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A REVIEW OF ECG DATA ACQUISITION FOR DRIVER DROWSINESS DETECTION

N. S. Nor Shahrudin[1], K. A. Sidek[2]

[1,2] Department of Electrical and Computer Engineering, International Islamic University Malaysia, P.O. Box 10, Jalan Gombak, 50728 Kuala Lumpur

shahirah.ciera@gmail.com[1], azami@iium.edu.my[2]

Abstract: Over the years, cases related to road accidents and road fatalities keeps increasing. Both cases have potential to put life of a person at risk. One of the factors that leads to accidents are drowsiness. However, several lives can be saved with accurate and reliable drowsiness detection system. Thus, many researchers take this issue seriously by developing drowsiness detection mechanism in reducing cases related to driver drowsiness. As drowsiness is strongly correlated with the heart activities, hence bio-signal is the most preferable indicator to measure the drowsiness level. Reflection of electrical signal in the human body known as Electrocardiogram (ECG) are widely used in monitoring human action and reaction to prevent the occurrence of these devastating incidents. Thus, this paper will review the drowsiness detection technique focusing in ECG data acquisition for driver drowsiness detection. As the first step plays an important role for the whole system, this paper discussed on some open issues in drowsiness mechanism. We hope that this review will support and give some ideas to the future researchers in increasing the reliability of ECG measures towards driver drowsiness detection in reducing accident cases

Keywords: drowsiness, electrocardiogram, data acquisition, bio-signal, steering wheel, technology

I. INTRODUCTION

Expertise in the need of health care application keepsgrowing. Current technology of daily life such as stress measurement, fall detection, emotions variation and driver drowsiness monitoring system were noticed to be upgraded day-by-day. By upgrading these technologies, life of a person can be saved. For example, developing a Watch for monitoring human body. There was a case that Watch saved a man by giving an alert notification on the incoming heart attack that might leads him to death while sleep [1]. People nowadays seeking such technological growth that could prevent from the unwanted deaths. As drowsy is a part of sleep level that distracts riveron road and has the potential to contribute to the mortality rate, hence, this issue is highlighted in this review paper.

Drowsiness is one of the main factors that threaten road safety that may cause injuries, fatalities, economical loses and unwanted death. According to Director General, Malaysia Institute of Road Safety Research (MIROS), a total of 6,740 road accidents occurred that brings them to death in 2017 [2]. Based on the case studies done by MIROS, a number of 10,716 deaths were predicted to be involved in road accidents issues by 2020.

MIROS also highlighted that Malaysia need to bear with 20.6 billion as cost for accidents fatalities in 2020 if no robust and effective system is proposed for all factors that could contribute in road accidents. Thus, many researches have been done to overcome the drowsiness issues in order to reach the targeted reduction as in Figure 1. However, it is predicted that the number of road fatalities will keep increasing by 2020 even though various technologies have been applied in securing a safe road.

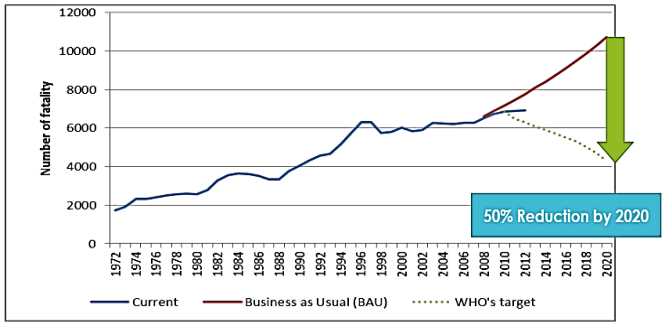

Figure 1. Expected number of fatalities predicted in 2020 [2]

This review also aligned with the Sustainable Development Goals (SDG) that have been introduce by United Nations Member States, consists of 17 goals for a better world by 2030 [3]. As SDG 3 works on ensuring healthy lives and promote well-being for all at all ages, the goal narrowed on sub-goal 3.6, which to halve the global road deaths and injuries by road traffic accidents by2020.

