Universidad del País Vasco

Euskal Herriko Unibertsitatea

vicomtech

MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

Visual computing techniques for automated LIDAR annotation with application to intelligent transport systems

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graphicsvision.ai

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2. Lane markings automated annotation
3. Evaluation
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Introduction

1. Motivation
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Motivation

The importance of transport

- Safety

WHO global status report on road safety (2018):

- 1.35 million deaths
- 20-50 million injured
- 8th leading cause of death, the first among children and young adults 5-29

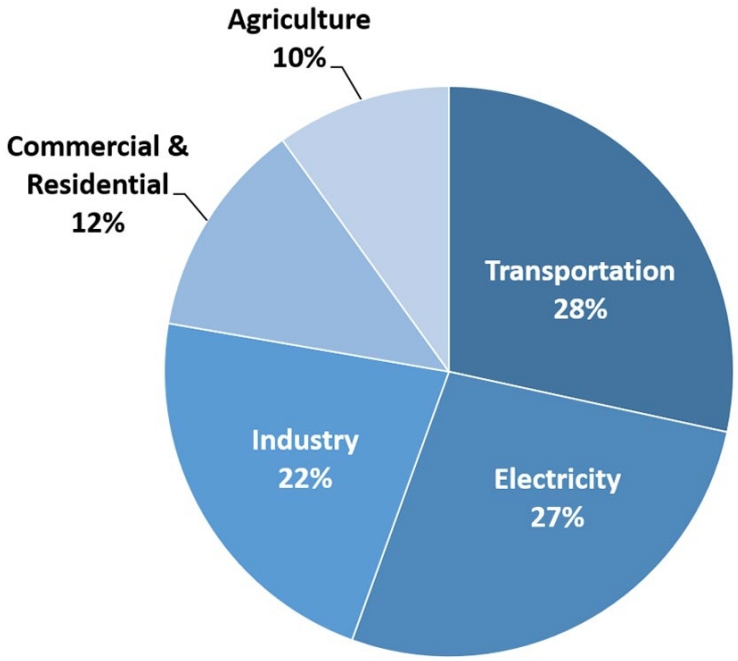
Spain DGT 2019:

- 1755 deaths

Motivation

The importance of transport

- Safety
- Environmental impact



U.S. Environmental Protection Agency (2020). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018

Road transport 70%

Air pollution contributes to 4.2 million deaths per year

Motivation

The importance of transport

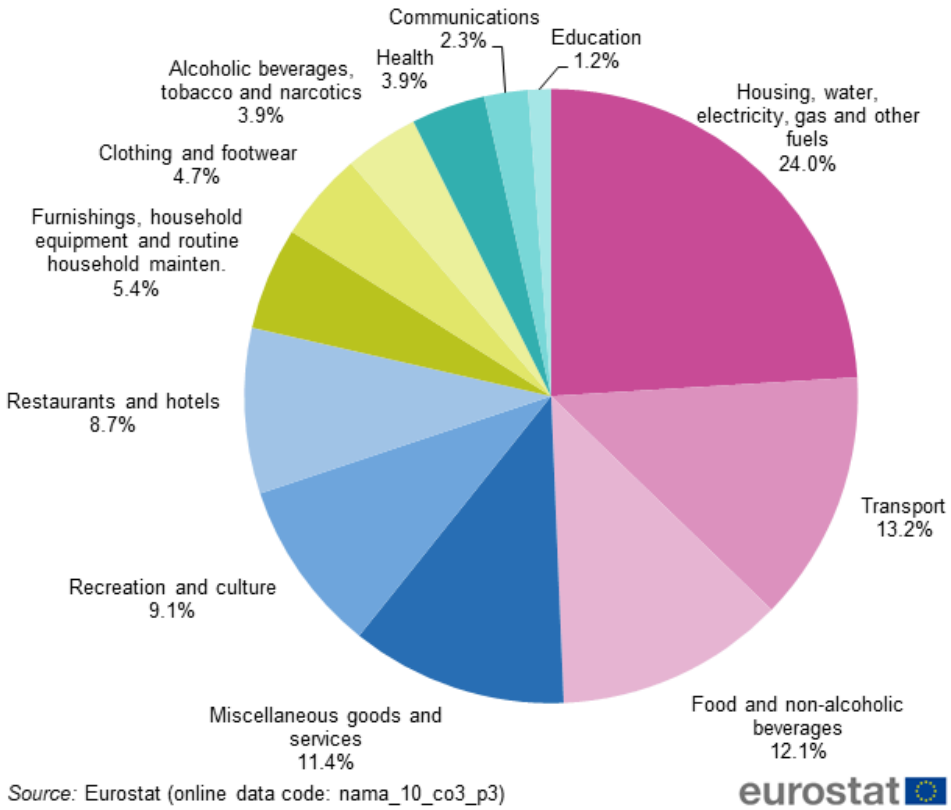
- Safety
- Environmental impact
- Economical value

- Europe: 11 million workers (5% of total employment)
- USA: 3.6 million truck drivers, 7.95 million related jobs

Motivation

The importance of transport

- Safety
- Environmental impact
- Economical value
- Social impact



Source: Eurostat (online data code: nama_10_co3_p3)

Motivation

The importance of transport

- Safety
- Environmental impact
- Economical value
- Social impact

USA 2018:

- Avg commute time (one way): 27 min
- 4.3 million workers with commutes of 90 minutes
- On average 225 hours to commuting

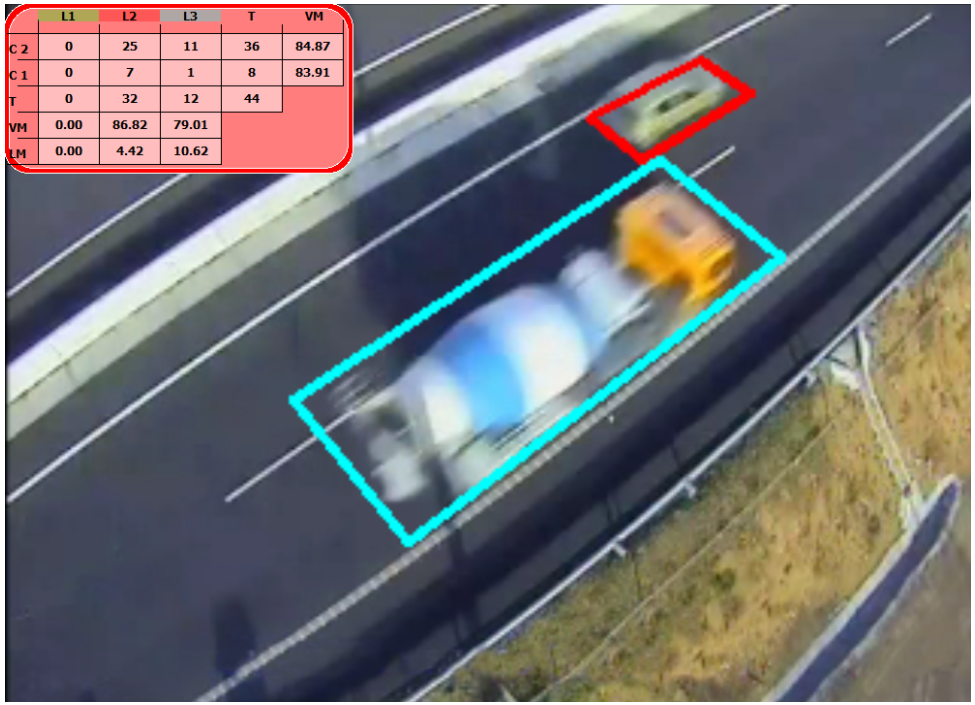
Motivation

Intelligent Transport Systems ITS

- Traffic monitoring, congestion and accident detection
- Vehicle counting and classification, vehicle tracking, license plate recognition
- Free flow tolling
- High occupancy lane control
- Parking management
- Information panels, adaptive signal control
- Infrastructure maintenance
- Traveler information systems, route guidance
- Driver monitoring
- Advanced driver-assistance systems (ADAS)
- Autonomous Vehicles (AV)

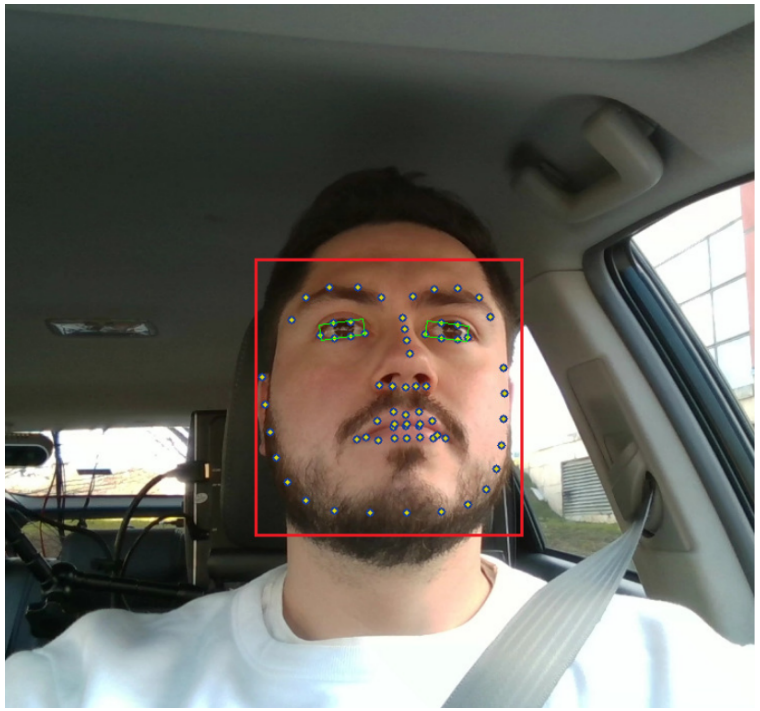
Motivation

Computer Vision for ITS



L. Unzueta, M. Nieto, A. Cortés, J. Barandiarán, O. Otaegui, and P. Sánchez, "Adaptive multicue background subtraction for robust vehicle counting and classification 2012

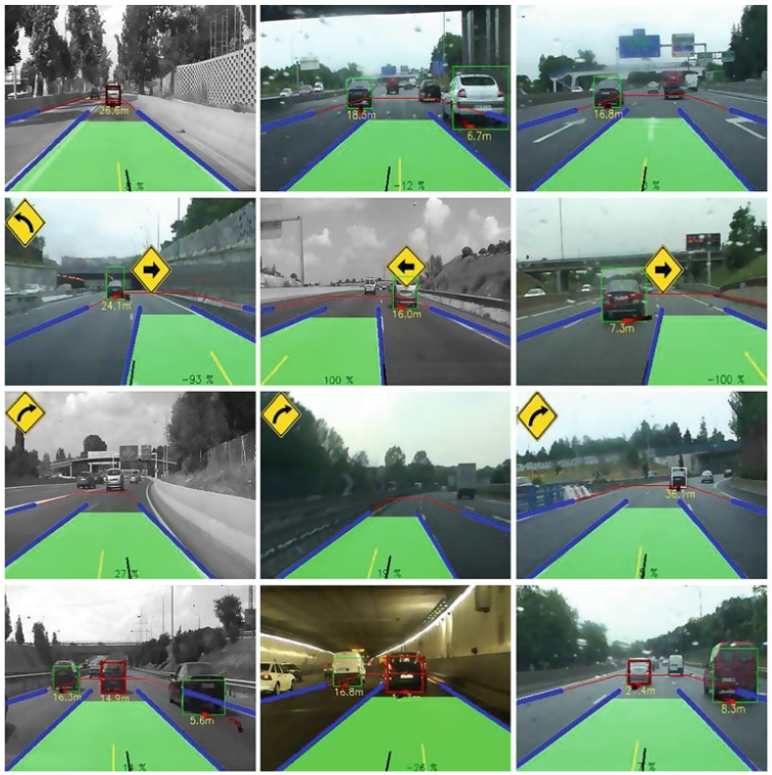
Motivation
Computer Vision for ITS



J.D. Ortega, M. Nieto, L. Salgado, and O. Otaegui, "User-adaptive Eyelid Aperture Estimation for Blink Detection in Driver Monitoring Systems" 2020

Motivation

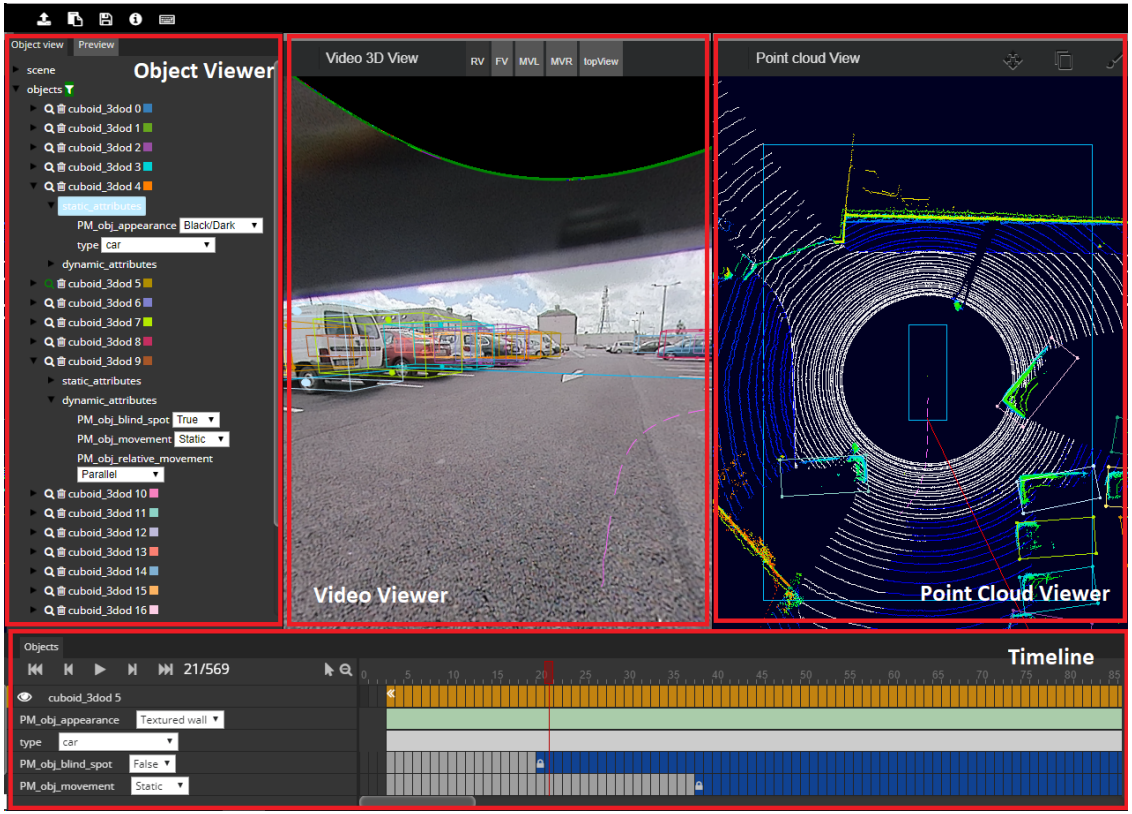
Computer Vision for ITS



Nieto, M., Arróspide Laborda, J. & Salgado, L., "Road environment modeling using robust perspective analysis and recursive Bayesian segmentation" 2011

