

Development of an Active System in Order to Detect Drowsiness

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ABSTRACT

Driving is a very complex activity which requires the driver's full attention. Nowadays, the human factor is linked to the majority of accidents [1], and driver distraction is a principal cause.

The objective of this project was to create an active safety system for testing with somnolent drivers in real driving conditions, and so it was necessary to create a system which allowed the driver to handle the car without interfering with driving. The system we developed is composed of a GPS which checks the position and velocity of the vehicle continuously, a robot which decides with GPS data if the vehicle is being properly driven and an actuator over the brakes to stop the car if necessary. The robot takes control of the vehicle if it is not being driven correctly in order to prevent a possible accident. Moreover, an environment closely representative of today's roads was created to make the driving experience more real. This included a circuit with bends or corners to check the capabilities or reactions of the driver.

The main objective of the tests was to acquire behavioral and biomedical signals of the drowsy drivers while driving, but keeping them safe in a controlled environment. Therefore, the task of stopping the vehicle depended entirely on the system. Additionally, there were redundant devices which would stop the car to prevent an accident in the event of any failure of the primary system.

The system developed in the project opens the doors to experimentation with drowsy drivers in real driving conditions, in which there is the possibility of loss of control of the vehicle. It can also be used to increase safety at test track facilities or for other control applications in which safety is fundamental.

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INTRODUCTION

The fatigue phenomenon involves an alteration in the levels of the driver's awareness and perception which affects the psychomotor processes that are crucial for safe driving. One factor that is particularly dangerous is the decrease in the driver's own ability to judge whether he or she is in a condition to drive. Symptoms of fatigue include frequent yawning, low concentration, and drowsiness, slow reactions, irritability, making few corrections and driving slower, difficulty staying in lane, having micro-sleeps, etc. The symptoms vary greatly among drivers, so the search for robust algorithms is not a simple task. Sleepiness is one of the most notable effects of fatigue, though not the only manifestation. Fatigue and sleepiness are extremely dangerous because they reduce driving capabilities [2].

Among the main factors involved in the phenomenon of fatigue and sleepiness are the circadian rhythms, which are

the biochemical and physiological processes that follow a 24-hour cycle by which people tend to stay awake during the day and sleep during the night. These cycles mean people have a significant reduction of their driving capabilities during night-time hours and also, but to a lesser extent, between 1 and 3 o'clock in the afternoon. Another factor is the phenomenon of micro-sleeps, which are a series of episodes of unintentional loss of attention (from minutes to a few seconds), associated with the phenomenon of daydreaming. These frequently occur when the person is fatigued or subjected to a monotonous task such as driving. In a micro-sleep the person is not capable of responding to external stimuli. The more a person has been subjected to sleep deprivation, the more likely they are to have micro-sleeps.

The main objective of this project was to identify, analyze and determine a minimum number of biomedical variables and/or variables of driver behaviour (movements of the steering wheel, the vehicle position in lane, etc.) necessary to



detect states of alertness which are unsuitable for driving because of drowsiness or fatigue, and the design and development of a prototype system for the detection of drowsiness or fatigue which can identify the different states of alertness.

Firstly, the following two kinds of tests to collect data from drivers were carried out:

- Tests on the road with drivers driving on monotonous and tiring roads, but without feeling sleepy. As soon as they felt drowsy or tired they had orders to stop the car and take a rest.
- Test with somnolence on a simulator until the driver fell asleep. The aim of those tests was to pick up data of the non-return moment, from which the driver is sleeping and the accident imminent. However, the data were not reliable because the environment was not representative of real driving conditions, as the subjects did not have the “tools” to prevent sleep (they can not open the windows, use air conditioning, the radio, etc.). These tests were done in a controlled environment and with all the devices to monitor the driver as shown in [figure 1](#):

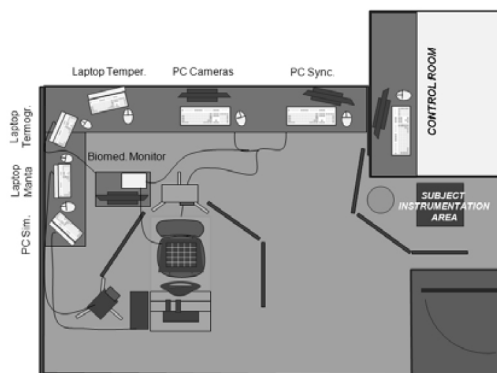


Figure 1. (a) Test equipment; (b) Test room (source FICOSA)

BODY

TESTS WITHOUT SOMNOLENCE

Measurement protocol

The objective of the real vehicle tests [3] was to prove that the behavioral and biomedical parameters that we chose

as indicative of somnolence in simulator tests were useful in detecting drowsiness in real driver performance using a fleet of professional drivers. The participants in the test were professional drivers (21 male, 2 female) with ages between 26 and 56 years (35.5 ± 8.9 years [mean $\pm$ standard deviation]) and no clinical conditions. These tests were performed on IDIADA's Proving Ground and on routes outside its facilities which were familiar to the drivers. The tests were carried out on two different routes: highway and mountain [4], to analyze the driver behavior with different concentration levels [5].

