## General driver monitoring module definition SoA

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Analysis of existing solutions for Driver monitoring

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<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>AVR</td>
<td>Amplitude velocity ratio</td>
</tr>
<tr>
<td>AVRUB</td>
<td>Amplitude velocity ratio of eye blinks</td>
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<tr>
<td>DMS</td>
<td>Driver Monitoring System</td>
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<tr>
<td>ECG</td>
<td>Electro-cardiography</td>
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<td>EEG</td>
<td>Electro-encelography</td>
</tr>
<tr>
<td>EMG</td>
<td>Electro-miography</td>
</tr>
<tr>
<td>EOG</td>
<td>Electro-oculography</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GS</td>
<td>Golden Standard signal (reference signal of the driver)</td>
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<tr>
<td>HMI</td>
<td>Human-Machine Interface</td>
</tr>
<tr>
<td>IR</td>
<td>Infra-red</td>
</tr>
<tr>
<td>IWI</td>
<td>Information, Warning, Intervention</td>
</tr>
<tr>
<td>LED</td>
<td>Light emitting diode</td>
</tr>
<tr>
<td>NMEA</td>
<td>National Marine Electronics Association (Standard communication protocol used for communication of GPS data for navigation)</td>
</tr>
<tr>
<td>ABBREVIATION</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>PERCLOS</td>
<td>Percentage of eye closure</td>
</tr>
<tr>
<td>PTW</td>
<td>Power two wheels (generic motor vehicle on two wheels)</td>
</tr>
<tr>
<td>UDOP</td>
<td>User Datagram Protocol</td>
</tr>
<tr>
<td>VCDD</td>
<td>Visual and cognitive distraction detection</td>
</tr>
<tr>
<td>VOG</td>
<td>Video-oculography</td>
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REVISION CHART AND HISTORY LOG

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<td>D. Daurenjou</td>
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<td>F. Palma</td>
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<td>P.Pyykönen</td>
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<td>M. Kunert</td>
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<td>0.7</td>
<td>21.10.2013</td>
<td>G.Dunand</td>
<td>Peer Review</td>
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<td>0.8</td>
<td>24.10.2013</td>
<td>A.Saccagno</td>
<td>Integration of Peer Review comments</td>
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EXECUTIVE SUMMARY

The present document aims to present the results of the activities performed in WP 3.2, tasks T3.2.1 “Analysis of existing solutions for driver monitoring” and T3.2.2 “Definition of a general driver monitoring module”.

The main objective of WP3.2 is the definition of a general driver monitoring module that will be integrated into the DESERVE platform. To achieve this, it has been carried out a preliminary analysis of existing solutions for driver monitoring and then identified the overall architecture and the characteristics of a driver monitoring module by taking into consideration all sensors and software modules that can be connected to the system.

In T3.2.1, have been considered several concepts related to driver monitoring considering both the aspects of a) Vigilance: Drowsiness and sleepiness and b) Inattention/distraction. In the present document it will be tried to present the current state of the art in driver monitoring.

Scope of T3.2.2. is to define the general driver monitoring module which will fuse information provided both by direct and indirect driver state assessment according to the solutions identified in T3.2.1, the results of the activities carried out in WP2.1 and in WP3.2 for the HMI. To define the general driver monitoring module has been selected the hardware and software modules already defined within the DESERVE platform.

Task T3.2.2 considers also the detection of driver’s inadequate state for driving through the analysis of driving, combined with real-time measures of biological parameters like the respiratory rate.

The activities related to the application motorcycles are presented in a dedicated chapter, due to its specificity with respect to other vehicles.
INTRODUCTION

Driver's limitations are very often related to his physiological and psychological states. An optimum pilot state includes:

- an optimum alertness level;
- a task-oriented attentiveness.

There are several factors that negatively influence these components:

- The aptitude of the driver can be reduced due to a lower vigilance, fatigue or sleepiness;
- Driver's availability can be reduced due to distraction or inattentiveness produced by internal or external attractors or executing additional non driving tasks like for example chatting on the phone (Visual distraction, cognitive distraction, auditory distraction, biomechanical distraction).

![Figure 1: General concept for driver state assessment](image-url)
The distinction between “alertness” and “attention” is justified in the way that driver “alertness” is presumed to be necessary but not sufficient for an appropriate focus on external events - i.e. attention (see Knipling & Wierwille, 1994 [4]). Thus, drivers may be alert but still inattentive. In the context of driving “inattentive” means that a driver has failed to perceive a visible crash threat due to “mind wandering”, “distraction” or “looked but did not see”. While driver alertness is mainly dependent on energetic factors, inattention is often a problem of information processing errors (perception or processing problems). The present distinction between “alertness” and “attention” is consistent with past research in this area (e.g. Davies and Tune, 1969 [5]).

To identify negatively influencing factors on the driver state, a monitoring system is required which is able to assess various states:

- drowsiness/fatigue;
- distraction.

The state has to be reconstructed from objective measurable parameters.

**Figure 2:** Distribution of Driver Attention status, CDS data
MEASURES FOR DROWSINESS DETECTION

1. Definition

Up to now, a universally valid definition of drowsiness still lacks. Therefore, many authors abstain from a concrete definition or refer to already existing models. The high variety in definitions refers to the different lines of research and the different focuses set. Some define drowsiness as a directly observable phenomenon, others as a hypothetical construct which can only be inferred with the help of some other objective measures. Hargutt (2003a [10]) collected a wide variety of definitions of drowsiness, including several mentioned causes, symptoms and consequences. It stated out, that actually three different phenomena, all of them characterised as processes in time, have to be discriminated:

An impairment of vigilance is mainly caused by task characteristics. Vigilance can be described as a state of watchfulness and a process of paying close and continuous attention to detect certain unexpected little changes in the environment. To stay vigilant, sensory stimulation is required. If this stimulation is missing or too low (e.g. driving in monotonous driving conditions with very few inputs) vigilance is reduced. An effective countermeasure against vigilance impairments is therefore to introduce task variation.

Fatigue mainly derives from performing a highly demanding task for extensive time periods ("time-on task"). It can be defined as weariness or exhaustion from labour resulting in a feeling of stress, an aversion to further exertion and the feeling to be unable to carry on with the task. Cameron (1973 [11]) states an additive, or even multiplicative interaction between workload and time-on-task: a highly demanding task leads to fatigue within much shorter time periods than a low demanding task. An effective countermeasure is to make a rest.

Sleepiness is the state of being ready to fall asleep. It is mainly caused by circadian rhythms and sleep disorders (reduced quality or quantity of sleep). Results from Stutts (2003 [12]) indicate that less than 5 hours of night sleep and poor sleep quality implies up to 5-fold accident risk for a sleepiness accident. Driving at night implies an approx. 4-
fold accident risk for a sleepiness accident. But also daytime sleepiness is said to be an important accident cause. The only way to reduce sleepiness is to sleep.

