The Future in Motion

We make AUTONOMOUS MOBILITY happen.

SIP-adus Workshop 2021

Virtual Validation of Radar Sensors for Assisted and Automated Driving

Frank Gruson, 2021-11-10

www.continental-automotive.com

Frank Gruson

Head of Advanced Engineering Radar

- ***Radar is the key technology for assisted and automated driving:*** *Proven technology since 1999, robust under all weather conditions and able to handle complex and highly dynamic scenarios.*
- *To develop new generations of radar sensors,* ***virtual validation*** *allows us to design even* ***better radar antenna and system concepts in a shorter development time*** *by leveraging the power of high-definition digital maps and automatic scenario generation.*
- *Deep learning* ***Radar CNNs*** *(convolutional neural networks) require a large amount of labeled training data.* ***Virtual validation will allow us to generate this training data*** *without the need for manual labeling of on-road test data.*

Continental's Autonomous Mobility Business

Leading Player with Track Record of Profitable Growth

> 100 mn
Units delivered
2017 – 2019
Radars
Cameras
Lidars
AD[1] Control Units

> 100 mn
Radar sensors delivered since 1999

25	OEMs
50	Brands
> 300	Models

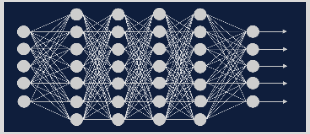
[1] Assisted / Automated Driving

We Are Ready for the Challenges of the Future

AI and Simulation for the Next Era of AD Technologies

The Vital Importance of Data Quality & Efficient Data Management

Neural Network Development



Global Test Vehicle Fleet

Collecting around 100 terabytes of data each day – equivalent to 50,000 hours of movies

Synthetic Data Generation

Validation & Simulation

Strategic joint Japanese-German Partnership DIVP™/VIVALDI

jama Japan Automobile Manufacturers Association

DAIMLER

Continental The Future in Motion

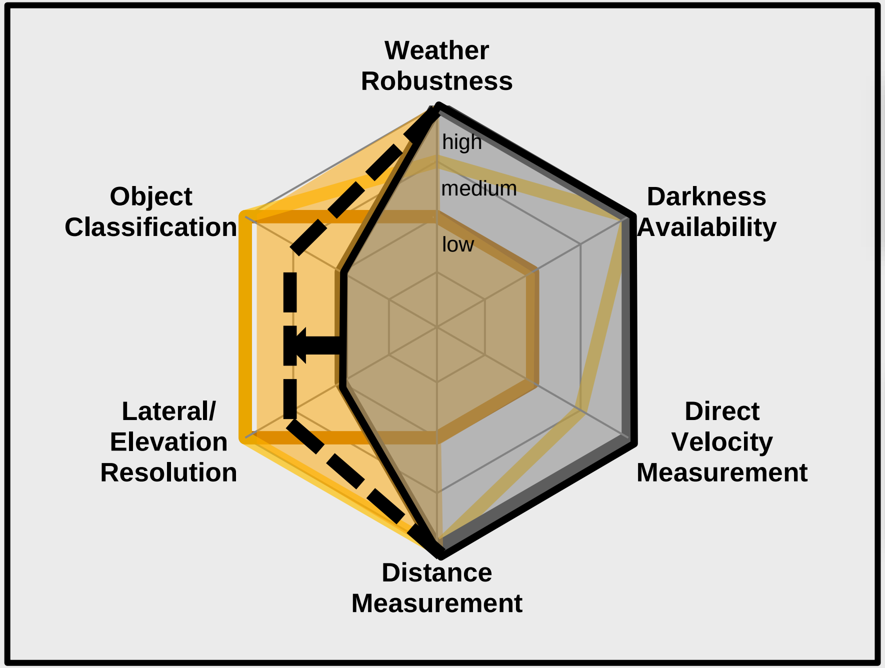
内閣府 Cabinet Office

Bundesministerium für Bildung und Forschung

AI Competence Center

- **Core development** of AI technologies
- **Roll-out** to product development teams

