

# Scenario Generation for Autonomous Driving Development and Testing

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[www.humusoft.cz](http://www.humusoft.cz), [www.dspace.com](http://www.dspace.com), [www.understand.ai](http://www.understand.ai)



# Challenges with autonomous driving

## Environment sensors

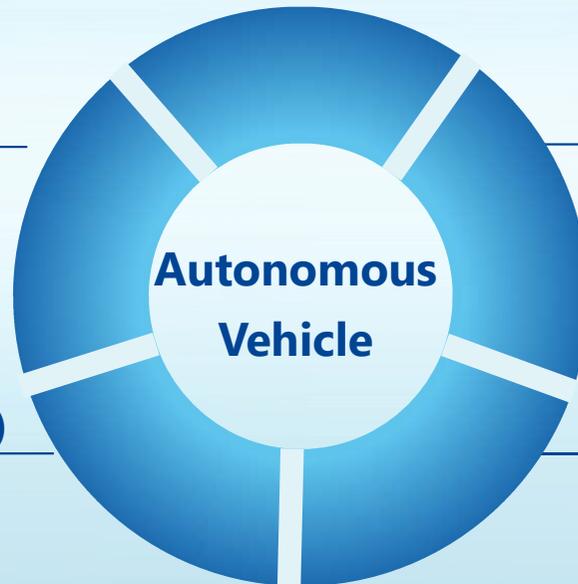
- New technologies
- 360° view, all weather conditions

## Data processing

- High performance computing
- Data management

## Artificial Intelligence (AI)

- Deep Neural Networks (DNNs)
- Data driven development



## Vehicle networks

- Increasing bandwidth
- Service-oriented communication

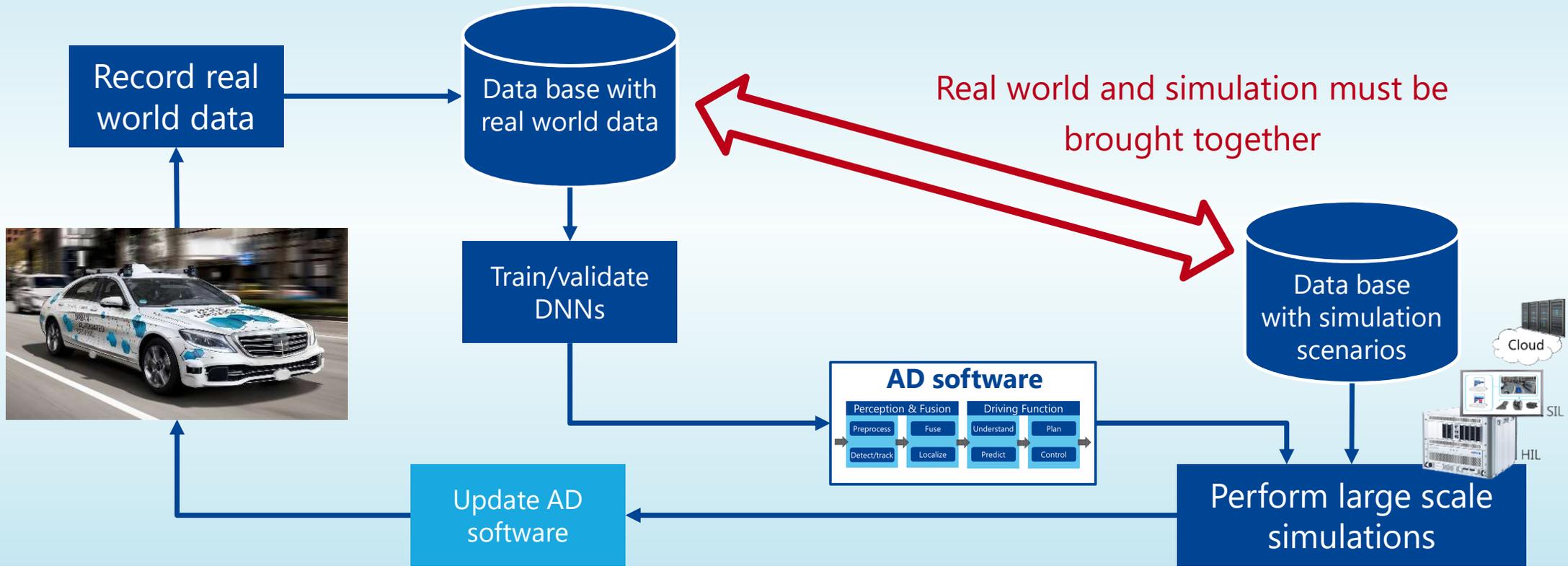
## Validation and homologation

- From real world to simulation
- New testing methodologies and operational safety

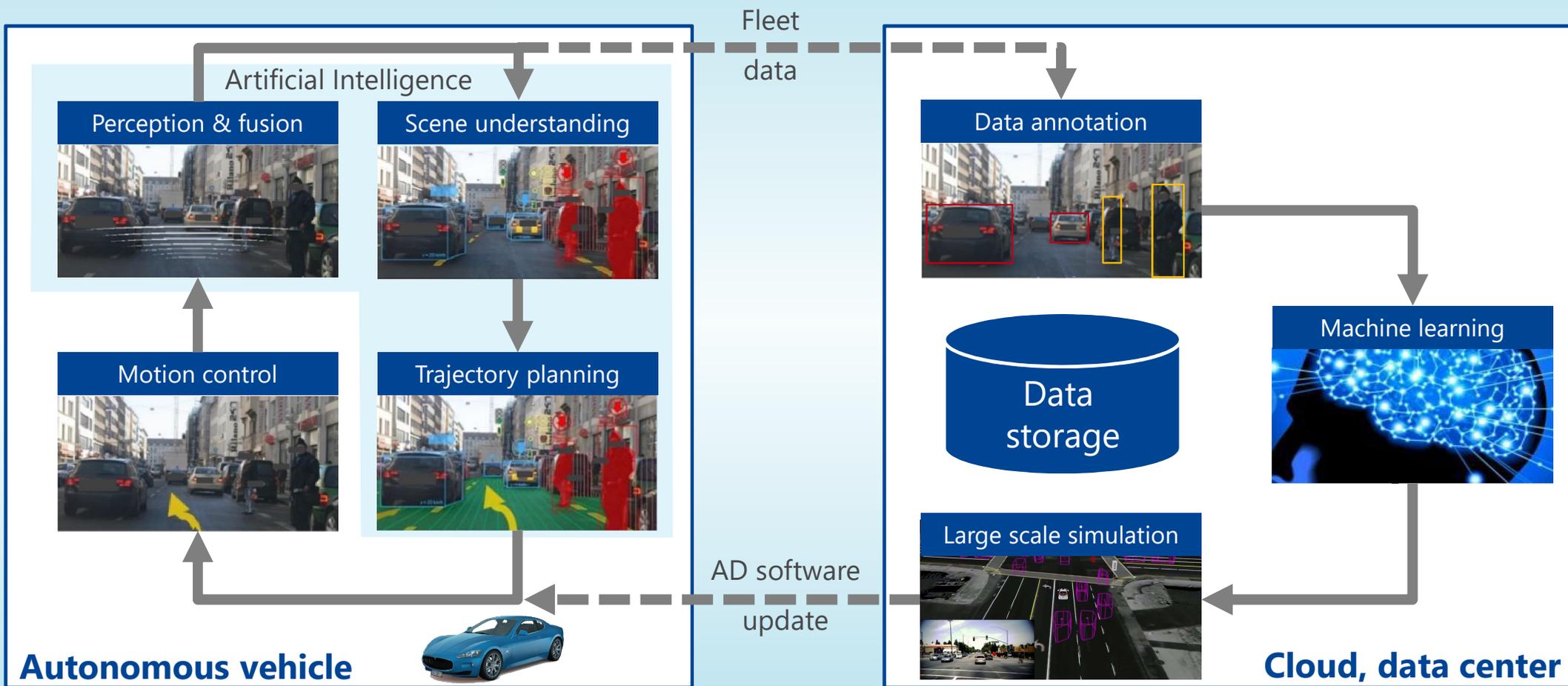


# Autonomous Driving – typical approach

## Data driven development



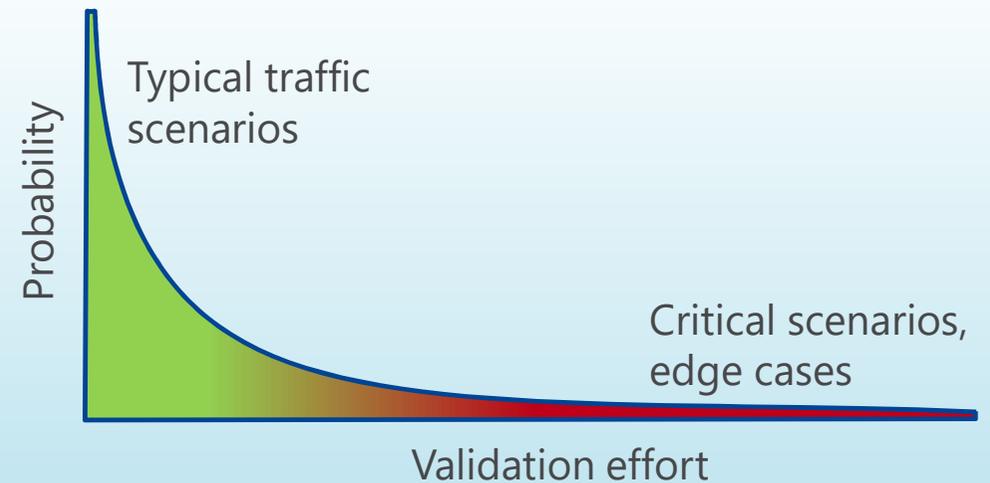
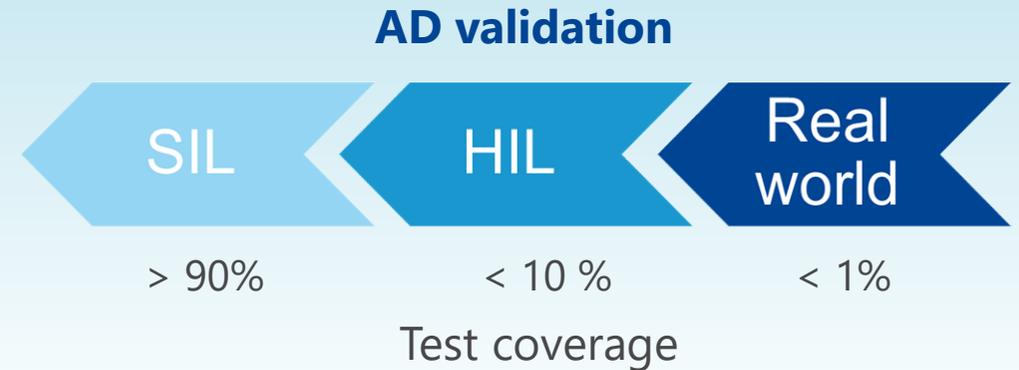
# Data driven development



