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REVIEW ARTICLE

Non-intrusive Methods used to Determine the Driver Drowsiness: Narrative Review Articles

FARIBORZ OMIDI[1], GEBRAEIL NASL SARAJI[2*]

[1]*Students' Scientific Research Center, Tehran University of Medical Sciences, Tehran, Iran;*
[2]*Professor, Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.*

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ABSTRACT

Driver drowsiness has been one of the main causes of on-road crashes, which can lead to death; physical injuries impose significant costs on the societies. The development of non-intrusive methods to be able to detect driver drowsiness in the early stages of drowsiness is very importance. This is an educational review and its purpose is to provide recent achievements on non-intrusive techniques used to detect driver drowsiness. Recent published related articles were searched in the scientific databases such as Web of Sciences, Scoupous, Pubmed and Google scholar. By studying the articles and extracting the important information, non-intrusive drowsiness detection methods has classified in three distinct categories: Vehicle based measures, behavioral measures and non-intrusive physiologic methods. Each of mentioned categories has its own advantages and limitations. Vehicle based methods are strongly influenced by the road geometry, whether condition and lighting. By tracking the facial expression of the driver, drowsiness can be detected. The main limitation of this method is lighting, because the cameras do not function well at night. However, physiological parameters such as electroencephalography are more reliable than vehicle and behavioral measures, the intrusive nature of these methods limit their applications. In concludion, combination of the mentioned method can reliably detect the drowsiness of the driver and further studies about the efficiency of the mentioned techniques in real environments are required.

KEYWORDS: *Driver Drowsiness Detection, Non-Intrusive, Eye Detection, Face Detection, Yawn detection*

INTRODUCTION

Increasing the number of traffic accident has imposed heavy costs to the modern life. More than 1.3 million people die in road accidents annually, and about 20 to 50 million people suffer from injuries caused by road accidents [1].

National Highway Traffic Safety Administration (NHTSA) estimated that 100 thousand vehicle crashes Out of the total traffic accidents, occur due to driver drowsiness. The result of these accidents led to approximately 1550 deaths, 71,000 physical injuries and financial losses of 12.5 billion dollars [2]. US National Sleep Foundation (NSF) reported that 54 percent of young drivers during driving feel sleepy and 28 percent of which sleep actually [3].

**** Corresponding Author: Gabraeil Nasleseraji***
Email: jnsarji@tums.ac.ir

Road accidents are the leading cause of death in men under 25 years in countries that are the member of Organization for Economic Co-Operation and Development [4]. The mortality and injury rate due to traffic accidents in Iran in 2015 were 16,584 and 313,017 respectively [5].

The number of death and injuries due to vehicle crashes in Iran are almost two and five times the global average respectively [6-7]. In fact, the number of deaths from all types of accidents, and on the top of them traffic accidents, is in the second place after the deaths occurred from cardiovascular diseases. With this difference that cardiovascular diseases mainly kill people over the age of 60 yr, while the average age of deaths from traffic accidents is about 27 to 36 years.

Thirty percent of all traffic accidents occur because of the drowsiness of drivers [8]. Our understanding of the accidents caused by driver sleepiness is mainly based on subjective evidences such as police reports and the driver self- report after the incident [9-10].

Accidents caused by sleepiness have the following features:

1- Most of these accidents involve a single vehicle running off the road [10].
2- These type of accidents occur on highways and main roads with speed as high as 55 miles or even more [11].
3- The driver does not have enough consciousness to do a proper and timely corrective action to minimize the consequences of an accident; in this type of accidents, there are no clear signs of braking and/ or lighting the brake lights during the accident [11].
4- In such accidents, the driver is often alone. In New York State, for the 82 percent of crashes caused from driver sleepiness, the driver was the only vehicle occupant [9].

In the past few years, many scientific studies have concentrated on the loss of driver's consciousness as one of the main causes of road accidents. Road traffic accident attributable to driver sleepiness in comparison with other types of car crashes have more serious consequences; the reason is that the sleepy driver could not to take timely and appropriate measures prior to collision to reduce the possible consequences [2, 12].

Several methods including the use of warning system in order to prevent driver sleepiness has been provided to identify driver drowsiness before falling asleep while driving. The use of warning systems needs reliable detection of drowsiness.

