Real-Time Automated Multiplexed Sensor System for Driver Drowsiness Detection

Maneesha V Ramesh
Associate Professor and Head
Email: maneesha@am.amrita.edu

Aswathy K. Nair
M Tech Student
Email: p2wna09006@students.amrita.ac.in

Abishek Thekkeyil Kunnath
Research Associate
Email: abishektk@am.amrita.edu

Amrita Center for Wireless Networks and Applications
AMRITA Vishwa Vidyapeetham (AMRITA University)
Kollam, Kerala, India-690525

***Abstract*—Increased stress level in working environments, reduced sleep, variation in sleep pattern and time due to the adaptation of global time zone in working environments, increase in alcohol consumption, larger distance travel using high power automobiles, etc., contributes to increased level of driver drowsiness and fatigue. In the past decade, steep increase in accidents and loss of life was experienced mainly due to the increase in the driver drowsiness and fatigue. This research work aims in developing an intelligent wireless sensor network to monitor, and detect driver drowsiness in real-time. This real-time system consists of multiple non-obstructive sensors which continuously monitor the driver's physiological parameters and disseminate the first level alarm to the driver and the passengers. The second level alarm will be disseminated, along with the vehicle identification number and the real-time location coordinates of the driver, to the nearby police station or the rescue teams using the available wireless ah-hoc network, if the driver's state does not change even after the first level alarm. This research work contributed to the design and development of system architecture for real-time monitoring and detection of driver drowsiness. This work also integrated effective real-time sensor fusion techniques for monitoring the heart rate collected from the driver. One of the novel ideas in this research work is the development of multiple sensors embedded in the steering wheel capable to measure the heart rate and dynamically alert the driver or the rescue team about the driver drowsiness, to avert accidents**

Keywords-Wireless Sensor Network, Wireless Ad-Hoc Network, Drowsiness detection, Heart rate variation, Photo reflective sensor, Real-time monitoring, Real-time data analysis, Alert dissemination

I. Introduction

Worldwide, reducing accidents is one of the major concerns due to the rapid proliferation of vehicles and its effective users. Driver drowsiness is one of the major causes of large number of fatal road accidents. According to National Sleep Foundations (NSF) nearly two million people were involved in vehicle crashes due to drowsiness and survey shows that 105 million people were admitted for driving while drowsy[10]. A survey on Thai bus/truck driver's reveals that among 69 percentage of drivers' accident one third of crashes were contributed by drowsiness.

People have limited ability to predict the onset of sleep, and many of them continue to drive by ignoring the signals of falling asleep. Drowsy people lose the ability to control the vehicle and may lead to major accidents. Federal motor carrier safety administration office of analysis (FMCSA) has performed a study on driver drowsiness detection measures and states that drowsiness plays a vital role in vehicle crashes. Most of drowsiness related accidents is due to drivers irregular time schedule, sleep deprivation, micro sleep, driving pattern, sedation of medicines, and alcohol consumption [1], [2], [3], [4]. These accidents can be reduced if we could develop and implement an effective prevention mechanism to mitigate accidents due to drowsiness.

Driver drowsiness can be effectively monitored using different physiological parameters. Monitoring of EEG, ECG, hand grip force, image capturing and speed of the vehicle are the different methods that have been used so far to determine driver drowsiness. Most of these need electrode contacts on drivers' body, which will annoy the drivers, and are impractical in real life scenario. Different devices to measure drivers' heart rate are wrist band, head band, chest band, ear clip etc. These devices will be uncomforted for the driver and it won't give assurance that the driver will wear these devices while driving. Measurement of hand grip force is not reliable because it may not assure that the driver always hold the steering wheel firmly. Prediction of decrease in speed of vehicle cannot come to the conclusion that driver is drowsy. Depending upon the state of mind the driver may change the speed of vehicle. The above cases will lead to increase in frequent false alarms. The camera based system will affect the privacy of the driver. In order to evade the difficulties mentioned a pulse rate detection system is introduced in this paper to determine the alertness of the driver.

This paper details a practical, real-time, non invasive and non obstructive, multi level warning system for driver alertness monitoring. The system comprise of multiple sensors embedded in the steering wheel, capable to measure the heart rate. The data from multiple sensors are fused together, analysed and processed to derive the relevant data on driver drowsiness level. If the driver is considered as drowsy the system invokes an alarm. A second level warning will be issued to the police, traffic control rooms, or rescue teams at remote centres if the driver remains in the drowsiness stage after receiving the first level warning.

Section 2 describes the state of the art of driver drowsiness

978-1-4244-6252-0/11/$26.00 ©2011 IEEE

detection system. Section 3 describes in detail the intelligent steering wheel sensor network, its implementation and its working. Section 4 and 5 elaborates the complete wireless sensor network for detecting driver drowsiness and also the unique heart rate variability detection algorithm. The experimentation is described in detail on Section 6. Section 7 provides the conclusion and future work about this research work.

II. Related works

Chieh et al. [5] described a driver fatigue detection methodology using steering grip force, which detects the drivers' alertness by monitoring the drivers grip force on the steering wheel. This system is not effective if the driver doesn't firmly hold on the steering wheel, leading large number of frequent false alarms. Whereas the proposed system will detect the driver drowsiness even if the driver doesn't firmly hold on the steering wheel, due to the usage of infrared sensors.

