Development of Automated Driving Functions

Dr. Stefan Berger, Opel Automobile GmbH
Outline

- Highly automated driving (SAE Level 3)
- Development of driving functions
- Scenarios and demo rides on test track
## Levels of Automated Driving

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<tr>
<th>Driver</th>
<th>Vehicle</th>
<th>SAE Level</th>
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<tr>
<td>Permanent longitudinal AND lateral guide</td>
<td>No interfering vehicle system</td>
<td>SAE Level 0</td>
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<tr>
<td>Permanent longitudinal OR lateral guide</td>
<td>System takes over the other function</td>
<td>SAE Level 1</td>
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<tr>
<td>Permanent monitoring</td>
<td>Longitudinal and lateral guide in special application</td>
<td>SAE Level 2</td>
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<tr>
<td>No permanent monitoring / driver prepared to take over</td>
<td>Longitudinal and lateral guide in specific application / Detects system limits → Take-over command with safety time</td>
<td>SAE Level 3</td>
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<tr>
<td>No driver necessary in specific application</td>
<td>System can manage any situation automatically in specific application</td>
<td>SAE Level 4</td>
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<tr>
<td>No driver necessary</td>
<td>The system can manage any situation automatically</td>
<td>SAE Level 5</td>
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- **SAE Level 0**: No interfering vehicle system. Only the driver.
- **SAE Level 1**: Permanent longitudinal OR lateral guide. Assisted.
- **SAE Level 2**: Permanent monitoring. Partly automated.
- **SAE Level 3**: No permanent monitoring / driver prepared to take over. Highly automated.
- **SAE Level 4**: No driver necessary in specific application. Fully automated.
- **SAE Level 5**: No driver necessary. Driver-less.

*Source: Verband der Automobilindustrie e. V. (VDA)*
SAE Level 3 – Highly Automated Driving

- Driver is prepared for take-over when systems limits occur

- Main objectives of Ko-HAF demonstrator vehicles:
  - Automated *longitudinal and lateral control* while driving
  - Watch out for *system limits*
  - Tell driver to *take over control* before system limit is reached *(HMI, WP3)*
Highly Automated Driving on Highways

- Objective: Drive on highway from A to B with preferred set speed and without collision
- Problem: "Obstacles" on the road: speed limits, slower vehicles, traffic jams, road works, break-down vehicles, ...
- Automated Driving Functions can be divided into 3 tasks: Sense – Plan – Act
Sense – Plan – Act

- Sensors: camera, radar, lidar, ...

Ko-HAF Partner 1:

Ko-HAF Partner 2:

- Sensors: camera, radar, lidar, …
Sense – Plan – Act

- Environmental detection:
  Lane markings, objects (static + dynamic), landmarks
- Lane markings $\rightarrow$ **lateral localization (WP2)**
- Landmarks (= e.g. traffic signs, bridges) $\rightarrow$ **longitudinal localization**
- Static objects $\rightarrow$ **road hazards** (exchange information via Safety Server, **WP1**)
- Dynamic objects (= other traffic participants) $\rightarrow$ **driving strategy**
- Gaps in neighboring lanes $\rightarrow$ maneuver planning
- **Not only sense** current environment **but also predict** future motion of dynamic objects
  $\rightarrow$ Tomorrow: Presentation on motion prediction, 12:00, **D. Augustin**, Opel
Sense – Plan – Act

- **Determine possible driving maneuvers, e.g.**
  - Lane Change Left, LCL
  - Lane Change Right, LCR
  - Keep Lane, KL

- **Decision making**
  - Cost functions
  - Low cost for legal maneuvers (e.g. changing lane)
  - High cost for illegal maneuvers (crossing solid line)
  - Very high cost for collision-afflicted maneuvers
  - \( \rightarrow \) Choose maneuver with lowest cost
Sense – **Plan** – Act

- **Trajectory Planning**

Trajectory = path + time information

What is the best trajectory for the lane change?
Sense – **Plan** – Act

- **Trajectory Planning**
  - Calculate several trajectories
  - Calculate maximum accelerations (longitudinal and lateral)
  - Check for physical limits
  - Check for collisions with other objects
  - Include motion prediction of other traffic participants
  - Add cost function with penalty for low comfort, too small distances to neighboring vehicles, etc.
  - Choose best trajectory (with lowest cost)

→ **Tomorrow:** Presentation on motion planning, 12:30, B. Reuber, IfF
Sense – Plan – Act

Highway Simulation

Planned Trajectory (next 1.5 s)

Safety distance 0.9 s
Safety distance 1.8 s

Current speed = 60 km/h
Maximum speed = 100 km/h

Car

Ego car
Sense – Plan – **Act**

- **Trajectory Control**
  - Control concepts for engine, steering, brake

- **Safety Concept – What to do when system failures occur?**
  - No driver reaction after take-over request
  - Sensor fault due to heavy rain, snowfall, fog
  - Digital map outdated
  - System limits reached (e.g. roadworks, accident, earthquake)
  - Unexpected motion of other traffic participants

  → Minimal risk maneuvers, fail-safe trajectories

→ Tomorrow: **Presentation** on minimal risk maneuvers, 13:00, **Th. Leonhardt**, Audi
Sense – Plan – Act

**Fail-safe trajectories**

- Fail-safe trajectories are collision-free with respect to any feasible future behavior of obstacles
- Ensure that the ego vehicle is able to execute a fail-safe trajectory at any time
Sense – Plan – **Act**

- **Fail-safe trajectories**

  - When traffic participants deviate from predicted motion, the ego vehicle has **two options**:
    - Execute previous *fail-safe trajectory*
    - Find a new pair of an intended motion and *fail-safe trajectory*
Scenarios and Demo Rides on Test Track

"Lange Gerade" ("Straight")
Scenario catalogue

Enter highway and merge

Exit highway
Scenario catalogue

Road Hazard (Traffic Jam)

Road Hazard (Break-down vehicle)
Demonstration Activities
# Driving Demos

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