

**2ND WORKSHOP ON USER CENTRIC PERVASIVE
ADAPTIVE SYSTEMS** | 06.12.2010

AN ADAPTIVE DRIVER ALERT SYSTEM MAKING USE OF IMPLICIT SENSING AND NOTIFICATION TECHNIQUES

Gilbert Beyer, Gian Mario Bertolotti, Andrea Cristiani, Shadi Al Dehni

Agenda

- 1 Adaptation Strategy
- 2 Sensor-Actuator Support
- 3 Hardware and Software
- 4 Performance Tests
- 5 Discussion

Driver Alertness



Causes of Driver Distraction

The driver himself (fatigue, drunkenness)

The vehicle (type, condition)

The environment (traffic, weather)

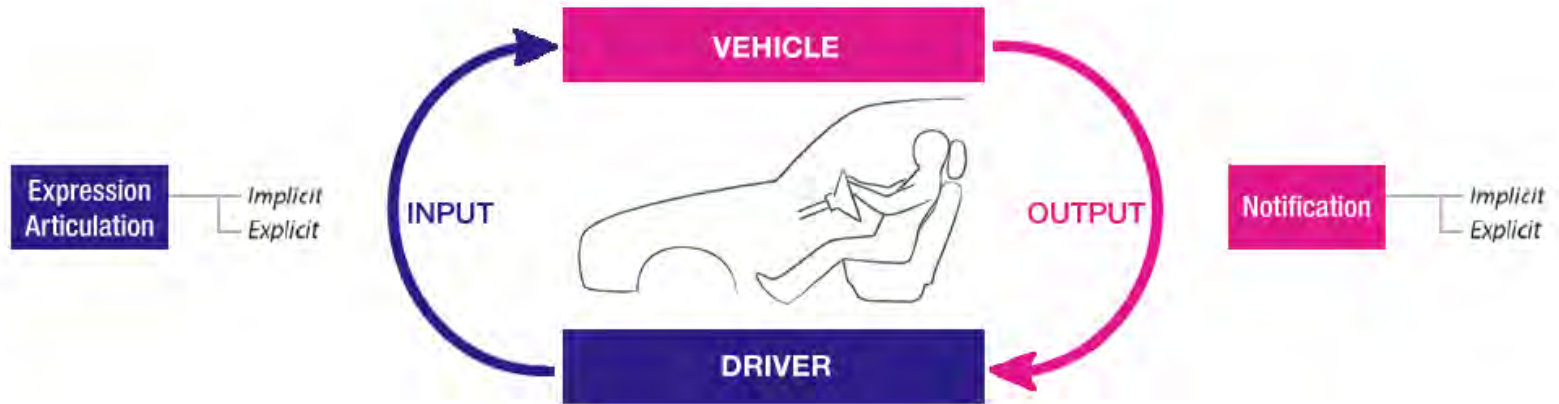
Long-Term Driver Distraction

Psycho-physiological state (fatigue)

Secondary tasks (operating car stereo)

Social activities (chatting with co-driver)

Feedback Loops in Vehicles



adapted from Riener and Ferscha (2009)

Sensing Driver Distraction

Hands-off-wheel Time

Eyes-off-road Time

Conversational Level

Emotional expressions

Signs of drowsiness

Notification Modalities

- 1 Vision, Hearing, Touch (each having it's own timely behavior)
- 2 Multimodal information

Adaptation Strategy

Actuator: Visual, implicit

Sensor 1: Drowsiness

Sensor 2: Head-position

Sensor 3: Can Bus data

Combing Car and User Data

Eyes-off-road while...