Motivation
Automated driving

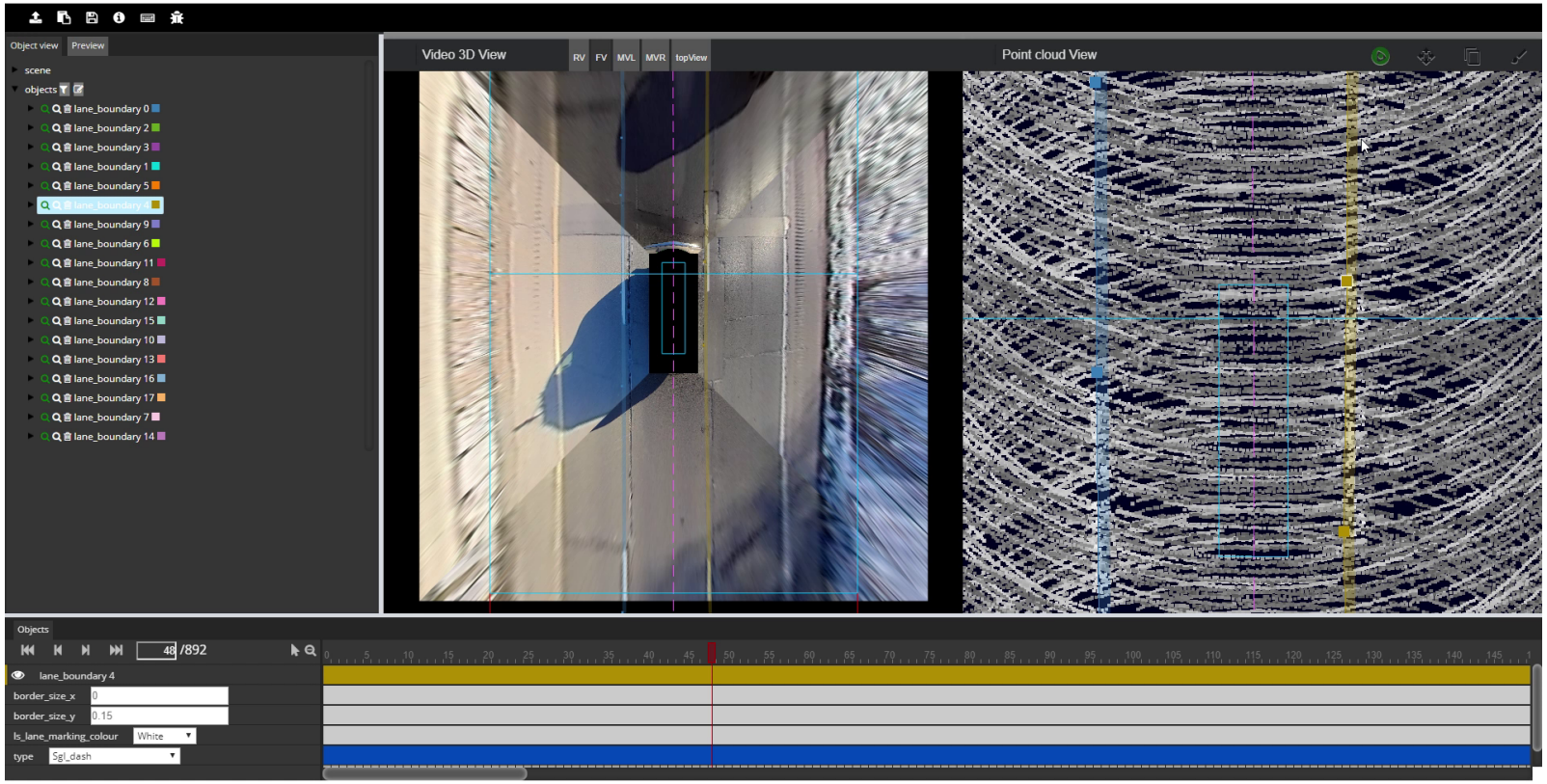
Motivation
Data annotation



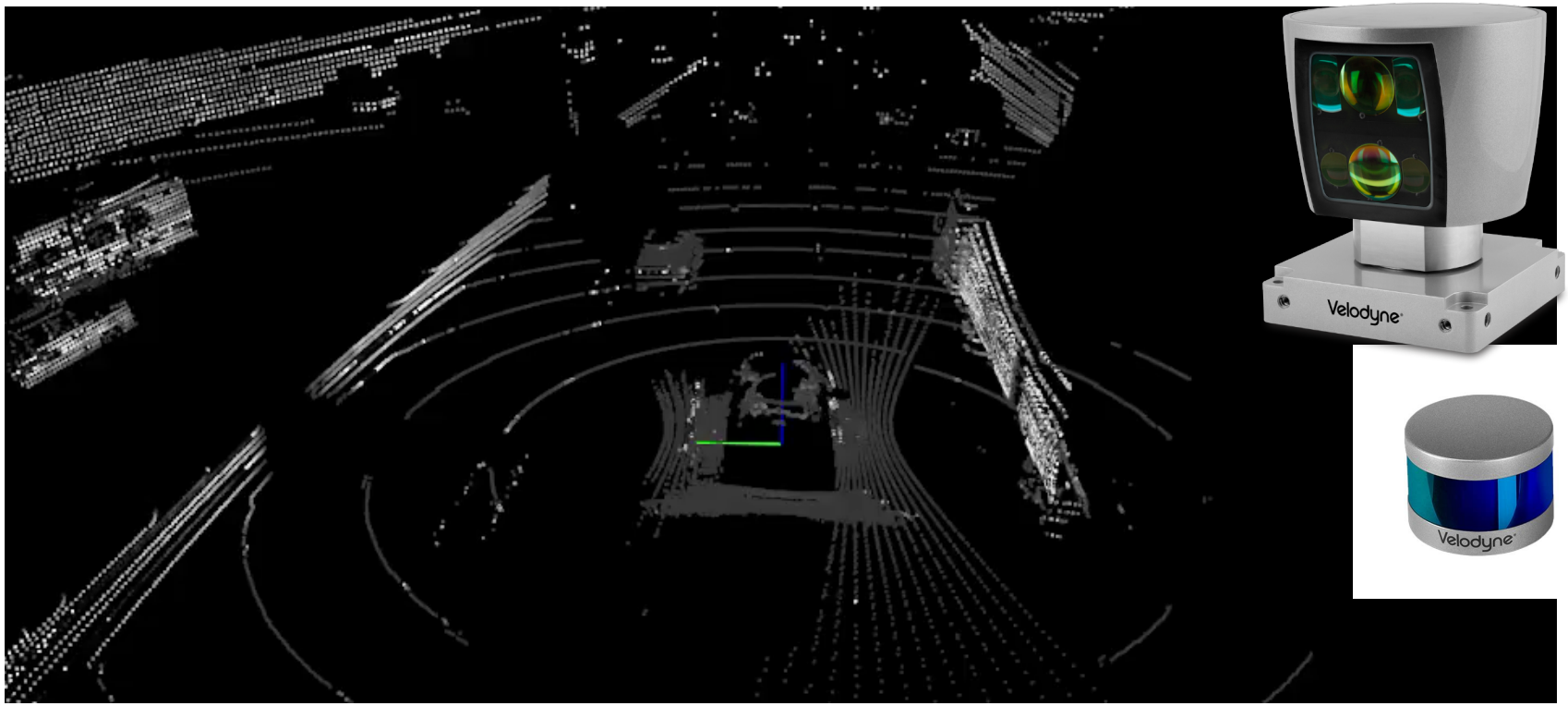
A. Mujika et al. "Web-based Video-Assisted Point Cloud Annotation for ADAS validation". 2019

