Consideration of Road Condition Influences on Driver Attention Classification

Dipl.-Ing. Fabian Friedrichs,
Dipl.-Ing. Peter Hermannstädter,
Prof. Dr.-Ing. Bin Yang
Institute for Signal Processing and System Theory
University of Stuttgart, Germany

September 7, 2011

Motivation

- *Is driving equal on all of these roads?*

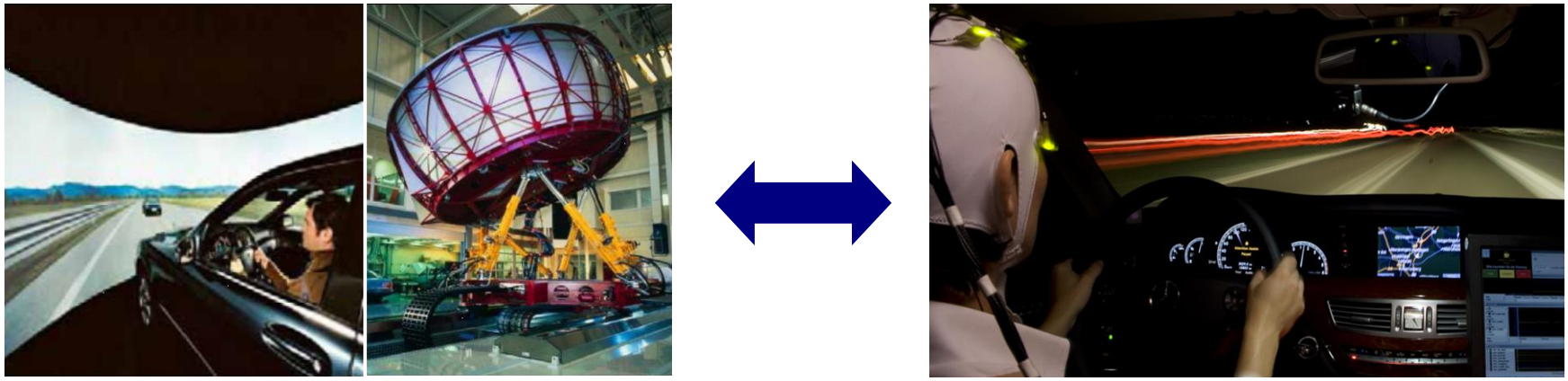
- Disturbance by contextual environmental, in-car or driver-intrinsic factors

➔Compensation is necessary to ensure robustness, specificity and sensitivity of drowsiness detection systems

Motivation

- Driver drowsiness:
  - Inattentive driving, without competing activity?
  - Up to one third of the severe accidents are related to drowsiness[1]
  - Detection and countermeasure development face similar challenges

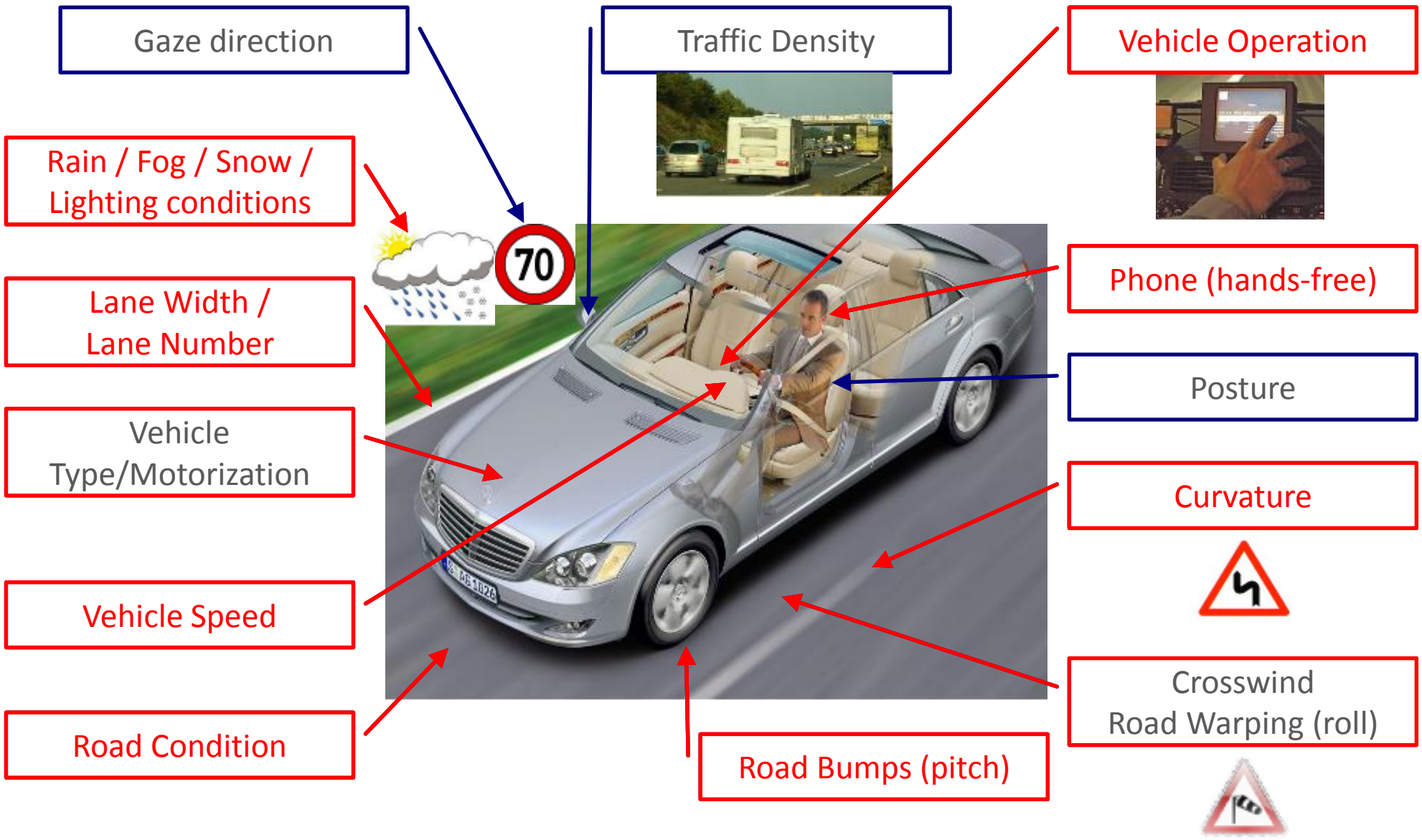
- Engineering driver drowsiness detection:
  Transferring drowsy driving pattern detection to real-world driving