It should be noted, however, that those phenomena are not independent, e.g. sleepiness may lead to impaired vigilance independently of variations in task characteristics. The result of all different phenomena is the same: they reduce driver’s arousal level and lead to decrements in driving performance. For an easier use it seems justified that we summarize these different phenomena into one concept of drowsiness.

<table>
<thead>
<tr>
<th>concept</th>
<th>definition</th>
<th>mainly caused by...</th>
<th>countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>impairment of vigilance</td>
<td>a diminished state of readiness to react...</td>
<td>task characteristics</td>
<td>variation in task</td>
</tr>
<tr>
<td>fatigue</td>
<td>weariness or exhaustion from labour, exertion or stress</td>
<td>time on task</td>
<td>rest, pause</td>
</tr>
<tr>
<td>sleepiness</td>
<td>ready to fall asleep</td>
<td>circadian rhythms</td>
<td>sleep</td>
</tr>
</tbody>
</table>

**Table 1:** Impairment of driver’s energetic state by impairment of vigilance, fatigue or sleepiness

### 2. Drowsiness Diagnostic

According to Dr. Alain Muzet, several parameters can be observed to diagnose sleepiness and drowsiness situation. Figure 3 presents an overview of the needed physiological functions for the monitoring of the wakefulness and the transition to sleep (SENSATION 2004-2008). It summarizes the evolution of various observations that characterize the involuntary transition from waking to sleeping states (extracted from Dr. Alain Muzet presentation during the SENSATION Plenary meeting in Lisbon/2006).
Of course, according to Dr Alain Muzet, there is not a direct time correlation between the various observations but the behaviours are respected for most of the subjects. Indeed, taking care of the current state of the technology most of these parameters are not directly measurable in an automotive and daily life context. The focus of these studies was on EOG/Blinks and Motor activity through the introduction of vision based and data fusion approaches.

**Starting unexpectedly in an active state with eyes open**

<table>
<thead>
<tr>
<th>EEG</th>
<th>EOG &amp; blinks</th>
<th>Motor activity</th>
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<tbody>
<tr>
<td>EEG beta waves</td>
<td>Normal eye movements</td>
<td>Increased motor activity by bursts and occurrence of specific motor behaviours</td>
</tr>
<tr>
<td>Occurrence of isolated alpha bursts</td>
<td>Reduced eye movements and fixed gaze</td>
<td></td>
</tr>
<tr>
<td>Extension of alpha activity to the whole scalp alternating with theta waves</td>
<td>Increased blink frequency</td>
<td></td>
</tr>
<tr>
<td>Desappearance of alpha activity, increased theta waves</td>
<td>Isolated slow blinks</td>
<td></td>
</tr>
<tr>
<td>Normal blinks</td>
<td></td>
<td>Eyes closed</td>
</tr>
<tr>
<td>Normal eye movements</td>
<td></td>
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</table>

**Figure 3:** Description of the needed physiological function for the Driver state diagnostic.
3. Direct measure of drowsiness

3.1 General overview about direct drowsiness indicators

From the literature several indicators give information that can be used in order to perform a direct measure of the human being drowsy and more specifically of the evolution of his physiological state. A list of such indicators is proposed in SENSATION project Deliverable 1.2.2 (Muzet, 2006 [13]). These indicators are reported in the following Table 2.

Most of these indicators are difficult to record inside a vehicle because they generally need intrusive or wearable sensors, or a complex implementation. Nevertheless some of them can reasonably be considered for an implementation into a vehicle. They are underlined in green in the following Table 2.

Only one of those, dealing with eye closure and blink analysis, has been really developed and existing validated prototypes or laboratory equipment have been set up. The prototypes are using vision based technology for observing the driver's face and eyes. It should be noticed that none of these systems has been commercialized in mass production. Others are mainly at a conceptual stage.
<table>
<thead>
<tr>
<th>Physiological system</th>
<th>Physiological function</th>
<th>Physiological indicator</th>
<th>Measurement technique</th>
<th>Comment</th>
<th>Pitfalls</th>
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<td>Central nervous system</td>
<td>Brain state</td>
<td>Brain activity</td>
<td>EEG (electroencephalography)</td>
<td>Intrusive</td>
<td></td>
</tr>
<tr>
<td>Sensorial system</td>
<td>Vision</td>
<td>Eye movements</td>
<td>EOG (electrooculography)</td>
<td>Intrusive</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Gaze (fixity)</td>
<td>Gaze direction VOG (video-</td>
<td>Camera looking to driver's face</td>
<td>2 cameras with quite resolution are necessary to perform a good reconstruction of the eye gaze</td>
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<td></td>
<td></td>
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<td>oculography)</td>
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<td></td>
<td></td>
<td>Eye lid closure and blinks</td>
<td>Vertical EOG</td>
<td>Camera looking to driver's face</td>
<td>Results obtained are different depending on conditions of the recording. Globally, main</td>
</tr>
<tr>
<td></td>
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<td>reasons for low detection rate are bright incident illumination by daytime driving (e.g.,</td>
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<td>sundown), glasses, fast head movement, driver specific behavior (hand on face, inclination</td>
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<td>of the head).</td>
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<td></td>
<td></td>
<td>Pupil size</td>
<td>Pupillometry</td>
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<td>If the recording conditions are not controlled the signal reflects more sympathetic influences</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>than sleepiness. Eye closure makes any recordings impossible. Eye blinks disturb recordings.</td>
</tr>
<tr>
<td>Motor system</td>
<td>Body muscle function</td>
<td>Muscle tone</td>
<td>EMG (electromyography)</td>
<td>Intrusive</td>
<td>Problems with the reliability of the signals. The measurements are strongly dependent on the</td>
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<tr>
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<td>Body motility</td>
<td>Body posture</td>
<td>Sensitive mattress</td>
<td>Implementation in the seat</td>
<td>subjects</td>
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<td>Measurement conditions are very constrained</td>
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<td>Body and limb movements</td>
<td>Actimeter</td>
<td>EMG of the tibialis anterior</td>
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<td>Autonomic nervous system</td>
<td>Cardiovascular function</td>
<td>Heart dynamics</td>
<td>ECG (electrocardiography)</td>
<td>Intrusive</td>
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<td>Heart rate</td>
<td></td>
<td>ECG</td>
<td>Intrusive</td>
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<td></td>
<td>Respiration</td>
<td>Respiratory movements</td>
<td>Strain gauges</td>
<td>Sensor in the seat or linked to the safety</td>
<td>Sensitivity</td>
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<td></td>
<td>belt</td>
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<td>Physical Parameter</td>
<td>Measurement Technique</td>
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<td>Inductance plethysmography</td>
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<td>Esophageal pressure</td>
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<td>Static charge sensitive bed</td>
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<td>Inter-costal or diaphragmatic EMG</td>
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<td>Aireflow</td>
<td></td>
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<td>Blood gas measurements</td>
<td>Pulse Oximetry</td>
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<td>Capnography or transcutaneous measurement</td>
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<tr>
<td>Snoring</td>
<td>Sound recording</td>
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<td>Skin conductance</td>
<td>Sensor in the steering wheel</td>
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<tr>
<td></td>
<td>Electrodes</td>
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<td>Skin resistance</td>
<td>Electrodes</td>
<td>Sensor in the steering wheel</td>
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<td>Skin potentials</td>
<td>Electrodes</td>
<td>Sensor in the steering wheel</td>
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<td>Intrusive</td>
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<td></td>
<td>Core temperature</td>
<td></td>
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<td>Skin temperature</td>
<td>reliability</td>
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<td>Sweat capsule</td>
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<td>Shivering</td>
<td>EMG</td>
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<td>Behaviour</td>
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<td>Camera looking to the driver</td>
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<tr>
<td></td>
<td>Complex image processing</td>
<td></td>
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**Table 2:** Subdivision of the different physiological systems, functions, indicators and measurement techniques which can bring valuable information for the determination of basic human physiological states and their transitions (most valid online measures are underlined in green).

