

# Multimodal human-computer interaction in the car

## Novel interface and application concepts

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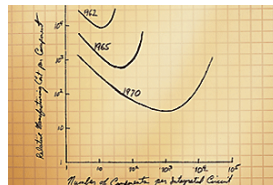
## Overview

- User Interfaces and Pervasive computing
- A networked car application platform
- Selected Projects
  - Communication in the car
  - Interaction on the steering wheel
  - Gazemarks
  - Classifying car UIs – a Design Space
  - Open Source Driving Simulator
- Where are we heading?

## Pushing the Boundaries of Human Computer Interaction

What is the ultimate user interface?

## Pervasive Computing Moore's Law and Implications



- calculator (<0,99€)
- digital watch (<0,99€)
- digital step counter
- "happy birthday" song card
- \*\*\*
- digital (video)camera
- digital picture frame
- mobile phone
- SatNav device
- image recognition
- netbook/tablet computer
- digital television
- \*\*\*
- Anoto Pen
- Eye tracker
- Bio-Sensing
- ...

### Informal implication:

A functionality that can be effectively realized with a digital circuit (e.g. with a fixed number of transistors) can become very cheap

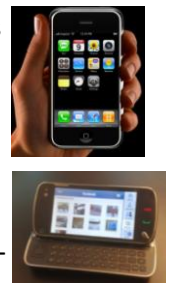
## Pervasive Computing is changing the value chain and product structures

- Digital devices (hardware) will be cheap and competition tough
- Services and content will become more specialized and NOT create the value in the large
- Platforms and Meta-services are the key to revenue
- Access to user activity and knowledge about the user will be essential



## Pervasive Computing is changing the understanding of technology

- Consumer behavior and consumers value will change
- Not available functionality but **usable functionality** will be the measure
- Functionality is less discriminative
- **Quality** – as experienced and expressed by one's social network – will play a major role



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## A Networked Car Application Platform

...an ongoing Research Project

- Cars share in real-time data about
  - Their environment and the car (e.g. location, temperature, weather, street surface condition, vibration, camera...)
  - Surrounding traffic (e.g. density, speed, ...)
  - User interaction (e.g. steering, interaction with pedals, ...)
  - Physiological Information (e.g. gaze direction, surprise, anger, ...)
- The information is collected, processed, abstracted, and accumulated
- Using an application programming interface (API) developers can create applications

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## A Networked Car Application Platform

...an ongoing Research Project

- Many applications that become possible, e.g.
  - Creating a map with street conditions information about damage (e.g. holes in the road surface) and temporary issues (e.g. ice on the road)
  - Virtual black box for insurance that allows specific tariffs (e.g. car is parked during the night indoors)
  - Linking the car to social software (e.g. facebook) and communication (e.g. twitter) and proving information
  - Detailed usage profile when selling the car
  - ...
- Great potential, but many open questions
- We are seeking collaboration with companies ...

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## A Networked Car Application Platform

...an ongoing Research Project

- Imagine all the information that goes over the bus systems in the car is shared and centrally collected
- Imagine 1%, 5%, 10%, 50% of the people share it?
- What new information could we create?
- What could the user do with it?
- What could a community do with it?
- What could a manufacturer do with it?

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## Communication in the car



**Making decisions in the car**

- going on holiday (63%)
- buying a car (50%)
- moving (40%)
- getting a pet (26%)
- getting married (23%)

**Why**

long journey being an effective environment for communication

people are close together for a long time and no-one can walk away (41%).

you have reason not to look the other person into the eyes

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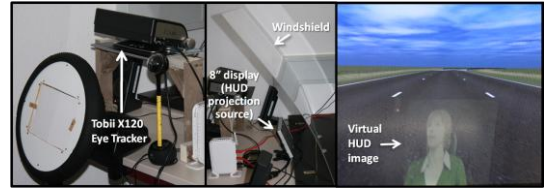
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### Bridging the Communication Gap Video link improves communication



|                        | Reference<br>(No driving) | No Video<br>System | Monitor Video<br>System |
|------------------------|---------------------------|--------------------|-------------------------|
|                        | Mean                      | Mean               | Mean                    |
| At Rear-seat Passenger | # glances/min             | 2.8                | 0.4                     |
|                        | # looks/min               | 2.3                | 0.0                     |
| At Monitor Display     | # glances/min             | 0.0                | 0.0                     |
|                        | # looks/min               | 0.0                | 3.3                     |

### Bridging the Communication Gap in the Car



| VideoSystem      | ReactionTime (seconds) |                        |
|------------------|------------------------|------------------------|
|                  | Mean                   | Standard Error of Mean |
| VideoSystem      | Reference              | 1.40                   |
|                  | No Video System        | 1.51                   |
|                  | Monitor Video System   | 1.53                   |
|                  | HUD Video System       | 1.50                   |
| ConversationTask | Article                | 1.50                   |
|                  | Game                   | 1.53                   |

Without compromising driving performance

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### Text input while driving