[1](Duncker, 2007; Künzel, 2008; Daimler, 2008; Fertner, 2009)

Identifying External Influences

- From the huge number of influences, a few can be targeted with state-of-the-art automotive sensors



Project Database

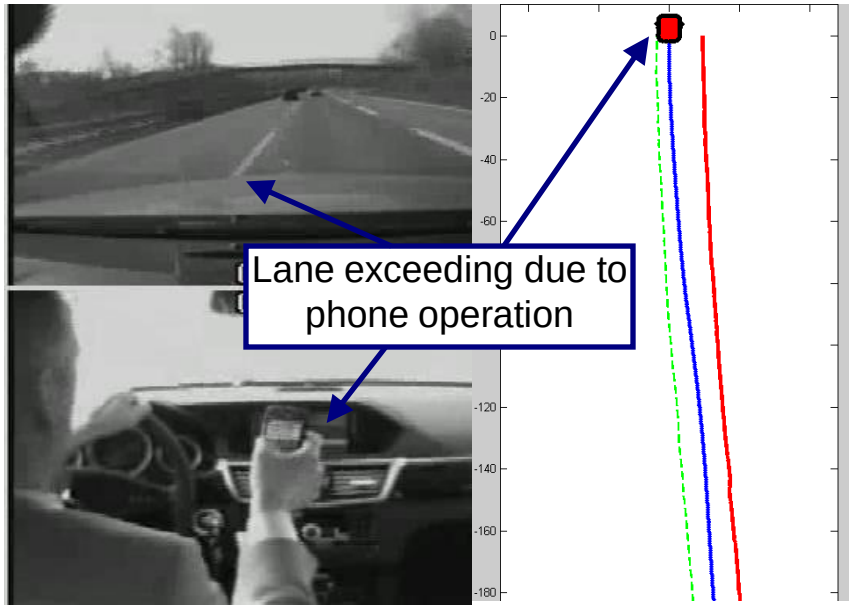
- General database (courtesy of Mercedes-Benz)
  - >1.4 million kilometers of light vehicle data
  - Supervised testdrives without SCEs
  - Several thousand recorded vehicle signals

- Specifically recorded, controlled and specially supervised testdrives:
  - Mercedes-Benz S-Class vehicle
  - Well-rested, awake drivers (KSS≤5) with trained co-pilots
  - German autobahn

