Outils technologiques pour la détection de la baisse de vigilance chez les chauffeurs routiers

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Driver Vigilance related accidents: some facts

- In the 1990s, the US National Transportation and Safety Board paid attention to driver fatigue as one of the most important causes of road accidents (National Transportation and Safety Board of US 1999).
- Horne *et al* (1999) stated that 10-20% of all accidents is related to driver fatigue.
- Almost 25% of all serious truck accidents result from drivers falling asleep at the wheel (Statistische Bundesamt)
- Boussuge, J., (1995) found that fatigue and/or drowsiness of the Driver caused around 30% of accidents in French highways in the period 1979-1994, whereas about 40% of fatal accidents on US highways are sleep-related (Garder, P, 1998).
- A French survey reveals that drowsiness is among the main causes of fatal accidents, with excessive speed and alcohol
- A French survey 2007 (internet and phone - motorway subscribers) shows that about 16% of the drivers recognize a critical situation (close to accident) due to sleepiness and about 7% report an accident due to sleepiness on the wheel.
- AFSA study shows that 43% of fatalities on French motorway are due to fatigue, hypovigilance or sleepiness

Major causes of Human related road accidents

- A bad perception of the environment (obstacle, .);
- A bad knowledge of the driving environment
- A low training ("Sunday" drivers, young drivers, etc);
- Over working load (driving in difficult conditions, in complex conditions, . . .)
- Under working load (monotonous driving conditions on motorway for example);
- Socio-economic pressure leading to over-speed long driving period etc..
- Reduced physical (old people, elderly drivers) conditions,

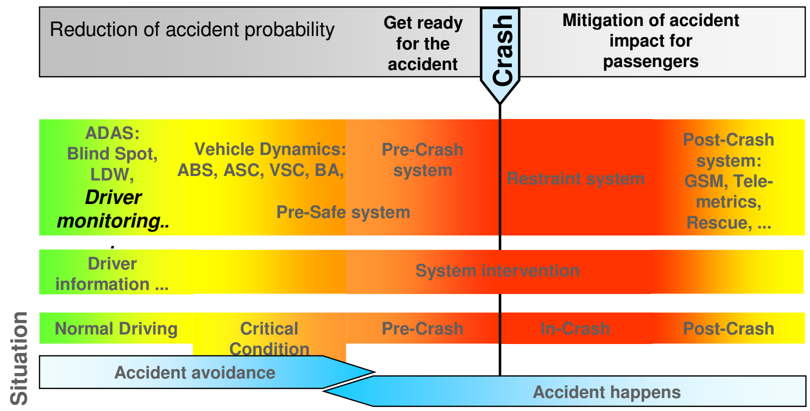
- **Reduced physiological state (drowsiness, sleepiness, . .)**
- **Distraction (telephone, chatting, external attractors, advertisements, . .)**

Is there any solution?

- Improved education
- Improved training
- Awareness campaigns
- . . .
- Technological solutions through on board systems monitoring driver state and activities.

- Driver monitoring systems aims to detect reduced driver vigilance or impaired driving and inform/warn the driver of potential accident risk.

When monitoring the driver?



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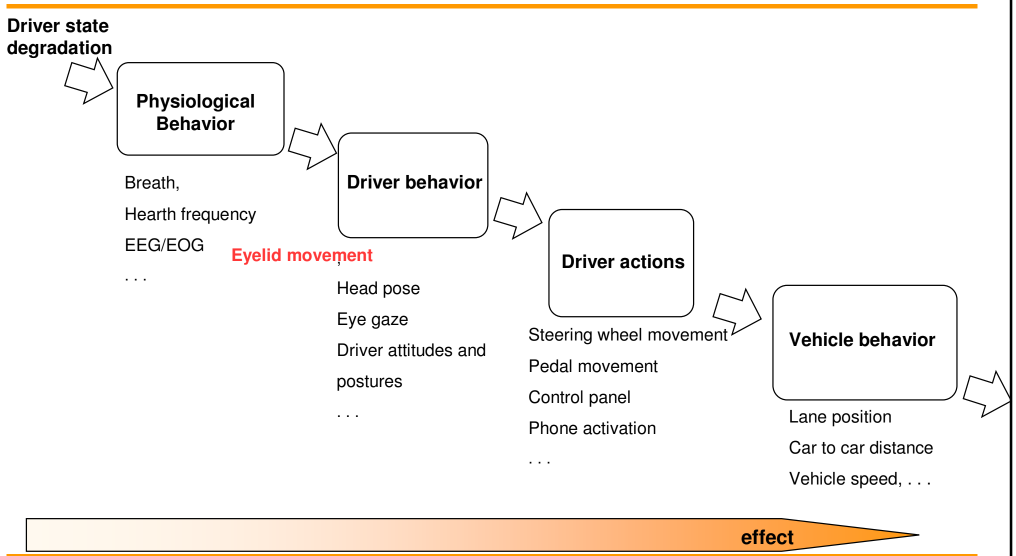
How to monitor the driver?



