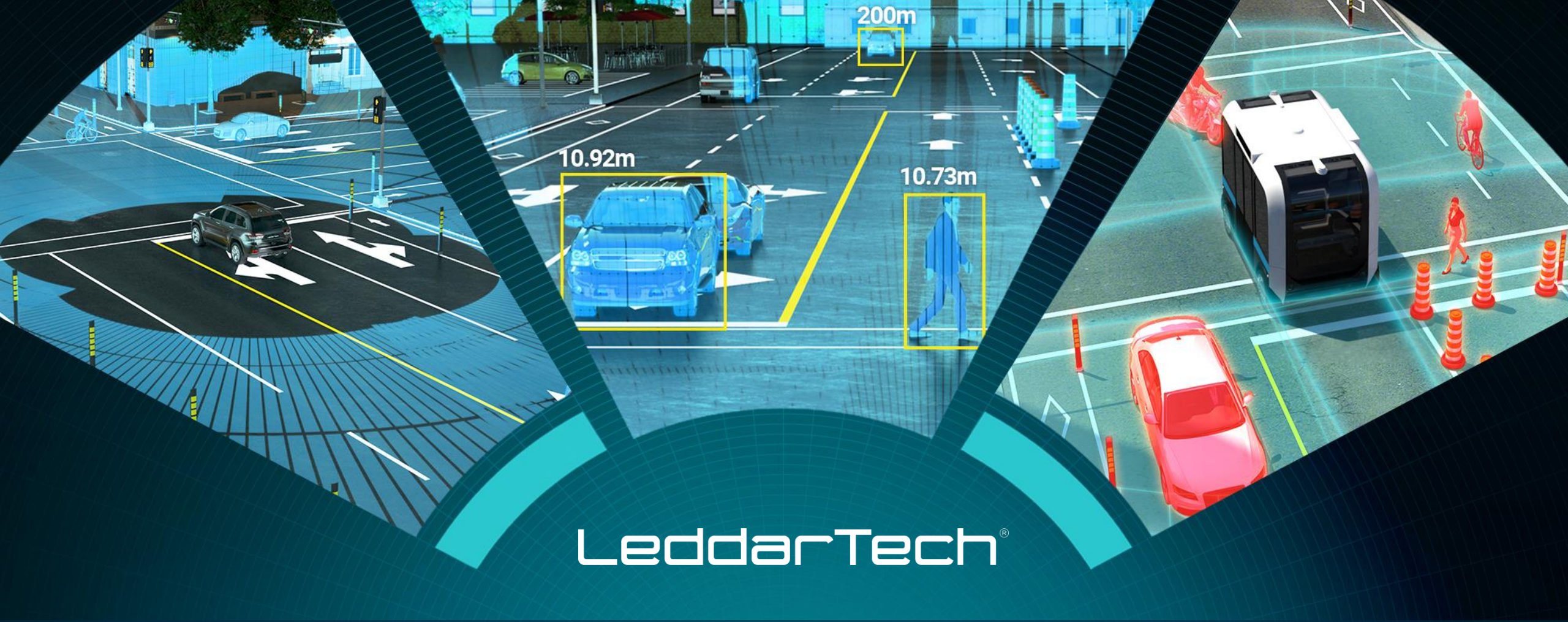



LeddarTech®

# VayaVision Technology

January 2021

Template/Gabarit Document ID: FT-006808 v04 3400P-W04-R02

# Agenda



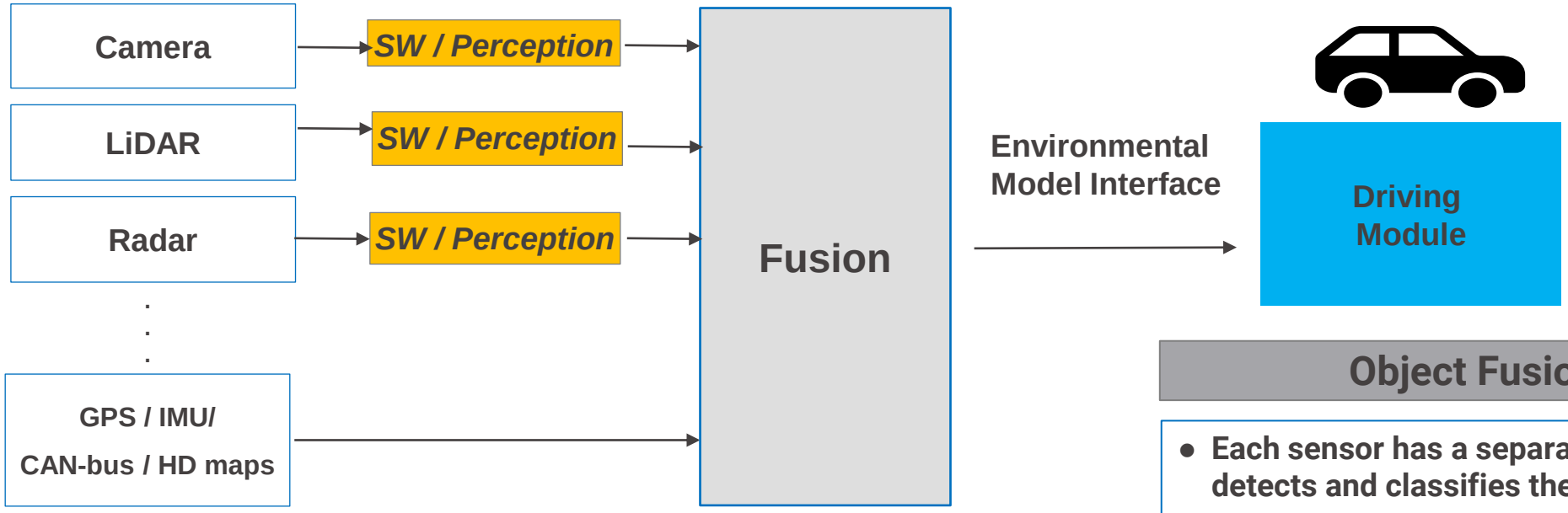
- Raw data fusion vs. object level fusion
- Supported use cases
- Benchmarks and KPIs