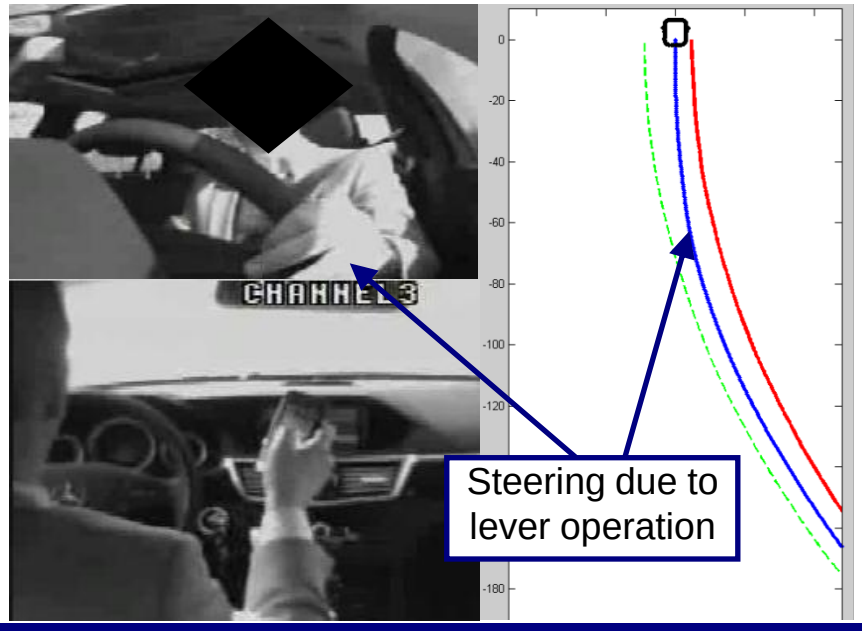
Analysis	Vehicle speed(s) [km/h]	Time of day	Number of drives (same route)
Vehicle speed	90, 110, 140, 180	2am to 5am	12
Road curvature	Ø 130	after 9pm	27
Road bumps Road condition Construction sites/ Narrow lane width	Ø 130	after 9pm	18

Distraction and Vehicle Operation

- Distinguish sleepiness patterns from steering errors associated with
  - Intentional short-term side-activities (vehicle/entertainment operation)
  - Long-term distraction (phone calls, in-car chats)
- Detectable distractors:
  - Phone calls over hands-free device
  - Operation of multi-media interfaces
  - Operation of hand-shifting, clutch, steering wheel levers and switches
- Attentional intensity of vehicle operation can be approximated
- Consideration:
  Disregard drowsiness patterns during short-term distraction



In-vehicle video and lane-keeping birdseye view



Rain, Snow, Fog, Light Conditions and Tunnels

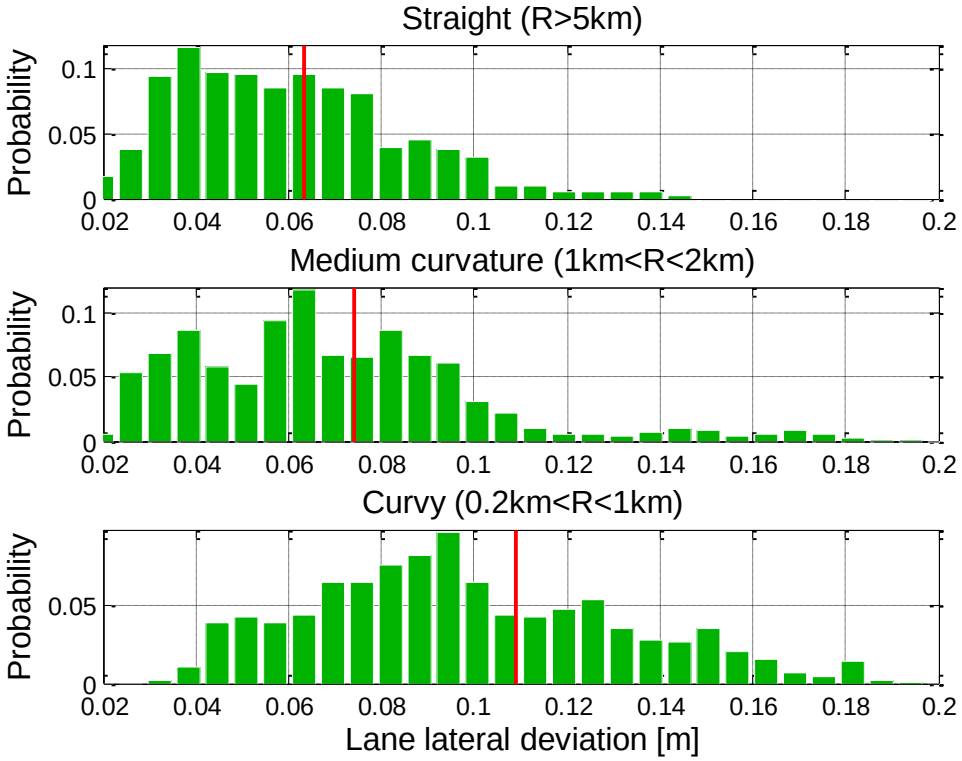
- Snow or heavy rain:
  - Steering more hectic
  - Detection by rain sensor and windshield wiper level position
- Foggy weather:
  - Generally requires slowing down
  - Detected by speed and fog light state
- Tunnel/road illumination:
  - Presents refreshing novelty, might improve level of attention
  - Detected by rapid change in light sensor signal
- Dark lighting conditions:
  - Affect steering and lane keeping performance of some (awake) people
  - Detected by light sensor signal