Radars for <u>Assisted</u> Driving ⇔ Radars for <u>Automated</u> Driving

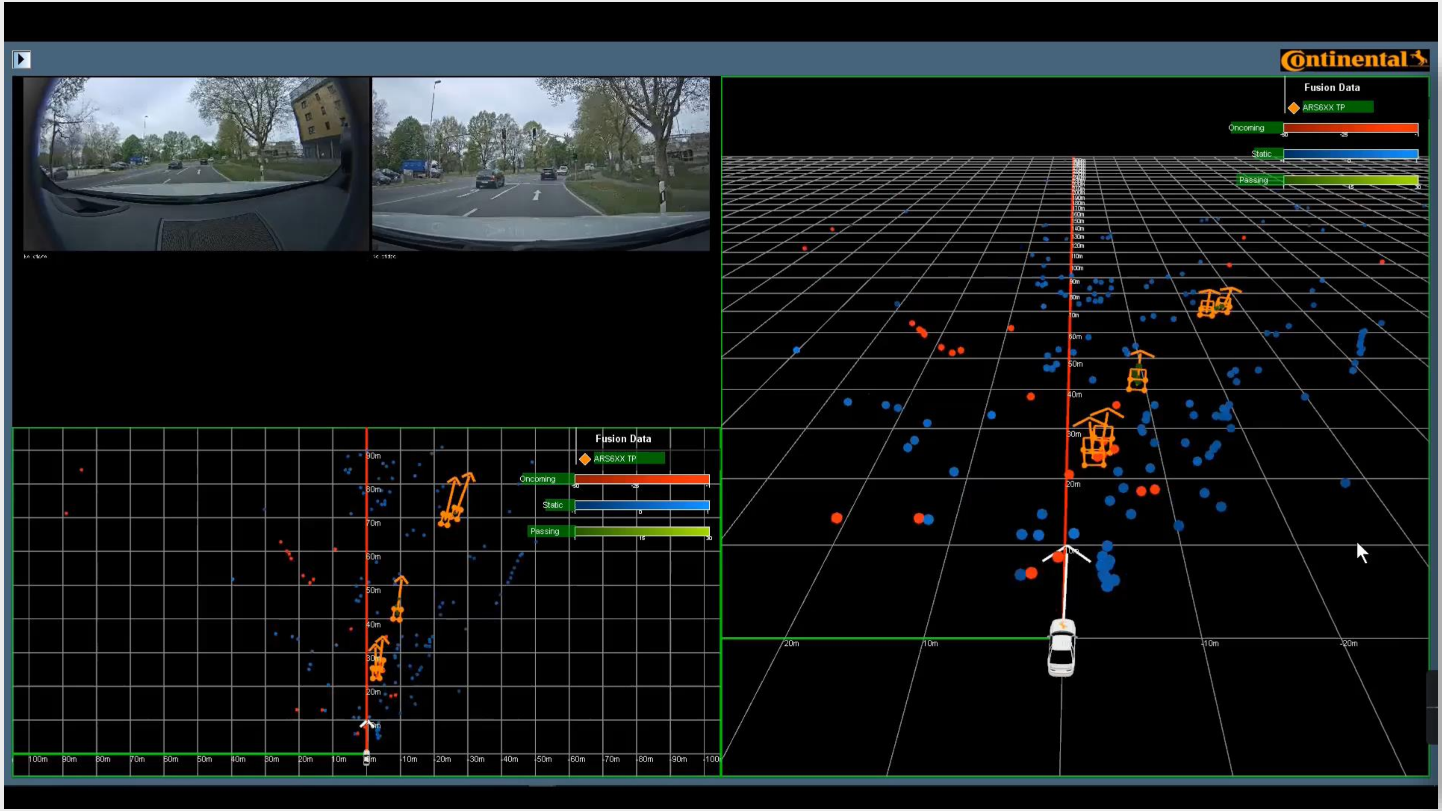


Standard Radar Sensors For Assisted Driving

Future Radar Sensors For Automated Driving

Continental ARS620 Radar sensor for Assisted Driving

Measured point cloud and object tracking

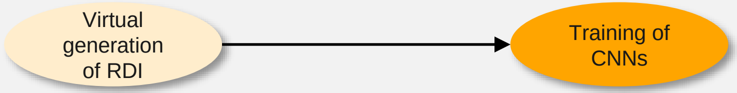


- Dense point cloud
- Leading edge detection range (250m)
- Excellent resolution
- Elevation measurement capability

Target of the VIVALDI project:
Can we simulate such a Radar point cloud by real-time ray tracing ?

