6th Summer School on Computational Interaction

Saarbrücken | June 16, 2022

User Modeling in (Automotive) Development and Products

Dietrich Manstetten, Bosch

User Modeling in (Automotive) Development and Products
Agenda

Part 1: About me – about Bosch Research – about HCI @ Bosch Research

Part 2: Modeling Driving Behavior
An Example of „User Modeling in Automotive Development“

Part 3: Driver Monitoring
An Example of „User Modeling in Automotive Products“

Part 4: Towards Personalized IoT Systems
An example of „User Modeling in Development and Products“

Questions & Discussion

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PART 1
ABOUT ME – ABOUT BOSCH RESEARCH – ABOUT HCI @ BOSCH RESEARCH

Dietrich Manstetten – about me

mailto:dietrich.manstetten@de.bosch.com

- 1979-85 Masters in Mathematics at RWTH Aachen
- 1985-88 Bull AG, Köln (Marketing)
  Ph.D. in Computer Science at RWTH Aachen
- since 1989 Robert Bosch GmbH, Stuttgart, Corporate R&D
  Main topics:
  - Software Safety & Reliability
  - Traffic Simulation & Traffic Control Systems
  - Fleet Management Systems
  - Driving Simulator
  - Driver Assistance Systems & Driver Monitoring
  - Human-Computer Interaction
  - User Experience

  Chief Expert & Director for „Human-Machine Interaction“
- External Convenor of FAT WG2 „Human as a Vehicle Driver“
  FAT = Forschungsvereinigung Automobiltechnik, research branch of VDA
  VDA = Verband der Automobilindustrie, German Association of the Automotive Industry
  Honorary Professor at Bundeswehr University Munich

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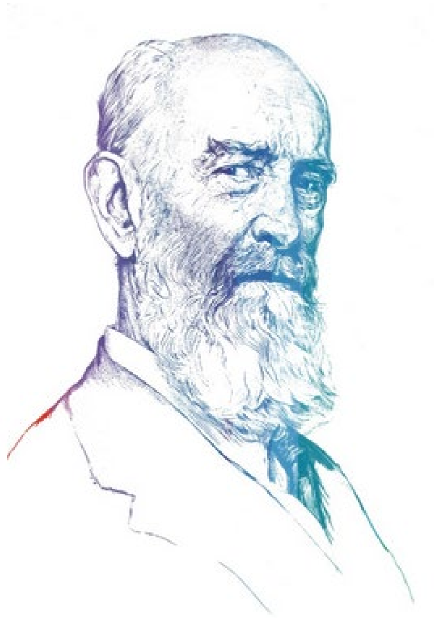
About Bosch Research

Bosch – Invented for Life

a guiding principle deeply rooted in our origin



“Improvements in the world of technology and business should always also be beneficial for mankind.”

ROBERT BOSCH

Bosch
Four Business Sectors with increasing synergies

Mobility Solutions

42.1

billion euros
sales revenue

Industrial Technology

5.1

billion euros
sales revenue

Energy and Building Technology

5.5

billion euros
sales revenue

Consumer Goods

18.8

billion euros
sales revenue

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Bosch
A worldwide leading IoT Company

In 2020

71.5

billion euros sales revenue

2.0

billion euros EBIT from operations

395,000

Bosch associates worldwide at year-end (approx.)

440

subsidiaries and regional companies in more than 60 countries

Bosch Research: Organization, Figures and Locations

Bosch Research

In 2020

1,740

highly specialized employees

90%

of associates are scientists

152

PhD students

+11

top research facilities around the globe

1,855

invention reports

74%

resulted in patents

328

mio. € invested in Bosch Research & Center for Artificial Intelligence

Bosch Research: Organization, Figures and Locations

An eye for the big picture through a global presence

Europe & Middle East

Corporate Research and Advance Engineering Germany
Research and Technology Office Russia
Research and Technology Center Tel Aviv

1,490 associates

North America

Research and Technology Center North America

130 associates

Asia-Pacific

Research and Technology Center India
Research and Technology Center Asia-Pacific

120 associates

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Our Research Campus Renningen
Location and figures of Renningen

Bosch Research: Purpose
Fields of innovation




Artificial intelligence research

Creating AI[1] solutions

Chemical energy conversion

Reducing greenhouse gas emissions

Electrified mobility and systems

Researching electric vehicle concepts

Healthcare solutions

Improving peoples' health and quality of life

[1]Artificial Intelligence (AI)

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Bosch Research: Purpose
Fields of innovation

Information and communication technologies

Ensuring digital transformation of Bosch

IoT @ life

Growing an ecosystem for consumer IoT solutions

AI-enabled fully autonomous systems

New innovative products for hundreds of millions of people

Modeling, simulation, optimization and new materials for engineering

Better and faster engineering

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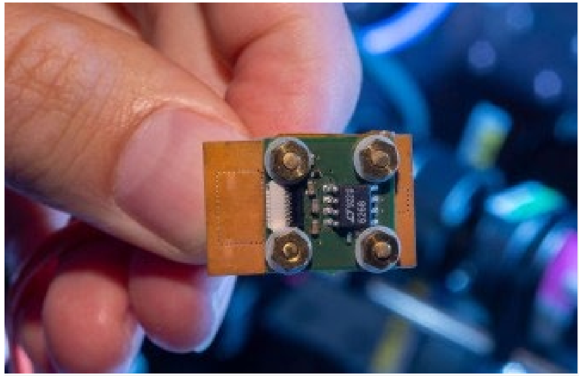
Bosch Research: Purpose
Fields of innovation



Sustainability innovations for resource and energy efficiency

New business

Creative space where innovation thrives

Production systems

Future production systems

Smart sensor & hardware systems

Bridge between physical and virtual spaces

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About HCI @ Bosch Research

Human Computer Interaction @ Bosch Research

We understand humans to design and evaluate successful HCI solutions

- We design the user interface to enable an efficient, safe and inspiring interaction between human and machine
- In a user-centered development process, we place human needs and capabilities in the forefront to identify base requirements for product development
- We operate, use and provide HCI labs and infrastructure, that enable us to rapidly evaluate products and systems in realistic scenarios with relevant end users
- With our research, we create economic value and ensure the future business success of Bosch

Human Computer Interaction @ Bosch Research
Competencies

User Research & Human Factors Studies

- Concept development for user testing
- Evaluation of attitudes
- Behavior and Performance evaluation
- Psychometrics
- Usability Testing & Ergonomics
- Development of User Requirements

User Interaction Design

- Analysis and Design of User Interfaces
- Evaluation of novel Interaction Techs
- HCI programming (embedded/mobile)
- Prototyping interactive systems
- HCI sensing technologies
- Touch and Haptic Feedback

User Modelling & Personalized Assistance

- User & Driver Monitoring / Modelling
- Eye tracking and gaze behavior
- Neurotechnology
- Evaluation of Physiological Data
- Applied Machine Learning
- Time Series Analysis

Domain competencies:

Automotive

Residential IoT

Robotics

Human Computer Interaction @ Bosch Research
Activity Examples

Ride Comfort in Automated Driving

The main promise of L3+ automated driving relates to enable non-driving related activities. However, a significant number of passengers are expected to experience discomfort up to motion sickness

We develop a test methodology to assess ride discomfort, and evaluate selected countermeasures to mitigate motion sickness symptoms.

Attention and Activity Assistant

The changing role from driver to passenger raises research questions regarding human-vehicle interaction.

Within publicly funded project TANGO, we develop an attention and activity assistant that adapts interaction based on driver attention, driving situation and level of automation. The focus is on truck drivers.

Internal and External Communication

We are evaluating human-machine interaction in the triangle AV – passenger – road users. One focus within the publicly funded project @CITY-AF is on dynamic HMI, i.e. using vehicle motion as a means to communicate AV intention both to the inside and to the outside. The key question is how to achieve consistent information while gaining trust and acceptance.

Advanced Driver Impairment

The detection of driver impairment due to sudden sickness or driving under influence enables new safety features for both automated and non-automated vehicles.

