al., 2019)

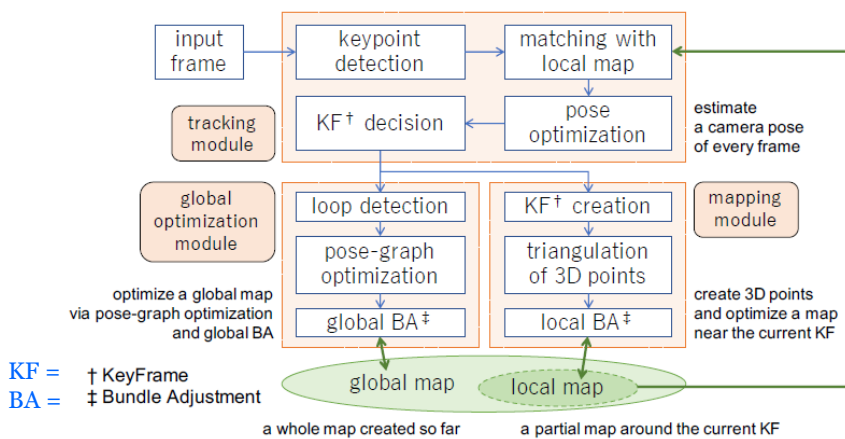


Figure 2: Main modules of OpenVSLAM: tracking, mapping, and global optimization modules.

# ORB-SLAM [1]

R Mur-Artal et al. IEEE Trans. On Robotics, Nov. 2015.

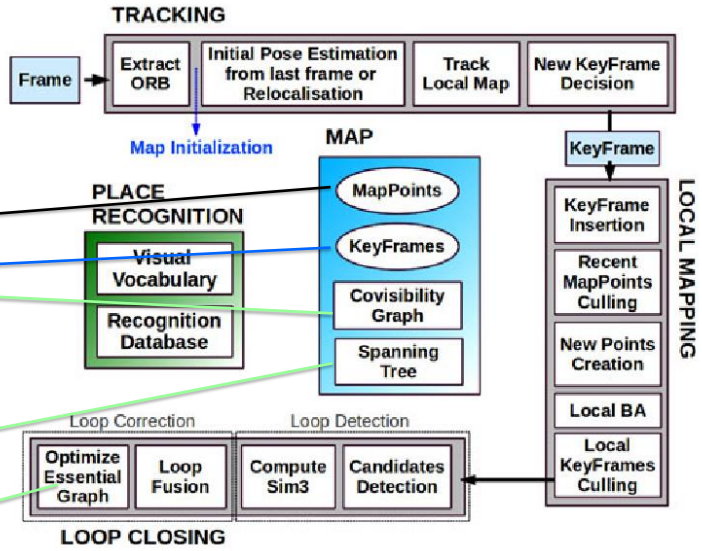
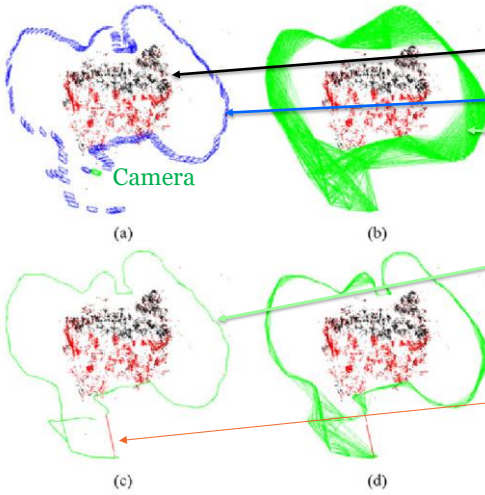
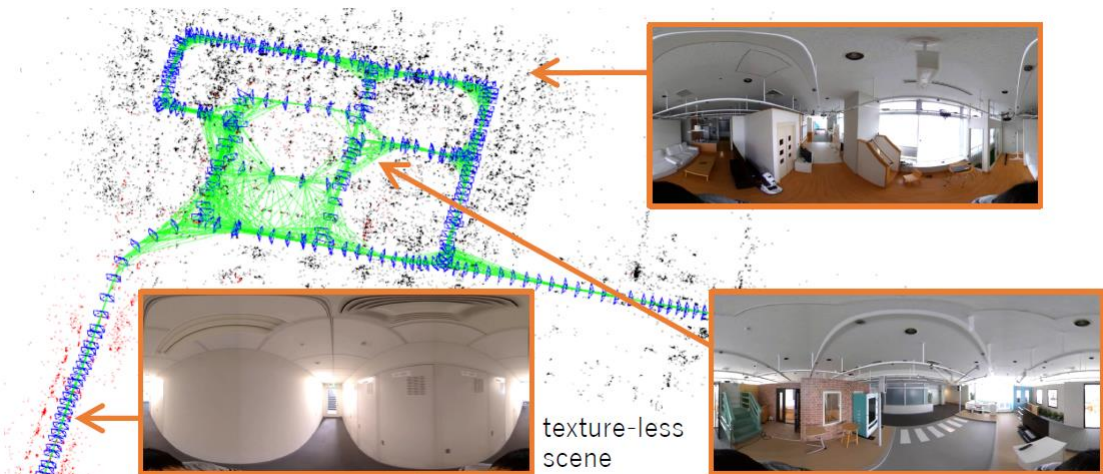