- **Limitations of current sensor development (Radar sensor optimization)**
  - Sensor development requires a significant amount of time to built up the samples
    - A sample ➔ B sample ➔ C sample
  - Small changes between different antenna designs and radar system designs are time-consuming to extract experimentally
  - Difficult / dangerous “corner scenarios” can not be recorded by on-road testing
- **Limitations of current approach to train Radar AI (Artificial Intelligence)**
  - CNNs require a large amount of training data
  - Today, these training data are recorded via on-road testing and require a time-consuming labeling process & expert knowledge

- **Possibilities for sensor development using the virtual validation approach**
  - A large amount of different antenna and system configurations can be evaluated in a reproducible and consistent manner without the effects of measurement inaccuracies
  - Difficult / dangerous “corner scenarios” can be simulated.
- **Possibilities to train Radar Artificial Intelligence using the virtual validation approach**
  - Test data can be generated virtually
  - No labeling of training data necessary
  - Variances and non-idealities can be realized easily,
  - which are required to generate robust CNNs



AAI Company Introduction

AAI was founded in February 2017 by experts from the automotive industry and has since grown to about 100 colleagues in Berlin, Munich & Islamabad *additionally* to a dedicated Image Annotation team of over 250.

Around **85%** of AAI´s staff has a technical background, including artificial intelligence, mathematics, software architecture, 3D and platform development.

ASAM Member

Certified:
Management System: ISO 9001:2015 • Information Security Management System (ISMS): TISAX Assessment Level 3, protection level very high

AAI Technology using ASAM open interfaces

3rd party interface | Standalone Products | Services

AAi

- ✓ Modular design
- ✓ Flexiblity for integration with other platforms

Customer Ego Vehicle
Integration via SDK or co-simulation
e.g. with 3rd party physics engine

Integration as standalone module
into 3rd party software

Synthetic Scenario Export
OpenSCENARIO + OpenDRIVE

Synthetic Image Export
- » RGB
- » Segmented
- » Depth

AAi Replica®

Engineering Portal
Web-based graphical user interface for test set-up

Endurance Test
- » Naturalistic traffic flow with spontaneous interactions for robustness testing
- » Discovery of edge cases

AAi Intelligent Traffic

Scenario Test
- » Deterministic with predefined actors and their trajectories
- » Allows test automation for regression testing

OpenSCENARIO® bringing content to the road

OpenDRIVE® managing the road ahead

Sensor Simulator
Ground Truth, Camera, Lidar, (Radar)

Interface to OptiX Rendering-Model added

Analyzer
Web-based Graphical User Interface for replay & analysis

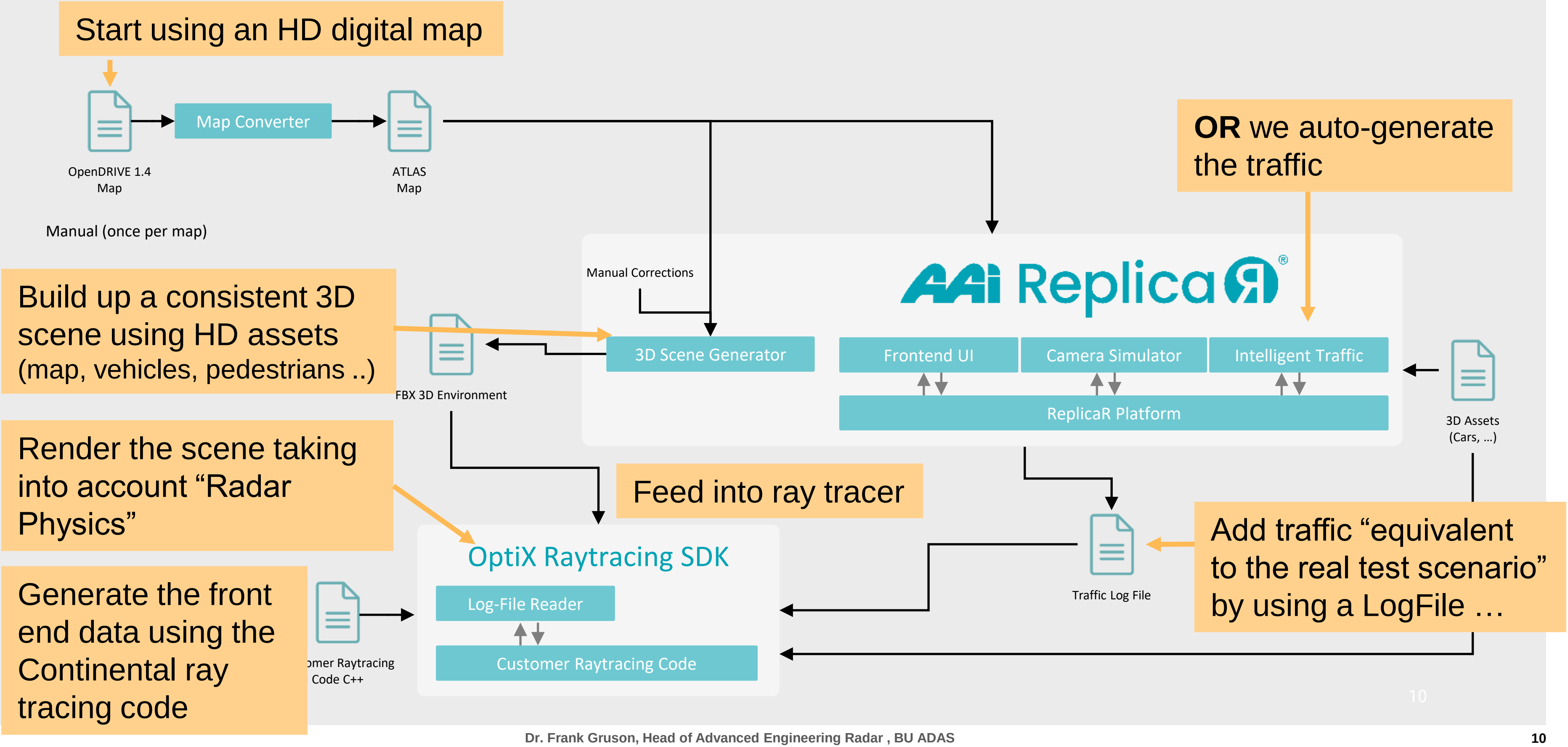
Image Segmentation
Classification & Analysis
Database Management

