



Development of Automated Driving Functions

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Outline

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



Levels of Automated Driving



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

Project Ko-HAF

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)



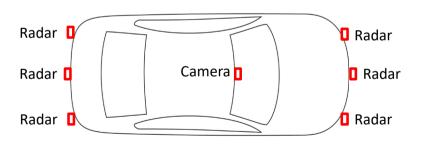
Highly Automated Driving on <u>Highways</u>



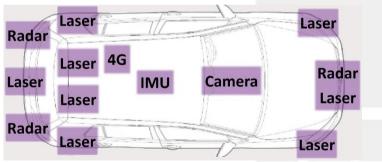
- Objective: Drive on highway from A to B with preferred set speed and without collision
- Problem: "Obstacles" on the road: speed limits, slower vehicles, traffic jams, road works, break-down vehicles, ...
- Automated Driving Functions can be divided into 3 tasks:
 Sense Plan Act

Sensors: camera, radar, lidar, ...



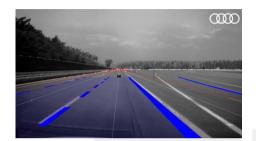


Ko-HAF Partner 2:





KOOPERATIVES HOCHAUTOMATISIERTES FAHREN



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

September 19th & 20th, 2018

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Determine possible driving maneuvers, e.g.

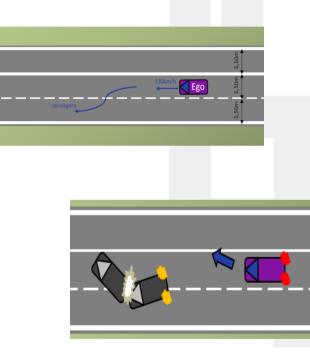
Lane Change Left, LCL

Sense – Plan – Act

- 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



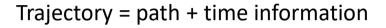


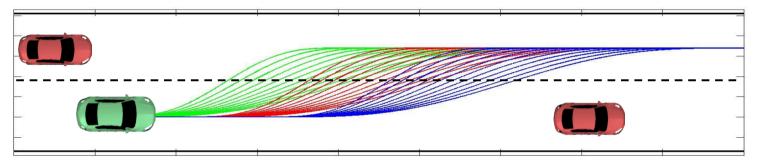
Project Ko-HAF





Trajectory Planning





What is the best trajectory for the lane change?

- 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 COOPERATIVES HOCHAUTOMATISIERTES FAHRE **Highway Simulation** Planned Trajectory (next 1.5 s) Car Safety distance 0.9 s Safety distance 1.8 s 50 100 Current speed = 60km/h Maximum speed = 100 km/h Ego car

- 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
- \rightarrow Minimal risk maneuvers, fail-safe trajectories

→ Tomorrow: Presentation on minimal risk maneuvers, 13:00, Th. Leonhardt, Audi







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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

intended

motion

- trajectory
- feasible other ego most likely vehicle vehicle behavior

fail-safe

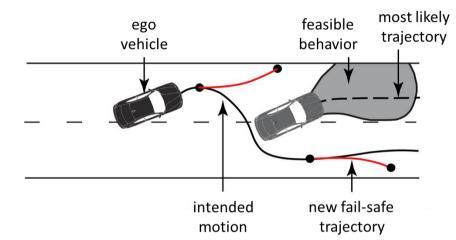
trajectory

Fail-safe trajectories

Sense – Plan – Act



Fail-safe trajectories







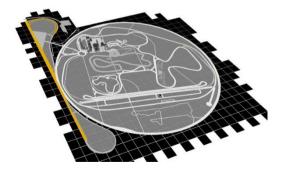
- When traffic participants deviate from predicted motion, the ego vehicle has two options:
 - Execute previous fail-safe trajectory
 - Find a new pair of an intended motion and fail-safe trajectory



Scenarios and Demo Rides on Test Track



"Lange Gerade" ("Straight")