- 1 driving fast, is dangerous
- 2 standing, is safe
- 3 turning, is required

Head-up Displays

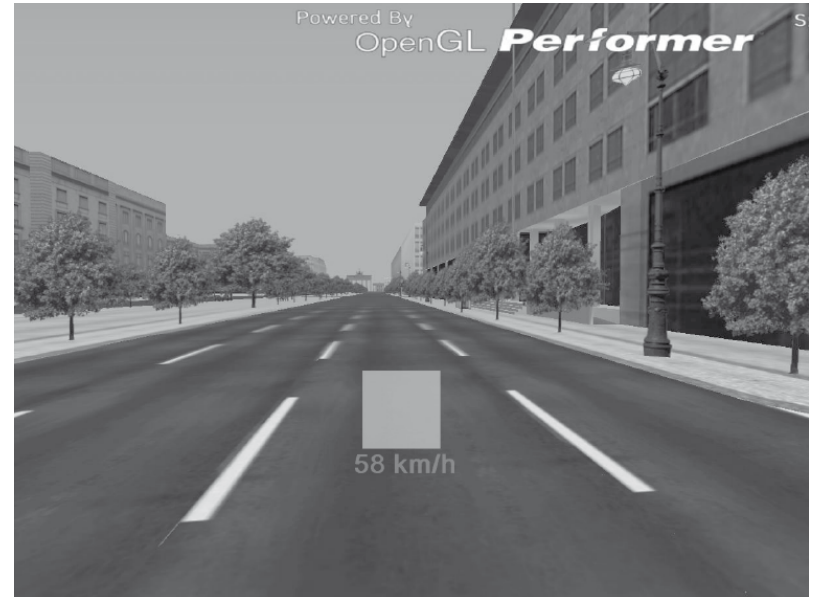


<http://www.bmw.com/> (2010)

Adaptive Head-up Displays

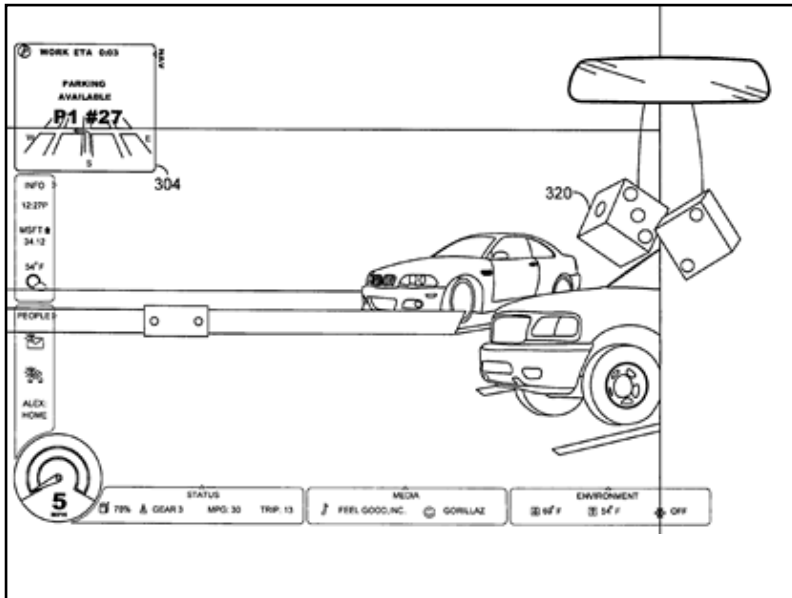


Karvonen et al. (2006)



Dienelt, M. (2005)

Adaptive Head-up Displays



Blanco et al., US Patent No. 7764247



AWAKE Project, IST-2000-28062

Sensing Drowsiness

- 1 Intrusive techniques:
Electromyogram, Respiration,
GSR, Electro-oculography
- 2 Non-intrusive techniques:
Vision-based

