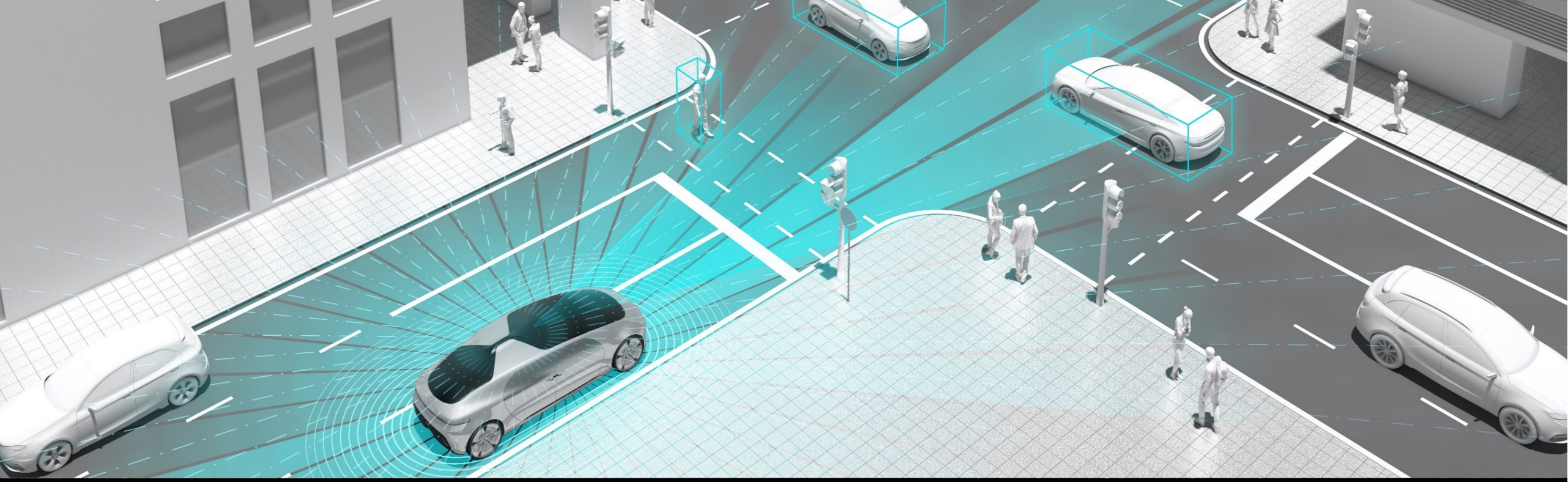


Percept and Understand Traffic – How to Build a Self-driving Vehicle

Fabian Flohr and Wilhelmus Kok, 17.02.2020

fabian.flohr@daimler.com

Credits to: Dr. Michael Hafner, Dr. Ulrich Kreßel, Markus Braun, Dr. Marius Cordts, Dr. Uwe Franke, Dr. Markus Enzweiler, Frank Preidel

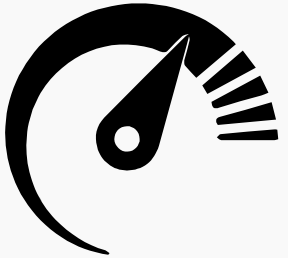
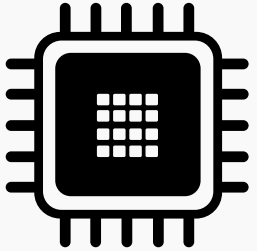
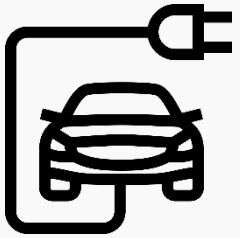
Mercedes-Benz
The best or nothing.

Intuitive Mobility – Shaping the Future

Mercedes-Benz

1 Motives

Different Reasons for Vehicle Automation

Improved Road Safety	Growing mobility needs & urbanization	Shared Mobility = Lower Traffic Density	Use Time more effectively	Maturity of Technology
				
Customer centered mobility = Comfort	**Seamless customer journeys**	**Max. connectivity of vehicle / services**	**Towards Zero Emissions**	**More affordable Transportation**
				

Mercedes-Benz has the Longest History in ADAS

1978 **ABS**
1980 Airbag, Belt Tensioner
1989 Automatic Rollover Bar
1995 **ESP®**, Sidebag
1996 Brake Assist System
1997 Sandwich Concept
1998 **Distronic** Windowbag, Adaptive Airbags
2000 Integral Safety Approach
2002 **PRE-SAFE®**
2003 Active Light Functions
2005 Adaptive Brake Lights, Brake Assist System BAS PLUS, NECK-PRO Head Restraint
2006 **PRE-SAFE® Brake**, Intelligent Light System
2007 **Blind Spot Assist**
2008 Active Park Assist
2009 Attention Assist, Adaptive Highbeam Assist, Lane Keeping Assist, Speed Limit Assist, Self-Adaptive Rear Belt Force Limiters
2010 Active Blind Spot Assist, Active Lane Keeping Assist
2011 **COLLISION PREVENTION ASSIST**, PRE-SAFE® Brake with City Braking Function, Night View Assist with Spotlight-Function
2012 360° Camera, Side Wind Assist by ESP®
2013 **Intelligent Drive**: DISTRONIC PLUS with Steering Assist and Stop&GoPilot, PRE-SAFE® Brake with Pedestrian Detection, BAS PLUS with Cross Traffic Assist, PRE-SAFE® PLUS, PRE-SAFE® Impulse, Beltbag, MAGIC BODY CONTROL, Adaptive Highbeam Assist Plus
2014 COLLISION PREVENTION ASSIST PLUS
2016/17/18 Intelligent Drive Next Level: Map enhanced Active Distance Assist DISTRONIC and Active Steering Assist, **Active Lane Change Assist**, Active Speed Limit Assist, **Active Emergency Stop Assist**, Active Brake Assist with Cross Traffic Function, **Evasive Steering Assist**, PRE-SAFE® Sound, **PRE-SAFE® Impulse Side**

AD - System scalability

Daimler Trucks

Mercedes-Benz Cars

Daimler Buses

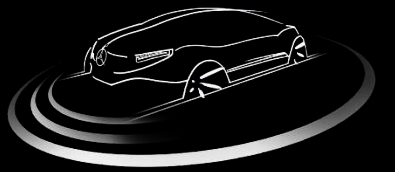
Mercedes-Benz Vans

Joint technology platform for all L4/L5 use cases:

- Synergies in SW, HW, processes, infrastructure
- Independent requirements gathering to ensure full suitability for each granular market
- Specific scope beyond platform optimized based on required market timing

We are able to scale our AD System across use-cases and regions

The Disruption Case Forms of On-Demand Mobility



Car Sharing
You are the driver

+ Flexible, no driver, affordable
- Limited coverage area, parking issues

Taxis / "Ubers"
Chauffeured

+ Versatile, convenient, anywhere
- Costly, needs driver

The Disruption Case Automated On-Demand Mobility

Car Sha You are the	**Robocabs** Self-driving	**/ "Ubers"** uffeured
+ Flexible, no driv - Limited coverage ar	Eventually the best of both worlds?	nvenient, anywhere needs driver

2
11:05 AM
3A
3B
1
11:04 AM
3
11:09 AM
4
11:25 AM

Truck logistics

There are a lot of Inefficiencies in Road Transportation Today

REST AREAS FULLY BOOKED

TRAFFIC JAMS

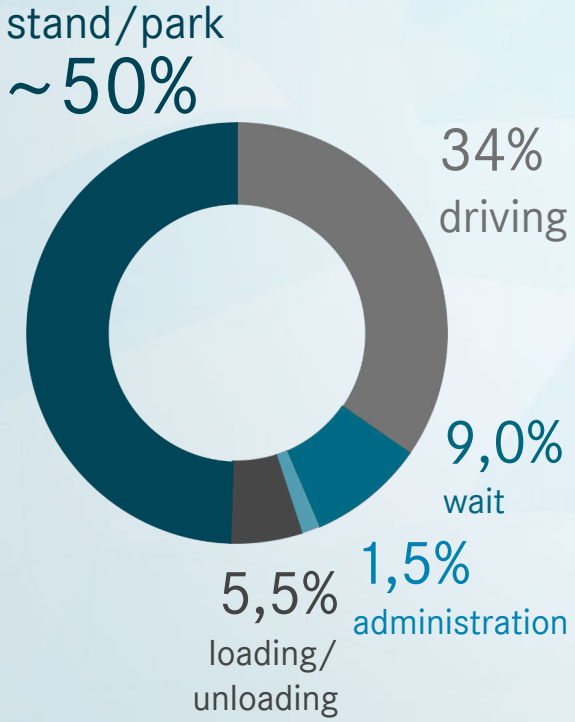
INEFFICIENCY IN CARGO TERMINALS

WAITING AT BORDER & CUSTOMS

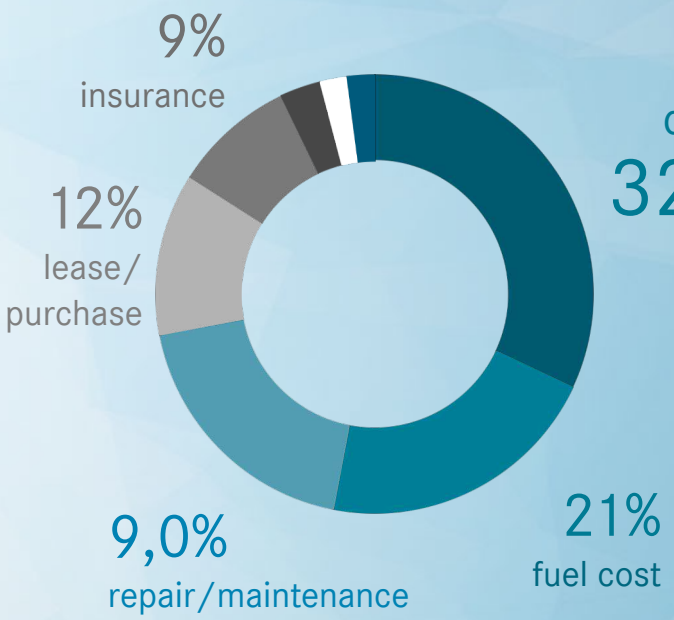
Logistics KPIs

Potentials for Automated Driving Example US Market

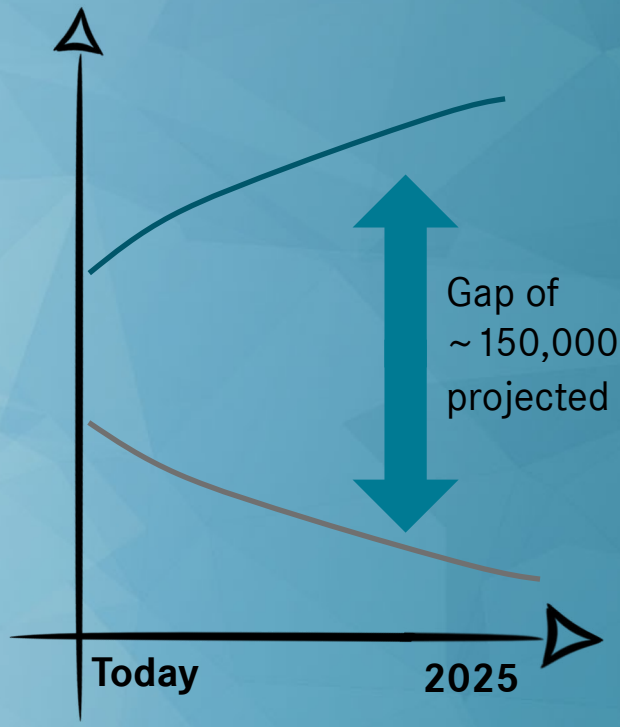
Time



Cost



Driver Shortage



Source: Daimler Trucks own research

Autonomous Driving for Transportation and Logistics

Safety
- Less accidents/fatalities
- Less work related injuries

Comfort
- Raised attractiveness of the job
- Less stress and work-related illness

Time
- Productive additional tasks
- Lower transport times

Profitability
- Higher Asset usage
- Optimized driving hours

Way Towards Autonomus Trucks

From Technology Research ...