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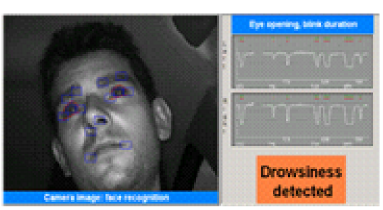
Driver vigilance diagnostic based on eyelid movement observation

Physiological diagnostic

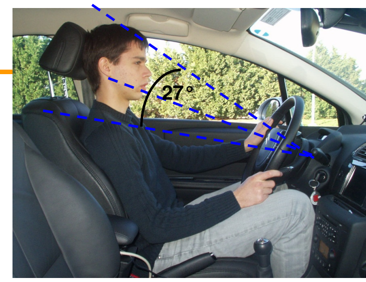
Concept

Main concern of the physiological diagnostic is to detect driver’s sleepiness and drowsiness signs from the video observation of his face and his eyelid motion

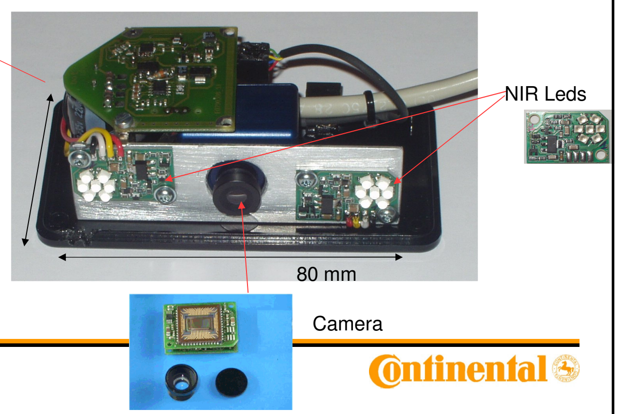


- Non-intrusive Monocular CMOS vision technology observing driver's face/eyelid movements
- Pulsed NIR light (non visible) for day and night operation, synchronized with camera shutter
- Real time image processing for face and eyelid detection and tracking.
- 4 levels« Physiological Diagnostic » - Fuzzy rules