Automotive Demonstrator



Sensor-Actuator Support



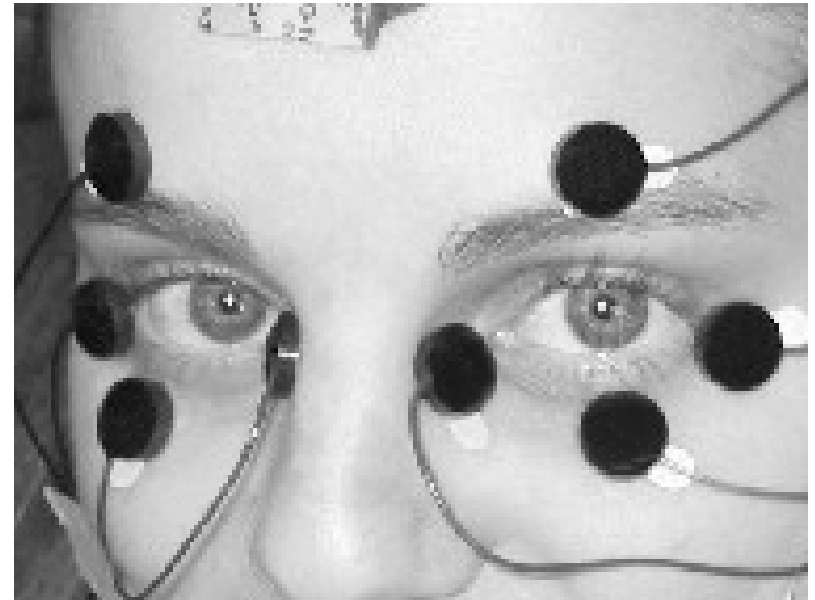
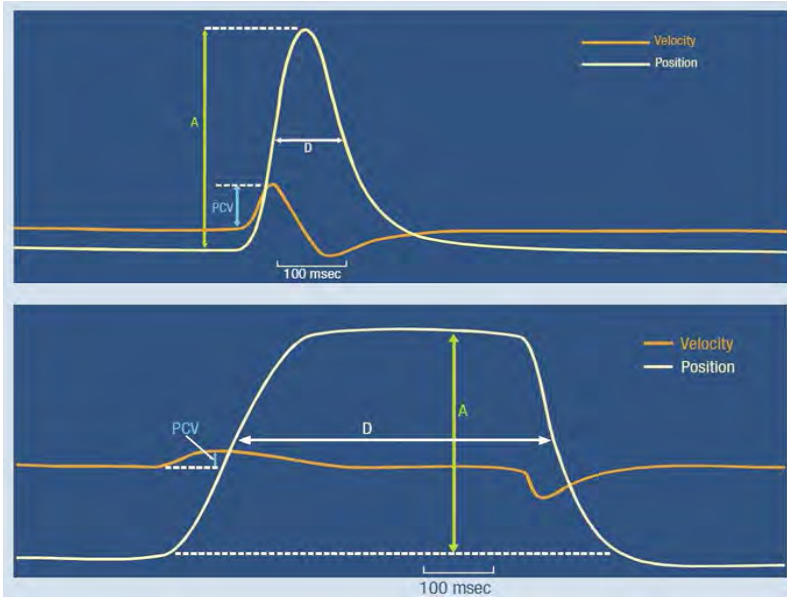
Simulator Setup



Implicit Sensing Software

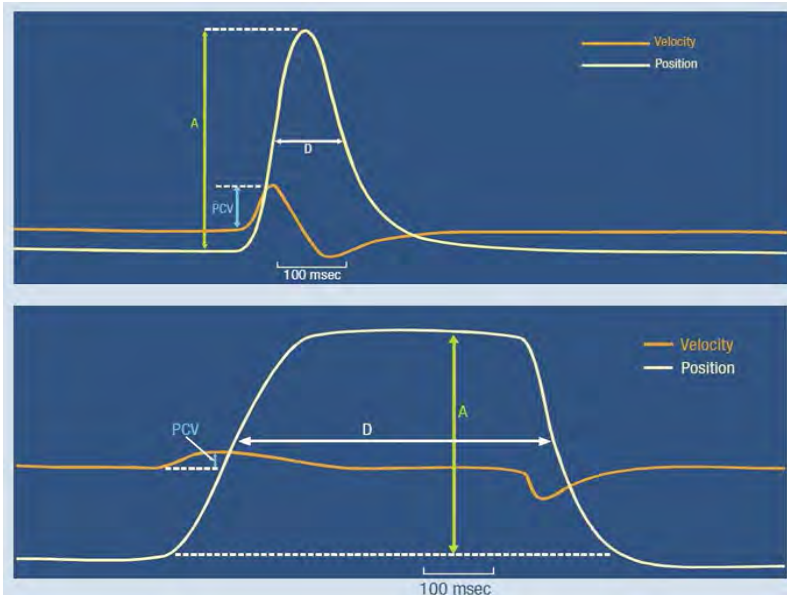
- 1 Drowsiness Detection
- 2 Head Position Detection