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3.2 Eye closure and blinks characteristic parameters

Eyelid motion and blink process are considered as some of the most pertinent non-intrusive indicators for the on-line analysis of drowsiness. From the analysis of this process several parameters can be extracted that are useful for assessing a diagnostic. A typical spontaneous blink for an alert person presents 3 phases (see Figure 3):

- a **closing phase** (the eyelid goes down)
- a **closed phase** (the eye is shut)
- an **opening phase** (the eyelid goes up)

The closing phase is faster than the opening phase, with corresponding maximum velocities of approximately 350mm/sec and 150mm/sec respectively, which is equivalent to 60 ms and 120 ms. The maximum velocity and therefore the respective durations of eyelid closing and opening do not depend on the starting lid position. Typically, the beginning of the closing phase and the end of the opening phase correspond to a 70% amplitude opening of the blink.

The **lid closure and opening velocities** are considered as sensitive to variation in sleepiness. The previous results suggest that sleepiness is associated with reduced lid closing and opening speed (Johns et al., 2005 [14]). More specifically the peak velocities are considered. The main drawback of these parameters is the high variability between subjects.

The **duration** depends directly on the driver’s state of vigilance, so the duration of a tired blink is about 1.5 times that of a normal one. The typical duration of short blinks is...
between 120 ms and 250 ms. Blinks with a duration that exceeds 300 ms are considered to be tired blinks (or long blinks): they signify a drowsy state. Blinks over 600 ms are called "eye closure" or "sleepy blinks". Their appearance is a signal of a critical state incompatible with a safe driving. Some drivers display eye closures over one second. The more critical the driver's state of fatigue becomes the more often long blinks are to be found between several short blinks, and also the duration of the blinks will increase in a non linear way.

The **blink amplitude** of an alert person with eyes wide open is characterized by a maximum value of 10 mm. The amplitude can be much lower in many cases: for example during day driving condition when the driver closes partly his/her eyes to reduce the light input, also for some morphologies like Asiatic people, etc. In such cases, amplitudes of 2 to 3 mm are possible. On the image side the amplitude is expressed in pixel. A typical value is around 20 pixels but can decrease to 5 pixels depending mainly on eyes characteristics, drowsiness level, sight orientation, head inclination, head distance to the camera, etc.

The **blink rate and blink interval** are of course sensitive to sleepiness but they can also be affected by other factors depending on the driving situation, environmental conditions (sun light), on the emotional state and stress.

The associations of parameters are also of interest. The most popular is of course the **PERCLOS** developed by Wierwille (1999 [15]) that describes the percentage of eyelid closure over time.

The **AVRBs** proposed by Johns (2003 [16]) and Johns et al. (2005 [14]) estimates the amplitude/peak closure velocity ratio of blinks. Hargutt et al. (2000 [17]) found that the blink velocity and the blink amplitude are strongly and linearly correlated for alerted subjects. They stated that there is a control process that strives to maintain constant this ratio. Furthermore it has been observed that the AVRBs ratio is changing from alert subjects to drowsy subjects.

The most pertinent and reliable parameters are obviously the closure duration and the AVR. Nevertheless in order to achieve a good estimation of the AVR a sampling frequency of 200 Hz minimum is required. In the DMS system by CAF for direct drowsiness
monitoring, that was not possible with the camera thus only the closure duration has been used within the driver drowsiness diagnostic.

An alternative diagnostic is provided by Hargutt (2003b [18]). The drowsiness index is also based upon the analysis of eye-lid movements. They are measured via copper coils fixed at the upper and lower eye-lid of a driver. With this setting the eye-opening level can be calculated.

The algorithm for detecting drowsiness is a combination of several parameters which are controlled by different psychological processes and are sensitive to different energetic states ([18]). The state of being awake (stage 0) is connected with wide open eyes, low blinking frequency and short blinking durations. If vigilance decrements occur, blinking frequency increases while eyes are still wide open and blinking duration is still short. In the next stage, drowsiness, beside the high blinking frequency, the eyes are now half closed and much longer blinks are observed. When falling asleep, eyes are now nearly closed.

**Figure 5:** Distinction between 4 stages of drowsiness based on the three parameters: blinking frequency, duration of blinks as well as eyelid opening level (Hargutt, 2003b [18])

It appears that increased blinking frequency is the earliest eyelid indicator of impaired vigilance, which identifies stage 1. Prolonged blinks in addition identify stage 2. Stage 3
is defined by small eyelid opening level in addition (or microsleep or very long closures). There is a significant correlation between the fatigue index shown in Figure 12 and the amount of alpha activity in the EEG. There is also a progressive increase in missings on a vigilance task across the stages and a decrease of tracking ability (measured by the standard deviation of lateral position SDLP) starting at stage 2.

The drowsiness level is defined as follows: each single blinking event is first identified as either stage 0, 1, 2 or 3. After that all classified blinking events are averaged over a certain time window (e.g. 2.5 minutes or 5 minutes). The resulting continuous drowsiness level has a range between 0 and 3.
3.3 Thoracic effort characteristic parameters as direct indicator of drowsiness

Biomedical variables as Thoracic Effort, which is related to autonomic nervous system can provide direct information of the driver physiological state. Therefore, they may be especially useful to collect detailed information of the drowsiness cycle and anticipate risky situations while driving.

The thoracic effort signal was analyzed to characterize several patterns of every state of attention (awake, fatigue or drowsy). As can be seen in Figure 6, during tests, the thoracic effort signal becomes irregular between transition of awake state to fatigue and more sharply between awake state and drowsiness.

![Thoracic Effort Signals during Test](image)

**Figure 6:** Thoracic effort signals during test

When the presence of yawns and sights becomes higher (line 2 of Figure 6) that means that the subject is going into a fatigue state. Also the amplitude and the frequency of the signal become lower than the basal state (first line of the data).