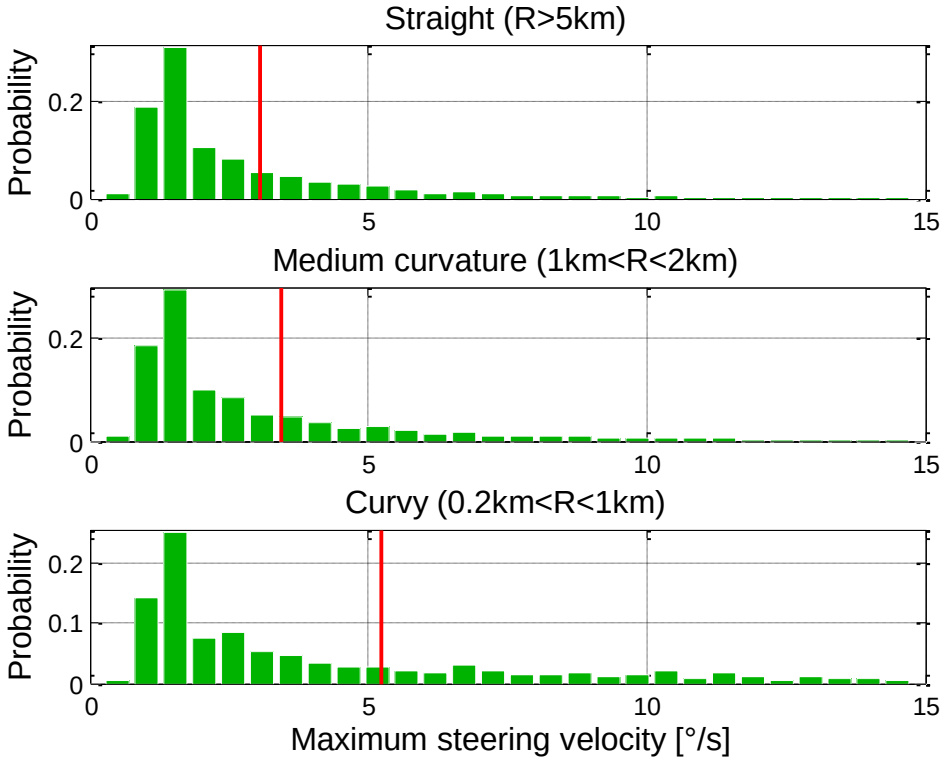
- Some conditions at first refreshing or alerting, but: all exhaust the driver more quickly.

- Consideration:
  - Appropriate stress and attention parameter estimation
  - In this project: treated as system inactivity

Road Curvature

- Thorough recording differently curved road sections with different radii
- Observations:
  - Overintensive steering adjustments during transition from straight into curve
  - Increasing lane deviation with curvature
  - Increasing steering velocities with curvature
  - Correlation between lane deviation and curvature stronger than between lane deviation and drowsiness[1]

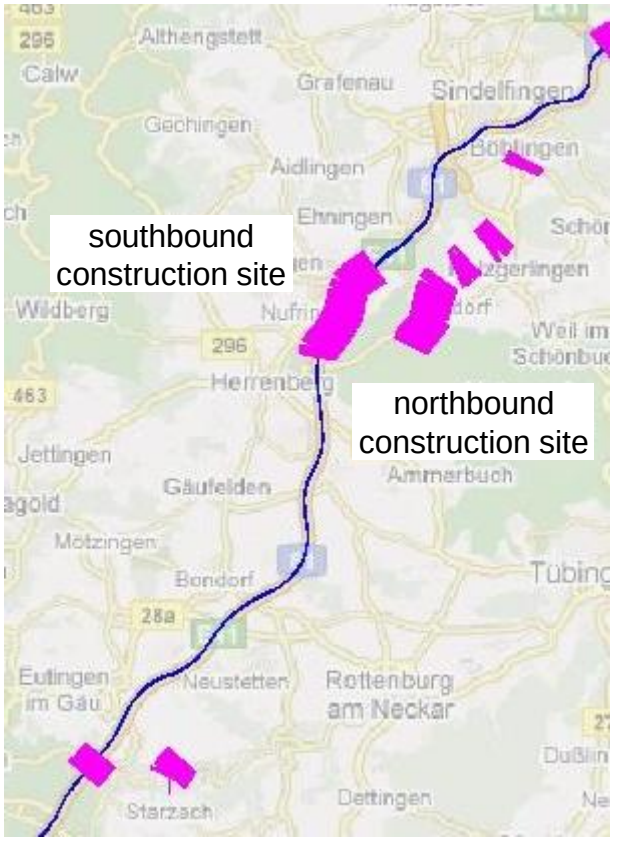




[1]Friedrichs & Yang (2010b)