We are assessing different use cases (e.g. cardiovascular, neurological or metabolic sickness) and describe their relevance. A further focus is on identifying potential sensors / sensing principles.

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Human Computer Interaction @ Bosch Research
Activity Examples

Smart Automotive Surfaces

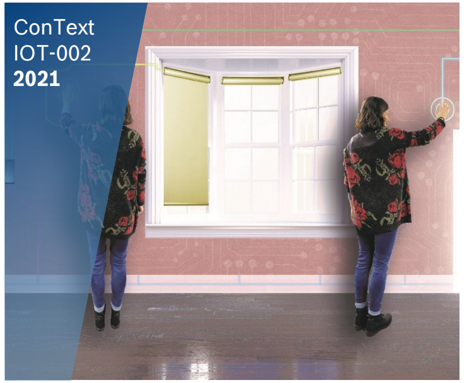
In line with the current trend for minimalistic interior designs, we are investigating opportunities to seamlessly integrate HMI technologies into automotive surfaces.

Within the smart surface activity, we are building upon experience from the previous smart textiles activity, mainly focusing on functionalizing textile surfaces with touch input and (visual/haptic) output capabilities

Pan Interaction

Embedding computational capabilities in everyday objects can enable novel interaction concepts that seamlessly integrate in users' tasks.

We conducted an elicitation study to find out whether and how subjects would use a pan to control functions related to cooking.



Connecting Textiles

Battery driven IoT devices with wireless connection are prone to disruptions and interruptions.

Within the publicly funded project ConText, we develop a wall-mounted textile-based IoT infrastructure. This infrastructure serves as energy supply for IoT devices, enables communication between devices, and serves as input surface for user interaction.

Fall detection

Previous research has shown that IMU data can be used to assess fall risk and recognize fall incidences

We support our colleagues from the business division to introduce fall detection onto the market. Here, we are focusing both on E-Bike and on Motorcycle applications.

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Human Computer Interaction @ Bosch Research
Labs and Infrastructure

Driving Simulator
- Actuated platform (DBox)
- Exchangeable mockup (car/truck)
- Separate operator room

Powerwall
- Large screen (3x7m) for data visualization
- Back projection, 6 projectors

Smart Life Lab
- Connected IoT devices in residential environment
- Prototyping of novel connected solutions
- UX lab, Showroom, Creativity area

Workshop
- vehicle preparation for user studies (e.g. WOz vehicle)
- with lifting platform

Hackathon Zone
- Collaborative working space

Electronics lab
- Soldering work places
- Electrical rapid prototyping
- Conductive ink printer for rapid prototyping

PART 2
MODELING DRIVING BEHAVIOR

Modeling Driving Behavior
Objectives of behavioral driver models

- In **system development**
  - As a role model for a technical control system (e.g. Adaptive Cruise Control, Automated Driving)
  - Understand good behavior, e.g. the chauffeur-like driving style
- In **system simulation**
  - Study the impact of driver assistance systems on traffic efficiency
    (mixed traffic with system-controlled / human-controlled vehicles)
- In a **driving simulator**
  - Reproduce vehicle behavior of surrounding traffic

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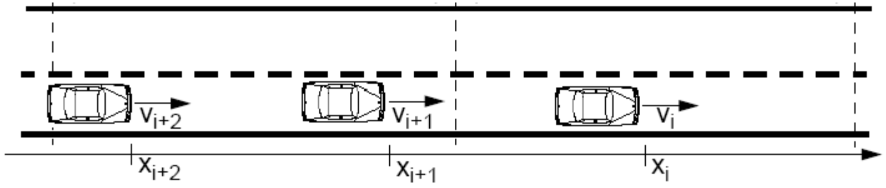
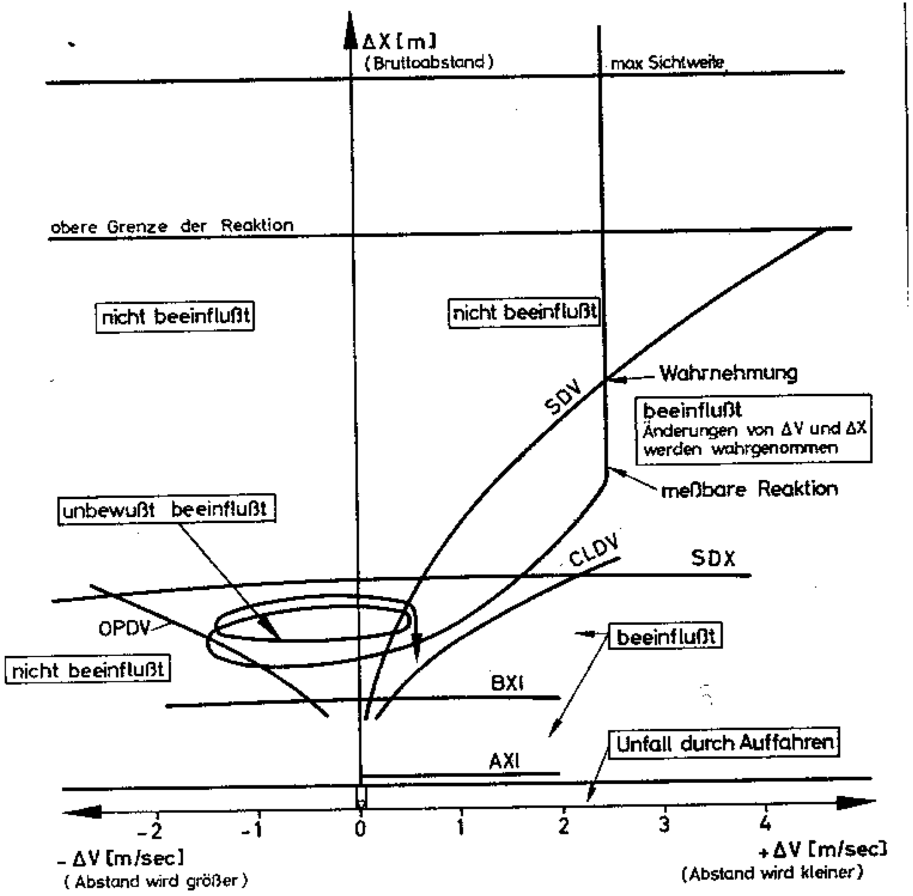
Modeling Driving Behavior
Modeling the longitudinal vehicle control

- Relevant starting points
  - Theoretical consideration of relevant steps
    - driver perception
    - reaction time & decision making
    - precision of actions
  - Empirical analysis of overall behavior
    - Measurement of distance, speed, vehicle reaction
- Definition of car-following model equation

$$\dot{v}_{i+1} = f(x_i - x_{i+1}, v_{i+1}, v_i)$$





Source: Wiedemann (1974)

Modeling Driving Behavior
The Intelligent Driver Model IDM

- Car-following model developed at TU Dresden
  - Reference: Helbing, Treiber (2000)
- Characteristics
  - Free of accidents (due to unlimited deceleration)
  - Use of parameters with a physical meaning
- Model equation

$$\dot{v}(s, v, \Delta v) = a \underbrace{\left[1 - \left(\frac{v}{v_0}\right)^4}_{\text{acceleration}} \underbrace{- \left(\frac{s^*(v, \Delta v)}{s}\right)^2\right]}_{\text{braking deceleration}}.$$

$$s^*(v, \Delta v) = s_0 + vT + \frac{v \Delta v}{2\sqrt{ab}}.$$

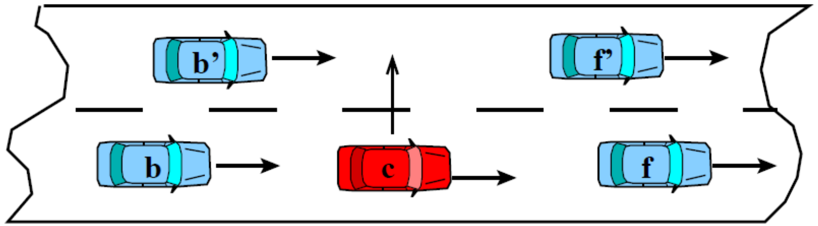
Parameter	Value Car	Value Truck	Remarks
Desired speed v_0	120 km/h	80 km/h	For city traffic, one would adapt the desired speed while the other parameters essentially can be left unchanged.
Time headway T	1.5 s	1.7 s	Recommendation in German driving schools: 1.8 s; realistic values vary between 2 s and 0.8 s and even below.
Minimum gap s_0	2.0 m	2.0 m	Kept at complete standstill, also in queues that are caused by red traffic lights.
Acceleration a	0.3 m/s^2	0.3 m/s^2	Very low values to enhance the formation of stop-and go traffic. Realistic values are 0.8 to 2.5 m/s^2
Deceleration b	3.0 m/s^2	2.0 m/s^2	Realistic values are around 2 m/s^2

