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Statistical, Probability and Spectral Analysis of Test Driver Trajectories – 24 Hours Monitoring

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Abstract: Driver's fatigue is a common source of traffic accidents. In this paper, a methodology is developed to measure and evaluate dynamic behavior of the driver, determine the differences between the behavior of unwearied and fatigued driver and to develop a mechanism to detect possible dangerous situations. The method for fatigue monitoring is based on monitoring and analyzes of the driver´s trajectories. Position of the vehicle on the road was continuously monitored by a camera and the lateral position was evaluated from the designed reference guide line. Sets of test drives were performed within 24 hours on a driving simulator.

Keywords: Driver fatigue, analysis of driver trajectory, Allan deviation, Poincare distance, probability analysis, spectral analysis

1. INTRODUCTION

A driver fatigue is a major cause of traffic accidents. The fatigue can acutely impair driver´s alertness and performance.

Fatigue is generally used in everyday speech to describe a general set of feelings, including any one of following: tiredness, sleepiness or physical wariness. However, the term is too vague and it is necessary to state fatigue in terms of an operational definition. Brown in 1994 defined fatigue as a disinclination to continue performing the task. Brown also distinguished physical fatigue from mental fatigue (Brown, 1994). Driver fatigue is defined as a state of reduced mental alertness, which impairs performance of a range of cognitive and psychomotor tasks including driving (Williamson, Freyer, Friswell, 1996). Driver fatigue depends on factors like time of the day and sleep dept. The fatigue and decreased attention take effect especially during long monotonous driver on the highway at high vehicle speed. Sleep dept also consequently reduced driver performance. People in fatigue show some visual changes. Fatigue is easily observable from changes in their facial features like eyes, head and face. Due to the fatigue, driver's reactions are slower and his abilities to analyze and evaluate a dangerous situation properly and soon enough are lowered.

The effect of fatigue on driving performance has been widely studied from physiologists and transportation experts. There are different approaches how to measure the driver fatigue (Lal and Craig, 2001). Numerous physiological parameters such as electroencephalography (EEG) (Lal and Craig, 2005; Jap et al, 2009) and electrooculogram (EOG) (Shuyan and Gangtie, 2009) can be used to measure the level of the driver fatigue. Other types of methods for the fatigue monitoring are based on video monitoring of the eyes (Kozak et al, 2005)) or monitoring driver head position. In the last decade many researchers have been working on the development of the monitoring system using these techniques. The problem of these techniques is that they are intrusive. They need to attach some electrodes on the drivers, causing annoyance to them. Other techniques monitor eyes and gaze movement using special helmet or special contact lens, which are still not acceptable in the practice. In order to enhance driving safety and comfort, some leading car manufacturers have already included the driver monitoring systems among the technical accessories of luxury vehicles and advanced trucks. Developing a system, that actively monitors the driver fatigue in real time and produces alarm signal when necessary, is important for the prevention of the accidents.

Other types of methods for fatigue monitoring are based on equipment parameters such as steering activity of lane deviation (Havlikova and Sediva, 2012). The lane-related measures are computed from the relative position of the car to the lane border. They include, for example: lane deviation, standard deviation of the lane position, the global maximum lane deviation and the mean square of lane deviation. The last of these is considered to be a reliable measure for detection of fatigue. This is also main focus of this paper.

2. FATIGUE AND ITS SYMPTOMS

Definition of fatigue is not uniform, but the fatigue can be classified into physical and mental categories (Lal and Craig, 2001). It is possible to distinguish several types of fatigue depending on the place of fatigue effect or based on the causes of fatigue.

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2.1 Physical fatigue

One type of the physical fatigue is a muscle fatigue. It is perceived as feeling the pain and is clearly identified.

2.2 Mental fatigue

The mental fatigue is observed as a reduced efficiency for mental tasks. It manifests indifference to the assigned functions. An attention is specifically affected by mental fatigue. This type of fatigue is in many cases not felt nor perceived by the affected person.

There are the individual´s subjective feelings, which are difficult to quantify. The most frequent example of this type of fatigue is visual fatigue. The mental fatigue may be caused by adverse factors like excessive noise or vibrations.

Very dangerous manifestation of fatigues is a micro sleep, which occurs when there is an excessive burden on the mental abilities mostly during monotonous activities. The micro sleep is a very complex neurophysiologic phenomenon.

3. MEASUREMENT AND METHODS

The aim of experiment was to monitor and evaluate of the driver fatigue and more specifically driver during stressful journeys. That means to find specific characteristics and quantifiers that would detect deterioration control driving skills with increasing fatigue. The intention of our work is to get as a maximum of information about the quality of the drives during the whole day monitoring and evaluate how the driver fatigue effect on the size of the characteristic.

3.1 Participant

A total of 13 participants volunteered to take part in this evaluation study. Twelve were male and the remaining one was female. The mean age of the participants was 28 years and ranged from 25 to 65 years. All participants held a drivers license and mean length of time the licence had been held was 9 years.

During the testing drives they did not have consumed any drugs (alcohol, medicines ...), coffee or other exciting agents.

3.2 Design of experiments

All experimental data were acquired by cooperation with Laboratory of Telematics, Czech Technical University in Prague, Faculty of Transportation Sciences.

The testing track was designed as monotonous drive without the need to respond quickly to ambient conditions, without interaction with other road users. The driver concentrates mainly to car control and he maintains the vehicle in the traffic lane. The position of the vehicle from the reference line is continuously monitored by camera.

At first the length of the testing track was 10 km. During the test experiment it was shown that the test drive was not sufficiently long and the driver fatigue occurred sporadically. For this reason the testing track structure has been changed. It was extended to 30 km (three laps with a length of 10 km).

The test drives underwent *N* testing drives within 24 hours. The break between the test drives was at least 2 hours. During the whole 24 test day the drivers were performing their standard daily job activities.

3.3 Driving simulator

Driving simulation is an attractive and safe method for assessing driving behaviours. The main advantages of using simulators are:

a) The simulators provide the opportunity to safely study dangerous situations for the driver.

b) The parameters relevant to the driving test can be recorded and experimental setups can be strictly controlled.

c) The simulators save time and money compared to real driving protocols (Davenne et al., 2012).

The experiment was carried out using a simulator utilizing a Škoda car cockpit (see Figure 1), which simulated behaviour of a real vehicle relatively exactly. The image of the open road being simulated was displayed in front of the vehicle, thus the virtual reality scene was created (Novotny and Bouchner, 2008). The camera for sensing of the position of the vehicle from the reference line – the line separating lane, was installed in the vehicle. The vehicle was equipped with the steering wheel angle sensor, vehicle speed sensor and sensor of travelled distance. The trajectory of the vehicle was assessed using the record and specially developed software for the image assessment. Method of the processing and evaluating data is captured in real time using MATLAB.

Fig. 1. Driver´s view from the simulator cockpit *(Novotny and Bouchner, 2008)*