Drowsiness Detection



Johns, M.W. (2003)

Drowsiness Detection



Johns, M.W. (2003)

Main Constraints



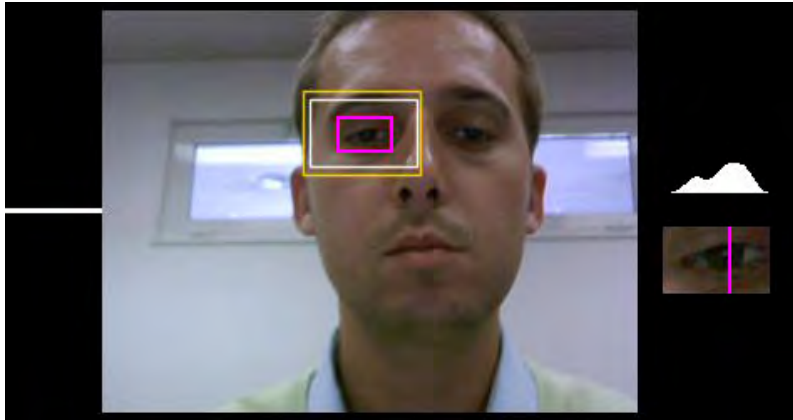
Main Constraints

- 1 Reduce computational load
- 2 Reduce error rate

Eye Detection Algorithm

- 1 Search eye using Viola-Jones
- 2 If eye is found, save copy as template
- 3 If eye is not found: template matching
- 4 Successive failures: re-initialization

Eye Detection Algorithm



Largest rectangle: Viola Jones, Template Matching

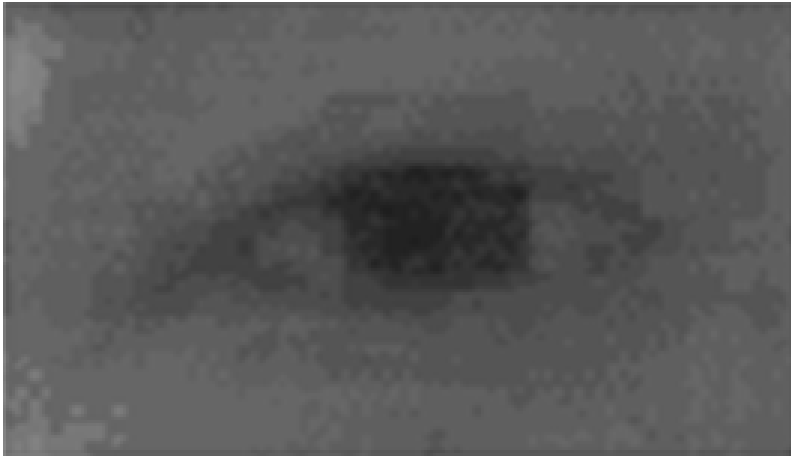


Adjusted search window

Blink Test Algorithm

- 1 Eye-image processed to binary picture
- 2 Eliminating pupil reflections and noise
- 3 Obtain vertical projection histogram
- 4 Calculate eye openness level