To perform these tests, a real vehicle was equipped with a biomedical monitor (Bitmed eXim Pro, BitMed) and an infrared high resolution camera. The biomedical signals selected as significant for this test were the external observer (video), Electroencephalography (EEG), Electrooculography (EOG) and thoracic effort. The thoracic effort signal was measured in all cases using an inductive band located at the middle trunk above the diaphragm. The respiratory signal was sampled at 100 Hz and filtered with a 5 Hz low-pass filter. The EEG signal was measured with a composition of four EEG single electrodes located on the vertex zone of the cranium and attached to the head surface with colloid. The EOG signal was measured with four Electromyography (EMG) single electrodes: two were located in the outer cantus of each eye in the case of the horizontal EOG setup, and two more electrodes were located in the upper part and in the lower part of the right eye. Video signal was recorded to generate the external observer variable with an infrared high resolution camera.

Once the subjects had been seated and connected to the acquisition systems, they were asked to drive for 8 hours on a real highway or a mountain route stopping for at least 10 minutes every two hours of continuous driving or every time they felt drowsy [6]. [Figure 2](#) shows an image of the measurement environment.



Figure 2. Instrumented subject in vehicle

TESTS WITH SOMNOLENCE

The aim of these tests was for a driver to drive the car until he or she fell asleep but without accident or injury to the car or driver. All the tests were done maintaining the safety of the driver and all the personnel involved. The car was equipped with the same instrumentation as the tests without

somnolence, and furthermore with special measures to keep the driver safe.

The tests were done during the night to increase the effect of the circadian rhythms and with a driver in a state of sleep deprivation to try to ensure the no-return point was achieved during the test. The driver was only allowed to drive on the test track, to avoid accidents before the test began. However, if the driver did not fall asleep during the test, the test was stopped when the night shift finished.

The tests were defined as follows:

The circuit

The tests were done in one of IDIADA's largest dynamic platforms which forms a cone with a 300 m diameter circle inside. The long straights and wide curves made the circuit very monotonous. The aim was to drive as fast as possible, and to try to get a similar feeling as on a highway, where somnolence more frequently appears.

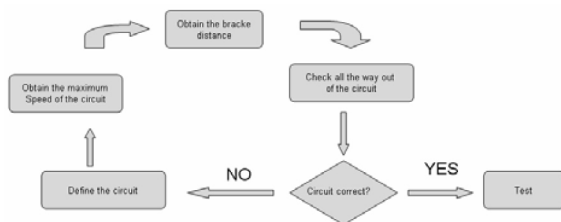


Figure 3. Flowchart of the test process in closed circuit

For a given brake force we obtained a deceleration curve for our car and for each deceleration curve we designed an appropriate circuit with a maximum speed from which a brake distance was obtained. All the runout area around the circuit had to fit with this safety distance; if not, a new circuit was defined and another loop of the flowchart shown in figure 3 was done, until the correct circuit was found. All the drivers found a medium deceleration curve to be suitable, but we were able to modify this if it was too hard.

Bends or corners were also necessary to check if the capabilities of the driver were still correct or if their reactions were too slow. For safety reasons, only our test vehicle was allowed on the dynamic platform.

The robot

A driving robot took control at the moment the driver lost it. This robot normally controlled all the parameters and the driver supervised its behavior, but in the case of this experiment it switched roles and the robot supervised the driver with a program created especially for this test.

This program started a thread which stopped the car when the following conditions were met:

- The vehicle goes out of a predefined area. This means that the driver was not able to keep the car on the defined route. According to the robot braking distance, minimum distances from the perimeter of this safe area and the perimeter of the platform are established. The experiment is finished when an

accident would appear in the real world. A small lane departure is allowed before the robot starts braking.

- The vehicle exceeds a defined speed. This is measured by the GPS system and if this speed is exceeded the robot will not be able to stop the car within the platform. The driver has lost perception of the speed and this can be unsafe. The experiment must finish. No lower limit is defined. If the driver must stop the car it is possible to do so without stopping the experiment.

- The GPS location of the robot has poor accuracy. This may be unsafe and the experiment must be stopped. The robot checks the accuracy of the GPS continuously and when it is over 2 cm it sends the order to stop, as in the two conditions above.

- The computer with the program fails. In this case the watchdog square signal emitted by the computer will either be alternated (amplitude or frequency change) or fully stopped. When this is detected by the robot, the car is then stopped.

The car is stopped by actuating its braking system. Figure 4 shows the actuator over the brake pedal of the car. The robot does this with a controlled deceleration which begins gradually and ends much harder. The robot is set up to stop a car at 65 km/h in only 50 meters and has been specially modified to be non-intrusive and not disturb the driver.

An extra signal is received when the robot actuates in order to warn the team supervising the test and to launch an actuator which stops the engine before it is stalled.



Figure 4. Image of the brake pedal of the robot mounted in the car (source IDIADA)

The environment

As the entire environment had to recreate the conditions of a normal road in order to acquire the data related to driving, and the driver had to be monitored, some road markings were placed on the dynamic platform with three different intentions:

- To guide the driver on the track.