DNNs: Deep Neural Networks

## Autonomous Driving – The challenge ...

- Realism in simulation
- Amount of simulation scenarios
- Critical traffic scenarios and edge cases



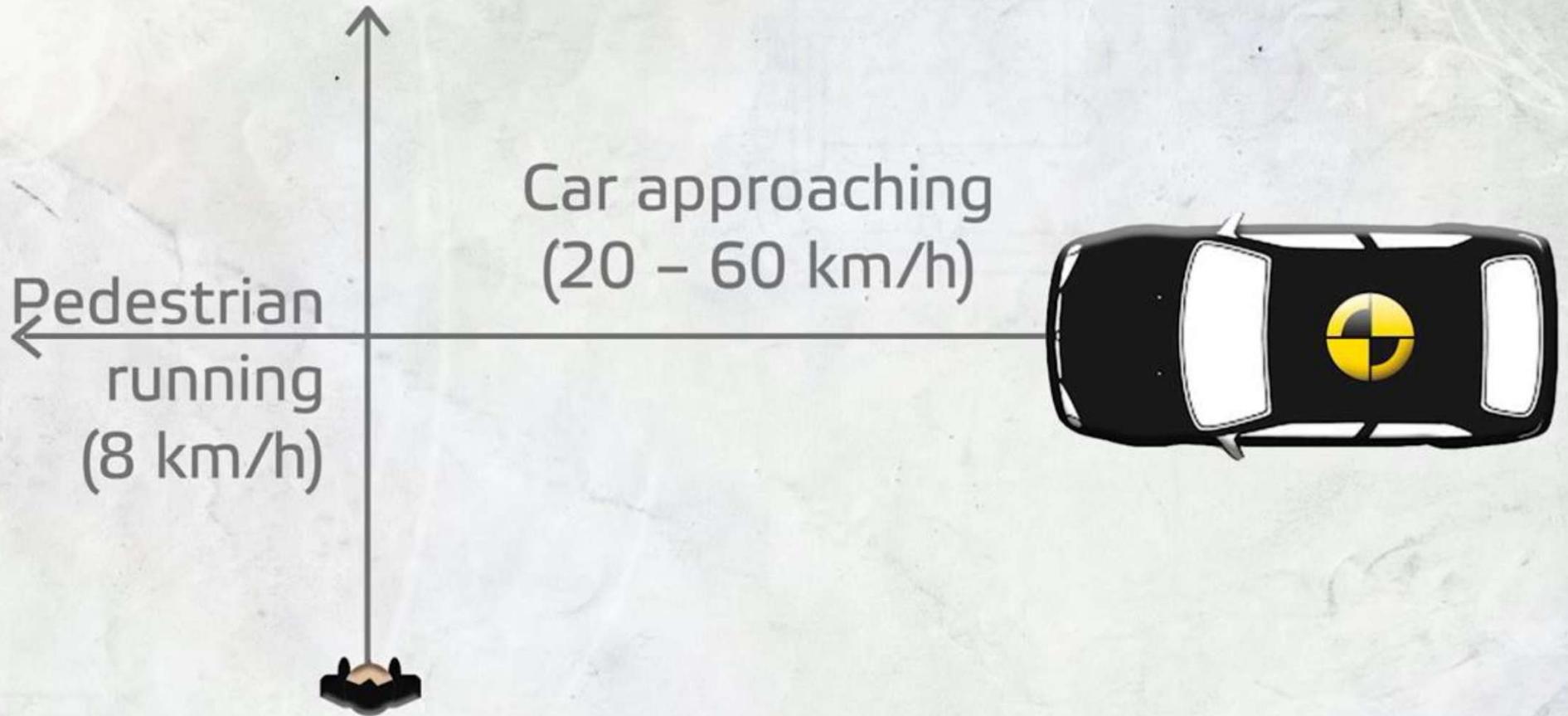
## Autonomous Driving – The solution ...

Bringing the complexity of the real-world into AV simulation



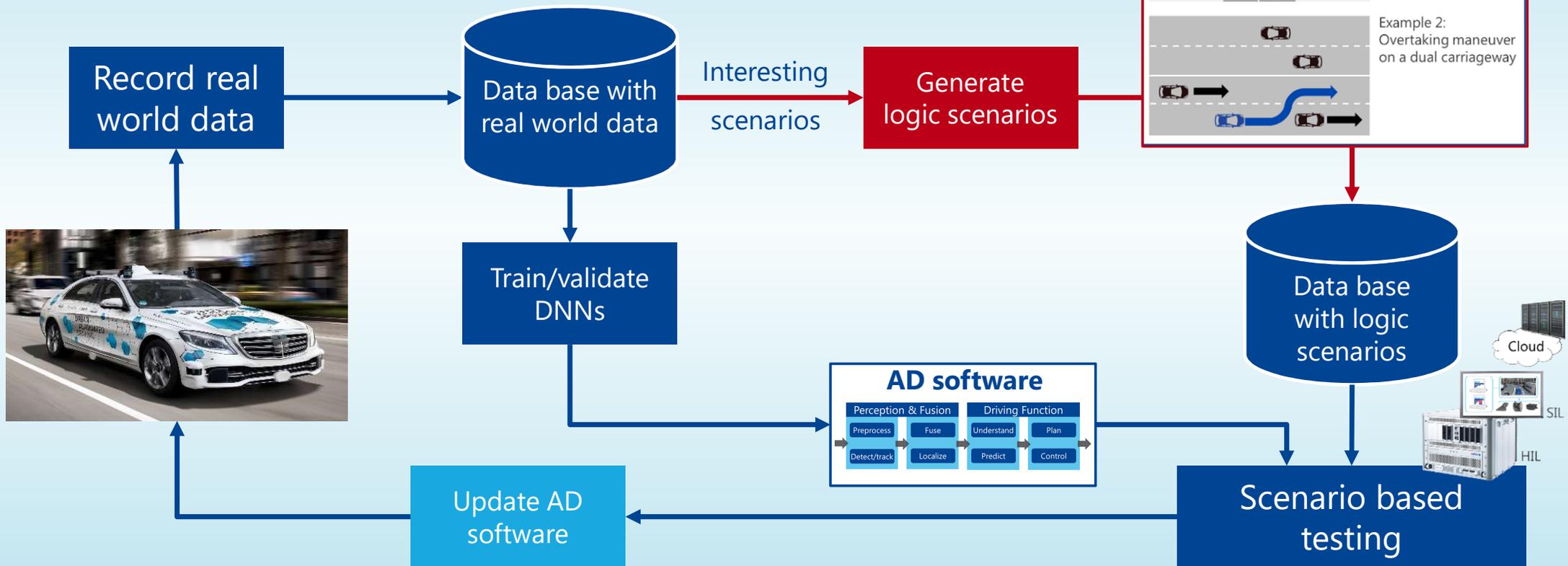
**The current approach is not realistic**

## Test with adult pedestrian



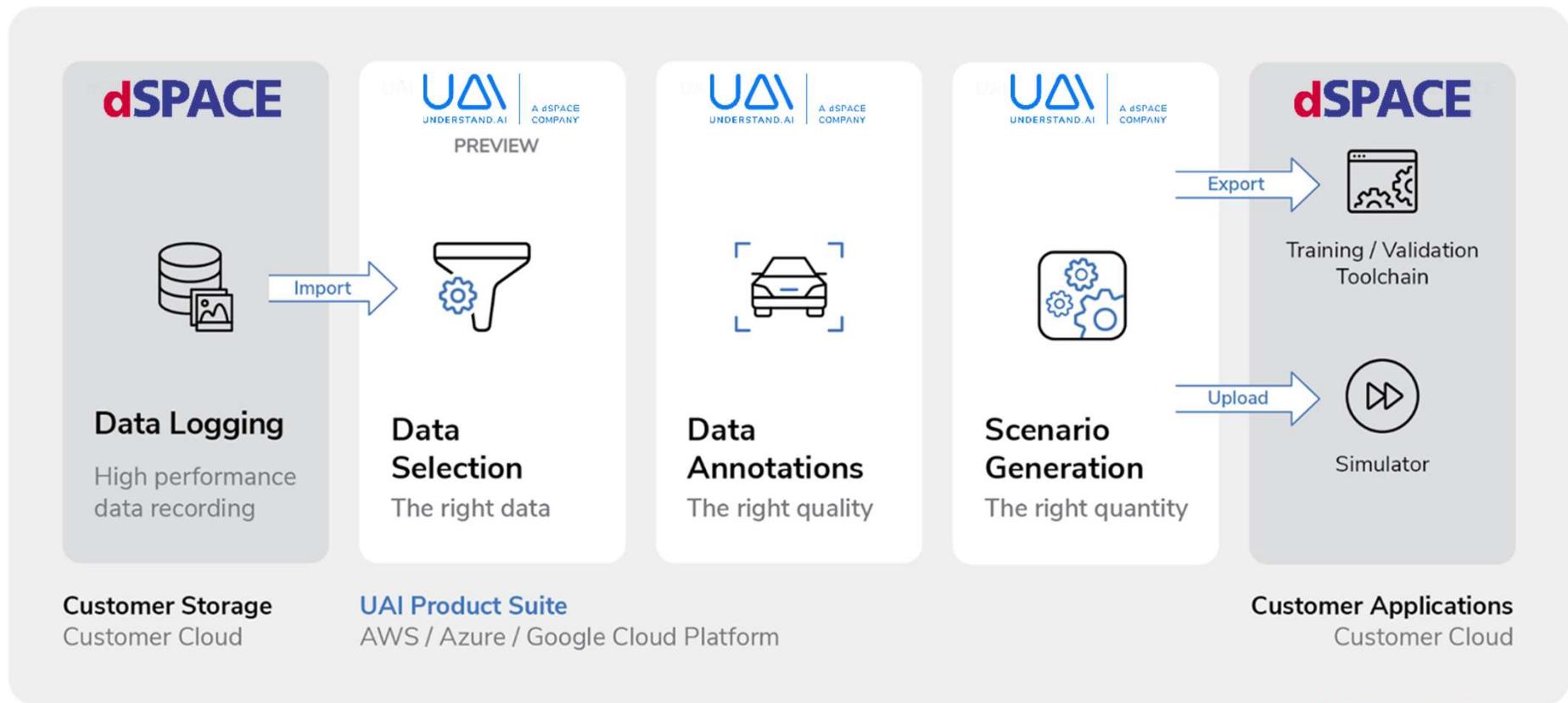
# Autonomous Driving – The solution ...

