38 Driver Condition Detection

Ingmar Langer, Bettina Abendroth, Ralph Bruder

The following chapter deals with driver condition detection. After delineating the factors relevant to detecting a driver's condition and discussing the reasons for addressing the subject in terms of accident risk and the corresponding potentials and challenges (Section 38.1), three potential uses of driver condition detection will be examined: detection of inattentiveness (Section 38.2), detection of drowsiness (Section 38.3) and detection of medical emergencies (e.g. a heart attack; Section 38.4). The respective driver conditions will be defined, relevant measuring variables and their corresponding measuring procedures will be presented and selected applications will be expanded upon. Section 38.5 will address driver condition monitoring systems currently available on the market as well as naming the measuring variables and procedures used by those systems, before a short overview of the problem of potential false alarms is given in Section 1.6.

38.1 Introduction and Motivation

38.1.1 Definition of the term "driver condition"

Driver condition encompasses all driver characteristics which change over the course of time and which can be relevant to the driving task. Since a driver's condition is subject to intra-individual fluctuations, it is possible to differentiate, depending on the time period over which a change occurs, between factors influencing driver condition which change over a short period (within minutes and seconds) and over a medium period (within hours or days) (based on [1]).

For example:

- factors which change over a medium period (days, hours)
  - fatigue
  - current state of health or illness
  - daily rhythm
  - influence of alcohol/drugs
- factors which change over a short period (minutes, seconds)
  - attention (e.g. selective, divided; visual, auditory)
  - sustained attention (vigilance, wakefulness)
  - stressors
  - acute health problems and medical emergencies (e.g. heart attack)
  - situational awareness
  - emotions

Furthermore, factors which do not change or which only change on a long-term scale also affect driver condition (e.g. constitution or personality). However, these will not be further examined (for more on this, see ▶ Chap. ID#0100). The following chapters cover fatigue, attention and medical emergencies in more detail.

38.1.2 Influence of critical driver condition on risk of accident

A driver's condition has a strong influence on the risk of accident. Analyses of accident causes demonstrate that inattentiveness, i.e. neglect of information intake, is the chief cause of accidents. According to the analysis of [2], 455 out of 695 accidents during turning/crossing (about 65 %) can be attributed to disregard for other road users due to inattentiveness. In the so-called 100-car study [3] a clear connection between accidents or near accidents due to inattentiveness and the performance of secondary tasks was identified. It has been shown that using mobile devices (e.g. mobile phones) is the most common form of secondary task and that eye diversions of more than two seconds significantly increase the risk of accident.

Other factors resulting in an increased risk of accident include fatigue (according to [4], 10 to 20

% of traffic accidents can be attributed to fatigue behind the wheel), alcohol consumption or driving under the influence of drugs. [3] discovered that existing fatigue increases the danger of accidents or near accidents by a factor of four to six and leads to accidents with the most serious consequences, (cf. [5]). This is because tired drivers have difficulty accomplishing the tasks necessary for avoiding collision (braking or steering) [6]. Approximately 3 % of all traffic deaths can be attributed to a medically-determined incapacity on the part of the driver [7].

38.1.3 Potentials and challenges in the driver condition detection

Considering traits which describe driver condition allows (novel) advanced driver assistance systems (ADAS) to further build upon their already very high potential for avoiding accidents. It is conceivable, for example, that relevant system information could be transmitted in such a way that the driver could effectively perceive them independent of driver condition, e.g. in the case of inattentiveness. Similarly, warning and system intervention strategies can be adapted to driver condition, thereby increasing both the effectiveness and acceptance of driver assistance systems. It seems directly useful, for example, to warn an inattentive driver earlier or more clearly – although an early or very conspicuous warning runs the risk of the “warning dilemma” (for more on this see ▶ Chap. ID#0704 and ID#0903).

In order to realise these potentials, it must be possible to determine driver condition. Currently, many research projects are engaged with the question of how to reliably ascertain driver condition and interpret the values determined.