Hardware implementation into the experimental vehicle

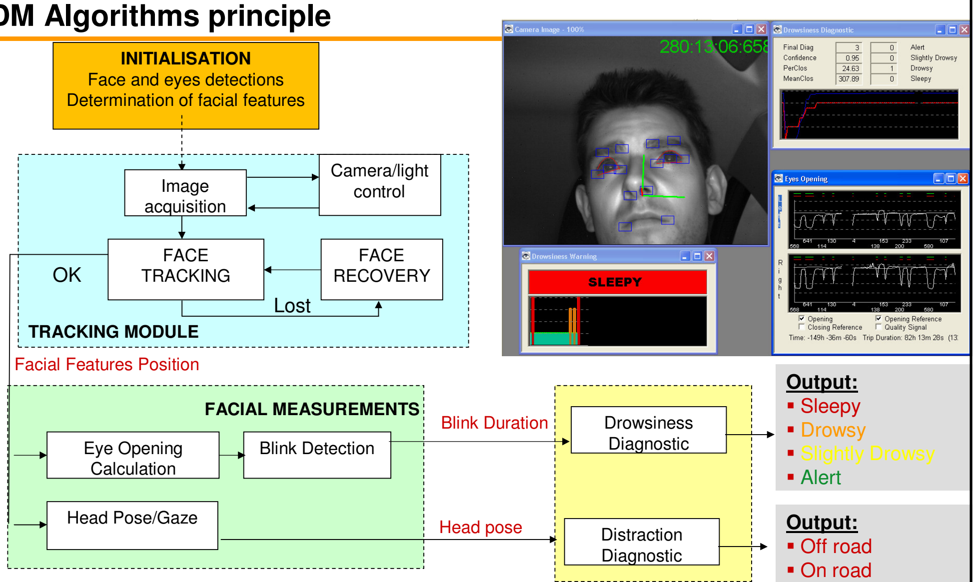


- Top of steering column
- Micron camera
- Cut visible optical filter
- Flashing NIR Lights: 2*7 Leds
- Angle of view : 41° (H) X 27°(V)
- Inclination: 16°



Camera integration

DDM Algorithms principle

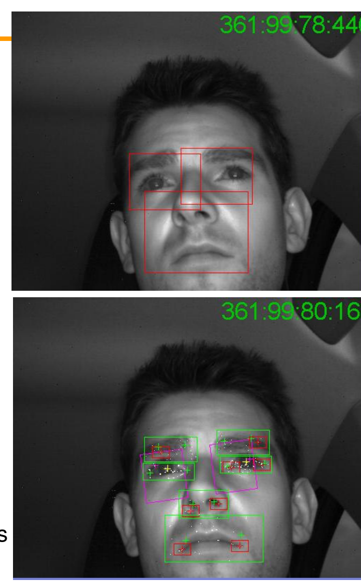


Face detection principle

- Feature based approach: small areas of the faces are used to locate eyes/eyelid. Features are determined during the off line initialization phase and then tracked at frame rate.

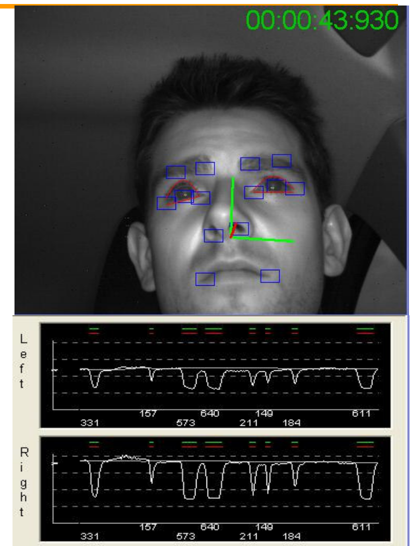
Initialization

- Detect drivers face through an ADABOOST learning based algorithm
- 3 Components: left eye, right eye and mouth
- Detection of nostrils and eyebrows, eyes corners and mouth corners features using Harris points and SIFT characterization..
- Initialization is done at the beginning of the drive once driving activity is stable; refreshed if quality index becomes low



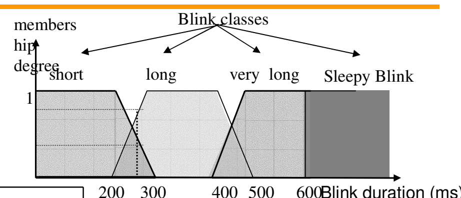
Face tracking principle:

- The 14 features are tracked at frame rate using ZNCC correlation and multiple geometrically constrained Kalman filter
- Quick (1 image) recovery of features after a quick head rotation
- Eyelid detection using elliptical model fitting for the upper eyelid and a line fitting for the lower one
- Opening measurement
- Blink extraction
- Blink duration measurement

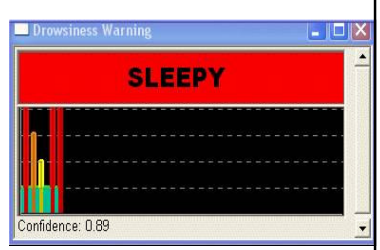


Drowsiness diagnostic:

- Drowsiness Diagnostic using fuzzy logic depends on the number of blinks of each category (Short, Long, Very Long, Sleepy Blink) that can be observed in a time window
- 3 Drowsiness warnings refreshed every 30 seconds



Warnings	Rule of detection	Description
Alert	The driver has very few long blinks and very few very long blinks;	Driver is alert; no sign of drowsiness;
Slightly drowsy	The driver has few long blinks and very few very long blinks.	First signs of drowsiness; Driver should only be informed;
Drowsy	The driver could have some long blinks and few very long blinks or simply some very long blinks.	Driver is drowsy; Fighting sleep; Degradation of his/her driving performances; Driver must stop and take a rest.
Sleepy	The driver has some sleepy blinks	Driver Almost falling asleep; Critical state; Driver must stop urgently.



