Tutorial
Introduction to Automotive User Interfaces

Albrecht Schmidt
University of Stuttgart, Germany

http://auto-ui.org

Overview

- Motivation
- Design Space
- Understanding the Users
- Tools and Methods
- Projects and lessons learned
- Conclusion
What is the difference?

Human Centred Design Process

Plan the human-centred activities

Design solution satisfies the requirements

Evaluate

Systematic assessment of automotive user interface context of use

Understand and specify context of use

Iterate where appropriate

Specify user requirements

Supporting requirements specifications in the car

Design and prototyping tools and methods

Specific tools for evaluating automotive user interfaces taking driver distraction into account

Produce design solutions

Human-centred design process according to ISO 9241-210 adapted into the automotive context, see [Kern,2012]
What has become of cars?

“...like an iPod touch that you can drive, too.” (comment on the concept car of the WV UP 2009)

The Car...

... a means for transport.
- ... an space for media consumption?
- ... is a personal communication center?
- ... alters our perception of the environment?
- ... creates user generated content?
- ... used as a inter-connected workplace?
- ... mobile (phone) terminal

Essentially a interactive computing platform and a node in a distributed (computer/social) network?
Trends: Automation of driving

- Increasing degree of automation
- Assistive functionalities ease the driving task
- Towards autonomous driving

Trends: Sensing and Context

- Sensing technologies have improved and are widely included in the car
  - Cameras, depth sensing, radar
  - Sensing of component functions
- Processing and sense making of (distributed) sensor information for driving
- Context acquisition becomes possible
  - It is a basic requirement to create autonomous cars
Trends: Life Style

- People live connected lives
  - information access always and everywhere
  - availability of communication as normal
  - expectation to be available
- Media consumption is digital and ubiquitous

(c) Albrecht Schmidt, 2012

Trends: Networked cars

- Cars become networked
- Access from the car to information from
  - Other cars (e.g. camera from the car in front)
  - Infrastructure (e.g. traffic signs, traffic lights)
  - Internet (e.g. virtually unlimited content)
- Providing information from to car to others
  - Sensing and cameras
  - Privacy control
- Accessing the car from remote

(c) Albrecht Schmidt, 2012
General Challenges

- Creating user interfaces that support various levels of automation
- Interaction with the car is large interaction with an intelligent system

Specific Challenges

- How to deal with joint control?
  - Distribution and transfer of control between human and machine
  - How (when, why) to keep the human in the loop when needed
Specific Challenges

- How to handle massive amounts of information available?

  - More information available
    - car data, e.g. sensors, night vision, ...
    - from the environment, e.g. signs, parking distance, ...
    - other cars, e.g. weather warnings, collision warnings, ...
    - from the backend, e.g. internet, online source, ...
    - From human to human communication channels, e.g. phone, instant messaging, ...
  
- Example project: How to best show several camera (from the own car and cars around)?

What has not changes?

- Primary function as transport vehicle is central and a prerequisite
- Primary task (basically driving or being driven) has priority
- "fun of use" and "ease of use" are essential
- Cars are a means for self-expressing
- Human users wants to be in control
- Driving is often a social situation
- Need for safety (gets even more emphasized)
...a means for Self-Expression

<Photos of cars that highlight that we use them as means for self-expression>

What needs to be changed?

“Just 100 years ago, it was normal that, in [such] a mine, on average one person per day got seriously injured and one person per week died while working. It seemed inevitable, and people accepted it because energy was necessary. Today, we don’t consider such working conditions acceptable. However, with current cars and personal transport, it’s somehow acceptable that more than 4,000 people per year are killed in road accidents in Germany alone”

[Schmidt, 2009] Schmidt et al., Driving Automotive Research, IEEE Pervasive Magazine
Selected areas to be addressed

- Shared control between human and system
- Safe communication while driving
  - Contextualizing as an essential step
- Text input and output
  - Essential for many application
- Making it easy that interactions can be interrupted
  - Minimizing the cognitive cost for the user for interrupting
- Interacting with all sense
  - Creating truly multimodal user interfaces

Overview

- Motivation
- Design Space
- Understanding the Users
- Tools and Methods
- Projects and lessons learned
- Conclusion
Background and Related work

Driving task

- Primary task: keep the vehicle on track
  - Navigation
  - Steering
  - Stabilization

- Secondary task: depending on driving requirements
  - Actions (blinking, blowing a horn, ...)
  - Reactions (turn on/off the lights, turn on/off the windscreen wiper, ...)

