Paper ID: 441

Survey on wearable sensor technologies on driver drowsiness detection

P.D.S.T Gunathilaka# and P.Kalansooria

Department of Computer Science, Faculty of Computing, General Sir John Kotelawala Defence University

sathygu95@gmail.com,SriLanka

Abstract: Intoxicated driving is dangerous , drowsiness is an another form of fatigue which claims hundreds of lives every year in fetal crashes.US National Highway Traffic Safety Administration has estimated that a total of 100,000 vehicle crashes each year are a direct result of driver drowsiness (Anon., n.d.).In order to prevent from these devastating accidents we should identify the drowsy moment and control it before mishap happen. For that driver drowsiness state should be monitored. But detecting drowsiness using face image behavior or drivers eye blinking is not accurate enough. Though we can measure rapid eye movement sleep and slow eye movement sleep, we cannot measure no eye movement sleep. Researchers have found that eye open sleep is quite common, so this human drowsy behavior also should be measured through the system (Anon., 2019). After analyzing drowsy behavior, has classified as normal, slightly drowsy and highly drowsy. Mention drowsy detection methods identify drowsiness when highly drowsy. But it's rarely possible to prevent from the highly drowsy state. Even if they prevent from that, it's too late to prevent from mishap. So the exciting drowsiness detection system is absolute. Now we have accurate sensors to detect heart rate, EEG, EOG Etc. Through those we can measure drowsiness in normal and slightly drowsy states where it's possible to prevent from mishap. Sensor signals will be processed by the desktop application and identify whether the driver is drowsy or not. For more accuracy, place the sensor in the steering wheel. The aim is an accurate drowsiness detection system which covers the weakness of absolute systems.

Keywords: Drowsiness Detection, No-eye movement, highly drowsy, heartrate.

Introduction

A road accident occurs every 10 minutes in Sri Lanka (Mirror, 2018). More than six or seven lives are always in danger. According to available statistics 150 admitted to hospital a day. National Council on Road Safety statistics proved that 18980 road accidents occurred from January 2017 to June 2017. From those 1473 had caused fetal injuries and 1547 had caused deaths (Anon., 2019).

Year	Fetal crashes	Small injuries	Serious injuries	Deaths
2012	2317	14680	7209	2444
2013	2190	13525	6870	2362
2014	2260	12781	7071	2440
2015	2600	13595	8186	2816
2016	2798	13961	8518	2961

Figure 1: details about fetal crashes in Sri Lanka (police media unit)

According to accidents happen between 2012 and 2016 more than 20,000 lives are lost each year. Not only Sri Lankan statistics, but also organizations such as National highway traffic administration (Anon., n.d.) and World health organization also proved that these devastating accidents are direct result of driver drowsiness (Hanwella, 2018).US National Sleep Foundation statistics reported that 54% of adults have driven in drowsy mode and 28% from them were actually sleeping (Anon., 2019).

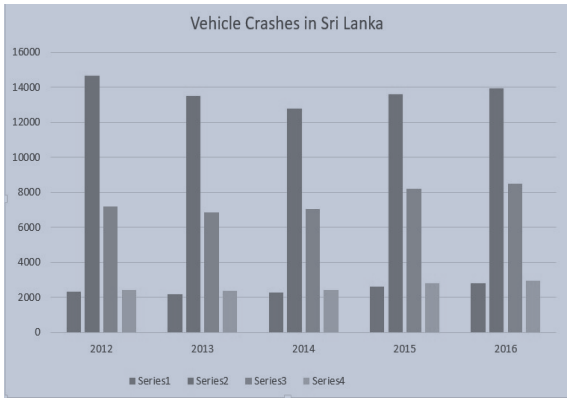

Figure 2 chart of yearly vehicle crashes to above chart

As mentioned in figure 2, every year number of accidents are increasing. The main cause of these accidents are fatigue, drowsiness, monotones and alcohol. From these, drowsiness is the most devastating problem. So, it's necessary to make a drowsiness detection system to prevent from these devastating mishaps.

So to prevent from these accidents most of the researches had made a drowsiness detection system by caring 3 main measures .They are vehicle based measures, Behavioral based measures and Physiological measures. In vehicle base measures they measure the drowsiness using lane position, steering wheel movement, etc. In Behavior based measures driver behavior was analyzed using yawning, eye closure, eye blinking, etc. In physiological measures they measure the drowsiness through heart rate, pulse rate, ECG, EEG, EOG etc. (Arun Sahayadhas, 2012).