Potential HMI:

- Seat or seat belt vibrations
- Buzzer for sleepy state
- Vocal messages
  - SLIGHTLY DROWSY: Upcoming drowsiness detected: Please be careful
  - DROWSY: Drowsiness detected:Please take a rest
  - SLEEPY: Sleepy behavior detected; Caution; Please take a rest immediately
- Break pulses
- ...

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Experimentations

- 11 drivers; 7 men, 5 women; ages: 25yo to 47; Total duration: 40 hours
- Real driving conditions, on motorway; night and day conditions
- Agreement given by the French ethic committee to perform bio-medical experiments
- Drivers are equipped with electrodes to record their EEG and EOG for providing a physiological expertise; 4 levels EEG/EOG expertise.
- Partnership with Dr Tiberge (Unité du sommeil de l'Hopital de Toulouse Rangueil)
- Driver self rating every 5 minutes on the Karolniska Sleepinees Scale

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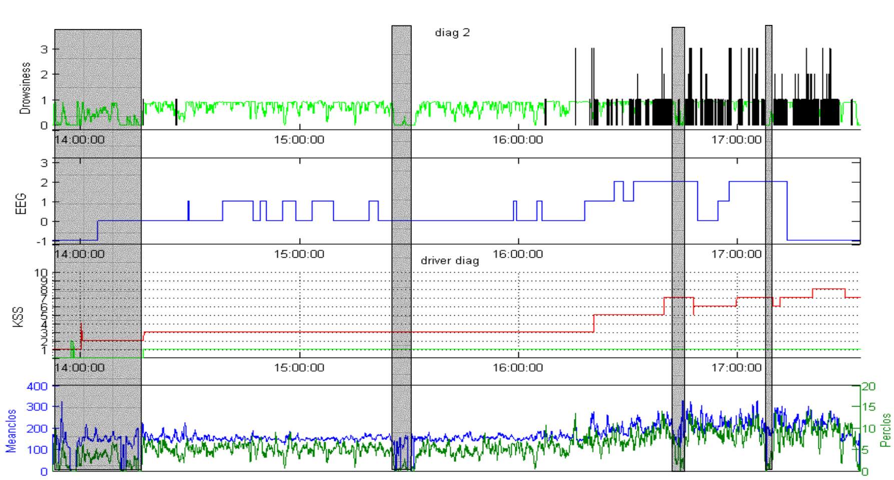
On-road experiments



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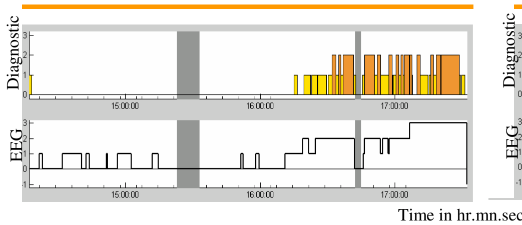
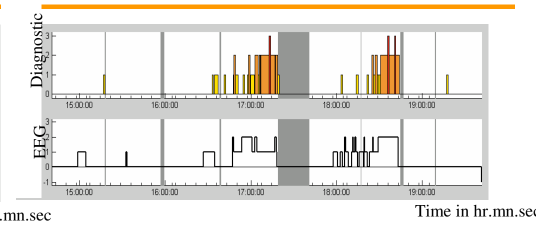
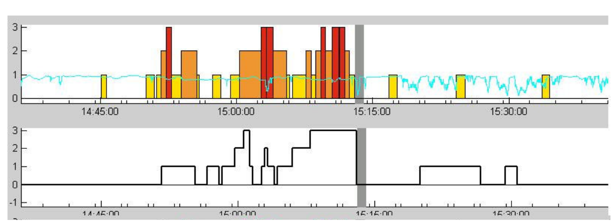
On-road experiments