Motivation

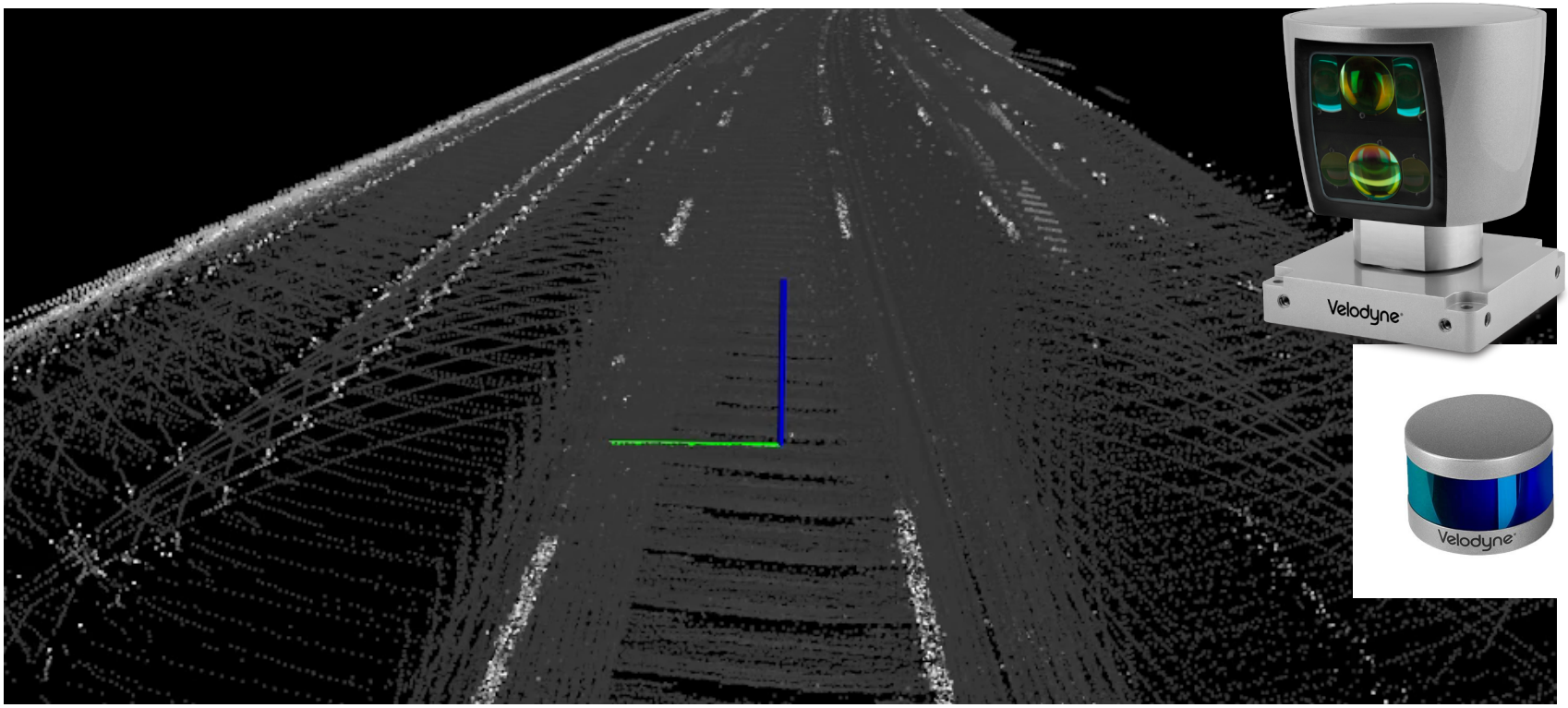
Data annotation



Motivation
LIDAR

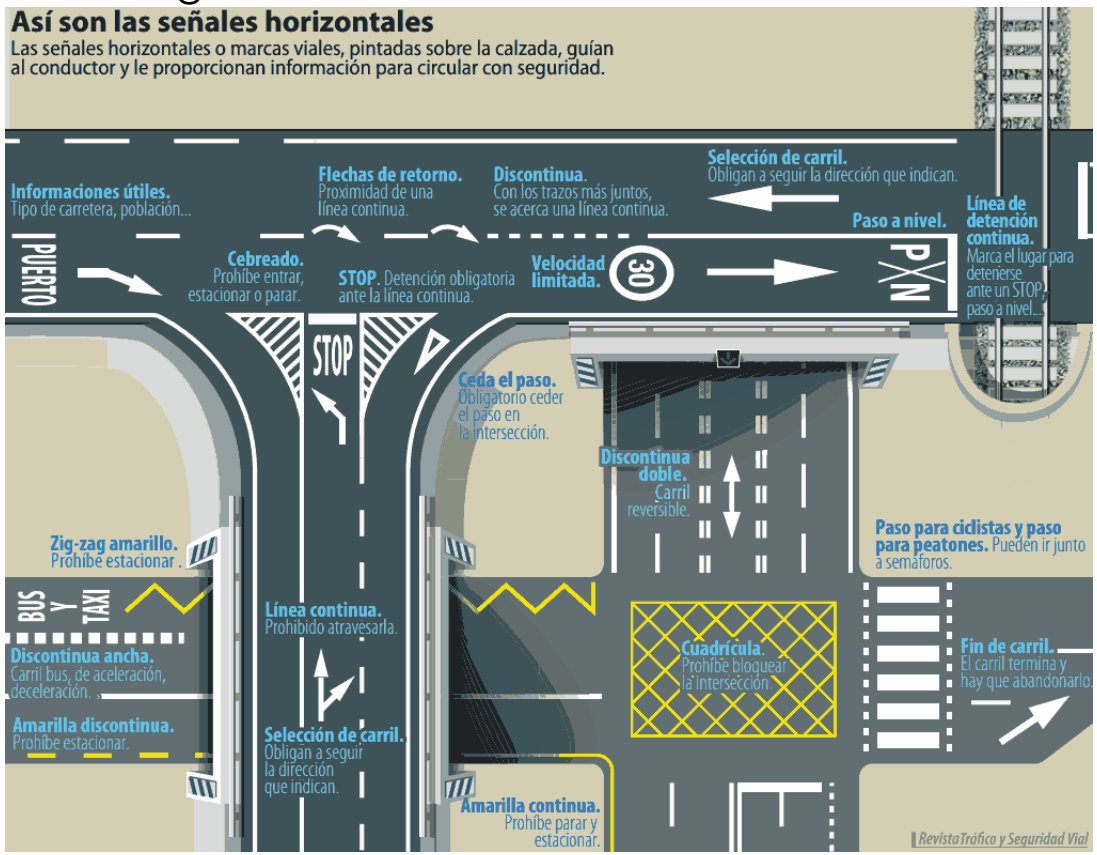


Motivation
LIDAR



Motivation

Horizontal road markings



Revista Tráfico y Seguridad Vial DGT

Motivation
Horizontal road markings

- LIDAR vs camera for road markings annotation:
  - Less sensitive to illumination
  - 3D reconstruction
  - Lower density
  - Expensive

Objectives

- Automated annotation of lane markings using LIDAR
  - Web-based annotation tool
  - Preprocessing steps that prepare the data
  - Quality evaluation
  - Validation with professional annotators

Contributions

- A method for the automatic annotation of lane markings using LIDAR
- Evaluation methodology
- Exploitation of cloud architectures
- Web-based annotation tool for remote work

Research environment and context

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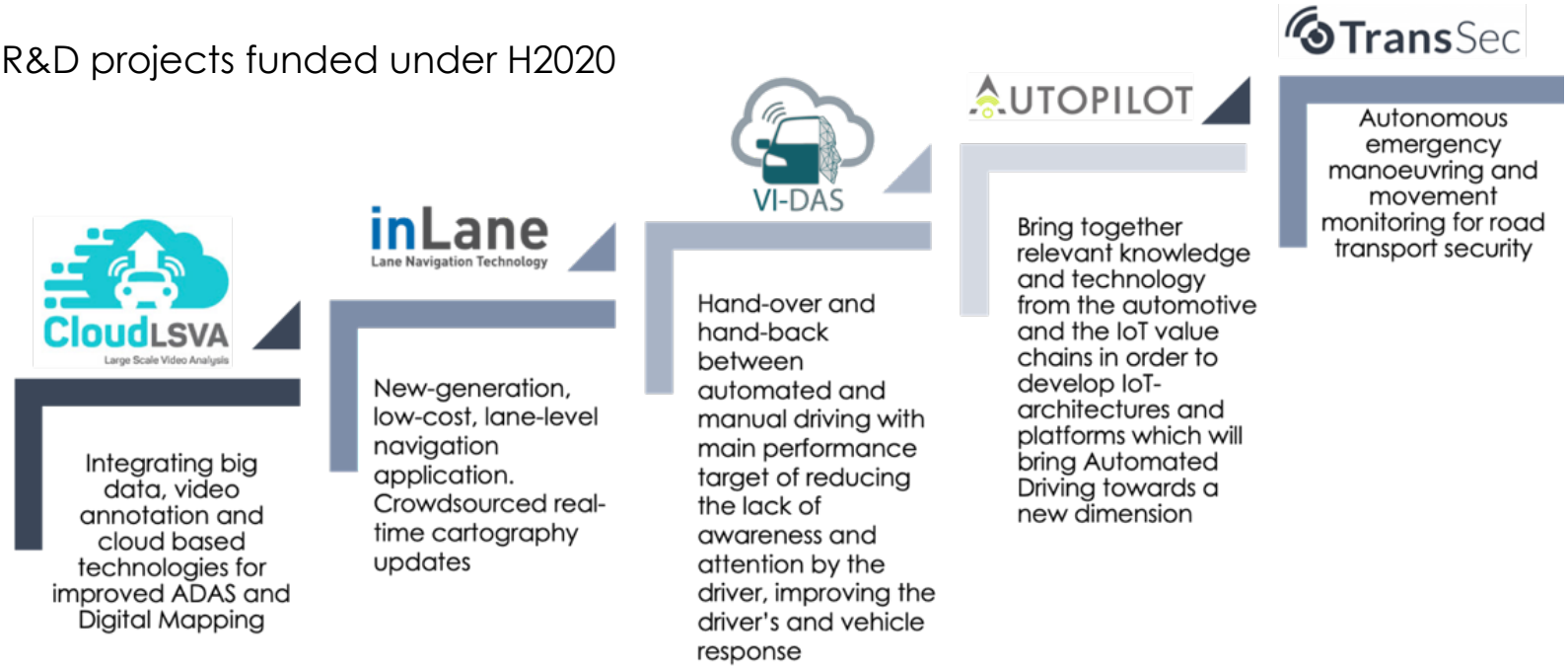
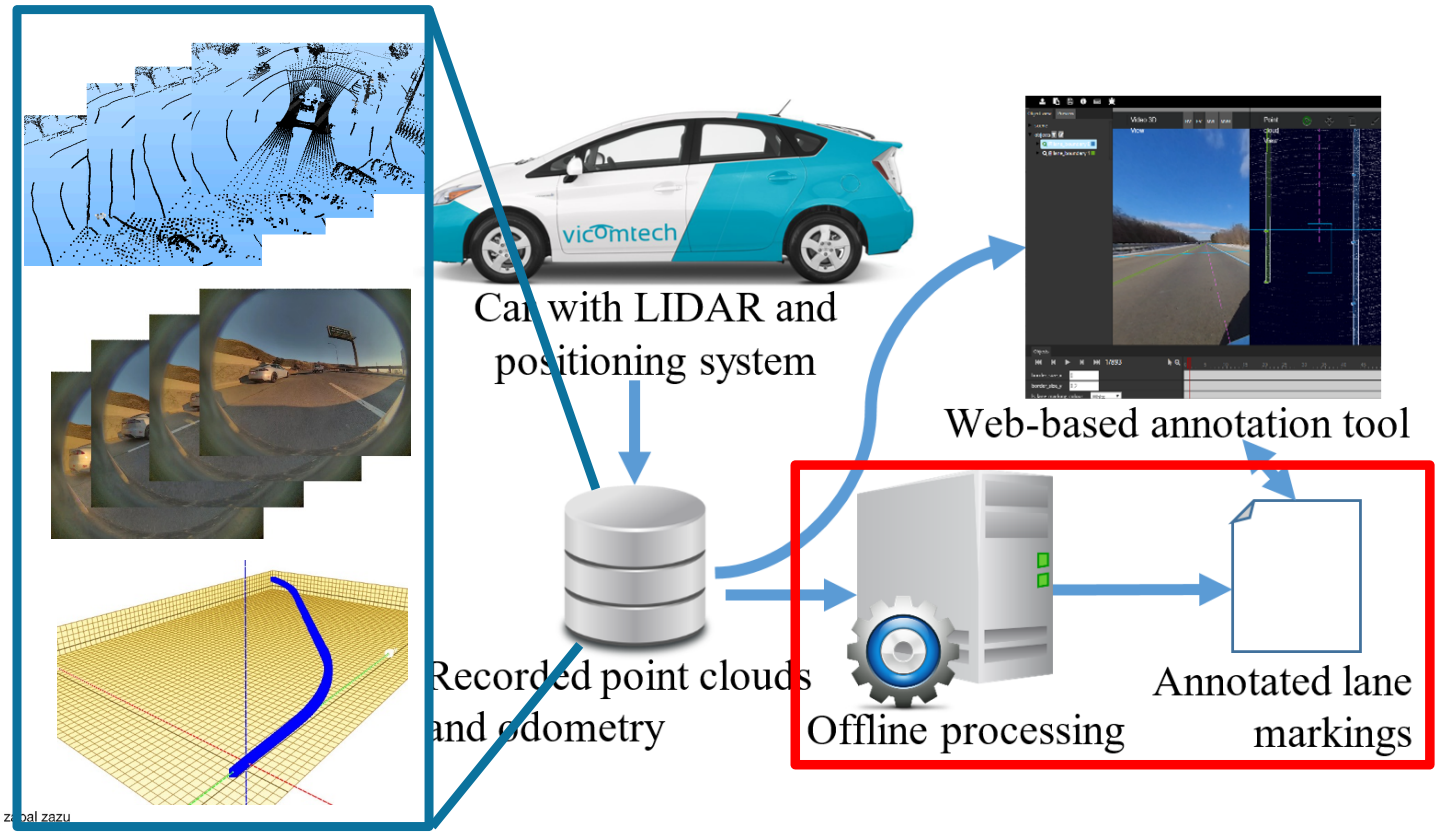
R&D projects funded under H2020



