Dipl.-Ing. Matthias Pfromm

Human Machine Interface
Agenda

Safety Corridor HMI
- Requirements
- Design of HMI
- Evaluation
- Final Design

Cooperative Automation HMI
- Requirements
- Design of HMI & Evaluation
- Final Design

Outlook
- Transitions of Control
Agenda

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Outlook

- Transitions of Control
Requirements – Safety Corridor

93.5 % of accidents in Germany happen due to driver error \[1\]

<table>
<thead>
<tr>
<th>Causes of driver error [^2]</th>
<th>Assistance Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of perception of essential information</td>
<td>Information</td>
</tr>
<tr>
<td>Misinterpretation of essential information</td>
<td>Warning</td>
</tr>
<tr>
<td>Wrong decisions made by the driver</td>
<td>Action recommendation</td>
</tr>
<tr>
<td>Faulty execution of driving tasks</td>
<td>Intervention</td>
</tr>
</tbody>
</table>

- 4 Assistance Strategies required
- Adaptive to driver’s state

Direction of Attention

- Direction of attention improves perception of stimulus and accelerates reaction \[^3, 4\]
- HMI must direct driver’s view towards relevant traffic objects
Requirements – Safety Corridor

**Sensory Channels** [5]

- Human
  - Transmit
  - Receive
  - Gestures, facial expression
  - Eyes
  - Speech
  - Hand, Feet, ..

- Machine
  - Transmit
  - Receive
  - Displays
  - Camera
  - Speaker
  - Microphones
  - Actuators
  - Manual controls

+ : fast, high bandwidth
- : gaze direction
+ : attract attention
- : low bandwidth
+ : very fast
- : low bandwidth

- Multimodal exchange of information required
Related Work

State of technology ADAS HMI

- Work in a limited number of use cases
- Driver may be overstrained by multiple HMI\s\[^6\]
- Are unspecific $\implies$ driver loses time $[^7]\$
- Don’t provide multiple assistance strategies
- Rarely multimodal support

PRORETA HMI

- Works in a high number of use cases
- Not bothering, not annoying
- Specific, multimodal support
Methodology

User Centered Approach (ISO 9241-210)

1. Context of use
2. Define user requirements
3. Design solutions
4. Evaluation
Design of HMI

Requirements from Use Cases

<table>
<thead>
<tr>
<th>Driver's tasks</th>
<th>Traffic Situations</th>
<th>Error</th>
<th>Accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Stabilization</td>
<td>201</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Guidance</td>
<td>231</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Support Content

<table>
<thead>
<tr>
<th>Information</th>
<th>Warning</th>
<th>Action recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>position in freespace</td>
<td>approaching lane markers</td>
<td>brake</td>
</tr>
<tr>
<td>position of relevant traffic object</td>
<td>approaching traffic object</td>
<td>steer left</td>
</tr>
<tr>
<td></td>
<td>approaching freespace</td>
<td>steer right</td>
</tr>
<tr>
<td></td>
<td>inappropriate speed</td>
<td></td>
</tr>
</tbody>
</table>
Design of HMI

Spacial reference
- 3D sound
- 360° LED Lights Strip

LED Lights Strip
- Submits the position and distance of a traffic object
- „Projecting“ relevant traffic objects on the LED strip
Evaluation of HMI

Design of Simulator Study

- Fixed-base driving Simulator (Silab 3.0)
- SMI eye-tracking device
- 13 subjects (f: 8; M=43.3 years)
- Scenarios represent 41.2% of German traffic accidents [8]

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Event</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>End of Traffic Jam</td>
<td>19.1%</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>Vehicle from left</td>
<td>9.2%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Vehicle from right</td>
<td>8.0%</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>Turn Left</td>
<td>4.0%</td>
</tr>
</tbody>
</table>

\[
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\]
Evaluation of HMI

Dependent Variables

Gaze attention time
- Focus of attention $\equiv$ visual fixation $^{[9]}$
- $t_{\text{gaze attention}} = t_{\text{visual fixation}} - t_{\text{appearance}}$

Acceptance
- General Acceptance: Questionaire by van der Laan el al. $^{[10]}$ + additional items
- Situation Specific: 5 items

