Driver fatigue detection based on eye tracking

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Abstract—Driver fatigue is among the most common causes of serious road accidents around the world. This is particularly evident in the transportation industry, where a driver of a heavy vehicle is often exposed to hours of monotonous driving which can result in fatigue without frequent rest periods. One possible way of detecting fatigue is to monitor the driver by means of a camera that is installed in the vehicle to track the driver's eyes. This work-in-progress (WIP) paper discusses the work that have been done thusfar to develop a robust eye tracker, which will ultimately be used to detect fatigue.

Index Terms—Driver fatigue, bright/dark pupil, PERCLOS, eye-tracking.

I. INTRODUCTION

Driver fatigue detection techniques can be divided into three main categories: physiological measurements, visual cues and driving performance. The first two categories monitor the driver directly, whereas the third category monitors the driver indirectly. Physiological measurements are made by attaching electrodes to driver to measure features such as brain waves (EEG), eye movements (EOG) and heart rate (ECG). An EEG-based system developed by [1] was able to detect fatigue with an error rate of approximately 10%, which the authors claim to be very reliable. Similar EEG-based studies were also conducted by [2], [3] and [4]. The main drawback with physiological measurements is that electrodes have to be attached to driver, making this approach both intrusive and impractical.

Visual cues from a driver's face can also serve as an indicator of fatigue. Useful visual cues include eyelid movement, facial orientation, eye-gaze as well as facial expressions (such as yawning). Visual cues are obtained by means of a camera installed within the vehicle and is probably the most widely used technique for driver fatigue detection, due to its reliable and non-intrusive nature. With visual cues, most of the fatigue-related information can be obtained from the driver's eyes, which resulted in the development of the PERCLOS (percentage of eye closure) metric of fatigue by [5]. The scientific validity of PERCLOS was confirmed by [6] and therefore the PERCLOS metric of fatigue has been used in a number of commercially available fatigue detection systems. Examples of such systems are AntiSleep developed by Smart Eye AB and faceLAB developed by Seeing Machines. It is the ultimate goal of the author to implement PERCLOS as one of the metrics used in an integrated fatigue detection system.

The third main category of fatigue detection techniques, consist of techniques that monitor how the driver handles the vehicle. Fatigue can be detected by variations in the steering wheel angle, vehicle lateral position and vehicle speed. The assumption can be made that an alert driver will make small amplitude steering wheel movements (and consequently small changes in vehicle lateral position) to keep the vehicle within the driving lane, whereas a fatigued driver will make larger amplitude and more imprecise steering wheel movements (large changes in lateral position) in an attempt to keep the vehicle within the driving lane. As a result the trajectory of the vehicle can be used as a metric of fatigue. Prototype systems based on this metric of fatigue have been developed by [7], [8] and [9].

II. IMAGE ACQUISITION

Obtaining visual cues from the driver by means of a camera was chosen as the main technique for detecting fatigue. Therefore the first objective is to detect the driver's eyes from a captured image. For such a system to function properly, a robust eye-tracker is necessary that can also operate in real-time. Traditional approaches to eye detection can require a significant amount of processing power and may also be very sensitive to different lighting conditions.

Synchronizing near-infrared (NIR) illumination with the camera is a different approach in detecting the driver's eyes and was proposed by [10]. The advantages of using near-IR illumination are threefold: the driver's eyes can be detected under various ambient lighting conditions, the bright/dark pupil effect (for actual eye detection) can be produced and finally near-IR light is hardly visible to the human eye and will therefore not interfere with the task of driving.

To achieve the bright/dark pupil effect, two sets of near-IR LEDs had to be synchronized with the camera. The first set of near-IR LEDs were placed in a circle as close as possible to the camera's lens to produce the bright pupil effect, whereas the second set of near-IR LEDs were placed in a circle around the lens with a radius of approximately 15cm, to produce the dark pupil effect. The LEDs chosen for this near-IR illuminator was the SFH-4232 from Osram, with the center of spectral emission being at 850nm. Since these are high power LEDs, only four LEDs were required for each set. A specific driver circuit (using the LM3404) also had to be developed for each set of LEDs. A PIC16F887 was used to control the LED driver circuits as well as the external triggering of the camera.



Fig. 1. Captured images from the embedded image acquisition system. (a) Bright eye image from the inner near-IR LEDs. (b) Dark eye image from the outer near-IR LEDs.

To obtain a bright pupil image, the inner set of LEDs is turned on while capturing the image. To obtain a dark pupil image, the outer set of LEDs are turned on while capturing the image. These two images are captured in very close succession so that the images are effectively the same image, but with different illumination. The images can now simply be subtracted from each other, and the difference image thresholded to produce a binary image. From this binary image the location of the eyes can then easily be determined by making use of a classifier such as a support vector machine (SVM).

The camera used to capture images was the monochrome version of the Prosilica GigE GC-1380, with a resolution of 1360x1024 pixels. The camera has a general purpose I/O port that was programmed with one pin to indicate when a trigger signal is acceptable and another pin programmed to receive the actual trigger signal from the embedded system. Two sample images captured from the embedded image acquisition system are shown in Figure 1.

In order to capture two consecutive images, the embedded system will therefore turn on the inner set of LEDs and then wait for the camera to indicate that it is ready to receive a trigger signal. The embedded system will then send a trigger signal to the camera and the bright eye image will be captured. Directly after the bright eye image has been captured, the inner set of LEDs is turned off and the outer set of LEDs is turned on. The embedded system will then again wait for the camera to indicate that it is ready to receive a trigger signal and then command the camera to capture the dark eye image. Since the two images are captured milliseconds apart, it is effectively the same image but with different illumination. This bright/dark pupil effect results in easier detection of the eyes, which in turn reduces the amount of image processing required to ultimately obtain the PERCLOS metric of fatigue.

III. INTENDED FUTURE RESEARCH

Preliminary results from the image acquisition system have shown that the bright/dark pupil effect have not yet been fully achieved. This can be due to a number of things, including the particular near-IR LEDs used, the physical location of the LEDs, the filter used on the camera or the camera itself. Further research is necessary to determine the optimal configuration of the image acquisition system, in order to accurately achieve the bright/dark pupil effect. Once the image acquisition system produces the desired results, the eye detection and tracking algorithms will be implemented and then finally the PERCLOS metric of fatigue can be computed. It is expected that the PERCLOS metric of fatigue alone, will not be sufficient to robustly detect driver fatigue under different conditions. It is therefore also necessary to explore other metrics of fatigue that can be combined with PERCLOS. In particular, how the driver handles the vehicle through steering wheel movements have shown some promising results in detecting driver fatigue and will therefore be investigated.

IV. CONCLUSION

At this point in time, a lot of research effort have gone towards developing a robust driver fatigue detection system. However, results thusfar have shown that every fatigue detection technique has some drawback, mainly due to the variability among human behavior. It is therefore necessary to combine different and possible unrelated metrics of fatigue to achieve the best results.

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Reinier Coetzer received his B.Eng(Computer) engineering degree in 2007 from the Univerity of Pretoria. In 2008 he worked in the industry as an embedded software engineer, while studying part-time. In 2009 he received his B.Eng(Hons)(Computer) degree also at the University of Pretoria. He is currently working towards his master's degree at the same institution in the field of computer vision.