Future Truck
World premiere of automated truck on the road

Inspiration Truck
Premiere on USA highway

Highway Pilot
Test licence for German Autobahn

Highway Pilot Connect
World premiere of platooning

Automated snow removal
Test operations with Fraport

2014 2015 2016 2017

Way Towards Autonomus Trucks

... to Technology in Production

Highway

Inner-City

Gated Areas

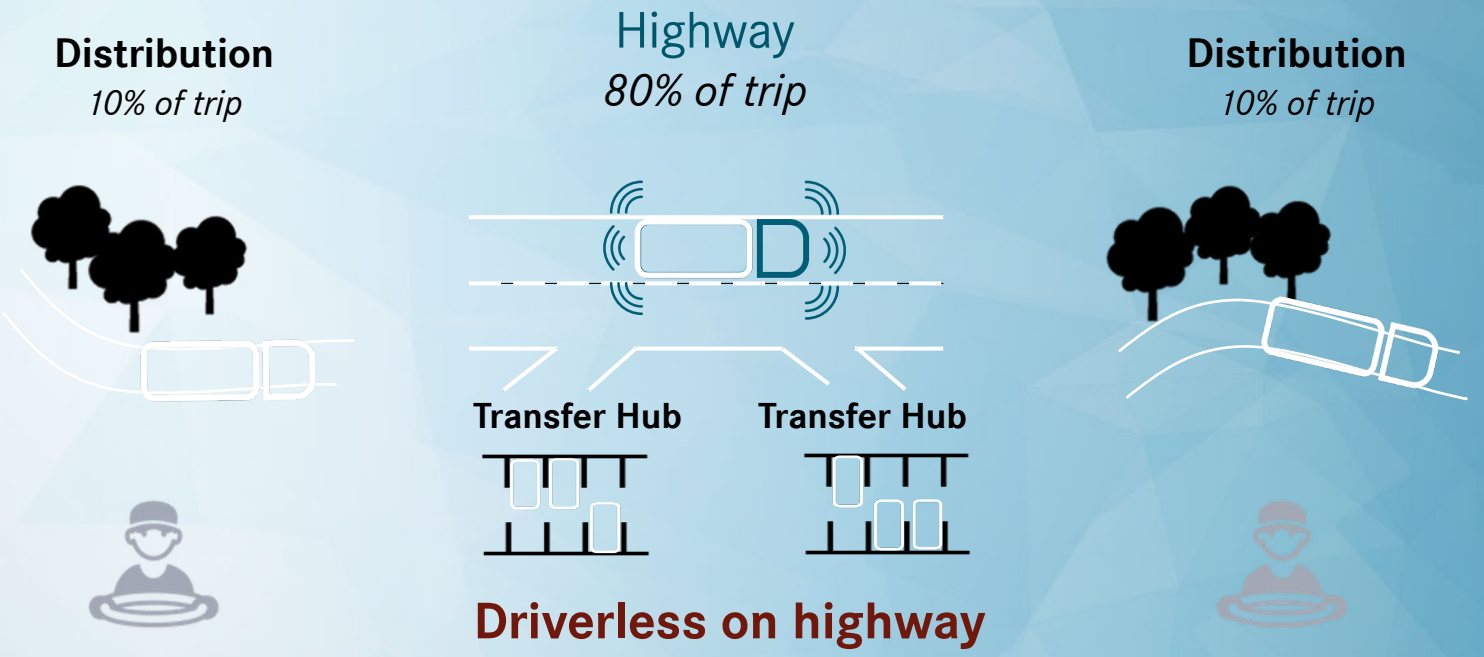
Rural

2019 2030 ff

Truck Focus on Highway Driverless to Reduce Complexity

First and Last Mile Still Operated by Driver

Level 4 MVP on Highway in the US



Future Bus Amsterdam

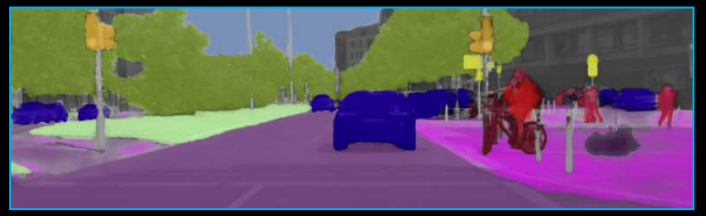
Autonomous Driving on Bus Rapid Transit

Mercedes-Benz

2 Safe Technology

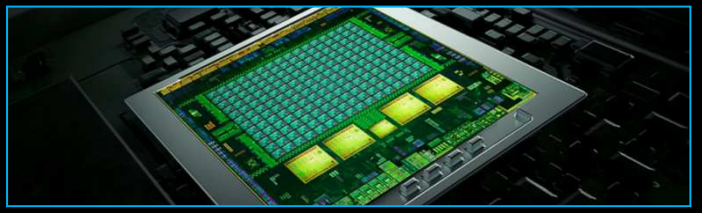
Vehicle Automation Components

Sensors



What an autonomous vehicle does not "see",
it is likely to drive into

Autonomous Vehicle "Brain"



Deciding which course of action is right
depending on the situation

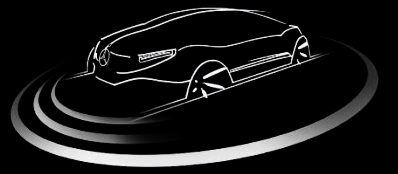
Backend

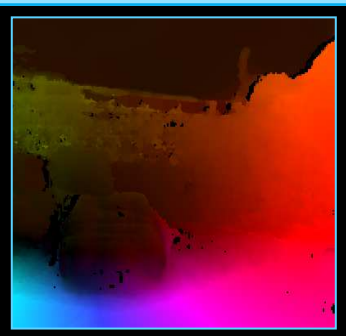
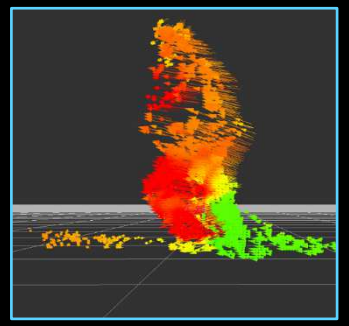
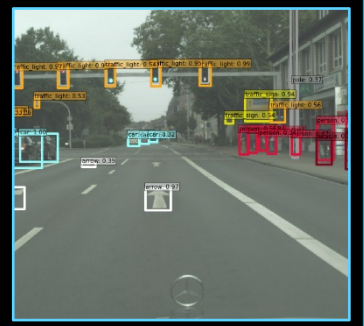
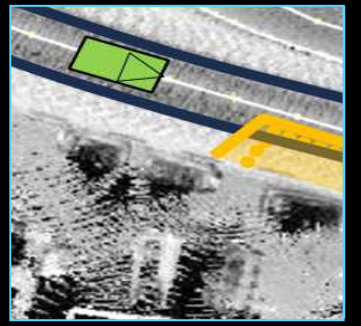
Data provisioning and collection
as well as operator commands

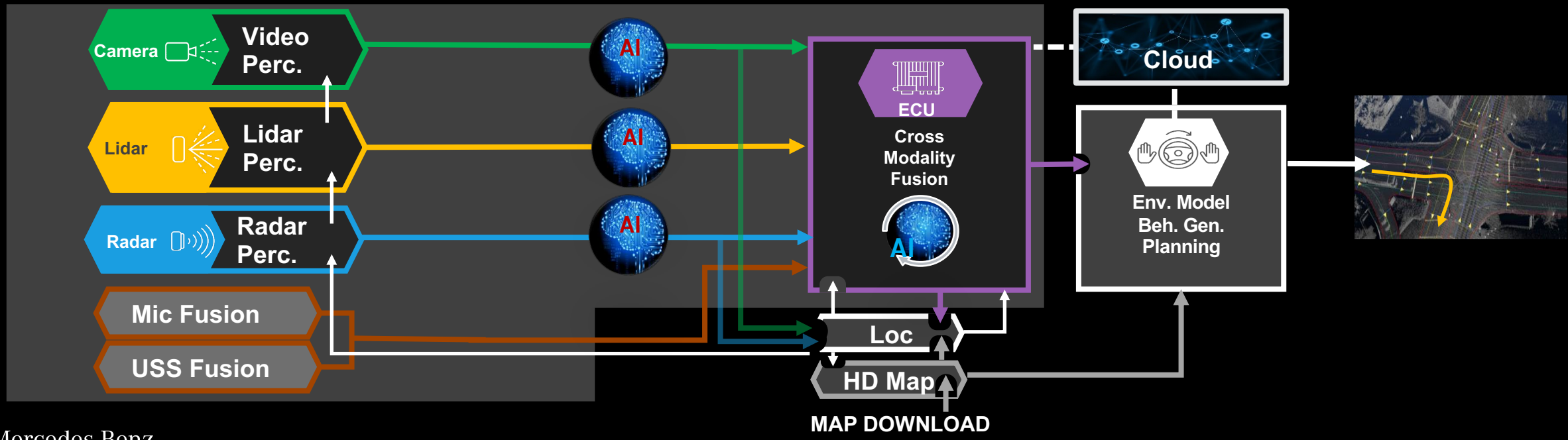
Redundant Actuators

Anything a driver would do
needs to be controlled electronically

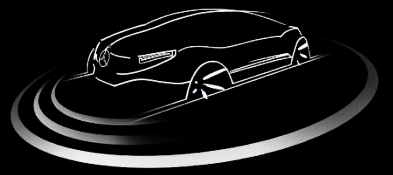
Artificial Intelligence (AI) is Key to understand Sensor Data

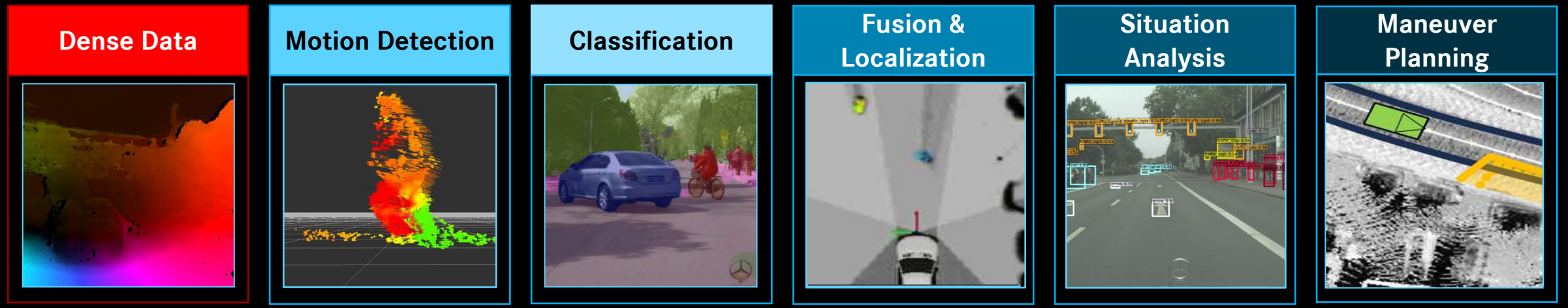


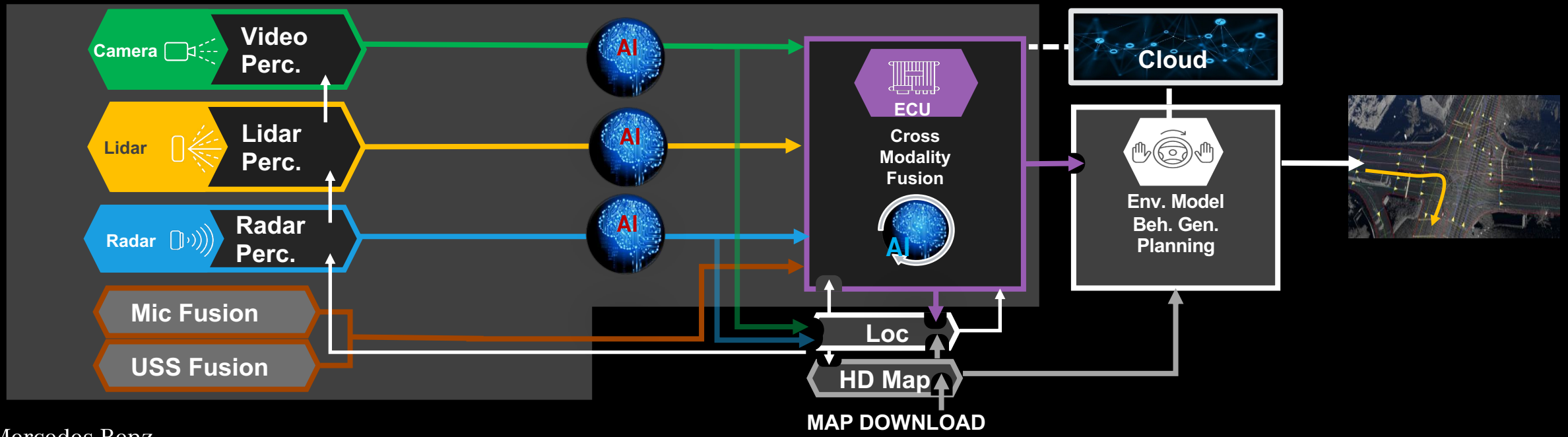
Dense Data	Motion Detection	Classification	Fusion & Localization	Situation Analysis	Maneuver Planning
					



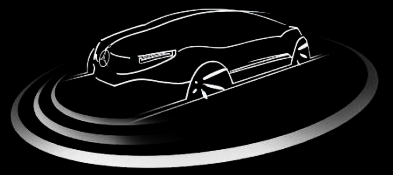
Artificial Intelligence (AI) is Key to understand Sensor Data

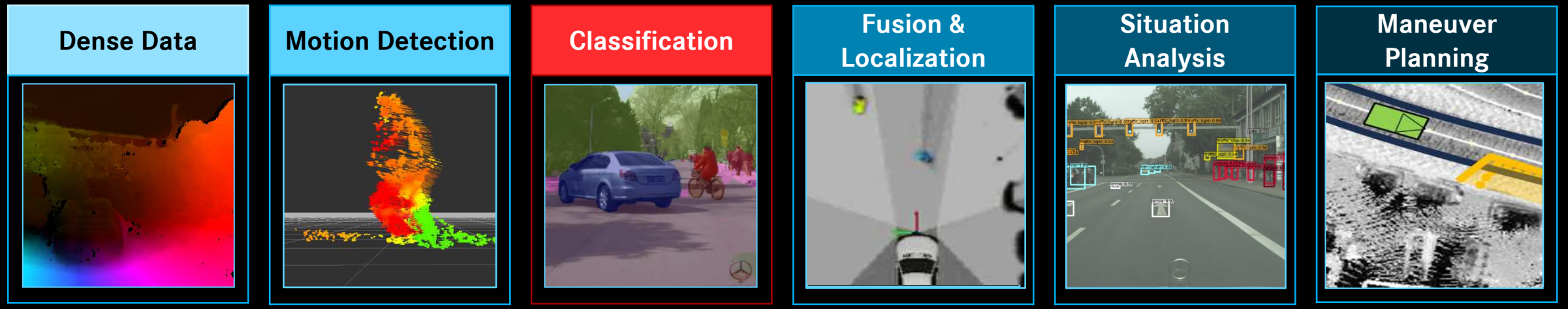


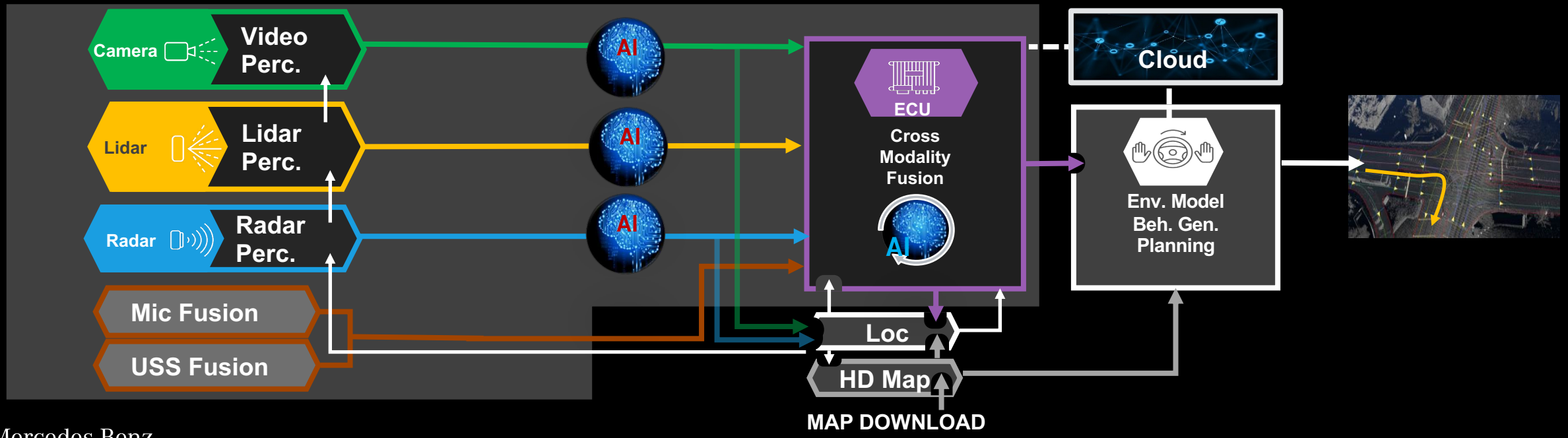




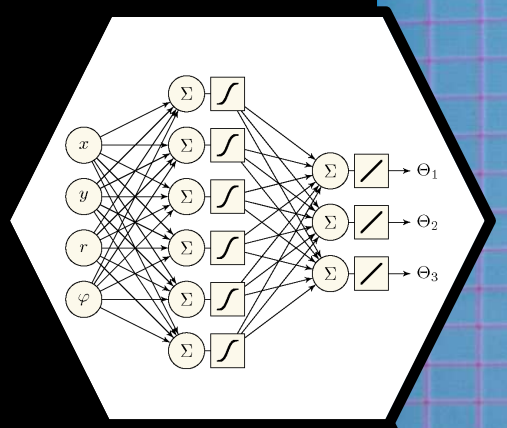
Artificial Intelligence (AI) is Key to understand Sensor Data