The next line (line 3 of Figure 6) shows the transition between fatigue and drowsiness. As we can see several bursts of irregular signal appear indicating that the subject is entering in a drowsiness state.
The line 4 of Figure 6 corresponds to a drowsiness state where the subject falls asleep during the simulator test. The first line of Figure 7 shows a very regular thoracic effort signal in amplitude and in frequency. This part of the data is representative of an awake or basal state.

To automate the analysis of this variability, the thoracic effort signal was analyzed with an algorithm (TEDD index) based on the quantification of the respiratory rate variability, normalized by the basal respiratory rate variability of each particular subject in normal conditions. A basal reference is taken during a fixed time window at the beginning of the recording.

In order to classify the state of the driver, a reference or Gold Standard signal (GS) was needed. The GS was obtained with an algorithm that combines the partial results by a majority ballot including the analysis of EEG, external observer evaluation of video recording and PERcentage of eye CLOSure (PERCLOS) in a 1 minute window around every instant, and from which ‘fatigue’ and ‘drowsiness’ thresholds were defined according to the personal basal signals in awake state.

**Figure 7:** Thoracic effort signals
The GS defined three phases: phase 0 or attentive corresponds to a fully awake driver, phase 1 or fatigue to a fatigued driver and phase 2 or drowsy to a drowsy driver. This system was tested in driving simulators and demo-cars driving in real conditions, and it was found to be robust to head turns, partial occlusions and illumination changes in both day and night scenarios.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Phase 0 (attentive)</th>
<th>Phase I (fatigued)</th>
<th>Phase II (drowsy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threshold for θ ratio: &lt; 1.92 (s.d. = 0.88)</td>
<td>Thresholds for θ ratio: &gt; 1.92 (s.d. = 0.88), &lt; 8.22 (s.d. = 3.0)</td>
<td>Threshold: &gt; 8.22 (s.d. = 3.0)</td>
</tr>
<tr>
<td>PERCLOS</td>
<td>Small PERCLOS. Low and fast blinking,</td>
<td>PERCLOS increase. More frequent and slower blinks.</td>
<td>High PERCLOS and slow blinks.</td>
</tr>
<tr>
<td></td>
<td>Threshold: &lt; 0.24 (s.d. = 0.19)</td>
<td>Thresholds: &gt; 0.24 (s.d. = 0.19), &lt; 0.45 (s.d. = 0.24)</td>
<td>Threshold: &gt; 0.45 (s.d. = 0.24)</td>
</tr>
</tbody>
</table>

**Table 3:** Classification criteria to obtain control signal
Table 4 shows the results of sensitivity and specificity for all subjects.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 0 (fully awake)</td>
<td>93.7%</td>
<td>86.3%</td>
</tr>
<tr>
<td>Phase 1 (fatigue)</td>
<td>49.3%</td>
<td>88.7%</td>
</tr>
<tr>
<td>Phase 2 (drowsiness)</td>
<td>83.1%</td>
<td>95.3%</td>
</tr>
</tbody>
</table>

**Table 4:** Sensitivity and specificity of proposed index while real driving

The results confirmed the viability of drowsiness detection while driving using the thoracic effort signal. The Phase 1 state shows a lower sensitivity because it is a transition zone.

**Fig. 8** Results for a drowsy driver
As a final sensor design in order to avoid contact with the user, Ficosa has been developing two different solutions for vehicle integration: a) Bioimpedance Contactless Respiration Sensor and b) Respiration from camera Sensor.

a. The Bioimpedance Contactless Respiration Sensor consists of a textile sensor integrated on the seat and steering wheel that injects current by a pair of textile electrodes and measuring the dropped voltage between another pair of textile electrodes. The measured voltage is related to the ventilation process. Moreover, placing this kind of electrodes on the seat belt is also possible. As can be seen in Figure 10, three different configurations are possible in order to adapt the analysis to the position of the driver. The results seem promising. Further work based on the filtering of movement and artifacts is in course, and partly planned within the DESERVE project.
Configuration 1: Steering wheel – Steering wheel

Configuration 2: Steering wheel – Seat

Configuration 3: Seat– Seat

Fig. 10: Possible configurations for Automotive integration of Bioimpedance Contactless Respiration Sensors of Thoracic effort.

b. The Respiration from camera Sensor consists of a camera device placed on the dashboard (or on the vehicle roof) that records the image from the thorax of the driver. Specific algorithms extracts the respiration signal from the video image. The statistical analysis between respiration signal from a contact band and respiration signal extracted from a video image show no significative differences between them for sleep onset high probability phases (static and Highway driving).
4. Indirect measures of drowsiness

Indirect driving behavior measures have the big advantage that they can be assessed unobtrusively by using sensors at the steering wheel, pedals or information about vehicle state and environmental conditions without disturbing the driver in his/her primary driving task.

In a literature review within the AKTIV\(^1\) project (Rauch, Schoch & Krüger, 2007 [19]) the detectability of driver inattention (drowsiness and distraction) via driving behaviour parameters was investigated. The main goal within one subproject of AKTIV-AS was to identify those parameters of the driving task which were clearly influenced by drowsiness and/or distraction and which may be useful as indicators for evaluating or predicting drowsiness and distraction from online driving behaviour. For drowsiness, the reported

\(^{1}\) AKTIV stands for „Adaptive and Cooperative Technologies for the Intelligent Traffic“. This German research initiative brings together 29 partners - automobile manufacturers and suppliers, electronic, telecommunication and software companies as well as research institutions.
results can be clustered according to activity measures (direct inputs on the steering wheel, pedals etc.) and performance measures (refer to an external criteria to evaluate driving quality), both in longitudinal and lateral control.

Longitudinal control:

- Driving performance measure: speed (mean and variability) and distance control (distance to lead vehicle)
- Driver activity measure: pedal activity (driver’s use of pedals)

Lateral control:

- Driving performance measure: lane keeping performance (standard deviation of the lateral position, time to line crossing, number of lane crossings, mean lateral position, mean yaw rate)
- Driver activity measure: steering behaviour (magnitude and frequency of steering activity), steering variability, slow and fast steering corrections

Another group is the assessment of driver’s reaction to specific events (e.g. braking reaction to suddenly braking lead vehicle). Also the performance in a secondary task or vigilance task (reaction times and error rates) is measured.
MEASURES FOR DISTRACTION AND INATTENTION

1. Definition


According to Stutts et al. (1995) “distraction is as a state when the “driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object, or person within or outside the vehicle compels or induces the driver’s shifting attention away from the driving task”. In a vehicle the driving task is of course the primary task. In some circumstances this primary task is quasi exclusive for example when doing some difficult manoeuvres (driving on the “Etoile” roundabout in Paris is one of the good examples). In that situation all the attention of the driver must be dedicated to the driving tasks. In other situation like for example driving on a free motorway, the driver has the possibility to perform some secondary tasks without taking any special risks. Problems occur when the importance of these secondary tasks increases with respect to those of the primary and sometimes becomes more important. In many situations this has no real consequences. But sometimes when there is a conjunction between these inattention phases and critical driving situation the effects become dramatic. Various studies held in US on accident reports demonstrate that inattention causes a quarter of the road accidents (Hendricks 2001, Wang 1996). Furthermore a large study held on a panel of more than 100 drivers during 12 months demonstrated that inattention was the first cause for accident (Dingus 2004). In that study 78% of the accident was linked with a driver’s inattention phase during the 3 sec before the accident.