## Generate simulation scenarios from real world data



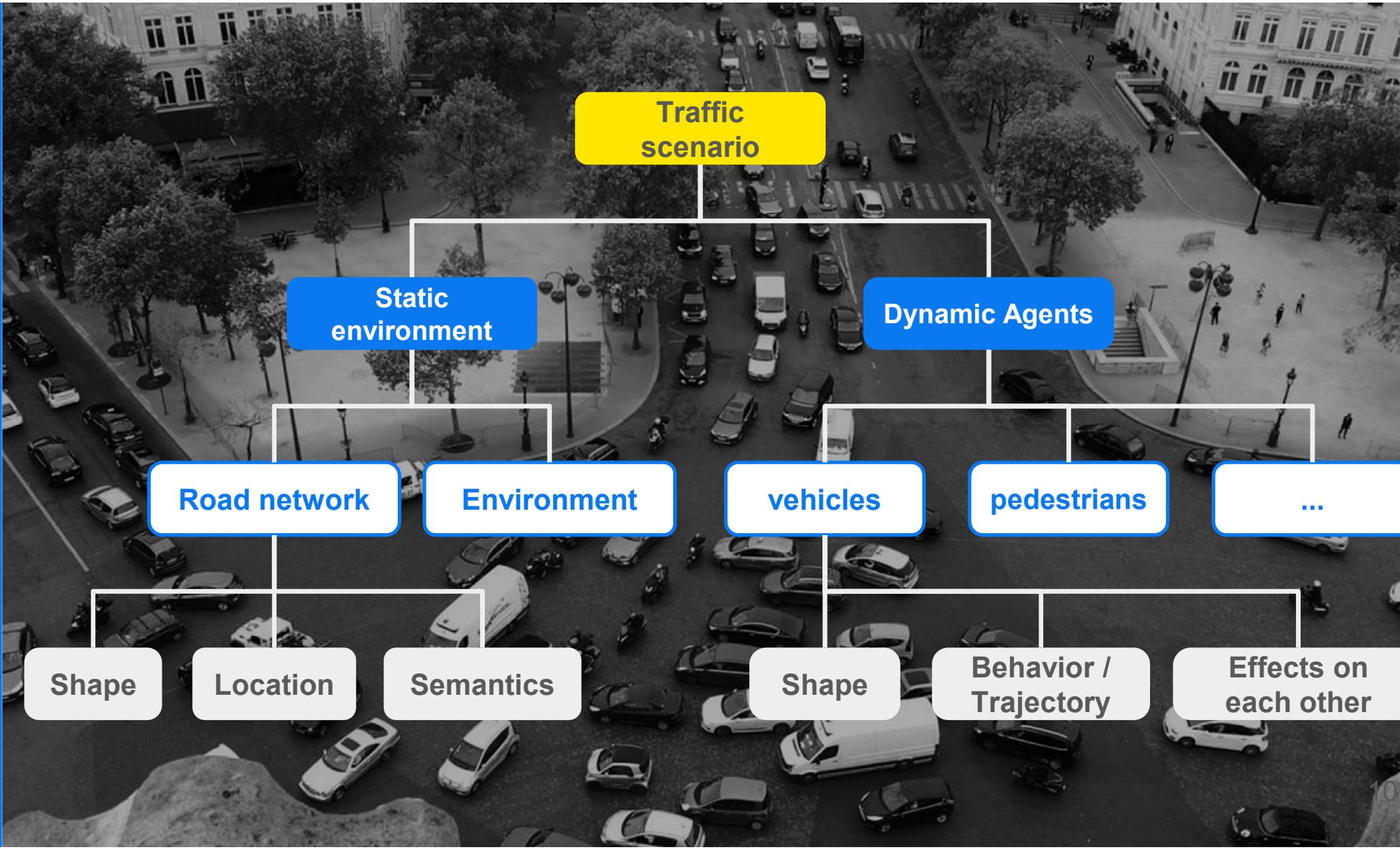
# UAI / dSPACE Toolchain

A suite to generate high quality training and validation data



**dSPACE**

**UAI**



**Traffic scenario**

**Static environment**

**Dynamic Agents**

**Road network**

**Environment**

**vehicles**

**pedestrians**

**...**

**Shape**

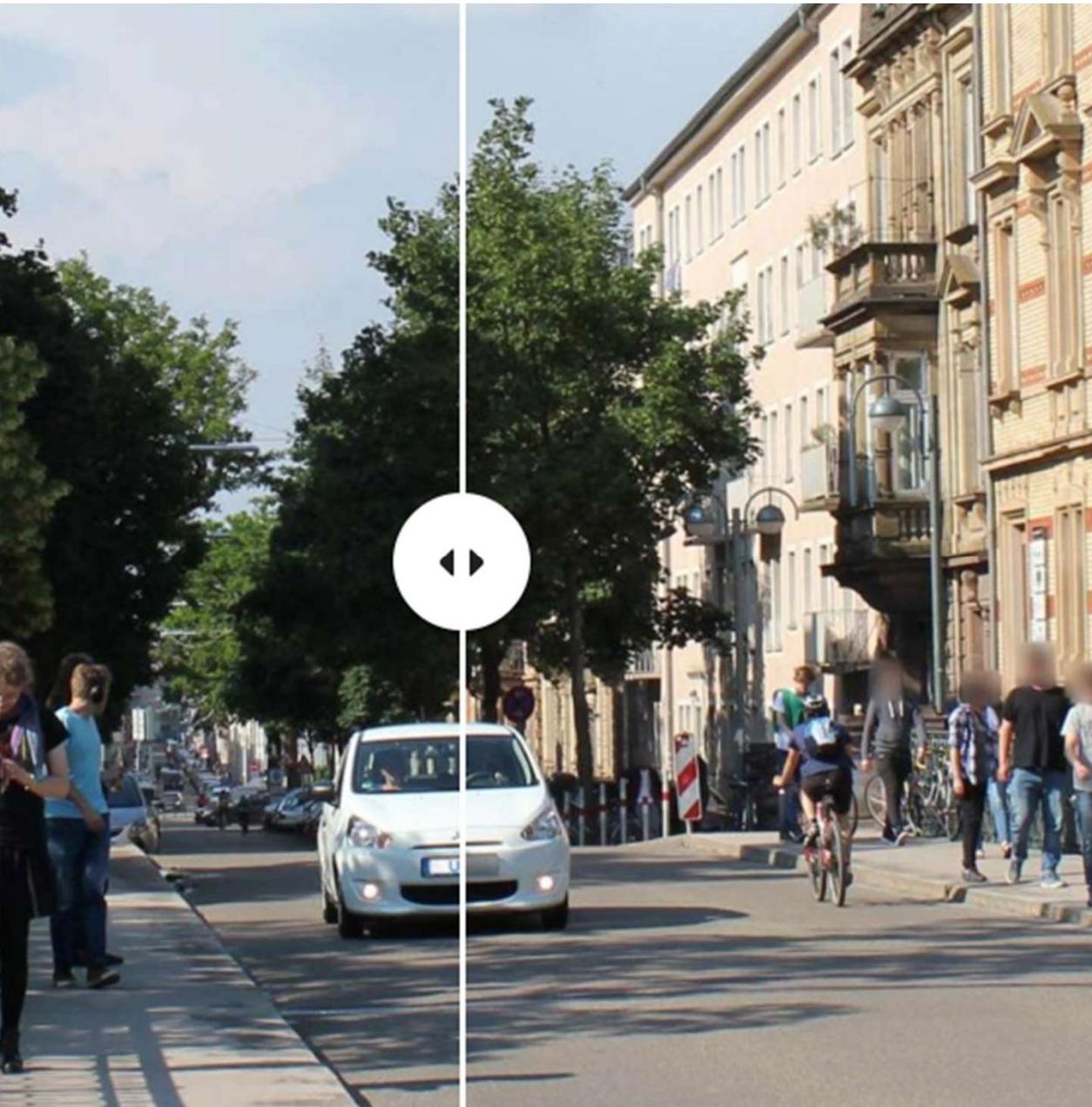
**Location**

**Semantics**

**Shape**

**Behavior / Trajectory**

**Effects on each other**



## The Problem:

With GDPR autonomous vehicles need to be able to collect street scene data with all the critical personal information automatically removed.