Source: http://www.traffic-simulation.de/

Modeling Driving Behavior
Simulation of Intelligent Driver Model

Source: http://www.traffic-simulation.de/

Modeling Driving Behavior
Enhancing the IDM with Lateral Control Behavior



- Lateral control model MOBIL (Teiber & Helbing, 2002) (Minimizing Overall Braking Induced by Lane-Changes)
- Lane change decision is taken, when ...
  - ... the execution is safe and there is an incentive for doing
- **Safety criterion**: the deceleration (as computed via IDM) is tolerable for the new car behind

$$a_{b'c} \geq -b_{\text{save}} \qquad a_{\alpha\beta} = a^{\text{IDM}}(v_\alpha, s_{\alpha\beta}, v_\alpha - v_\beta)$$

- **Incentive criterion**:
  The total situation for all participants is better after a lane change. (at least by a threshold δ). With a politeness factor *p* (*p=0* for an egoistic driver), the change from right to left is done

$$\text{IF} \quad \underbrace{a_{cf'} + p(a_{b'c} + a_{bf})}_{\text{with lane change}} > \underbrace{a_{cf} + p(a_{bc} + a_{b'f'})}_{\text{w/o lane change}} + \delta.$$

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PART 3
DRIVER MONITORING

Early Development: Driver Drowsiness Detection
Problem Field

Accident Statistics

- Study about accidents with fatalities on freeways in Bavaria 1992 (n=204): 24% directly caused by falling asleep
- Naturalistic driving studies
- Very high relevance in truck environment

Individual Accidents

- Typical situational environment
- Sequence of actions during accident

Detection Approaches

- Subjective knowledge
- External observation
- Theoretical models of sleep process
- Physiological measurement (incl. cameras)
- Decrease in performance

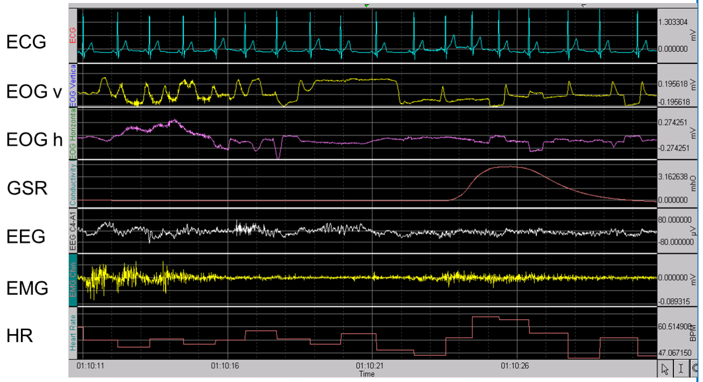
Images: http://www.sprint-driving.com/drowsy-driving-and-facts/ | youtube.com | WIVW

Early Development: Driver Drowsiness Detection
Development of Algorithms

Driving Simulator Experiment

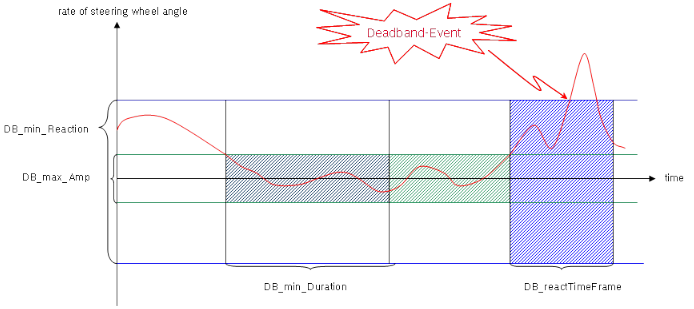
- 63 subjects in 2 ½ drive
- Induction of sleepiness by monotony
- About half of the subjects showed events of microsleep

Data Analysis



- Analysis of physiological data
- Analysis of driving data

Design of Algorithm

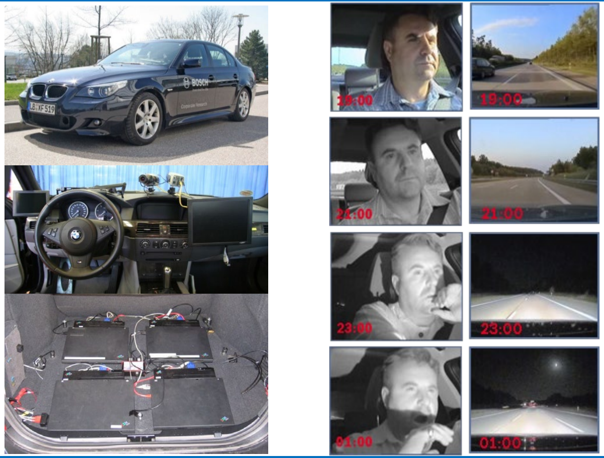


- Frequency of specific patterns in steering angle derivative as indicator for drowsiness

Images: Bosch

Early Development: Driver Drowsiness Detection
Product Development

Validation in Vehicle Test

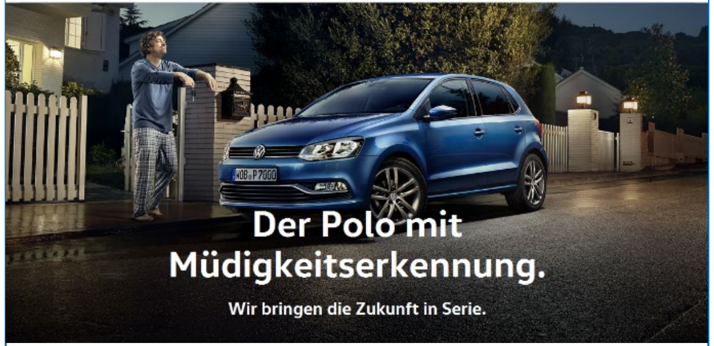


- Controlled long drives in real traffic
- Lower degree of drowsiness to ensure safety
- Three references for validation: subjective rating, observer rating, interior camera
- Positive rating of algorithmic performance

Series Development

- Bosch-internal transfer to business unit
- Joint development with vehicle manufacturer

Product Phase



- Market introduction by Volkswagen in VW Passat 2010
- Similar systems were introduced in the market about the same time, first by Volvo and Daimler
- Still state-of-the-art in vehicle technology

Images: Bosch | Bosch | Volkswagen

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The Safety Case: Driver Monitoring and Automated Driving
The Distraction Issue (another part of driver inattention)

Distraction-related Accidents (USA)

3,142	NUMBER OF PEOPLE KILLED BY DISTRACTED DRIVING IN 2019.
400,000	ESTIMATE OF PEOPLE INJURED IN CRASHES INVOLVING DISTRACTED DRIVERS IN 2018.
2.9%	PERCENTAGE OF DRIVERS USING HANDHELD CELL PHONES IN 2017, DOWN FROM 3.3 IN 2016.