Based on the type of gained data, drowsiness detection methods can be divided into two major categories including intrusive and non-intrusive procedures. Intrusive techniques are those which electrodes and wires is attached to the driver to obtain data such as Electroencephalograms (EEGs) [13-14] and Electrocardiograms (EKG) [15]. Although these techniques have a good accuracy to detect of drowsiness, they are limited to laboratory studies. Unlike intrusive methods, non-intrusive methods are based on measurements of parameters such as individual driving behavior, characteristics related to eye movements and other parameters that are related to the real driving situations. The measurement of these parameters is carried out without interference with individual driving.

This is an educational review and its purpose is to provide recent achievements about non-intrusive techniques used to detect driver drowsiness and its application in the real driving situations.

MATERIALS AND METHODS

The main keywords including: driver drowsiness detection, non-intrusive, eye detection, face detection and yawn detection were used to perform searches in the scientific databases. The related articles were searched on databases such as Web of Science, PubMed, Scopus and Google scholar from 2005 to 2016. Considering the title and abstract of the articles, the most related were chosen for further studies. Then the whole sections of the selected articles were carefully studied and necessary information was extracted. The obtained data was placed in three categories, which is thoroughly been reviewed in detail in the result section.

RESULTS

Considering data provided in the reviewed articles, non-intrusive driver drowsiness detection techniques were grouped in three categories including: Vehicle-based measures, Behavioral measures and Physiological measures.

Behavioral based methods: These methods search finding special key clues, observable in sleepy driver, during driving. The focus of these techniques is on the facial expression of the driver including blinking rates, nodding or swinging of the head and yawning numbers [16]. Typically, systems based on this methodology use camera recorder to obtain image of the driver face. Then, the obtained images are analyzed and decision is made whether driver is drowsy or not. If the sequence of obtained images and measured parameters confirmed that the driver is sleepy, measures such as audio alarm will be activated.

Driver drowsiness detection using eye related parameters: Most conducted studies for detection of driver drowsiness, based on behavioral techniques, have focused on the eye movements [17-18]. These types of studies have mainly focused on eye related parameters such as the blinking rate, blinking duration, pupil diameter and PERCLOS [19]. The results of various studies showed that the mentioned parameters are affected due to increasing workload and driver fatigue [20-

21]. Remarkable differences have been obtained for blinking rate in various studies has. In some studies [22-23] the blinking rate has increased with increasing driving time and driver fatigue but other studies [24] has showed that the blinking rate tend to decrease as driving time and fatigue is increased. Twist and curves of the road affect the blinking rate, with the increasing of the bends and curves of the road the blinking rate is decreased [25]. In addition, the visual and mental workload adversely effect on the blinking rate [24]. This theory may answer the question, why in some studies with the increasing of driving time and driver fatigue blinking rate decreases but in other studies, blinking rate is increased. In summary, the road geometry and visual and mental workload affect the eye blinking rates. Increasing mental workload reduce the duration of blinking [19]. PERCLOS and pupil diameter positively correlate with increasing driver fatigue [26-27].

Although there are different methods to measure the driver drowsiness, but because driving is a multi-dimensional task, using a single method alone cannot effectively measure driver drowsiness.

Driver drowsiness detection using head posture: Various researches have been carried out to develop a method to determine driver fatigue and sleepiness based on head posture in research laboratories, industries and academic research centers [28-30]. The position of the head can show a person's fatigue levels. If driver look around for a long time continuously, the driver is tired or inattentive toward d driving [31]. Teyeb et al. using head position and Viola and Jones algorithm, proposed a system that can effectively detect and identify driver drowsiness [30]. Due to the different methods and algorithm used in the analysis of obtained data, differences can be seen in various studies.

Driver drowsiness detection using facial expressions: This approach is a combination of methods in previously mentioned sections. Beginning of drowsiness and fatigue is accompanied with a series of observable changes on the face, head and eyes of sleepy person. The human face form, because of joints that have degree of freedom, is dynamic. Several studies have been conducted to evaluate the dynamic anthropometric changes and its relation to drowsiness [32-34]. In this technique, camera recorder is used to record face changes of the driver then recorded movies is been analyzed by various algorithms.

Driver detection drowsiness based on Vehicle measures: In this method, driver drowsiness measurement is determined in a simulated environment by placing sensors on various vehicle components, including the steering wheel and the acceleration pedal; then the received signals from the sensors are analyzed to determine the level of drowsiness. Two most frequently used of these measures are the steering wheel movement and the standard deviation of lane position.