In addition, SDG 11, sub-goal 11.2 also mention on improving road safety by 2030. However, we are afraid that our current road safety measures at a pace are small enough to compensate for the rising population and transportation.

Table 1: Summary of driver drowsiness techniques

Techniques	Parameters	Pros	Cons
Vehicle-based Measure	• Steering Wheel Movement (SWM) - Steering angle derivation • Standard Deviation in Lateral Position (SDLP) - Lane changing pattern	• Non-intrusive	• Affected by geometric characteristics of roads • Unreliable
Behavioural Measure	• Eyes – blinking, size • Face – eye brow • Head – nodding • Mouth – yawning	• Non-intrusive • Easy to use	• Affected by illumination • Lightening condition
Physiological Measure	• EEG – brain wave • ECG – heart activity • PPG – pulse oximetry • Pulse – pulse rate	• Efficient • Reliable	• Intrusive

Thus, drowsy driving is a prevalent and serious public health issue that deserves more attention, education, and policy initiatives so a substantial amount of lives can be saved and disability can be avoided due to drowsy driving accidents.

II. DRIVER DROWSINESS DETECTION TECHNIQUES

Drowsiness issues worried the road users as the effect of drowsiness in not only harm the drowsy driver but will affect other drivers too. This situation could sudden be happen, unintentionally especially in monotonous driving. Various factors that could lead to drowsiness such as reckless, on medication, stress, sleep deprivation etc. Many researchers agree that drowsiness detection can be classified into three techniques [4-7] which are i) vehicle-based measures [8-9], ii) behavioral measures [10-11] and iii) physiological measures [12-13]. Table 1 summarizes the common parameter used for driver drowsiness detection, including the pros and cons for each technique.

In addition, drowsiness detection also could be monitored using physiological measures. This technique helps in monitoring driver's heart rate, brain activity, pulse rate, breathing rate etc. Many researches recommended that physiological signals are the right technique to be used on driver drowsiness detection as it relates to our emotions and reactions. As these physiological signals are more reliable and provide high accuracy in driver drowsiness as illustrates in Figure 2, thus physiological signal's technique is preferred to be explored further in drowsiness detection. Previous research that have been done using these three techniques are summarized in Table 2.

Table 2. Summary measurement by previous research for driver drowsiness detection

Techniques	Features	Method and Classifier	Description	Efficiency / Accuracy
Vehicle based Measure	Steering wheel behavior [8]	Temporal detection window	Used novel approach of time series analysis of steering wheel angular velocity to detect drowsiness	N/A
	Steering wheel angle [9]	Steering wheel angle-based fatigue detection method, binary classifier	Detects driver drowsiness in real time using steering wheel angle data collected from sensors.	78.01% (accuracy)
Behavioral Measure	Yawning [10]	Support Vector Machine(SVM), Circular Hough Transform (CHT)	Use 3 steps face extraction, mouth region selection and wide, mouth open detecting using SVM. CHT is applied to the results proposed wide, mouth andopen detector.	98 % (efficiency)
	Eye blinking [11]	Viola Jones algorithm, Adaboos computational approach, Haar cascade classifier, Luminosity Algorithm & Harris Corner Detector	Non-intrusive and work well in realtime. Requires clear visibility oftheeye. In poor lightening or sun glasses,system become unable to detect eye region and falls.	94% (efficiency with good lightening condition)
Physiological Measure	Heart pulse wave (Sensor: Pulse sensor) [12]	HRV frequency domain, LF/HF ratio	Used non-intrusive sensor to see heart pulse wave from driver finger or hand to calculate the drowsiness level.	98.3% (efficiency)
	ECG [13]	Heart Rate, QRS detection by Pan Tompkins's algorithms, Cardio based graph	Electrical signal of the heart was usedto calculate the difference valuebetween normal and drowsy states.	95% (efficiency)