The following various requirements for systems which recognize driver condition are mentioned in the literature ([8], [9], [10] among others):

- unobtrusiveness of sensors through contact-free measurement
- low rate of false alarms (see ▶ Sect. 38.6),
- adequate warning and intervention strategies which, for example, motivate the driver to rest when fatigued or bring the vehicle into a minimal-risk state during a medical emergency (this would mean, at the least, stopping by the side of the road)
- consideration of undesired behaviour adaptation (cf. risk homoeostasis).

One complication is that the borders between various states are difficult to define due to large fluctuations between individuals (cf. [11]). Furthermore, most sensors for monitoring driver condition require a high degree of robustness against artefacts (including movement, forces and environmental light).

A further challenge with recognizing inattentiveness is that such a state can only be confidently identified if the attention resources necessary for a particular driving situation and the resources supplied by the driver for the task (or the control processes underlying them) are known. Since this is not possible with technical measurements, attention can only be evaluated with the help of other criteria [12]: for example, eye and head movements can demonstrate the driver’s line of vision and thus identify potential visual inattentiveness. In order to examine the demands on attention arising from a given driving situation, it is necessary to obtain confident environment recognition and classification as well as knowledge of what level of attention is sufficient in each situation. A study by [11] also shows that the impact of disruptive factors relevant to attention is strongly situation-dependent and that various indicators for recognizing the state of attention are suitable depending on the type of inattentiveness which occurs. Long-term impairments to vigilance (see also ▶ Sect. 38.2.1) can be recognised by continuous indicators which describe horizontal or longitudinal adjustment. Short-term distractions, on the other hand, are more readily identified by readiness to react to specific events – for example brake reaction time to a sudden decelerating vehicle in front of the own vehicle.

Fatigue is not directly measurable, but can only be quantified based on measuring aftereffects. However, aftereffects can fluctuate from person to person. In order to evaluate them it is necessary to know the values at which a reduction of a driver’s performance capacity has an impact on driving safety.

It must be noted that not all measurement categories for evaluating driver condition which will be delineated in the following sections fulfil the aforementioned demands. Although the following chapters primarily occupy themselves with methods which can be implemented using currently-available sensors, they represent starting points for further research thanks to their potential for continued development.

38.2 Detection of inattentiveness

38.2.1 Definition of attention

Attention is commonly subdivided into the following three categories [13]: selective attention, divided attention and sustained attention.

Under selective attention, relevant information is selected from the environment and irrelevant information is filtered out. Closer examination of selective attention is pertinent to a driving context, since drivers must allocate attention to all potentially relevant sources in order to process information necessary to a driving situation [12]. If the driver receives an influx of too much information at one time (reaching a capacity limit), there is a risk that relevant information will be perceived at a time delay or not at all.

Under divided attention, information is simultaneously received and processed, allowing the simultaneous accomplishment of various tasks (with sufficient performance among the various tasks). This requires coordination of attention distribution: for example, divided attention is required of a driver in order to visually monitor distance to a vehicle in front and follow the acoustic instructions of the navigation system. Depending on which sensory channels are simultaneously addressed, attention distribution will be more or less successful (cf. [14]).

Sustained attention – also called vigilance – describes the ability to extract relevant information from the environment over a longer period of time and react to it (cf. [13]).

These components of attention show that processing resources are limited not only with respect to scope (selection and division) but also with respect to being maintained over a long period of time (sustained attention). During vehicle guidance, most information is gathered through the visual sensory channel. All previously mentioned factors play a large role here, since the driver needs to select important information, detect relevant changes in the driving environment or in the vehicle itself (system information), while carrying out the primary driving task (distribution of attention) and remaining as attentive as possible in order to react to changes, even in time-critical situations.

Attention is often discussed in conjunction with distraction: distraction during driving is when the driver's attention is focused on an object, task or direction not belonging to the primary task of driving. When information perception is not disrupted through distraction by other information, the term "focused attention" is also used [15].