AAi Scencario Cloning
- » **Replay**: Converting sensor measurements to readable log files
- » **Scenario Extractor**: Translating Replay into OpenSCENARIO + OpenDRIVE for AD testing

Scenario Database
Classification & Analysis
Database Management

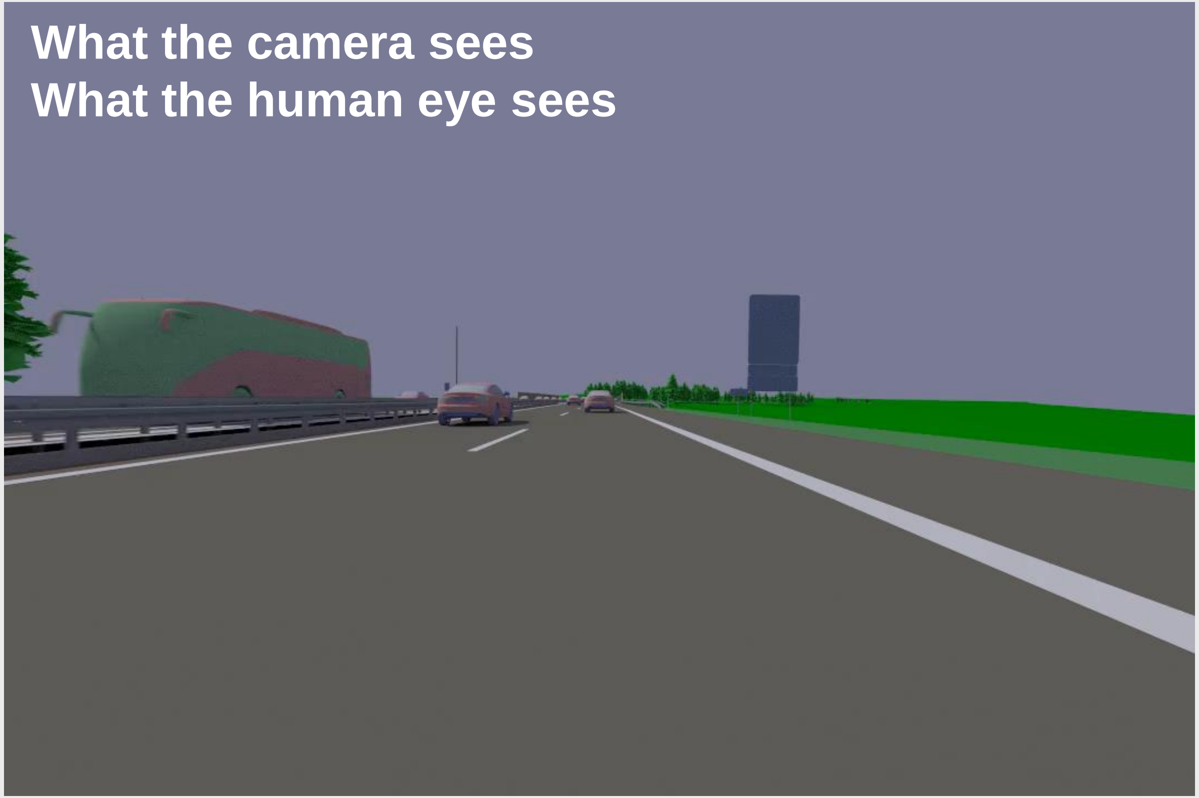
3rd party scenario test SW
supporting OpenSCENARIO standard

How to generate such a point cloud by virtual simulation ?