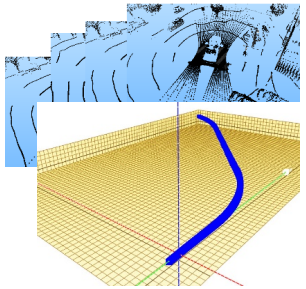
Lane markings automated annotation

1. Outline of the proposed approach
2. Point cloud preprocessing and preparation
3. Lane markings detection

Outline of the proposed approach



Point cloud preprocessing and preparation



LIDAR scans
LIDAR extrinsics
Odometry

1: Filter scans

2: Scans accumulation

3: Noise reduction

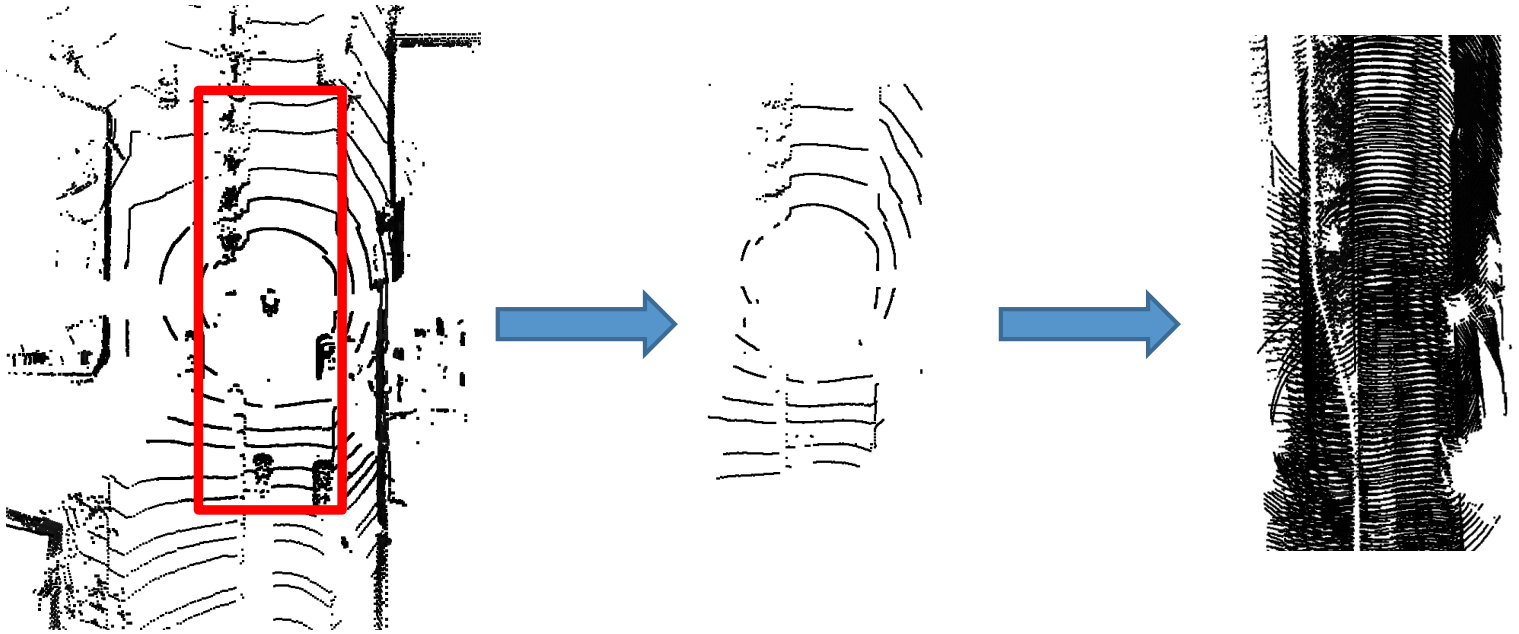
4: Intensity calibration

5: Contrast enhancement

Accumulated and filtered point cloud

Point cloud preprocessing and preparation

1-2. filter and accumulate scans



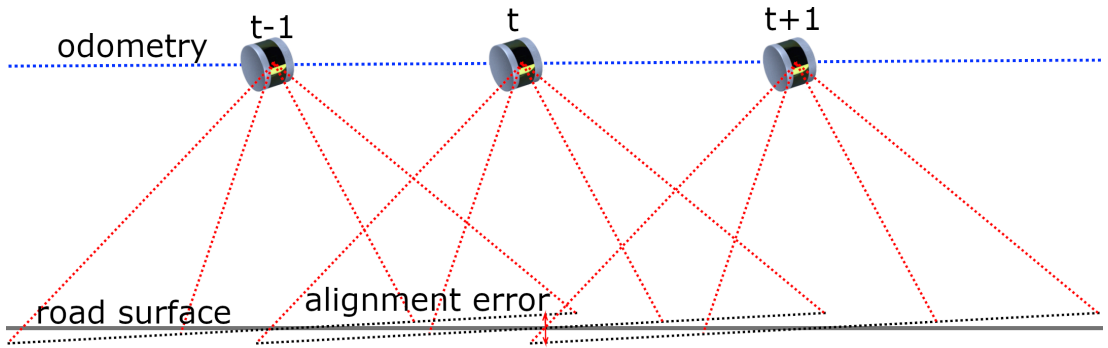
Input scan

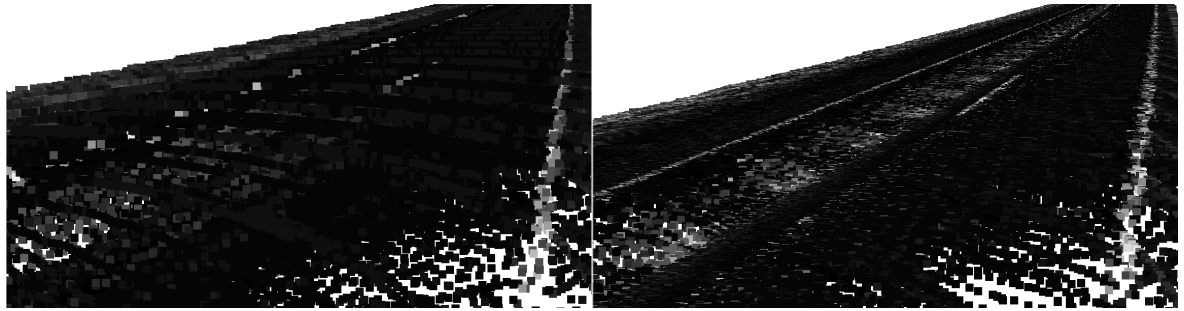
filtered scan

accumulated scans

Point cloud preprocessing and preparation

3. noise reduction

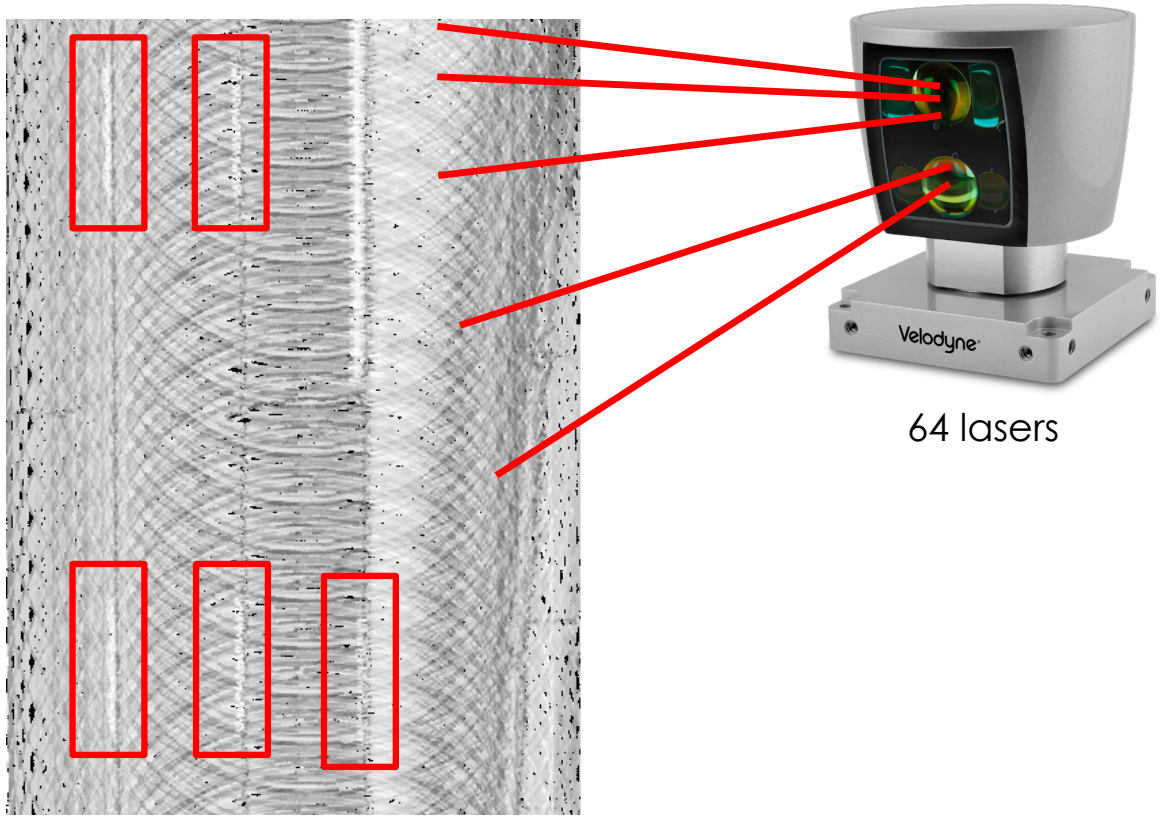




Accumulated point cloud before (left) and after (right) noise reduction

Point cloud preprocessing and preparation

4. intensity calibration



64 lasers

Point cloud preprocessing and preparation

4. intensity calibration

	0	1	2	…	254	255
Laser 0	0	1	2	…	254	255
Laser 1	0	1	2	…	254	255
Laser 2	0	1	2	…	254	255
…	…	…	…	…	…	…
Laser N-1	0	1	2	…	254	255

Levinson, J., & Thrun, S. (2010). Robust vehicle localization in urban environments using probabilistic maps.

Point cloud preprocessing and preparation

4. intensity calibration

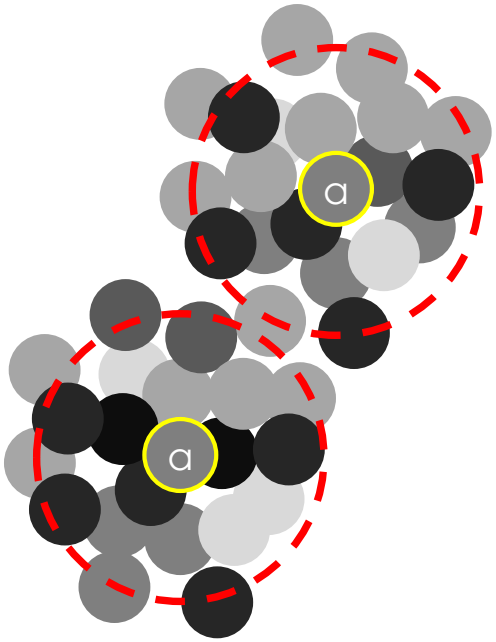
	0	1	2	…	254	255
Laser 0	0	1	2	…	128	129
Laser 1	0	5	8	…	220	221
Laser 2	0	3	9	…	200	204
…	…	…	…	…	…	…
Laser N-1	0	2	3	…	254	255

← observed

← calibrated

Point cloud preprocessing and preparation

4. intensity calibration

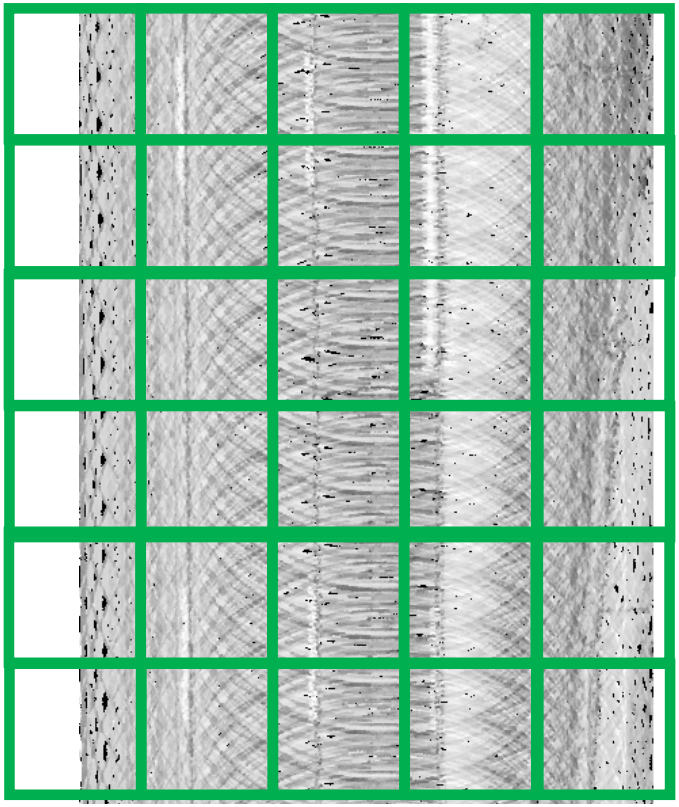


	0	…	a	…	255
Laser 0	…	…	…	…	…
…	…	…	…	…	…
Laser j	…	…	c(j,a)	…	…
…	…	…	…	…	…
Laser N-1	…	…	…	…	…

$$c(j,a) = \frac{\sum a_k}{n} \quad k! = j$$

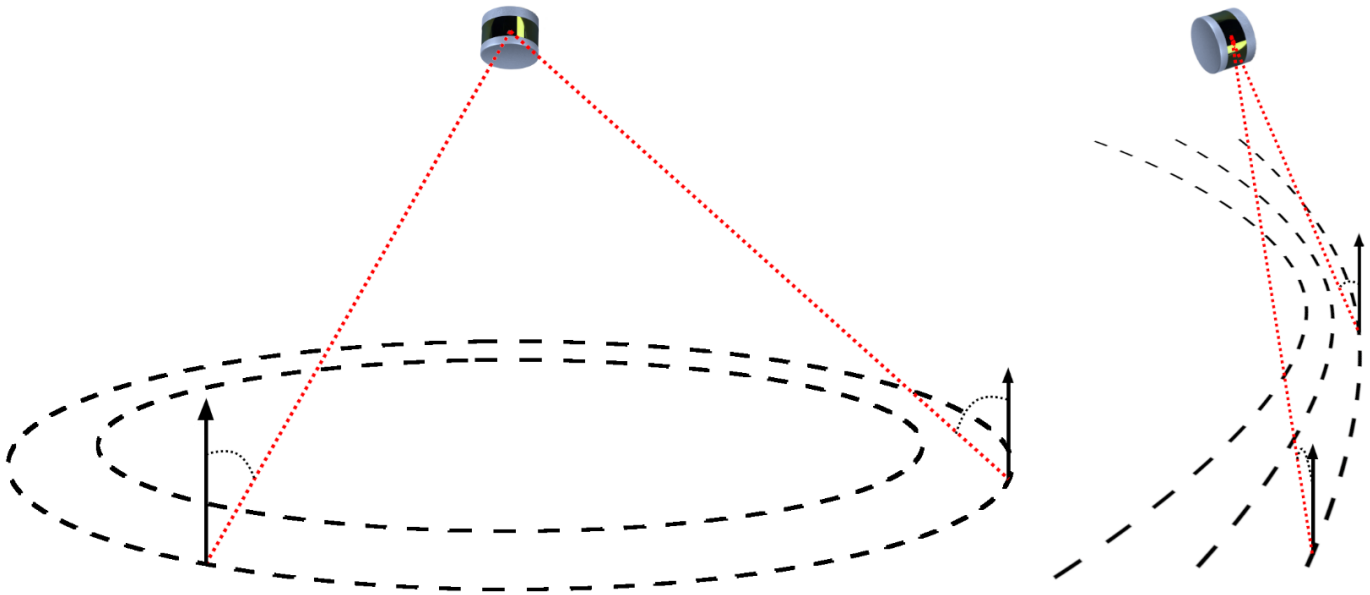
Point cloud preprocessing and preparation

4. intensity calibration



Point cloud preprocessing and preparation

4. intensity calibration (angle of incidence)