Driver 05



Driver 11



Driver 10

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Statistical results

- ***Blink Detection***
  - *Tested on a 86 subjects of different sex, skin color, age.*
  - *Blink Average-detection rate: 88 %*
  - *Blink Average false-alarm rate: 0.35%*

- **Drowsiness diagnosic** compared to biomedical expertise EEG/EOG based
  - 11 drivers on real driving conditions
  - Average detection rate: 84%
  - False Alarm rate: 4%

Conclusions

- A robust vision based system for monitoring driver's vigilance has been designed, able to work autonomously in various conditions by night or day with critical sun illuminations.
- This system has been implemented in an experimental vehicles (truck and light vehicles).
- The camera has been fully integrated in the vehicle instrument cluster leading to a good driver acceptance.
- The system has been tested in real driving conditions with different drivers.
- The results achieved are very promising with a very high detection rate and an extremely low false alarm rate for most of the drivers.
- Some problems remains with drivers wearing glasses

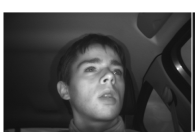
- Future steps:
  - Test and evaluation on a wider driver sample
  - Test of the complete process including HMI in regard with Driver acceptance.
  - Fusion with behavioral diagnostic to reduce false alarm rate

Driver visual distraction diagnostic based on head movement observation

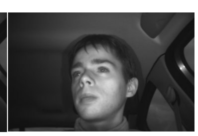
Driver Visual Distraction Monitoring concept

(Based on head pose measurements)

- Detection of driver's visual inattention based on head orientation. Two head poses are identified:
  - ON-ROAD: head is turned toward the road
  - OFF-ROAD: head is **not** turned toward the road



OFF ROAD



OFF ROAD

ON ROAD

Highlights:

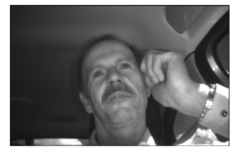
- Same camera as drowsiness one
- Robust to Glasses, sun glasses, partial face occlusion, etc…
- Learning based approach: only on-road poses are learned
- Visual time sharing and Visual distraction diagnostic

ON road poses definition

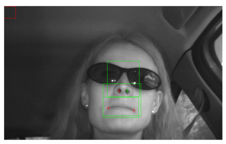
- Left/right rotation range: ± 20°
- up/down rotation range: ± 15°

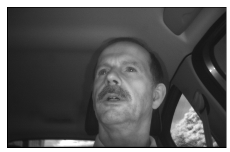
- Some examples of ON road poses

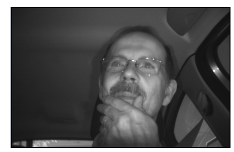
Looking 20° to the left



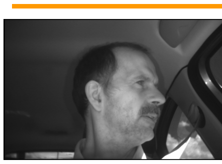
Looking 20° to the right



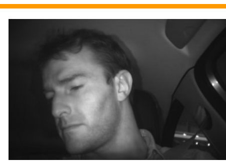




Examples of OFF road poses

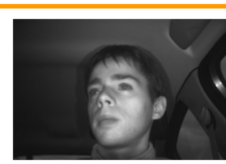


Looking though the left window

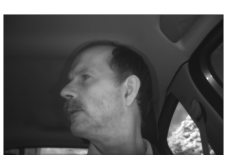


Looking at radio display (-25°, 28°)

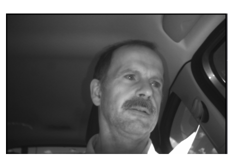
Looking backward



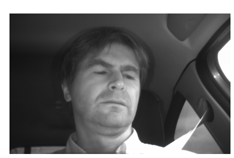
Looking at central mirror (5°, 37°)



Looking at right mirror (-6°, 64°)



Looking at left mirror (-6°, 45°)



Looking at gloves box (54°, -39°)

Principle of head pose detector

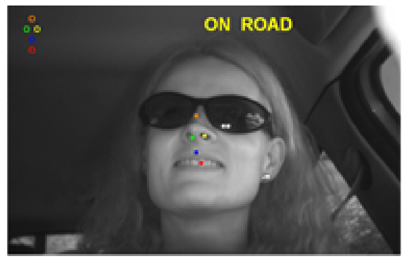
- Learning component based approach; learning of on-road pose
- A defined number of components must be detected to detect an on-road pose.

