ENABLING DATA DRIVEN DEVELOPMENT FOR AUTONOMOUS DRIVING.
PROMISES OF AUTONOMOUS DRIVING TO CUSTOMERS AND SOCIETY.

NEW MOBILITY CONCEPTS
VEHICLES BEING PART OF OUR LIVING SPACE

HIGHER SAFETY
MORE COMFORT
HIGHER FLEXIBILITY
MORE TIME

LESS EMISSIONS
LESS ACCIDENTS
LESS TRAFFIC

PROMISES OF AUTONOMOUS DRIVING TO CUSTOMERS AND SOCIETY.
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NEW MOBILITY CONCEPTS
VEHICLES BEING PART OF OUR LIVING SPACE

CHALLENGE 1: COMPLEX FUNCTION DEVELOPMENT
CHALLENGE 2: PROVE SAFETY
ARTIFICIAL INTELLIGENCE VALUE LOOP.
AUTONOMOUS DRIVING.
ARTIFICIAL INTELLIGENCE VALUE LOOP. AUTONOMOUS DRIVING.

ON-BOARD

CONNECTIONED ENVIRONMENT

ARTIFICIAL INTELLIGENCE

DEPLOYMENT

OFF-BOARD

DATA COLLECTION

DATA ECO SYSTEM

TRAINING

PROCESSING
SEVERAL TB PER HOUR PER CAR
TARGETED DATA COLLECTION
FREQUENTLY UPDATED SW & HW
CAN COVER MILLIONS OF MILES
CUSTOMER FLEET DATA COLLECTION.

STABLE SW & HW
TARGETED DATA COLLECTION
SEVERAL MB PER HOUR

CAN COLLECT BILLIONS OF MILES

FULL RANGE RADAR.
NIGHT VISION.
SIDE RANGE RADAR.
SIDE VIEW CAMERA.
SURROUND VIEW.
STereo FRONT CAMERA.
SIDE RANGE RADAR.
ULTRA-SONIC.
CROSSROAD ASSIST.

SPEED LIMIT ASSIST.
STEERING AND LANE CONTROL ASSISTANT INCL. LANE CHANGE ASSISTANT.
EMERGENCY STEERING ASSIST.
WRONG WAY ASSIST.
ACTIVE CRUISE CONTROL.
SPEED LIMIT ASSIST.
EMERGENCY STEERING ASSIST.
CROSSROAD ASSIST.

TARGETED DATA COLLECTION
SEVERAL MB PER HOUR

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ARTIFICIAL INTELLIGENCE VALUE LOOP.

AUTONOMOUS DRIVING.

DATA LANDSCAPE.

- COLLECT
  - Privacy (e.g., GDPR)
  - Data recorder
  - Synthetic Data
  - Campaign mgmt.
  - Deployment
  - Reprocessing
  - Analytics (e.g., test space coverage)
  - Varying sources (e.g., sensor setups, versions, …)

- STORE
  - Data Trustworthiness
  - Data transfer and Ingest
  - Data Quality
  - Data Retention
  - Indexing
  - (Auto-)labeling
  - Versioning
  - Security

- PROCESS
  - Function dev.
  - KPIs

- ACCESS
  - Data export
  - Scalability and Orchestration
  - Distributed Infrastructure (due to technical or legal constraints)
BUILDING A AUTONOMOUS DRIVING DATA FACTORY.

INTRODUCTION & DATA SOURCES:
Data-driven development needs large amounts of data.

AUTOMATION & ARCHITECTURE:
Automated processes are necessary to handle the volume.
DATA FACTORY.

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DATA FACTORY.

Data Collection & Preparation:
- Development Fleet
- Customer Fleet

Data quality assurance, Data access API

Raw Data
Ground truth generation
Data clearing & post processing
Labeling & Indexing
Classify sequences

Evaluation Framework:
Evaluation of safety, performance, comfort, test coverage etc.

Post Processed Data

Simulation:
- Environment Simulation
- Traffic Models
- Sensor Models
- Vehicle Model
- Bus Simulation
DATA FACTORY.

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Data Collection & Preparation

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Evaluation Framework

Evaluation of safety, performance, comfort, test coverage etc.

Simulation

Environment Simulation

Traffic Models

Sensor Models

Vehicle Model

Bus Simulation

Scenario Descriptions
DATA FACTORY.

Data Collection & Preparation
- Development Fleet
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Data, Simulation & Test Management
- Traffic to Description
  Derive (simulatable) scenario from post-processed data
- Evaluation Framework
  Evaluation of safety, performance, comfort, test coverage etc.

Simulation
- Environment Simulation
- Traffic Models
- Sensor Models
- Vehicle Model
- Bus Simulation

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EXTENDING THE SCENARIO SPACE WITH SIMULATED DATA.

Number of pedestrians vs. Vehicle Speed with observed scenarios marked.
EXTENDING THE SCENARIO SPACE WITH SIMULATED DATA.