- Tertiary task: Tasks independent of driving
  - Comfort functions (air condition, power seats, ...)
  - Entertainment (radio, CD, ...)
  - Communication (mobile phone, Internet, ...)
**Input Modalities**

a) Button  
b) Button (haptic feedback)  
c) Discrete knob  
d) Continuous knob  
e) Lever  
f) Multifunctional knob  
g) Slider  
h) Touch screen  
i) Pedals  
j) Thumbwheel  
k) Microphone / Speech recognition  
l) Touch pad  

Sources: BMW (k), Audi (l)  
[Kern and Schmidt, 2009]

---

**Output Modalities**

a) Analog speedometer  
b) Digital speedometer  
c) Virtual analog speedometer  
d) Indicator lamp  
e) Shaped indicator lamp  
f) Multifunctional display  
g) Digital display  
h) Head-up display  
i) Loudspeaker  
j) Vibration feedback  

Source: BMW (h)  
[Kern and Schmidt, 2009]
Positioning Input & Output Devices

- Dashboard left
- Steering wheel
- Floor
- Windshield
- Center stack
- Periphery

Graphical Representation - Example

- BMW 507 (1956)
Graphical Representation - Example

- BMW 520d (2007)

Mobile Devices
Vehicle Systems

- **Comfort systems:** air conditioning, radio, seat heating, power window regulator, etc.
- **Passive safety systems:** seat belts, crush zone, roll-over bar, etc.
- **Advanced Driver Assistance Systems (ADAS):** ABS, (adaptive) cruise control, parking assistant, night vision, lane departure warning, etc.
- **In-vehicle Information Systems (IVIS):** Navigation, telecommunication, traffic information, online services, etc.

Driver Assistance Systems

**Assistance Functions**

Roadmap – Time Horizon for safety relevant ICT-Systems in the 4 Domains

(c) Albrecht Schmidt, 2012
Overview

- Motivation
- Design Space
- **Understanding the Users**
- Tools and Methods
- Projects and lessons learned
- Conclusion

The 100-Car Naturalistic Driving Study

- Collecting large-scale naturalistic driving data
- No special instructions
- No experimenter was present
- Data collection instrumentation was unobtrusive
- Approximately 2,000,000 miles of driving
- 43,000 hours of data
- 241 primary and secondary driver participants
- 12 to 13 month data collection period for each vehicle
- Five channels of video

The 100-Car Naturalistic Driving Study


(c) Albrecht Schmidt, 2012
The 100-Car Naturalistic Driving Study

Designing Automotive User Interfaces

Designers need to understand
- who drives vehicle (users)
- what in-vehicle tasks they perform
- the driving task
- task context
- the consequence of task failures

Measuring driver and system performance
Who are the Users?

Distribution of driver age groups developed from U.S. Department of Transportation data.


(c) Albrecht Schmidt, 2012
Overview

- Motivation
- Design Space
- Understanding the Users
- Tools and Methods
- Projects and lessons learned
- Conclusion

What is the difference?
Measuring Usability and Safety

**PC**
- Task completion
  - Time
- Errors
- Rating ease of use

**Automotive**
*(additionally)*
- Driving performance
- Ratings of workload
- Measures of situation awareness
- Measures of object and event detection
- Physiological measures
- Subjective measures

Driving-Specific Usability Measures

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure</th>
</tr>
</thead>
</table>
| Lateral  | Number of lane departures  
|          | Mean and standard deviation of lane position  
|          | Number of larger steering wheel reversals  
|          | Time to line crossing  
|          | Steering entropy |
| Longitudinal | Number of collisions  
|             | Time of collision  
|             | Headway (time or distance to lead vehicle)  
|             | Mean and standard deviation of speed  
|             | Speed drop during a task  
|             | Heading entropy  
|             | Number of breaking events over some g threshold |
| Visual    | Number of glances  
|           | Mean glance duration  
|           | Maximum glance duration  
|           | Total eyes-off-the-road time |

Methods for Evaluating Automotive User Interface

Increasing confidence that data correspond to real phenomena

Real road field trials
Real road test trials
Test track studies
Dynamic vehicle simulations
Static vehicle simulations
Part task/laboratory studies

Increasing control of variables and replication


Selected Methods

1. Occlusion
2. Peripheral Detection Task
3. Lane Change Task
4. Low-fidelity Simulator (lab based)
5. High-fidelity Simulator
6. Field Study
7. Building a concept car
8. (low fidelity) Prototyping
Occlusion

- Laboratory-based method
- Focuses on the visual demand of in-vehicle systems
- Simulation of successive changes of glances between traffic situation and information systems
- Computer-controlled goggles with LCDs as lenses which can open and shut in a precise manner
- Speed (TTT, TSOT) and accuracy of subjects task performance (errors)


- How many participants are required?
- How much training to give?
- How many task variations to set?
- Data analysis procedures?
- Vision interval: 1.5 s
- Occlusion interval: 2.0 s
- TSOT = total shutter open time
- TTT = total task time
- $R = \frac{TSOT}{TTT}$ (ratio of total shutter open time to task time when full vision is provided)

ISO 16673:2007
Road vehicles -- Ergonomic aspects of transport information and control systems -- Occlusion method to assess visual demand due to the use of in-vehicle systems
Occlusion