- Different categories of distractions should be considered, for example:
• Visual (external attractors for example advertisement on the side of the road or internal attractors e.g. looking to his children at the back of the vehicle, or displaying an address onto a navigation device)
• Acoustic (ringing phone, listening music)
• Cognitive (conversing at phone but also internal thought and rumination,...).

Rockwell (Rockwell 1971 [2]) demonstrates that driving task is “90% visual in nature”. However, it is obvious that cognitive demand should also have a dramatic impact on driving performance. The Gazel cohort set up in 1989 by Unit 88 (now Unit 687) from INSERM, in partnership with several teams of the EDF-GDF company, thanks to the participation of 20 000 volunteers, showed that for persons that are under a divorce or separation situations the risk of accident is increased by four.

Furthermore the introduction in our vehicles of new infotainment devices like navigation systems more and more sophisticate audio systems generates new potential attractors that could derive the driver from the driving tasks. This new devices can require at the same time both important visual, cognitive and motoric resources. Last but not least the use of mobile phones without hands-free operation kits leads to critical inattention and distraction situations when dialing a number (visual and cognitive) but also when speaking with an operator that could mobilize some important cognitive resources.

In parallel to the fundamental research activities related with the analysis of the cognitive and physiological mechanisms of inattention and distraction, applied research has focused on the developments of techniques, technologies and tools able to provide, in real time, good indications about the current inattentiveness situation of the driver. The first focus is of course on visual distraction based on the use of camera and image processing techniques analysing in real time the driver’s head orientation. The second approach is based on indirect techniques trying to build up distraction indicators based on the observation and analysis of the driving and secondary activity of the driver inside the cockpit.

2. Assessment of visual distraction

Visual distraction, among the potential loss of driver’s attention phenomena, is one of the important causes of accidents. Visual distraction corresponds to the situations where the
driver is almost not looking to the road for a while. Such situations can occur many times when driving. Most of the time there is no real consequences but in some critical situations this could lead to accidents.

Visual distractions can be due to external attractors, looking to advertisement to the side of the road, to pedestrian on sidewalk... but also to many internal attractors, for example looking to the passenger seats, to the rear of the vehicle, dialing a new destination on a navigation system or a number on the mobile phone.

The duration of the visual distraction phenomenon is also to be considered. According to many authors the situation becomes critical when visual distraction phase is longer than 2 seconds. But, this of course depends a lot on the driving situation, the environmental traffic, the vehicle speed and inter-vehicle relative speed, the location, cities, freeways, motorway etc... Thus, determining when and how long the driver is not looking to the road is really an interesting information. Of course, as far as we are considering mass production vehicles this information must be completed with non intrusive measurement systems. Then the use of camera(s) looking to the face of the driver to perform such measurement is obvious.

Visual distraction can be assessed by measuring the eye gaze, but this approach is quite complex and needs generally high precision camera and stereoscopic vision, not fully compatible with automotive mass production constraints. Nevertheless, some very efficient laboratory tools using this technology have been developed (Seeing Machine, Smart eyes web sites).

A simpler approach aims to consider that long visual distraction situation (>2 sec) mostly corresponds with head rotation, assuming that this is quite uncomfortable to stay for more than 2 sec with the “eyes in the corners”. All the experiments we performed confirmed this assumption. Thus, observing the head orientation could provide reliable information about visual distraction.

3. Indirect measures of driver distraction

Beside the information about the visual attention of a driver using camera-based systems, also more indirect measures have been discussed in AKTIV and HAVE-IT.
projects that may be suitable to detect driver distraction. One approach would be to observe driver’s performance and driver’s activity in the primary driving task. When impairments occur one can assume that the driver is no longer fully attending to the task-relevant elements but is occupied with some other tasks in the vehicle. Nevertheless, this approach should be problematic, as short term distractions have to be detected and as some tasks do not directly emerge in detrimental driving performance.

Another problem is that tasks with mainly cognitive load have different influences on driving task than mainly visual distracting tasks.

Another method for detecting a distracted driver is to directly observe his/her activities on in-vehicle tasks, such as onboard systems, mobile phone use and so on. The assumption is that when we know that the driver is just using the mobile phone we can expect that the probability that he/she will be distracted from the driving task is very high. Especially when he/she is not looking away from the road but is mainly cognitively distracted this information source will be helpful. It may support the direct observation of driver’s head or gaze direction via camera.

An important precondition would be that sensors exist that make these information available for detection. This might be the cause why up to now only few attempts exist that tried to use this method for detecting distraction. In addition, there are a lot of tasks that require no motoric inputs and will therefore remain not assessable by this technique. Another problem are nomadic devices that are not installed in the vehicle and will therefore not be detectable by onboard sensors.

Assuming that the preconditions are fulfilled and the sensors are able to assess the in-vehicle activities, a classification can be made according to the distraction potential of the different tasks. Here the visual, cognitive and physical load has to be considered as well as the expected duration of the task.
APPROACHES FOR ON-LINE DRIVER MONITORING

Since a couple of years extensive research was carried out to identify and describe issues as well as countermeasures to tackle the problem of driver drowsiness. Profiled road markings serve as a good example of countermeasures that have been tried out, but without clear and consistent impacts on accidents. Also, laws were enacted in the whole EU-area for controlling professional drivers driving times.

In the 1990's a new approach for solving driver impairment problems emerged. When sensor technology made improvements and the processing capacity of computers was rapidly increasing, R&D in vehicle telematics opened up new frontiers, among them monitoring driving environment, vehicle movements, driver status and behaviour.

In Europe, basic work for driver monitoring was carried out in the EU funded project, DETER-EU (Brookhuis, 1995 [37]) and next in PROCHIP /PROMETHEUS program (Estève et al., 1995 [38]). Continuation for driver impairment monitoring was realized in the SAVE-project ([36]) were a solution for all kinds of driver impairment monitoring was proposed by means of sensor fusion ([36])

In the AWAKE project (AWAKE, 2000 [39]) and more recently the HAVE-IT project a multi-sensor system has been set up. It is combining information provided by an eyelid sensor, a lateral position sensor, a steering grip sensor and additional data available on the vehicle like steering wheel movements, vehicle speed and other behavioural parameters ([39]).

The SENSATION project (SENSATION, 2004 [40]) aimed at promoting novel micro and nano sensors and related technologies of low-cost and high-efficiency for physiological state monitoring. The focus of the work was the detection, the prediction and the management of the sleep and wakefulness states and their boundaries, stress, inattention and hyper-vigilance.