Steering Wheel Movement measure (SWM): Various studies have assessed the relation between steering wheel movement and the level of driver consciousness. Researchers have frequently observed the relation between micro correction made on the vehicle steering wheel and the driver drowsiness level in different studies [22]. Different methods are used for monitoring of the steering wheel movements of the vehicle [35-37]. The number of micro-corrections on the steering wheel in drowsy drivers reduces in compared to normal driving. Drivers feeling sleepy make lesser steering wheel reversal than normal drivers [38]. Nissan and Renault automobile Company have adopted SWM as a safety system in their productions but this system work in the limited circumstances. The reason is that these systems function only in the particular environment and are strongly dependent on the geometric characteristics of the road [39].

Standard Deviation of Lane Position measure (SDLP): SDLP is another method through which the level of the drowsiness is assessed. The drowsy driver is very susceptible to deviate from the main route; then tracking the path of the vehicle can be used as clues to discover the drowsiness [37]. In this method in a simulated environment, the lane position of the car is calculated by the SDLP software and in the real field experiment, camera and external sensors track the lane position. The main limitation of this method is that it is strongly dependent on external parameters such as road marking, climatic and lighting conditions. This method is not specific to drowsiness and it is poor predictor of the risk of operating errors caused by drowsiness. Moreover, any unusual driving situations such as alcohol and drug use influence on these indicators [40-41].

Non-intrusive physiologic parameters: Physiological method used to determine the driver's drowsiness are reliable and with high accuracy because they express the inner state of the driver. The interventional nature of the physiological methods has limited their use [42]. Electroencephalography and electrooculography by placing electrodes on the skull and close to the eyes of the driver would interfere to driving task [43-44]. Among all physiological methods, electrocardiography with lesser intervention in driving task can be measured. The progress being made with regard to non-interventional physiologic / wireless sensors in the experimental works, it is expected that the use of these sensors will be practical in near future [45-46]. In recent years, wireless devices to obtain signals and using electrodes on the steering wheel have been extensively used as non-intrusive physiological methods for driver drowsiness detection [47].

DISCUSSION

The various method of driver detection drowsiness reviewed in this study. In summary, three categories of non-intrusive method for detection of drowsiness were explained. Each of the mentioned methods has advantages and disadvantages that will be discuss in more detail.

Comparison of behavioral and vehicle based methods: Behavioral based methods are an effective way to detect and identify driver drowsiness. The main limitation of this approach is lighting. Normal cameras do not function well at night. Moreover, the different lighting conditions influence on the reliability and accuracy of these measurements [42]. Vehicle based method do not have good reliability compared to behavioral based method, because they are highly dependent on the geometry of the road, marking the middle of road, whether conditions, road lighting and also they are influence by driver performance. In general, non-intrusive approaches have lesser reliability in comparison to intrusive physiologic methods; because non-intrusive methods will become apparent just after the driver begins to sleep, which is often too late to avoid an accident, but physiological methods such as EEG signals start to change in earlier stages of drowsiness. The intrusive nature of physiological parameters is the main drawback of these methods, which has limited their use. Using wireless devices to track physiological signals in a less intrusive way will be practical in the near future.

Combination of various methods to detection driver drowsiness

The mentioned methods have their own advantages and limitations. Simultaneous combination and application of these methods can reliably detect driver drowsiness in the early stages. Numerous studies have combined vehicle and behavioral based methods. Cheng et al. has combined vehicle and behavioral based techniques, the reliability and accuracy of the resultant hybrid method were significantly higher than any of them lonely [48]. Cyganek and Gruszczyński measured PERCLOS parameter by combining two separate cameras (infrared and visible light camera) for monitoring driver eyes under real driving conditions. The applied hybrid system has provided direct monitoring of the driver status via PERCLOS parameter. The accuracy of obtained data was 97% [49]. Furthermore, lee et al. combined both computer vision and physiological bio-signals for detection of drive drowsiness. The proposed method was reliable and valid for driver drowsiness detection [50].

CONCLUSION

In this study, various non-intrusive methods were used to determine the driver's drowsiness and their advantages and limitations, were discussed. Combinations of various non-intrusive techniques can detect driver drowsiness in the early stages of the drowsiness with high precision and accuracy. The most reviewed articles were conducted in the simulated environment. The obtained results from simulated environment in compared with driving under real conditions will have considerable differences. Therefore, further studies on the efficiency of the mentioned techniques in real environments are required.

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