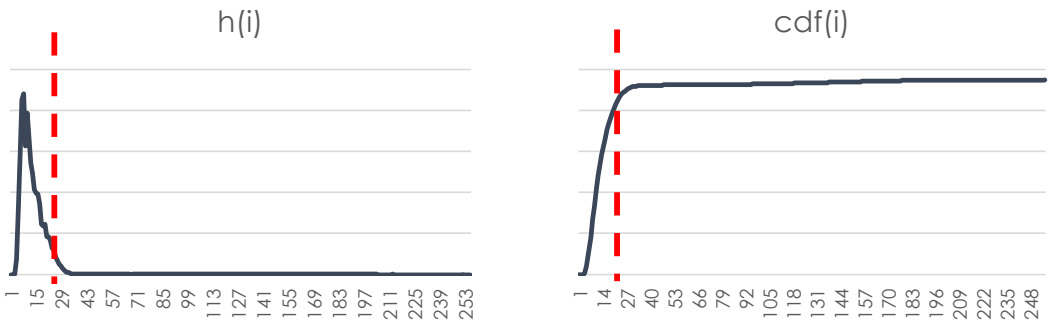


Point cloud preprocessing and preparation

5. contrast enhancement

$$h\left(i\right)=\frac{n_i}{n},0\leq i<256$$

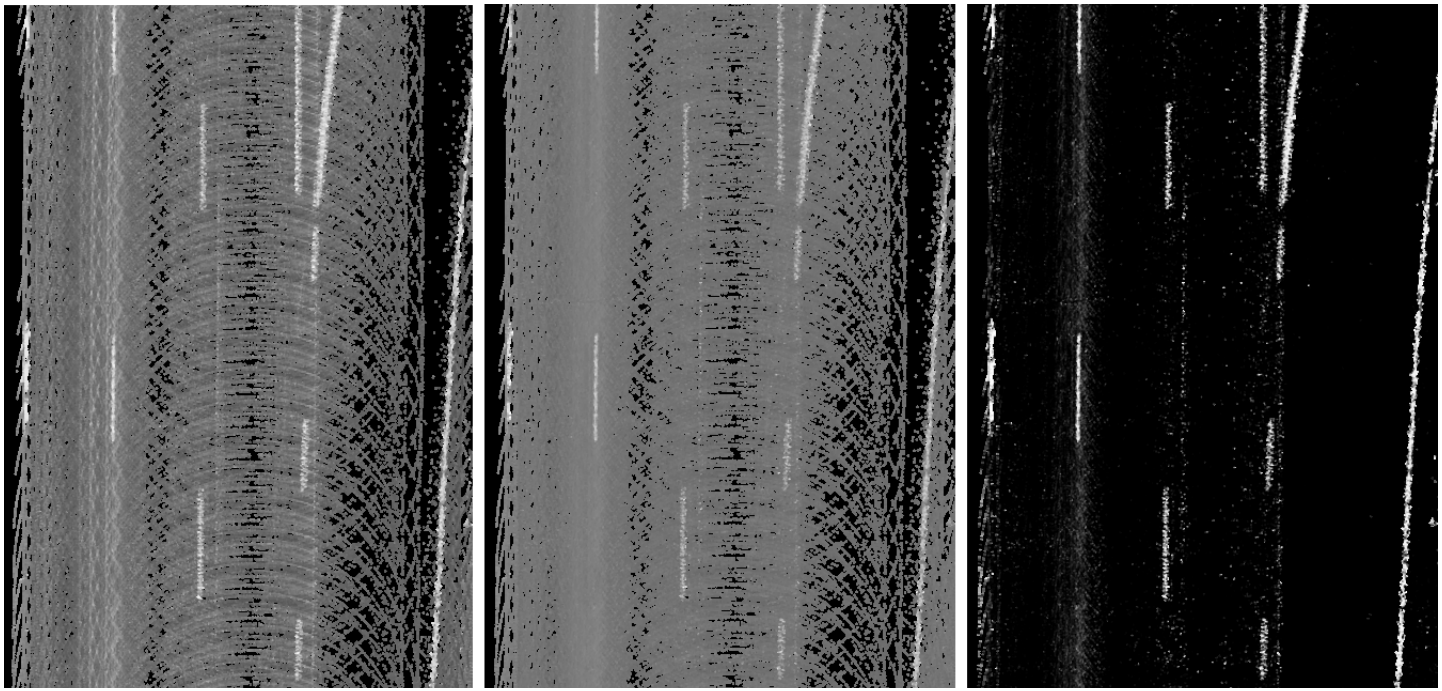
$$cdf\left(i\right)=\sum_{j=0}^{i}h\left(j\right)$$



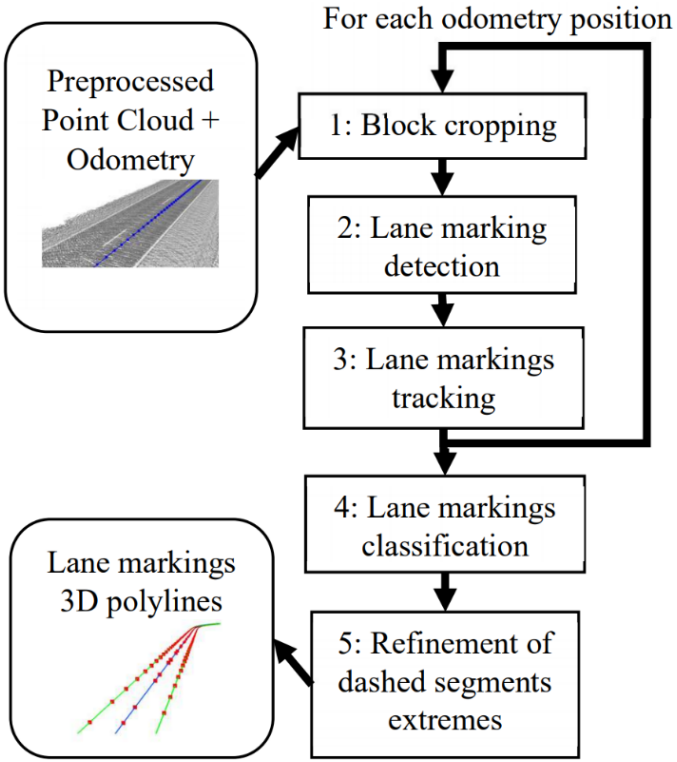
Histogram equalization $$h\left(i\right)=round\left(\frac{cdf\left(i\right)-cdf_{min}}{n-cdf_{min}}*254\right)+1$$

Point cloud preprocessing and preparation

5. contrast enhancement

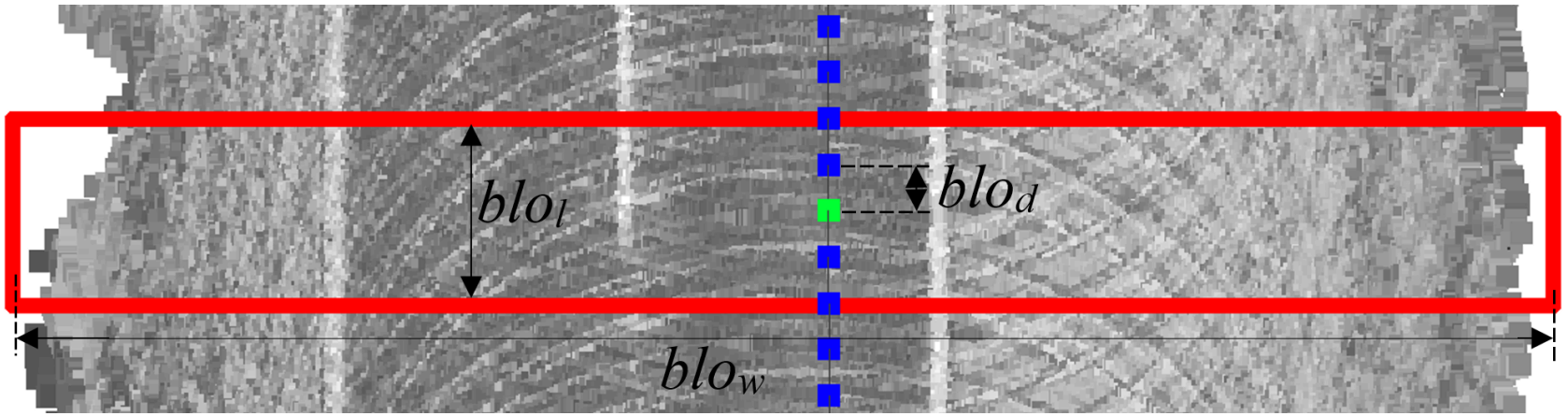


Lane markings detection



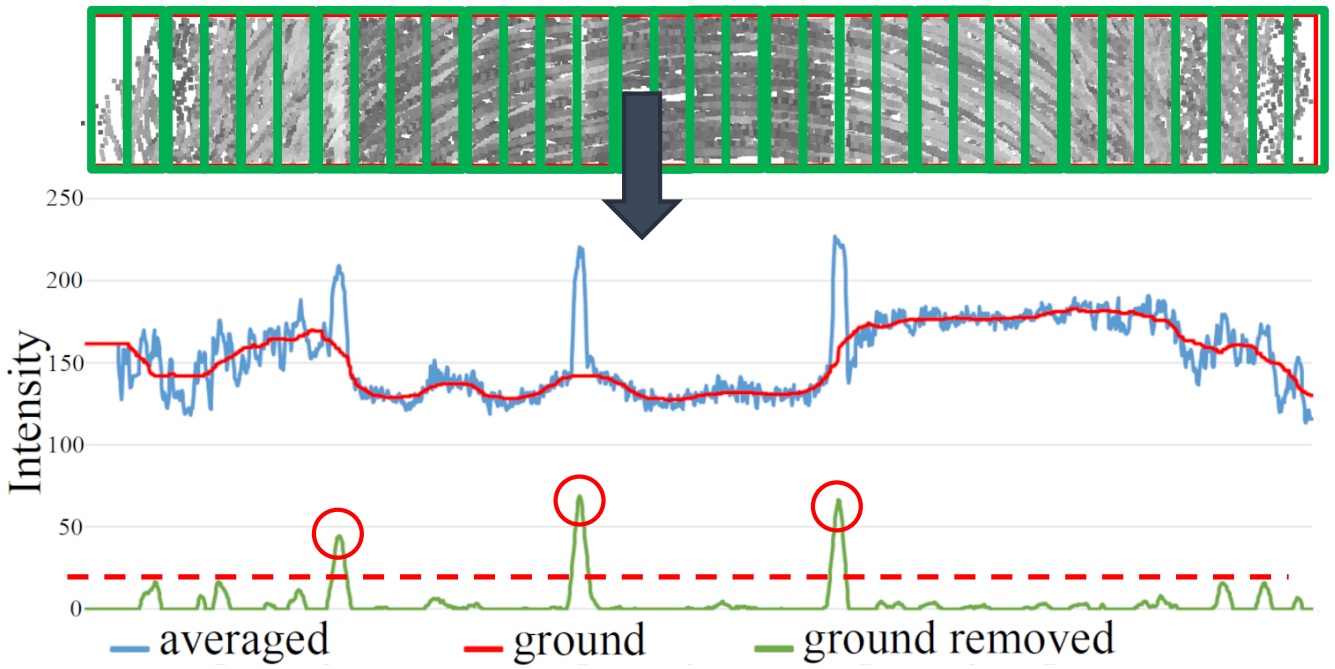
Lane markings detection

1. block cropping



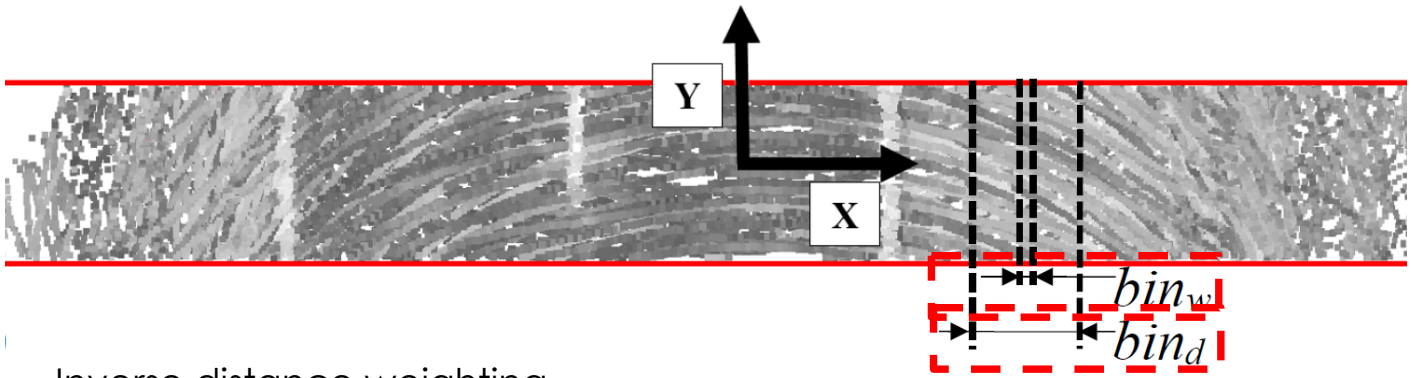
Lane markings detection

2. detection



Lane markings detection

2. detection



Inverse distance weighting

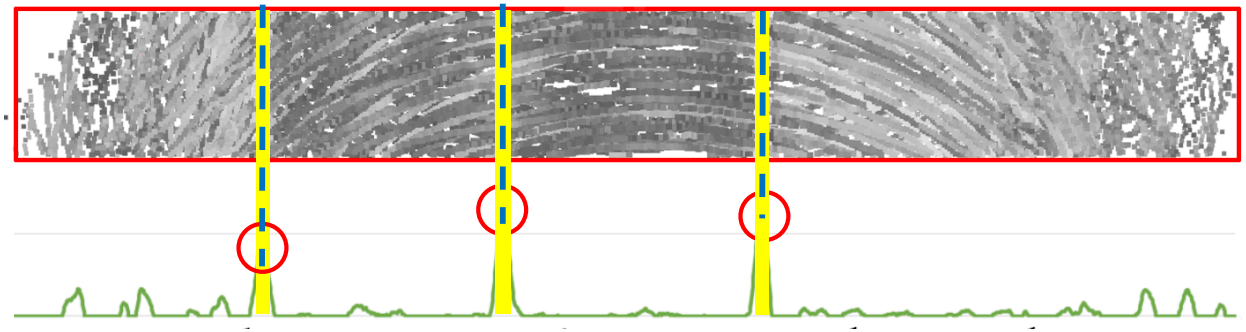
$$b_i = \frac{\sum_{j=1}^{np} w_{ij} a_j}{\sum_{j=1}^{np} w_{ij}}$$