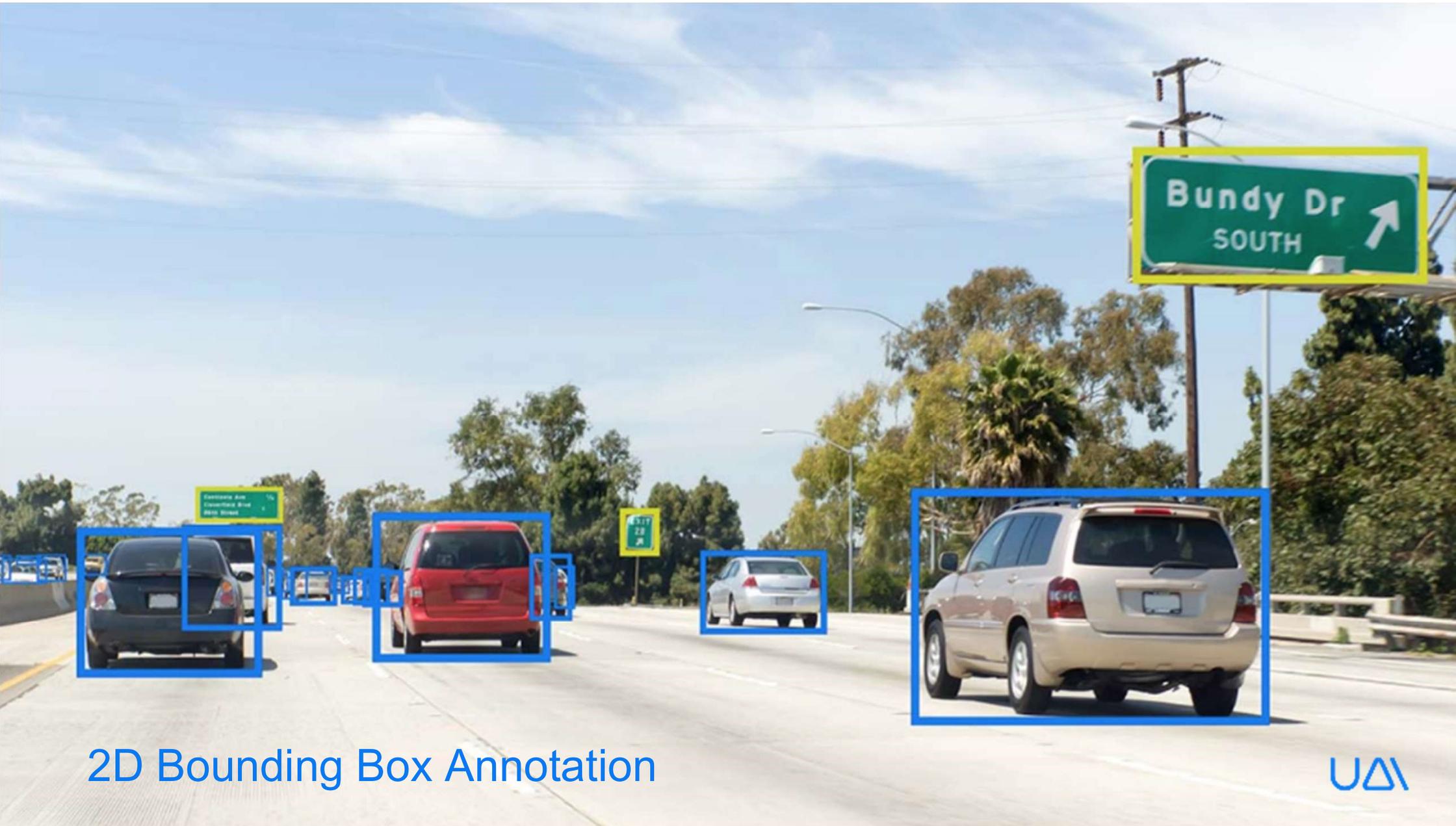
## Solution:

### UAI Anonymizer

- Detects and anonymizes faces and licence plates in a wide range of situations
- Fully integrated into the UAI data enrichment pipeline
- covers > 99.9% of all readable license plates and > 99.5% of all identifiable faces
- Keeps getting better and better over time!

dSPACE

UAI

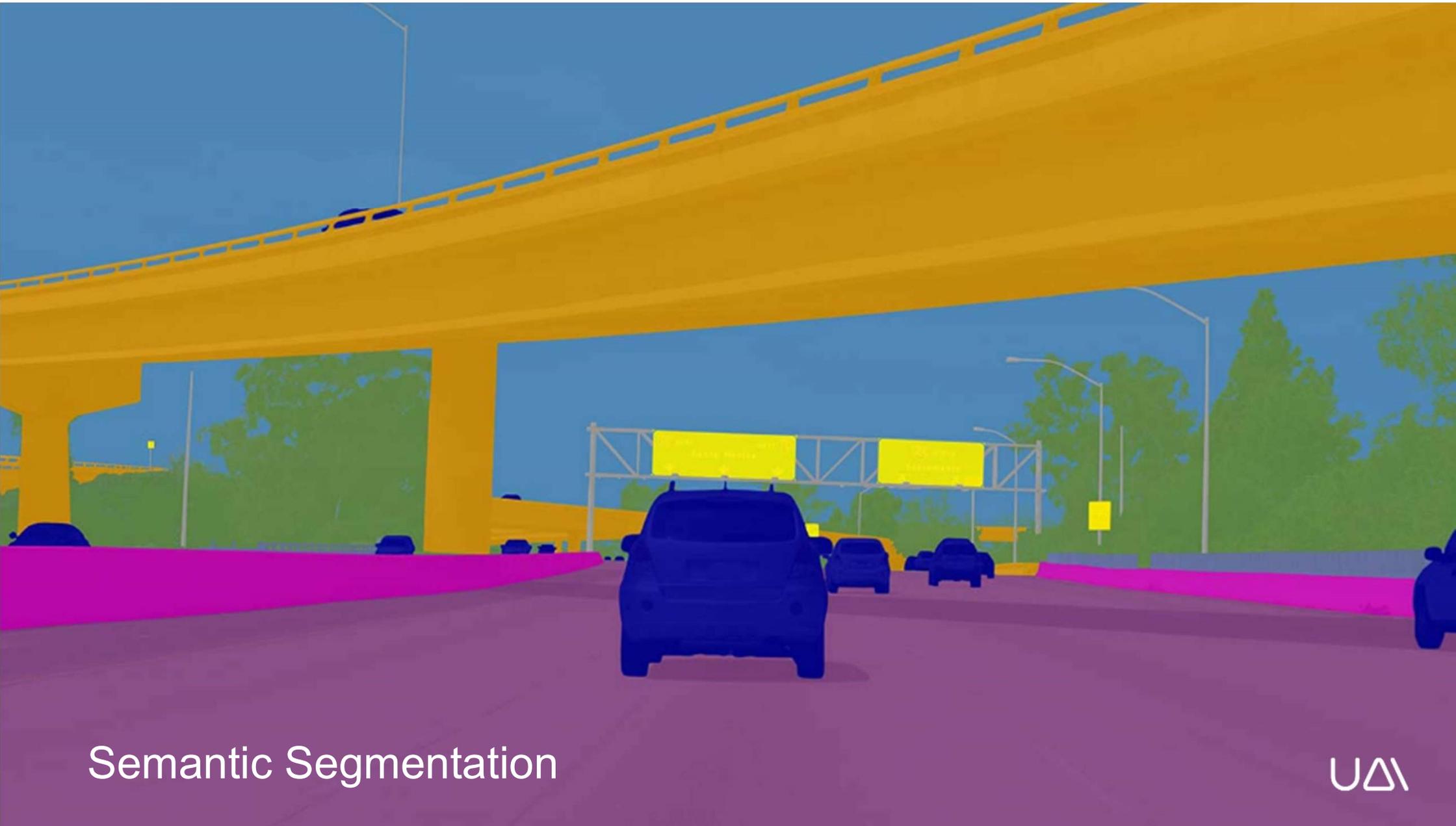


2D Bounding Box Annotation

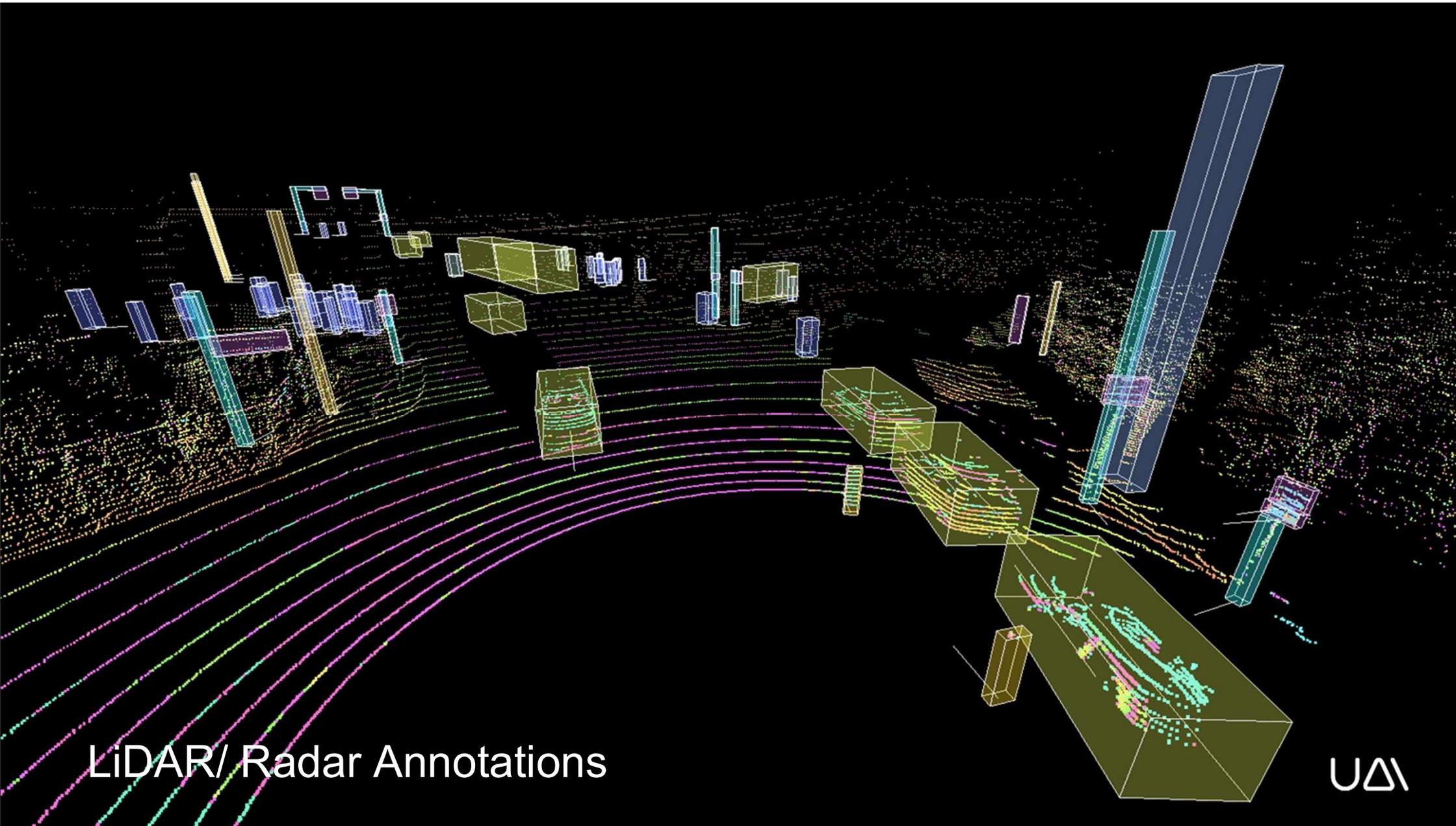


Polyline Annotation





Semantic Segmentation



LiDAR/ Radar Annotations

# Automation Strategy

UAI combines a variety of different automation strategies which build upon one another in order to achieve industry leading automation rates.

