Highly automated driving
InteractIVe Summerschool 2012

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Agenda

- Different levels of automation in a highly automated vehicle
- **Technical development** for highly automated driving
- Design of the **Human-Machine-Interaction** for highly automated driving
- Outlook and summary
Imagine…
Definition of different levels of automation

- Much discussed e.g. in
  - Projects such as PATH, HAVEit, interactIVe, …
  - BASi group „legal consequences of increasing automation“
  - iMobility Automation Working Group
  - IHRA (International Harmonized Research Association)
  - TRB (Transportation Research Board)
  - …

Different levels of automation in one vehicle

**BASt Definition:** Human driver executes manual driving task
Different levels of automation in one vehicle

**BASt Definition:** The driver permanently controls either longitudinal or lateral control. The other task can be automated to a certain extent by the assistance system.
Different levels of automation in one vehicle

**BASSt Definition:** The system takes over longitudinal and lateral control, the driver shall permanently monitor the system and shall be prepared to take over at any time.
**Different levels of automation in one vehicle**

**BASt Definition:** The system takes over longitudinal and lateral control; the driver must *no longer permanently monitor* the system. In case of a take-over request, the driver must *take-over* control with a *certain time buffer.*
Different levels of automation in one vehicle

**BASt Definition:** The system takes over longitudinal and lateral control completely and permanently. In case a take-over request that is not carried out, the system will return to a minimal risk condition by itself.
Different levels of automation in one vehicle

Driver

Automation

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Concept of Cooperative Automation

- Common action execution
- Common action planning
- Compatibility
  - External compatibility
  - Internal compatibility
    - Cognitive compatibility
    - Compatibility of values
Cooperative Automation: Cognitive Compatibility

Löper, Kelsch and Flemisch (2008)
Löper and Flemisch (2009)
Representation of Cooperative Automation Behaviour on Layers

- Valential (from Valency + Potential)
  - Value of feasible action
    (e.g. of available manoeuvre)
- Manoeuvre planning: Manoeuvre Tree
- (Shortterm) Trajectory planning: Trajectory Valential Field
- Control: Actuation Valential Field
Implementation on Manoeuvre Level

- Explicit communication with driver
- Regard currently driven manoeuvre:
  - Implicit communication
  - Enables common and shared action execution
Application in Project IMoST
Application in Project FAMOS
Application in Project FAMOS

Löper, Knake-Langhorst, Scheibitz, Schießl and Köster (2011)
Steer-by-wire technology

- **Steer-by-wire driving:**
  - Steering wheel can be used for different purposes
  - Manoeuvre-based driving
  - Free haptic interaction design (tics, vibrations)
  - Steering wheel parameters adaptable to different levels of automation and different driving situations
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Design aspects of the Human-Machine-Interaction

- Communication Channel
- Communicate System Status
- Adaptness and Adaptability
- Trust, Mental workload, Situation awareness, Driver mental model
- Sequence of Interaction
- Arbitration
- State, Modes and Mode Transitions
- Prioritisation and Scheduling
- System purpose Layer of driving task
- Level of Assistance and Automation
Design aspects of the Human-Machine-Interaction

Sequence of Interaction

Arbitration

State, Modes and Mode Transitions

Prioritisation and Scheduling

Communication Channel

Communicate System Status

Adaptivity and Adaptability

Trust, Mental workload, Situation awareness, Driver mental model

Level of Assistance and Automation

System purpose Layer of driving task
Levels of assistance and automation

- Define how many different levels of automation are suitable
- Choose clearly distinguishable levels of automation
Levels of automation in HAVEit

- Driver Only
- Driver Assisted
- Partial Autom.
- High Autom.
- Full Autom.

BASI Definition

HAVEit D 33.2
Design aspects of the Human-Machine-Interaction

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- System purpose Layer of driving task
  Level of Assistance and Automation
Transitions between levels of automation

- Define which transitions should be allowed
- Driver initiated transition vs. Automation initiated transitions
- Normal transitions vs. transitions at system limits
Transitions between levels of automation

- From existing to future levels of automation:
  - Driver needs to build up a correct mental model
  - **Integrated and consistent concepts** for the transitions
  - Include already existing standards for systems like ACC (ISO 15622)

* manual and/or automatically after self test

= system state
HAVEit: Example of transition design

Prototype A

Prototype B

Prototype C

HMI Workshops
Simulator studies
Standardisation

Schieben et al. (2011)
Transitions: Mode Confusion
Transitionen: Interlocked Transitions

- Explicit transition design
- Hand-over of control only after confirmation by the other partner („Interlocked Transition“, „Handshake“)
Transitions: Concept for take-over requests

Driver

Driver Only

Driver Assisted

ACC

Highly Autom.