Several system prototypes for detecting driver fatigue have been developed and evaluated.

Direct Driver Monitoring systems are mainly based on the real time analysis of the eye gaze and blink process (Boverie et al., 2002 [41], 2007 [42], 2008a [43], 2008b [44];
Wierwille, 1999 [15]). These systems are generally using cameras looking to the drivers' faces and associated image processing algorithms, but not only. Despite their interest most of these systems have not reached a sufficient reliability and their costs are still not fully compatible with automotive constraints. Nevertheless various prototypes or lab equipments have been developed in the last 15 years.

The indirect supervision systems are generally based on the analysis of the vehicle behavior that can be correlated with driver actions (steering wheel movement for example) and other information available on the vehicle. It should be noticed that the first Driver Drowsiness Monitoring systems being already commercialized are belonging to this class.

The following table summarizes the known systems available on the market or under advanced development.
# OEMS and Tier one

<table>
<thead>
<tr>
<th>Name</th>
<th>Method</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMW/Bosch</td>
<td>Eye lid movements (recorded by camera)</td>
<td></td>
</tr>
<tr>
<td>Continental</td>
<td>Driver attention system: Video camera that monitors the eye-lid movement (blink rate) and gaze direction</td>
<td>Under development</td>
</tr>
<tr>
<td>Daimler-Chrysler (E-class, S-class)</td>
<td>Attention Assist: phases of non-steering followed by larger steering corrections; considering side winds and road surface conditions; driver activities like indicator use and pedal activity, speed, lateral and longitudinal velocity; considering day time, driving duration, driving style and traffic density; based on individual driver profile</td>
<td>Commercialized</td>
</tr>
<tr>
<td>Daimler-Chrysler (trucks)</td>
<td>Vehicle speed, steering angle, and vehicle position related to road delimitation (recorded by camera)</td>
<td>?</td>
</tr>
<tr>
<td>Ford (Falcon)</td>
<td>Driver fatigue warning: solely based on driving duration; reminds the driver after 2 hours driving to rest (can be modified according to driver preferences)</td>
<td>Commercialized</td>
</tr>
<tr>
<td>FORD+MIT</td>
<td>Driver stress monitoring</td>
<td>Research</td>
</tr>
<tr>
<td>Honda</td>
<td>Pupil diameter fluctuations</td>
<td>Under development</td>
</tr>
<tr>
<td>Mazda</td>
<td>Driver’s postural change: pressure between a driver and a seat; change of load center position represent the change of driver’s posture- used as index for presume fatigue</td>
<td>?</td>
</tr>
<tr>
<td>Mitsubishi (cars)</td>
<td>Dash-mounted cameras to monitor and analyze eye position and blinking</td>
<td>Under development</td>
</tr>
<tr>
<td>Nissan (cars)</td>
<td>Eye movements (blinkings), registration through infrared camera; analysis of steering wheel corrections</td>
<td>Under development</td>
</tr>
</tbody>
</table>
### Rehabilitation

<table>
<thead>
<tr>
<th>Company</th>
<th>Feature Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renault</td>
<td>Infrared lights, camera that monitors eyelid movements of the driver</td>
<td>Under development</td>
</tr>
<tr>
<td>Toyota (Lexus)</td>
<td>Inattention detection: head direction (if head is turned away from the road more than 15°)</td>
<td>Commercialized</td>
</tr>
<tr>
<td>Visteon</td>
<td>Drowsiness monitoring from Visteon</td>
<td>R&amp;D</td>
</tr>
<tr>
<td>Volvo (S80, V70, XC70)</td>
<td>Driver Alert Control: assesses vehicle course on the road, detects lane crossings and evaluates lane keeping performance</td>
<td>Commercialized</td>
</tr>
<tr>
<td>Volvo and VTT</td>
<td>Driver Status monitoring</td>
<td>Research</td>
</tr>
<tr>
<td>VW</td>
<td>Attention control: eyelid movements (recorded by camera)</td>
<td></td>
</tr>
</tbody>
</table>

**Tier 2 and others**

<table>
<thead>
<tr>
<th>Company</th>
<th>Feature Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraunhofer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optalert</td>
<td></td>
<td>Commercialized</td>
</tr>
<tr>
<td>Seeing Machine</td>
<td>Infrared lights, camera that monitors eyelid movements of the driver and eye gaze (monoscopic and stereoscopic vision)</td>
<td>Commercialized for lab</td>
</tr>
<tr>
<td>SMART eyes</td>
<td>Infrared lights, camera that monitors eyelid movements of the driver and eye gaze (monoscopic and stereoscopic vision)</td>
<td>Commercialized for lab</td>
</tr>
</tbody>
</table>

1. **Attention assist from Mercedes**

Drowsiness-Detection System ATTENTION ASSIST warns drivers to prevent them falling asleep momentarily from Daimler:

ATTENTION ASSIST observes the driver's behaviour and, at the start of every trip, produces an individual driver profile that is then continuously compared with current sensor data. This permanent form of monitoring is important for detecting the floating
transition from awareness to drowsiness and for warning the driver in plenty of time. The system is active at speeds of between 80 and 180 km/h.

At the heart of this Mercedes system is a highly sensitive sensor which allows extremely precise monitoring of the steering wheel movements and the steering speed.

Based on these data, ATTENTION ASSIST calculates an individual behavioural pattern during the first few minutes of every trip. This pattern is then continuously compared with the current steering behaviour and the current driving situation, courtesy of the vehicle's electronic control unit. This process allows the system to detect typical indicators of drowsiness and warn the driver by emitting an audible signal and flashing up an unequivocal instruction on the display in the instrument cluster: "ATTENTION ASSIST: Pause!"

2. Driver Alert from Volvo

Volvo offers from the model XC60 an optional Driver Assist Pack. The solution adopted by Volvo integrates data on lane position with vehicle speed and turn indicators. It is active at vehicle speed comprised between 65 and 180 km/h. In the considered version, it does not perform any driver characterization. The HMI shows an instruction on the instrument panel similar to the one used by Mercedes.
3. **VW**

Volkswagen offers a Driver Fatigue Detection system which evaluates steering wheel movements along with other signals in the vehicle on motorways and other roads at speeds in excess of 65 km/h, and calculates a fatigue estimate. If it is over a threshold, the driver is warned by information in the Multi-function Display and an acoustic signal. The warning is repeated after 15 minutes if the driver has not taken a break. A driving time of 15 minutes is required in order to assess the driver correctly. The functionality of the system is restricted given a sporty driving style, winding roads and poor road surfaces.

4. **Driver attention monitor from Toyota**

**Driver Attention Monitor**, is a vehicle safety system first introduced by Toyota in 2006 for its Lexus latest models. It was first offered on the GS 450h. The system's co-operate with the Pre-collision System (PCS). The system uses infrared sensors to monitor driver attentiveness. Specifically, the Driver Monitoring System includes a CCD camera placed on the steering column which is capable of eye tracking. If the driver is not paying attention to the road ahead and a dangerous situation is detected, the system will warn the driver by flashing lights, warning sounds. If no action is taken, the vehicle will apply the brakes (a warning alarm will sound followed by a brief automatic application of the braking system).