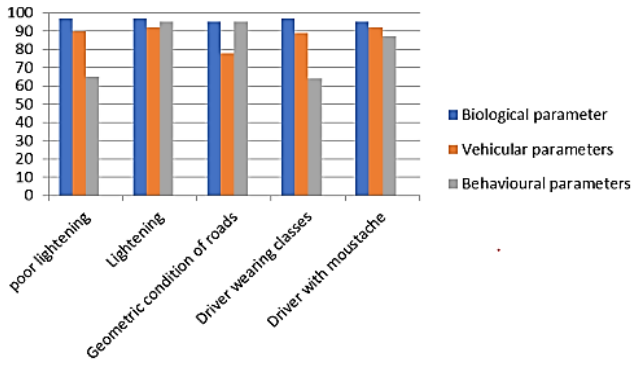

Figure 2. Comparative graph on efficiency of driver drowsiness detection [14]

The above figure compares different accuracies in driver drowsiness detection in terms of poor lightening, geometrical conditions of road, wearing glasses and have moustache. This graph illustrates that biological parameter (internal signal based physiological signals) are important in detecting driver drowsiness due to the highest accuracy that dominant in all aspects as seen in figure.

Based on Table 2, we can summarize that physiological measures are more reliable than the other methods. This is due to the body reactions are responding to our action and emotions that can be used as an indicator to measure the occurrence of drowsy state. Hence, this research is narrowed down to the physiological measure perspective towards driver drowsiness mechanism in the next section.

III. DRIVER DROWSINESS DETECTION TECHNIQUES USING PHYSIOLOGICAL MEASURES

Physiological signals refer to the signals that can be derived from our body such as sweat, respiration rate, heart rate, brain activity, body temperature etc. All of these parameters can be measured using ECG, Electroencephalogram (EEG), Electrooculogram (EOG) Photoplethysmogram (PPG), pulse sensor etc. As the body can experience various situations in any seconds, the signals in our body also reflect and make changes from the normal signal. Thus, the different pattern on the change's signals can be furthered studied in driver drowsiness.

Researchers agree that ECG can be used in detecting driver drowsiness using machine learning algorithms. A total of 25 subjects were included in the experimentation stage, whereas the data used was extracted from HRV, which is initialized by ECG signal [15]. Two machine learning techniques are compared, SVM (unsupervised techniques) and KNN (supervised technique) method that give results 3.23% and 87.5% respectively (normally the accuracy could reach below 80%). In addition, the detection time also could be reduced by applying the proposed technique. Yet, some improvement can be done in terms of increasing number of subjects for firming the result.

As an example, two different HRVs have been extracted from the ECG signals, which are original HRV and 'New Signal HRV' [16]. The 'New Signal HRV' was constructed using Poincare map. Both signals proceed to be extracted in frequency domain and nonlinear features. As a

result, 'New Signal HRV' which is constructed using Poincare map attains higher accuracy, specificity and sensitivity rather than original extracted HRV. Thus, Poincare map is one of the ideas in increasing the reliability of the proposed method.

The pulse sensor is also capable in improving driver drowsiness detection [12]. A pulse sensor was attached at the steering wheel for calculating HRV that derived from ECG signal in frequency domain. Two subjects (1 male and 1 female) undergoes the experimentation and the result shows that LF/HF ratio for normal state is higher and fluctuating, that reflect that the subject was in awake and active state. In contrast, during the transition of drowsy state, LF/HF ratio starts decreasing. A research in [17] support the argument by supporting the results by [12]. However, the result is not promising since minimal subjects were taken for the experimentation process.

In the end of this section, this paper reviewed all the physiological based current techniques to detect driver drowsiness. The best physiological measures that have the highest potential are ECG. This is due to fact that the ECG is a sensor which is well-established in the clinical perspective and makes it more flexible rather than other sensors. At this point, it can be summarized that EEG got limitation to be applied in driving environment as not everyone is willingly to wear EEG caps during driving. PPG also have disadvantage on taking the acquisition signal, as it uses finger as the main point of the measurement that makes driver feel uncomfortable with their driving conditions. Thus, the driver drowsiness detection using ECG were further discussed on the next section.