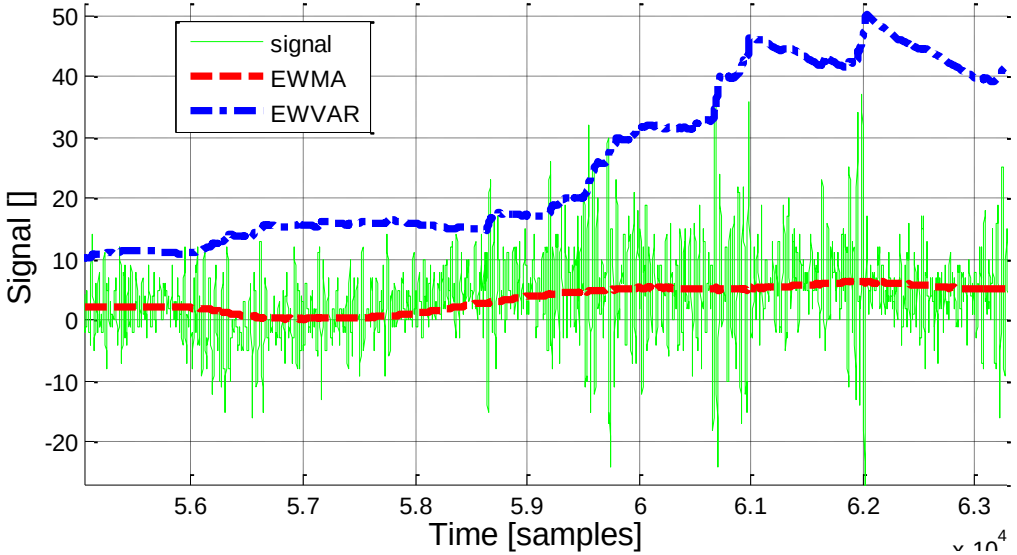
Construction Sites and Narrow Lanes

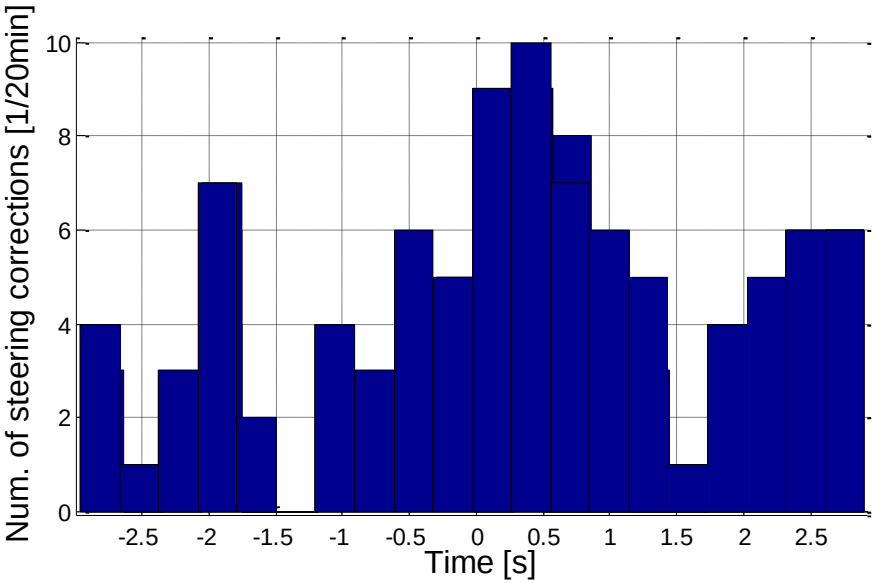
- More hectic steering in road construction sites with narrow lanes
- Criteria used to detect construction site passages:
  - Narrow lane with < threshold
  - Vehicle speed below 85km/h
  - Bad lane tracking quality signal
  - Specific lane colors or markings (country-dependent)
- Robustification by fuzzy combination of the detection rules
- Matching evaluation by location mapping showed accuracy >90%
- Consideration:
  Disregarding construction sites as system inactivity