Figure 3, 4, 5 shows mention 3 kinds of measures current systems. Here vehicle based measures and behavior based measure recognize the drowsiness when the drivers are in a deep sleep. So, it's too late to avoid from accident even if they are alerted.

(Figure 3 research based on vehicle based measures, Figure 4 behavior based measures based research, Figure 5 physiological measures based measures)

But physiological measures measure driver drowsiness when driver is awake to asleep stage. So physiological measurement is a good measurement when compare to other two. In physiological measurement also has two kinds of components .They are wireless components and wired components. When there is a wired component it's intrusive to the driver. But when it is wireless its non-intrusive .Sleep also can be categorized as awake ,non rapid eye movement sleep(NREM) and Rapid eye movement sleep(REM).Detecting drowsiness when the drivers eyes are open (NREM) is a critical point in drowsiness detection (Arun Sahayadhas, 2012). If research use vehicle based measures and behavior based method to driver drowsiness detection, its impossible to measure non rapid eye moment sleep. So the research is not covering all type of subjects, but if system use physiological measures to measure driver drowsiness it's possible to identify NREM sleep. So rest of the research use physiological measures to detect drowsiness.

In Section II of this paper, a literature review on drowsiness detection system and other methods are presented .This is followed by a description of the methodology used in Section III. Comparison of the existing system is presented in section IV. The proposed solution is stated in Section V. The conclusion of the study is given in Section VI.

Literature Review

Many methods have been employed to identify Driver Drowsiness out of which a selected number from the literature are reviewed in the section.

In the literature drowsiness had been detected using three main measures. Vehicle based measures, behavior based measures and physiological measures are them. Some Researchers have recognized the drowsiness using deviation from lane position, Movement of steering wheel and pressure in the acceleration pedal etc. However, these sorts of measures are poor predictors since these changes also could be happening because of alcohol and drugs. (Arun Sahayadhas, 2012).

Behavior based measures, such as eye closed, yawning and head bending also had been used to detect drowsiness. The aim of that project was to build a model of drowsiness identification framework .Through this framework they collect the pictures and measure the condition of eye, mouth ratio and head node rate as a predetermined calculation .For implementing this framework some of OpenCV libraries were utilized including Haar-cascade .The target has achieved by processing video images by OpenCV. The Outcome of the video was used to determine drowsiness level and then provide warning to the drowsy driver. As they mention drowsiness can be measure using manual and automatic approaches. Manual method is not efficient .it could cause accidents because it's based on human perception of the situation .According to this project head bending is the final state to detect drowsiness but it's too late to prevent from accidents (Shreya A Kulkarni1, June 2019). But this research can be used for other occasions such as detecting class room sleepers or for night workers to detect whether they are sleeping or not. All the movements are caught through the camera's so whole thing depend on the availability of lighting and speed of image processing on video. So this research has proved that behavior based measures are poor predictors to measure driver drowsiness (Shreya A Kulkarni1, June 2019).

Physiological based method detect drowsiness by using driver's physiological signals such as ECG, EMG, EEG, EOG etc. Even though these predators are good, it's not comfortable for a driver to ware such a device .So Researchers has develop a smart seat belt that sense heart rate to combat driver fatigue (Pai, 2014).The target of implementing this project was to overcome some of the weakness such as not adjusting for noise and vibrations and some products asking wearable. Here they have realized that heart rate and breathe rate as good indicators (Pai, 2014). .As they were targeted drowsiness was measured unobtrusively. According to their research attach a sensor in to a car which is already initialized also a challenging task. Some companies had used ECG sensors for vehicles and had crashes resulting from it. So as they mention we need to make the ideal trade when we select sensors to the sheet belt.

The latest release of wireless wearable devices is biosensors .Through this we can measure people's physiological data .In this paper they have use a wearable bio sensor called bio Harness to detect driver drowsiness. bio Harness is produced by Zephyr technology (Brandy Warwick1, 2015) .They have carry out the system using two phases .In the first phase it collect driver physiological data using bio sensor and analyze the measured facts to find the key parameters related to drowsiness. In the second phase it design a drowsiness detection algorithm, then a mobile app to alert driver. In this research also they have proved that breathing rate and heart rate are related to drowsiness .According to their experiment there is an objective increase in their heart rate and decrease in breathing rate (Brandy Warwick1, 2015). The device with the sensor has to wear close to chest while he is driving .So if the analysis data

passed certain threshold the driver will be alerted. Here the device has to wear separately so it disturb normal flow of driving. Though we can measure heart rate, heart beat to beat interval, breathing rate, posture, activity level, peak acceleration, respiration rate, heart rate and RR interval has a significant varies between different stages of drowsiness. When driver move from awake state to drowsy state ratio of Low Frequency to high frequency decreases progressively. Even though, Heart rate variability is a good indicator but bio harness 3 doesn't report it (Brandy Warwick1, 2015).