Semi-structured interviews
- understood intuitively?
- hints for improvement

Mental effort
- measured by RSME-Scale $^{[11]}$
Results

Gaze Behavior – Gaze Attention Times

Situation-Specific Assessment of Acceptance

lower acceptance, due to unnecessary warning => eye tracking required
Results

General Assessment of Acceptance

van der Laan et al. [10] Scale

<table>
<thead>
<tr>
<th>Scale</th>
<th>Usefulness</th>
<th>Satisfying</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Semi-Structured Interviews

- LED band ist intuitively understandable
- 10 out of 13: LED becomes active in dangerous situations
- 3 out of 13: did not understand LED band
- 5 out of 13: stated that LED band showed the distance to critical vehicle

Mental Effort

- no difference between baseline and LED band
Design Solutions

Instrument Cluster: Design Draft

- First prototype
- Submits the position and distance of relevant traffic object
- 3 level support concept
  - Information
  - Warning
  - Action recommendation

prototype HMI
Evaluation

Goals

- Determination of escalation-level trigger times
- Usability Evaluation

Methodology

- driving tests: 23 subjects (f: 5; M=23.2 years)
- “Herstellung“ method to determine trigger times
- Evaluation of support functions by custom questionnaires
**Evaluation**

**Results**

- Determination of escalation-level trigger times
- High general satisfaction with support functions
- Subjects identify direction of danger by representation in display as well as by LED Lights strip
- Support content in display generally rated as helpful
- Acoustical warnings make driver gaze on display
- AFFP makes driver brake faster in case of danger
- Lower ratings of “radar” design in higher escalation levels => takes time to interpret
- Lower satisfaction-rating for escalation level 1 => only visual support
- Too much information represented on the display
Methodology

User Centered Approach (ISO 9241-210)

1. Context of use
2. Define user requirements
3. Design solutions
4. Evaluation

[Diagram showing the flow between the steps]
Final design

Safety Corridor

Warning: „Critical Object ahead“
Final design

Safety Corridor

Action recommendation: „brake!“
Final design

Safety Corridor

Automatic intervention
Final design

Safety Corridor
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Requirements – Cooperative Automation

Maneuver based driving

- Parallel sequential assistance [12]

- Simple and efficient method for maneuver delegation required
Requirements – Cooperative Automation

Conventional Driving

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<thead>
<tr>
<th>Targeting</th>
<th>Monitoring</th>
<th>Regulating</th>
<th>Tracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>set destination, driving criteria</td>
<td>monitoring traffic / surroundings</td>
<td>target speed</td>
<td>maintain speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>specific position</td>
<td>Maintain dist. from car front/behind</td>
</tr>
<tr>
<td></td>
<td></td>
<td>maneuver demand</td>
<td>control lateral position</td>
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Driving Tasks [13]
### Requirements – Cooperative Automation

#### Task sharing – Cooperative Automation

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<td>set destination, driving criteria</td>
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**Driving Tasks** [13]
Requirements – Cooperative Automation

Task sharing – Cooperative Automation

- Distribution of tasks must be made clear to driver
- Current system state must be transparent (Mode Awareness)
- System behavior must be understandable
- Transitions of control must be manageable
Related Work

State of research

- H-Mode & CbW: Highly sophisticated interfaces needed
- Applied in driving simulators only

Goal

- Maneuver based driving with common interfaces in a real car
- Simple and efficient method for maneuver delegation

H-Mode [14]

Conduct by Wire [15, 16]
Design Solutions & Evaluation

Interaction Cooperative Automation

- Investigate different means of maneuver selection

  ![Different Means of Maneuver Selection](image1)

- in different contexts of use

  ![Different Contexts of Use](image2)

- in workshops an a field study

  ![Workshops and Field Study](image3)
Design Solutions

**Interaction Cooperative Automation**

- Model Interaction for different use cases

- Final design
Final design

Cooperative Automation

Maneuver „lane change left“ possible
Possible speed 50 km/h
Set speed 70 km/h
Maneuver „straightforward“ active

300 km
16142 km
70 km/h
Final design

Cooperative Automation

Maneuver „lane change left“ active
Outlook

Investigation of Transitions

Safety Corridor

Cooperative Automation

Questions

- Does the driver take back tasks from the system safely?
- Does the driver understand, which tasks are performed by the automation and which have to be performed by him?
- Driver strain – is the driver relieved by the system?
- Acceptance/ Ux – Does the driver accept the system?


