Driver Drowsiness Detection Systems

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PROCEEDINGS OF THE INSTITUTE OF VEHICLES 3(112)/2017

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DRIVER DROWSINESS DETECTION SYSTEMS

1. Introduction

The development of technology allows introducing more advanced solutions in everyday life. This makes work less exhausting for employees, and also increases the work safety. Vision-based systems are becoming more popular and are more widely used in different applications. These systems can be used in industry (e.g. sorting systems), transportation (e.g. traffic monitoring), airport security (e.g. suspect detection systems), and in the end-user complex products such as cars (car parking camera). Such complex systems could also be used to detect vehicle operator fatigue using vision-based solutions. Fatigue is such a psychophysical condition of a man, which does not allow for a full concentration. It influences the human response time, because the tired person reacts much slower, compared to the rested one. Appearance of the first signs of a fatigue can become very dangerous, especially for such professions like drivers.

Nowadays, more and more professions require long-term concentration. People, who work for transportation business (car and truck drivers, steersmen, airplane pilots), must keep a close eye on the road, so they can react to sudden events (e.g. road accidents, animals on the road, etc.) immediately. Long hours of driving causes the driver fatigue and, consequently, reduces her/him response time [1]. According to the results of the study presented at the International Symposium on Sleep Disorders, fatigue of drivers is responsible for 30% of road accidents [2]. The British journal “What Car?” presented results of the experiment conducted with the driving simulator and they concluded that a tired driver is much worse dangerous than a person whose alcohol in blood level is 25% above the allowed limit [2]. Driver fatigue can cause a microsleep (e.g. loss of concentration, a short sleep lasting from 1 to 30 seconds), and falling asleep behind the wheel.

Therefore, there is a need to develop a system that will detect and notify a driver of her/him bad psychophysical condition, which could significantly reduce the number of fatigue-related car accidents. However, the biggest difficulties in development of such a system are related to fast and proper recognition of a driver’s fatigue symptoms. Due to the increasing amount of vehicles on the road, which translates into the road accidents directly, equipping a car with the fatigue detection system is a must. One of the technical possibilities to implement such a system is to use vision-based approach. With the rapid development of image analysis techniques and methods, and a number of ready Component-on-the-Shelf solutions (e.g. high resolution cameras, embedded systems, sensors), it can be envisaged, that introducing such systems into widespread use should be easy. Car drivers, truck drivers, taxi drivers, etc. should be allowed to use this

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solution to increase the safety of the passengers, other road users and the goods they carry.

2. Currently used driver fatigue detection systems

One of the examples of a system detecting a driver's fatigue is the system implemented into the Driver Assistant in Ford cars [3]. It analyzes rapid steering movements, driving onto lines separating lanes, irregular and rapid braking or acceleration. The system collects and processes these data, assigns the driver using one of the 5-degree concentration levels (5 – the driver is concentrated, drives properly, 1 – the driver is very tired, should immediately stop driving and rest) [3]. When the rating falls to level 1, the driver is notified by beeps and warnings on the instrument panel's middle screen. The system can be reset and the warnings will disappear, only when the driver stops and opens the door. Skoda cars use a similar system. It analyzes the steering movements and compares them to the movements in normal driving. The system begins to analyze how the vehicle performs 15 minutes after starting the engine and at the speeds of more than 65 km/h [4]. When the system detects that driving is abnormal, the driver's fatigue status is displayed on the screen, followed by a beep, informing the driver to take a break [4, 5]. Volkswagen uses the Bosch Driver Drowsiness Detection system (Fig. 1). It also analyses how a car behaves on the road. Based on the information from the power assisted steering sensor and the steering angle sensor, the system detects sudden changes in the trajectory of the vehicle, which translates into driver's fatigue [6].

Some driver fatigue detection methods use the heart rate analysis [7]. The psychophysical state is determined by the HRV (heart rate variability). DENSO (manufacturer of car parts and systems) at the Detroit Auto Show presented a system that relies on a driver's heart rate analysis and the use of the cameras to observe a driver's eyes. Such a solution allows detecting a fatigue at the operator of the vehicle. There are also ideas for the use of electroencephalogram (EEG) to detect the driver's brain wave changes, which may indicate the first symptom of fatigue. The panel view implemented in Android is shown in Figure 2.