An algorithm has improved to drowsiness detection for non–intrusive driving. There they have use sensor parameters to detect drowsiness. They mainly test the sources such as head movement, steering grasping and driving under influence of alcohol. If one of these conditions prevail it recognize the person as a drowsy one. According to the calculations probability of accident could be increase when alcohol in the blood is beyond 0.08g/100ml (Ratnarup Dey, 2018). They use Load cell, Alcohol Sensor and Accelerometer to detect above mention characteristics. Load cell measure the force with the steering wheel driving. The three axis accelerometer is used to detect irregular head movement. Breathalyzer is used to estimate the alcohol level in the blood and it was measured through breathing. In the implementation algorithm they have use Arduino programming language by merging C and C++ functions (Ratnarup Dey, 2018). But taking 10 second to capture one breath has taken as a limitation of that project. Not only that ,driver not being with in the 10 centimeter from the sensor could also cause not detecting drowsiness .The current sensor which use in the existing system also not detecting alcoholic content in the drivers breath if the driver is in their driver position.

Another research has conduct for non–contract sensing platform to detect physiological signals of the driver. There they have mainly focused on electrocardiogram (ECG) and electroencephalography (EEG) .Using this monitoring system we can monitor on set and extent of drowsiness. Physiological signals are a good indicator. But conventional bio electrical signal measurement need electrode to be connect to human body. If we use that to normal driver drowsiness detection it affect normal driver operation .So it is not effective for long-term monitoring. So In this project they have use a non-contract ECG sensor which use high input impedance circuitry .Using this effective sensor we can measure electrocardiography(ECG) ,breathing and eye blinking .In this sensor package ECG signals effectivity work up to 30cm away from body (Dr. Xiong (Bill) Yu, 2012 July) . The sensor which they use here is validated on high fidelity driving simulator .Here they have used digital signal processing algorithm to reduce the noise and automate signal analysis .Using measured physiological signal (heart rate, heart rate variability, breathing frequency and eye blinking frequency) we can measure driver fatigue .To achieve high reliability, drowsiness indicator has developed by coupling several physiological parameters. Evaluation of sensor has conducted under various conditions such as ordinary laboratory and official environment conditions. Performance of this sensor also monitored using high fidelity simulators and operational truck. As they say this sensor technique also can be applied for railroad train operators and truck drivers.

A Smart car seat has design for drowsiness detection based in pressure distribution of the drivers body (Ines Teyeb, 2018 April).They have use mesh of pressure sensors to cover the sheet surface. From these sensors they have highly care about head support sensors and back cushion

support sensors. After analyzing the pressure distribution they take two decisions which are zero pressure state and high pressure state. For measuring pressure they have use a fundamental physical concept of pressure .In the algorithm they have mention 3 sitting positions and the pressure distribution of it. Then they have created a table which contain result of sitting position recognition .This research totally contain the details about recognizing movement. Through that they say driver is in a fatigue mode when he is moving to right. However to confirm drowsiness they ask to combine eye state based wavelets networks. As for further work they ask to develop a multi-parameter vigilance monitoring system by combining heart and breathing rate (Ines Teyeb, 2018 April).

A review has been released from the Tezpur University based on "correlation of drowsiness with electrocardiogram". There they used ECG signal to measure driver's drowsy behavior. According to their study spectral analysis of HRV signal cause different frequency bands. From those Low frequency band and high frequency band can be used as input to measure drowsiness state (Ananya Bonjyotsna and Sanjay Chandra Roy, 2014).

Research Gap

The proposed research solution is different rather than above mentioned existing products because I'm using Non-rapid eye movement sleep detection which they did not use. For this research my measuring point is heartrate using pulse sensor to identify driver drowsiness which did not use for previous researches.

Aim

Identify driver drowsiness accurately and efficiently in awake to drowsy state.

Objectives

- To identify drowsiness using physiological measures, Heartrate viability.
- To develop algorithm to identify drowsiness using FFT.
- To identify whether driver is drowsy or not.