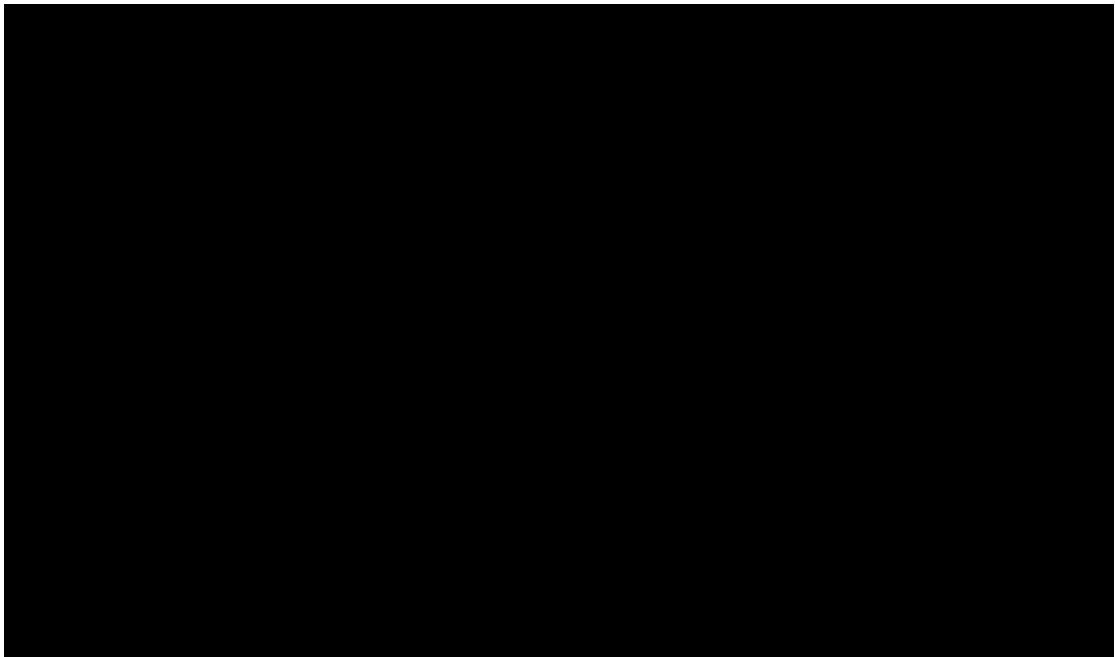
Fig. 1. ORB-SLAM system overview, showing all the steps performed by the tracking, local mapping, and loop closing threads. The main components of the place recognition module and the map are also shown.