Road Condition and Road Bumps

- Ragged roads cause small lateral disturbances to the vehicle
  - Cummulation of disturbances results in displacements of the vehicle
  - Requires more steering corrections by the driver
- Classification of road unevenness:
  - Reference generation by 2D position estimation using GPS and odometry
  - Calculation of simultaneous vibration in all inertial sensory using *Exponentially Weighted Moving Average* (EWMA) and *Exponentially Weighted Moving Variance* (EWVAR)
- Road bump detection and road condition consideration:
  - Peak detection within the road vibration measure
  - Discarding passages containing road bumps or ragged roads





Vehicle Speed

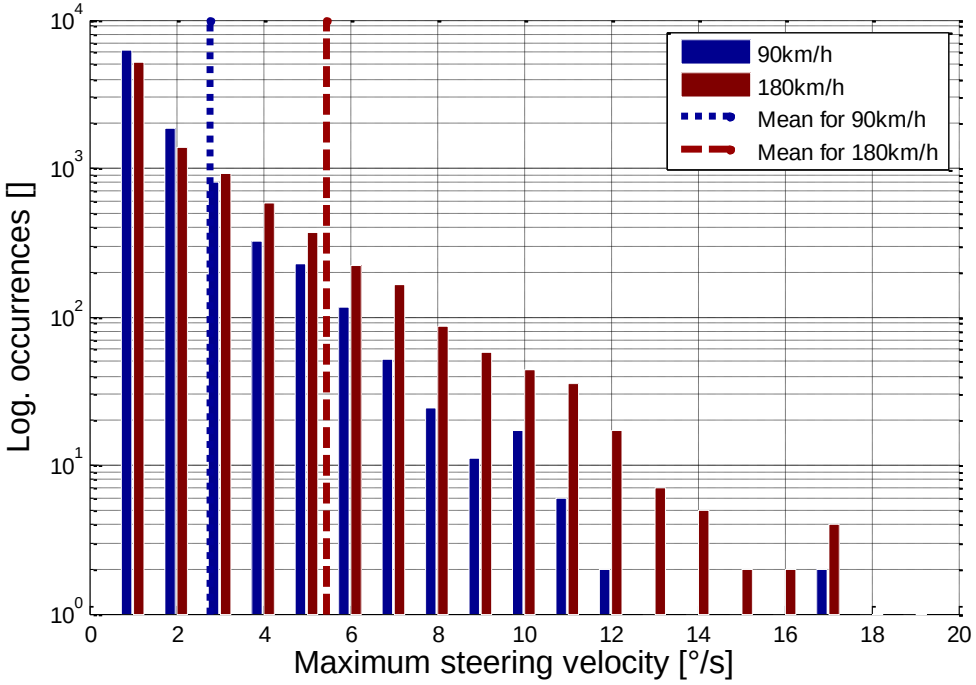
- Very thorough data recording:
  - Traffic interference at a minimum at night
  - Constant speeds withouth use of cruise control
  - Suppresion of overtaking maneuvers using signals from acc. pedal, turn indicator lever and steering wheel angle
- Observed effects in extracted features:

	Increasing vehicle speed (90, 110, 140, 180 km/h)
Steering velocity	↑
Steering amplitudes	↗
Num. of overtaking maneuvers (per hour) [1]	↑
Lane deviation	→
Lane oscillation frequency	↗
Variance of acceleration pedal	↗
Frequency of curvature (same road)	↗
Lateral acceleration (same road)	↗