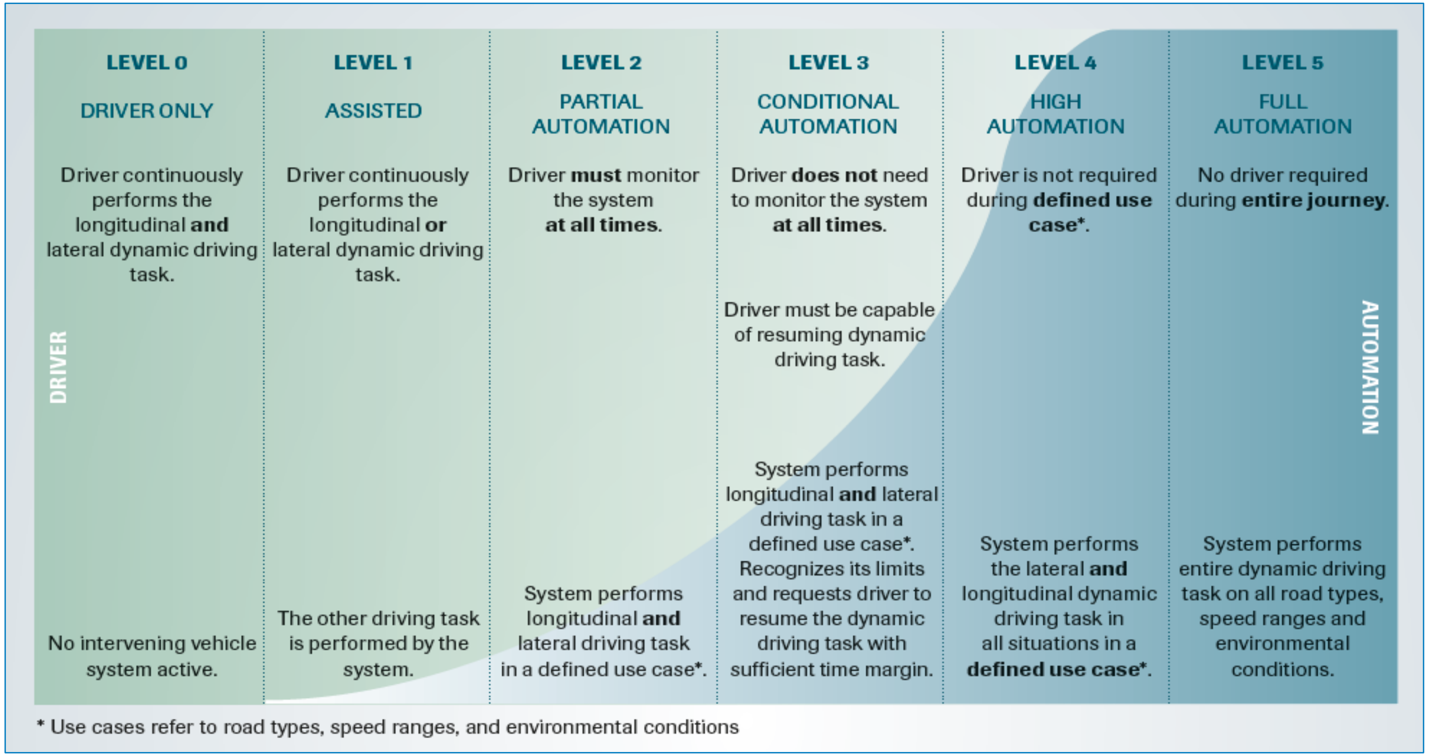
Types of Distraction

- Manual Distraction "hands off the wheel"
  - results in errors in activity
- Visual Distraction "eyes off the road"
  - results in missing information
- Cognitive Distraction "mind off driving"
  - results in wrong decisions

Source: NHTSA (2020). https://www.nhtsa.gov/risky-driving/distracted-driving | NHTSA (2014), www.distraction.gov

The Safety Case: Driver Monitoring and Automated Driving
Automated Driving as a Game Changer

Levels of Automated Driving



Changed Perspectives

The level of automation changes the driver's tasks (no access to performance data)

LEVEL 0 / 1
Perform longitudinal and/or lateral dynamic driving task
→ Measure performance or attention

LEVEL 2
Monitor the system at all times
→ Measure attention

LEVEL 3
Be capable of resuming driving task
→ Measure readiness / availability

Image: VDA

The Safety Case: Driver Monitoring and Automated Driving

Camera-based Driver Monitoring

Images: Bosch Car Multimedia (2019)

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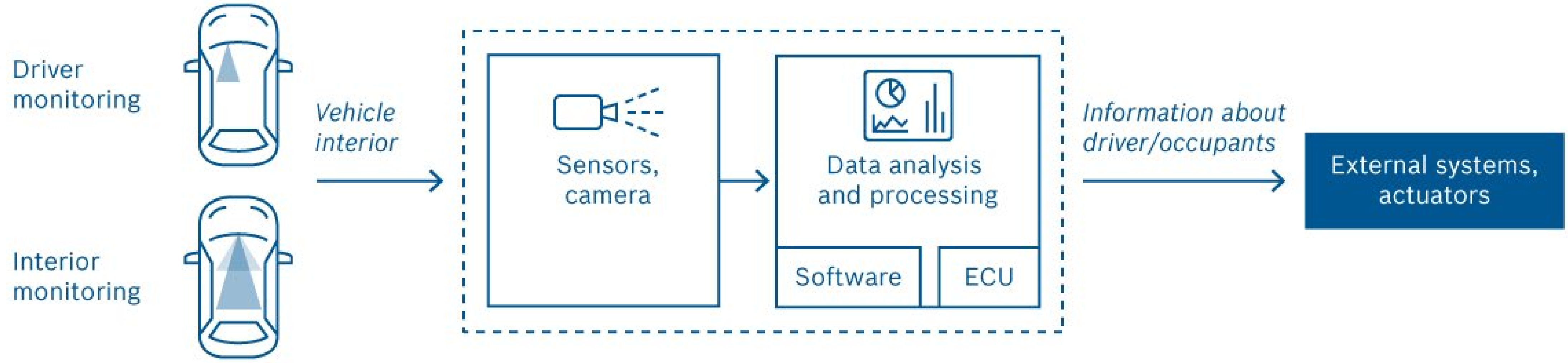
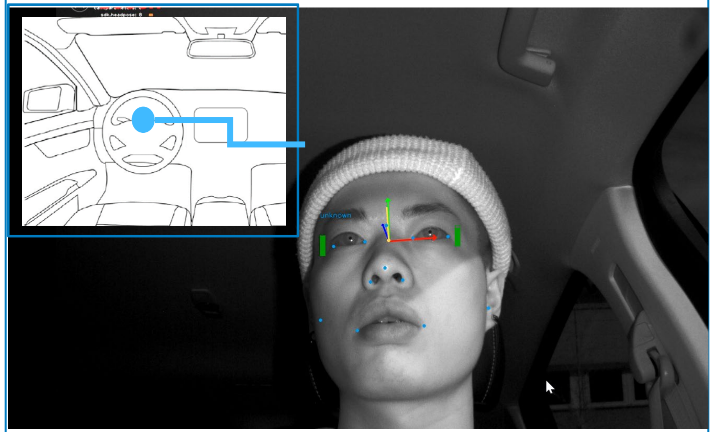
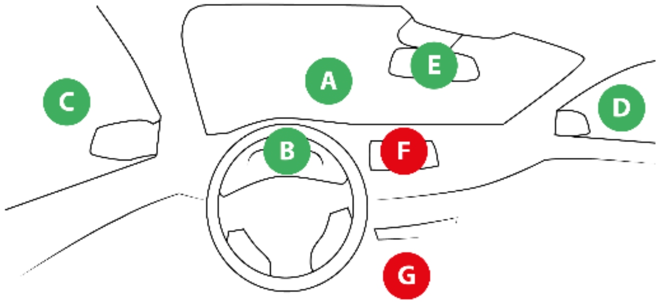
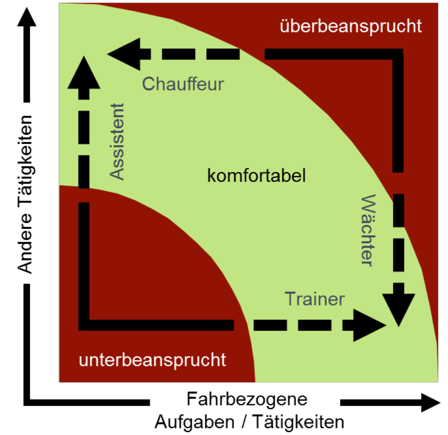
Camera-based Driver Monitoring
From Sensors to Actuation