IV. DRIVER DROWSINESS DETECTION USING ECG

In this section, driver drowsiness detection using ECG were focuses into two main concepts, which are i) ECG in steering wheel; and ii) ECG in hybrid method. Both scopes can be further discussed in the next subsections.

The reason why ECG in steering wheel was pointed out is due to the limitation of ECG in encountering the intrusive method of physiological signals. Wireless ECG helps in monitoring driver drowsiness, however, the signal received reduce the accuracy of the system since wireless data have potential in data loss during the operation [18]. Many researchers found that developing the steering wheel for monitoring driver drowsiness is one of the good ideas for developing driver drowsiness detection. This is due to the natural driving environment i.e. the driver needs to be in contact with steering rather than the sensors to be attached to the human body directly that makes them feel uncomfortable and uneasy to drive [18].

A research by [19] implements smart steering wheel design for driver's emergency situation using physiological sensor as shown in Figure 3. It is noted that drowsy state of a driver is considered as an emergency situation on the road. The sensor was designed using thin copper plate and conductive fiber for ECG sensors, LED for PPG sensors and pressure sensor. The ECG sensor is positioned outside the steering wheel, while PPG sensor is located inside the steering wheel and pressure sensor is placed in the lower side.

In addition, emergency action such as lamp warning system design, vibration warning system design and beep warning system design also designed to alert the driver when the drowsy state is identified from the data state. The system is identified as a smart way in implementing steering wheel as a drowsy measurement system, yet the research didn't considered that not all drivers will place their hands on certain position at all time. We, as a driver usually change our position on the steering wheel to keep the driving environment convenient from time-to-time.

Figure 3. System configuration for smart steering wheel [19]

Cardio Wheel [20] as in Figure 4 is one of the interventions in conducting experimentation of ECG in steering wheel. The idea of the experimentation is to collect ECG data on steering that has been improved for biometrics recognition and driver conditions towards an off-the-person sensing approach [21]. The study was divided into two parts; i) hardware and ii) software parts. The hardware parts contain the signal acquisition and filtering process. In addition, software part will be connecting through a USB that pass the information through the lead detection. After detecting QRS complexes, baseline removal, feature extraction and classification, the system will calculate the heart rate and simultaneously capable to identify the drowsiness conditions.

Another research proposed the real time driver drowsiness detection embedded ECG sensor in steering wheel [22]. ECG sensor were placed on the steering wheel that wrapped by conductive fabric electrodes. As the palm were in contact with the ECG sensor, the ECG signal is recorded and transfer wirelessly through Personal Area Network (PAN). This research capable in analyzing the changes of ECG patterns between normal, fatigue and drowsy states using time and frequency domain. As heart beat decreased during drowsy state, ECG signal turns to have high number of RR interval (RRI) as compared to normal state but the RRI is not exceeding the ECG signal in fatigue state.

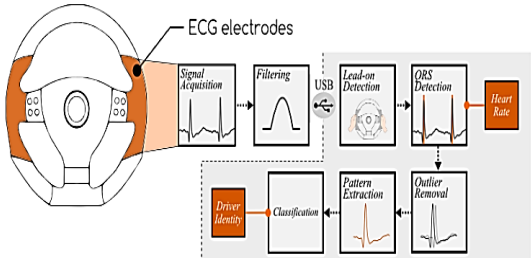

Figure 4. System architecture presented in CardioWheel [20]

In order to increase the reliability, accuracy and efficiencyof the ECG signal in drowsiness detection, many researchers recommend using the hybrid method [23]. Hybrid method is the combination between two or more methods to enhance the reliability of the proposed system.

V. DRIVER DROWSINESS DETECTION USING HYBRID ECG

This section describes fusion method that has been proposed to improve the accuracy and efficiency for a better performance in drowsiness detection. There are two subsections that will be discussed which are i) Hybrid ECG and other physiological signals and ii) Hybrid ECG and other measurements.