Motivation

All the human beings are busy with their own lifestyles under these evolution of technological era. None of the human beings are physically and mentally fit to live a balance life. They don't have mental rest. Most of the time people get drowsy when they are driving, this cause most of the motor accidents. I personally faced the same experience when I was driving. It drives me to motivate to do this research to avoid motor accidents and saved the human life.

Methodology

Initially, statistical data on drowsiness detection in Sri Lanka was obtained from police media unit reports and newspaper articles .Other than that National Council on Road Safety statistic data also taken to prove the increment of accident due to drowsiness. National highway traffic organization and World health organization data also directly proved that these divesting accidents directly cause by drowsiness. So introduction was directly based on above statistical data. For searching purposes the keyword "wireless drowsiness detector", "physiological based drowsiness detector", "Detect drowsiness using heart rate and respiration" were used either together or separately.

Altogether eight journal articles were obtained from the literature review. Research papers for the reviewing of existing systems were accessed and obtained from google scholar, Scientific Research publishing, Sci-Hub and international

research conference etc." Wireless drowsiness detector" or "Detect drowsiness" were the key words used to retrieve the research papers. Attempt to retrieve some research papers through databases such as IEEE Explorer, Web of Science and Scopus were unsuccessful due to logging restrictions. And also some papers were partially visible due to login restrictions. This cause missing some of the valuable information. The selections were based on the date of publication and inspecting abstract and the content body. Some of the papers had to drop out due to lacking relevant information and uncertainly about authenticity .Altogether eight papers were selected for the review. The aim and goals of the selected research paper were used for this study along with the method and result.

Comparison

As we mention in the literature review many method had been implemented to detect drowsiness. From those Vehicle based and behavior based measures are not good indicators to measure drowsiness. All the mention researches has proved physiological measures as a good drowsiness indicator. Drowsiness based research had used different technologies such as Fast Fourier transform, signal processing, video image processing, pressure analyzing etc. From these Fast Fourier Transform is more efficient than other technologies. In the above mention researches, drowsiness had been measured through physiological measures such as breathing rate, heart rate, EEG, ECG.

Table 7 : Literature review summary

Description	Use physiological based measures	Pub. Yr.	Type of physiological measures which use in the project	Technique use for drowsiness detection
Driver Drowsiness using wireless wearable	True	2015	Bio sensor to measure (heart rate, heart beat to beat interval, breathing rate, posture ,activity level ,peak acceleration , respiration)	Fast Fourier Transform.
Non-Contact Driver Drowsiness Detection	True	2012	EEG,ECG	Digital signal processing algorithms
Smart Seat belt	True	2014	Respiration, heart rate	Signal processing
Drowsiness monitoring	False	2019	- They use condition of eye, mouth ratio and head node rate.	Processing video images using opencv and haar-cascade
Improved algorithm for drowsiness Detection	False	2018	- Head movement and steering grasping	Arduino by merging C and C++
Smart car seat design for pressure distribution	False	2018	- Use body pressure	Pressure analyzing techniques
Correlation of drowsiness using ECG	True	2014	ECG	Fast Fourier Transform

But according to above researches, using heart rate to measure drowsiness is more accurate than other physiological measures. Most of the research also had mention this

measurement as good indicators. Even though people can use wired and wireless devices to detect drowsiness. Wireless detection is more unobtrusive. Detecting fatigue through pressure distribution is a new approach. It can detect driver movement but cannot exactly say whether driver is drowsy or not. So it's not enough to prevent from crashes. So up to best of my knowledge , using wireless sensor like heart rate detecting sensor & Fast Fourier transform technique is best way to detect drowsiness .

Proposed Solution

After reviewing existing research based on drowsiness detection I came to know that driver drowsiness detection is still not accurate enough. So I proposed to make a wireless drowsiness detection system to identify driver's drowsiness. Since the Heart rate is the best measure to detect drowsiness, I ll create a heart rate detecting module using Nodemcu and pulse sensor. Then the system will use Arduino code to publish the data in the MQTT Cloud. The python based application is used to subscribe these data and do furture processing using fast Fourier transform to detect drowsiness. Using the key parameters like low frequency to high frequency ratio and drowsiness detection algorithms we can confirm driver drowsiness. Finally system will give a system notification saying driver is conscious. Since we alert the driver in the awake to sleep state driver can prevent from it. Even the drivers who sleep non rapid eye movement also can detect their drowsiness clearly and can prevent from it. So most of the accidents will decrease through that.