(Note: ORB, SIFT, SURF key-point detectors are available in OpenCV)

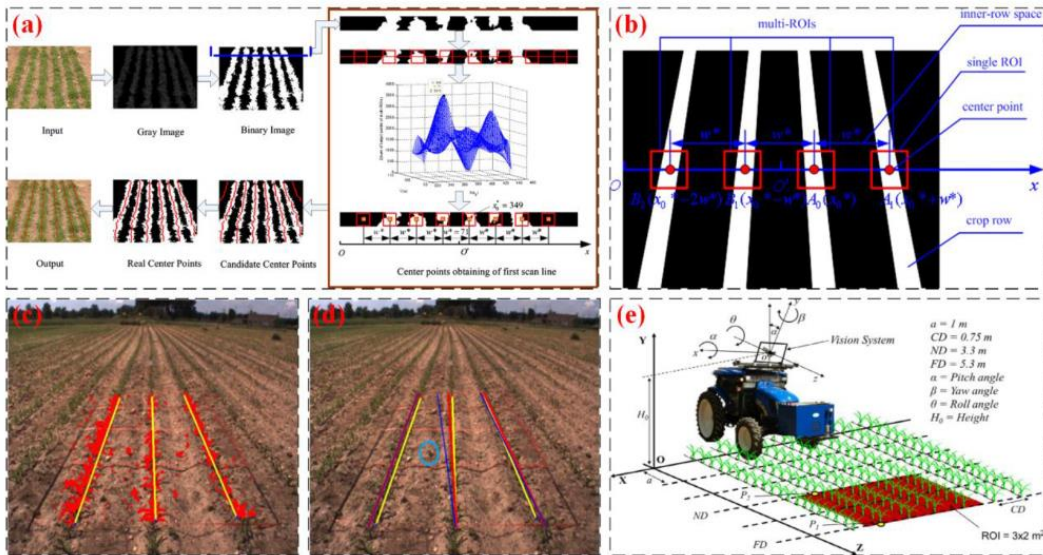
# OpenVSLAM [3]

NB OpenVSLAM: termination of release because of concerns regarding similarities with ORB-SLAM2) [https://github.com/raulmur/ORB\\_SLAM2](https://github.com/raulmur/ORB_SLAM2)





- Bai, B. Zhang, N. Xu, J. Zhou, J. Shi, Z. Diao, Vision-based Navigation and Guidance for agricultural autonomous vehicles and robots: A review. Computers and Electronics in Agriculture, Vol. 205, 2023.



automatic crop rows detection methods

- Bai, B. Zhang, N. Xu, J. Zhou, J. Shi, Z. Diao, Vision-based Navigation and Guidance for agricultural autonomous vehicles and robots: A review. Computers and Electronics in Agriculture, Vol. 205, 2023.