Inattentiveness refers to insufficient or non-existent attention to activities which are crucial for safe driving ([16]; also cf. [17]).

38.2.2 Measuring variables and procedures for the detection of inattentiveness

There are various possibilities for determining a driver's level of attentiveness [12]:

- detecting eye movement or head orientation via camera,
- detecting secondary activities/operational actions via vehicle sensors or cameras,
- detecting vehicle operation behaviour (e.g. steering and braking patterns) via vehicle sensors

Head orientation is of limited use, since glances at an infotainment display are also possible without large movements of the head; however, detection of eye movement has strong potential to detect a driver’s level of distraction.

According to [11] it is useful to distinguish between long-term (continuous) and short-term driving indicators. Long-term indicators allow decreases in vigilance to be recognized, while the current state of attentiveness can be described by means of short-term indicators.

According to [11], suitable long-term indicators include:

- tracking, above all of standard deviation in lateral position (SDLP) within the lane,
- variations in steering behaviour (increase in fast, large steering movements; decrease in small corrective movements),
- variations in distance and speed,
- length of time before speed is adjusted to external conditions.

However, situational dependence must always be taken into account.

In order to detect the current state of attentiveness or short-term decreases in attention, [11] assert that it is possible to use indicators which are typically implemented as criteria in warning systems. These include, for example, TTC (Time-To-Collision), how hard the brakes are applied or reaction time while braking. What becomes problematic is that these indicators are only active when the situation has already become critical.

In certain circumstances, the performance of a secondary activity and associated driver inattentiveness can be inferred from changes in steering movements and it is possible to detect secondary activities – such as controlling the infotainment system – directly [12].

According to [11], the repeat occurrence of longer phases without steering intervention followed by large, rapid steering motions is a sure sign of an inattentive driver (cf. also ▶ Sect. 38.3.2).

[18] assert that alpha spindle rates from an electroencephalogram (EEG, see also ▶ Sect. 38.3.2) make it possible to evaluate driver distraction and to differentiate between driving with or without secondary tasks in real traffic.

38.2.3 Applications of inattentiveness detection

Inattentiveness detection can, for example, influence adaptive warning strategies – in which a warning is issued or suppressed depending on the state of attentiveness – and adjustment of warning times, depending on whether a driver is inattentive or not.

In order to monitor attention orientation, a research vehicle from Continental AG (“driver focus vehicle”) was fitted with a camera on the steering column. By using an infra-red camera, the driver’s line of view can be detected at the highest degree of independence from environmental light conditions. In order to direct the driver’s attention towards a dangerous situation, [19] describes an approach using an LED light strip (◉ Fig. 38.1). Directing attention is particularly relevant if it can be determined beforehand that the driver’s attention is not currently focused on the critical area.

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Fig. 38.1 LED light strip to guide the driver’s attention [20]

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38.3 Detection of Fatigue

38.3.1 Definition of fatigue and tiredness

Fatigue is generally understood to be the reversible reduction in an organ or organism's functional capacity as a consequence of activity. Fatigue can be fully reversed through recovery.

Following the modificated stress-strain concept [21], fatigue can appear as a result of stressors and lead to an adjustment of human resources and capacities.

[22] defines fatigue as a state of temporary impairment to performance conditions because of sustained demands on activity where the potential for continual restoration of performance conditions is exceeded.

Using various characteristics, the concept of fatigue can be unpacked into stress consequences which differ systematically (see ◉ Fig. 38.2): in the literature, the terms fatigue, tiredness and drowsiness are rarely differentiated clearly. In this chapter the terms will be used synonymously, since detection of drowsiness is often discussed in a driving context.