Conclusion

Yearly number of vehicle crashes are increasing. After analyzing reason behind that researchers came to know that it's direct result of drowsiness. Number of deaths related to drowsy driving is increasing because of not having a proper and accurate drowsiness detection system. Exiting systems has measure drowsiness through three type of measures such as vehicle based measures, behavior based measures and physiological based measures. Vehicle based measures has detect drowsiness through deviation from land position, steering wheel movement etc. But as I mention in the literature review it's a poor predictor to detect drowsiness. Behavior based measures detect drowsiness throw eye blinking, head movement, yawning type of behaviors. Since all the measurements are grab through cameras drowsiness level is depend on the angle of the camera and camera quality. Not only that, it detect drowsiness in the last state of drowsiness. So, even they have detected drowsiness it's too late to prevent from accidents. So we can say it also as a poor predictor. But physiological measures detect drowsiness through driver's physiological states such as ECG, EOG, EEG, Heart rate, respiration etc. Since it detects drowsiness before the final state of drowsy it can prevent from a lot of accidents. And also it measure not only the rapid eye movement sleep it also show the non-rapid eye movement sleep. So physiological measures are a good indicators. From physiological measures heart rate has a special important since it shows a proper variation when convert to frequency domain. For monitoring these two type of measurements we can use wireless and wired sensors. From that wireless sensors are good because it's non-intrusive. Even though a different type of sensors are there bio sensors plays a major role when detecting heart rate. These sensors could be embedded in sheet or sheet belt or as an external device. But sheet embedded sensors could cause accidents because embedding sensors to an already initialized vehicle could change the balance of the vehicle. So embedding devices in to vehicle sheet is dangerous. But we can add the device in to the steering wheel. Then we need a signal

processing and analyzing unit to detect drowsiness for that we can use a monitor .This desktop monitor based system detect the drowsiness and give a system alert.

Reference

Anon., 2019. National Council for Road Safety. [Online]Available at:http://www.transport.gov.lk/web/index.php?option=com_content &view=article&id=90&Itemid=191&lang=end [Accessed 20 09 2019].

Anon., 2019. National sleep foundation. [Online] Available at: https://www.sleepfoundation.org/ [Accessed 17 09 2019].

Anon., 2019. National Sleep Foundation. [Online] Available at: https://www.sleepfoundation.org/articles/myth sand-facts-about-sleep [Accessed 21 09 2019].

Anon., n.d. national highway traffic safety administration. [Online] Available at: https://www.nhtsa.gov/road-safety [Accessed 15 September 2019].

Arun Sahayadhas, K. S. a. M. M., 2012. Detecting Driver Drowsiness Based on Sensors: A Review. journal/sensors, p. 17.

Brandy Warwick1, N. S. X. C. K. X., 2015. Detecting Driver Drowsiness using Wireless Wearables. Rochester, NY , s.n.

Dr. Xiong (Bill) Yu, P., 2012 July. Non-Contact Driver Drowsiness Detection System, Cleveland, OH : Transportation research board of national acadamy.

Hanwella, P. R., 2018. The Sunday Times. [Online] Available at: http://www.sundaytimes.lk/180520/mediscene /read-this-andhave-a-good-nights-sleep-294295.html [Accessed 16 09 2019].

Ines Teyeb, O. J. M. Z. a. C. B. A., 2018 April. Towards a Smart Car Seat Design for Drowsiness Detection Based on Pressure Distribution of the Driver body. Tunisia, Research gate.

Mirror, S. L., 2018. A road accident every 10 minutes!. [Online] Available at: https://srilankamirror.com/news/6874-a-roadaccident-every-10-minutes

Pai, A., 2014. Researchers develop smart seatbelt that senses heart rate to combat driver fatigue. s.l., s.n.

Ratnarup Dey, J. P., 2018. An Improved Algorithm for Drowsiness Detection for Non-Intrusive Driving. Bengaluru, Karnataka, India, International Journal of Applied Engineering Research.

Shreya A Kulkarni1, D. S. S. K., June 2019 . Driver Drowsiness Monitoring System. , Bangalore, India , International Research Journal of Engineering and Technology (IRJET) .

Ananya Bonjyotsna and Sanjay Chandra Roy (2014). Correlation of Drowsiness with Electrocardiogram : A Review. [online] Available at: https://www.semanticscholar.org/paper/Correlation-of-Drowsiness-with-Electrocardiogram-%3A-Bonjyotsna Roy/602394553991cd7bf1d026e4e8777cf22e88114a [Accessed 29 Jul. 2020].