Keyframe Selection

World Coordinate Transformation

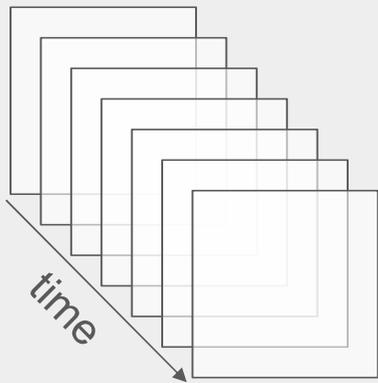
Hyperdense Point Cloud Transformation

Velocity Based Propagation

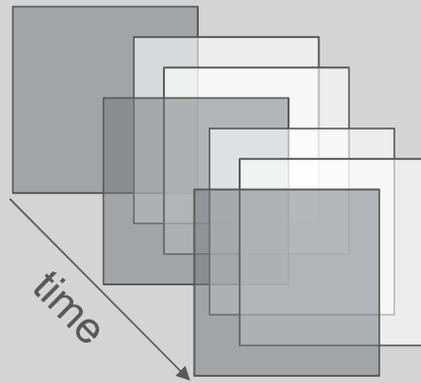
Interpolation

# Keyframe Selection

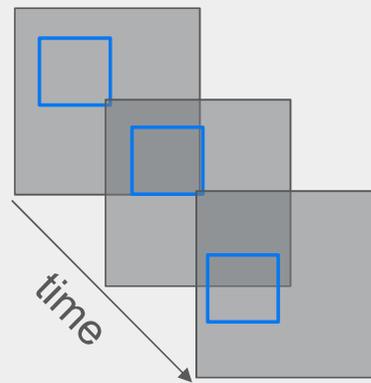
our base level automation works for 2D and 3D



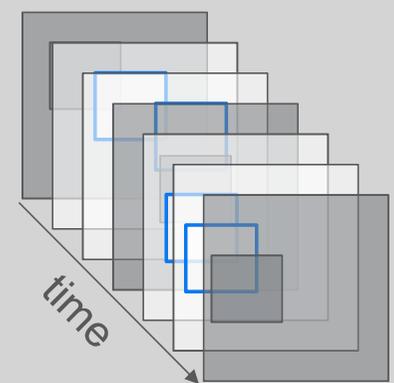
Raw data from customer



UAI removes frames from the stack



Manually annotate objects on remaining frames



UAI merges removed frames back into stack and automatically **interpolates** annotations

# World Coordinates

prerequisite for advanced 3D automation  
on top of Interpolation

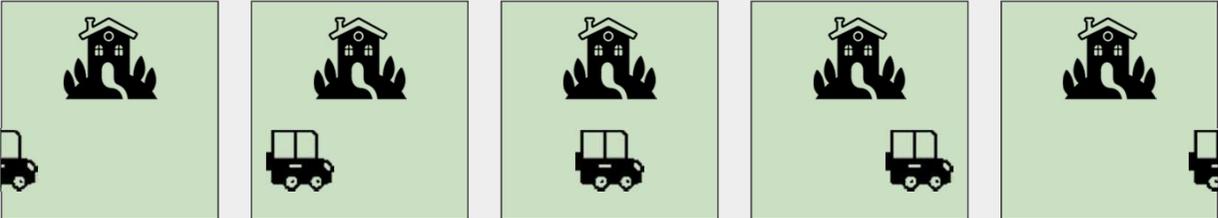


Data is recorded relative to the position of the car. Thus, static objects like houses are moving backwards through the scene. As a consequence, all objects will be dynamic which makes labeling super hard.



UAI transforms data into [world coordinates](#) so that static objects stay at a fixed position and dynamic objects move less. Labeling gets much, much easier this way!

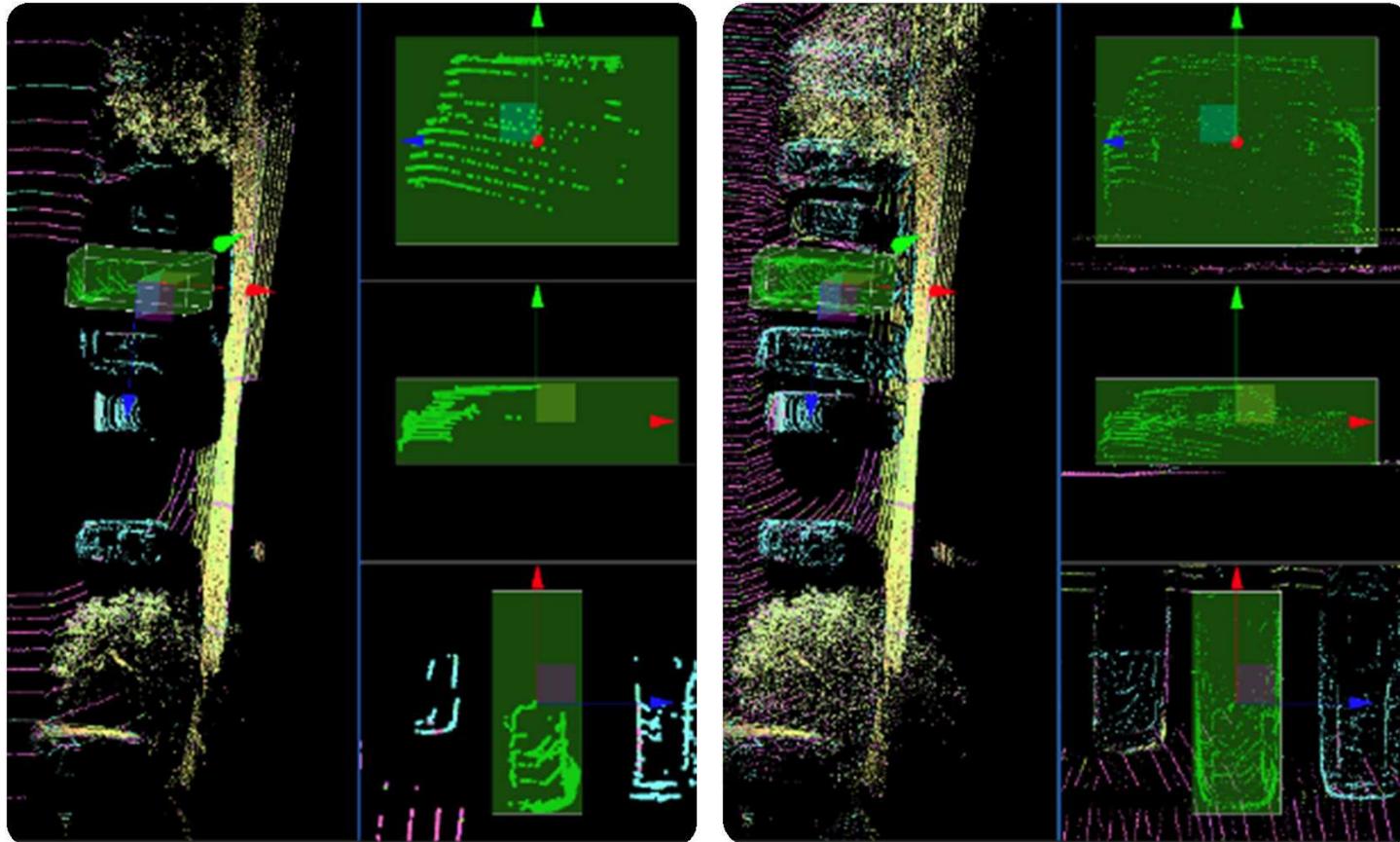
# Hyperdense Point Cloud™ on top of Interpolation & 3D World Coordinates



UAI merges point clouds into one hyperdense point cloud.