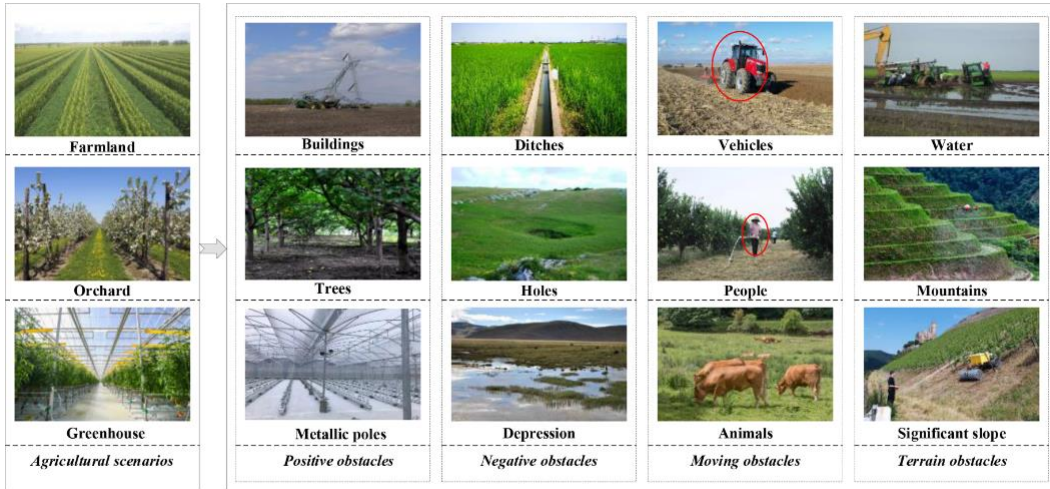
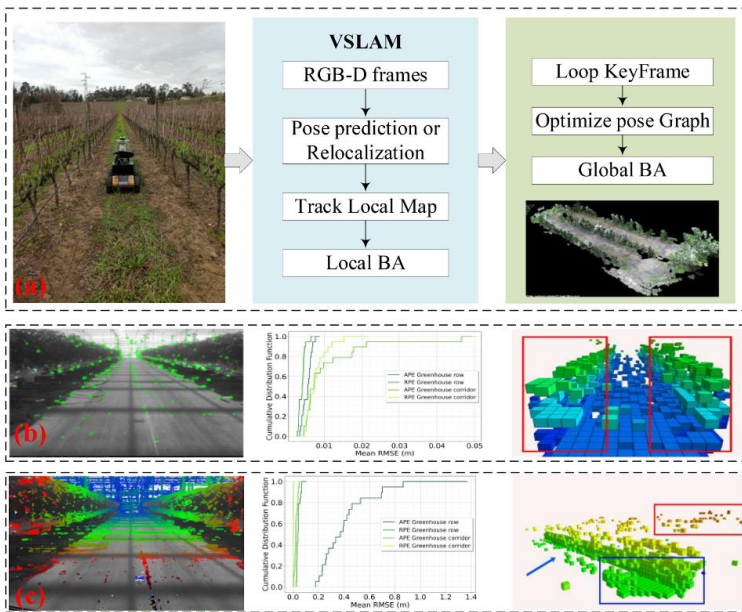


Fig. 3. Typical obstacles that can be encountered in agricultural environments.

