VOL. 11, NO. 18, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A STUDY ON DRIVER FATIGUE NOTIFICATION SYSTEMS

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ABSTRACT

This paper is an introduction to our research which aims to develop a driver safety assistant system using an in vehicle video camera. It is a real-time recognition system which uses vision sensors to detect passengers and driver fatigue conditions. The system assesses the ability of conducting safe driving and notifies the driver for any dangerous situation. Moreover, safety actions are to be performed by an embedded vehicle controlling system. This review paper is to assess the current status of research.

Keywords: computer vision, safety, fatigue assessment, intelligent transportation systems.

INTRODUCTION

Traffic accidents are a serious global problem. “Global status report on road safety 2013” [1] indicates that worldwide the total number of road traffic deaths decreased from 1.3 million per year in 2009 to 1.24 million per year. This number remains unacceptably high. Moreover, on the local level, traffic accidents rank fifth among the leading cause of deaths in Malaysia [2]. Studies show that for personal injury accidents, estimates of sleep and fatigue involvement are in the range of 10 to 30 percent of accidents [3]. One solution to reduce this huge number of loses is developing driver assistant systems. In our research we plan to develop a driver safety assistant system which uses vision sensors to detect passengers and driver fatigue conditions. The new in this research is the real-time safety actions to be performed by an embedded vehicle controlling system. The fatigue assessment system is based on real-time face and gesture recognition.

The motivating application for this research is to design an integrated system for safety of vehicle users based on visual information only. Restricting the methods to visual information is to reduce the time complexity of integrating information from many sensors and to reduce the expenses on the sensors. This research aims to contribute in reducing the number of accidents and consequently the socioeconomic effects of them like property losing costs, long-term medical costs, funeral costs, vehicle repair costs or losing the household.

The most recent literature revision we found was published in 2005 [4]. A newer revision is needed to cover the gap since the last revision.

DRIVER FATIGUE DEFINITION AND ASSESSMENT

“Fatigue concerns the inability or disinclination to continue an activity, generally because the activity has been going on for too long”. The causes of fatigue can be physical, physiological, or psychological [5]. There is no standard fatigue measurement, because the direct measures are few [4]. Most measures are of the outcomes of fatigue rather than of fatigue itself. To overcome fatigue, human beings need to sleep. Sleep is essential and inescapable solution for fatigue. In case of fatigue, sleep will overpower any effort to remain awake [6]. Therefore the best fatigue measurement is drowsiness which is the clearest outcome of fatigue. Detecting drowsiness and taking action to prevent it while driving is not an easy task. Moreover, detecting fatigue/drowsiness depending on visual information only, adds more restricts on the reliability of the fatigue measurement. This is because it depends mainly on pattern recognition of facial gestures. One of the bottlenecks challenges of object recognition, in general, is finding efficient and discriminative descriptors that are invariant even in difficult illumination cases.

REVIEWING METHOD

Although our search for “drive fatigue” leads to considerably big amount of the literature, we focus in this review on papers which are applied on-road and/or on real-time cases. We tried to avoid simulation and modelling studies because we want to assess the current realistic applications.

QUICK VIEW ON APPROACHES USED FOR VISUAL INFORMATION

Although many researchers worked in this field, fundamental problems still need to be solved. Few researches use methods depending on inputs from devices which are not visual sensors. But most of the algorithms, as we will see in this paper, are depending on visual information. There are many drawbacks regarding these methods. For example, most of the algorithms are time-costing and are not fit for real-time applications. Some researchers work on static scene images, but movement blur, bad illumination and other changes are adding more difficulties for object detection and recognition in video streams. The problems become more severe when the objects to be recognized are as delicate as the facial gestures. Night vision and special cases like when the driver wears sunglasses add more constrains. Robust face and gesture recognition system in uncontrolled illumination environment is still one of the unsolved challenges [7]. Facial expressions which are the key for understanding the person's situation are difficult to be detected and recognized even in normal cases.

For pattern recognition, in general, there are two main approaches: geometric feature-based descriptors and appearance-based descriptors. Geometric descriptors can be hard to extract reliably under variations in facial appearance and difficult lighting conditions. On the other hand, appearance-based descriptors tend to blur out small details. Most of the researchers use methods derived from Local Binary Patterns (LBP) or Edge Orientation Histogram (EOH) for Feature extraction [8, 9]. The results are still insufficient for applications like real-time risk assessment system. Therefore novel visual integrated and optimized systems to check the driver condition robustly in real-time are needed to be proposed. It is stated in [8] that "It is by no means impossible to detect the desired events, but the task is challenging". The observation of human visual perception shows it is well-adapted to extracting local structural visual information [10]. Therefore, in our research we plan to study human vision system comprehensively and mimic it for artificial gesture recognition system.