# Raw data fusion vs. Object level fusion

# Two Approaches to Sensor Fusion: *Object Fusion*



## Object Fusion Architecture



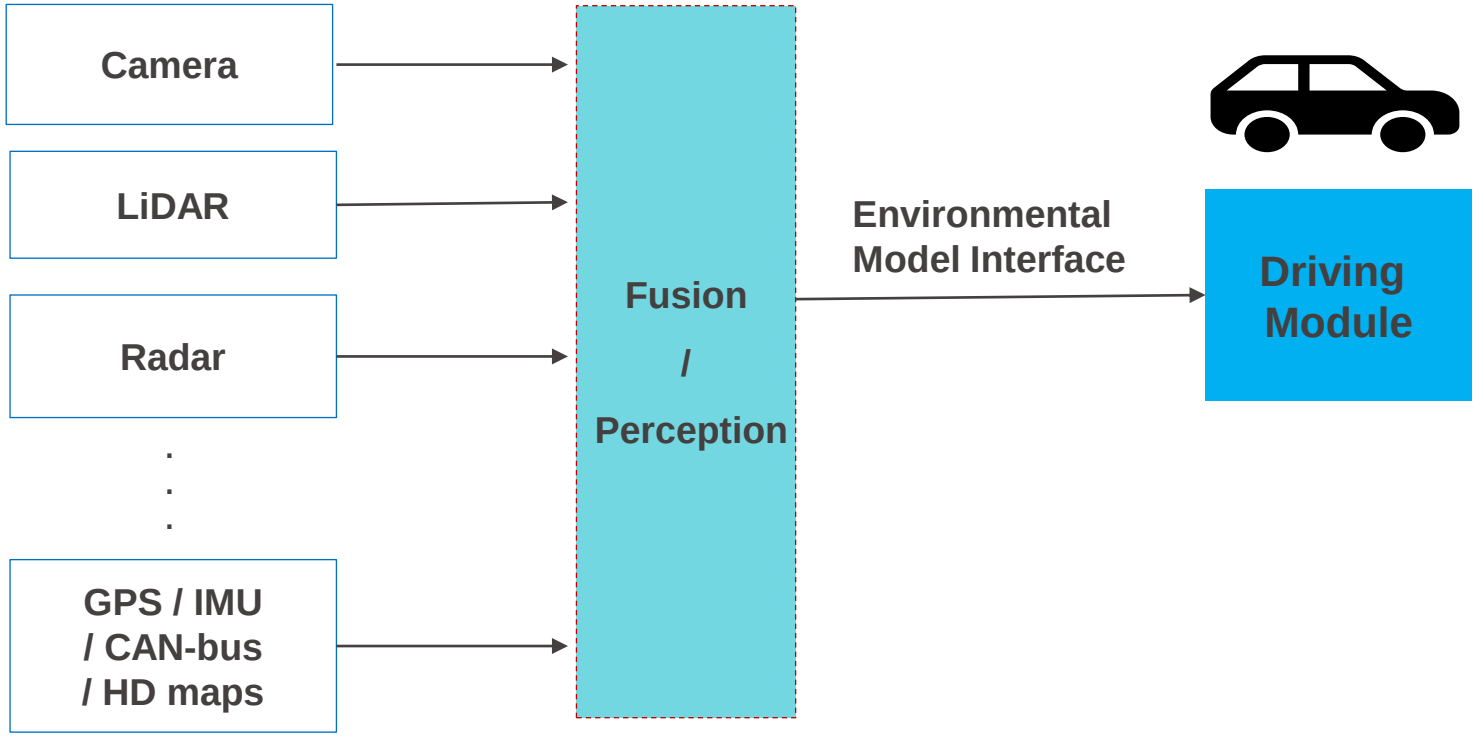

## Object Fusion Key Features

- Each sensor has a separate “cognition engine” which detects and classifies the scene.
- The output from each sensor is then integrated, or fused, into a coherent model, called the “environmental model”.

- Performance is not sufficient in terms of safety and driving comfort (too many missed detections and numerous false positives).
- Current cost structure of self-driving car platforms shows that this approach is inadequate for large-scale commercialization.