**Annotate static objects with one single box across the entire clip for superior precision, consistency and speed!**

# Hyperdense Point Cloud™ in action



# Velocity Based Propagation

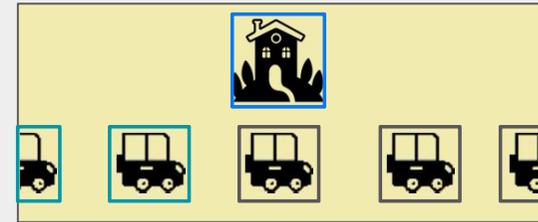
on top of Interpolation, World Coordinates & Hyperdense Point Cloud



Manually annotate dynamic object

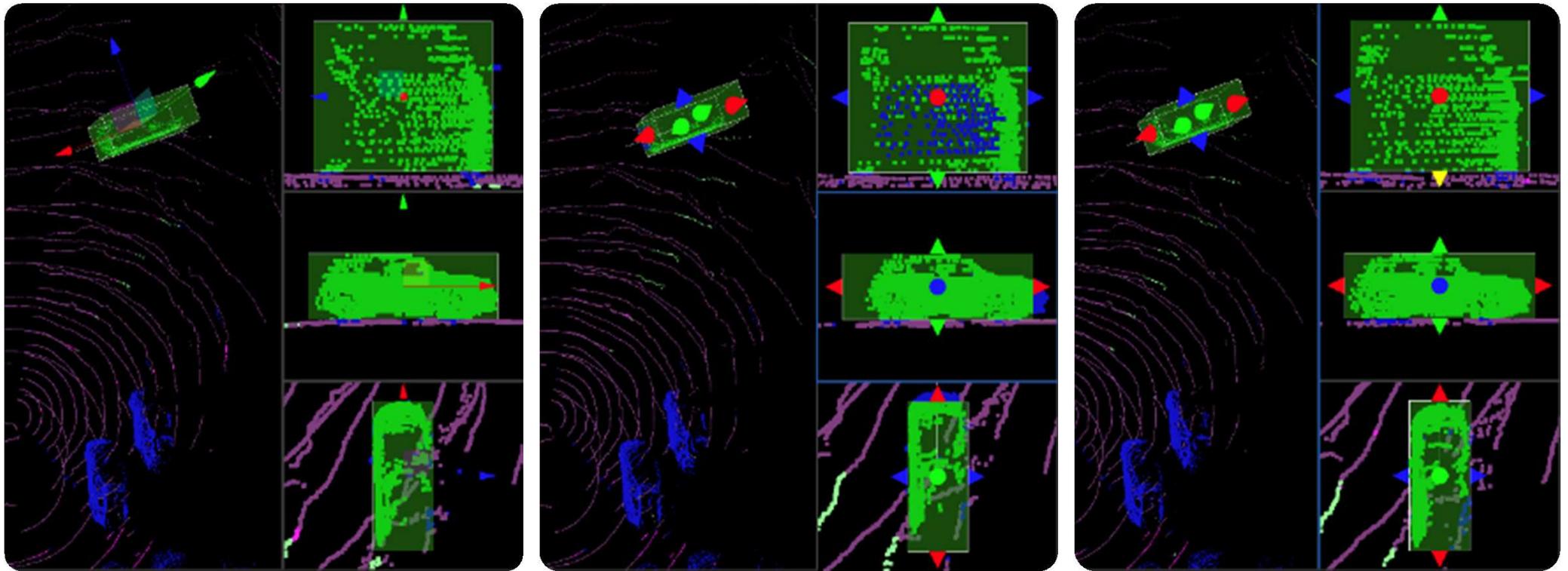


Propagate box to next frame and manually updated position



Via [velocity based propagation UAI](#) correctly propagates box to subsequent frames

# Velocity Based Propagation in action



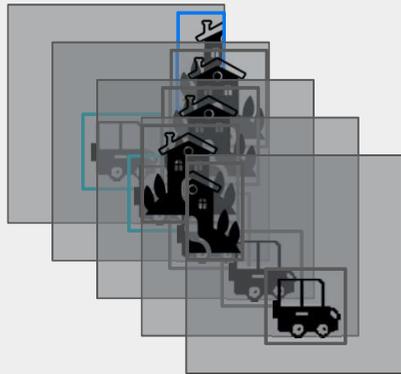
# Zero-Touch Magic

resolve Hyperdense Point  
Cloud™ back into keyframes

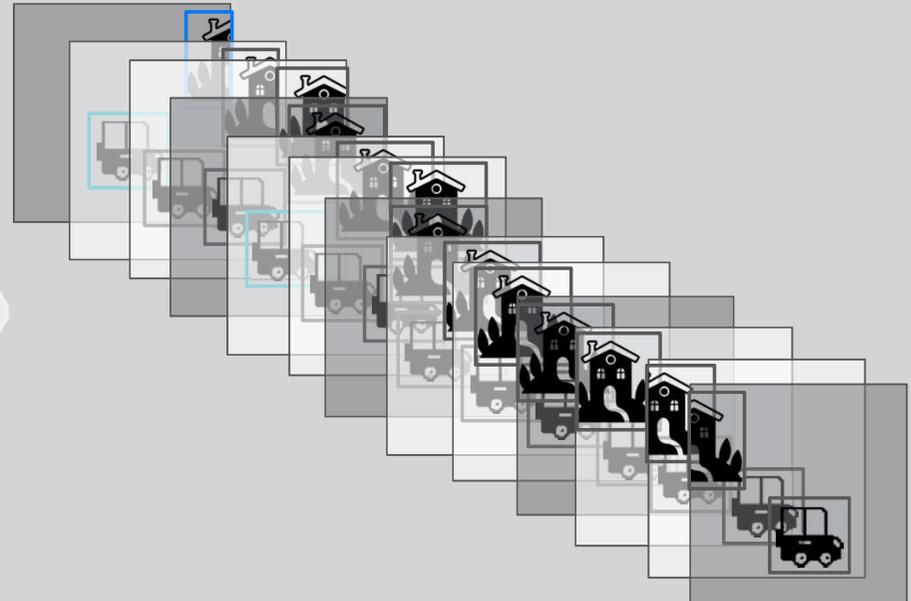


UAI transforms annotations back into relative coordinates and composes **zero-touch boxes** on the way. Results are fed into Interpolation.

# Interpolation

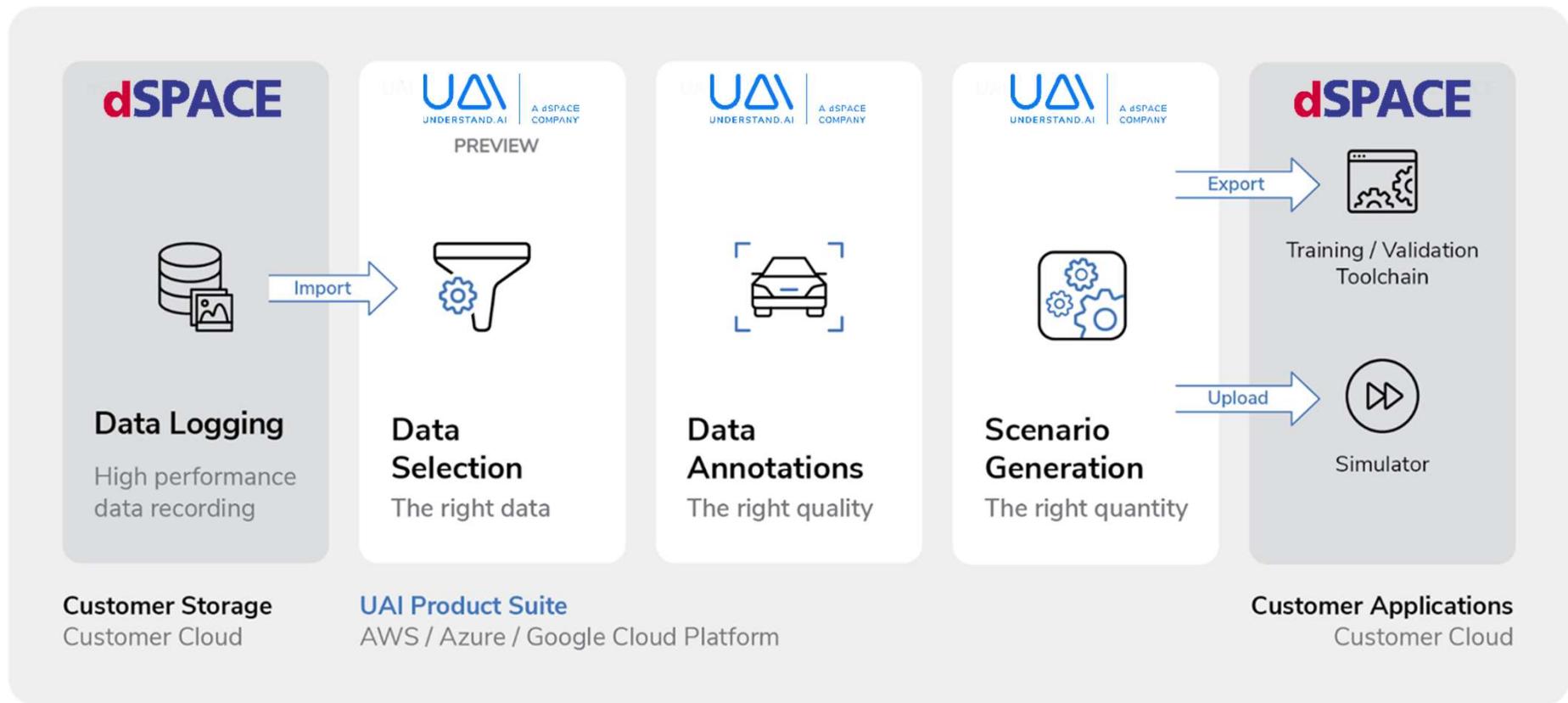


UAI adds non-keyframes back into the stack and on the way zero-touch boxes are **interpolated**