A. Hybrid ECG and other physiological signals

Sudden sleep that is considered as drowsy state are one of the unexpected actions by our body response, even we try to deny the situation. A research was done to generate warning flag for heart abnormality while sleeping [24]. A free database in Physionet was used for having input of EEG and ECG signal (we only focused on ECG for this review paper). Then, QRS detection using wavelet transform were applied to measure the heart rate. Then, LabView was proposed to show the different between normal and awake state, graphically.

Next, a database was provided to study the drowsiness cases, called DROZY [25]. This database contains multiple modalities to improve driver drowsiness detection including providing the Polysomnography (PSG) signal. PSG are commonly related to physiological signals in sleep studies, which include EEG, EOG and ECG signals. As recommended by the author, the DROZY database can be used to develop cognitive distraction, drowsiness detection, sleep studies etc. A research by [26] explore the database in applying it in detecting driver drowsiness system using multiple algorithms in enhancing the system performance.The result shows that MLP and IBk could increase the performance rather BN. This is because, the performance of neural networks that inhibit additional hidden layer works better rather than non-neural network. The study also concludes that false alarm between early and deep sleeps should be monitored for drowsiness studies.

Electrocardiogram (ECG) based humans' status detection (ECG-HSD) measure is proposed to detect the status of drowsy and drunk drivers [27]. The proposed ECG-HSD extracted similarities of ECG signals under normal, drowsy and drunk conditions. The corresponding feature vector was built and the important data points on ECG samples were weighted which is capable to improve the detection accuracy. Besides, two criteria of classifiers which are accuracy and testing were considered with the aid of multiple criteria decision making (MCDM). After that, K-fold validation was carried out for training and validating the classifiers. ECGHSD and the evaluation are summarized in Figure 5. Based on the graph, the results revealed that the proposed ECGHSD achieved satisfied accuracy and short testing time (7seconds). The results also discovered that the proposed ECGHSD are suitable in real-time monitoring.

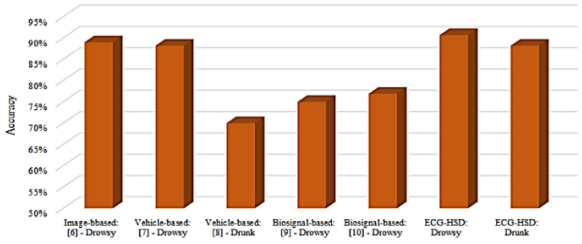

Figure 5. The comparison between previous works and proposed ECG-HSD (red box) [27]

B. Hybrid between ECG and other measurements

A study was conducted by [28] in measuring driver drowsiness detection by comparing intrusive (EOG and ECG) and non-intrusive (video camera) methods. EOG, ECG and video camera alone produce low accuracy in five machine learning classifiers (SVM, RF, ANN, GBT and KNN). However, when the study used the fusion method incombining ECG + EOG, and ECG + camera video, the accuracy leads to a better performance in driver drowsiness detection. Based on this finding, the hybrid approach using ECG has the potential in providing extra robustness to the proposed system.

VI. CONCLUSION

This paper presents a thorough review of proposed techniques in presenting data acquisition measure in detection of driver drowsiness using ECG. Though various methods exist to detect the occurrence of drowsiness, physiological measures are the most prevalence technique. This is due to fact that the body signals are close to the actions and reactions of a driver which are proven correlates with the drowsiness condition. Though, limitation of several sensors have been identified, thus ECG acts as the most prevalence measure in detection of driver drowsiness.

Two measure of ECG that have been described well are i)ECG in steering wheel and ii) ECG in hybrid method. The hybrid method also was classified into two parts which are i) Hybrid ECG and other physiological signals and ii) Hybrid ECG and other measurements. Overall, this review can summarize that even though ECG signals are capable

in detecting drowsiness more accurately rather than other sensors, yet hybrid method seems to produce higher accuracy and efficiency in driver drowsiness system. By combining two or more signals, it is proven that higher reliability of detection in driver drowsiness can be developed. Hence, it is hope that developing driver drowsiness detection system could contribute in establishing half of road death reduction during 2020.

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