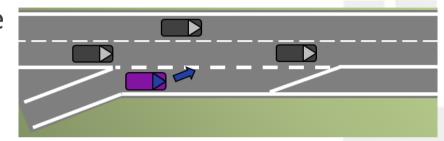


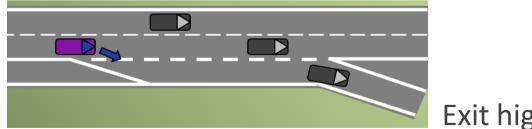


Scenario catalogue



Enter highway and merge

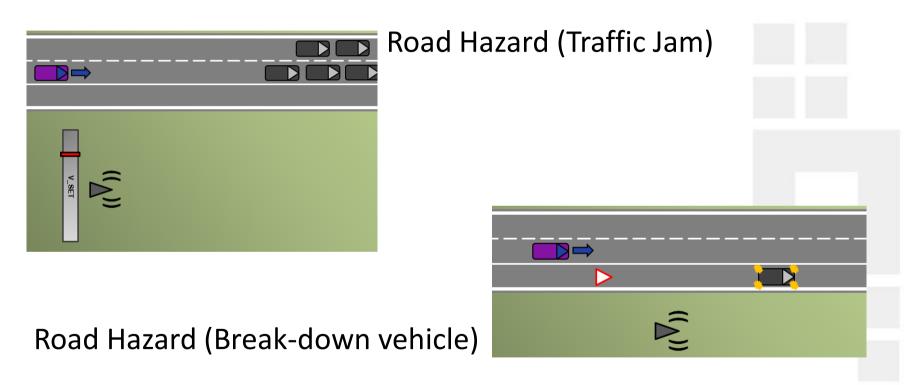




Exit highway

Scenario catalogue

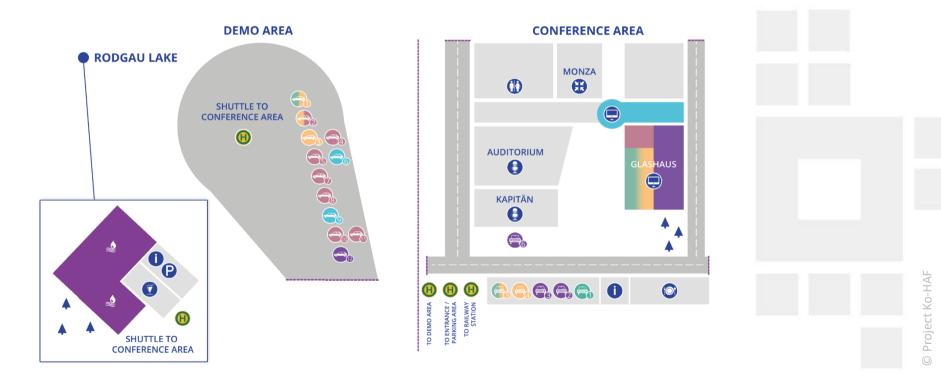




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Demonstration Activities

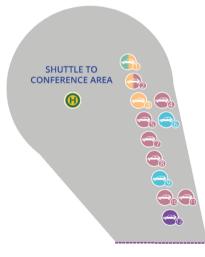




Driving Demos



DEMO AREA



#	Titel				
1	LTE measurements and prediction				
2	Cooperative HAD from Motorway Entry to Exit				
3	Visual Localization & Preaggregation				
4	HAD-Functions in public traffic				
5	Tactical Decision-Making for HAD				
6	Testmanager - A Tool for reproducible Test Execution				
7	Highway Drive and Hazard Detection				
8	Autonomous Reaction to Safety-Critical Situations on Highways				
9	Testtool				
10	HAD-Functions: Merging, Strategic Handling of break down vehicles, MRM				
11	HAD-Functions in public traffic				
12	Wizard-of-Oz Vehicle for Automated Driving Experience				





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