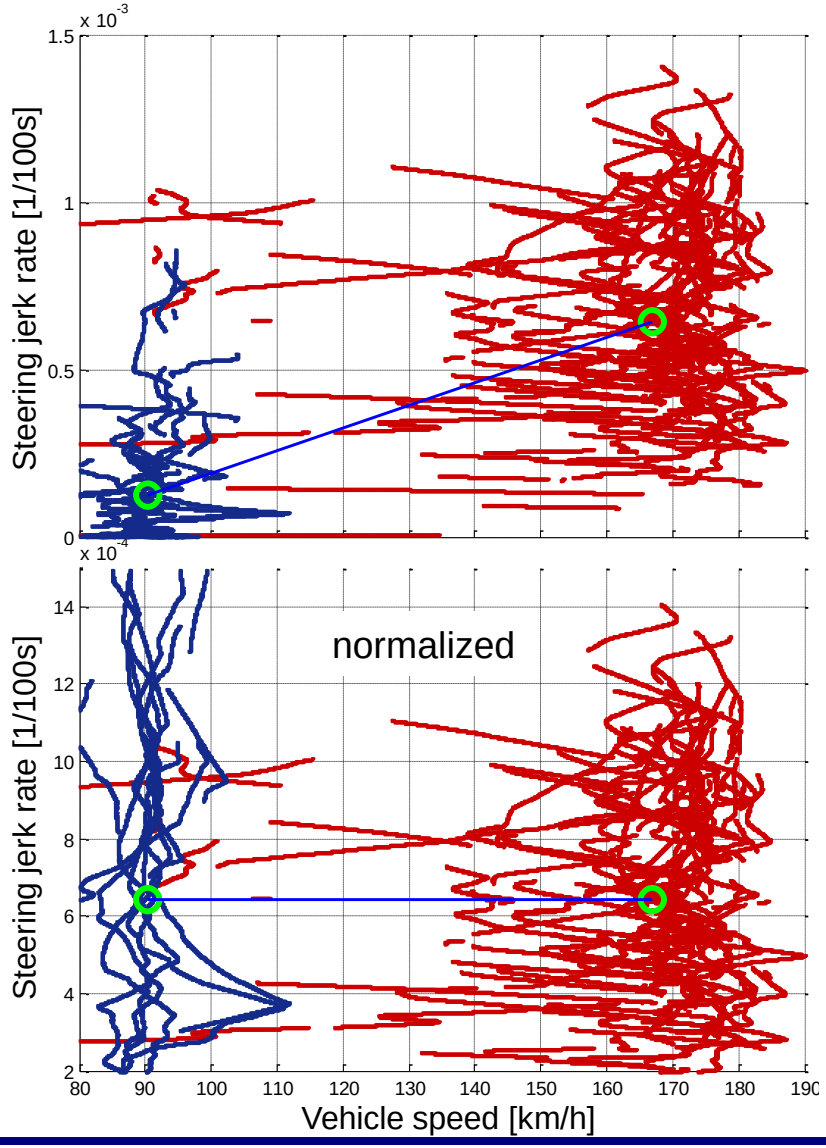
[1]from 2 @ 90km/h to 84 @ 180km/h

Vehicle Speed: Compensating in Max. Steering Velocity

- Maximum steering velocity between inflection points: occurrences with increasing speed



- Maximum steering velocity over vehicle speed: compensation by normalization



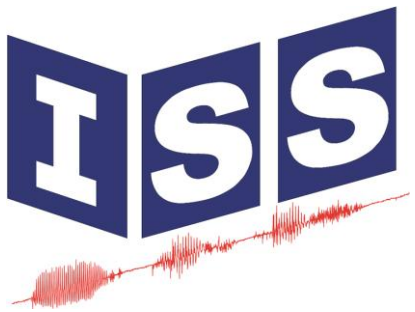
Conclusion and Future Work

- Summary
  - Huge effort of conducting controlled experiments to isolate disturbances and environmental effects
  - Demonstration of compensation approaches for a selection of influences on driver drowsiness features:
    - Proposed decoupling of steering velocity and vehicle speed
    - Suppresion of disturbances as by overtaking maneuvers, vehicle operation or road bumps

- Conclusion:
  - *Impact of external influences on features in many cases more severe than the impact of drowsiness patterns*
  - *Context consideration is crucial to a reasonable performance of a driver monitoring system*[1]

- Future work:
  - Conduct a large number of further controlled experiments
  - Introduce workload and intensity measures for distractors
  - Research interference of short-term distractors with long-term drowsiness

[1]Friedrichs, F. & Yang, B. (2010b).



Thank you for your attention.

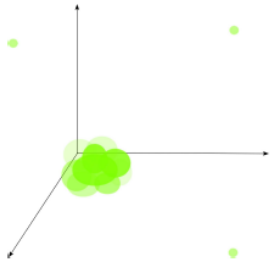
Questions?

- Daimler. (2008). Hightech report 2/2008 – feature Attention Assist.
- Duncker, G. I. W. (2007). Jeder vierte Autofahrer sitzt übermüdet am Steuer (Tech. Rep.). Deutsche Ophthalmologische Gesellschaft e.V.
- Fertner,M.-L. (2009). Sekundenschlaf &Ablenkung (Tech. Rep.). ÖAMTC - Der Österreichische Automobil-, Motorrad- und Touring Club.
- Friedrichs, F., & Yang, B. (2010a). Camera-based drowsiness reference for driver state classification under real driving conditions. IEEE Intelligent Vehicles Symposium.
- Friedrichs, F., & Yang, B. (2010b). Drowsiness monitoring by steering and lane data based features under real driving conditions. European Signal Processing Conference
- Gärtner, C. (2009). Driving style classification for drivermonitoring. Unpublished master's thesis, Lehrstuhl für Systemtheorie und Signalverarbeitung, Universität Stuttgart.
- Kuhn, K., & Heidinger, A. (1997). On-line driver type classification. International journal of vehicle design,18(6), 616–25.
- Künzel, D. (2008). Die Rolle von Ablenkung und M¨udigkeit bei Verkehrsunf¨allen: Nationale und internationale Statistiken.
- Martin, E. (2006). Breakthrough research on real-world driver behavior released. National Highway Traffic Safety Administration. Available