Fig. 1. View at a driver fatigue information (Ford Driver Assistant) [8]

The PSA Group (formerly PSA Peugeot Citroën), in collaboration with the Lausanne University of Technology, are working on a camera-based system to analyze the facial expressions of a driver. It is interesting to note that the very early aim of this system was a detection of emotions of a driver, but they decided to develop it into the fatigue detection system) [9, 10, 11]. It is based on the analysis of eye movement, the closing and opening of the eyelids as well as the movement of the mouth. It allows detecting the first symptoms of a fatigue. Information provided by this system will inform a driver on the state of her/his psychophysical state.

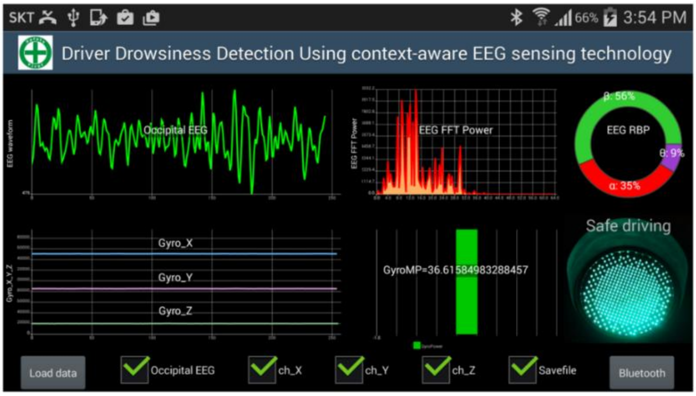

Fig. 2. Driver Drowsiness Detection System using EEG [12]

3. Using a vision-based system to detect a driver fatigue

Fatigue detection is not an easy task. It requires taking into account many factors. Using a video system for this purpose can be a good solution. This system would allow for precise detection of a fatigue in real time. The speed of such a system is very important because even slight delays in the operation of such a system could be fatal (excessive reaction of the system while traveling along the highway).

An important issue in the design of the vision-based driver fatigue detection system is the right choice of the analyzed symptoms of fatigue. In a situation, where it is not possible to monitor all potential symptoms of a fatigue, it should be limited to the detection of the most important ones such as: closing the eyelids, slow the eye movements, yawning and drooping a head.

The basis of the fatigue detection system are the algorithms responsible for detecting facial features and their motion. There are many methods that allow detecting individual facial elements. They are based both on the vector operations and the pattern classification. Particular methods are based on an image filtering in complex space or an image processing in spatial-frequency domain. Some methods are very effective in detecting characteristic facial features, but sensitive to changing lighting conditions. There are also methods that rely on analyzing a 3D image. The most popular methods are Main Component Analysis, Neural Networks, Gabor filters, and frequency-spatial methods. Principal Components Analysis (PCA) is based on its own vectors. It is often used during preprocessing (to get rid of noise from the image – they correspond to a small variance that is correlated with the corresponding own vectors) [13]. The method based on neural networks is used for processing input data. Neural networks are used for identification and classification of pattern data, and therefore they are also used in face detection and recognition systems [3]. Gabor filters are one of the most commonly used methods for representing facial features, using complex functions. Frequency-spatial methods are based on frequency analysis of the image in conjunction with the methods based on a geometric model. Frequency-spatial methods allow for the proper isolation of the characteristic facial features and minimizing the influence of lighting conditions during the acquisition [13].