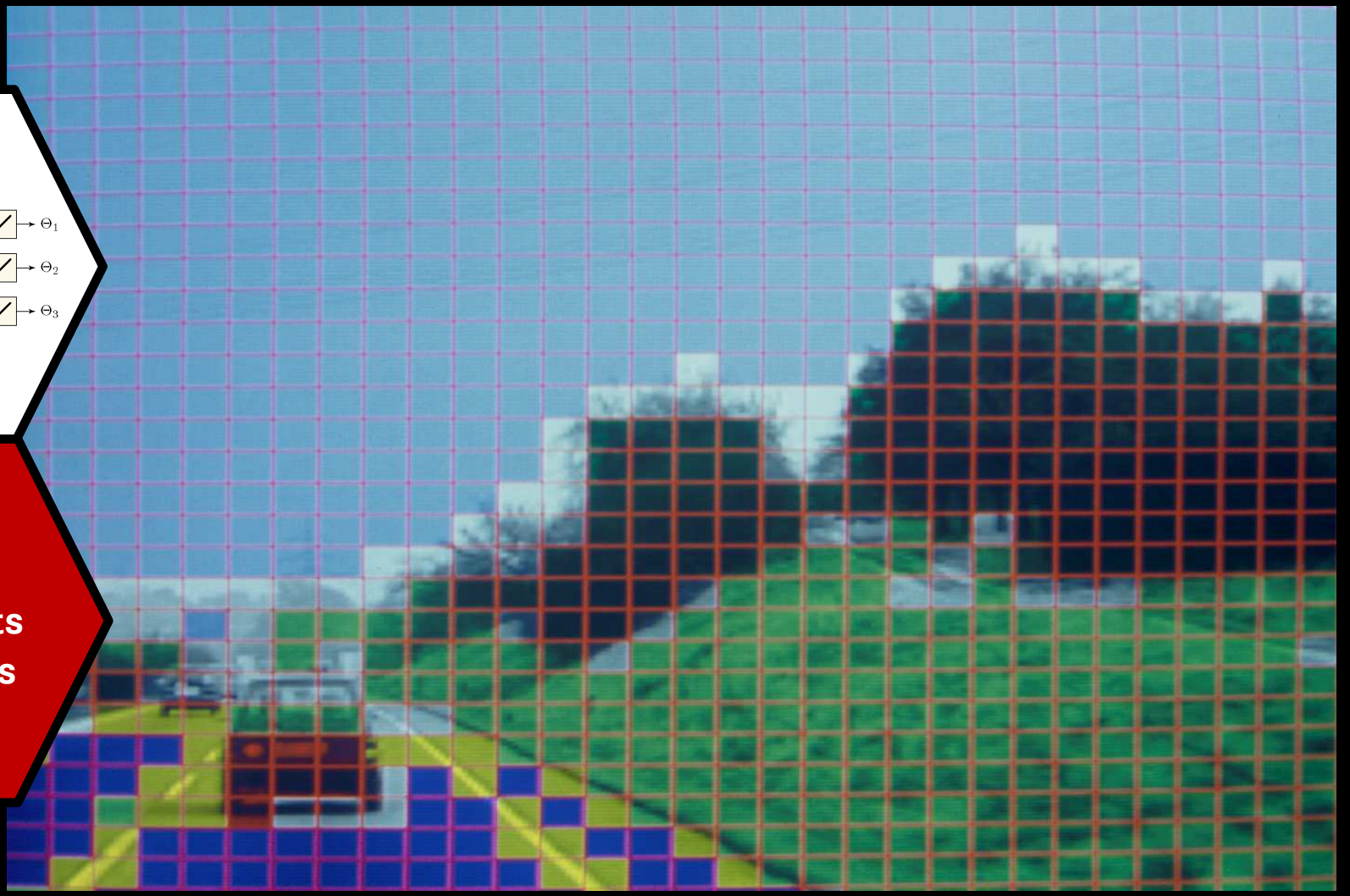




Shallow Neural Networks 1989

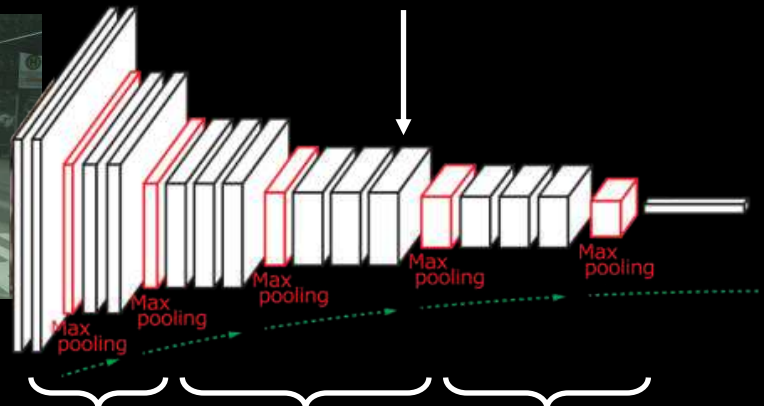


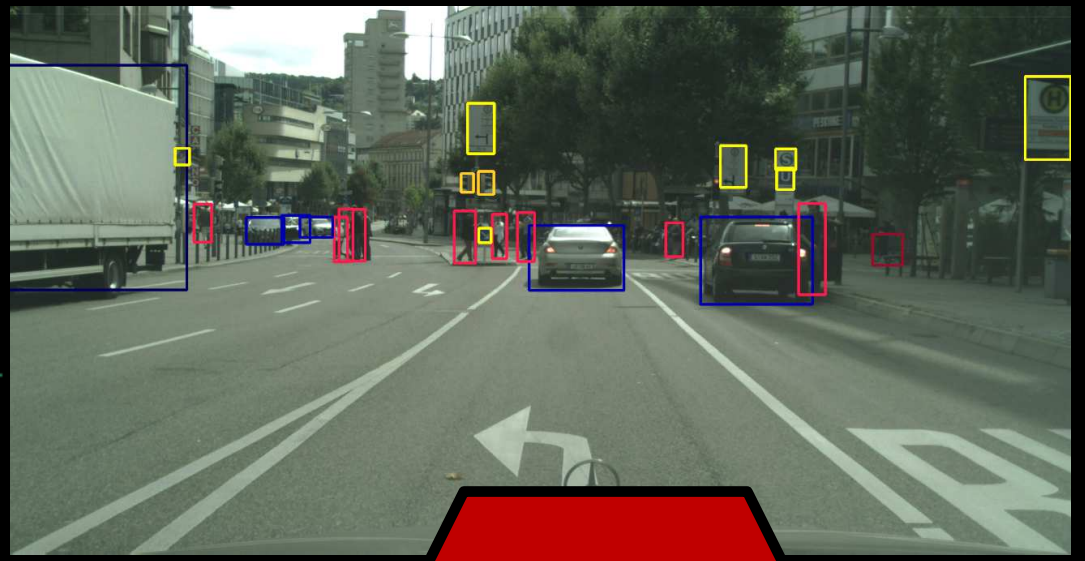
22 neurons
4.000 weights
1.000 images



Deep Neural Networks 2018

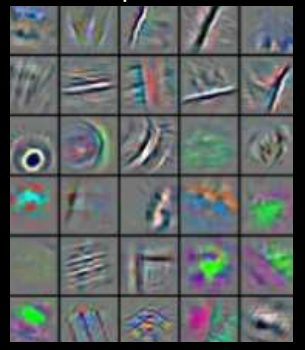
each **layer** computes one of a few simple mathematical operations that can be *highly parallelized* (GPUs)



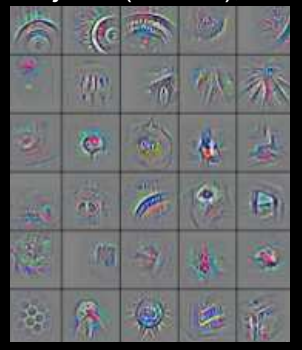


low-level features
first layers typically learn simple **edge-detection** and color filters

mid-level features
typically detect **simple shapes** like corners, circles, patterns, …