Backup: Data distribution

- Cluster analysis[1]
  - Tiredness level:

d to cen.	Awake	Quest.	Drowsy
Cen. Awake	3±2%	4±1%	4±2%
Cen. Quest.	4±2%	4±2%	4±1%
Cen. Drowsy	4±2%	3±2%	3±2%



  - Drivers:

Mean intracluster distance	Mean intercluster distance	Centroids mean distance
2.0± 0.8%	4.7±4.3%	4.1%

  - Drives:

Mean intraclass distance	Mean interclass distance	Centroids mean distance
2.5± 0.7%	4±1%	3%

[1]Pimenta, P. (2011). Driver Drowsiness Classification Based on Lane and Steering Behavior. Diploma thesis. Institute for Signal Processing and System Theory, University of Stuttgart.

Backup: Selection of Features

TABLE II

SELECTION OF FEATURES[1]

ID	CLASS	Feature Name	Description
41	META	VEHSPEED	Vehicle speed [km/h]
47	META	DAYTIME	Seconds since midnight
44	META	ACTIVE	System active
24	META	LNACTIVE	Active
15	LANE	LANEDEV	Lane deviation
17	LANE	ZIGZAGS	Num of ZigZag Events
19	LANE	LATMEAN	∅ Lateral Mean
32	LANE	LANEX	Lane Exceeding
33	LANE	LNERRSQ	LANEX Squared
29	LANE	LNMNSQ	Lane Mean Squared
34	LANE	ORA	Overrun Area
35	LANE	TLC1MIN	Time-to-Lane Crossing
36	LANE	VIBPROP	Warnings
48	LANE	AmpD2Theta	Amp_D2_Theta
14	LANE	*LANEAPPROX*	Approximation to Lane
16	LANE	*LATPOSZCR*	Lateral Pos. ZCR
30	LANE	*LNIQR*	IRQ of Lateral Pos.
31	LANE	*LNCHGVEL*	Lane Change Velocity
37	LANE	*DELTADUR*	Duration betw. infl. points
38	LANE	*DELTALATPOS*	Lateral displacement
39	LANE	*DELTALATVELMAX*	Max lateral velocity
40	LANE	*LANEAPPROXADAPT*	Adaptive Lane Approximation
18	STW	*STWZCR*	Steering ZCR
25	STW	*STWVELZCR*	Steering velocity ZCR
42	STW	ELLIPSE	Steering angle and velocity abs.
50	STW	NMWRONG	Number of times Stw is corrected
69	STW	NMRHOLD	Number of times Stw is hold
66	CAN	TOT	Time-on-task
22	CAN	DEGOINT	Degree of interaction
23	CAN	REACTIM	Reaction time
72	CAN	VHAL	Ratio High/Low STW corrections
71	CAN	MICROSTEERINGS	Small Steering Adjustment Rate
52	CAN	*STV25*	Steering Vel. 1^{st} Quartile
53	CAN	*STV50*	Steering Vel. 2^{nd} Quartile
54	CAN	*STV75*	Steering Vel. 3^{rd} Quartile
45	CAN	*CIRCADIAN*	Circadian weighting
51	CAN	*STWEVNT*	Steering Event Rate
55	CAN	*CROSSWIND*	Cross-wind / warping intensity
58	CAN	*DYNDRIVINGSTYLE*	Dynamic driving style
59	CAN	*MONOTONY*	Monotoneous driving
61	CAN	*OPERATION*	Vehicle operation
63	CAN	*ROADBUMPS*	Road Bump detection
67	CAN	*TOTMONO*	Monotoneous TOT
68	CAN	*TOTSPEED*	TOT around 130km/h
70	CAN	*LIGHT*	Light intensity (day/night)
26	CAN	*TRFCDENS*	Traffic density
27	CAN	*TURNINDADVANCE*	Blinking time before lane change
28	CAN	*TURNINDDUR*	Turn indicator duration
...			

[1]Friedrichs, F. & Yang, B. (2010b). Drowsiness monitoring by steering and lane data based features under real driving conditions. *Proceedings of the 18th European Signal Processing Conference.* Aalborg, 2010.

Backup: Classification Performance

- Classification results:
  - Feature database accumulated to a sampling rate of 0.1Hz
  - Feature selection using Sequential Floating Forward Selection (SFFS)
  - Cross-validation at a training to test ratio of 80/20 of complete-drive sets

TABLE V

CLASSIFIERS ERROR FOR 15 FEATURES AND THREE CLASSES

Classifier	Training Error	Test Error
Bayes	-51%	59%
GMM (2. Modes)	-57%	61%
GMM (3. Modes)	-49%	57%
k-NN	-76%	79%
ANN	-42%	49%
SVM	-50%	57%
Boosting	-49%	56%

Backup: Routes in Dataset