Validating the safety of automated driving

Ulrich Eberle, Adam OPEL GmbH
Vera Jütten, Daimler AG

Final Event
Aachen, Germany
28 June 2017
Today we talk about…

- ... research fields of RESPONSE4
- ... challenges on the way to automated driving
- ... highlights and further research needs
## Research fields of RESPONSE4

### System classification

What do we mean when we say automated driving (AD) functions?

### Technical system limits

Which sensor technologies are relevant for AD functions?

What are examples for limitations of these sensors and systems required for AD?

### Safety validation

What is the challenge with the „demonstrable level of safety“?

Which knowledge will help us to find answers and new methodologies?
What do we mean when we talk about AD?

**System classification**

<table>
<thead>
<tr>
<th>OPERATION TYPE A</th>
<th>OPERATION TYPE B</th>
<th>OPERATION TYPE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFORMING &amp; WARNING</td>
<td>CONTINUOUS AUTOMATED FUNCTIONS</td>
<td>INTERVENING EMERGENCY FUNCTIONS</td>
</tr>
<tr>
<td>INDIRECT INFLUENCE ON VEHICLE VIA DRIVER</td>
<td>DIRECT INFLUENCE: TASKS SHARED BETWEEN DRIVER &amp; FUNCTION</td>
<td>IMMEDIATE &amp; DIRECT TAKEOVER OF CONTROL IN NEAR ACCIDENT</td>
</tr>
</tbody>
</table>

4 // 28 June 2017 AdaptIVe Final Event, Aachen
What do we mean when we talk about AD?

System classification

Term „Automated Driving“ should be used instead of „Autonomous“
What do we mean when we talk about AD?

**System classification**

**Decision Tree**

- Are lateral control (steering) and/or longitudinal control (accelerating/braking) – in part or completely – continuously assigned to the system?
  - No → Level 0
  - Yes → Is the driver still constantly required to steer or to accelerate/decelerate in response to certain driving events?
    - Yes → Level 1
    - No → Is the driver still obliged to constantly monitor the system and the driving environment and to be ready to intervene when necessary?
      - Yes → Level 2
      - No → Is the driver – with increased response time – still obliged to respond to a take-over request?
        - Yes → Level 3
        - No → Must the system accomplish the dynamic driving task only in a restricted use case and operational design domain and not for any on-road journey from origin to destination?
          - Yes → Level 4
          - No → Level 5

**If No**

**Level 0**

Lane Departure Warning
Green Light Speed Advisory
What do we mean when we talk about AD?

Decision Tree:

- Are lateral control (steering) and/or longitudinal control (accelerating/braking) - in part or completely - continuously assigned to the system? 
  - no: Level 0
  - yes: Is the driver still constantly required to steer or to accelerate/decelerate in response to certain driving events?
    - yes: Level 1
    - no: Is the driver still obliged to constantly monitor the system and the driving environment and to be ready to intervene when necessary?
      - yes: Level 2
      - no: Is the driver with increased response time still obliged to respond to a take-over request?
        - yes: Level 3
        - no: Must the system accomplish the dynamic driving task only in a restricted use case and operational design domain and not for any on-road journey from origin to destination?
          - yes: Level 4
          - no: Level 5

Must the system accomplish the dynamic driving task just in a restricted use case?

If Yes: Level 4
Valet Parking
Motorway Pilot

If No: Level 5
Universal
Robot Vehicle
What do we mean when we talk about AD?

- Provided a **SYSTEMATIC APPROACH** on the description of Automated Driving
- Collection and Priorisation of **RELEVANT PARAMETERS** for AD classification
- Provided a **COMPARISON** on AD nomenclature
- Collected a **GLOSSARY** of technical AD terms and functions
- Establish a unified community-wide **COMMON UNDERSTANDING**
- Dissiminated and supported **SAE J3016** in Europe and beyond

→ For details, see **PUBLIC DELIVERABLE „System classification“** on AdaptIVe website
What do we mean when we say automated driving (AD) functions?

Which sensor technologies are relevant for AD functions?

What are examples for limitations of these sensors and systems required for AD?