This paper is a brief review of the literature on fatigue detection technology and approaches in general with special focus on visual related approaches. The objective of this review is to assess the current status of research.

LITERATURE REVIEW

Commercial products

Driver fatigue has been intensively studied during the last two decades. Few commercial products are already available in markets. For example, Lumeway Product: Eye Alert uses infrared camera/sensors to monitor driver's eye closure rate and duration. When the driver starts exhibiting unsafe patterns, it sounds an alarm [11]. Driver Attention Monitor is a vehicle safety system first introduced by Toyota in 2006 for Toyota and Lexus latest models with closed-eye detection [12, 13]. The system is designed to detect if the driver is not looking forward and will signal an alert if it detects an object ahead. SMI's InSight system [14] has been conceived to detect driver fatigue and inattention using cameras monitoring the driver's face. DADSTM (Driver Alertness Detection SystemTM) [15] is a cloud based service that monitors a driver's state of alertness in real-time to reduce the risk of road accidents caused by drowsiness and fatigue. To use the system, a driver needs a smartphone and a certified Bluetooth camera. The camera captures information from a driver's face, and then software analyses this information to monitor the state of alertness while driving. If a threshold of risk is reached, driver will receive an alert on the phone. The producers claim that the system warns the driver up to two hours before reaching a critical state.

Other in-vehicle integrated products such as Volvo's Driver Alert Control system [16], Ford's Driver Alert [17], Volkswagen's Fatigue Detection system [18] and Subaru EyeSight Driver Assist [19], are based on road monitoring and steering wheel movements to detect fatigue. "Vigo" is another similar fatigue system [19]. It is a smart Bluetooth headset that detects signs of drowsiness through the eyes and head motion, and uses a combination of light, sound and vibration to alert the user. In 2009, Mercedes-Benz unveiled a system called "Attention Assist" [19]. The system monitors the driver's fatigue level and issues a visual and audible alarm. The significant feature in this system is the linking with the car's navigation system. This allows the system to tell the driver where coffee is available.

The practical use and efficiency of these devices in preventing accidents are still under inspection. UK Royal society for the prevention of accidents published a literature review on driver fatigue and road accidents [20]. The study investigated number of technical devices to detect when drivers are feeling sleepy and provide warnings to them, or even to take control of the vehicle. The study concluded that such devices may prove beneficial, but there are concerns that drivers would rely on them instead of managing themselves for safety. The study raised the question: "Drivers are normally well aware that they are sleepy, so why is a device necessary to tell them so?"

As a conclusion, more efficient actions should take place to achieve the main goal of preventing and reducing accidents.

Related academic work and researches

The problem of fatigue detection has been studied by many researchers using a range of different approaches. According to the literature revision done by Ann Williamson and Tim Chamberlain in 2005 [4], most of the methodologies used can be divided into three categories: Methodologies which are focusing on the driver's current state, driver performance, or a combination of the driver's current state and driver performance. In our revision, we added a fourth category, which is: Methodologies focusing on vehicle's current state. Tables-1, 2, 3 and 4 list the literatures related to each methodology.

Table-1. Summary of fatigue monitoring approaches focusing on driver's current state.

Reference numbers	approach
[21]* [22]* [23]* [24]* [25]* [26]* [27]* [28] [29] [30]	Eye gaze, Blink and closure detection
[24]* [31] [32] [33]* [34]	Other face feature tracking and head motion
[35]*[36]	Electroencephalograph (EEG) measures
[37] [38]	heartbeat and respiratory rate measures
[39] [40] [41] [42]	Voice & speech

* reviewed in [4], check it for more details

VOL. 11, NO. 18, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Table-2. Summary of fatigue monitoring approaches focusing on driver performance.

Reference numbers	approach
[43]*	steering wheel input
[44]	steering wheel and pedals speed and acceleration; steering wheel angle and heading error

* reviewed in [4], check it for more details

It is clear from the tables that most of the researchers are focusing on the eye movement as indicator of fatigue. Most of the approaches are based on eye closure rate monitoring. The false finding rate of drowsiness is still high in most of the researches. It is at the rate of 10% at minimum [24, 30].