Fully Autom.

Automation

Driver does not react

Minimum Risk Manoeuvre

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Transitions: Concept for take-over requests

Example: HAVEit take-over request:

- Try to bring the driver back in the loop
  - Acoustic & visual alarms
- Check if driver takes over as intended
  - Hands-on check
  - Attention monitor
- If driver does not react, bring vehicle to a safe stop
  → Minimum Risk Manoeuvre
Transitions: Concept for take-over requests

- Also after automatic emergency interventions e.g. collision avoidance by steering
Transitions: Devices and strategies

- Interface for transitions between different levels of automation
  - Common switching devices
  - Smart transition (e.g. hands-off detection on steering wheel)
- Adaptive automation
Design aspects of the Human-Machine-Interaction

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Interaction concepts: Displays

- Provide information and assistance in lower levels of automation
- Raise awareness for the current automation actions
  - Contact analogue displays
  - Head-up-displays
Interaction concepts: Displays

- **Integrated display and interaction concept** for different levels of automation
- Indicate the available and active levels of automation
- Standardized display elements in the cluster instrument

![Diagram showing interaction concepts](image)
Interaction concepts: Displays

Joint System Demonstrator + Automation Monitor + Message Field

Flemisch, Schieben, Strauss, Lueke & Heyden (2011)
Interaction concepts: Displays

- Integrated display and interaction concepts
- Standardized display elements in the cluster instrument
  - Automation scale: available and active level of automation
  - Safety shield: available and active protection functions
  - Message field (overlay)
Design aspects of the Human-Machine-Interaction

- Communication Channel
- Communicate System Status
- Adaptness and Adaptability
- Trust, Mental Workload, Situation Awareness, Driver mental model
- Sequence of Interaction
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- Prioritisation and Scheduling
- System purpose
  Layer of driving task
  Level of Assistance and Automation
Other tasks than driving?

„What would you like to do while driving highly automated?“

- Write emails
- Surf in the internet
- Make phone calls
- Look out of the window
- Watch TV
- Listen to music
- Read something
- Eat something

HAVEit Usability Assessment, 2009
8 participants, multiple answers were possible
Interaction concepts: Other tasks than driving?

- If other tasks than driving are allowed:
  - Changes in cockpit design
  - Changes in the interaction between driver and passengers
Interaction concepts: Other tasks than driving?

- **Driver State Assessment**
  - Check the state of the driver to ensure that he can take over and to avoid misuse
  - Camera
  - Tracking of input
  - Hands-on sensor on steering wheel

![Driver monitoring](image1)

![Driver monitoring](image2)

HAVEit D32.1
Effects of automation

- Critical effects might occur due to the introduction of automation
  - Mode Confusion
  - Misuse
  - Complacency/Overtrust
  - Loss of skills
- Effects need to be monitored
- Countermeasures need to be introduced if necessary
Agenda

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Summary

- Different levels of automation in one vehicle
- **Technical issues:**
  - Appropriate hardware enables additional degrees of freedom
    - X-by-wire, Head-up displays, novel inceptors, etc.
  - Cooperative, user-compatible automation
    - Outer and inner user compatibility
    - Uncertainties
- **Human-Machine-Interaction:**
  - Vehicles with different levels of automation → Challenges in HMI design
    - Transitions
    - Take over requests
  - Secondary tasks and influences on cockpit design
Outlook

Human Factors Investigations
- Driver Behaviour and Performance
- Situation Awareness
- Mode Confusion
- Overtake Ability
- Controllability

Holistic System Design
- Arbitration & Interaction
- Integration of Functions
- Modes & Transitions
- HMI: visual, acoustic, haptic, kinaesthetic,…

Technical Development
- C2X
- X-by-Wire
- Cooperative Automation
- Sensors
- Inceptors & Interfaces
- Contact-Analogue Displays

Modelling
- Driver Behaviour
- Reaction to Assistance
- Interaction
- Traffic Flow

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Thank you for your attention!

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References