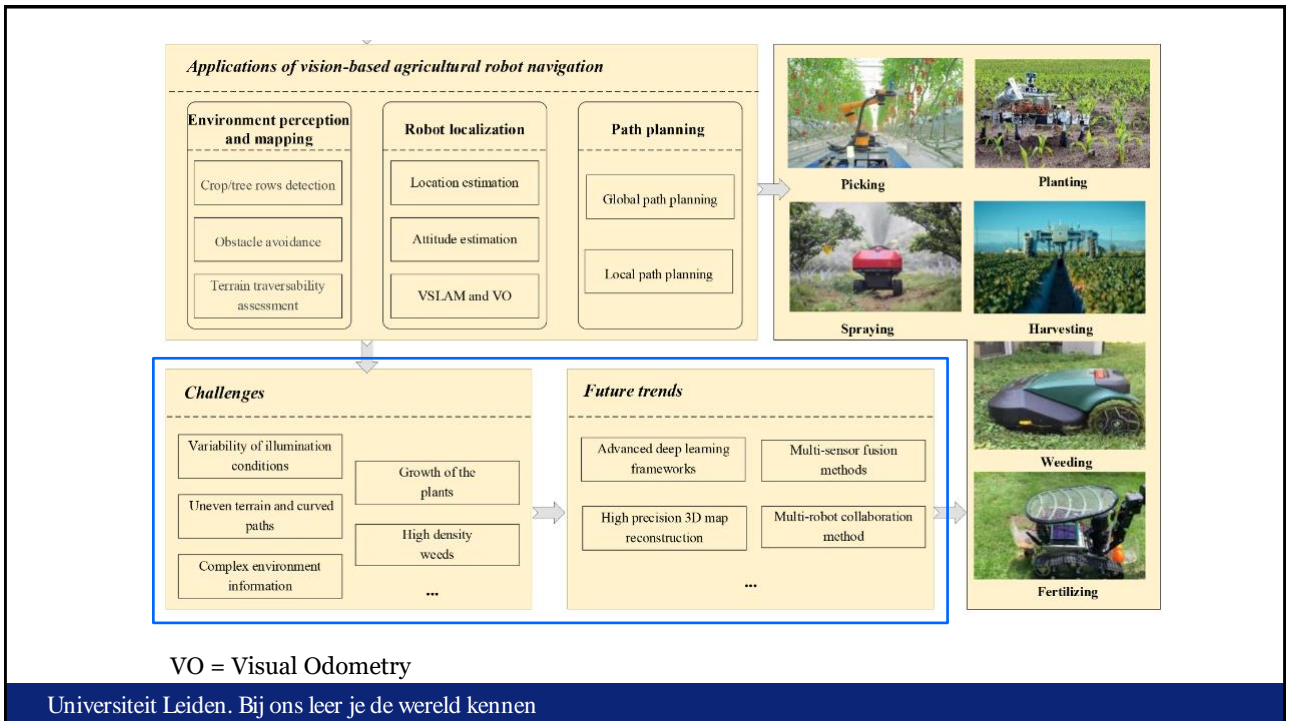
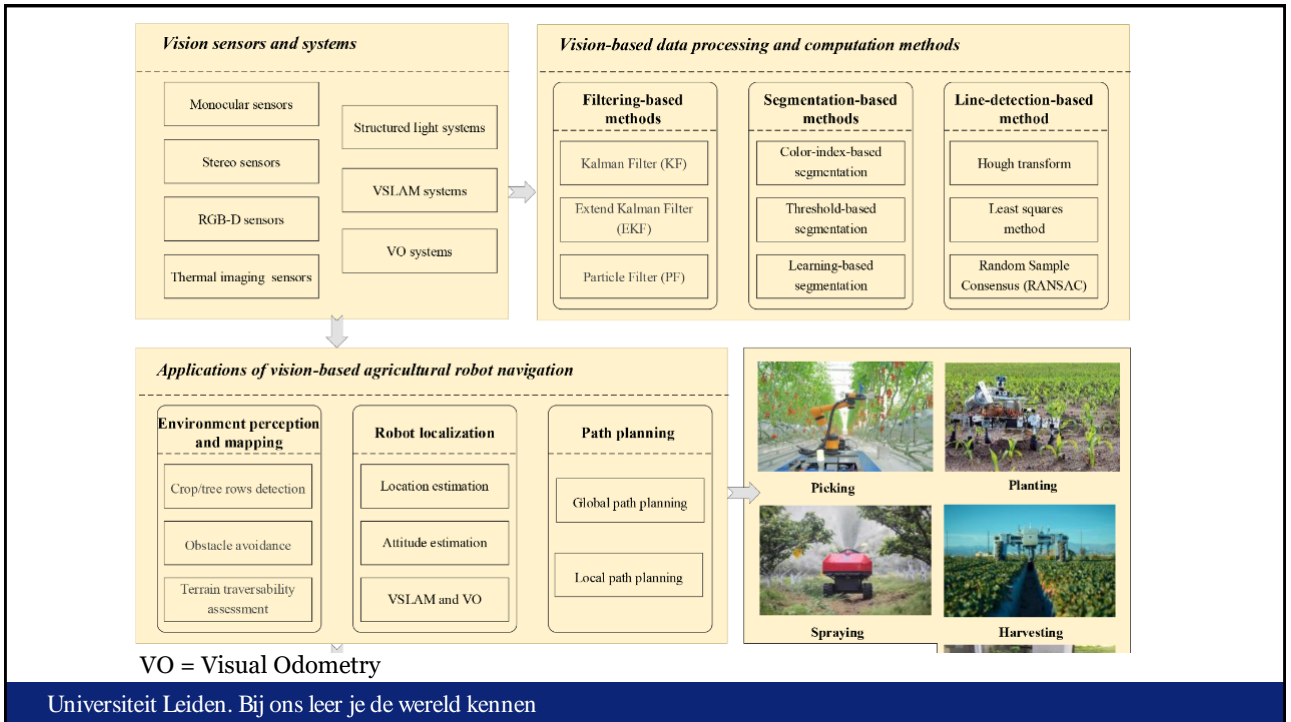
Universiteit Leiden. Bij ons leer je de wereld kennen