No glasses components

- Right eye
- Eyes pair
- Left eye
- whole nose
- nostrils

Glasses components

- whole nose
- mouth + nose
- Mouth
- nostrils



Driver visual distraction diagnostic

- Visual Distraction Diagnostic: time driver is continuously off-road
- Visual Time Sharing Diagnostic: proportion of off-road time on a sliding time window

Results

Pose detection

- No initialization. Detection is performed at frame rate.
- Frame rate: 50 ms
- Position Range: >95% eye ellipse
- On-road gaze Range
  - Yaw range: ± 20°
  - Pitch range: 10° up, 20° down
  - Roll range: ±18°
- First real driving tests: Good detection rate, very low false alarm rate:
- Robust to glasses and sun glasses

Inattentiveness diagnosis:

- Accuracy: 2 levels (attentive, distracted) updated at frame rate
- Latency:
  - 400 ms for On-road to Off-road transition
  - 100 ms for Off-road to On-road transition

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Behavioral diagnostic

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Behavioral diagnostic

Main concern of the behavioural diagnostic is to detect abnormal driving behaviours and to distinguish between safe and unsafe driving

- Abnormal driving is not only due to drowsiness It can also be due to, fatigue, etc.
- Different information can be used to perform this diagnostic, depending on the task the Driver has to perform; lateral control, lane keeping, longitudinal control, frontal distance keeping, etc. . . .
- The diagnostic must be personalized and then should include learning phase
  - each driver has a personal way to drive.
  - each driver reacts differently to hypo-vigilance.
  - only learning of vigilant state is possible.

Behavioural diagnostic includes several processing steps:

- The Learning process.
- The abnormal driving event detection and classification.
- The abnormal driving condition detection and classification providing a 3 levels score.

Behavioral diagnostic

Dynamic input variables:

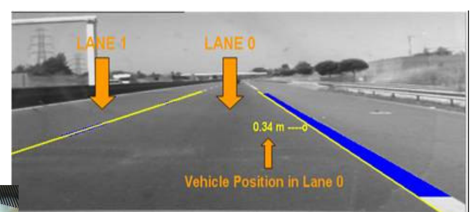
- Video image of the road (10 frames per second)
- Left indicator status (flashing or off).
- Right indicator status (flashing or off).
- Steering wheel angle position.
- Vehicle speed

Static inputs:

- Vehicle Width (m).
- Lane Width (m).

Output:

- 3 levels behavioral score: 0=Normal, 1=Abnormal driving, 2=Dangerous

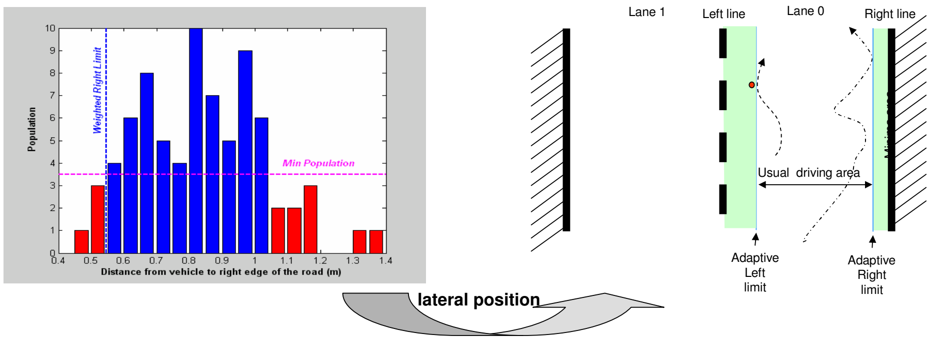


Estimated/calculated variables:

- Lateral position.
- Lateral speed,
- Weighted Lateral Speed (mean value of the Lateral Speed between two extremes of the vehicle trajectory).
- The Vehicle Lateral Acceleration
- Position, on the road, of the lane
- Vehicle position in the lane (processed from a camera image