Table-3. Summary of fatigue monitoring approaches focusing on a combination of the driver's/Vehicle's current state and driver performance.

Reference numbers	approach
[45]*	lane tracking, eye-closure and changes in physiological state
[46]*	Combination of eyelid changes, steering grip change, lane tracking, preceding car tracking, use of accelerator and brake and steering position.
[47]	**Multi sensor system**

* reviewed in [4], check it for more details

Table-4. Summary of fatigue monitoring approaches focusing on vehicle's current state.

Reference numbers	approach
[43]* [48]* [49]* [50]* [51]*	Lane tracking

* reviewed in [4], check it for more details

In order to enhance visual data acquisition, some researchers use special vision sensors. Infrared camera coupled with an infrared illuminator makes better data extraction, as it is less sensitive to illumination. Therefore it works even at night. More information about such systems is in [21, 22, 24, 32, 33]. Other type of special vision sensors is using the Kinect [47]. The advantage of Kinect is its depth map which can be associated with the captured images.

The results of the above mentioned systems are still insufficient for real-time robust applications. The European Union Project "AWAKE", which is a System for Effective Assessment of Driver Vigilance and Warning According to Traffic Risk Estimation, is a good example of a multi-input integrating system [46]. The aim of the AWAKE project was not only to demonstrate the technological feasibility of driver vigilance monitoring systems but also to explore the non-technical issues that may influence the success of implementing these systems in real life traffic. It intended to develop an unobtrusive, reliable system, which monitor the driver and the environment and detect in real-time hypo-vigilance. The project employed driver state measures including eyelid movement, changes in steering grip and use of accelerator and brake and steering position. Moreover, it employed the vehicle state measure of lane tracking. These measures were then combined and evaluated against an assessment of current traffic risk obtained from digital navigation maps, anti-collision devices, driver gaze sensors and odometer readings. The project has produced a series of comprehensive design guidelines for the assessment of driver vigilance and warning signals. Although the results of this research are likely to have considerable impact on the implementation of fatigue detection devices in the future, but a significant number of unanswered research problems still need to be studied [4].

Approaches which are classified under "approaches focusing on vehicle's current state" are mainly using the lane tracking techniques. They detect lane departure as a measure of fatigue. In [43], the authors included the steering wheel input besides to lane tracking to detect driver fatigue.

The outcome of most of the systems is an audible alarm. Few researchers suggested different ways for overcoming drowsiness. For example, Singh H. *et al.* [29] proposed a system for detecting driver fatigue in advance. The system is to give warning output in form of sound and seat belt vibration. To make the system efficient the warning was suggested to be deactivated manually rather than automatically.

DRIVER'S ATTITUDE TOWARD THE NOTIFICATION SYSTEMS

One important concern is driver's attitude toward the notification systems. Some researchers [52, 46] have discussed this matter in their publications. In [52] the authors suggested that warning devices should be able to be turned off or have their volume modified significantly. The AWAKE project study [46] concluded that drivers should be trained in appropriately responding to warning devices, especially if they occur infrequently. This is because the alarm system may negatively cause startle effects which can affect driver safety.

CONCLUSION AND FUTURE WORK

Many researchers have studied fatigue detection. Even though a significant number of publications can be found in this field, fundamental problems still need to be solved. Few researches use methods depending on inputs from devices other than visual sensors. But most of the algorithms are depending on visual information. There are many drawbacks regarding these methods. For example, most of the algorithms are time-costing and are not fit for real-time applications. The false finding rate of drowsiness is still high in most of the researches. It is at the rate of 10% at minimum as far as we know according to our literature survey. The outcome of most of the systems is an audible alarm. There are worries about the efficiency of the alarm systems as they may negatively cause startle effects which can affect driver safety. Moreover, if drivers are normally aware that they are sleepy, why a device is necessary to tell them so?

Our future plan is to design a driver safety assistant system using an in vehicle video camera. It is a real-time recognition system which uses vision sensors to detect passengers and driver fatigue conditions. The system assesses the ability of conducting safe driving and notifies the driver for any dangerous situation. Because one of the bottlenecks challenges of object recognition is finding efficient and discriminative descriptors that are invariant even in difficult illumination cases. And since the observation of human visual perception shows it is well-adapted to extracting local structural visual information. We plan to propose a new method to mimic the human vision system for artificial fatigue recognition system. Moreover, safety actions are to be performed by an embedded vehicle controlling system to give more efficiency for the system.

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