- Easy to use
- Less effort
- Highly applicable in the early stages of the development process

But

- Not sensitive in combination with short tasks or pure auditory tasks or pure manual tasks
- It might get on your nerves…

Peripheral Detection Task PDT

- Task: detection of peripheral stimuli
- Simulation of visual workload when simultaneously driving and interacting with IVIS
**Lane Change Test (LCT)**

- **PC-based driving simulation**

![Diagram of Lane Change Test](http://ppc.uiowa.edu/drivermetricsworkshop/documents/LCToverviewMattes.pdf)

- Velocity: constant 60 km/h
- Distance between signs: $M=150$ (140-188 m, exponentially distr.)
- Duration: ~3 min.
- Blank signs are always visible, symbols appear at distance of 40m

Lane Change Test (LCT)

- Analysis

**Area** indicates driving quality.

This comparison of the behavioral data to the normative model provides one single index of performance which allows automatic and objective analysis.

The area is sensitive to:
- Perception (missed sign)
- Reaction
- Manoeuvre
- Lane keeping


Lane Change Test

- The LCT provides one single value for "Mean Deviation" for each secondary task under test.
- The mean deviation values can be compared statistically with typical methods of statistical inference (t-Test, ANOVA).

Low-Fidelity Driving Simulator

- CARS—“Configurable Automotive Research Simulator”
- Open source
- Low cost (regarding hardware requirements)
- Adjustable
- Three components
  - Map editor
  - Simulator
  - Analysis tool

http://cars.pcuie.uni-due.de/

(c) Albrecht Schmidt, 2012

High-Fidelity Driving Simulator

- Very expensive
- Sometimes the only possible way for studies (danger)
- Experimental control
- Large number of driving performances
- Simulator sickness
- Validity not easy to assess


(c) Albrecht Schmidt, 2012
Field Test

- Need instrumented car
- Expensive
- Ethical limitations (e.g. fatigue warning)
- Many factors uncontrolled (e.g. traffic situation)
- High validity


(c) Albrecht Schmidt, 2012

Concept cars

(c) Albrecht Schmidt, 2012
Overview

- Motivation
- Design Space
- Understanding the Users
- Tools and Methods
- Projects and lessons learned
- Conclusion

Multitouch steering wheel

- The whole steering wheel is a interactive multitouch display
- We conducted experiments to find intuitive gestures for common tasks, e.g.
  - Change volume
  - Navigate on a map
- Reduces the time that people look away from the street

Gestural Interaction on the Steering Wheel - Reducing the Visual Demand

Bridging the Communication Gap
Video link improves communication

<table>
<thead>
<tr>
<th>Reference (No driving)</th>
<th>No Video System</th>
<th>Monitor Video System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At Rear-seat Passenger</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td># glances/min</td>
<td>2.6</td>
<td>0.4</td>
</tr>
<tr>
<td># looks/min</td>
<td>2.3</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>At Monitor Display</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td># glances/min</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td># looks/min</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

[Döring, 2011]
[Tai, 2009]
Bridging the Communication Gap in the Car

Without compromising driving performance

Tactile Output Embedded into the Steering Wheel

- Directional tactile output as an additional modality
- Motivation: turn off audio when in conversation and then missing the exit

(c) Albrecht Schmidt, 2012
Tactile Output Embedded into the Steering Wheel

Results show that adding tactile information to existing audio, or particularly visual representations, can improve both driving performance and user experience.

[Kern et al 2009]
Experiment & Result

- **Tasks**
  - Map search task on small screen
  - IQ questions on large screen

- **Procedure**
  - Find given letter
  - Attention switch, solve IQ task
  - Find given letter again

- **16 Participants** (23 to 52 years old)

- **Result**: Participants were considerably (about 3 times) faster in searching with **Gazemarks**
  - With **Gazemarks**: 625.75 ms (median)
  - Without **Gazemarks**: 1999.50 ms (median)

---

Secondary tasks while driving

- **Without Gazemarks**
  - Eyes on road
  - Switching task
  - Eyes on road
  - Switching task
  - > 2 seconds

- **With Gazemarks**
  - Eyes on road
  - Switching task
  - Eyes on road
  - Switching task
  - < 2 seconds

---

(c) Albrecht Schmidt, 2012
Overview

- Motivation
- Design Space
- Understanding the Users
- Tools and Methods
- Projects and lessons learned
- Conclusion

Conclusion

- It is not a PC and not an office environment
- The field is challenging and moves quickly
- Many tools and methods are out there

- We hope that with the tutorial today we can give you “starting point” in the field
References


ISO 9241-210

Dagmar Kern, 2012. Supporting the Development Process of Multimodal and Natural Automotive User Interfaces. PhD Dissertation at the University of Duisburg-Essen, Germany