Source: Bosch Car Multimedia (2019)

Camera-based Driver Monitoring
From Sensors to Actuation

Camera sensor	Development of Algorithms	Actuation
		

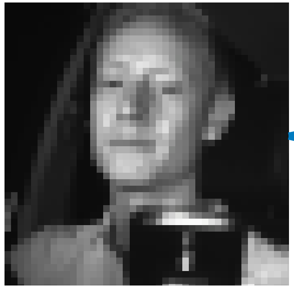
– NIR camera system with base signals
  – Head pose
  – Eye state
  – Eye gaze
  – Face identification
	– Algorithms identifying visual distraction by Gaze Region Estimation (from classical eyetracking to deep learning)
	– ML approaches to analyze further types of inattention (tunnel vision)
		– Distraction warning
		– Adaptation of thresholds of assistance systems
		– Assisting the driver in keeping the right level of attention, balancing overload and underload wrt automated driving

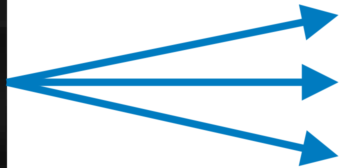
Images: Bosch | Bosch | Project TANGO https://projekt-tango-trucks.com/en/

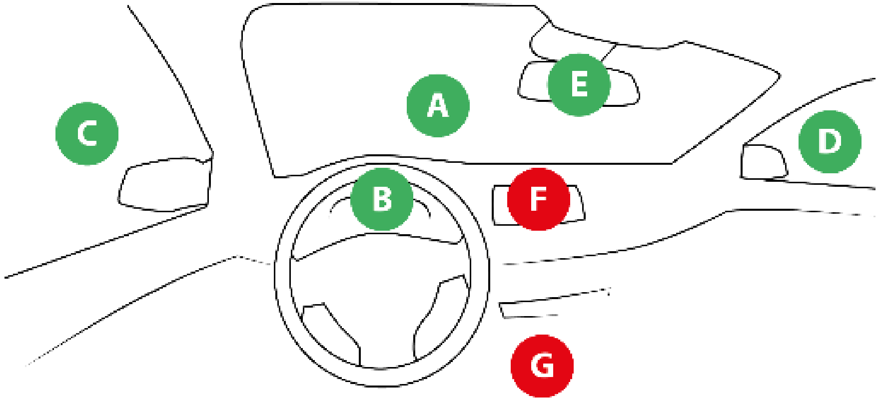
Camera-based Driver Monitoring
Development of algorithms – AI potential

IR Video of Driver

Gaze Region



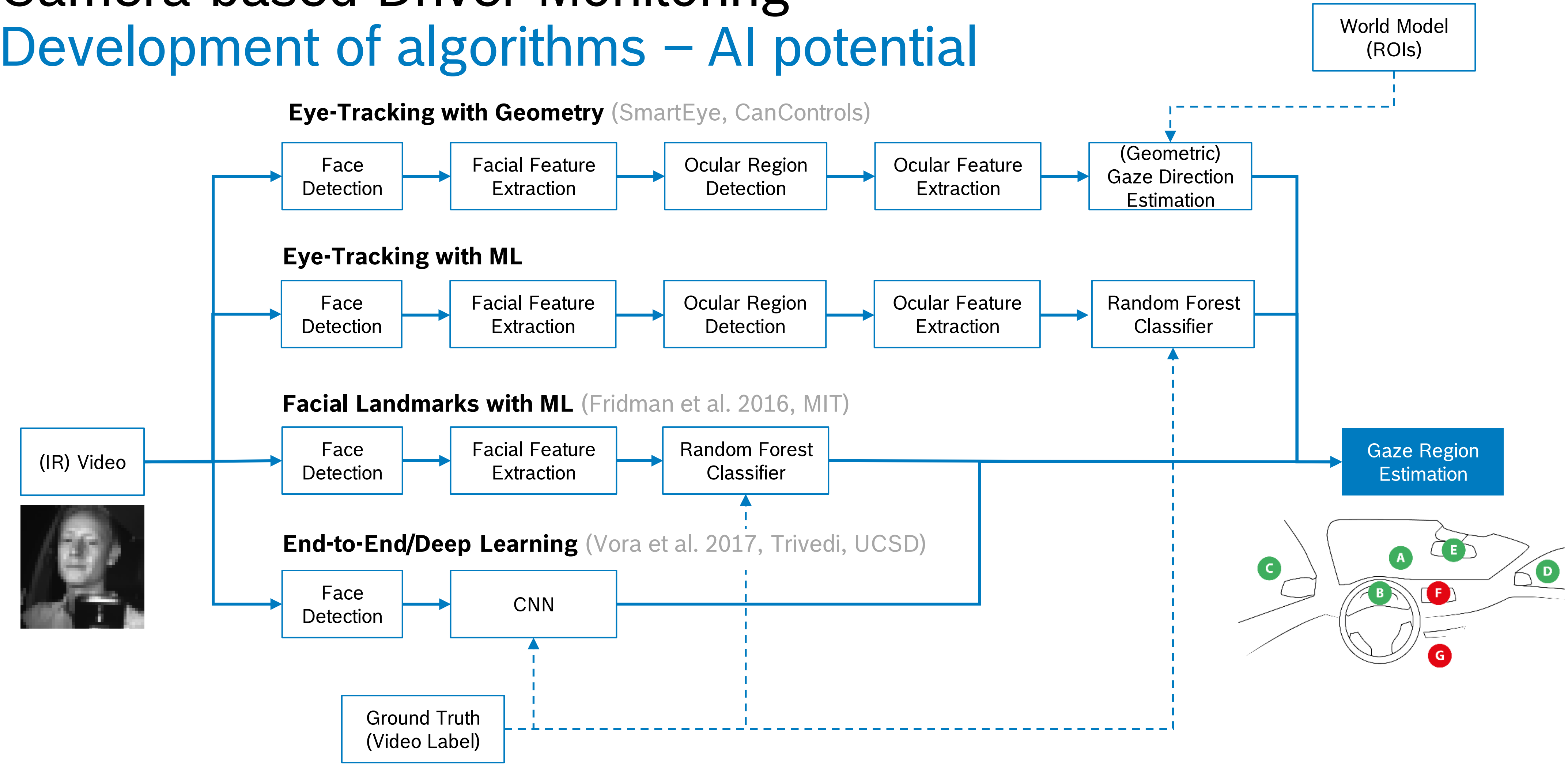




Problem Statement for Gaze Region Estimation

Source: J. Bieg (2021)