Example (complex scenario):

Highway A96 close to exit “Lindau” with virtual traffic



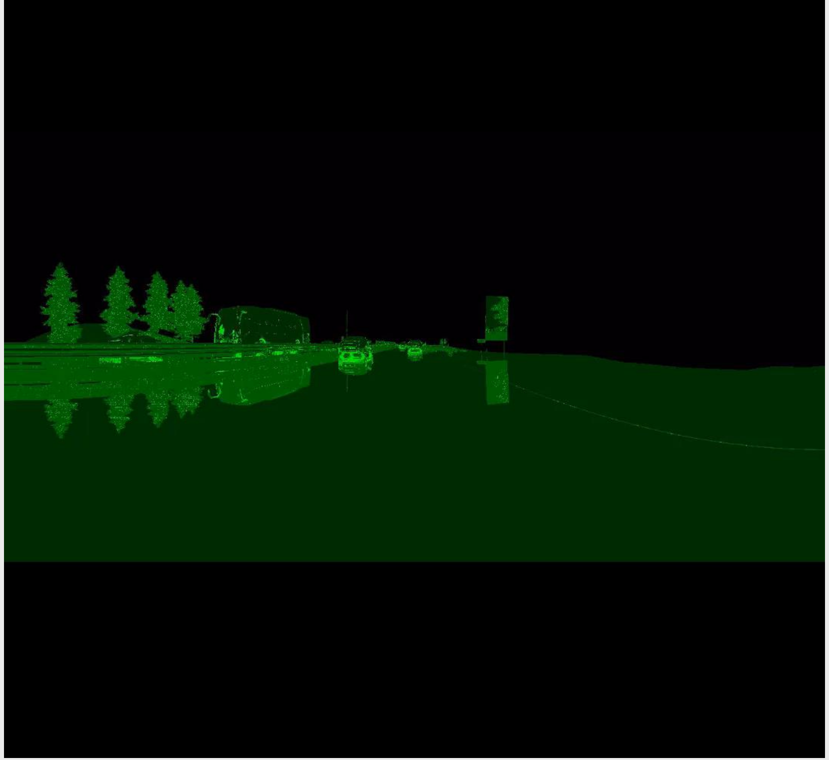
- Environment created from HD map
- Traffic is “auto-generated” by AAI´s intelligent traffic module
- 3D scene generated in AAI´s 3D scene generator
- Radar ray tracing applied in OptiX SDK to generate the front end data
- Front end data are converted into detections by the ARS620 SiL tool chain (SiL = Software in the Loop)
- SiL raw data processing of ARS620 applied (no sensor model!)

- **Next steps**:
- Add real traffic from log-file
- Comparison of virtual data with real data within the same video

Example (complex scenario):

Highway A96 close to exit “Lindau” with virtual traffic

What the Radar sensor sees: Intensity View



What the Radar Sensor sees: Intensity view = RCS (Radar Cross Section)