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Fig. 38.2 Delimitations of the concept of fatigue according to [23] (translated by the authors)

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In his successive destabilization theory, [23] defines four degrees of fatigue which enable a description of the fatiguing process. While at the first level, the first scarcely noticeable disruptions in psycho-physiological functions appear, disruptions at the second degree of fatigue can be observed directly by the fatigued individual. Their average on the performance curve remains the same even if a high degree of performance variation occurs and the incidence of erroneous actions (e.g. driving errors) increases. At level 3 fatigue, however, performance diminishes. A further intensification to the fourth degree leads to conditions similar to exhaustion, which generally end in a refusal to perform.

This shows that fatigue is a slowly incipient process and that detection of fatigue is pertinent even at early stages of the process in order to undertake initial measures (e.g. warning the driver) during phases of fatigue which have not yet led to critical reductions in performance.

A study of truck drivers identified weakening attention and delayed reaction times to critical events as some of the consequences of fatigue [24].

38.3.2 Measuring variables and procedures for fatigue detection

Identifying driver performance (via steering behaviour and lane-keeping), blinking behaviour (e.g. via special eye-tracking systems), EEG and the pupillography sleepiness test are considered among the most valid possibilities for determining fatigue (cf. [4]). An electrocardiogram (EKG, used to measure heart rate among other factors) or subjective inquiry regarding fatigue can also be implemented. More reliable detection of fatigue is generally achieved through the combination of two or more measuring procedures.

Indicators which make fatigue recognizable can be fundamentally subdivided into human-oriented and vehicle-oriented indicators. The following section illustrates some of the potential indicators. An overview of potential procedures for measuring fatigue and existing systems for measuring fatigue is presented in [4].

Human-oriented measuring variables

Detection of eye activities is a valid, widely-used procedure for detecting fatigue during vehicle guidance (see ◉ Tab. 38.1). Detection of blinking behaviour is principally accomplished through camera-based systems or detection of glance behaviour through eye-tracking systems.

Tab. 38.1 Descriptions of a range of potential eye-oriented measuring variables

Measuring variable	Explanation of measuring variable	Literature
Pupil diameter	measured by pupillometry (camera-based, infrared light) fatigue can be determined through changes in diameter (frequency of pupil oscillations decreases) high susceptibility to environmental factors (brightness above all)	[10], cf. [25]
Eye openness	camera-based measurement is possible distance between upper and lower eyelid (smaller with emerging fatigue)	[6], [10]
Blink duration	camera-based measurement is possible longer if fatigue is present	[6], [9], [10]
Time delay before reopening of eyelid	camera-based measurement is possible longer if fatigue is present	[9]
Blink frequency	camera-based measurement is possible increases if fatigue is present	[9], [10]
Blink speed	camera-based measurement is possible becomes slower with increasing fatigue	[4], [6], [9], [10]
PERCLOS (PERcentage of eye CLOSure)	percentage of time for which the eyes are closed 80% or more with regards to the space between the eyelids camera-based measurement is possible increases with fatigue, but only begins to respond at advanced stages of fatigue	[26], [27]
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Using duration of eye opening and blink duration as indicators, [5] identified four stages of fatigue in road trials (partially comparable with [23], ◉ Fig. 38.3).

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Fig. 38.3 Classifying stages of fatigue [5] (translated by the authors)

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While at Stage 1 (“decreased vigilance”), attention performance lessens, driving performance still remains unchanged. Changes are identified in secondary tasks, while the driver potentially still considers themself absolutely wakeful. At Stage 2 (“tired”), the driver’s impaired condition affects driving performance. If fatigue continues, the driver reaches Stage 3 (“drowsy”), at which all resources are used up, making gross driving errors much more probable. At this point, at the very latest, the journey should be interrupted. Combining duration of eye opening with blink duration was determined to be superior to comparison using PERCLOS, since this affords higher sensitivity for earlier stages of fatigue (before, only ca. 40% of earlier stages of fatigue could be resolved) and since phases on the brink of falling asleep can be identified more reliably [5].