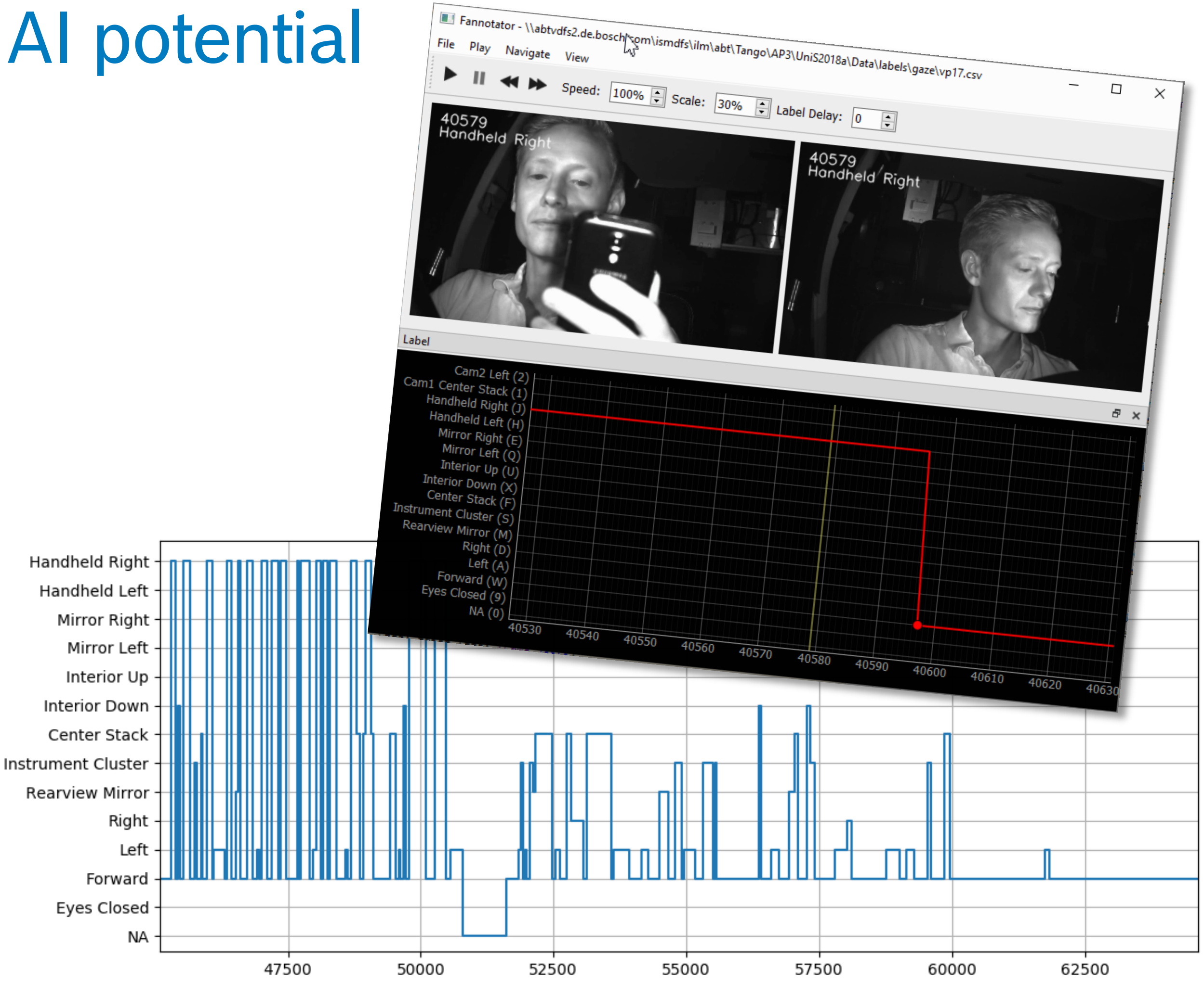
Camera-based Driver Monitoring
Development of algorithms – AI potential



Source: J. Bieg (2021)

Camera-based Driver Monitoring
Development of algorithms – AI potential

- **Dataset**
  - 24 participants (of 32 in total)
  - SAE Level 2 automated drive
    (with monitoring task)
  - Driving simulator, different secondary tasks
    (handheld use, video, sports, ...)
  - Manually labelled glance regions
  - Balanced dataset:
    approx. 800 annotated frames per (main) region per participant = ca. 130.000 frames



Source: J. Bieg (2021)

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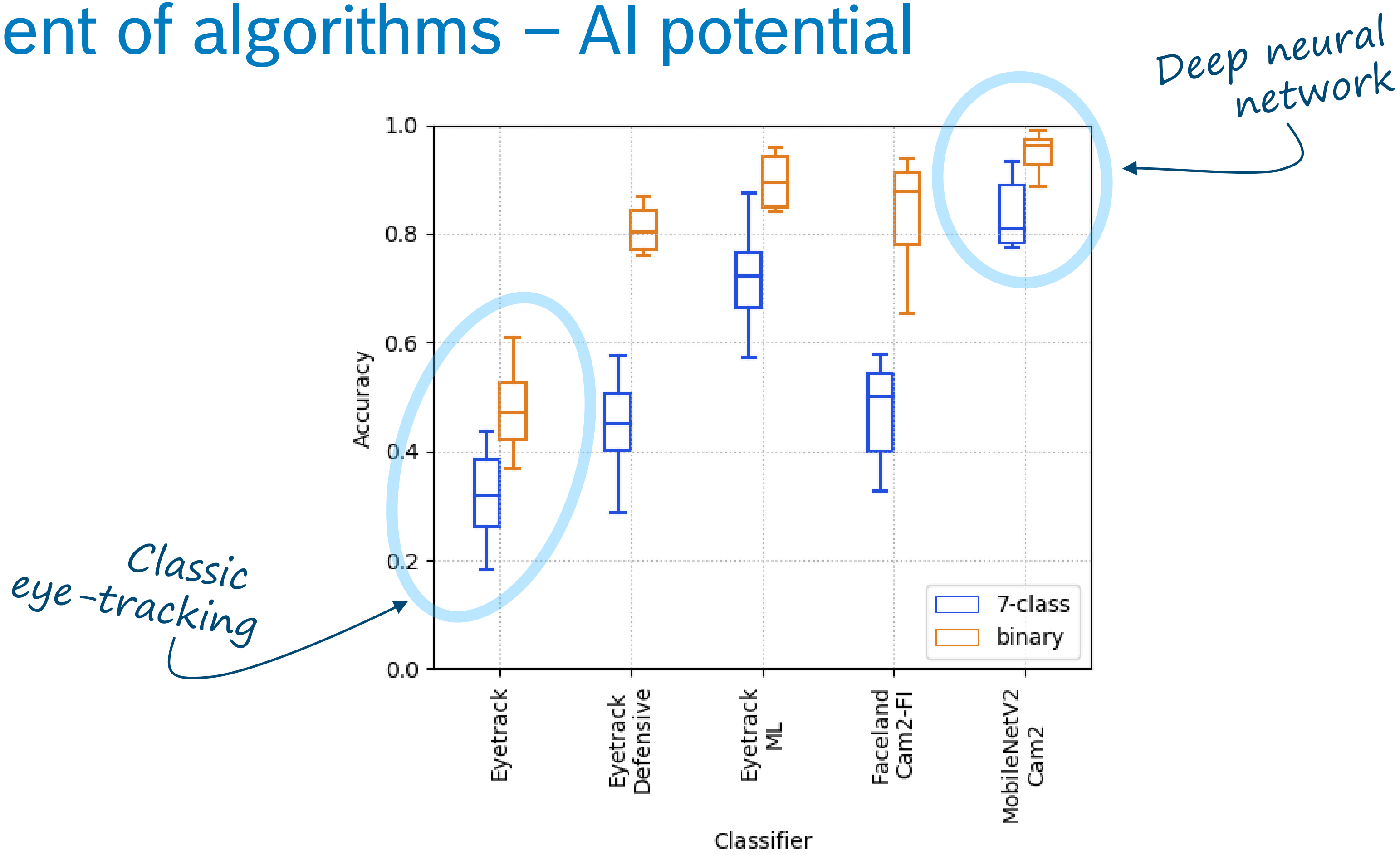
Camera-based Driver Monitoring
Development of algorithms – AI potential



Summary of Results

Source: J. Bieg (2021)

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The Safety Case: Driver Monitoring and Automated Driving
Further Topics in Driver Monitoring

Hands-free Driving

- Level 2 systems w/ hands-on detection
- Level 2 hands-off systems available in specific markets outside Europe
- Driver monitoring avoiding visual distraction

Driver Impairment

- Sudden sickness (heart attack, hypoglycemia)
- Driving under the influence (alcohol, drugs)
- In-vehicle cameras or other built-in sensors, e.g. radar