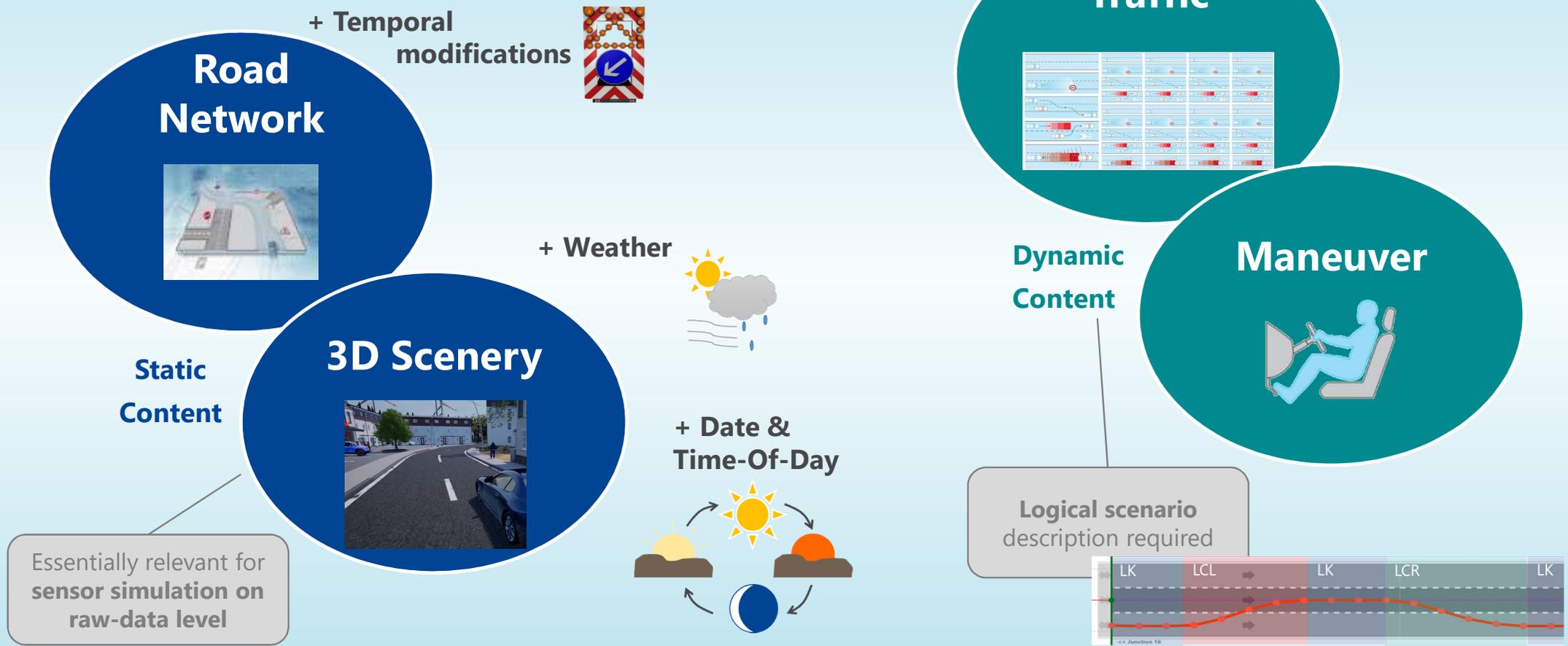


# UAI / dSPACE Toolchain

A suite to generate high quality training and validation data



# Scenario Generation - What is a simulation scenario ?



## Scenario Generation - What is a simulation scenario ?

6-Layer model, describing relevant factors and their geometric, temporal and/or logic relationship  
according to [1], based [2], integration planned

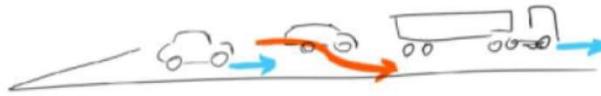
Layer 6



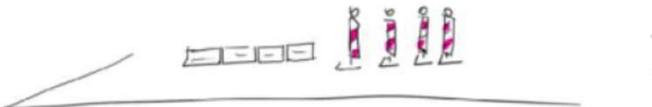
Layer 5



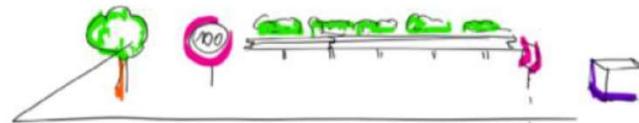
Layer 4



Layer 3



Layer 2



Layer 1



### Digital information:

e.g. V2X information on traffic signals, digital map data  
=> Availability and quality of information communicated to ownship

### Environmental conditions

Light situation, weather (rain, snow, fog...) temperature  
=> environmental influences on system performance

### Moving objects

Vehicles, pedestrians moving relatively to ownship  
=> relevant traffic participants and their motion incl. dependencies

### Temporal modifications and events

Road construction, lost cargo, fallen trees, dead animal  
=> temporary objects minimizing / influencing the driving space

### Road furniture and Rules

traffic signs, railguards, lane markings, bot dots, police instructions  
=> including rules, where to drive how

### Road layer

road geometry. Road unevenness (openCRG),  
=> physical description, no scenario logics

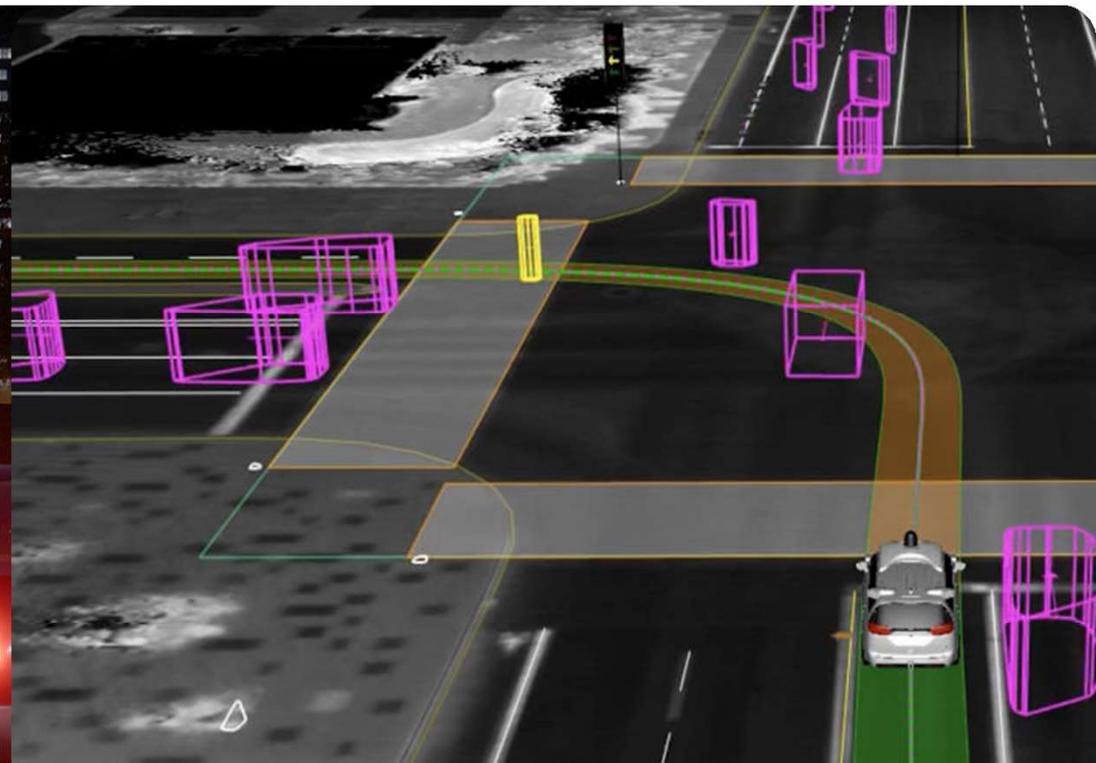
[https://www.pegasusprojekt.de/files/tmp/Pegasus-Abschlussveranstaltung/PEGASUS\\_Abschlussveranstaltung\\_Wie\\_weise\\_ich\\_dies\\_nach.pdf](https://www.pegasusprojekt.de/files/tmp/Pegasus-Abschlussveranstaltung/PEGASUS_Abschlussveranstaltung_Wie_weise_ich_dies_nach.pdf)

# Different types of scenarios

Usable for testing different parts of the pipeline



**Sensor Realistic scenarios for perception tests**  
Road and 3D Scenery required

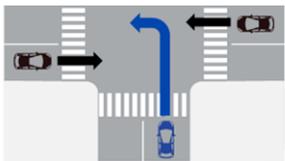


**Low-fidelity scenarios to test planning**  
Only road required

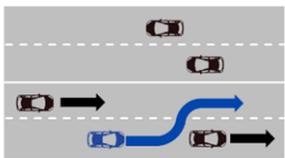
# Logical Scenarios vs. Replay-Scenarios

## Logical Scenario

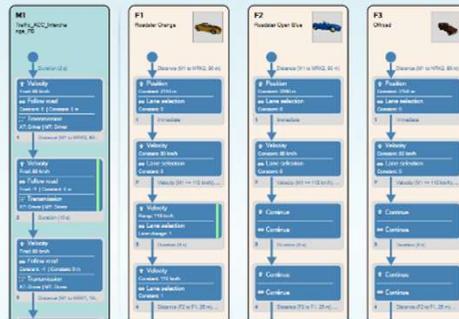
A scenario is a description of a driving situation



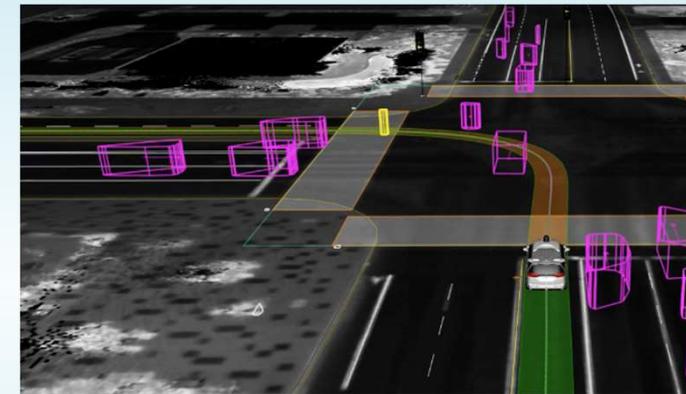
Example 1:  
Left turn at  
an intersection



Example 2:  
Overtaking maneuver  
on a dual carriageway



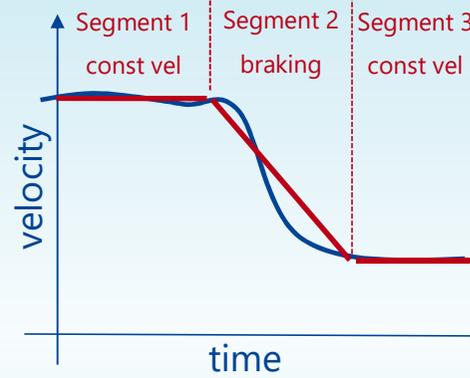
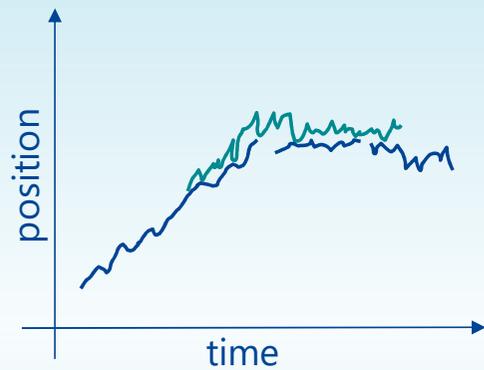
## Replay Scenario