Using electrodes on the scalp, an EEG can determine changes in the frequency bands of brainwave activity, during which the incidence, duration and amplitude of so-called alpha spindles give indications of the existing degree of fatigue (for example [10]). At the moment, however, EEG measurement does not fulfil the requirement of contact-free measurement.

Finally, heart rate, heartbeat variability and skin conductivity can be used as measuring variables to register signs of fatigue.

Vehicle-oriented measuring variables

As fatigue rises, driving errors occur more frequently ([4]; cf. Stage 2 fatigue [23]). There are many approaches to evaluating data regarding driving behaviour (e.g. steering motions, speed and braking behaviour, deviations from the ideal course or parameters such as TTC; [8]) in order to determine a driver’s level of fatigue. The advantages of detecting fatigue from driving behaviour data lie in the contact-free and cost-effective recording of data. However, one disadvantage is that fatigue detection using data for horizontal vehicle guidance is difficult in city traffic due to the susceptibility to disruption based on route characteristics (cf. [4]).

In trials conducted by [28], during which fatigue was induced over the course of a three-hour test drive in the monotonous environment of a test facility, significant correlation was discovered between steering wheel reversal rate (SWRR, according to [29] the frequency at which the direction of steering was adjusted beyond a minimum angle (“gap”)) and a self-evaluation. With increasing fatigue, the frequency of large steering wheel movements grows, while the total number of steering wheel movements decreases. High standard deviations appear in the results of [28], which demonstrate the presence of strong differences between individuals.

Various applications of fatigue recognition are described in ▶ Sect. 38.5.

38.4 Detection of medical emergencies

The performance capacity of an individual is influenced by their current health condition, among other factors. This becomes particularly relevant in the case of changes to health condition which arise suddenly during a journey – e.g. the occurrence of medical emergencies, including heart attack or stroke.

Due to changing demographics, the number of older participants in road traffic is going to increase. A rise in medically-determined loss of control at the wheel can be expected. In particular, increased occurrence of cardiovascular conditions (heart attacks, for example) is to be expected [7], which can cause sudden incapacitation of the driver, often resulting in serious accidents. Monitoring health condition in order to be able to intervene during problems and e.g. bring the vehicle to a complete stop will therefore gain in significance.

38.4.1 Measuring variables and procedures for recognizing medical emergencies

[30] summarize that data from EKG, plethysmography (a procedure which measures volume fluctuations of an organ or part of the body) and monitoring blood pressure can be used to identify cardiac emergencies (heart attacks and cardiac arrhythmia) and syncopes (circulatory collapse) (see also ◉ Tab. 38.2). Additionally, indicators for epilepsy and strokes are also useful, with EEG data making both of these emergencies more readily detectable. While blood-sugar concentration can help to detect sugar shock, monitoring breathing can help to detect epilepsy and syncopes – at the moment, however, neither of these indicators are measurable during a journey with the current sensors.

Tab. 38.2 Measuring variables for detecting medical emergencies in vehicle (Excerpt from [30]; translated by the authors): + readily detectable, (+) detectable, o less readily detectable

	Cardiac Emergencies	Epilepsy	Syncopes	Sugar shock	Stroke
Electrocardiogram(EKG)	+	(+)	+	o	(+)
Plethysmography	+	(+)	+	o	(+)
Blood pressure	+	(+)	+	o	(+)
Electroencephalogram (EEG)		+			+
Blood sugar concentration				+	
Breathing	o	(+)	(+)	o	o

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Similarly, information about oxygen saturation levels in the blood, body temperature, along with the driver's position and movements are, in principle, suited to the identification of driver medical emergencies [31].

Recent research results demonstrate which sensors are capable of detecting health indicators during a journey – here, emphasis is placed on detecting heart rate. Assessment procedures using EKG, skin conductivity and oxygen saturation are also under discussion. Some research studies have evaluated the suitability of camera-based procedures, since they fulfil the requirement of contact-free measurement and can be combined with further applications in the vehicle (e.g. detection of fatigue or inattentiveness). Camera-based procedures can detect heart rate through changes in blood volume to blood vessels in the face (plethysmography), since this presents no limitations due to clothing. However, potential artefacts arise due to the lighting environment.