high-level features
complex shapes, parts of larger objects (wheels), …



24 Mio neurons
128 Mio weights
1 Mio images

Source: H.Noh et al., https://arxiv.org/abs/1505.04366

Feeding the Brain More Data

Cityscapes Dataset

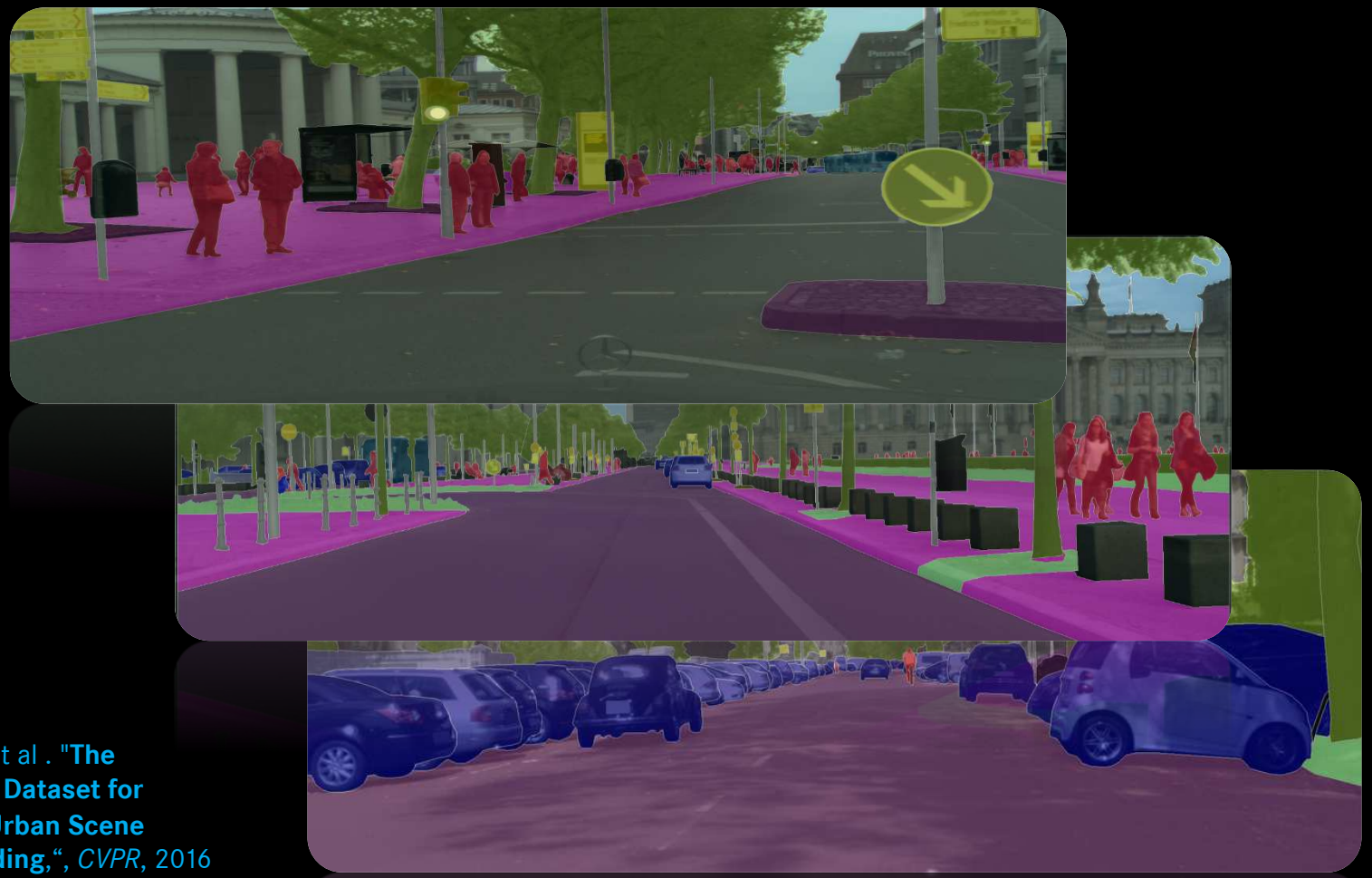
50 major German Cities

5000 precisely labeled frames

>4000 downloads

www.cityscapes-dataset.com

→ Universities/Experts can compare the performance of their CNNs



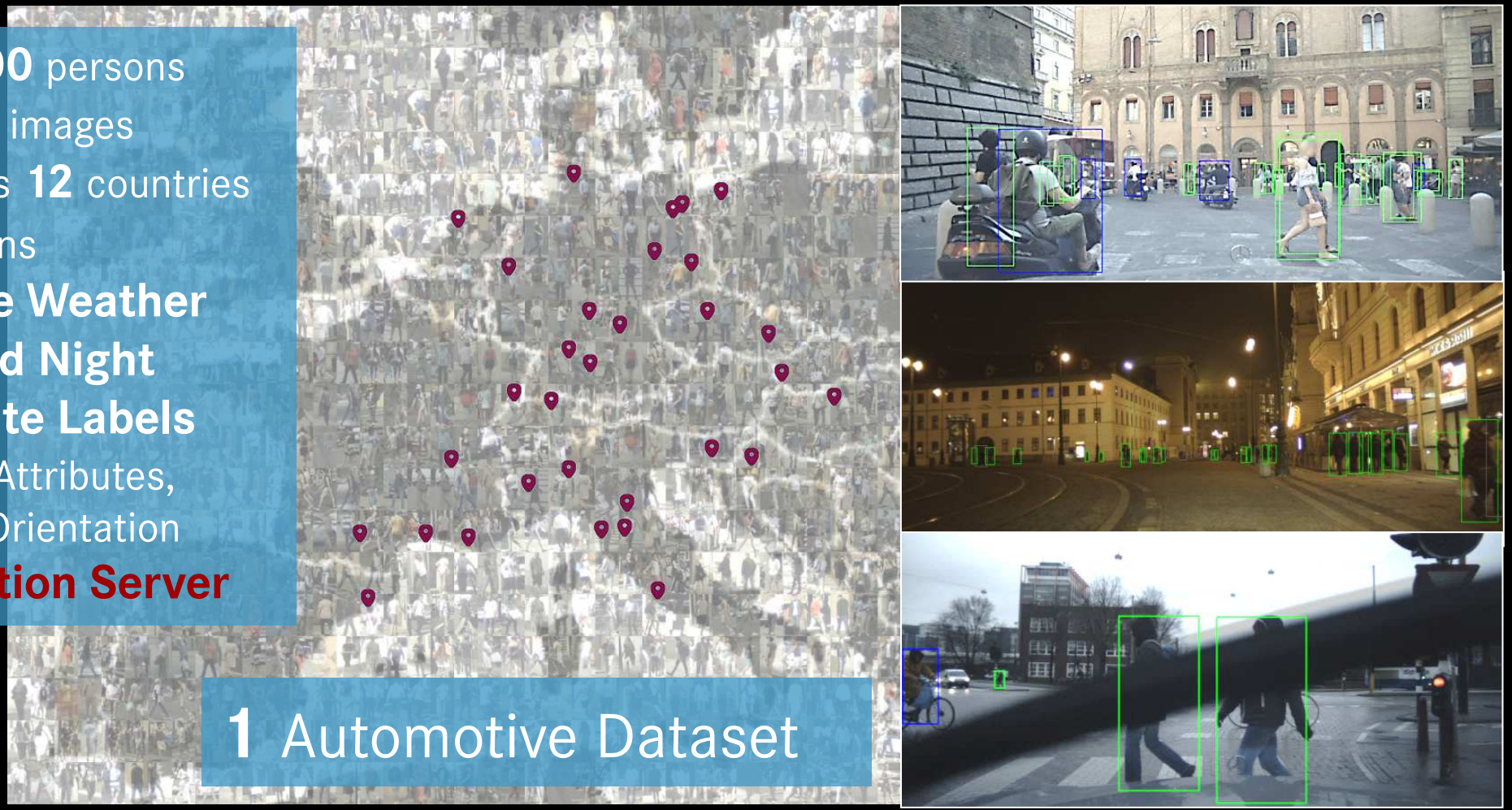
M. Cordts, et al . "**The Cityscapes Dataset for Semantic Urban Scene Understanding**,", *CVPR*, 2016

Neural Networks Today

Semantic Classification

Feeding the Brain More Data

The EuroCity Person Detection Dataset



238.200 persons
47.300 images
31 cities **12** countries
4 seasons
Diverse Weather
Day and Night
Accurate Labels
Class, Attributes,
Bbox, Orientation
Evaluation Server

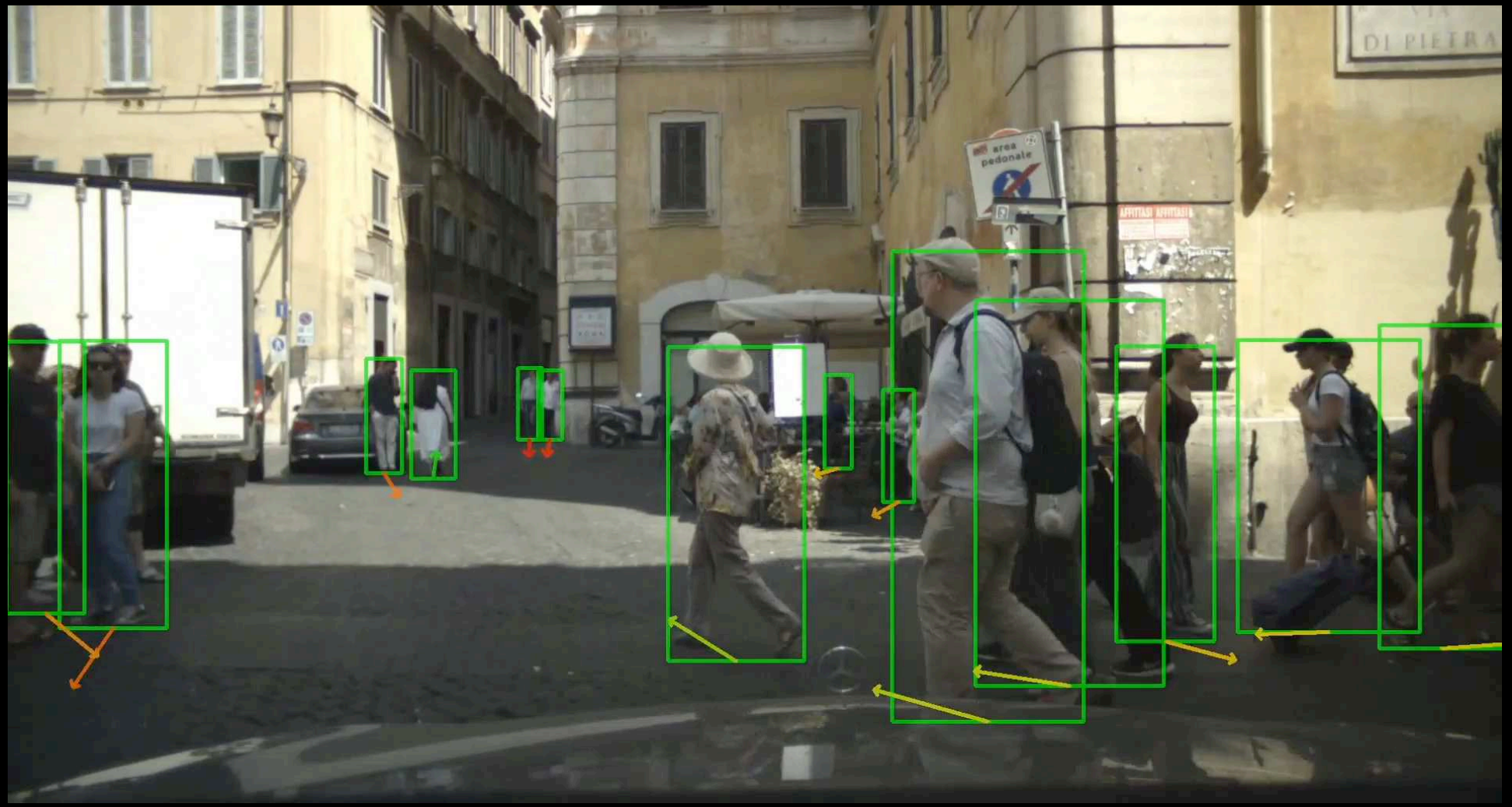
1 Automotive Dataset

TU Delft
Intelligent Vehicles Group (IV)

M. Braun, S. Krebs, F. Flohr, and D. M. Gavrila *"The EuroCity Persons Dataset: A novel benchmark for object detection"*, PAMI 2018

Using the Brain Instance Detection

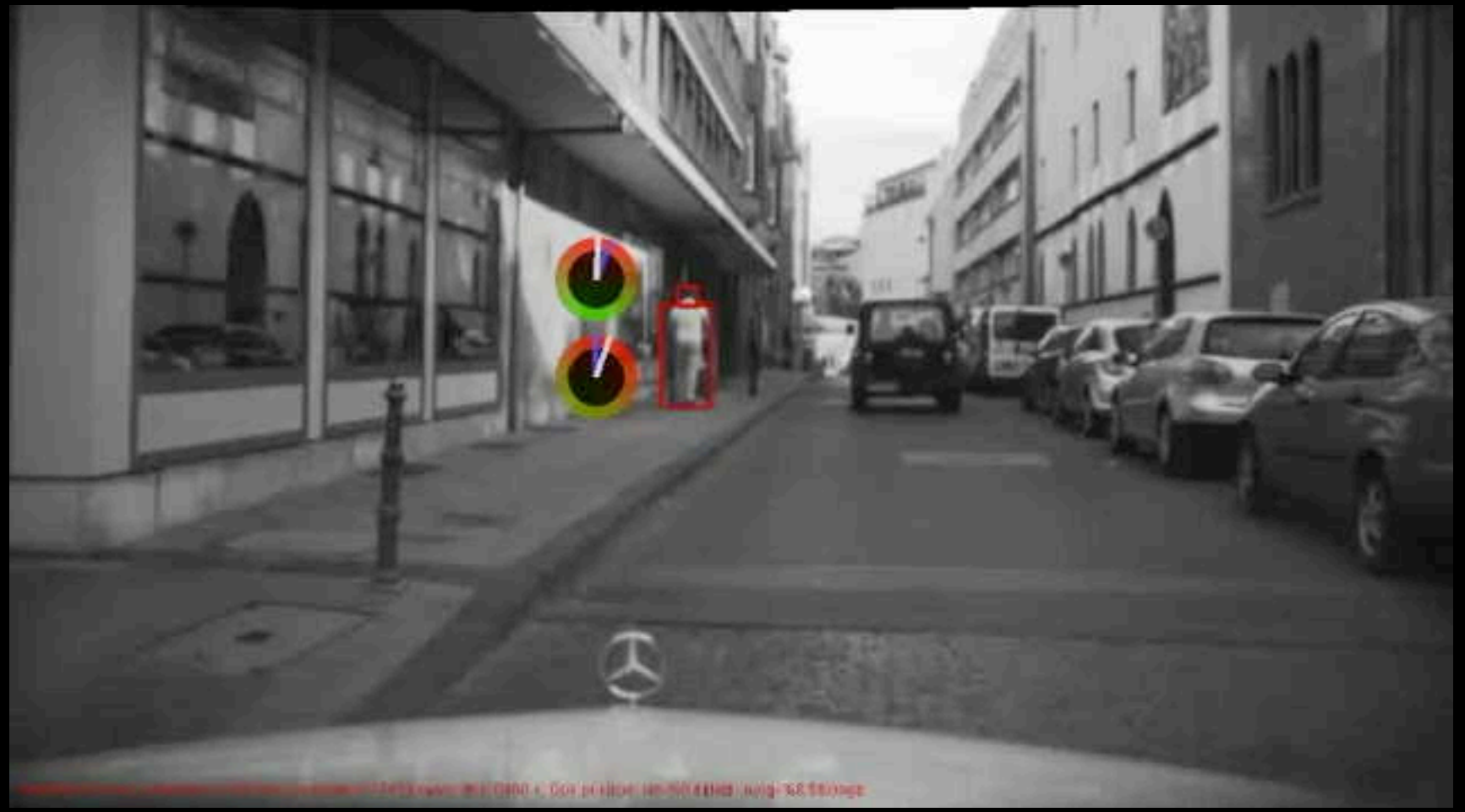
Joint Instance Detection and Orientation Estimation



TU Delft
Intelligent Vehicles Group (IV)

Intent Recognition Pedestrian Torso & Head Orientation

CNNs for Instance Detection and Orientation Regression



Head and torso estimation takes into account physical constraints.

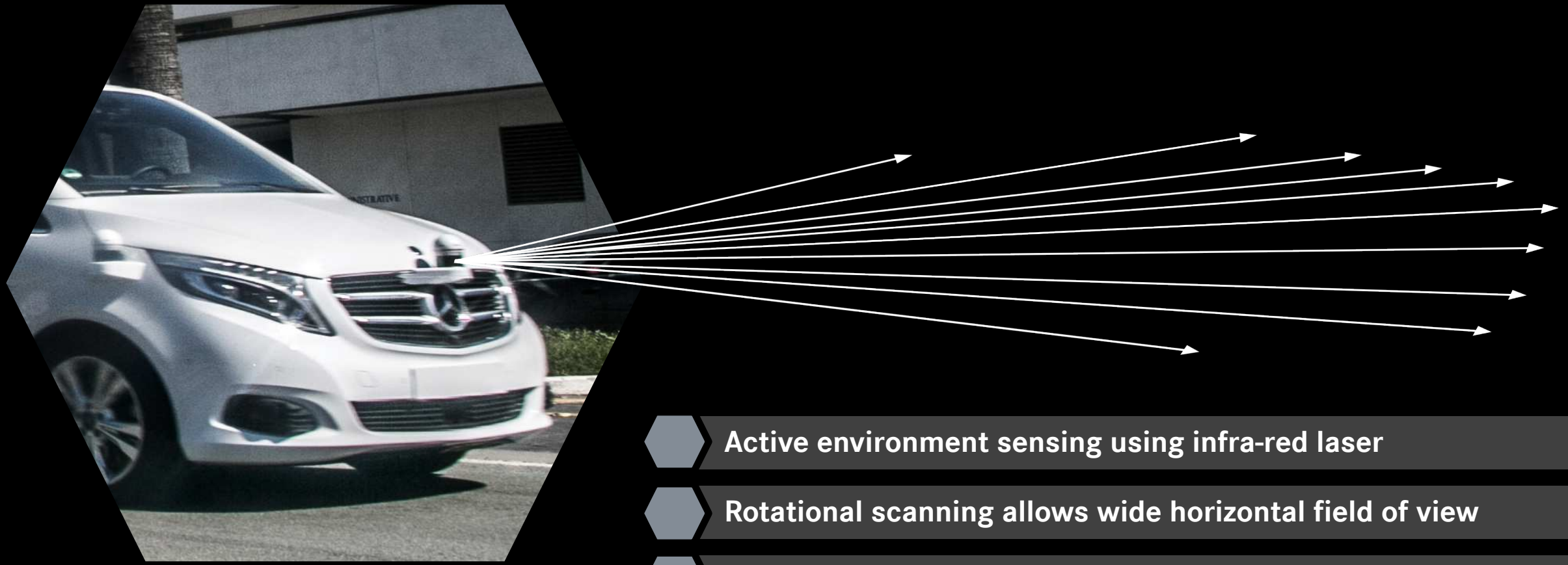
For clarity, results are only shown for one pedestrian at a time.