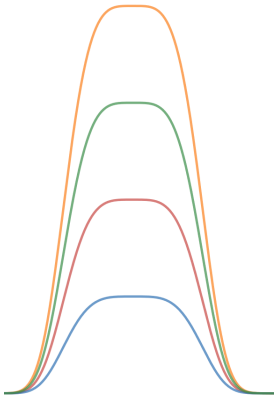
$$w_{ij} = \begin{cases} 1 - (d_{ij}/bin_d) & d_{ij} < bin_d \\ 0 & otherwise \end{cases}$$

np: number of point in the block

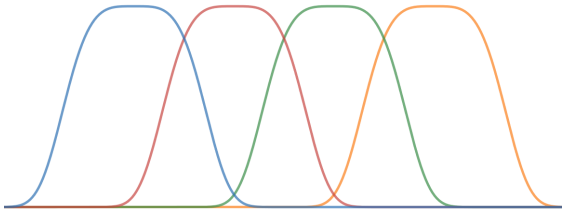
Lane markings detection

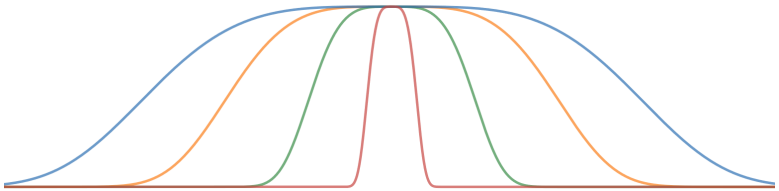
2. detection





flat-top Gaussian $f(x) = p_0 e^{-((x-p_1)/p_2)^4}$

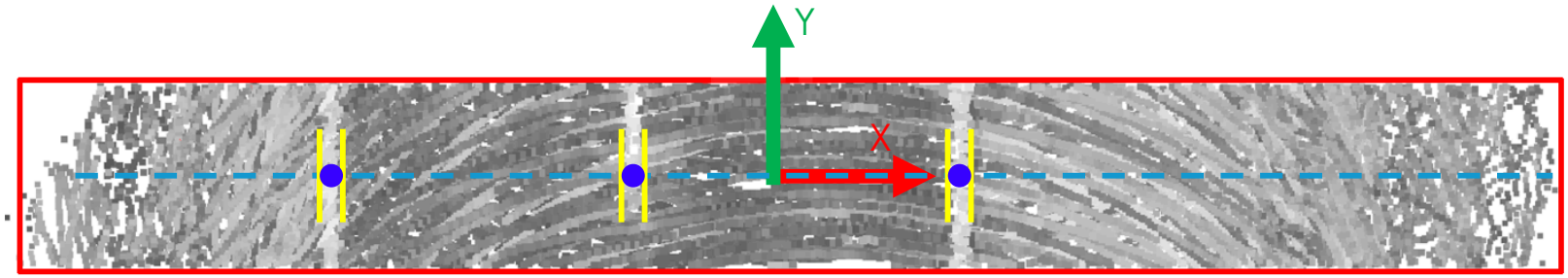




p_0 p_1 p_2

Lane markings detection

2. detection

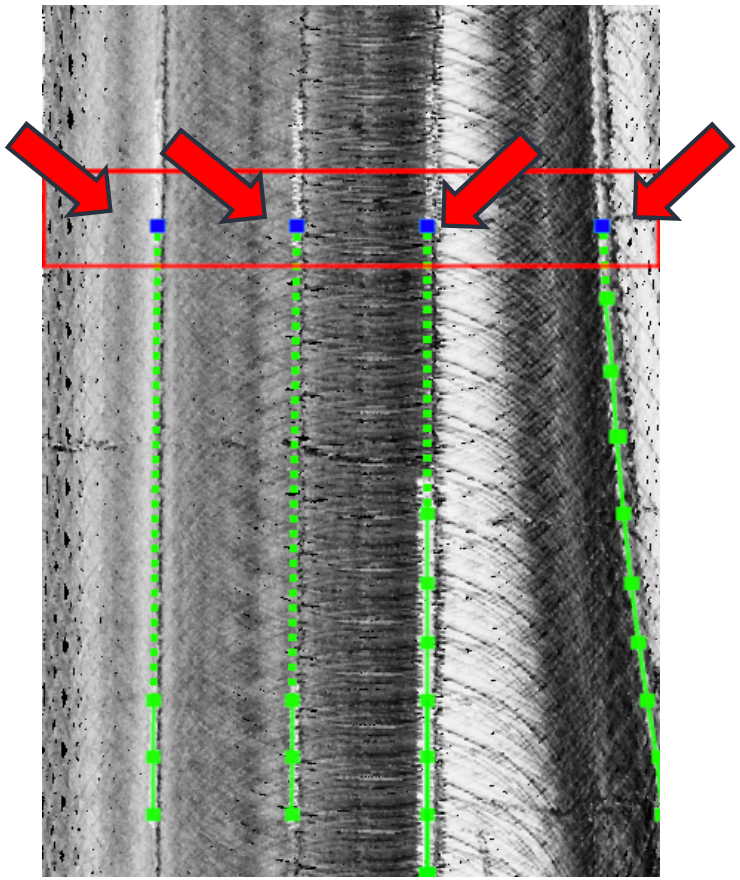


Vehicle located at (0,0,0)

$$p(x, 0, 0)$$

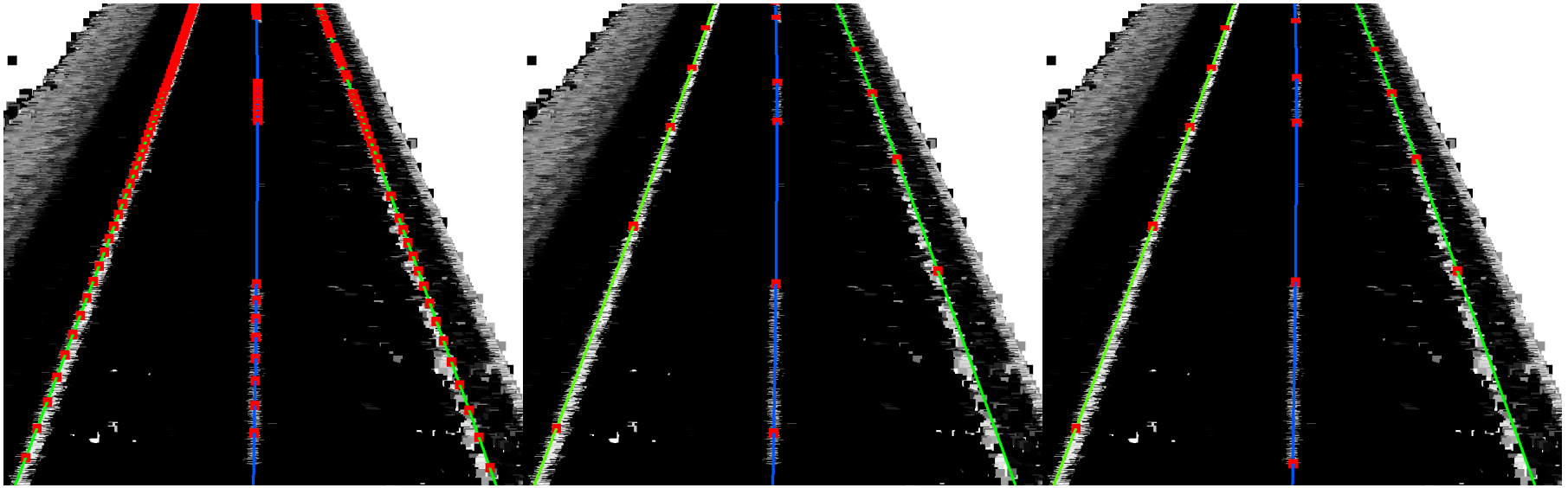
Lane markings detection

3. tracking



Lane markings detection

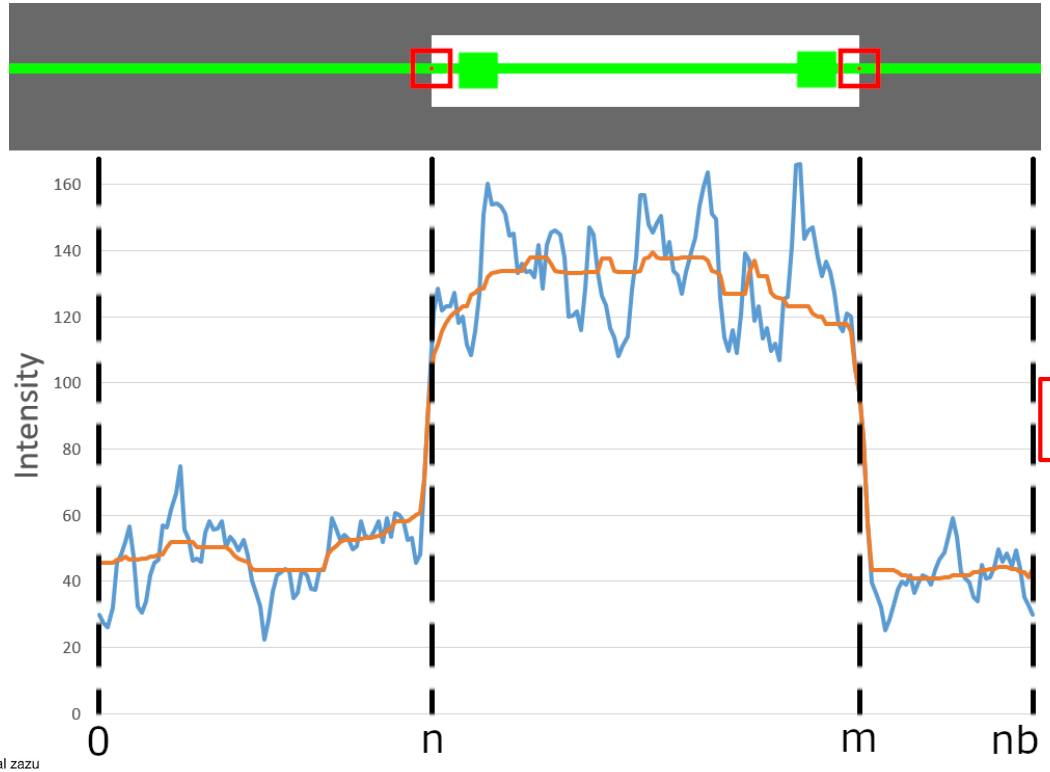
4-5 Classification and refinement of dashed segments extremes



detected points | intermediate points removed | segments extremes refined

Lane markings detection

5. refinement of dashed segments extremes



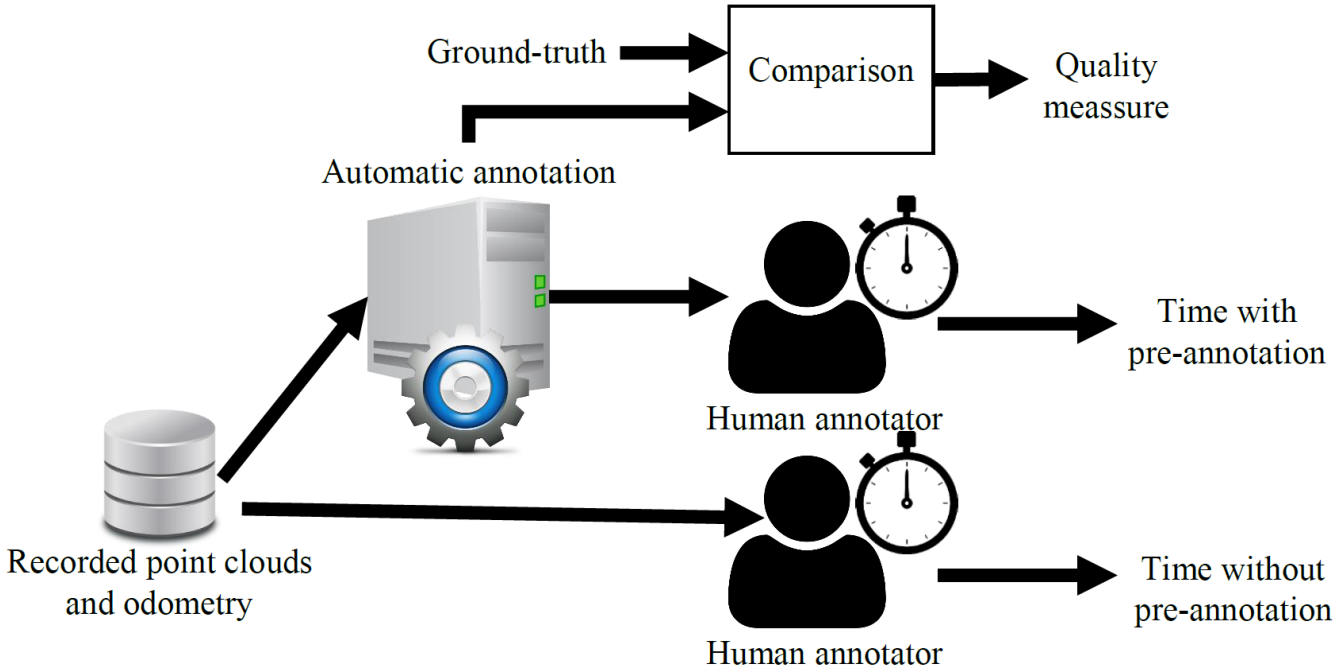
$$g(n,m) = 2(b'_n - b'_m) + d(n,m)$$

$$d(n,m) = \frac{\sum_{i=n}^{m} b_i}{m-n+1} - \left(\frac{\sum_{j=0}^{n-1} b_j + \sum_{j=m+1}^{nb} b_j}{nb-(m-n+1)} \right)$$