In vision-based systems it is important to correctly identify the specific elements as well as to analyze their movement. Common methods used to detect a motion in video systems are differential and gradient methods. Differential methods determine the difference between the subsequent image frames. This allows determining the brightness level in the grayscale or the color intensity of the pixel during the frame changes. So, the movement of the object can be detected (this is related to the change in the brightness of the pixels that appear next to each other in the image). This is a simple way to detect a movement, however, its implementation can be tedious. One of the limitations of this method is to have the stationary background, the lighting should be constant, and the noise in the film should be reduced to a minimum (otherwise, the algorithm may work not properly). Additionally, in order to improve a movement detection, the moving object should contrast with the background [14]. Gradient methods rely on the optical flow. They use spatial and temporal derivatives of the consecutive video frames. In order to make an effective use of this group of the methods, the following conditions should be met: invariability of the light, a small displacement of moving objects in one sequence and spatial coherence of the contiguous dots [14]. Two most popular gradient algorithms are Lucas-Kanade and Horn-Schunk algorithm. The principle of operation of the first algorithm is a characteristic assumption: the brightness of the dots in the image is unchanged over the time, the movement of the frames is constant. This method is intended for the methodological purposes, that is, the section of traffic in the area devoted to the area (not exceeding the registration process). Its performance can be improved by solving this algorithm into the form of a pyramid (image analysis of a small improvement and then its gradual change) [15, 14]. The Horn-Schunk algorithm is based on the use of the optical flow equation, taking into account two conditions: the brightness of the dots (the pixel brightness of the moving object in the image is constant) and the speed of the dots (the speed of the pixels belonging to the moving object are close to each other, the motion field changes smoothly). This method belongs to the global methods. Thanks to this, we get a high density of the flow vector, which results in a more accurate information about the movement of the object, including information about the area under investigation in which the object is moving. The disadvantage of this algorithm is that it is more susceptible to interference compared to the local methods (e.g. Lucas-Kanade) [14, 16, 17]. The example of the application of an optical flow is shown in Figure 3.

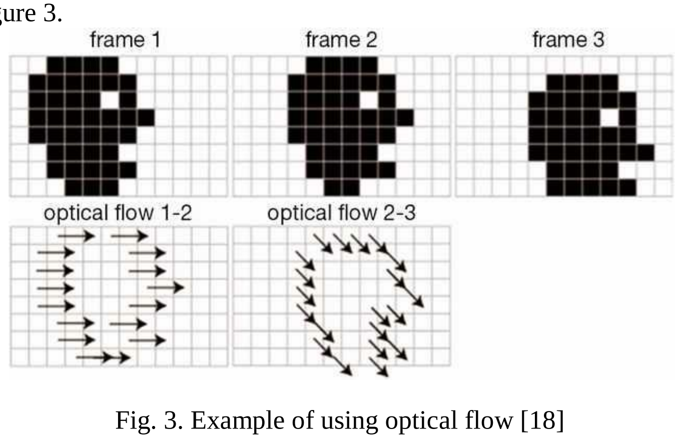

Fig. 3. Example of using optical flow [18]

When designing a video system that records moving objects, one should choose algorithms that are resistant to interference. Interference occurrence may disturb the processing and the analysis of the data, which may lead to misinterpretation by the system. If the selected methods are susceptible to interference, then the system will not analyze the movement of the elements. It may lead to a kind of dynamic "jumps" of the system between the observed objects. The next procedure is to register and analyze the movement of the classified features. It should be remembered that real-time systems require a rapid response to the changes in observed objects. For example, if the eyelid is closed for a long time, the system response: "eyelids close" should be immediate. Any delay in the identification of a fatigue can have catastrophic consequences. If the system does not respond in time to the driver's microsleep, an accident may occur.

Problems related to design vision-based fatigue detection system operating in real-time also apply to the hardware used for the video signal acquisition and processing. One of the issues is the number of cameras recording the object of the interest. We can install three cameras in front of a driver, apply algorithms that generate a 3D image, and then implement the appropriate data analysis methods. Information will be the most accurate, but assiocated costs of the final system may disqualify it for the industrial scale. Limiting the number of the cameras to one will allow you to cut costs considerably. The quality of the recording equipment is also of great importance. Using equipment of poor quality, recorded video signal may become noisy, affecting the performance of the algorithms for video processing and analyzing, which ultimately can lead to misinterpretation of the results by the system. In addition, since capturing details of the face is of the great importance to the system, the vision system should use cameras high resolution image.