# Two Approaches to Sensor Fusion: *Raw Sensor Fusion*

## Raw Data Fusion Architecture




## Raw Data Fusion Key Features

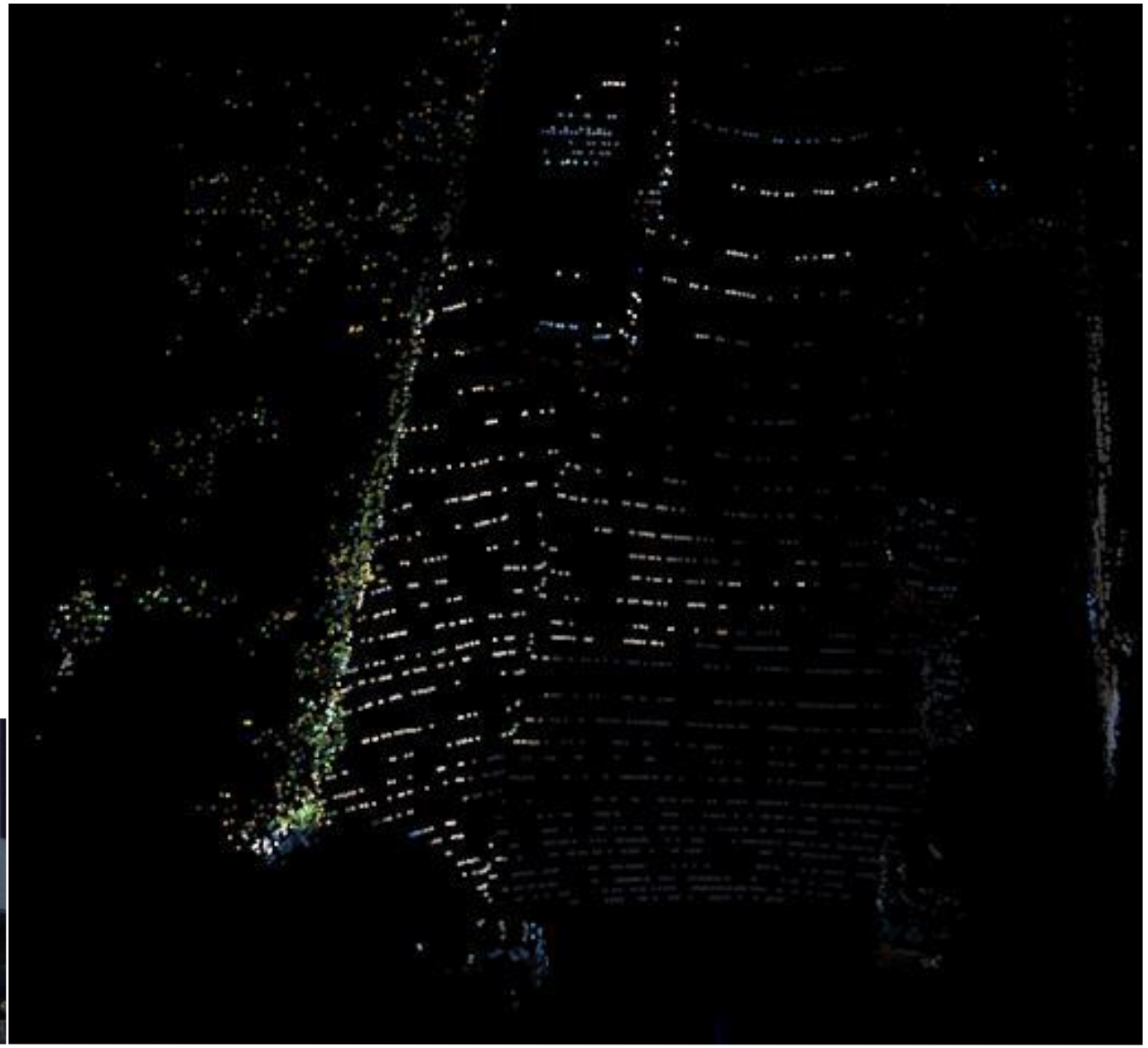
- Raw data from sensors is fused together.
- Detection and classification algorithms then run on the fused model rather than each sensor separately.
- Functional safety can improve if done properly.

- Model is richer and more robust with less false positives, as each sensor's advantages complement the other's.
- Lower cost structure due to a leaner architecture and savings on 3D sensors and on-sensor processors

# Object Fusion



- **Object fusion is limited by the individual sensor's inherent characteristics.**
- **Data can't be added back once it's been filtered by the individual perception engines.**



# Raw Data Fusion



- Raw data fusion combines the individual sensor's data into a fused, high-resolution RGBD 3D model using patented algorithms.
- Perception can then be accomplished on this high-quality 3D model.

# 3D HD Model


RGB
Car
Car
Car
RGBD
Car
Car

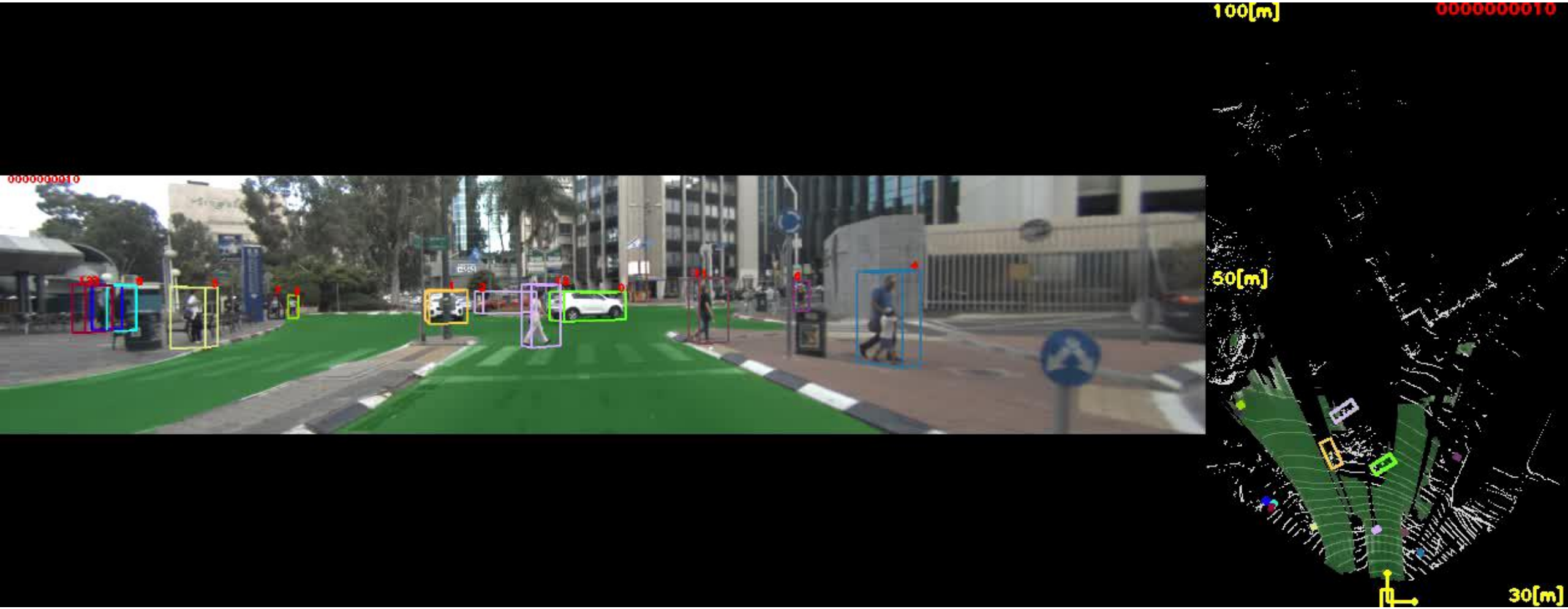
# Lane Detection and Segmentation




- Polynomial fitting
- Lane line classification: full, doted, yellow, white, double, etc…
- Bird-eye-view projection