The Driver attention monitor is equipping Lexus models from 2006:
- 2006 Lexus GS 450h and Lexus LS 460
- 2007 Lexus LS 600h
• 2010 Lexus HS 250h and Lexus GX 460 and from 2008 Toyota Crown Hybrid models

![Driver Attention Monitor on LS 600h](image)

**Figure 12: The Driver Attention monitor on LS 600h**

5. **Nissan**

• Detection using facial monitoring

A camera is mounted on the instrument cluster facing the driver to monitor the driver's face. The system is calibrated to monitor the driver's state of consciousness through the blinking of the eyes. When the system detects signs of drowsiness, a voice and message alert is triggered via the navigation system. Additionally, a seatbelt mechanism is activated which tightens around the driver to gain his or her immediate attention.

• Detection of the driver's state from the Driving behavior
By constantly monitoring the operational behavior of the vehicle (e.g. sensing if the vehicle is drifting out of its driving lane), the system can identify signs of inattentiveness or distraction in the driver. When the system detects such behavior, voice and message alerts are issued via the navigation system. The seatbelt alert mechanism is also activated, tightening around the driver to gain immediate attention.

6. **Ford and MIT have developed a driver stress monitoring system**

Partnering with MIT’s renowned AgeLab, the project will identify specific stress-inducing driving situations, monitor a driver’s reaction to the situations using biometrics, and evaluate methods to incorporate new stress-reducing features into the next generation of Ford products. For the scope is used a specially equipped 2010 Lincoln MKS, a vehicle already recognized for its advanced safety features.

By monitoring biometrics such as heart rate, skin conductivity and eye movement, researchers at MIT have been working to develop a specific set of parameters for an embedded detection system that could be engineered into future Ford vehicles.
“Through the use of our existing technologies such as Adaptive Cruise Control with Collision Warning or SYNC, our voice-activated communications system, we are proactively guiding drivers away from difficult situations.”

“The goal of this program is to take this one step further by creating the most comfortable driving environment possible so that our driver is always relaxed, calm and able to perform at peak performance,” said Jeff Rupp, Ford manager, Active Safety Research.
7. Drowsiness monitoring from Visteon

Like other automakers, Visteon is working on new technology to catch drowsy drivers before they go into a full-on snooze.

The system uses an IR camera and emitters mounted in the dash to track the driver’s eyes, whether in daylight or at night, to determine where the driver is looking and how wide his eyes are.

From that (and other parameters), the vehicle can tell just how alert the driver is, sounding an alarm and even vibrating the seat to snap the driver back into reality.

8. Volvo and VTT

Volvo and VTT Technical Research Centre of Finland have developed a new method for monitoring driver status, which adapts the vehicle control system according to the driver, vehicle, or traffic status. The method is based on an assessment of the driver's eye direction and behaviour. Both road safety and driver comfort are increased as the method protects the driver from distractions, such as warnings about the level of windscreen washing fluid or in-coming phone calls, when traffic conditions require the driver to be particularly alert and focused. The project also included testing a solution where a mobile phone functions as an integrated part of the vehicle interface.
9. **Optalert**

Optalert drowsiness monitoring glasses work by measuring the velocity of the operator’s eyelid 500 times a second using a tiny invisible LED built into the frame of the glasses.

Core to the success of this safety technology are two key measurements that tracks the amplitude velocity ratio – essentially how fast and how far a person opens their eyelid after they close it.

This measurement is translated into a score, which the operator sees inside the cab of their vehicle on the Optalert Dashboard Indicator.

10. **Seeing machines**

The main product by Seeing Machines is faceLAB, which is a head and eye tracker system for research.
FaceLAB is based on stereo camera approach, but additional cameras can be added for extending the field of view. Infrared-light illuminators are used in order to operate the system in changing light environment. Besides the driver cameras, several forward-facing cameras can be used to capture the subject’s interactions with the dynamic scene in-front of the vehicle.

FaceLAB delivers the following output data: head position and rotation, eye position and rotation, eye gaze, pupil diameter, eye vergence distance, saccade events, blink events, blink frequency, blink duration, eyelid aperture. Furthermore, FaceLAB delivers PERCLOS fatigue metric.

FaceLAB has an automatic initialization feature for quick subject registration. A more accurate gaze data refinement is possible using a user-defined calibration sequence.
11. Smart Eye

Smart-Eye AB produces eye-tracking systems which use single or multiple cameras and infrared-light illuminators, in order to be able to work both in darkness and sunlight. There are two types of systems: Smart Eye Pro and AntiSleep.

**Smart Eye Pro** – It is a multi camera system which can use up to 8 cameras for very large field of view and it is capable to give 3D eye and head tracking data. The tracking principle is based on pupil and iris / corneal reflexion and head model. The system delivers in output the following data: head orientation (6 Degree Of Freedom), Eye positions, Eye gaze, Pupil diameter, Saccades, Fixations, Blinks, Eyelid opening; data are available in real time via TCP/UDP at a sampling rate of 60 Hz or as a log-file.

Smart Eye Pro is a research system and typical use include instrumented vehicles and driving simulators.

![Smart Eye Pro inside an instrumented vehicle with four eye cameras](image)

**AntiSleep** – It is a compact system designed for automotive in-cabin measurement of driver head pose, gaze direction and eyelid closure. It uses a single standard CMOS camera of VGA resolution, together with IR flash illuminators. One useful feature is the automatic driver initialization.
The system delivers output data at 60 Hz and can be used to monitoring driver fatigue and attention.

There is also an embedded version of the system, the Embedded AntiSleep, which is even more compact.

12. Continental

The Continental driver supervision system is based on the real time monitoring of two independent parameters, the drowsiness level (sleepiness vs. awareness) and the visual inattention (e.g. the driver "is/is not" looking to the road).

The Driver state monitoring includes a compact low consumption and high dynamic range (120db) CMOS camera sensor. The camera is equipped with a global shutter for the synchronization with a set of pulsed NIR lights (850nm).
Continental architecture of the Driver monitoring

Algorithms are implemented in a distant processing unit. This set of algorithms analyzes in real time the image flow provided by the camera to extract information about the driver's eyelid and blinking patterns, the head position and orientation. It delivers a four levels vigilance diagnostic and two inattention diagnostics: the estimation of the visual distraction level (VDD) and the visual time sharing level (VTSD). The system is fully automatic and works by night and day.

13. Fraunhofer Institute for Digital Media Technology

Researchers at the Fraunhofer Institute for Digital Media Technology in Ilmenau, Germany have created a system for warning drivers when they’re getting too drowsy to drive. The Eyetracker system utilizes two or more dashboard-mounted cameras to monitor drivers’ eyes, and sounds an alarm if their eyes are off the road for too long. It

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can apparently be mounted in any car, and doesn’t require complicated calibration of the cameras, or an external computer.