- Bai, B. Zhang, et al., 2023. [4]



Universiteit Leiden. Bij ons leer je de wereld kennen





See also:

H. Yin et al. A Survey on Global LiDAR Localization: Challenges, Advances and Open Problems. International Journal of Computer Vision, 2024

Y. Zhang et al. LiDAR-Based Place Recognition for Autonomous Driving: A Survey. ACM Computing Surveys, Vol. 57, No. 4, December 2024.

Q. Li et al. An Efficient Point Cloud Place Recognition Approach based on Transformer in Dynamic Environment. ISPRS Journal of Photogrammetry and Remote Sensing, 2024.

Universiteit Leiden. Bij ons leer je de wereld kennen

## Organization and Overview

### Lecturer:

Dr Erwin M. Bakker ( [erwin@liacs.nl](mailto:erwin@liacs.nl) )  
Room LIACS Media Lab (LML)  
Please email for a meeting.

Period: February 11<sup>th</sup> - May 13<sup>th</sup> 2025

Time: Tuesday 11.15 - 13.00

Place (Rooms): Van Steenis F1.04

Exceptions:

Gortaeus Building BM.1.33 on April 1st

Gortaeus Building BM.1.23 on May 20th

### Teaching assistants:

TBA

### Schedule (tentative, visit regularly):

Date	Subject
11-2	Introduction and Overview
18-2	Locomotion and Inverse Kinematics
25-2	Robotics Sensors and Image Processing
4-3	SLAM + Workshop@Home Introduction
11-3	Robotics Vision + Introduction Mobile Robot Challenge
18-3	Project Proposals I (by students)
25-3	Project Proposals II (by students)
1-4	Robotics Reinforcement Learning + RL Workshop@Home
8-4	Project Progress Reports I
15-4	Project Progress Reports II
22-4	Mobile Robot Challenge I
29-4	Mobile Robot Challenge II
6-5	TBA
13-5	Project Demos I
20-5	Project Demos II
27-5	Project Deliverables



### Grading (6 ECTS):

- Presentations and Robotics Project (60% of grade).
- Class discussions, attendance, 2 assignments (pass/no pass)
- 2 Workshops (0-10) (20% of the grade).
- Mobile Robot Challenge (0-10) (20% of the grade)
- ***It is necessary to be at every class and to complete every workshop and assignment.***

Website: <http://liacs.leidenuniv.nl/~bakkerem2/robotics/>

Universiteit Leiden. Bij ons leer je de wereld kennen

# Robotics Project Proposals Presentations

Tuesday 18-3 and 25-3 2025

Present your Robotics Project Proposal during a **5 minute (max)** talk. Clearly state the title of your project, the team members, your goals, how you will pursue them, what are the challenges and what at least can and should be delivered on the demo day on **May 13<sup>th</sup> and May 20<sup>th</sup> 2025**.

**Note: Groups of 1-5 members are allowed.**

**Please form your project group in the coming week. (Due Friday 14-3)**

The presentation should contain slides for:

1. Title and group members.
2. Goal of the project: **what is novel? Refer to at least one relevant and published research paper!**
3. How will you pursue these goals: division of work per group member
4. What are the challenges of your project.
5. What at least can and should be delivered on the demo days on **May 13<sup>th</sup> and May 20<sup>th</sup> 2025**.