Robust head and torso estimation used as context information

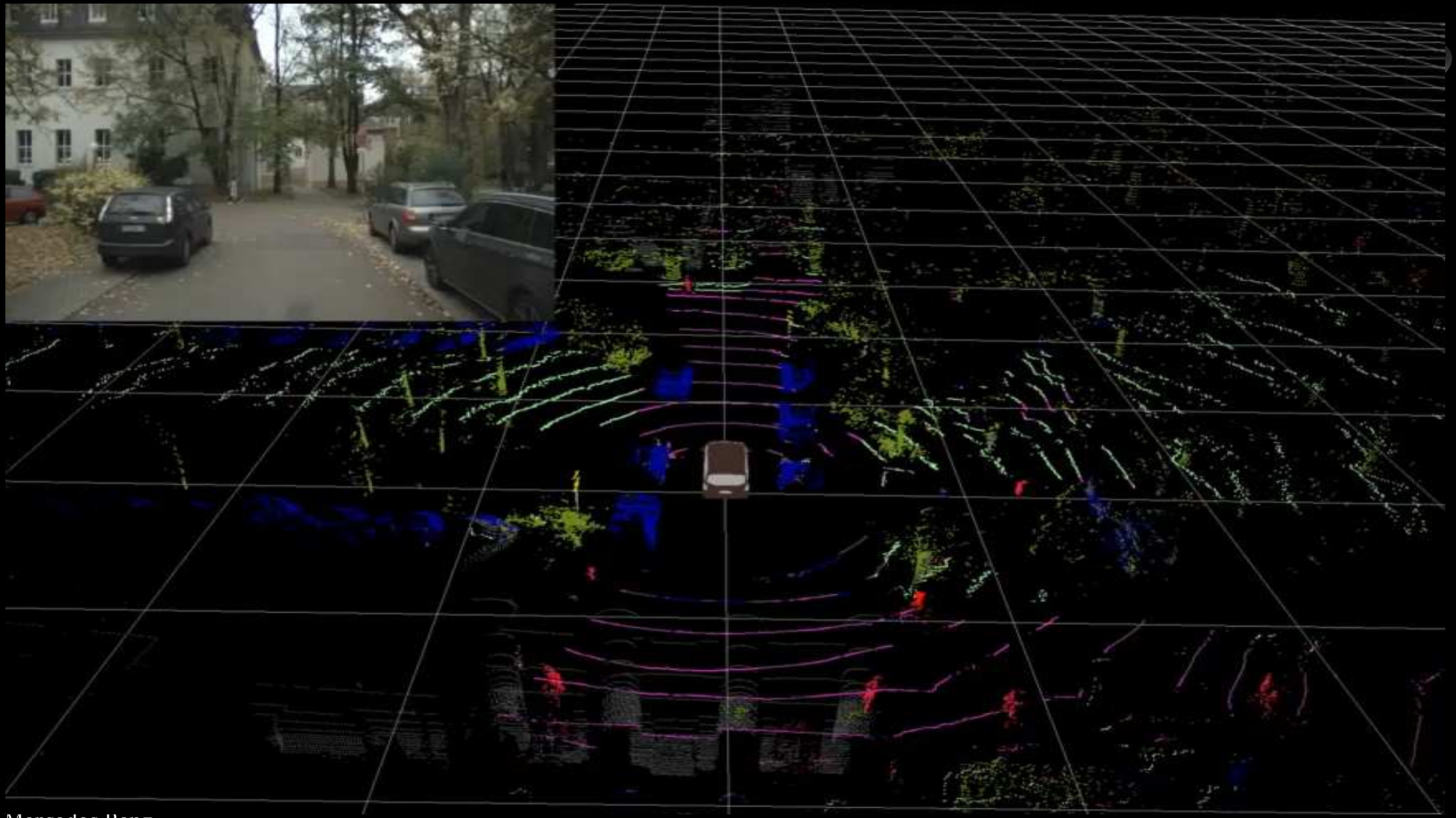
F. Flohr, M. Dumitru-Guzu, J. F. P. Kooij and D. M. Gavrila. A probabilistic framework for joint pedestrian head and body orientation, *T-ITS*, 2015.

Sensors Lidar Principles

Accurate Object Meassurements with Infra-red Lasers



- Active environment sensing using infra-red laser
- Rotational scanning allows wide horizontal field of view
- Real 3D and intensity measurements via time-of-flight
- Up to 1.3 Mio. 3D points per second in up to 128 layers



Mercedes-Benz

Sensors Radar

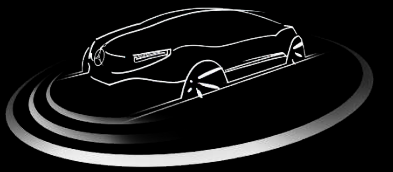
Bertha Benz 2013

LR-Radar
STEREO CAMERA
SR-Radar
90°
80 m
60 m
56°
40 m
44°
56°
150°
150°
56°
200 m
80 m
18°
LR-Rada r
LR-Radar
60 m
80 m
130 m
200 m
150°
150°
CAMERA
56°
SR-Radar
CAMERA
SR-Radar
LR-Radar

SHORT RANGE RADAR
LONG RANGE RADAR

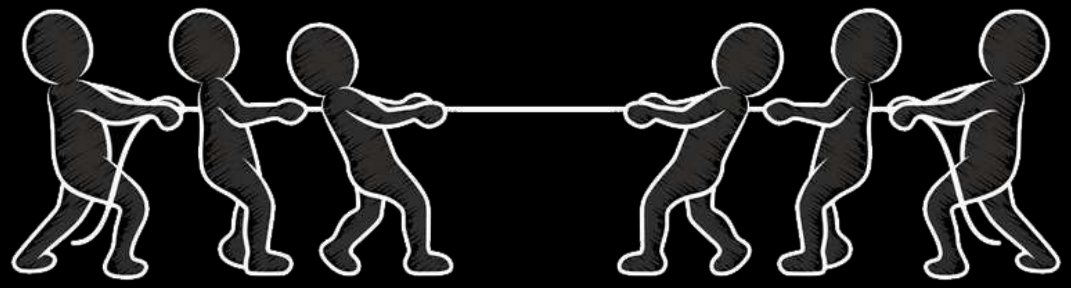
Sensors Radar

Hardware-Software-Co-design



UNTIL TODAY

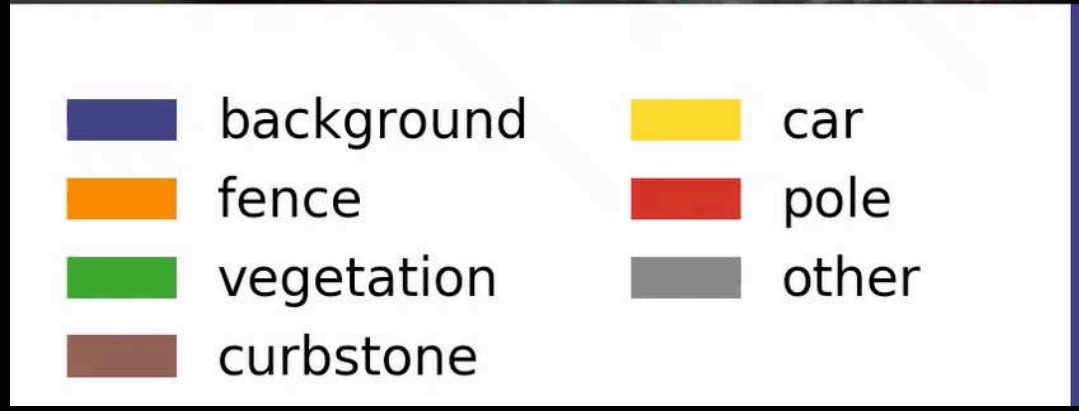
Radar hardware and algorithm-concepts pushed each other equally



TOMORROW

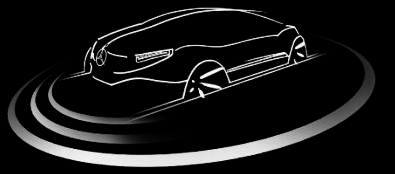
New algorithm-concepts demand imaging radar resolution and massive computational power

Scene understanding classification level

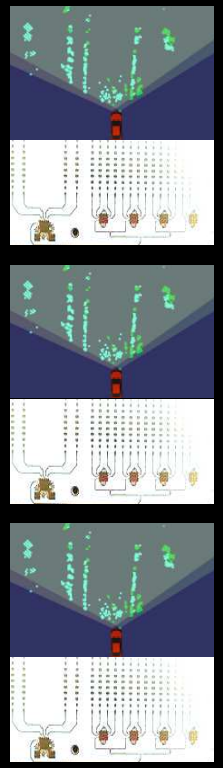


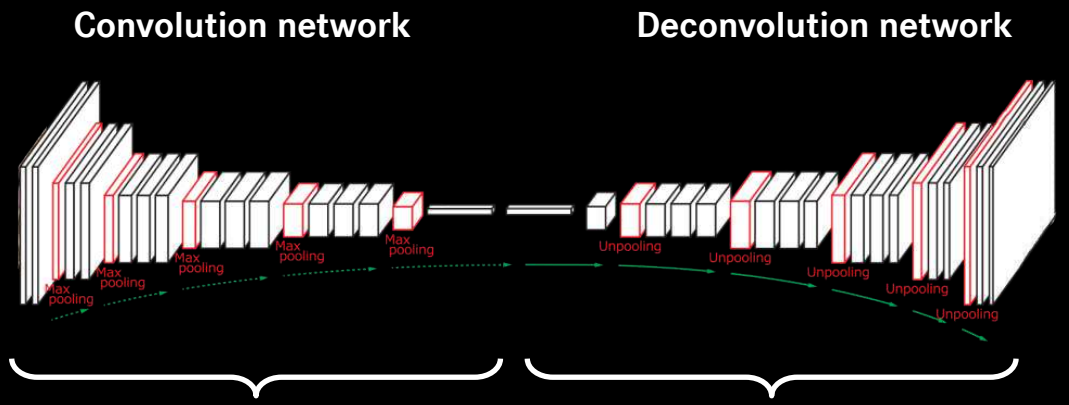
Sensors Radar

Scene Segmentation with Radar



Radars ▶ **Radar Pre-Processing** ▶ **Deep Neural Network** ▶ **Radar Semantics**





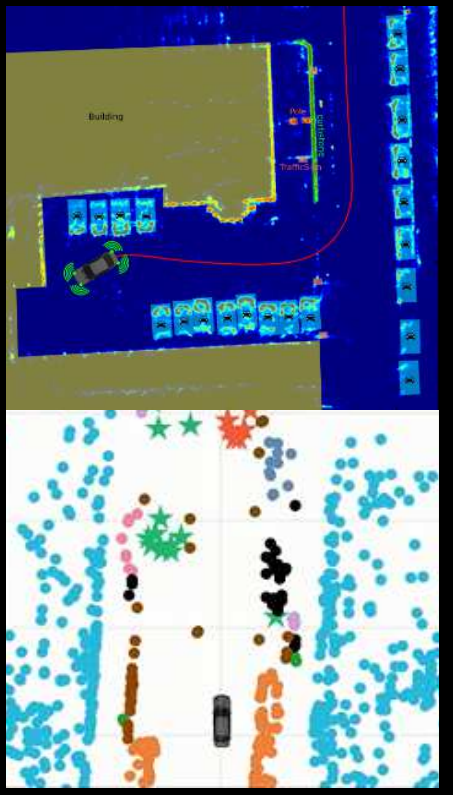
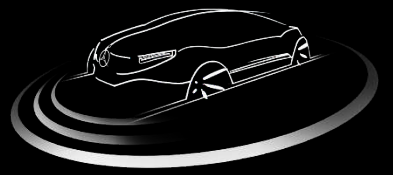
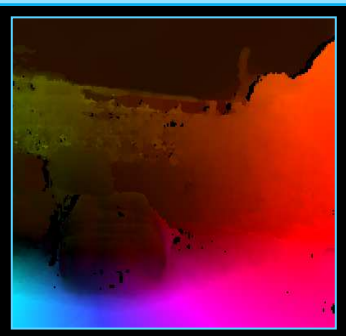
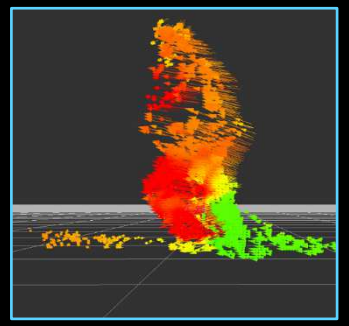
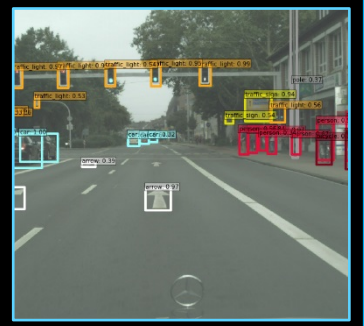
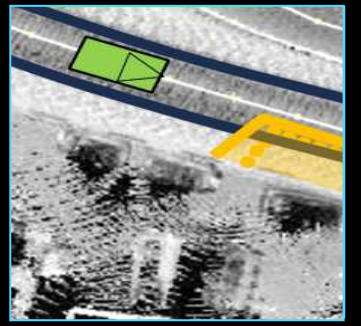
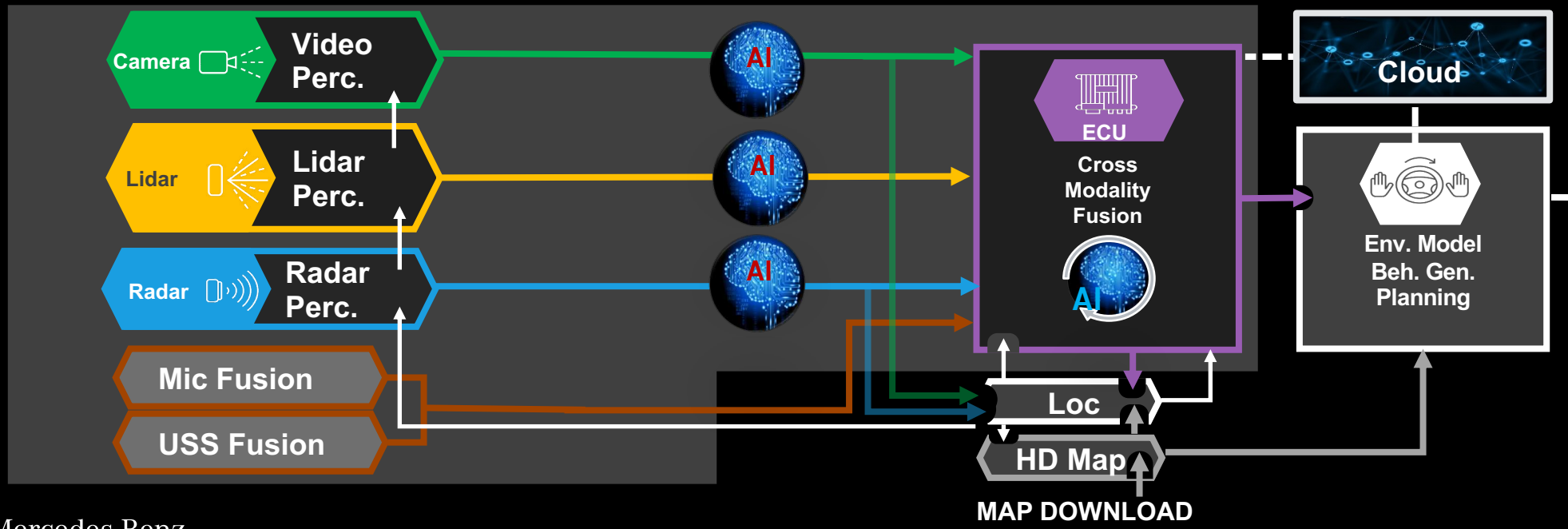