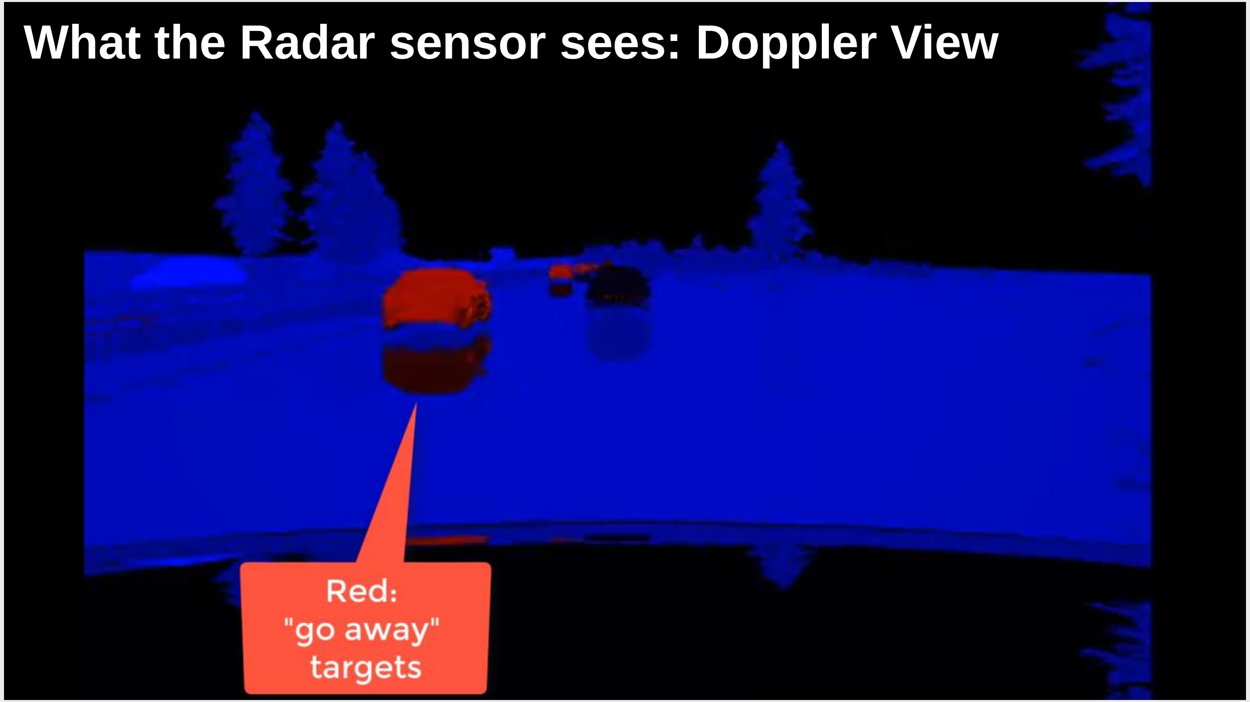
- Mirror objects due to reflections of Radar waves from street surface and guard rails.
- Rotating wheels to generate consistent micro-Doppler reflections.

Next steps:

- Determine the proper Radar reflection coefficients as well as the proper material parameters for Camera and Lidar by efficient cooperation with research labs and Universities and the DIVP™ project.
- Enter this information into a material database using the “Open Material” standard which is currently being defined by ASAM members.

Example (complex scenario):

Highway A96 close to exit “Lindau” with virtual traffic



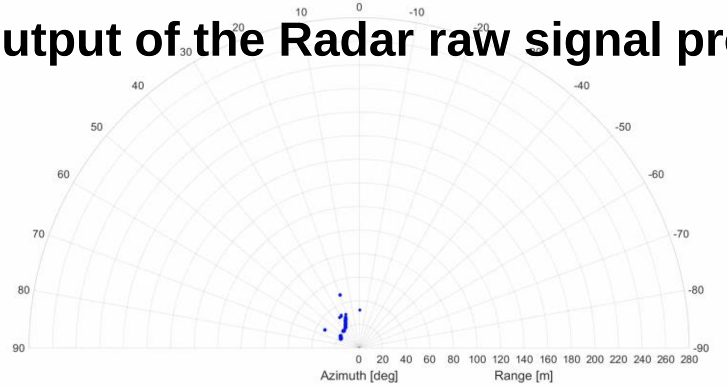
What the Radar Sensor sees (Doppler View):

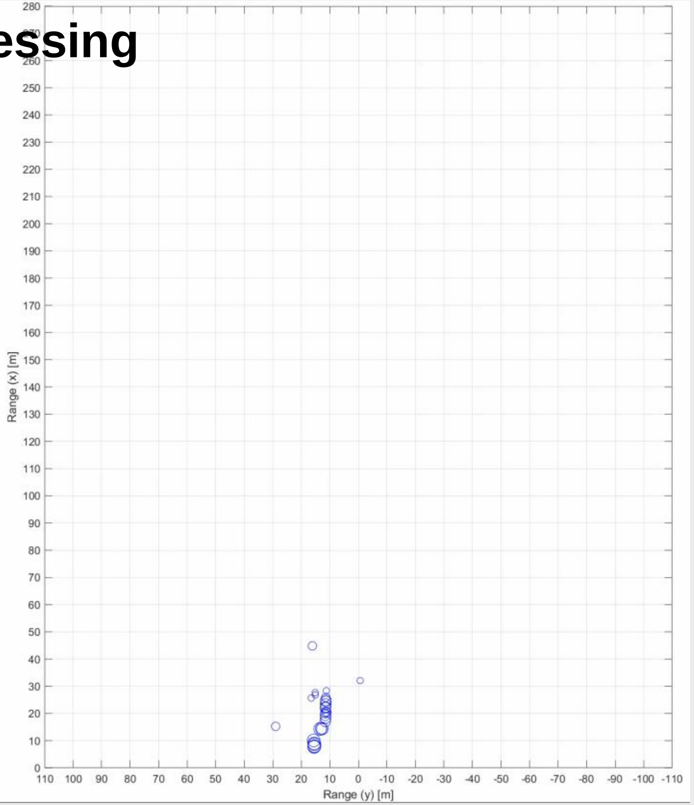
- Doppler velocity is color-coded with relative speed (relative to ego vehicle)
    - Blue: oncoming targets
    - Red: Passing (“go away”) targets
- Rotating wheels to generate consistent micro-Doppler reflections:
    - Fast micro-Doppler on top of wheel
    - Slow micro-Doppler on bottom of wheel