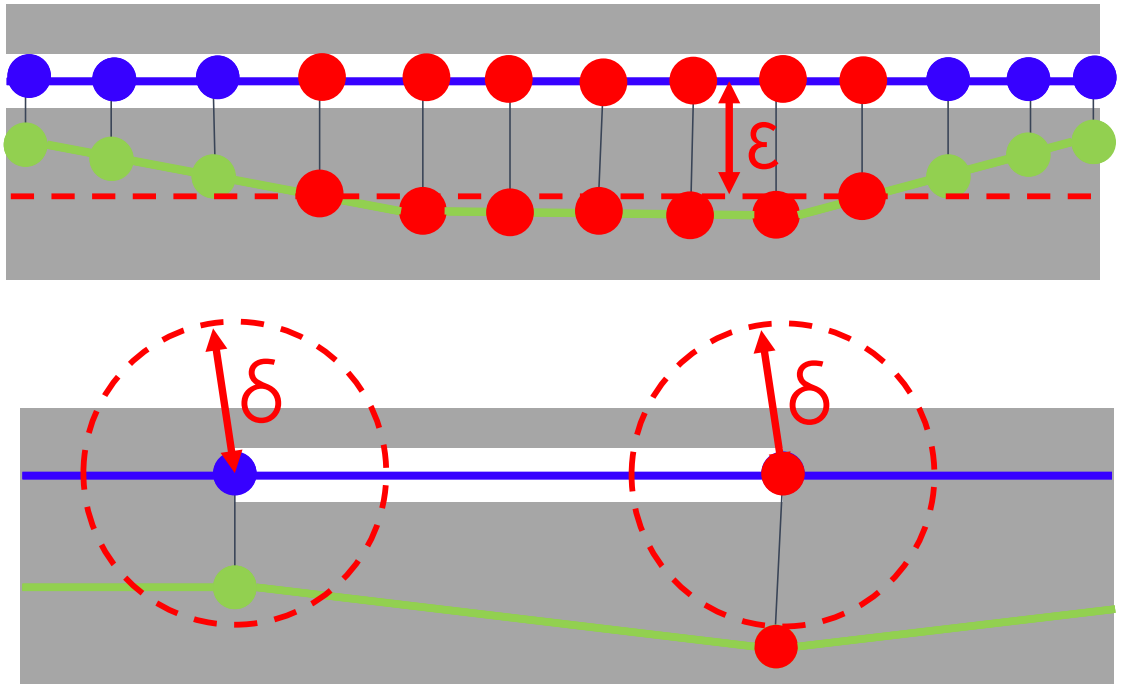
Evaluation

1. Evaluation methodology
2. Dataset description
3. Results

Evaluation methodology

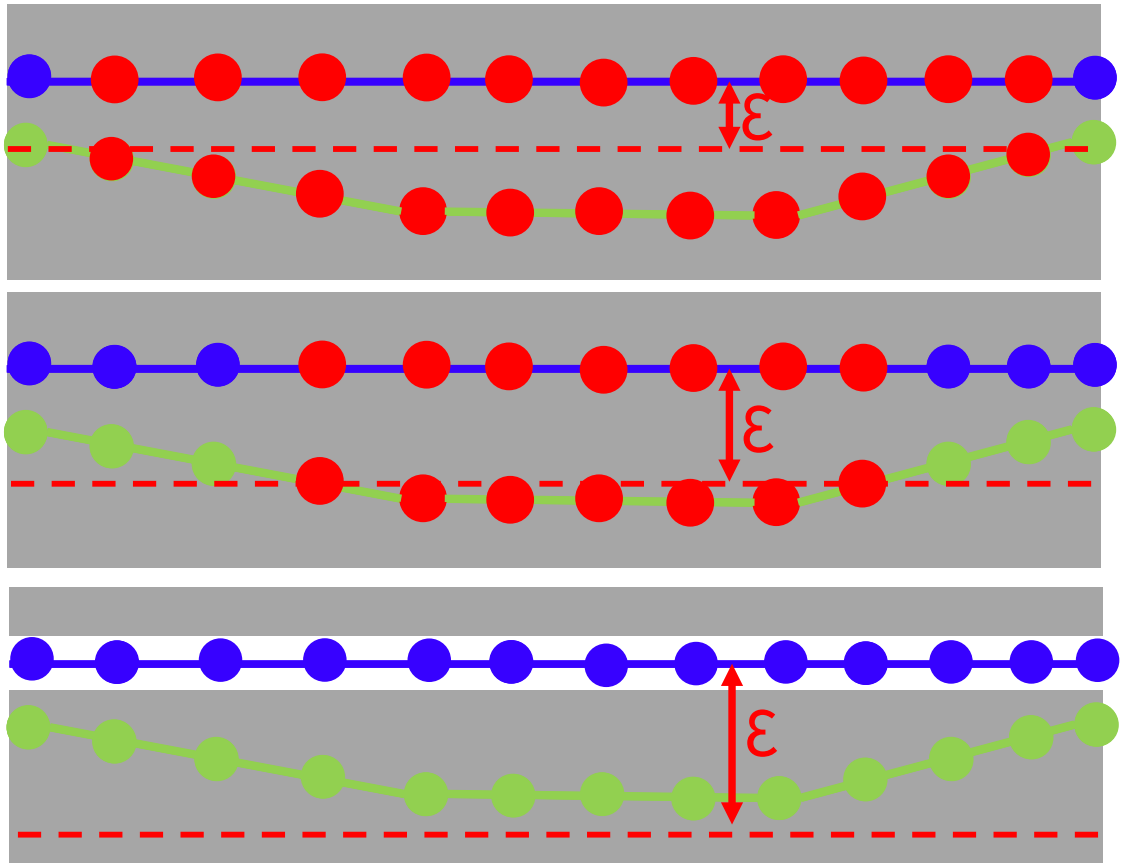


Evaluation methodology

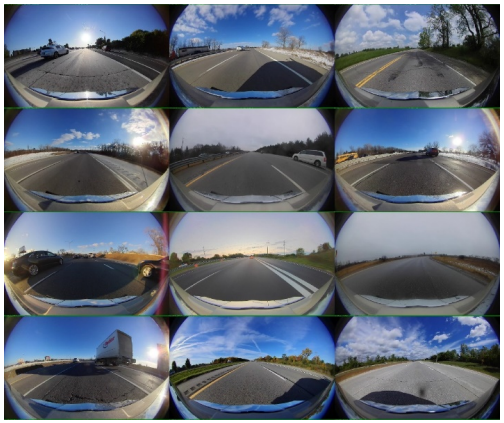


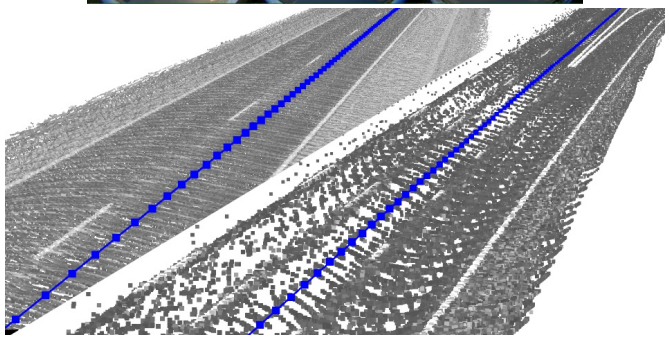
$R=TP/(TP + FN)$
$P=TP/(TP + FP)$
$F=2RP/(R+ P)$

Evaluation methodology



Dataset description

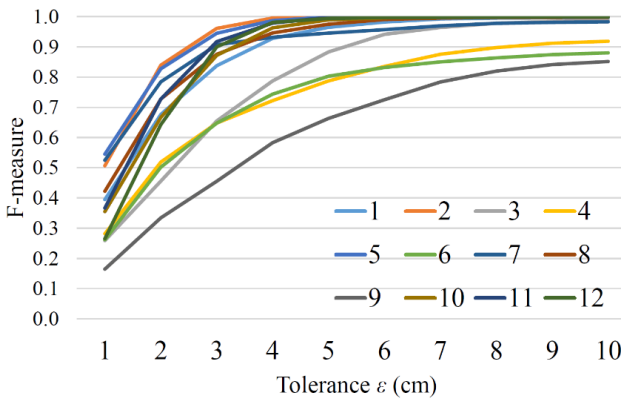


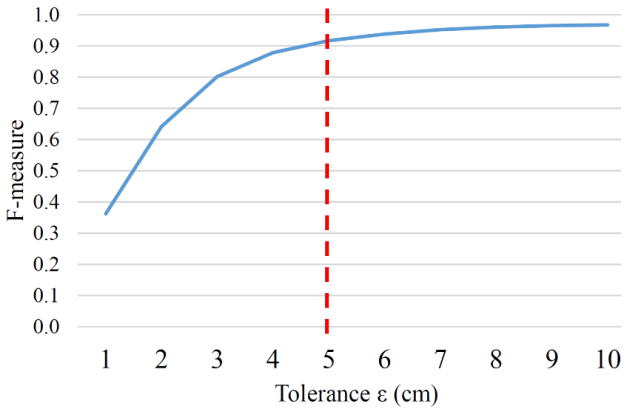


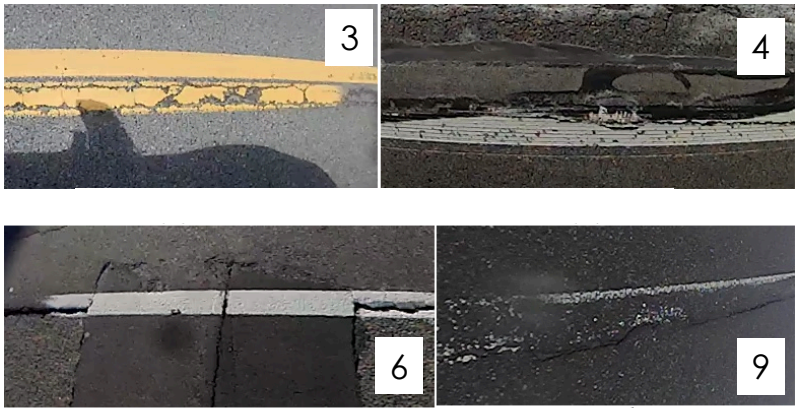
Trace	Weather	Hour	Lanes	Type	Road
1	sunny	18	4	straight	concrete
2	sunny	15	2	slight curve	grey asphalt
3	sunny	12	2	straight	grey asphalt
4	sunny	15	3	slight curve	grey asphalt
5	foggy	11	3	straight	grey asphalt
6	sunny	16	3	slight curve	dark asphalt
7	sunny	17	3	straight	dark asphalt
8	clear evening	19	4	straight	dark asphalt
9	cloudy wet	14	1-3	tight curve	dark asphalt
10	sunny	16	3	slight curve	dark asphalt
11	sunny	9	2	straight	dark asphalt
12	sunny	11	3	slight curve	concrete

- Total distance: 11 km
- Sensors: 64-Layer LIDAR + GNSS/INS + 4cameras
- Highways and non-urban roads
- Average points density: 350 points/m^2

Results

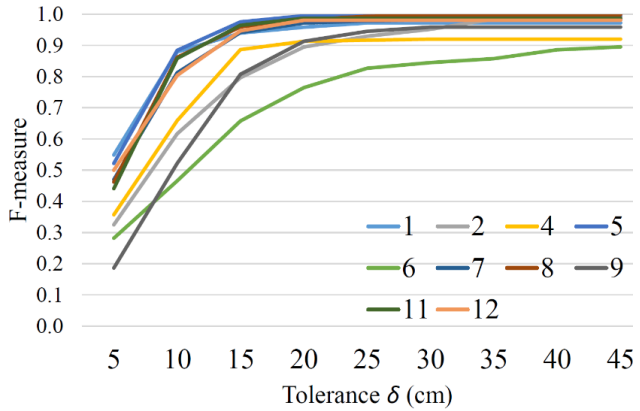


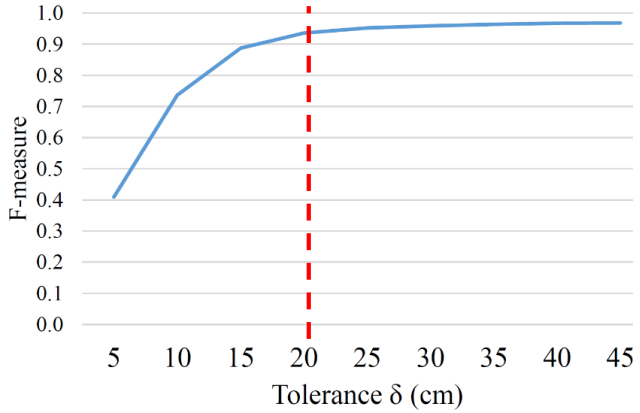




F=0.92 (ε=5cm)