[30] have determined that a colour camera built into the combination instrument ensures good detectability of heart rate frequency at medium rates of artefact exposure, while other sensors (for example capacitive or magnetic inductive) are more susceptible to artefacts.

Even simple webcams are capable of detecting abnormalities in the heart's circulatory system by means of changes in degree of light reflection [32]. The ascertained values correlate up to r = 0.98 with the reference value, measurement via finger sensor. Even though the best results were ascertained from subjects sitting peacefully, equally good results were achieved during small movements. Problems arise in the case of large head movements and poor lighting conditions [32]. In addition to heart rate, which was investigated in the study, other indicators such as heartbeat variation can be measured with this method.

In the passenger car seat developed by [33] with a multi-channel EKG system in the backrest, capacitive electrodes measure heart activity imperceptibly and without contact, since this can be detected from potentials on the surface of the body even through clothing. Signal quality depends on pressure applied on the seat and is thus also dependent on body weight, height and stature. With a suitable configuration of electrodes, statistical tests can determine values for approximately 90 % of subjects. Factors which further influence signal quality include movement artefacts, which could arise during very dynamic driving behaviour, and the driver's clothing.

Using a sensor unit in the steering wheel, it is possible to measure heart rate, oxygen saturation and skin resistance [34]. With this sensor installed on the edge of the steering wheel, values were ascertained more than 81 % of the time in realistic driving tests. Over 90 % of test subjects wanted an emergency braking system which can identify a medical emergency and subsequently bring the vehicle to a safe halt.

38.4.2 Applications of an “emergency stopping assistant”

The requirements for an automatic emergency stopping system on highways, according to [30], are automatic continuation of driving and lane change execution until a risk-minimal stopping position is reached, no automatic increase in vehicle speed, strategies for warning or informing other road users, maintaining certain minimum speeds, integrating map data to determine suitable stopping possibilities and choosing a suitable control concept in order to avoid involuntary oversteering or braking (for example due to unconsciousness).

[35] describes an emergency stopping assistant which would make it possible to avoid accidents caused by health-related loss of control or to reduce the severity of such accidents. To this end, the assistant would bring the vehicle into a safe position in which a secured emergency stopping manoeuvre would be carried out, in an ideal case allowing the vehicle to come to a halt in the emergency lane of a highway (see ◉ Fig. 38.4). After coming to a stop, further steps such as first-aid or an emergency call could be initiated (eCall, see ▶ Sect. 38.5). [35] see particular challenges in the safe execution of a lane change – particularly in the case of heavy oncoming traffic.

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Fig. 38.4 Schematic execution of safe lane change (Source: BMW Group Forschung und Technik)

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38.5 Driver condition monitoring systems available on the market

This chapter describes systems for monitoring inattentiveness and fatigue which are currently available on the market in current vehicle models.

In addition to these, there are further systems which react, for example, to inattentiveness, but which are not assigned to monitor a driver’s condition. One such system is Daimler’s traffic sign assistant, which according to [36] was further developed such that warnings are also issued to drivers entering the highway incorrectly (“ghost drivers”). Another example are systems which warn when drivers unintentionally leave their lane (for example Audi’s “lane assist”, see also ▶ Chap. ID#0905). Distance and collision warning systems also become active when a driver does not react because of his or her present condition. So-called “eCall” systems (for example BMW’s “advanced/enhanced emergency call”), which become active during an accident after restraint systems (airbag, belt tensioner) are triggered – and automatically transmit data such as accident location and some data on the severity of the accident to a service centre – enabling an initial evaluation of the occupant’s condition.

It can be expected that, in the future, more systems will refer to driver condition as a direct input value.