Technical system limits

Safety validation
What are the technical limits of our systems?

Categorisation of Sensor Types
CAMERA ... RADAR ... LIDAR ... ULTRASONIC
Exemplary Sensor Technologies

• Camera
  - Very high resolution for vertical and horizontal displacement
  - Objects could be classified
  - Traffic signs are visible and could be recognized by a camera
  - Vehicle-Lane assignment

• Radar
  - Active sensors: 77-79GHz for long range radars and 24GHz for mid/near range radars.
  - By measuring time of flight and the Doppler effect, distance and relative speed could be measured.
  - Small and far away objects can be measured

• LIDAR
  - Very high resolution
  - Wide field of view
  - Long detection range
  - Do not need special materials for reflecting the emitted light
  - Small and far away objects can be measured

Each sensor technology has specific deficiencies that require the application of a combination of multiple technologies
Sensor Fusion

Since each sensor technology also provide specific drawbacks and do not cover all aspects required over the complete chain:

Sensing - Interpreting - Decision making

SENSOR FUSION

BUT: Sensor fusion could also have side effects. Measurements have to be assigned to an object:

- If they are assigned to the wrong object, Ghost objects could occur
- Real objects will be tracked with a lower probability of existence.
- Higher uncertainty caused in case of conflicted information
Vehicle - to - X

- Using **V2X technologies** will reduce the occurrence of critical situations and is a helpful addition to onboard-technologies
  - **Objects** are recognized even before a sensor can detect them
  - Driving **Comfort** enhanced
  - When combined with a defensive driving style, **safety** enhanced as well
Research fields

System classification

Technical system limits
Which sensor technologies are relevant for AD functions?
What are examples for limitations of these sensors and systems required for AD?

Safety validation
What is the challenge with the „demonstrable level of safety“?
Which knowledge will help us to find answers and new methodologies?
A Comparison for Automated Driving Technology

... the control system „Homo Sapiens“

E.g. Distance between two severe accidents on a German Autobahn

→ **12 Mio. km** or **120,000 operating hours**

About 10x the distance is required for AD tests in order to reach a sufficient statistical significance

→ **Ca. 120 Million km** or ca. **1.2 million operating hours**

→ Enormous cost and time effort
→ Procedure needs to be repeated for new AD functions
What is the challenge with a demonstrable level of safety?

**Response3** Code of Practice (CoP) comprises a suitable ADAS (Advanced Driver Assistance System) description concept including:

- ADAS specific requirements for system development.
- Summary of best practices and
- Proposals for risk management and controllability evaluation.

**Response4**

Transition from **Driver Assistance**

to **Automated Driving**

An eventual AD CoP has two main targets:

- **Systematics**: the CoP should provide the developers with the relevant aspects systematically with regard to the development phases.
- **Methodological recommendation**: the CoP should support the developers by recommendation of methods and activities, which could be taken in the consideration in the context of their Automated Driving functions.

Requirements derived - Foundation stone laid for further research
**Highlights**

**System classification**
- Dissemination of SAE levels to harmonize communication with institutions, manufacturers, suppliers as well as technical and legal experts
- Creation of a community-wide common understanding

**Technical system limits**
Overview of technical systems and sensors with their technical system limits including the challenges and opportunities via sensor fusion and V2X

**Safety validation**
RESPONSE4 derived requirements for an Automated driving CoP as a foundation stone for further research and development

17 // 28 June 2017
AdaptIve Final Event, Aachen
"Outlook „Towards an integrated approach“

- A common understanding on nomenclature has been reached
- Methodologies for ADAS system development have been analysed
- Technical system limits have been analyzed

Requirements for a new Automated Driving Code of Practice have been derived

- Integrated approach for each phase of the development, it should not only focus on specific phases (e.g. testing)
- Integration of derived methodologies and activities into the established DEVELOPMENT PROCESSES
- AD CoP should be DOWNWARD COMPATIBLE to lower levels of automation
Thank you.

Ulrich Eberle
Adam Opel GmbH
Ulrich.Eberle@Opel.com

Vera Jütten
Daimler AG
Vera.Juetten@Daimler.com