- People do it... but it may be dangerous
- Many applications
  - Navigation system
  - Entertainment / News
  - Internet access
  - Communication (SMS, messaging, email)
- Speech has not taken off yet (not in cars nor on the desktop)

### Handwritten Text Input While Driving



### Handwritten Text Input While Driving Study

- Driving simulator CARS
- 16 participants (5 female)
- inputting address and names
- 5 minutes drivers under each condition
  - steering wheel/steering wheel (sw/sw)
  - steering wheel/dashboard (sw/db)
  - central console / central console (cc/cc)
  - central console/dashboard (cc/db)
  - one reference drive

|    | input | output | speed | lane keeping |
|----|-------|--------|-------|--------------|
| cc | cc    | 29.5   | 121.0 |              |
|    | db    | 29.6   | 103.5 |              |
| sw | sw    | 30.7   | 104.6 |              |
|    | db    | 31.4   | 113.0 |              |
| wt |       | 33.5   | 87.9  |              |

- Text input while driving will inevitably impact driving performance
- steering wheel is well accepted by users and lead to 25% fewer corrections and remaining errors

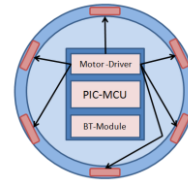
## Multitouch steering wheel

- The whole steering wheel is an 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



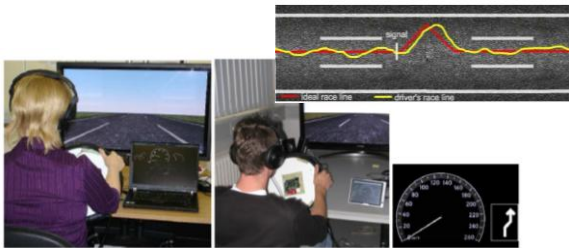
## Haptic feedback

### 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

## 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.

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## Implementing Gazemarks

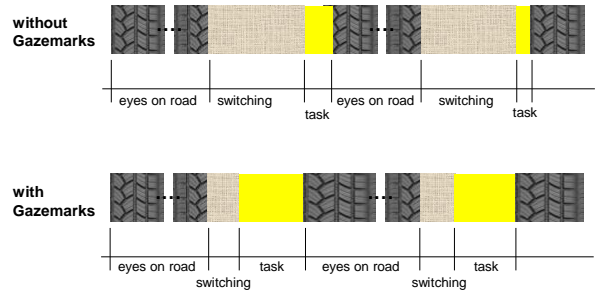
- **Detect** when the user switches **attention** between displays
- **Save last gaze position** when the user “leaves” the screen
- On “returning” to a display **visualize the last gaze position**



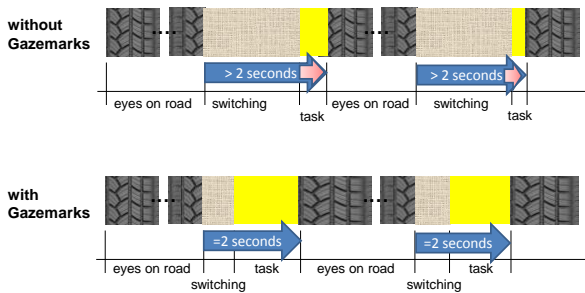
## Results

- Participants were considerably (about 3 times) faster in searching with *Gazemarks*
  - with *Gazemarks*: **625.75 ms** (median)
  - without *Gazemarks*: 1999.50 ms (median)
- Comparing search times
  - Strong significant difference (non-parametric Wilcoxon signed-rank test)
- Qualitative results
  - Preferences for *Gazemark*
  - Mean value 4.26, standard deviation 0.53, on a scale from 0 (completely senseless) to 5 (very sensible)
  - Reported benefits as perceived by the user: enabling rapid task switch and less attention required

## Enabling secondary tasks while driving



## Secondary tasks while driving



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## An Automotive Design Space

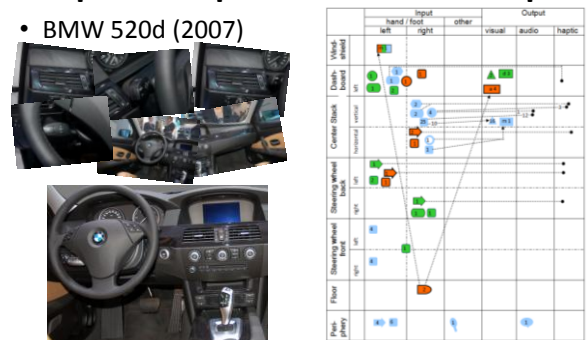
- We analyzed 117 car models from 35 manufacturers shown at IAA 2007 (over 700 photos<sup>1</sup>)
- I/O elements on photos manually classified
  - input (buttons, sliders, knobs, thumbwheels, pedals, touch-screens, ...)
  - output (Speedometer, Indicator lamp, multifunctional display, Loudspeakers, vibration modalities)
  - position (windshield, dashboard left, steering wheel, floor, center stack, Periphery)



<https://www.pcuie.uni-due.de/AUI/>

## Graphical Representation - Example

- BMW 520d (2007)



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## Open Source Low-Fidelity Driving Simulator CARS Configurable Automotive Research Simulator



<https://www.pcuie.uni-due.de/projectwiki/index.php/CARS>

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## What becomes of cars?