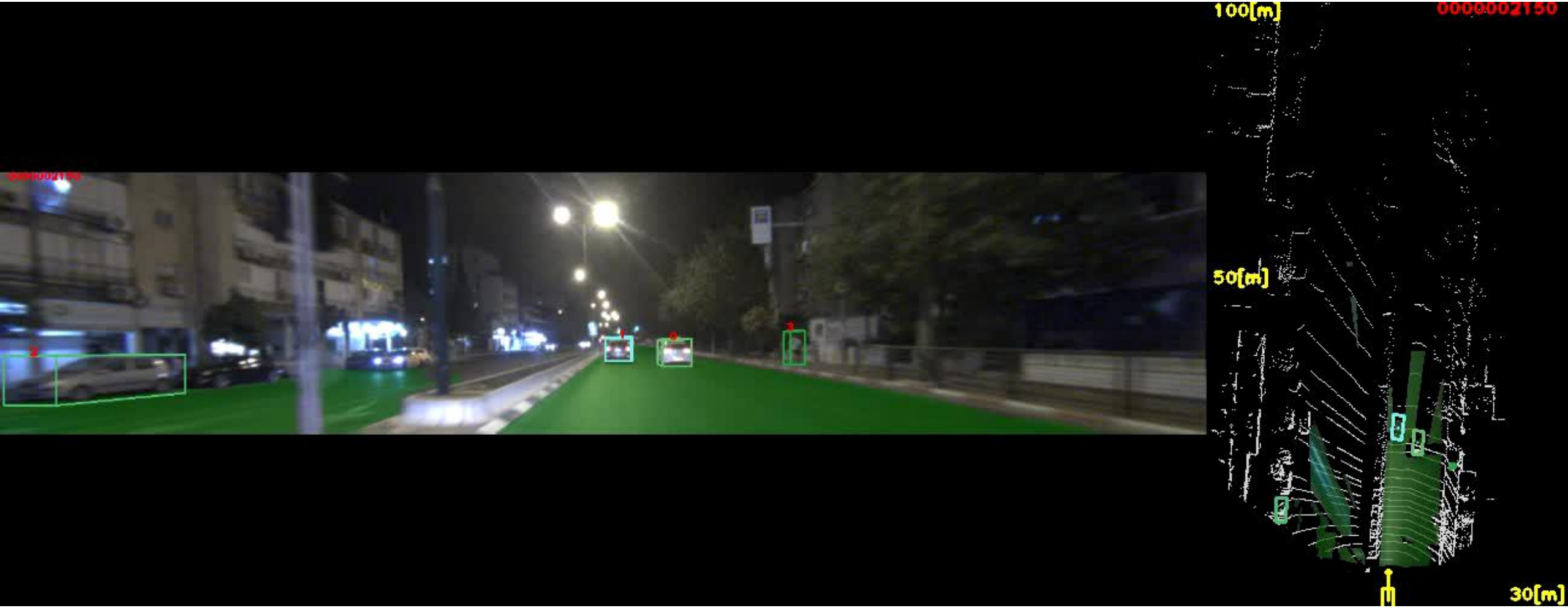
**Internal dataset**
**Camera, LiDAR – Velodyne 32**

# Supported use cases


0000000010
100[m]
0000000010
50[m]
30[m]


32: Car
49.4m
100%
kM/H
3: Ground
4: Obj
5: Lidar
6: UpSample
7: Segmentation
I: Obj Info
frame 897
0: Camera Coords
1: OB img
2: BEV img
3: arrow
4: max_dist:100


100[m]
0000000320
50[m]
30[m]