Example (complex scenario):

Highway A96 close to exit “Lindau” with virtual traffic

Output of the Radar raw signal processing





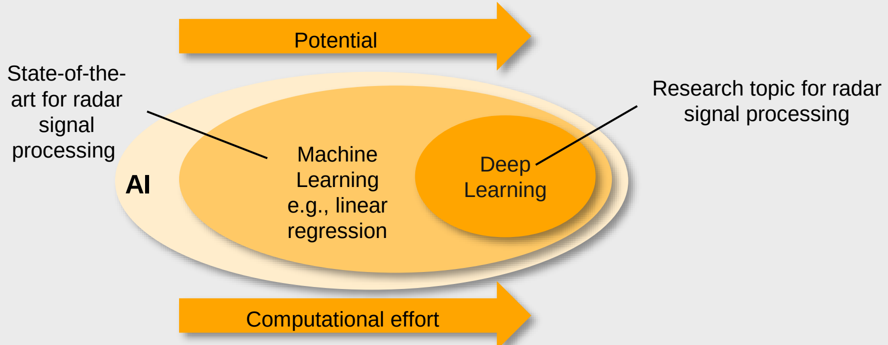
Result:

- Radar point cloud is consistently generated for on-coming and passing traffic

Note:

- For simplicity, only Radar detections from **dynamic traffic** are calculated.
- Detections from the **static scene** are currently not calculated.

Leveraging the potential of AI



Venn. diagram: Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016

- Today: RDI by on-road tests → Data labeling → Training of CNNs
- Tomorrow: Virtual generation of RDI → Training of CNNs

➔ Eliminate the time-consuming and error-prone labeling process by creating synthetical training data for Radar CNNs

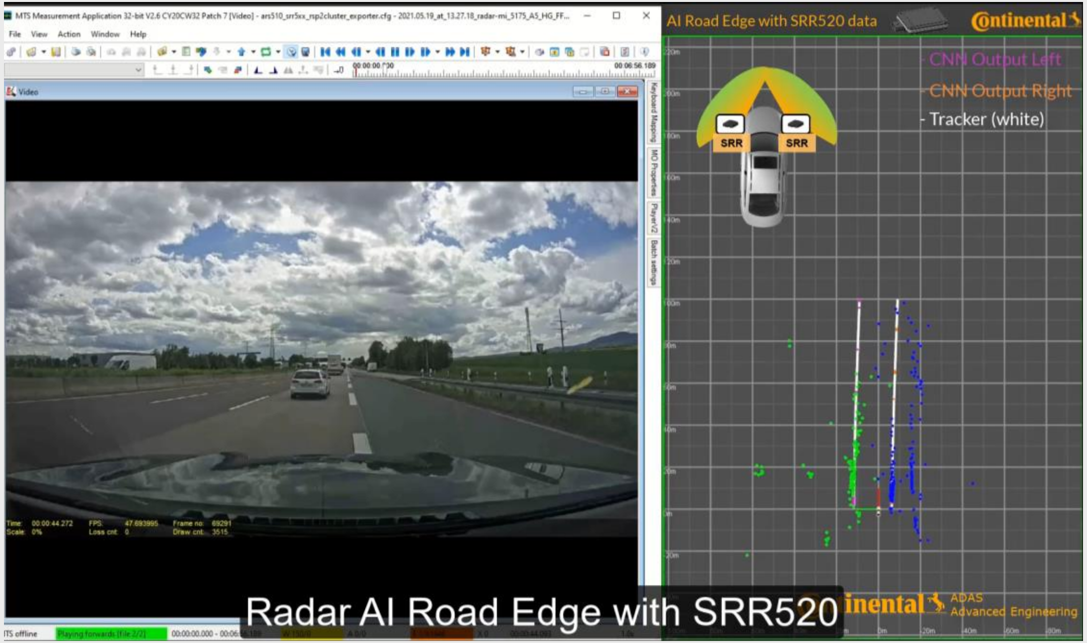
RDI: Radar Detection Image

CNN: Convolutional Neural Network
https://de.wikipedia.org/wiki/Convolutional_Neural_Network