Behavioral diagnostic

Drive SAFE Project



The learning module records, analyzes and models some parameters characterizing the way of driving for each Driver, in normal driving conditions.
These parameters are learned during the first ten minutes of the trip that is considered as the reference period and then re-adapted all along the trip

Behavioral diagnostic

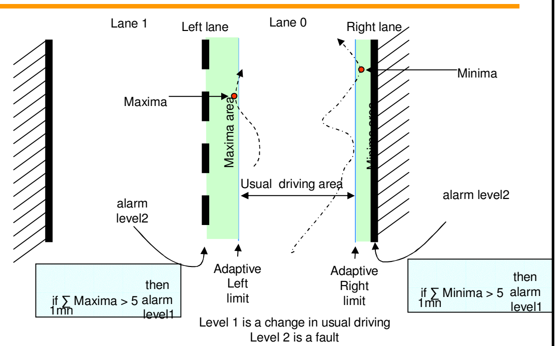
Drive SAFE Project

Abnormal driving event detection and classification is performed by comparing the current data acquisition and derived variables to the characteristic variables issued from the learning process.
It is using a set of predefined deterministic *if – then* rule.

Abnormal driving condition is achieved by analyzing the number, the frequency and the distribution of the detected abnormal events.

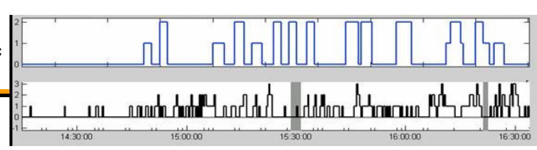
A set of rules deduced from on-road experiments and databases has been set up.

The output is delivered each $\Delta T_{1...}3$ behavioural score [0, 1, 2] (Normal, Critical, Dangerous)



There is at least N consecutive fault detections.
or
M groups of less than N consecutive faults appear in less than T seconds .
Then
Abnormal driving index is set

Behavioral diagnostic



Reference expertise

Driver vigilance diagnostic based on data fusion

Fusion objectives

Combines behavioural and physiological diagnostic; Use of contextual parameters (time of day, driving duration)

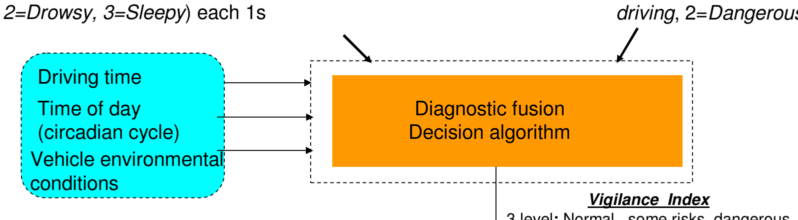
- reinforce vigilance diagnostic
- reduce false alarms
- requires longer time window of analysis → delayed warning

Physiological Diagnosis (Eyelid):

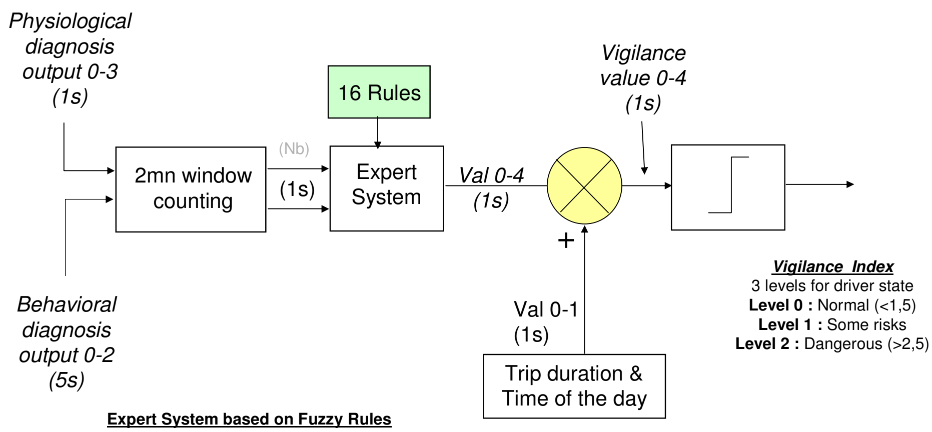
Input : number of eye blinks and duration
Time window for Diagnose= 30 seconds
Output : 4 diagnosis levels (0=Alert, *1=Slightly Drowsy, 2=Drowsy, 3=Sleepy*) each 1s