# Unidentified Obstacle Detection

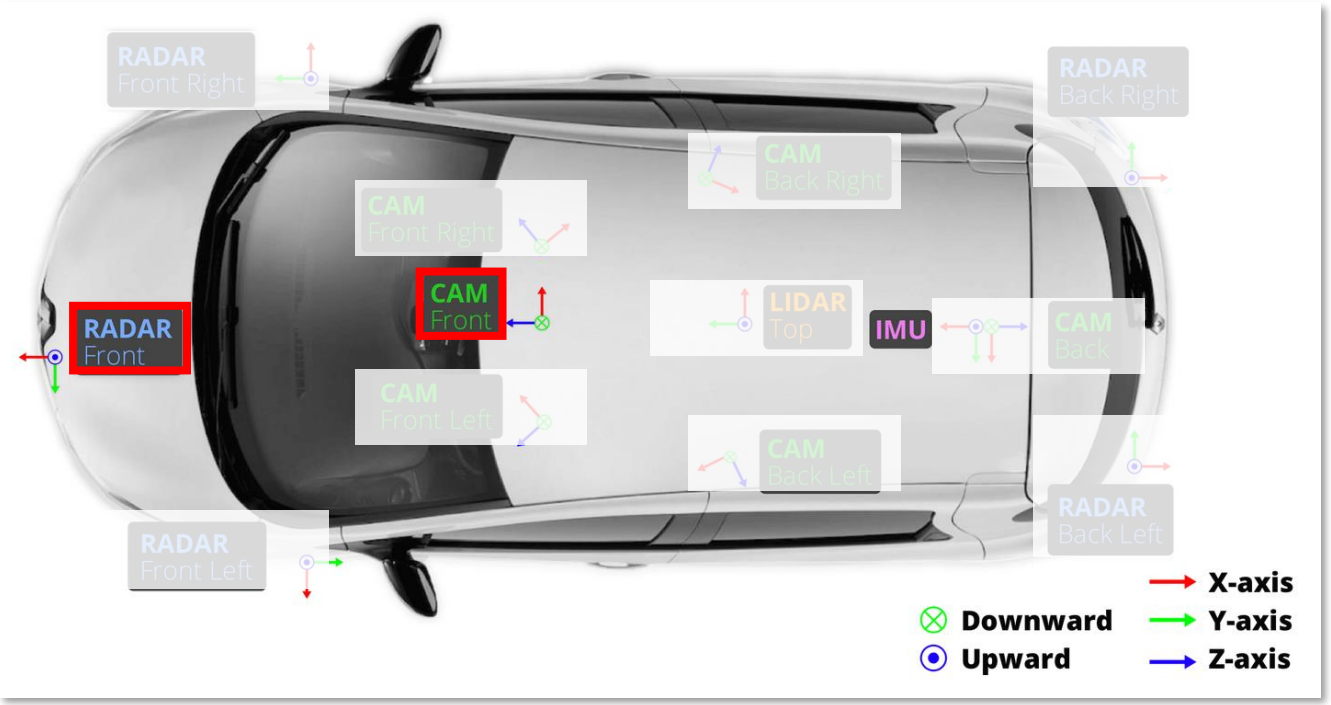


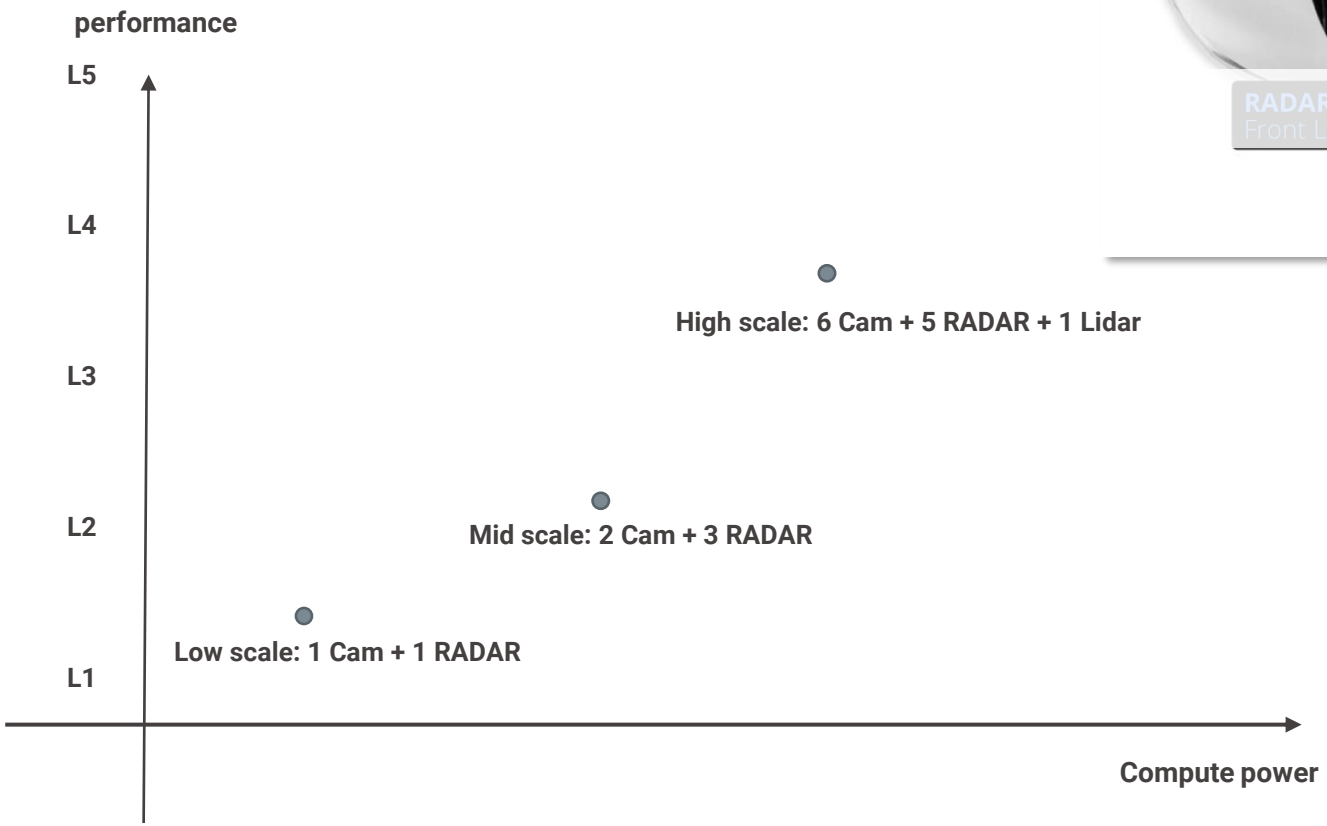

**Internal dataset**
**Camera, LiDAR – Velodyne 32**

# Scalability

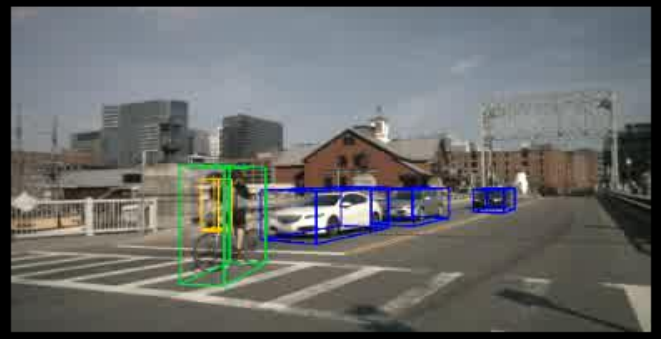


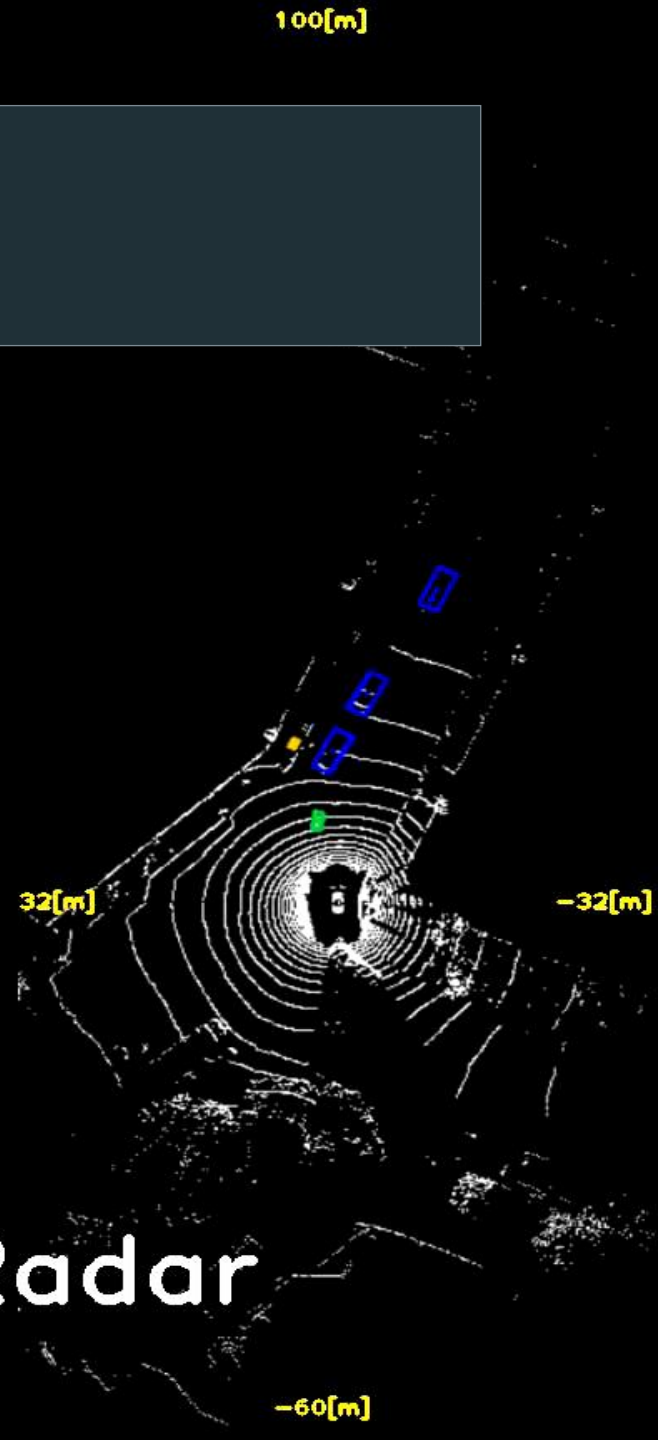
One SW architecture HW independent
One training set format
Unified network infrastructure