- Vehicle Speed
- Number of pedestrians

Observed Scenario
Simulated Scenario
DATA VARIATION.
Data Collection & Preparation

- Development Fleet
- Customer Fleet
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Data, Simulation & Test Management

- Scenario Extraction
  - Traffic to Description
  - Derive (simulatable) scenario from post-processed data

- Scenario Variation
  - Auto. Scenario Variation

Simulation

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Data, Simulation & Test Management

- Scenario Extraction
  - Traffic to Description
  - Derive (simulatable) scenario from post-processed data
- Test Space Analytics
  - Derive model and statistics for scenarios
- Scenario Evaluation Framework
  - Evaluation of safety, performance, comfort, test coverage etc.
- Test Space Coverage
  - Statistical coverage of the test space

- Scenario Variation
  - Auto. Scenario Variation
  - Test Space Exploration
    - Generate necessary parameter variations

Simulation

- Environment Simulation
- Traffic Models
- Sensor Models
- Vehicle Model
- Bus Simulation

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**DATA FACTORY.**

1. **Development Fleet**
   - RAW DATA
   - Raw Data
   - Ground truth generation
   - Data clearing & post-processing
   - Labeling & Indexing

2. **Customer Fleet**
   - Data Collection & Preparation
   - Raw Data
   - Ground truth generation
   - Data clearing & post-processing
   - Labeling & Indexing

3. **Data, Simulation & Test Management**
   - Scenario Extraction
     - Traffic to Description
     - Derive (simulatable) scenario from post-processed data
   - Test Space Analytics
     - Derive model and statistics for scenarios
   - Scenario Evaluation
     - Evaluation of safety, performance, comfort, test coverage etc.
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     - Statistical coverage of the test space
   - Scenario Variation
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4. **Simulation**
   - Environment Simulation
   - Traffic Models
   - Sensor Models
   - Vehicle Model
   - Bus Simulation

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Data, Simulation & Test Management

Scenario Evaluation
Evaluation Framework
Evaluation of safety, performance, comfort, test coverage etc.

Scenario Extraction
Traffic to Description
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Test Space Coverage
Statistical coverage of the test space

Data Collection & Preparation
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Customer Fleet

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Reprocessing Platform

Data, Simulation & Test Management

Data, Simulation & Test Management

Simulation
Environment Simulation
Traffic Models
Sensor Models
Vehicle Model
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Data, Simulation & Test Management

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Scenario Evaluation

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Sensor Models
Vehicle Model
Bus Simulation

Data Retention
Data quality assurance, Data access API

Development Fleet
Customer Fleet

Raw Data
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Classify sequences

Data Collection & Preparation

Data retention

Reprocessing Platform

Simulation

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DATA FACTORY.

Data Collection & Preparation
- Development Fleet
- Customer Fleet
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Data retention
- Raw Data
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Data, Simulation & Test Management
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Reprocessing Platform
- Test automation

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Data, Simulation & Test Management

Scenario Evaluation

Evaluation Framework
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Reprocessing Platform

Embedded test platforms
- Test automation

Data, Simulation & Test Management

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Raw Data
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Post-Processed Data

Scenario Evaluation

Version management
- Testcase automation

Machine Learning Platform

New Software Increment

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THANK YOU FOR YOUR ATTENTION.

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TEST LANDSCAPE.

Vehicle test
- Verification on proofing ground
- Evaluating on public roads

SiL – Software in the Loop
- Identification of critical traffic scenarios
- Scenario variation representing stochastic road tests

ViL – Vehicle in the Loop
- Evaluating fail back scenarios
- Evaluating human machine interfaces

Performance assessment
- Compatibility due to objective criteria
- Crossverifying test domains

HiL – Hardware in the Loop
- Integration on system level
- Functional verification of E/E components
WHAT IS ARTIFICIAL INTELLIGENCE?
THE AUTOMATION OF INTELLIGENT BEHAVIOR.

ARTIFICIAL INTELLIGENCE [AI] is a subdivision of computer science. AI describes a set of algorithmic methodologies to solve complex optimization problems. Automates and supports decisions.

MACHINE LEARNING [ML] enables the recognition of patterns and correlations in data automatically as opposed to applying static rules and definitions. Allows the identification of formerly hidden semantics.

DEEP LEARNING [DL] describes a class of optimization methods loosely inspired by the structure of biological nervous systems. DL is able to produce results comparable to and in some cases superior to human experts, especially in the field of image recognition and natural language processing.

Knowledge representation
Perception and cognition
Planning and reasoning
Random forest
Neural networks
Support vector machine
Artificial neural nets
Deep neural nets
Deep neural nets
WHAT MADE THESE BREAKTHROUGHS POSSIBLE?
ONE FACTOR, THE EMERGENCE OF ACCESS TO HIGH-QUALITY DATA.

INFORMATION TECHNOLOGY [IT]

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