Image Source: Hyeonwoo Noh et. al. : Learning Deconvolutional Network for Semantic Segmentation, 2015

Artificial Intelligence (AI) is Key to understand Sensor Data

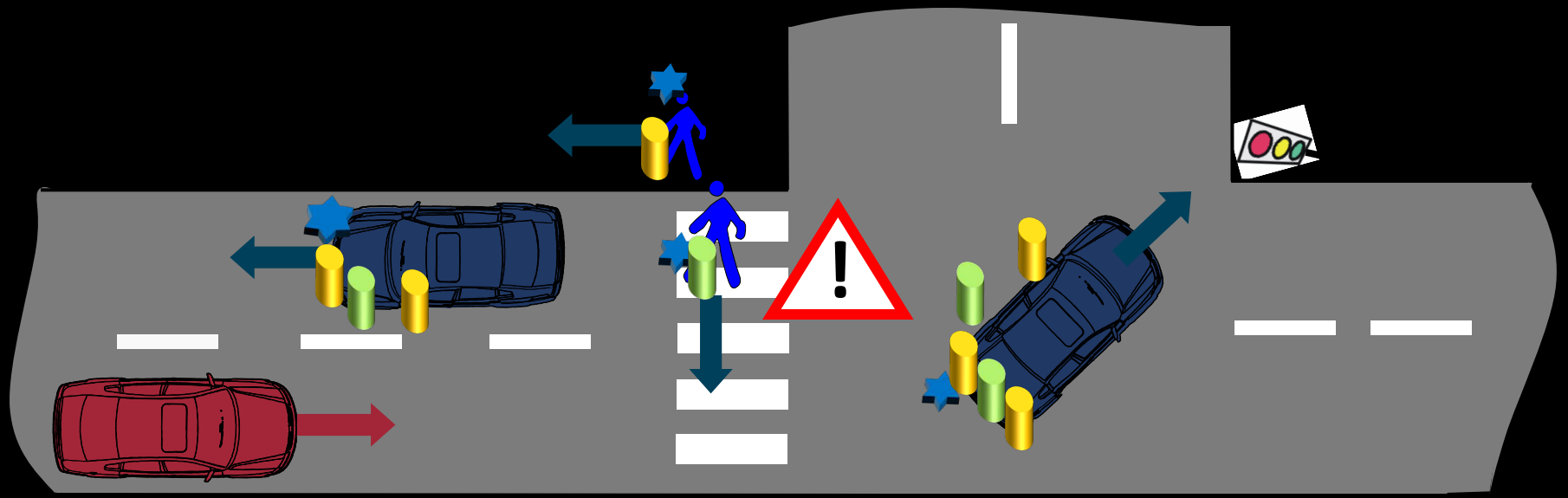


Dense Data	Motion Detection	Classification	Fusion & Localization	Situation Analysis	Maneuver Planning
					



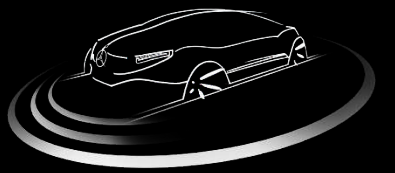
Fusion of Sensor Results

The Important Step Between Perception and Planning

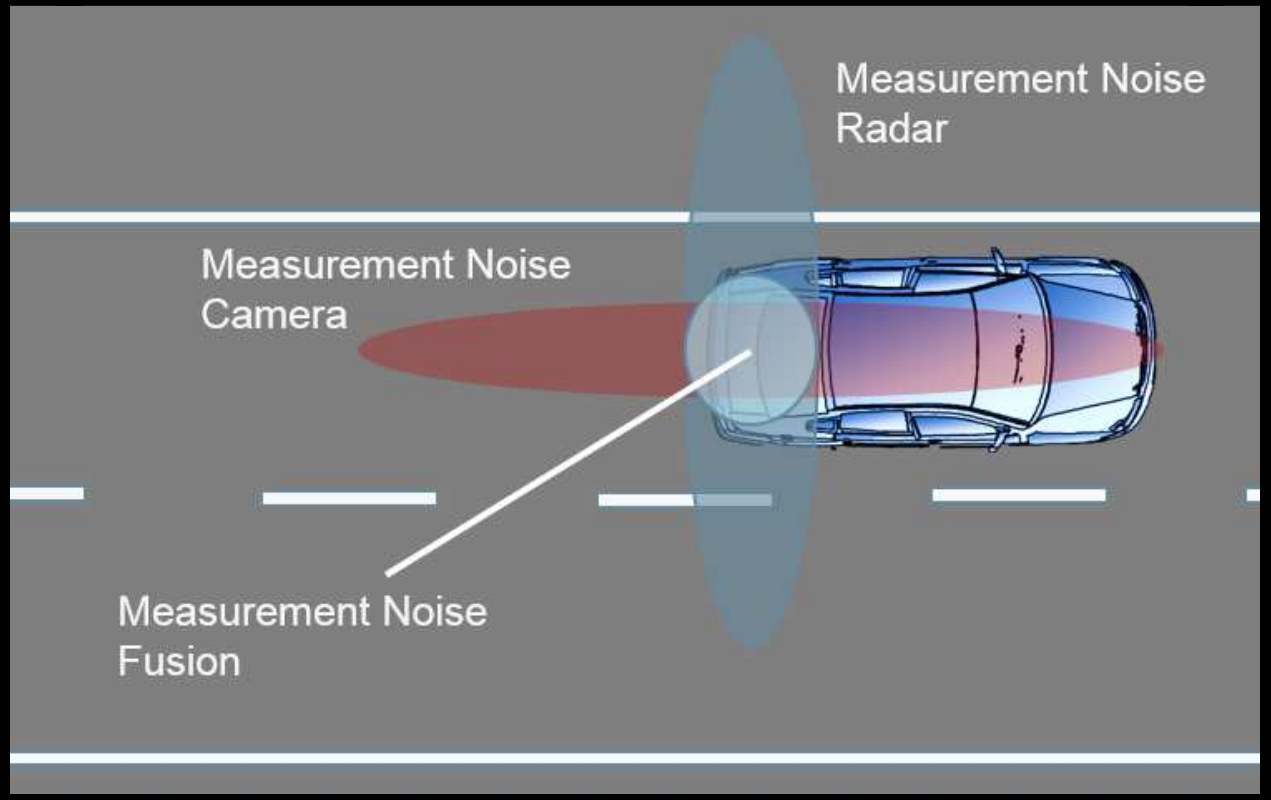


Fusion of Sensor Results

Fusion Tasks



IMPROVE ACCURACY

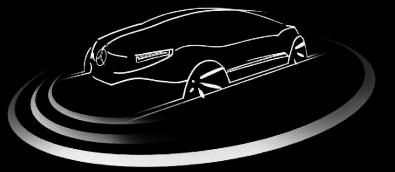


REDUNDANCY

Combine information from different sensors to generate an accurate and robust representation of the environment

Fusion of Sensor Results

Fusion Tasks

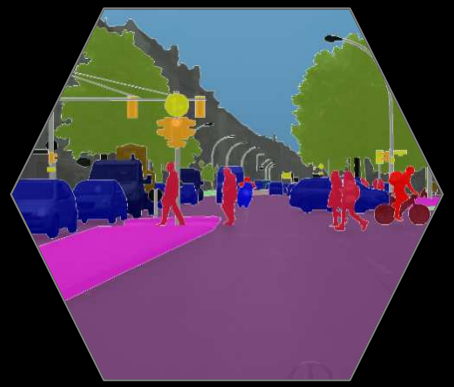


FUSION PROVIDES:

basis for planning the car's behavior

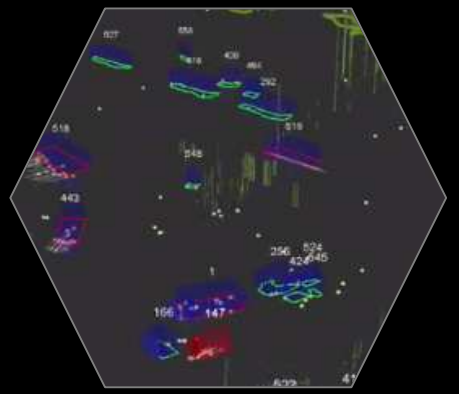
an accurate and detailed picture of the environment on a more aggregated level, i.e. the consolidated sight of the car

NO LONGER ABSTRACT FEATURES FROM SINGLE SENSORS BUT:



Classified object

Movement over time



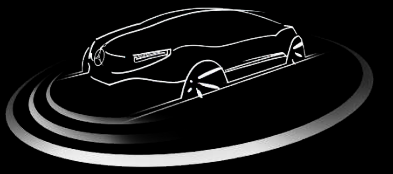
Contours of obstacles

Road infrastructure

Visible space

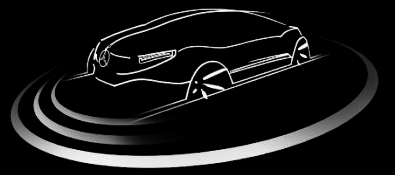
Fusion of Sensor Results

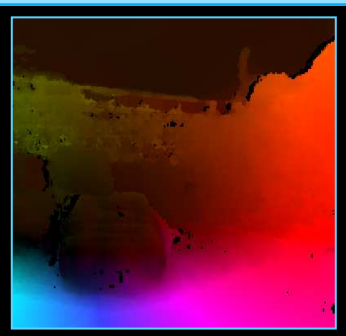
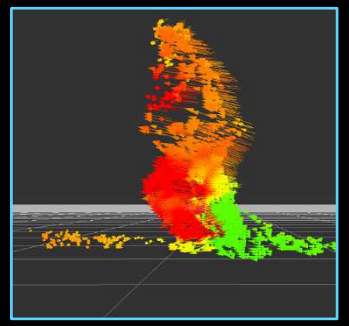
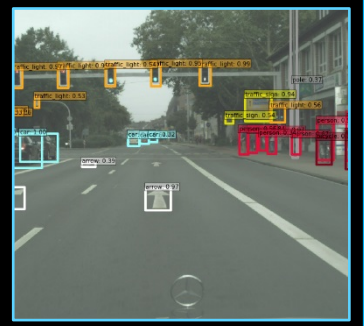
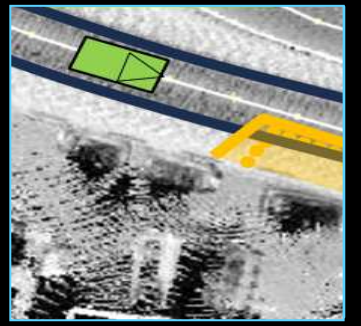
Fusion Tasks