Single verification process
Supporting Multiple ECUs and sensors



1 Cam + 1 RADAR






Only with Front Camera and Radar

# 360 Perception

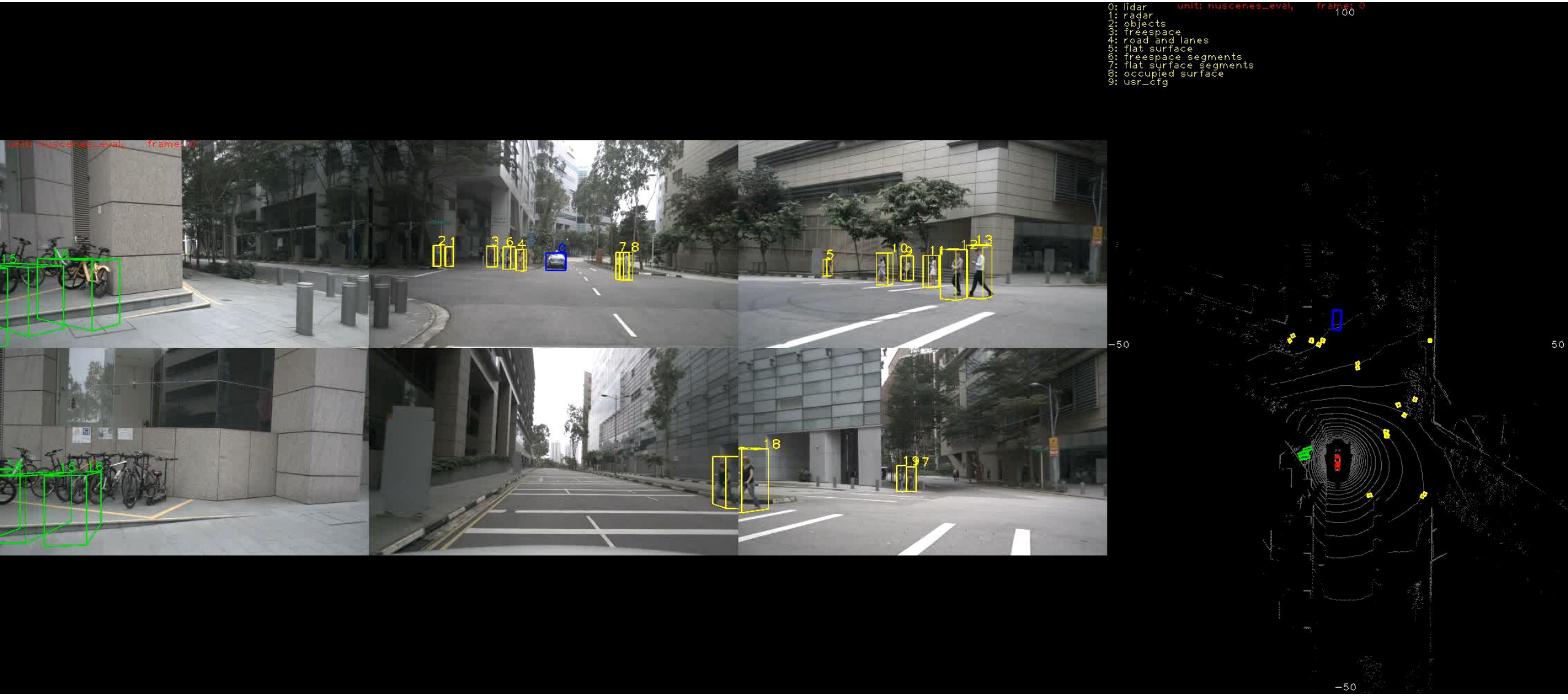
## 6 Camera + 5 radars


- LiDAR free perception SW
- Detection, classification, tracking
- 3D bounding boxes
- Position, orientation, velocity
- Multiple sensor support
- Real-time