“With conventional systems, every person whose line of vision is to be monitored has to complete more or less time-consuming preparations. Because every head, every face, every pair of eyes is different,” said Fraunhofer’s Prof. Peter Husar. “What we have developed is a small modular system with its own hardware and programs on board, so that the line of vision is computed directly within the camera itself. Since the Eyetracker is fitted with at least two cameras that record images stereoscopically – meaning in three dimensions – the system can easily identify the spatial position of the pupil and the line of vision.”

Using two, four, or even six cameras, the system evaluates up to 200 images per second, and follows the driver’s eyes even when they turn their head. Despite the appearance of the system in the supplied photo, the commercial version of Eyetracker is said to be about half the size of a matchbox, with camera lenses that are just three to four millimeters in diameter.

Besides its use in automobiles, designers of the system believe it could also be used to track patients’ eyes during eye surgery, to change perspectives in video games without the use of joysticks, and to let advertisers know what parts of posters viewers are looking at most. The system was presented at Stuttgart’s VISION trade fair.
DEFINITION OF A GENERAL DRIVER MONITORING MODULE.

The DESERVE platform framework is organised in a Perception platform, an Application platform and an Intervention-Warning-Information Controller, as summarised in following Figure 13.

**Perception Platform:** Processes the data received from the sensors that are available on the ego vehicle and sends them to the Application Platform.

**Application Platform:** Uses the data received to develop control functions and to decide the actuation strategies. The output is sent to the IWIC Platform.

**IWIC Platform:** Informs the driver in case of warning conditions and activates the systems related to the longitudinal and/or lateral dynamics.
ARCHITECTURE LAYOUT OF THE GENERAL DRIVER MONITORING MODULES

The Layout of the general Driver Monitoring Module is shown in Figure 14:
Fig. 14: DESERVE Driver Monitoring General Layout
The sensors considered are:

**Camera**: an interior camera is dedicated to the observation of the driver face. The camera is operating in the near infrared, too and it is equipped with a specific IR illuminator. The camera is installed on the vehicle dashboard. The output is raw video signals sent to the application platform.

**Bioimpedance biological sensors**: it is a contactless respiration sensor that consists in sets of conductive textiles located on the steering wheel and seat. Those sets combine acting like current injectors and current receivers. The variability of current due to the air in to the lungs is interpreted as respiration motion. This signal is analyzed with the drowsiness algorithm to evaluate the state of the driver.

**Camera for the respiratory signal**: it is an optional alternative to the bioimpedance sensors to extract the respiratory signals. In this case they are measured from the driver image supplied by the camera.

The Perception Platform includes:

An Eye Gaze – Head pose module; an Eyelid Motion module, and the optional Image respiration extraction module. These modules use the video input from the camera. A specific module is dedicated to the Bioimpedance biological sensors.

An impairment detection algorithm using several parameters (like Steering wheel angle, LDW data, pedal actions and so on…) from the vehicle CAN is also implemented in the platform. Impairment level diagnostics module then elaborate the alarm signal with a confidence level.

The eye gaze and head position data are sent to a distraction detection module, which elaborated them with other parameters from the vehicle CAN, like actions on radio and navigation system in order to infer a driver level of distraction sent to the application platform.

The data of eyelid movement are used by a specific drowsiness detection module; similarly another module elaborates the data from the biological sensor (or/and from the camera). Both supply their warning combined with a confidence level. These warnings and the ones form the impairment level diagnostics are used, combined with their
confidence levels in the drowsiness detection fusion module to elaborate the data to send to the Application Platform.

In the Application Platform a Driver Intention Module will make use of the data from the distraction module, while threat assessment module, the IWI manager and vehicle control module will provide to take the appropriate actions through the Intervention-Warning-Information Controller.
EXPERIMENTAL DRIVER MONITORING MODULE:

Due to the limitation of time and resources, not all the modules will be included in the experimental driver monitoring module to be installed on the demo vehicles.

Discussion with CRF lead to the suggestion to split the driver monitoring function in two CRF vehicle demonstrators:

a. Urban scenarios: AEB pedestrian + driver distraction
b. Interurban scenarios: AEB interurban + driver intention + driver drowsiness.
MOTORCYCLE RIDER STATUS MONITORING:

The Layout of motorcycle rider status monitoring module is shown in Figure 15. Layout of the module is the same as in the simulator environment for driver status monitoring.

![Fig. 15: DESERVE Motorcycle rider status monitoring module layout.](image)

The sensors considered are:

**Rider Monitoring camera and IR illuminator**: Rider monitoring camera is dedicated to the observation of the rider’s face and helmet. The camera is operating in the near infrared and it is equipped with a specific IR illuminator. The camera is installed on the motorcycle dashboard. The output is uncompressed acquired image frames with full resolution.

**Monitoring platform**: monitoring platform contains all modules dedicated to rider monitoring. Platform acquires images from the rider monitoring camera and provides monitoring output to a local database for motorcycle applications. The motorcycle applications module, which contains an NMEA transmitter, controls the monitoring...
platform application by controlling GPS NMEA data. Monitoring platform consist of head and eye detection, visual and cognitive distraction detection and local database modules.

Head and eye detection module; Head and eye detection module receives captured images from the camera module. Module also listens to UDP data from the rider monitoring platform NMEA transmitter. If GPS data is received from NMEA transmitter, head and eye detection starts analysing image data from the rider monitoring camera. As output, head and eye detection provides x and y pixel coordinates in image area. These coordinates indicate the gaze direction. Head and eye detection module calculates also the area of the gaze direction in driving environment. For the PTW simulator application of eye detection, the gaze areas are located differently and do not contain all of the above mentioned gaze areas. Also the dashboard area is divided into smaller sub-areas which will be defined during the design phase. The actual PTW application will be designed and implemented later in the project.

Visual and cognitive distraction detection module: Visual and cognitive distraction detection module (VCDD) receives gaze detection coordinates from the head and eye detection module. These coordinates are used to calculate visual and cognitive distraction as a distraction index. If the rider's gaze direction is not varying enough, the module will decrease the distraction index for riding.

Local database/riding simulator database module: Local database is used to store measurements from VCDD module and head and eye detection module. Database will also store timestamps of the measurements and GPS position from the NMEA transmitter. Local database is part of the monitoring platform and communicated in a local network.

**Motorcycle applications:** Motorcycle applications platform contains controlling functions for monitoring platform modules. Platform contains NMEA Transmitter module.
NMEA Transmitter module: In motorcycle application platform, NMEA transmitter reads GPS data from the GPS receiver and sends the data to monitoring platform and the head and eye detection module through UDP socket. Monitoring platform waits for GPS coordinates from UDP socket and starts measurements when GPS coordinates are detected.
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