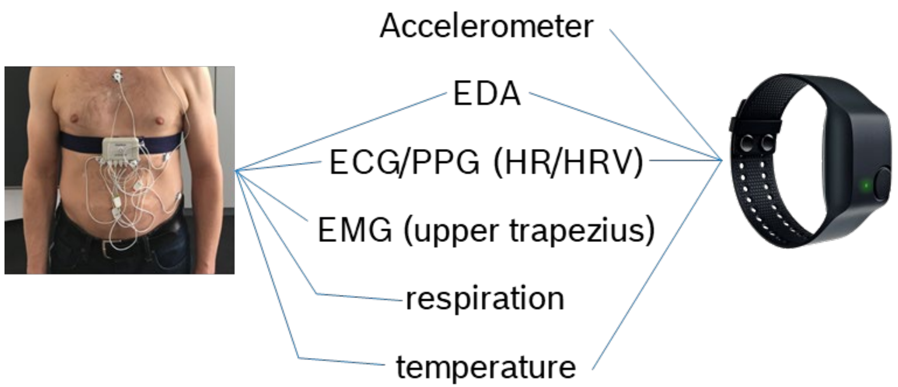
Driver Intention

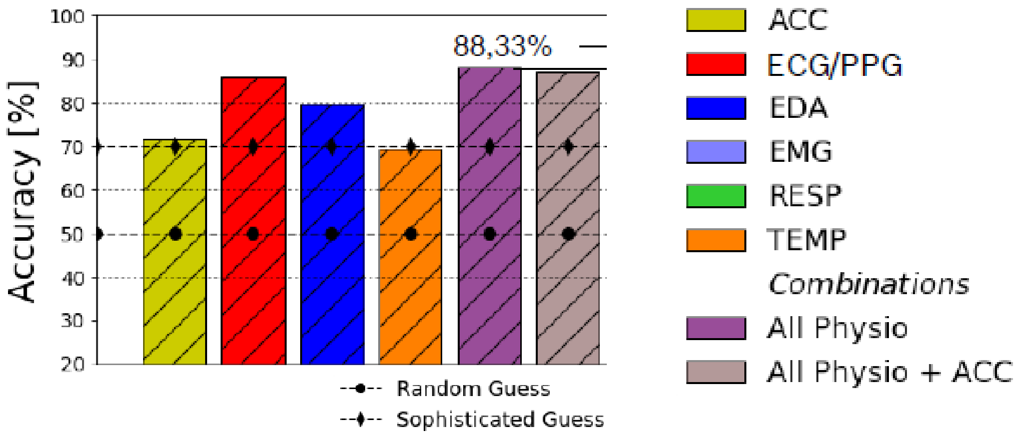
- Early identification of driver intention on maneuver level
  e.g. turn left/right, change lane, start/stop
- Comfort functions as automatic activation of turn indicators

Images: Cadillac | Bosch | Project UR:BAN

PART 4
TOWARDS PERSONALIZED IOT SYSTEMS

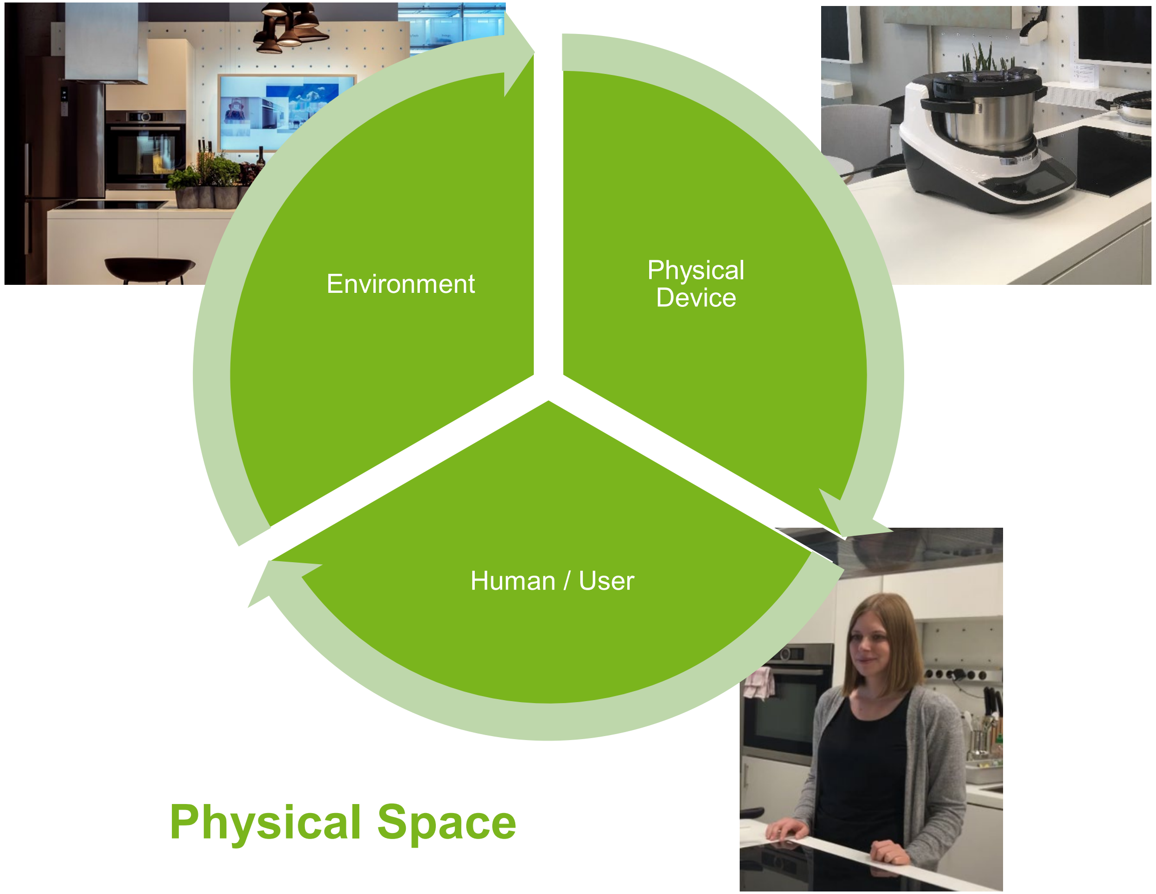
Towards Personalized IoT Systems
Wearable-based Affect Recognition