Results

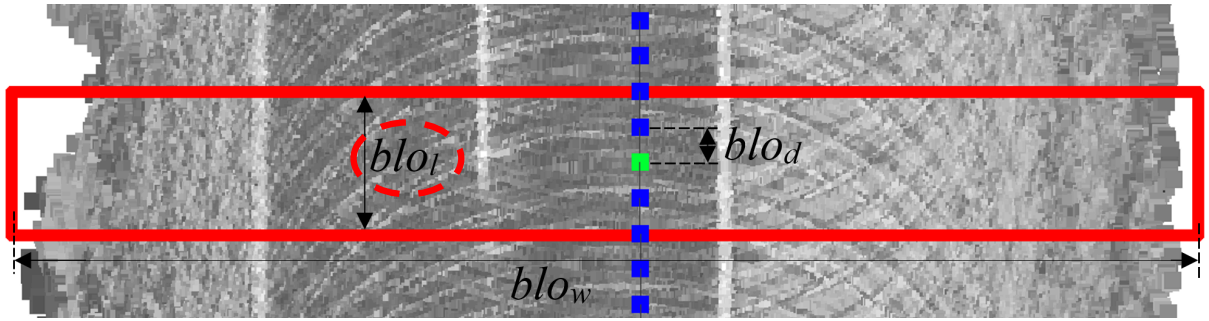


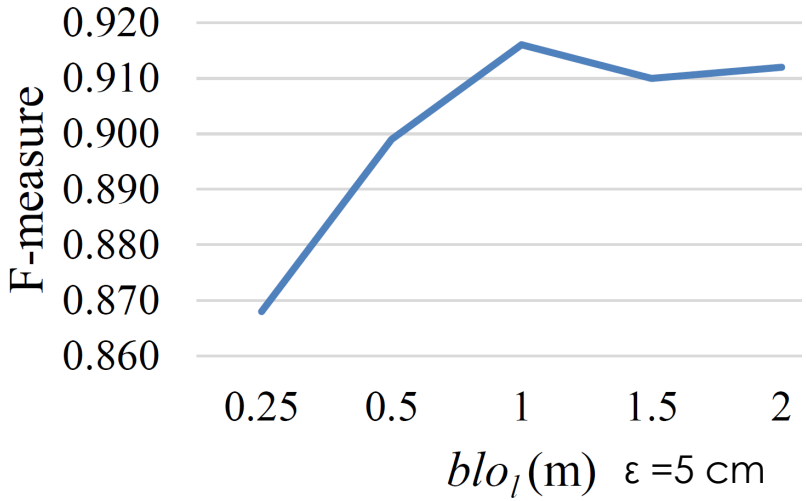


F=0.94 (δ=20 cm)

Results

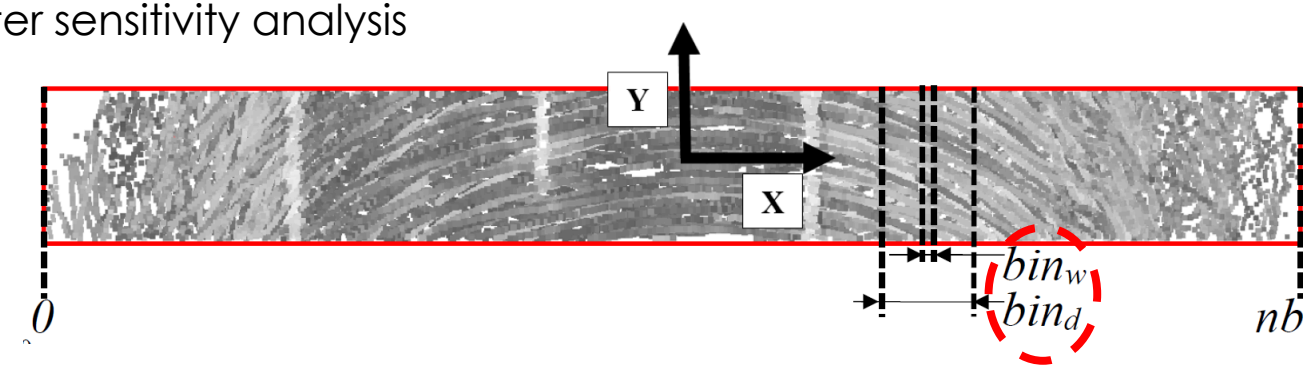
Parameter sensitivity analysis

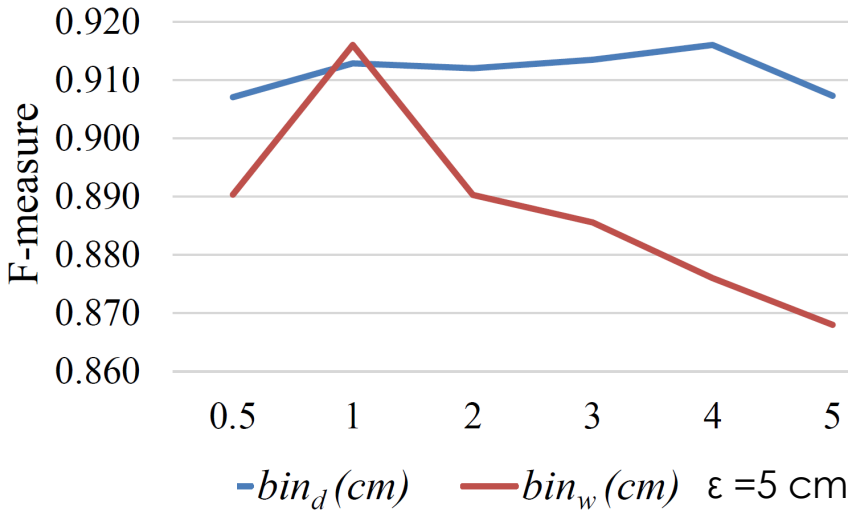




Results

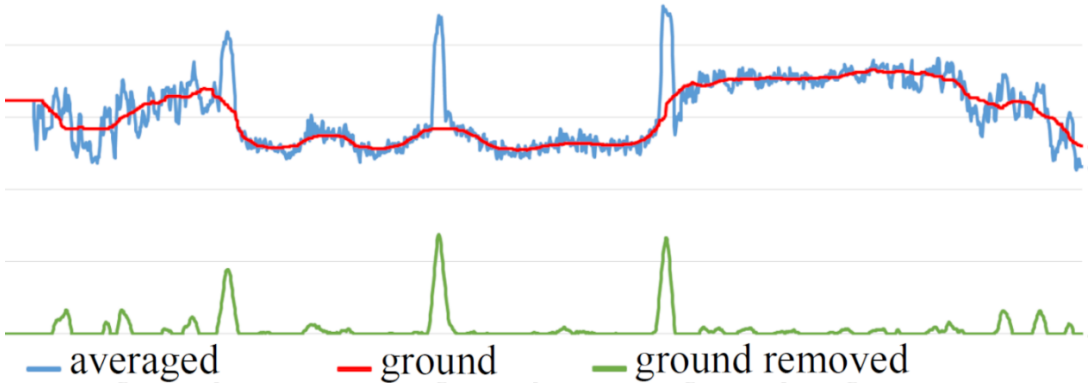
Parameter sensitivity analysis

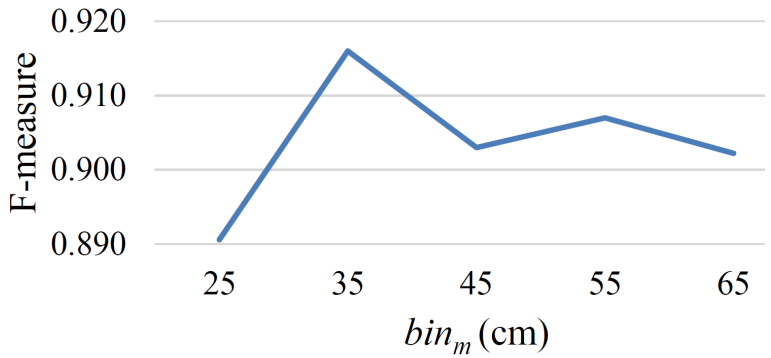


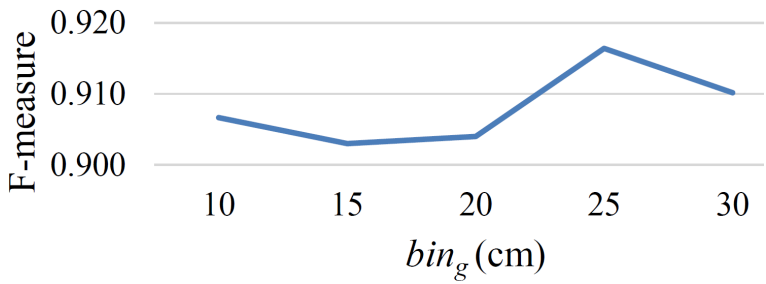


Results

Parameter sensitivity analysis

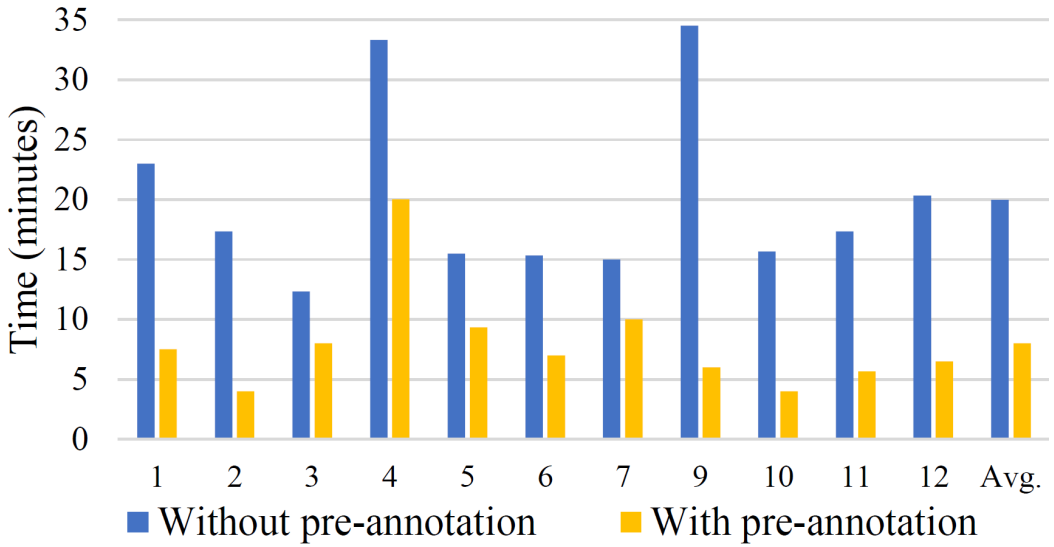






ε =5 cm

Results



without pre-annotation: 20 min
with pre-annotation: 8 min
60% reduction
Computation time: 1min

Conclusions and future work

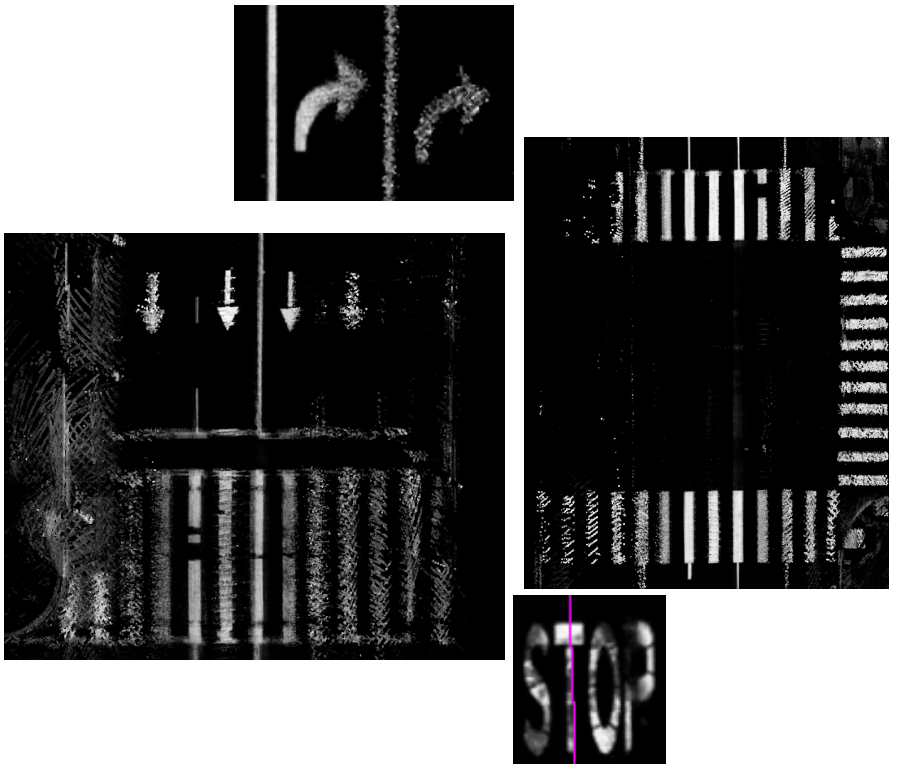
1. Conclusions
2. Future work

Conclusions

- Collection, preprocessing and preparation of the LIDAR data.
- Contributions to the development of a Web-based annotation system.
- Implementation of a computational pipeline for the detection of the line markings with LIDAR data.
- Implementation of an evaluation methodology focused on the precise positioning of the lines.
- Validation experiments showed a reduction of 60% in the time required for manual annotation.

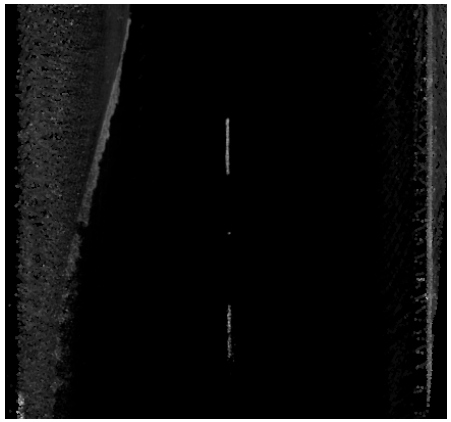
Future work

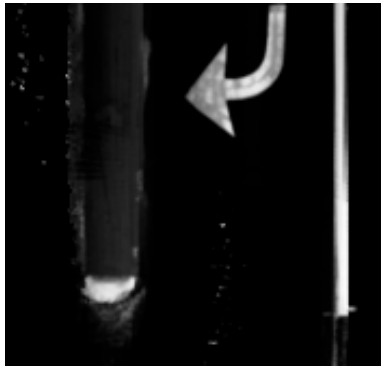
- Detect other road markings



Future work

- Detect other road markings
- Detect road edges





Future work

- Detect other road markings
- Detect road edges
- Improve LIDAR extrinsic parameters

Future work

- Detect other road markings
- Detect road edges
- Improve LIDAR extrinsic parameters
- Combine LIDAR with cameras

Wikipedia

vicomtech
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

¡MUCHAS GRACIAS!