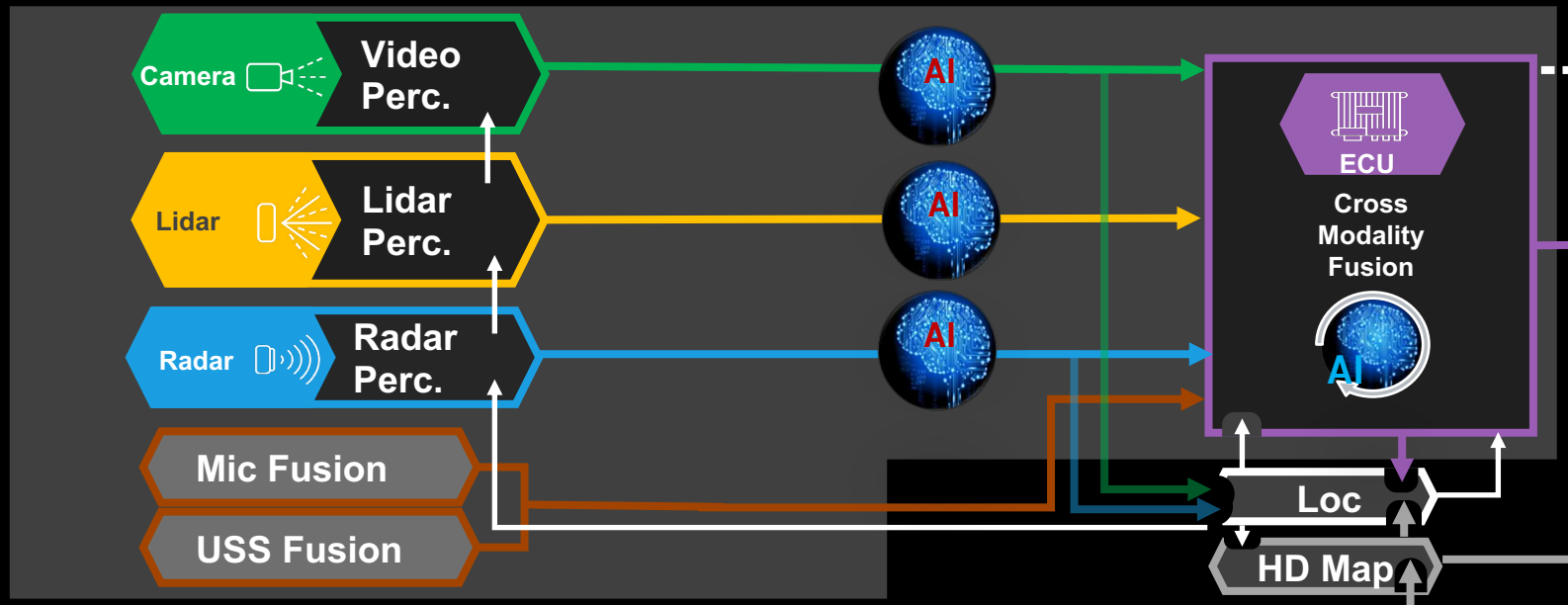


Through the eyes of a car

Artificial Intelligence (AI) is Key to understand Sensor Data

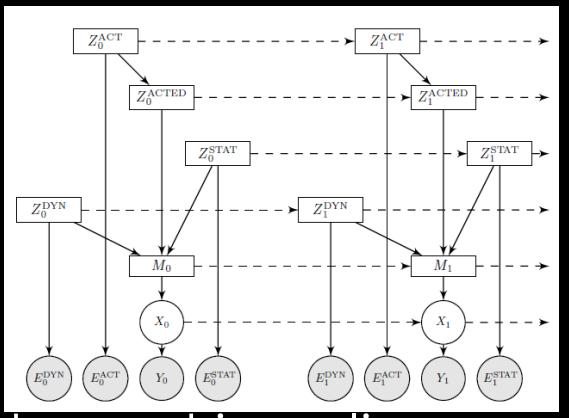


Dense Data	Motion Detection	Classification	Fusion & Localization	Situation Analysis	Maneuver Planning
					



Vulnerable Road User Understanding

Dynamic Bayesian Networks with Context Cues



A human driver relies heavily on context cues to anticipate how a traffic situation will evolve.

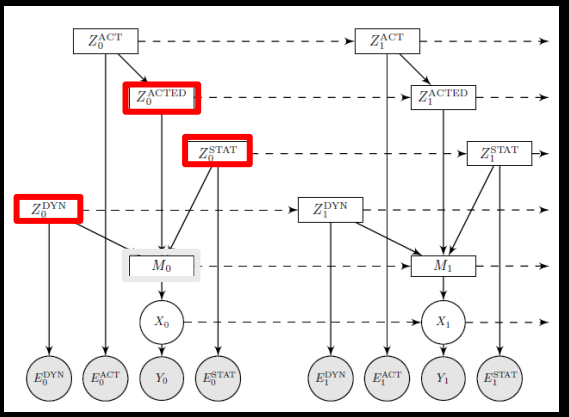
TU Delft
Intelligent Vehicles Group (IV)

Various context cues influence the pedestrian motion

J. P. F. Kooij, N. Schneider, F. Flohr and D. M. Gavrila. Context-based pedestrian path prediction. *ECCV*, 2014.

Vulnerable Road User Understanding

Dynamic Bayesian Networks with Context Cues



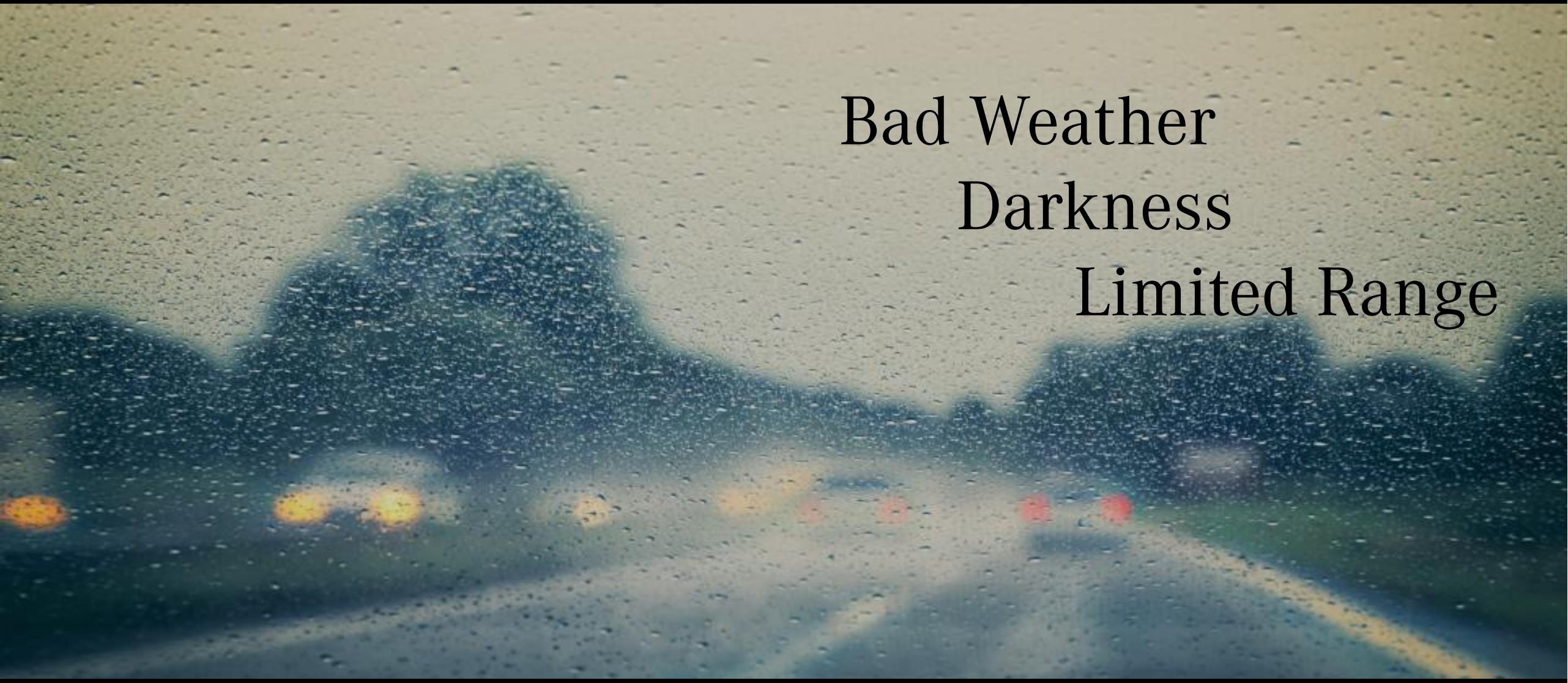
At intersection?
On collision course?
Hand gesture?

TU Delft
Intelligent Vehicles Group (IV)

J.F.P. Kooij, F. Flohr, E.A.I. Pool and D.M. Gavrila. *"Context-based Path Prediction for Targets with Switching Dynamics"*, IJCV 2018

3 Challenges

Technology Challenges for Sensors



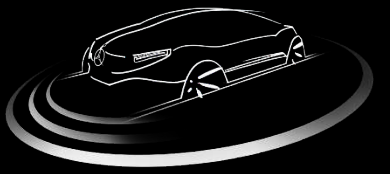
Neural Networks

Test your own perception capabilities vs. a Neural Network

Check the image for three (3!) seconds and then have a look at the result of the Neural Network, which had only a mere 30 milliseconds glance at it. Ready to start?

Not sure whether some “New Players” would have detected the crossing truck …

Neural Networks CNNs perform only well, if training data and training parameters are chosen carefully



Example: Night performance of CNN: if trained with day data...

... and if trained with proper night data

The Right Data is Gold

Relevant Data Corner Cases

The Right Data is Gold

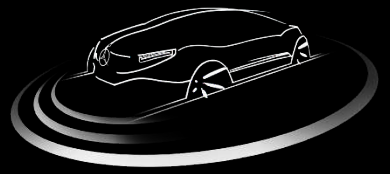
Relevant Data Corner Cases

The Right Data is Gold

Relevant Data Corner Cases

Big Data Data Science

What is the Right Data?



Data Ingest

100 Gigabytes in 1 minute

Data Selection

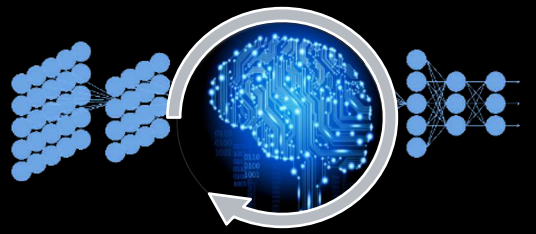
Continuous Fleet Driving

Most efforts go into this data loop!

10 vehicles driven 5 hours on 100 days
create 30 Petabytes

Data Annotation

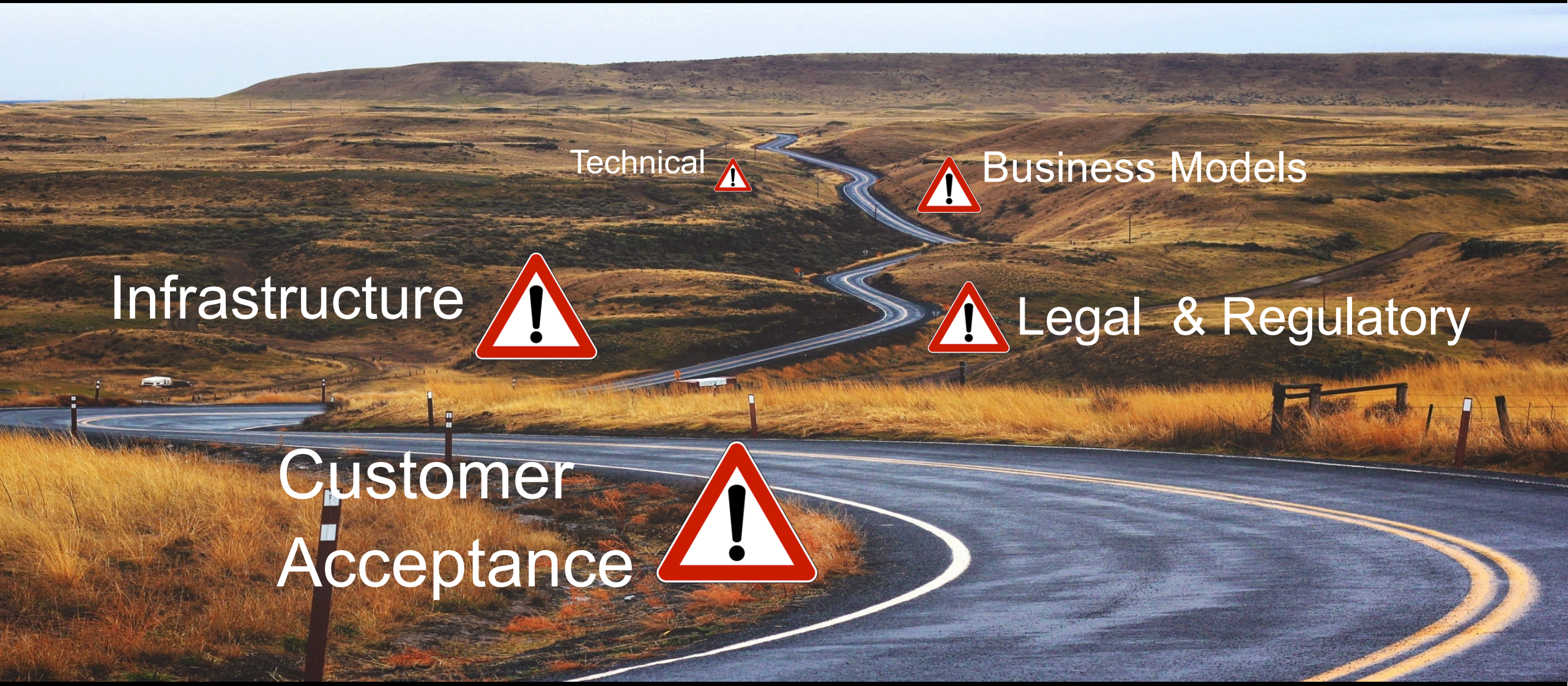
Testing & Validation



Training

And More Challenges ...

The Road to Full Autonomy May Have a Few Curves



4 Enablers

Customer Acceptance: Remember ...

Humans are actually
pretty good drivers ...

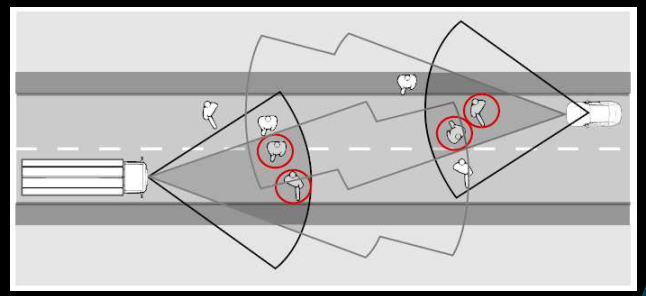
Fatality ~100 million
miles driven

... and most believe
they‘re even better!