4. Summary

In order to reduce the number of road accidents resulting from a driver fatigue, it is of great importance to introduce to the automotive industry a system that would effectively detect the first signs of a fatigue and notify the driver. A system based on real-time face analysis can be one of the most effective approaches for detecting fatigue symptoms. There are many problems associated with its design such as uneven illumination of a driver’s face or the selection of effective real-time data processing algorithms to name a few. Current technological advances in video recording and processing help reduce and even eliminate such problems. It is envisaged that by integrating such a system with other on-board car driving system would increase road safety definitely. The block diagram of the hypothetical system, and principle of its operation is presented in Figure 4. The investigations of the proposed drowsiness detection vision system will be continued and the results of the research will be delivered.

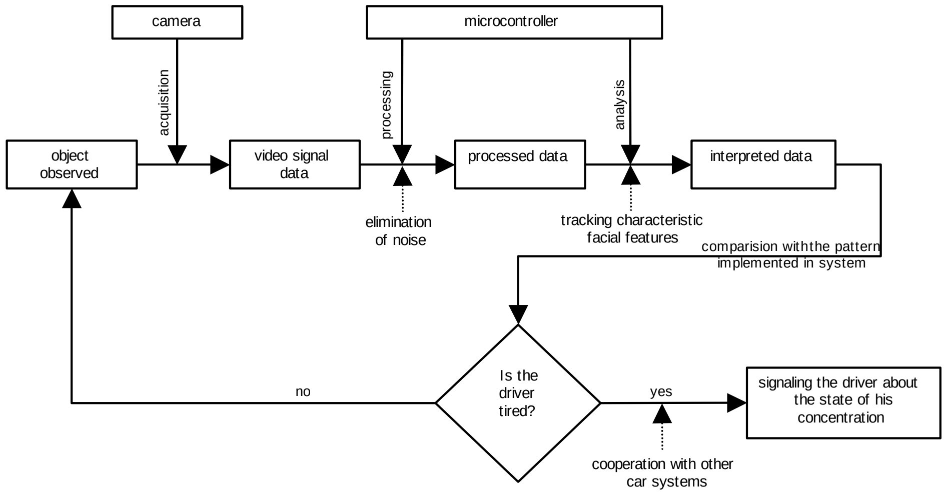

Fig. 4. Block diagram of driver drowsiness detection vision system

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Abstract

Nowadays, more and more professions require long-term concentration. Drivers must keep a close eye on the road, so they can react to sudden events immediately. Driver fatigue often becomes a direct cause of many traffic accidents. Therefore, there is a need to develop the systems that will detect and notify a driver of her/him bad psychophysical condition, which could significantly reduce the number of fatigue-related car accidents. However, the development of such systems encounters many difficulties related to fast and proper recognition of a driver's fatigue symptoms. One of the technical possibilities to implement driver drowsiness detection systems is to use the vision-based approach. This article presents the currently used driver drowsiness detection systems. The technical aspects of using the vision system to detect a driver drowsiness are also discussed.

Keywords: drowsiness, driver, automotive, car

SYSTEMY WYKRYWANIA SENNOŚCI KIEROWCY

Streszczenie

W dzisiejszych czasach coraz więcej zawodów wymaga długotrwałej koncentracji. Kierowcy muszą stale obserwować drogę, aby w porę zareagować na nagłe zdarzenia na jezdni. Zmęczenie kierowcy często staje się bezpośrednią przyczyną wielu wypadków drogowych. Pojawia się zatem potrzeba budowy systemów, które umożliwiłyby wykrycie i zasygnalizowanie zmęczenia operatorów pojazdów, gdyż ich zastosowanie pozwoliłoby na znaczne zredukowanie liczby wypadków wynikających ze zmęczenia kierowców. Budowa takich systemów napotyka jednak wiele trudności związanych z automatycznym rozpoznawaniem symptomów zmęczenia kierowcy. Jedną z technicznych możliwości realizacji systemów wykrywania senności kierowcy jest wykorzystanie w tym celu odpowiednio przystosowanych systemów wizyjnych. W artykule przedstawiono używane obecnie systemy detekcji senności kierowcy. Omówiono również techniczne aspekty użycia systemu wizyjnego w celu wykrycia zmęczenia kierowcy.

Słowa kluczowe: senność, kierowca, motoryzacja, samochód