The LIACS Media Lab can support your project with some materials for your project. Please clearly state any materials that you would need for your proposal. **Note that these materials are limited so project goals may need to be adjusted accordingly.**

**Each presentation will be followed by a short class discussion.**

Universiteit Leiden. Bij ons leer je de wereld kennen

Thursday 12-3 2025 at 12.00 Kaltura Project Questions Sessions

## Unitree Go2 Pro



- Orin NX
- Voice Module (SR)
- **Navigation Lidar**
- **Radar Module**
- **Camera**
- **IMU**
- 12 DOF
- Payload ~8kg
- Speed 3.7 m/S (max 5m/s)

<https://github.com/unitreerobotics> (not all may apply)  
<https://wiki.theroboverse.com/en/about> ( after Jailbreak )

Universiteit Leiden. Bij ons leer je de wereld kennen

## UFactory uArm Swift Pro



uArm Links

- [Specifications](#)
- [Documentation](#)
- [UFactory uArm Github](#)

Universiteit Leiden. Bij ons leer je de wereld kennen

## IROBOT CREATE 3



### Sensors

- 1x Power button
- 2x User buttons
- 2x Front bumper zones
- 2x Wheel encoders
- 4x IR cliff sensors
- 7x IR obstacle sensors
- 1x Downward optical flow sensor for odometry
- 1x 3D gyroscope
- 1x 3D accelerometer
- 1x Battery level monitor



### Technical Details

- 14.29 cm x 40.64 cm x 47.31 cm, 4.68 kg

### Connectivity

- Wi-Fi or Ethernet over USB Host: Connect and control the robot using ROS 2.
- Bluetooth® Low Energy: Connect to and control the robot using [iRobot Education's Python Web Playground](#).

### Battery

- 1800 mAh Li-Ion rechargeable battery

### Actuators

- 2x Drive motors
- 6x RGB LED ring
- 1x Speaker

### Charging and Expansion

- 1x Docking port
- 1x USB-C™ port, 3A at regulated 5V
- 1x Payload power, 2A at unregulated (nominal 14.4V)

Universiteit Leiden. Bij ons leer je de wereld kennen



Universiteit Leiden. Bij ons leer je de wereld kennen

## Previous Projects

- |   |                             |                               |
|---|-----------------------------|-------------------------------|
| 1. Evolutionary Locomotion                                      | 1. AimBot                   | 1. Autonomous driving copilot |
| 2. Nao plays Tic-Tac-Toe  | 2. Artificial Muscles       | 2. Self Balancing robot       |
| 3. Slam Robot Project.  | 3. Ball Tracking Car        | 3. Tennis playing robot       |
| 4. Dolphin Drone: Drone Recognition and Maneuvering with Hoops. | 4. BorrelBot                | 4. PongBot                    |
| 5. Delivery Drone.  | 5. Fetch Bot                | 5. Bipedal Balancing Robot    |
| 6. Programming a NAO to play a tune using a xylophone.          | 6. Floor Mapping Robot      | 6. Chess Game                 |
| 7. Floor mapping with Swarm Robotics                            | 7. Gesture Control Pachenko | 7. Etc.                       |
| 8. Tootballing Yetiborg   | 8. Hexapod                  |                               |
| 9. Cat Flap Opening Based on Audio/Video/RFID                   | 9. Nao Pose                 |                               |
| 10. DrawBot   | 10. Position Estimation     |                               |
| 11. Traffic coordination (simulation).                          | 11. Race Car Training       |                               |
| 12. Plane filling curves (simulation).                          | 12. Face Touch              |                               |

Universiteit Leiden. Bij ons leer je de wereld kennen

## References

1. R. Mur-Atal, J.M.M. Montiel, J.D. Tardos, ORB-SLAM: A Versatile and Accurate Monocular SLAM System. *IEEE Transactions on Robotics*, Vol. 31, Issues 5, 2015.
2. G. Liu, W. Zeng, B. Feng, F. Xu, DMS-SLAM: A General Visual SLAM System for Dynamic Scenes with Multiple Sensors. *Sensors*, 2019.
3. S. Sumikura, M. Shibuya, K. Sakurada, OpenVSLAM: A Versatile Visual SLAM Framework. *MM'19 Open Source Software Competition*, October 2019.
4. Y. Bai, B. Zhang, N. Xu, J. Zhou, J. Shi, Z. Diao, Vision-based Navigation and Guidance for agricultural autonomous vehicles and robots: A review. *Computers and Electronics in Agriculture*, Vol. 205, 2023.