Up to 90% say they‘re
„above average“ drivers

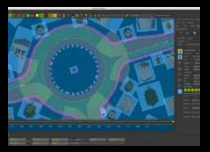
SiL-Simulation as Key Component for Validation

Sensor Simulation



Environment Simulation

Maps



Traffic

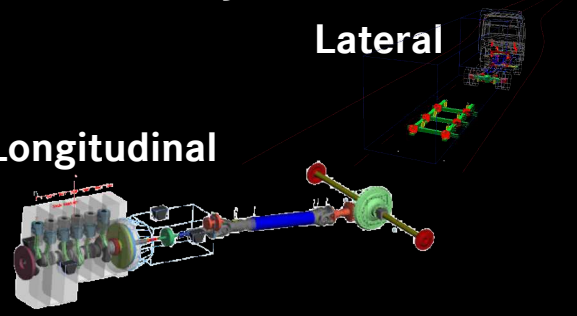
Weather

source: www.vires.com

Vehicle Dynamics Simulation

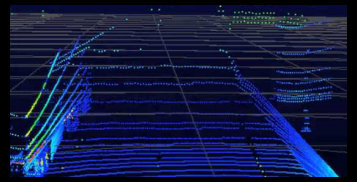
Lateral

Longitudinal

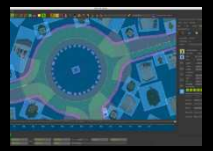


Autonomous Software

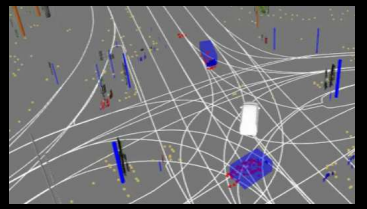
Environment Perception



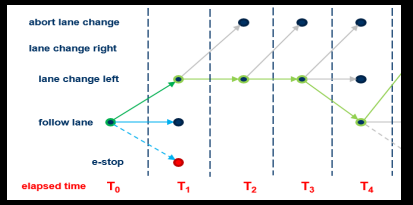
High Definition Maps and Localization



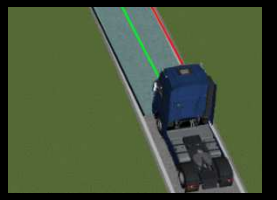
Fusion



Behavior Generation and Trajectory Planning



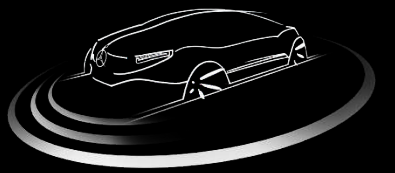
Motion Control



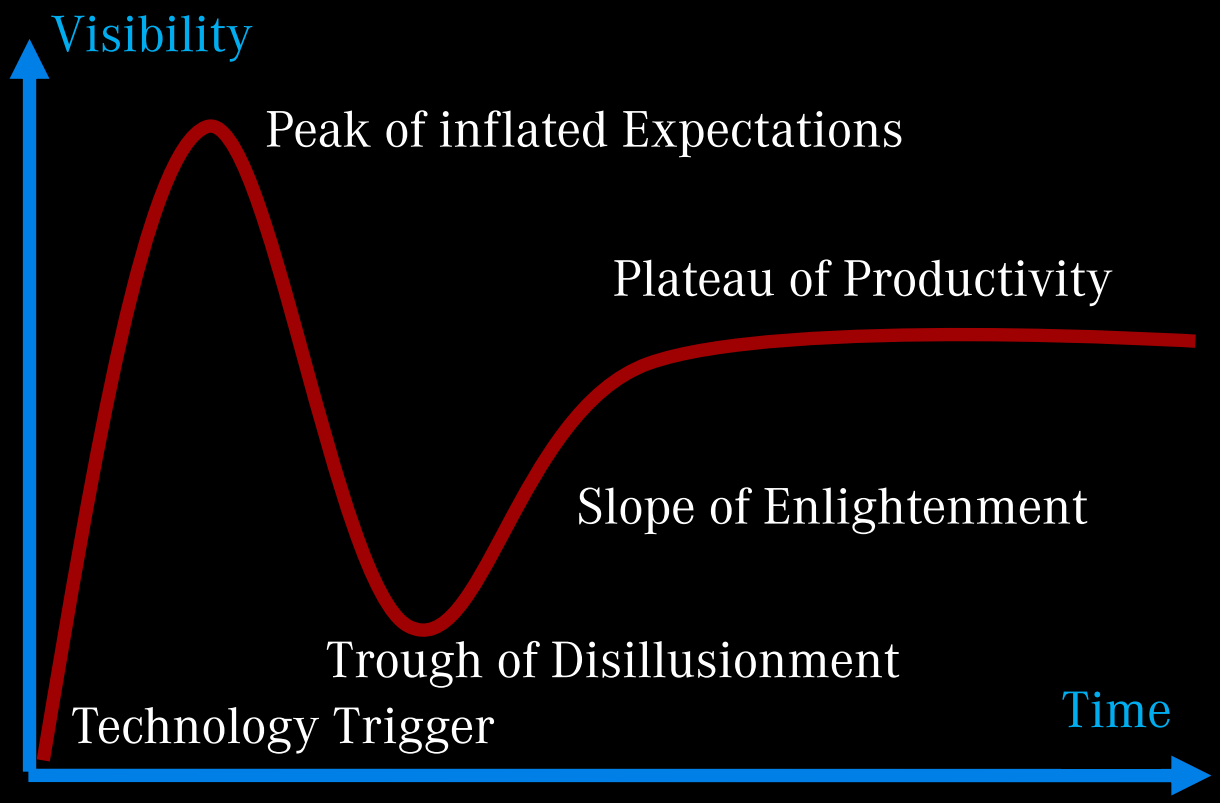
Good Enough?

CALIFORNIA USA DRIVER LICENSE
ID 01100111011011110110111101100111011011000110010 1
EXP 10/31/2024
CLASS AD
END NONE
LN CAR
FN GOOGLE
1600 AMPITHEATRE PKWY
MOUNTAIN VIEW, CA 94043
DOB 10/31/2014
RSTR RAIN, SNOW
021758
DONOR
SEX R
EYES BLUE
HGT 5' 2" WT 1800 lb
ISS 09/30/2015
DD 09/30/201160221/21FD/15

Where Are We in the Hype Cycle?



GARTNER HYPE CYCLE



"We're going to end up with complete autonomy, and we will have [it] in approximately 2 years."

- Elon Musk, Tesla (December 2015)

"Maybe it's 3 years, maybe it's 30 years. I am here to tell you that honestly, it's a bit of both."

- Chris Urmson, Google (March 2016)

Daimler joined forces with Bosch in common Project House

to combine strenths of OEM and Tier1

BOSCH

- Hardware (Sensors, Actors, ECUs)
- Software for HW components

BOSCH + DAIMLER

System

Sensor Algorithms	Embed. SW Infrastr.
Motion Control	Testing
Environment Fusion	IT & Process Support
Behavior Generation	Vehicle Control Center

Project House with locations in **Germany** and **USA**

DAIMLER

- Vehicles
- Integration of systems in vehicle line

- **Common Development of** AD-Kit to be used in **Robo Cars**
- **Artificial Intelligence enabler for Autonomous Driving (Nvidia)**
- **Functionally SAVE** acc. to ISO26262

Experiencing Urban Automated Driving @ San José

BOSCH ⟷ Mercedes - Benz

First Pilot of
Autonomous service in 2019

Several new S-Class vehicles
mounted with latest AD Systems

Start in 11/2019
with demonstration of autonomous service

On-demand ride-hailing service
to simulate a real-life operating scenario

Day time operations
from dawn to dusk

Valuable Research Collaborations

Intelligent Vehicles Group @ TU Delft

TU Delft
Intelligent Vehicles Group (IV)

Prof. Dariu Gavrila
(Head IV)

Mercedes - Benz

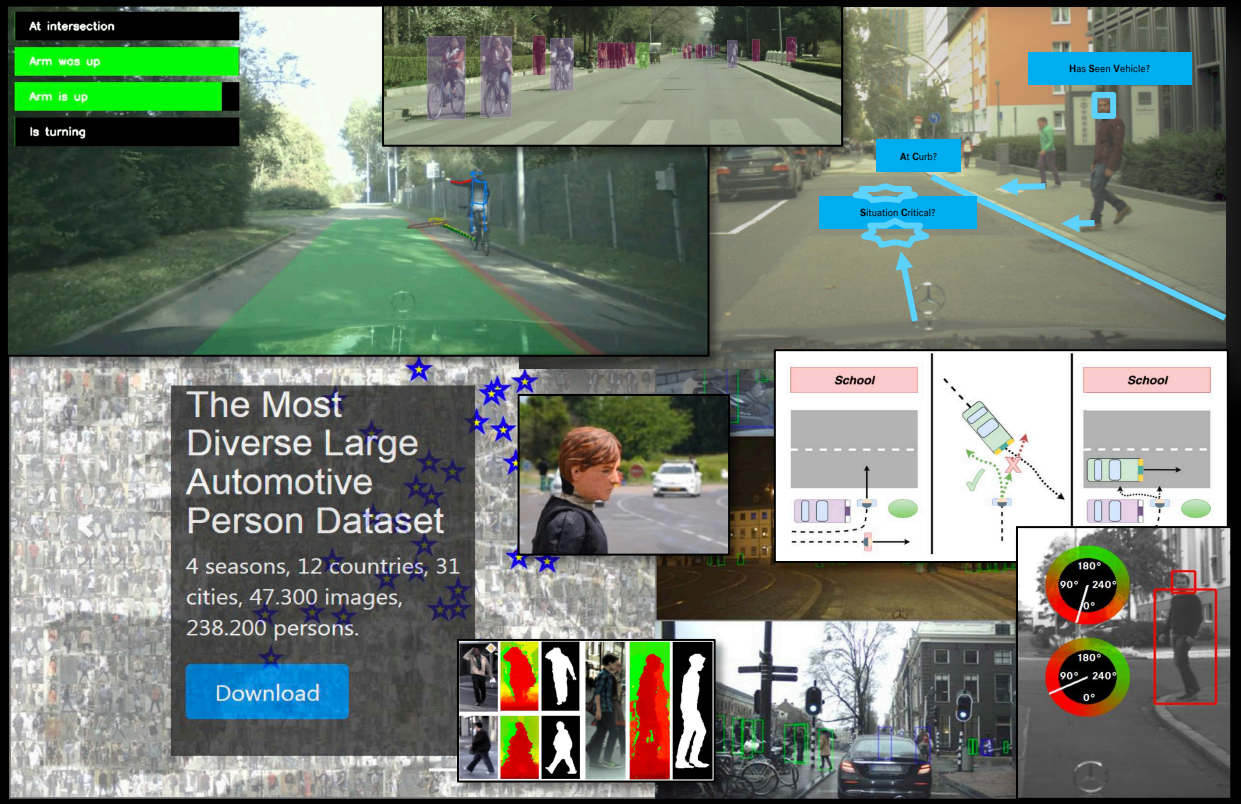
Long-term research collaboration

Vulnerable Road User Handling
to understand and protect other traffic participants

PhD and Master Thesis / Internships
on interesting and cutting-edge topics

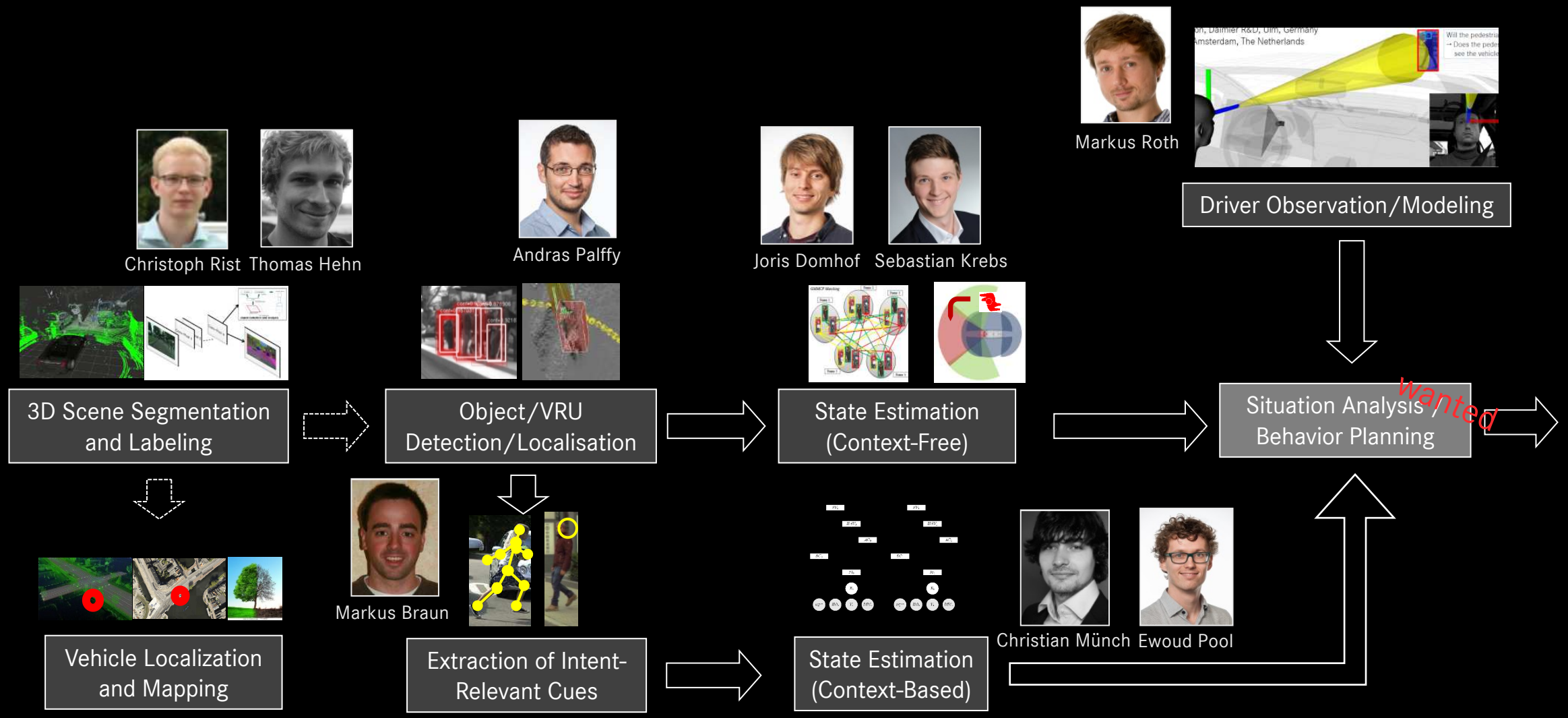
Joint Publications / Proof of Concepts
at top conferences and journals

Joint Benchmark Datasets
to accelerate research and evaluate development



Valuable Research Collaborations

PhD topics @ Intelligent Vehicles Group



The Reinvention of the car is happening right now and together we will revolutionize future mobility ...

... in order to provide space and time smartly used for essential things.
For this revolution ...
WE NEED YOU!
www.daimler.com/career