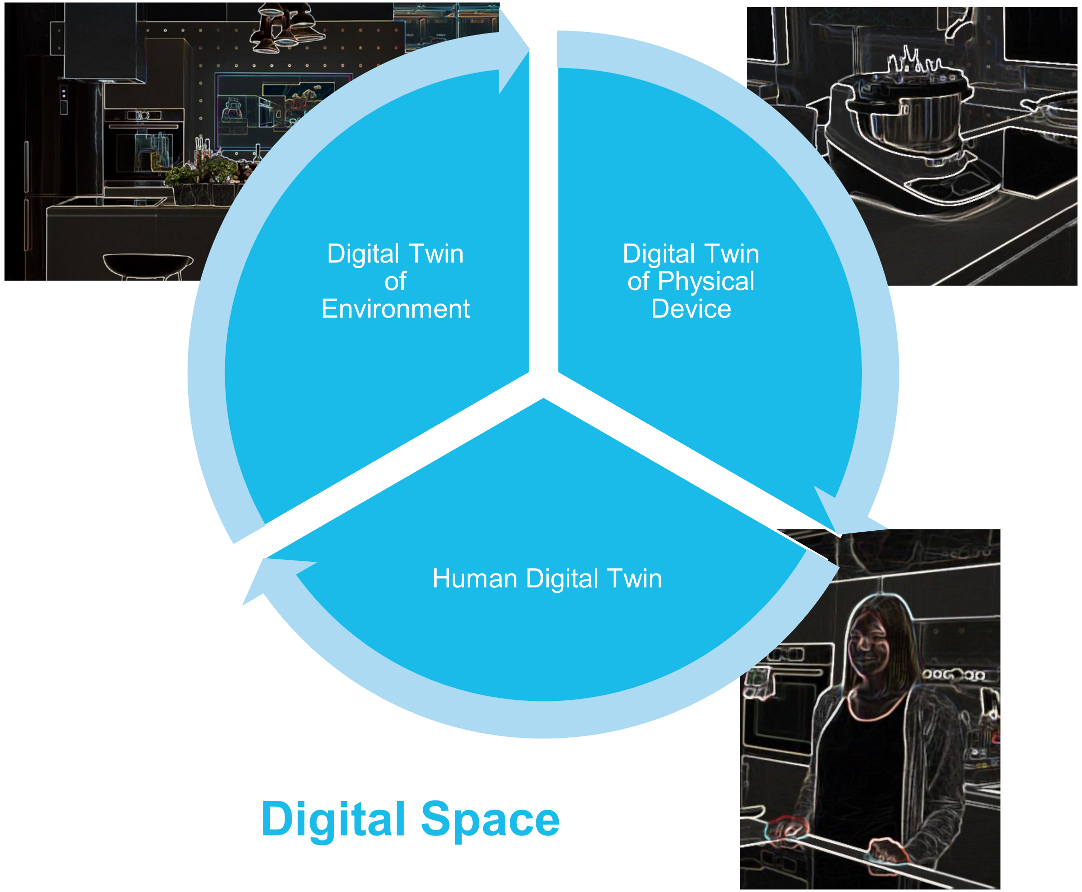




- Affective state for a holistic user model in system interaction, healthcare or automotive
- Use wearable-based data sources
  - Worn directly on the body
  - Lightweight ubiquitous available
  - Popular among users
- Studies in the lab and in the wild
  - Lab: Respiban and Empatica E4, well-defined stimuli (Trier social stress test) and comparison to cortisol levels and subjective ratings
  - Field: Empathica E4 only, 16 day observation, comparison to app-based subjective ratings
- ML algorithms for signal analysis
- PhD work (Philip Schmidt) finalized 2019

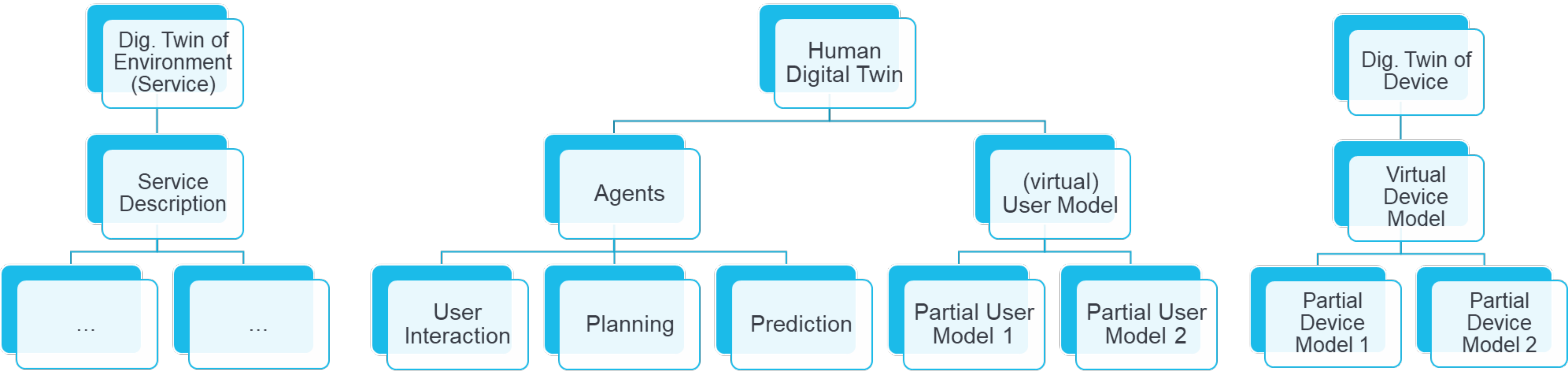
Towards Personalized IoT Systems
Concept of a Human Digital Twin





Towards Personalized IoT Systems
Sketch of Digital Twin Architecture

ForeSight



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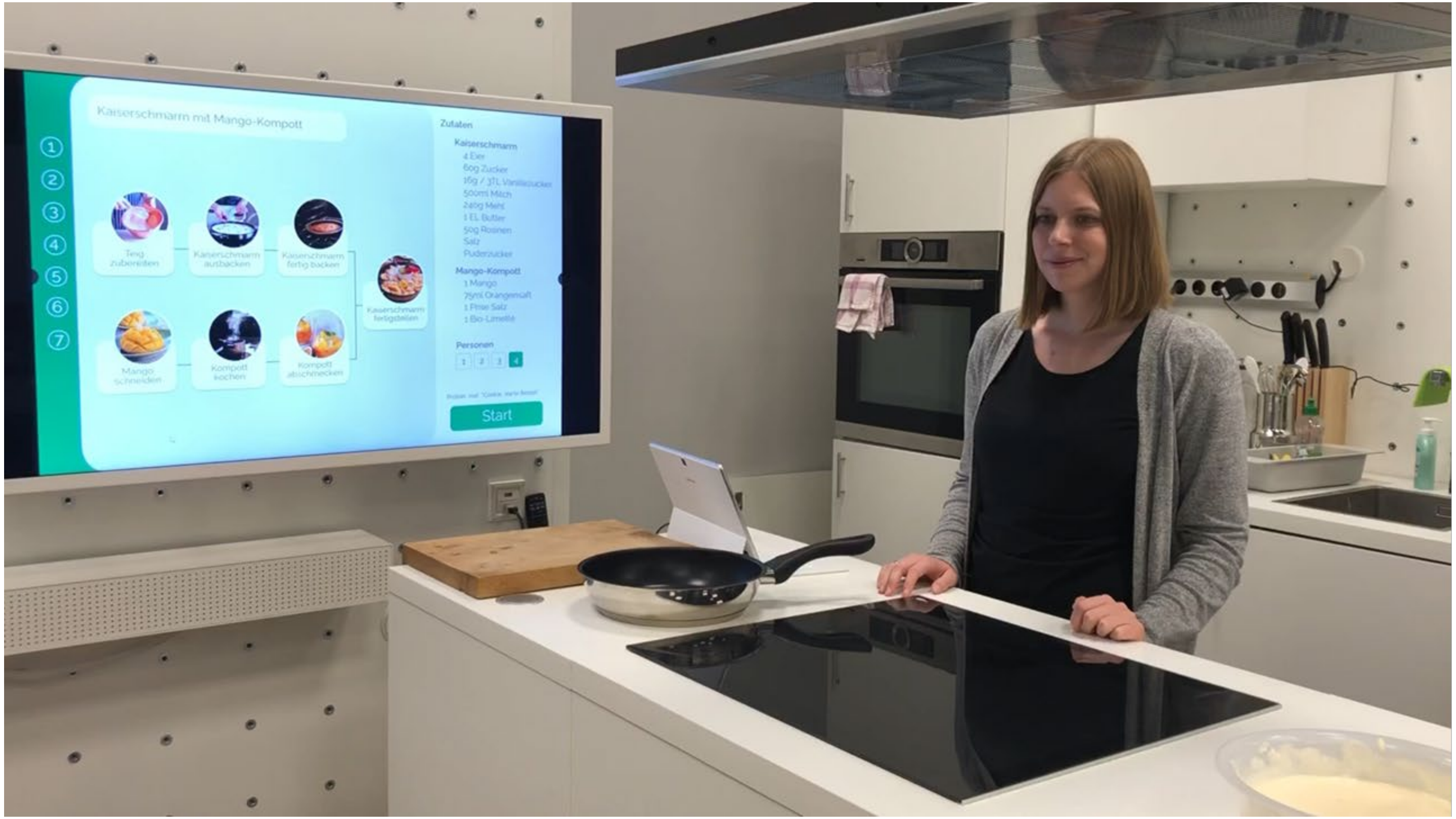
Towards Personalized IoT Systems
Application as a Personalized Cooking Assistance

ForeSight



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Towards Personalized IoT Systems
The final Commercial – #LikeABosch

Image: Bosch – Video: https://www.youtube.com/watch?v=v2kV6pgJxuo

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QUESTIONS & DISCUSSION

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THANK YOU FOR YOUR ATTENTION. STILL CURIOUS? CHECK US OUT ONLINE.

Scan the QR-Code or visit us on:

bosch.com/research

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