ATTENTION ASSIST (Mercedes-Benz)
This system monitors driver condition with respect to fatigue and resulting inattentiveness. According to [36], drivers can always remain informed of the so-called “attention level” (state of attentiveness in five levels) detected by the system and begin planning a break at an early stage. If the driver is recommended to take a break, the system displays the “coffee-cup symbol” (see ◉ Fig. 38.5) already seen in the first generation. After issuing a warning message, the navigation situation offers a rest stop search. The system is active between speeds of 60 to 200 km/h. The driver has the option of setting the system to “sensitive” mode (alternative mode: “standard”), in which the algorithm reacts more sensitively and the driver receives earlier warning.

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Fig. 38.5 Various stages of attention levels from low (left) to high (right) [36]

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At the start of a journey, the system creates an individual driver profile which is then continuously compared with the driver's current behaviour [37]. The following indicators are consulted for recognition of increasing fatigue or inattentiveness: steering behaviour, driving conditions (speed, current time and length of journey), external influences such as crosswinds or road unevenness and behaviour regarding controls (e.g. the question of whether the turn signal is activated when changing lanes).

Driver Alert (Ford)
Using a front camera installed behind the inside rear-view mirror, Ford's system detects lane markings on both sides [38]. By comparing the ideal lateral position and the vehicle's current position, it is possible to infer whether the driver is fatigued, since a tired driver tends to swerve from side to side. As soon as a significant deviation is ascertained – and as long as this cannot be attributed to a lane change – a two-stage warning process is initiated. First, a warning signal is displayed on the combination instrument for 10 seconds, along with an auditory warning; if the driver subsequently shows further signs of fatigue, a more intrusive warning follows, which the driver must confirm by pressing a button.

Driver Alert Control (Volvo)
This system analyses how a driver proceeds between lane markings using a front camera, using a warning tone and display on the combination instrument to warn if the driver is fatigued or distracted [39]. The system compares steering behaviour with previously observed patterns and recognizes fluctuations in horizontal distance from lane markings.

Driver Monitoring Camera (Toyota) and Driver Attention Monitor (Lexus)
In this system, a camera installed on the steering column observes whether the driver is looking straight ahead and issues a warning if there is a threat of collision with an obstacle. Additionally, the system can provide braking support [40].

Fatigue Detection (Volkswagen)
Volkswagen's system (in the VW Passat, for example) warns the driver by means of a display on the combination instrument and an auditory signal when fatigue is detected and a break is recommended. According to [41], steering angle is the most important signal for detection. Other signals such as pressing the accelerator, lateral acceleration and the driver's activity with system controls are taken into account. The signals are compared with characteristic behaviour from the beginning of the journey.

38.6 False alarms and failure to alarm during detection of driver condition

The fewer false alarms ("false positives", i.e. the driver is not tired, but the system detects fatigue anyway) which occur in a warning system, the higher the system's degree of acceptance (cf. ▶ Chap. ID#0704). During system design, the target conflict between false alarms and failure to alarm ("false negatives", i.e. the system detects no fatigue although the driver is tired) must be taken into account by adjusting limit values and system algorithms accordingly.

This results in the issue that although there are possibilities for evaluating a driver's condition through various measuring procedures, research studies have not reached agreement as to limit values beyond which relevant effects of driver condition on driving safety are to be expected.

Since driver condition cannot be measured directly, but can only be inferred based on indicators of condition, it is recommended that several different indicators be used to measure and evaluate in parallel, even though the necessity of different sensors results in cost disadvantages.

Trust in the system can be lost, particularly when the driver receives false feedback about potentially recognized driver conditions such as fatigue, since drivers can generally evaluate their own condition and identify respective system errors. The driver may then potentially ignore further warnings from the system.

Current measuring procedures only seldom cite convincing proof of validation and also statements about the number of false or failed alarms are rare [4]. Since driver condition recognition systems represent a clear improvement in safety, further research and development is needed here.

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