“VW up! ... like an iPod touch that you can drive, too.”

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## The Car...

... a means for transport.

- ... an space for media consumption?
- ... a fun place to be
- ... 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?

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## 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”

*Driving Automotive Research  
IEEE Pervasive Magazine*

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## Resulting challenges for the UI

- 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, ...
- New interaction demands from assistive systems (joint tasks – human and car)
- Increased complexity of interaction while driving due to secondary tasks

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## Questions? Comments?

- Visit my websites at:  
<http://www.pervasive.wiwi.uni-due.de/>  
<http://albrecht-schmidt.blogspot.com/>

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## Bio: Albrecht Schmidt

Albrecht Schmidt is a professor for Pervasive Computing and User Interface Engineering at the University of Duisburg-Essen. He studied computer science in Ulm and Manchester and receive in 2003 a PhD from the Lancaster University in the UK. His research interest is in human computer interaction beyond the desktop, including user interfaces for mobile devices and cars. Albrecht published well over 100 refereed archival publications and he is on the editorial board of the IEEE Computer Magazine.

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- Schmidt, A., Spiessl, W., and Kern, D. 2010. Driving Automotive User Interface Research. *IEEE Pervasive Computing* 9, 1 (Jan. 2010), 85-88. DOI=<http://dx.doi.org/10.1109/MPRV.2010.3>
- Kern, D., Marshall, P., and Schmidt, A. 2010. Gazemarks: gaze-based visual placeholders to ease attention switching. In *Proceedings of the 28th international Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA, April 10 - 15, 2010). CHI '10. ACM, New York, NY, 2093-2102. DOI=<http://doi.acm.org/10.1145/1753326.1753646>
- Pfeiffer, M., Kern, D., Schöning, J., Döring, T., Krüger, A., and Schmidt, A. 2010. A multi-touch enabled steering wheel: exploring the design space. In *Proceedings of the 28th of the international Conference Extended Abstracts on Human Factors in Computing Systems* (Atlanta, Georgia, USA, April 10 - 15, 2010). CHI EA '10. ACM, New York, NY, 3355-3360. DOI=<http://doi.acm.org/10.1145/1753846.1753984>
- Kern, D. and Schmidt, A. 2009. *Design space for driver-based automotive user interfaces*. In *Proceedings of the 1st international Conference on Automotive User interfaces and interactive Vehicular Applications* (Essen, Germany, September 21 - 22, 2009). AutomotiveUI '09. ACM, New York, NY, 3-10. DOI=<http://doi.acm.org/10.1145/1620509.1620511>
- Kern, D., Hornecker, E., Marshall, P., Schmidt, A., Rogers, Y. 2009. Enhancing Navigation Information with Tactile Output Embedded into the Steering Wheel. In *Proceedings of the 7th Int. Conference on Pervasive Computing 2009 (Pervasive 2009)*. Nara, Japan. Springer LNCS 5538, pp 42-58.

23.06.2010

Albrecht Schmidt, Stuttgart, 2010

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- Graf, S., Spiessl, W., Schmidt, A., Winter, A., and Rigoll, G. 2008. In-car interaction using search-based user interfaces. In *Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy, April 05 - 10, 2008). CHI '08. ACM, New York, NY, 1685-1688. DOI=<http://doi.acm.org/10.1145/1357054.1357317>
- Dagmar Kern, Albrecht Schmidt, Michael Pitz, Klaus Bengler. Verbesserung der Telekommunikation im Auto unter Ausnutzung von Status- und Kontextinformationen. *Mensch und Computer* 2007.
- Holleis, P., Kern, D., and Schmidt, A. 2007. Integrating user performance time models in the design of tangible UIs. In *CHI '07 Extended Abstracts on Human Factors in Computing Systems* (San Jose, CA, USA, April 28 - May 03, 2007). CHI '07. ACM, New York, NY, 2423-2428. DOI=<http://doi.acm.org/10.1145/1240866.1241018>
- Schmidt, A., Kern, D., Streng, S., Holleis, P. Magic Beyond the Screen, *Multimedia, IEEE*, vol.15, no.4, pp.8-13, Oct.-Dec. 2008
- Schmidt, A. 2010. Ubiquitous Computing: Are We There Yet? *IEEE Computer* 43, 2 (Feb. 2010), 95-97. DOI=<http://dx.doi.org/10.1109/MC.2010.54>
- Albrecht Schmidt, Anind Dey, Thomas Seder, Oskar Juhlin. *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. ACM 2009. ISBN:978-1-60558-571-0. Essen, Germany, September, 21-22, 2009. <http://portal.acm.org/toc.cfm?id=1620509>

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