Blink Test Algorithm

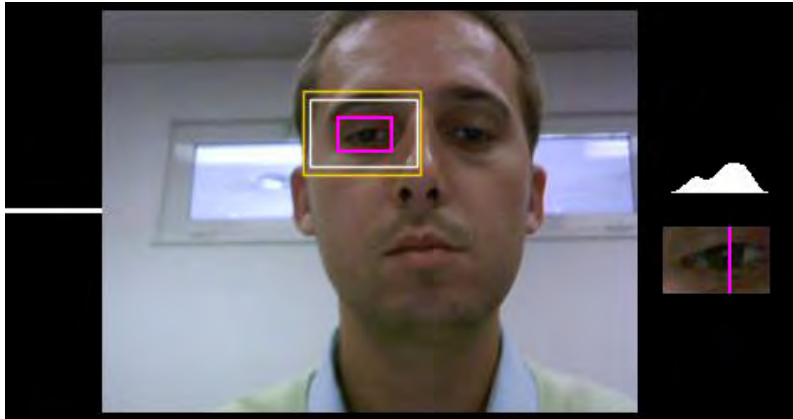


Greyscale image



Binary image

Blink Test Algorithm

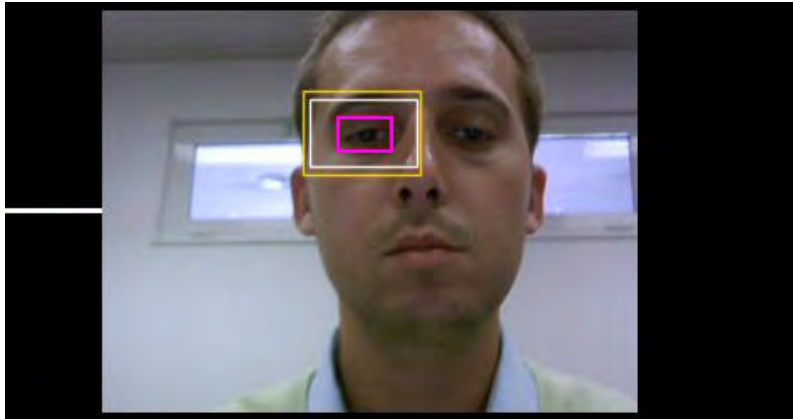


Open eye

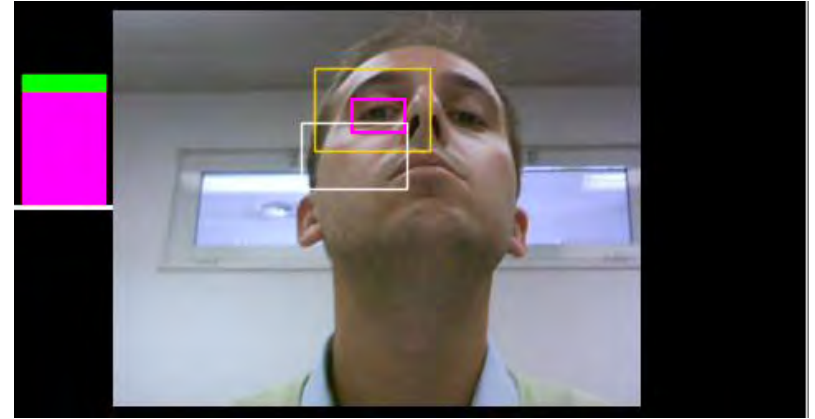


Closed eye

Head-Position Detection



Eye within rest area



Eye outside rest area

Experiments and User Analysis

- 1 Performance Tests
- 2 Driver Observation in the Lab
- 3 Road Tests

Passive Sensing Performance Tests

Collected sets of data:

- 1 Recognition of slow/fast blinks
- 2 Tracking of slow/fast eye movements
- 3 Slow/fast head movements
- 4 Blink fail errors

Passive Sensing Performance Tests

Kinds of error:

- 1 tracking miss (in successive frames)
- 2 detection miss (shadows or occlusions)
- 3 blink miss (e.g. due to rapid blinks)
- 4 blink fail (erroneously detected blink)

Passive Sensing Performance Tests

Table 1: fast blinks

| <i>Lighting</i> | <i>Ferrari</i> | <i>Various cars</i> | <i>Room</i> |
|--------------------|----------------|---------------------|-------------|
| Daylight | 97.3 | 95.4 | 98.6 |
| Little/no lighting | -- | 97.5 | 98.9 |
| Changing light | 95.9 | 94.5 | -- |