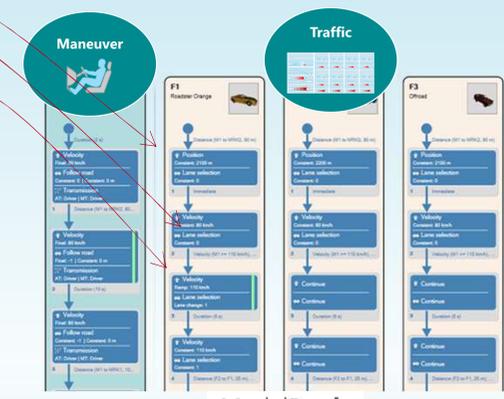
- Might not exactly replay scenario due to **abstraction** and **generalization**
- Scenario can be changed by scenario-parameters  
→ Scenario can be varied by user → ScBT
- Scenario will be consistent in valid parameter space

- Replay of **trajectories**  
→ Exact reproduction of real scenario in the simulation
- Not possible to change scenario
- Scenario might become inconsistent if ego motion changes due to different reaction of AD algorithm

# Trajectories to logical scenario



ModelDesk OpenSCENARIO

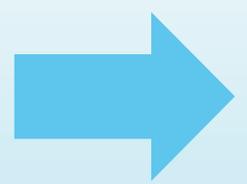


Object Lists

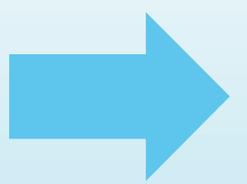
Raw Trajectories

Trajectory-based Scenario

Logical Scenario



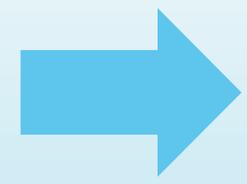
Advanced Tracking / Fusion



Fitting / Filtering / Extrapolation / Mapping to Road and Lanes



Convert Object-Trajectories to logical scenario description

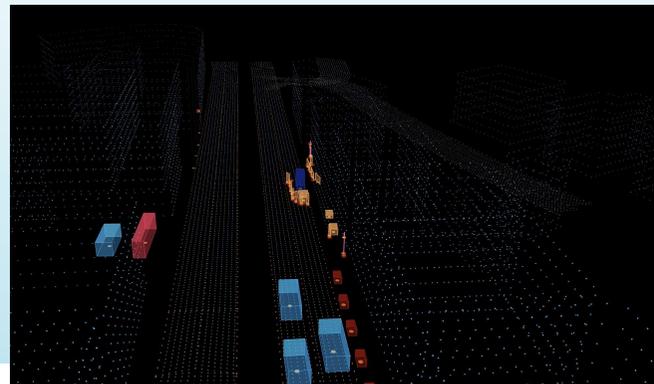


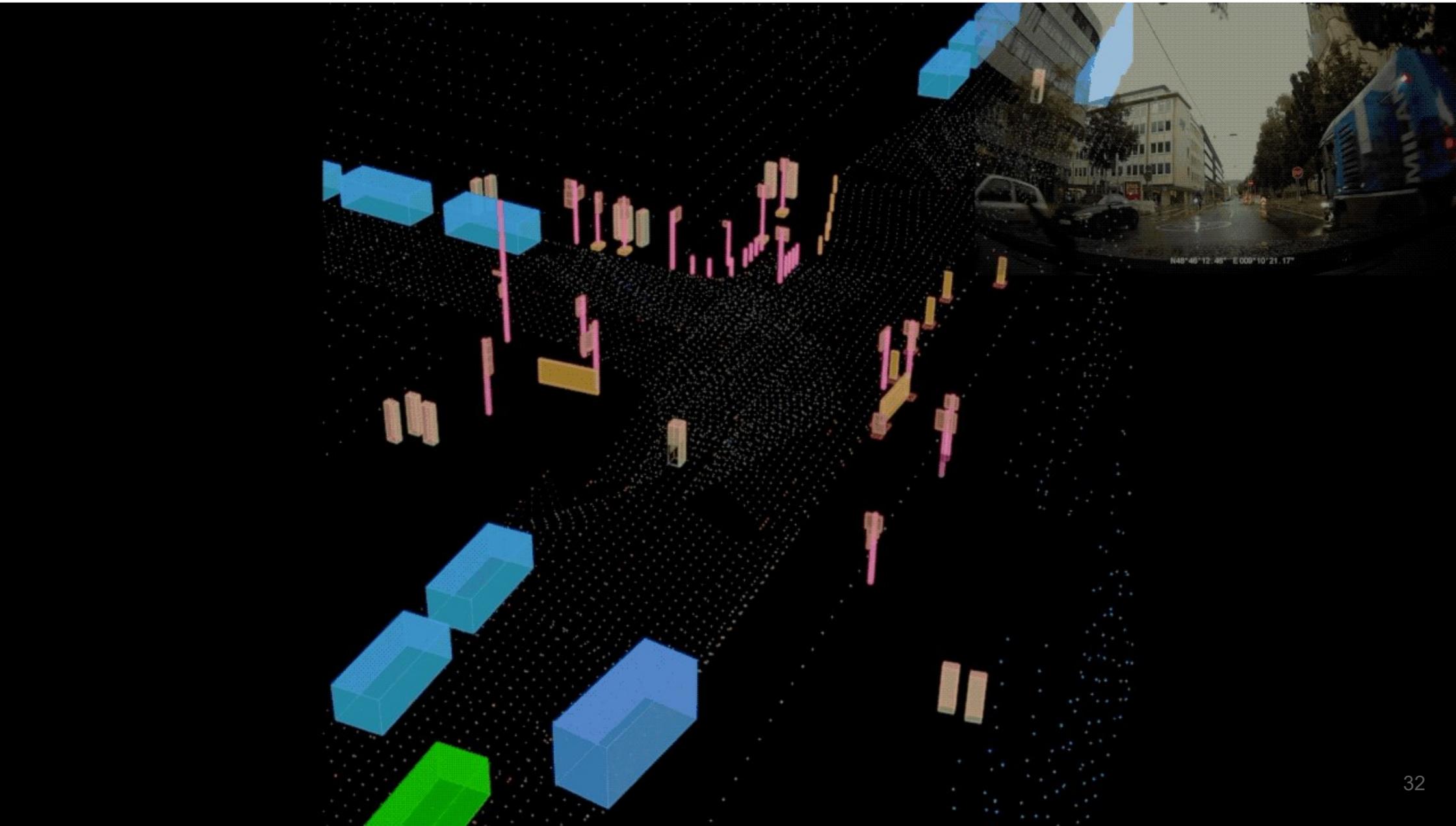
Lane Index of Ego and Traffic (from Camera data)

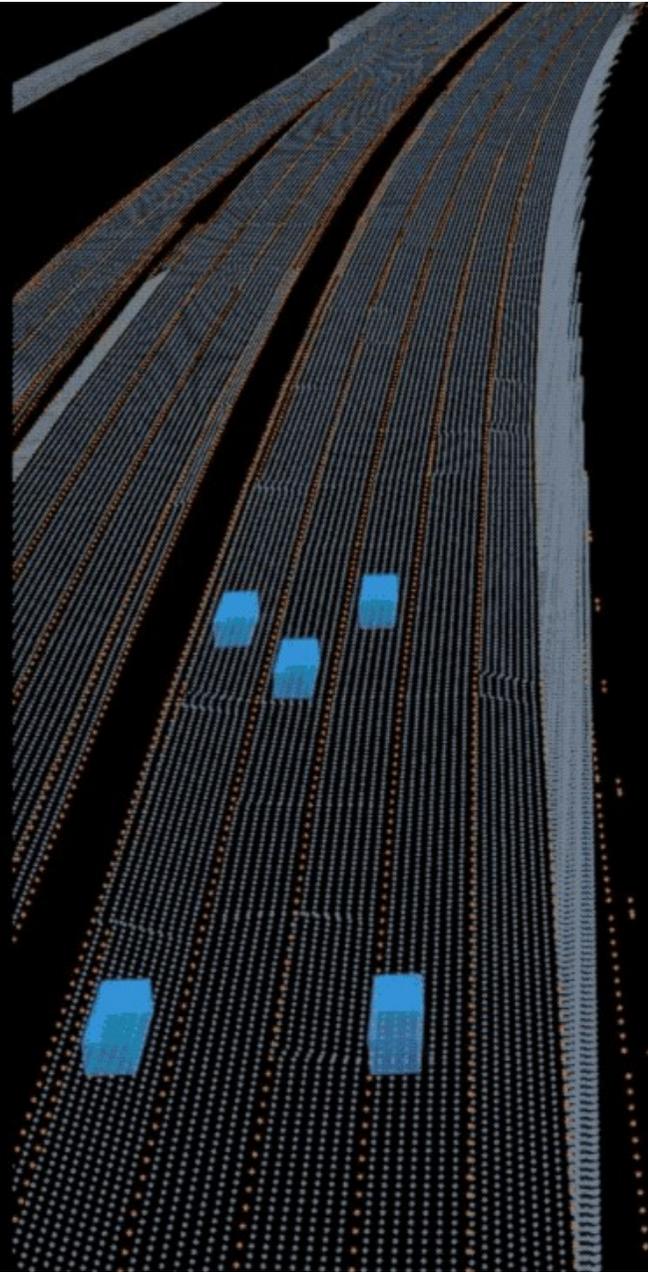
Replay in Closed-Loop Simulation

Parameter variation Scenario-based testing

## Demo Scenario from Only Camera







## ADAS/AD – Beat the Challenge





**Thank you for listening!**

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