Behavioral Diagnosis (LDW):

Input : Vehicle position on the road
Learning time for diagnose = around 5 minutes
Output : 3 diagnosis levels (0=*Normal,* 1=*Abnormal driving*, 2=*Dangerous*) each 5s



Fusion principle



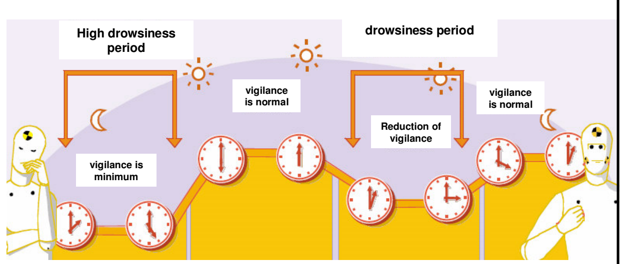
Expert System based on Fuzzy Rules

Example : *IF Nb of Level 2 of Behavioral Diagnosis is MEDIUM*
AND Nb of Level 1 of Physiological Diagnosis is BIG
THEN Output Value is BIG

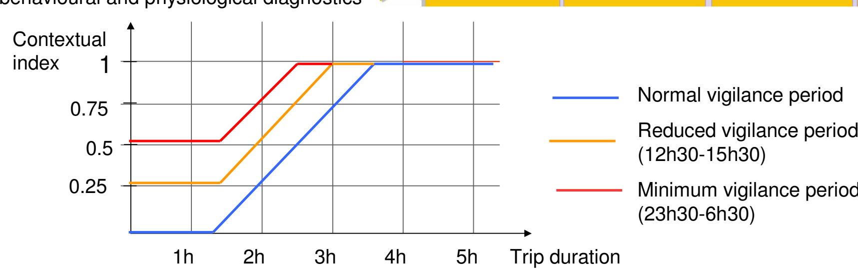
Contextual information and final diagnostic

Trip duration :
2 hours driving the Reaction time is increased by 2 (2s)
Increases of the braking distance

- Time :
vigilance cycles (Circadian cycles):

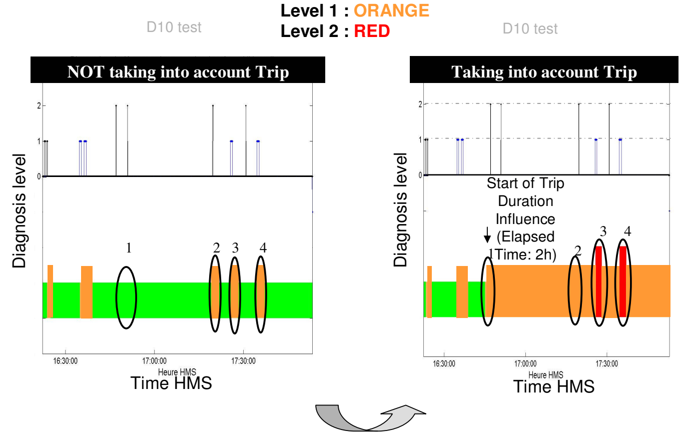


- The contextual information reinforces the decision provided by the fusion of the behavioural and physiological diagnostics



Influence of the Trip duration

Level 0 : GREEN
Level 1 : ORANGE
Level 2 : RED



Conclusions

Diagnostics issued from each of this individual information are not reliable enough to guarantee a high level of performance.

Fusion of multisource diagnostic should compensate the individual gaps to provide more robust information.

Furthermore, the addition of complementary in-vehicle and contextual information should also contribute to the improvement of the diagnostic.

Multi-sensorial techniques has been proposed.

The fusion of driver's and vehicle behavioural information as well as contextual information is obviously very promising.

The first experiments performed in real driving conditions with normal drivers have proven its efficiency.