Table 2: slow blinks

| <i>Lighting</i> | <i>Ferrari</i> | <i>Various cars</i> | <i>Room</i> |
|--------------------|----------------|---------------------|-------------|
| Daylight | 98.3 | 97.8 | 99.1 |
| Little/no lighting | -- | 97.2 | 98.8 |
| Changing light | 97.4 | 96.4 | -- |

Passive Sensing Performance Tests

Table 3: slow eye movements

| <i>Lighting</i> | <i>Ferrari</i> | <i>Various cars</i> | <i>Room</i> |
|--------------------|----------------|---------------------|-------------|
| Daylight | 99.0 | 98.6 | 99.7 |
| Little/no lighting | -- | 96.4 | 97.8 |
| Changing light | 98.4 | 97.1 | -- |

Table 4: fast eye movements

| <i>Lighting</i> | <i>Ferrari</i> | <i>Various cars</i> | <i>Room</i> |
|--------------------|----------------|---------------------|-------------|
| Daylight | 96.0 | 95.9 | 96.1 |
| Little/no lighting | -- | 94.2 | 94.6 |
| Changing light | 94.8 | 95.1 | -- |

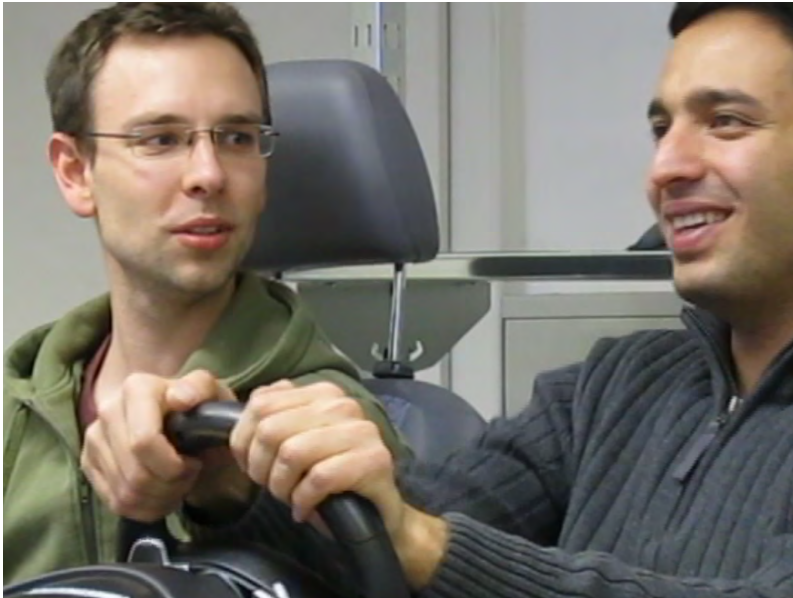
Table 5: blink fail

| <i>Lighting</i> | <i>Ferrari</i> | <i>Various cars</i> | <i>Room</i> |
|--------------------|----------------|---------------------|-------------|
| Daylight | 1.3 | 1.4 | 0.9 |
| Little/no lighting | -- | 1.7 | 1.3 |
| Changing light | 1.6 | 2.1 | -- |

Night Vision Camera



Lab Study



Lab Study

- 1 Eyes-off-road and Car State Symbols
- 2 15 Participants (students, colleagues)
- 3 Co-Driver was investigator
- 4 Semi-structured Interviews and Camera Observations

Lab Study

- 1 80 % understood that displayed icons related to their driving behavior
- 2 66 % found notifications helpful to adapt their driving style

Onboard Testing Session

- 1 Displaying Car State Information
- 2 Thinking Aloud Method
- 3 Refinement of the hardware
and software setup

Onboard Testing Session



Discussion

Algorithm Improvements

Sensing Techniques

Future Tests and Studies

HUD Development

System Design