**Nuscenes dataset**
**6 Cameras, 5 radars**

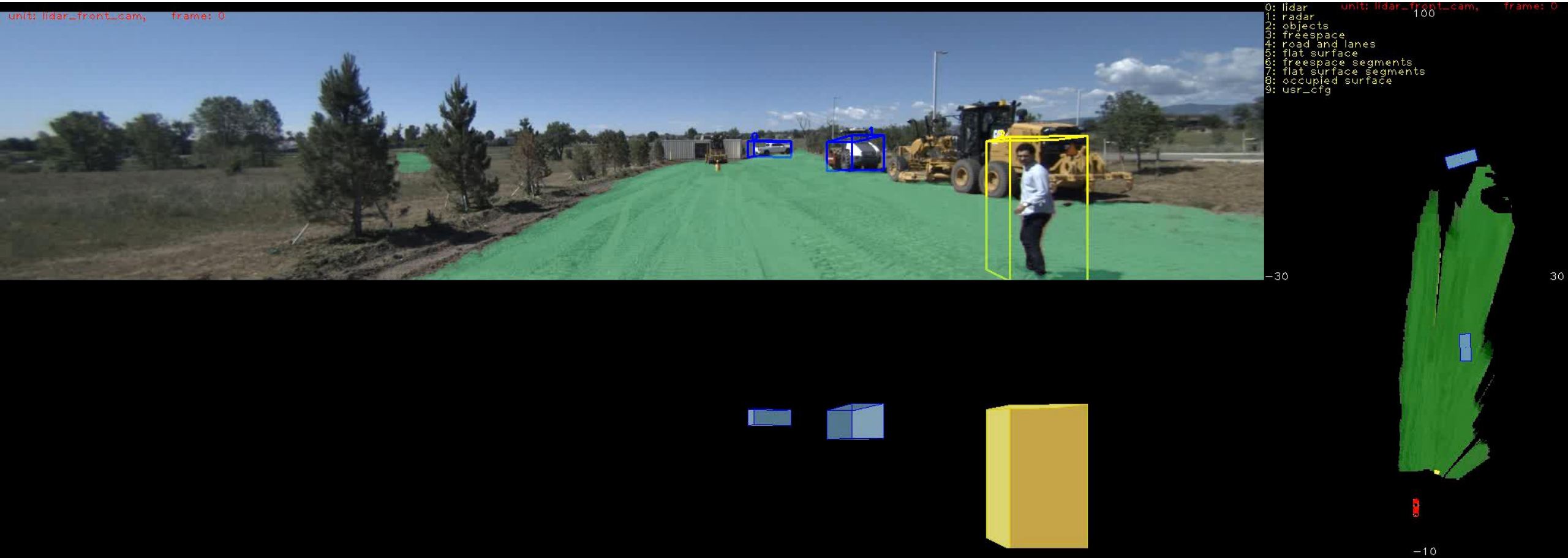
# 360 Perception

## 6 Cameras 5 radars 1 Lidar



# Off-road






- Object detection, classification, and tracking
- Off-road drivable area detection
- “Non-standard” sensor configuration
- Optimization for construction, agriculture, and mining environments

# Modular and scalable architecture

## Various use cases

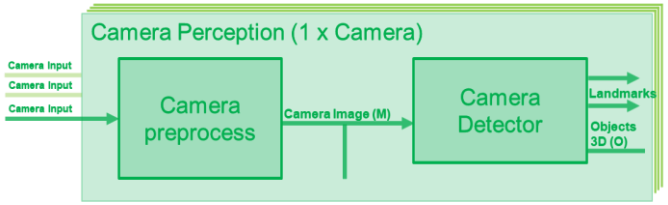
L4-L5 Mobility

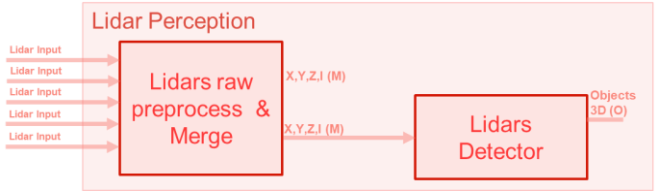
Off-Road
Construction
Agriculture
mining

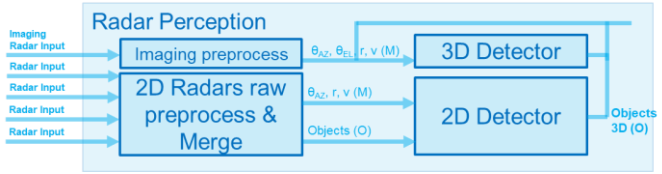
L2 ADAS

L3 AD


## Different sensor sets




## Building blocks


## Supporting all ADAS active safety systems

- Speed Assist Systems (ACC)
- Lane Support System (LKA)
- AEB
- Parking assistance

# Benchmarks and KPIs

# Public dataset results: Nuscenes

## 3D detections

### Camera, LiDAR, radar

| | Method | | | | | Metrics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Name | Modalities | Map data | External data | mAP | mATE (m) | mASE (1-IOU) | mAOE (rad) | mAVE (m/s) | mAAE (1-acc) | NDS | FPS (Hz) | Stats |
| > | 2020-05-26 | LRCF360 | Camera, Lidar, Radar | no | no | 0.541 | 0.350 | 0.261 | 0.543 | 0.394 | 0.133 | 0.603 | n/a | |

Top 3 real-time | highest mAP of comparable entries | Out of ~40 summations

**Nuscenes dataset**
**6 Cameras, 5 radars, 1LiDAR**

### Camera, radar

| | Method | | | | | Metrics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Name | Modalities | Map data | External data | mAP | mATE (m) | mASE (1-IOU) | mAOE (rad) | mAVE (m/s) | mAAE (1-acc) | NDS | FPS (Hz) | Stats |
| > | 2020-05-17 | RCF360 | Camera, Radar | no | no | 0.330 | 0.547 | 0.271 | 0.582 | 0.449 | 0.130 | 0.467 | n/a | |