Example: Road edge detection

- Example: Road edge detection of an entry level Radar sensor for Assisted Driving using Deep Learning

RDI by on-road tests → Data labeling → Training of CNNS



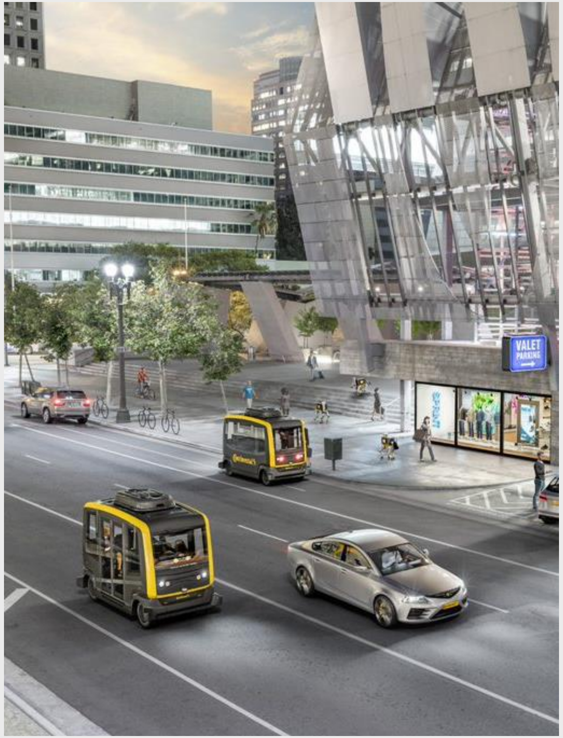
Today:

- Generate the training data for the CNNs by on-road testing and a time-consuming and error-prone labeling process

Tomorrow:

- creating **synthetic training** data for Radar CNNs by **virtual validation**

Virtual Validation of Radar Sensors for Assisted and Automated Driving
Summary



- **Radar is the key technology for assisted and automated driving:** Proven technology since 1999, robust under all weather conditions and able to handle complex and highly dynamic scenarios.

- To develop new generations of radar sensors, **virtual validation** allows us to design even **better radar antenna and system concepts in a shorter development time** by leveraging the power of high-definition digital maps and automatic scenario generation.

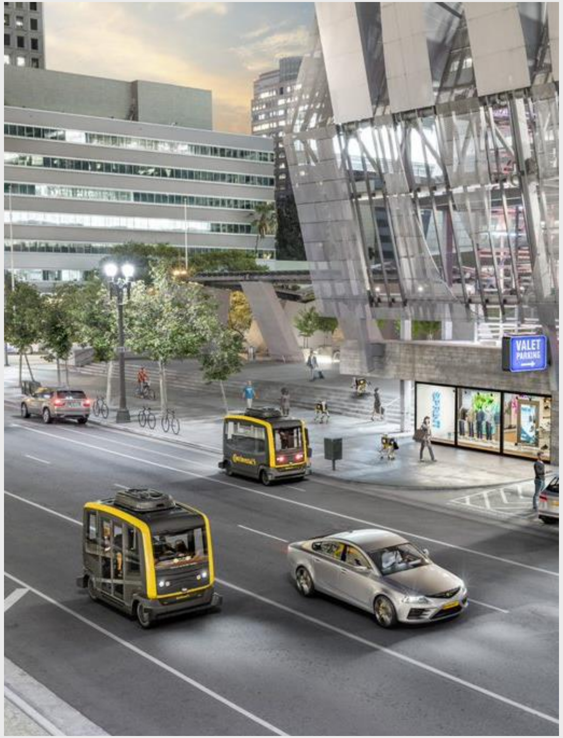
- **AAI´s simulation framework** – which is **based on open data interfaces of ASAM e.V.** – allows us to generate consistent 3D scenes from HD maps of real environments and 3D HD assets such as vehicles and pedestrians.

PEGASUS

- Deep learning **Radar CNNs** require a large amount of labeled training data. **Virtual validation will allow us to generate this training data** without the need for manual labeling of on-road test data.

Virtual Validation of Radar Sensors for Assisted and Automated Driving

Thank you !



I would like to thank

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