Better than all camera-only | Better than many LiDAR

**Nuscenes dataset**
**6 Cameras, 5 radars**

### 2.1.1. VayaVision's Object 2D - AP results

*Average Precision*

| | 0 - 50[m] | 50 - 80[m] | 80 - 150[m] | 0 - 150[m] |
|---|---|---|---|---|
| Car | 0.92 | 0.68 | 0.58 | 0.9 |
| Truck | 0.89 | 0.53 | 0.26 | 0.78 |
| Bus | 0.8 | 0.7 | 0.43 | 0.83 |
| Pedestrian | 0.78 | 0.16 | 0.02 | 0.68 |
| Person_sitting | 0.67 | 0.02 | 0 | 0.57 |
| Cyclist | 0.79 | 0.19 | 0.04 | 0.53 |
| Biker | 0.81 | 0.39 | 0.16 | 0.73 |
| Human | 0.78 | 0.17 | 0.02 | 0.68 |
| Vehicle | 0.91 | 0.66 | 0.53 | 0.89 |

### 2.1.2. VayaVision's Object 2D Det on Tracker

2.1.2.1. Tracking

*Recall*

| | 0 - 50[m] | 50 - 80[m] | 80 - 150[m] | 0 - 150[m] |
|---|---|---|---|---|
| Car | 95.45 | 85.9 | 49.89 | 84.81 |
| Truck | 87.64 | 78.98 | 48.65 | 72.78 |
| Bus | 87.63 | 89.51 | 67.77 | 84.95 |
| Pedestrian | 78.12 | 24.49 | 5.71 | 64.63 |
| Person_sitting | 68.52 | 7.14 | 0 | 55.53 |
| Cyclist | 86.26 | 10 | 4.42 | 53.67 |
| Biker | 81.23 | 52 | 14.84 | 69.66 |
| Human | 78.19 | 25.32 | 6.01 | 64.62 |
| Vehicle | 94.58 | 85.47 | 50.23 | 83.81 |

*Precision*

| | 0 - 50[m] | 50 - 80[m] | 80 - 150[m] | 0 - 150[m] |
|---|---|---|---|---|
| Car | 97.16 | 90.04 | 87.36 | 94.29 |
| Truck | 94.83 | 96.44 | 97.59 | 95.8 |
| Bus | 99.54 | 99.64 | 92.96 | 98.71 |
| Pedestrian | 88.2 | 55.74 | 43.43 | 84.91 |
| Person_sitting | 86.01 | 100 | nan | 86.12 |
| Cyclist | 93.33 | 75 | 100 | 93.14 |
| Biker | 83.9 | 80 | 47.92 | 82.01 |
| Human | 88.05 | 57.09 | 44.54 | 84.86 |
| Vehicle | 97.11 | 90.73 | 88.85 | 94.56 |

*FA Rate*

| | 0 - 50[m] | 50 - 80[m] | 80 - 150[m] | 0 - 150[m] |
|---|---|---|---|---|
| Car | 0.0839 | 0.1108 | 0.0687 | 0.2634 |
| Truck | 0.0107 | 0.0029 | 0.002 | 0.0156 |
| Bus | 0.0006 | 0.0001 | 0.0017 | 0.0025 |
| Pedestrian | 0.3696 | 0.1257 | 0.0274 | 0.5227 |
| Person_sitting | 0.0042 | 0 | 0 | 0.0042 |
| Cyclist | 0.0016 | 0.0001 | 0 | 0.0017 |
| Biker | 0.0199 | 0.0032 | 0.0031 | 0.0261 |
| Human | 0.3952 | 0.129 | 0.0305 | 0.5547 |
| Vehicle | 0.0952 | 0.1138 | 0.0724 | 0.2815 |

# VayaVision Evaluation Report

**VayaVision**

Version : Branch - develop

Date : 16-08-20

## 1. External DataSet

### 1.1. nuScenes

#### 1.1.1. nuScenes Object 3D Detection and Tracking Challenge

Total GT Frames: 799

Total GT Objects: 2991

1.1.1.1. Detection

***nuScenes Full Results***

| | AP | ATE | ASE | AOE | AVE | AAE | GT |
|---|---|---|---|---|---|---|---|
| Car | 0.54 | 0.33 | 0.18 | 0.44 | 1.92 | 0 | 1176 |
| Truck | 0.21 | 0.47 | 0.23 | 0.18 | 0.42 | 0 | 341 |
| Bus | 0.42 | 0.39 | 0.16 | 0.86 | 1.64 | 0 | 138 |
| Pedestrian | 0.64 | 0.14 | 0.33 | 1.21 | 0.59 | 0 | 852 |
| Person_sitting | 0.16 | 0.43 | 0.42 | 1.54 | 0.16 | 0 | 128 |
| Cyclist | 0.64 | 0.43 | 0.32 | 0.38 | 3.99 | 0 | 39 |
| Biker | 0.4 | 0.46 | 0.26 | 0.13 | 3.28 | 0 | 16 |
| Misc | 0.14 | 0.24 | 0.35 | 1.09 | 0.08 | 0 | 301 |
| Human | 0.58 | 0.16 | 0.33 | 1.16 | 0.76 | 0 | 1035 |

# Run time analysis



| Setup | | Run Time [ms] |
|---|---|---|
| # radars | # cameras | |
| 5 | 1 | 46.5 |
| 5 | 2 | 55.1 |
| 5 | 3 | 64.7 |
| 5 | 4 | 74.2 |
| 5 | 5 | 84.2 |
| 5 | 6 | 93.5 |

Nvidia 2080ti 16TOPS
half precision
img size: 800x288
BEV grid size: 512x512
X range: +- 51.2 [m]
Y range: +- 51.2 [m]
BEV res: 0.2 [m]

# Compute flexibility



**Platform agnostic, examples:**

- **Nvidia Xavier at 20 TOPS, 40W**
- **Renesas at 60 TOPS, 30W (available 2022)**

**LeddarTech Expands its Collaboration with Renesas to Accelerate Autonomous Driving and ADAS Development**

RENESAS R-Car Consortium

CANADA

USA

AUSTRIA

FRANCE

GERMANY

ISRAEL

ITALY

HONG KONG

CHINA

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