Zocchi et al. [6] presents their project PSYCAR which is aimed to study the feasibility analysis on a car control system by psychic-physical parameters. They used multivariate statistics methods for evaluating the correlations between the physiological parameters acquired (EEG, galvanic skin response or resistance, peripheral temperature and heart rate variability). But this system is invasive since all the sensors to monitor the above parameters need to be in contact with the body.This will not give assurance that the driver will wear the device while driving but the proposed system is non-invasive. Ruei et.al [7] developed an EEG based system with fuzzy neural network for determining driver drowsiness. Qing et al. [8] implemented a wireless oxygen saturation using wrist band pulse oximeter, for real-time monitoring from a remote health-care centre [8]. However the systems mentioned above will function only if the driver wears the system that requires driver's cooperation. The proposed system uses a non intrusive technique by embedding infrared pulse rate sensors array on the steering wheel to detect the heart rate, which does not require driver's cooperation for effective functioning of the system.

The camera based face detection method [12] has been mostly used but it consumes more computational power for processing the data. Another method is assessing drivers' eye blinking rate using video monitoring techniques. It is difficult for the system to obtain the value if the driver is wearing spectacles also the processing power is high and lighting condition inside the vehicle is an important factor for getting reliable data, and the system may question the privacy of the personals. The economic cost is high besides affecting the privacy of the driver.

III. Intelligent steering Wheel Sensor network(ISWN)

Intelligent steering wheel sensor network (ISWN) consists of multiple embedded infrared sensors aimed to monitor the driver drowsiness by measuring the heart- rate of the driver. The pulse readings of the driver can be congregated from multiple infrared (IR) reflective sensors. The IR emitter and detector are packed in a single sensor unit and embedded on the steering wheel which makes no inconvenience to the driver. When the driver holds the steering wheel, the pulse rate reading will be initiated by the sensor unit. A direct contact is enough to measure the heart beat rate using this system. The ISWN detection system consists of four modules namely,

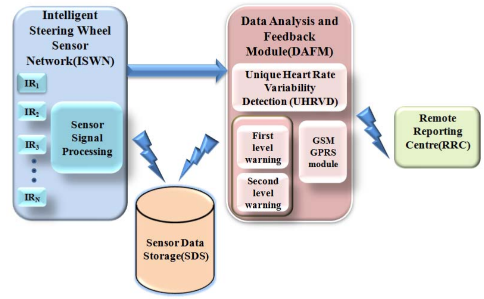

Fig. 1. ISWN detection system

IR sensor, amplification and filtering module, data conversion module and data aggregation and processing module, as shown in Fig. 1. The reflective IR sensor array consists of IR emitters and phototransistor detectors. The light reflected back from the tissue has intensity variation that occurs as the blood volume changes and these results in voltage variations. This voltage variation determines the heart rate level. However the output obtained from the IR reflective sensors is in the range of mV. Hence sufficient amplification is performed to increase the signal strength for interfacing to the analysing module. The gain of the pre- amplifier should be set in accordance with the signal obtained from the sensors since too much amplification increases the noise and results in signal distortion. After pre-amplification the signal is fed to a signal conditioning circuitry that consists of band pass filter and low pass filter. BPF is used to get the required pulse signal frequency and to reject power line frequency of 50/60 Hz a low pass filter is designed.

Frequency selection is one of the main criteria for filter design. Since the frequency of pulse signal is very low, a band pass filter is required. Gain has to be set in accordance with the pulse frequency and falls within the desired range so that noise suppression will be better. The filtered signal is further amplified to a sufficient level for data analysis. Subsequent to signal conditioning the signal is given to sample and hold circuitry that holds the output voltage from the preceding stage to a minimum period of time for conversion. The analog mux selects the active input samples and is fed to an ADC in build in the microcontroller. The digitized signal is processed using microcontroller and decision making is performed using the Unique Heart Rate Variability Detection (UHVD) algorithm (discussed in Section V), to check the drivers' alertness.

IV. Wireless sensor network architecture to detect driver drowsiness

The architecture for the proposed wireless sensor network system, to detect driver drowsiness, includes an intelligent steering wheel sensor network (ISWN), a sensor data storage

(SDS), a data analysis and feedback module (DAFM), and remote reporting centre (RRC). The proposed system design is given in Fig. 2. The wireless sensor system will gather signals from multiple sensors placed on the steering wheel, provides real time monitoring and feedback, data analysis and reporting driver performance to remote centre. The main module of the system is Intelligent Steering Wheel Sensor Network(ISWN). The ISWN comprises of multiple pulse sensors embedded on the steering wheel and the sensor signal processing circuitry. The pulse signals originated from the heart is captured by pulse sensors. To enhance quality signals from these sensors the signals are given to a signal conditioning circuitry that consists of band pass filter, low pass filter and notch filter to suppress the noise and boost the signals.

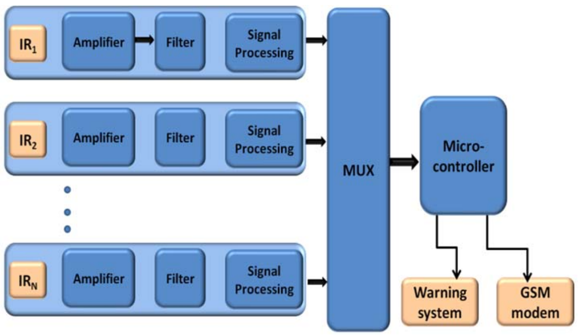

Fig. 2. Proposed system

The obtained signals are given to a sensor data storage(SDS). SDS is the repository of the data from the sensors. The SDS maintains two tables-the conditioned signal obtained from the ISWN is stored in the one table of SDS and the computed heart rate data is stored in another table in the data base. The user can later on check the data stored in the SDS to analyse his heart condition.

The data from ISWN is given to a Data Analysis and Feedback Module(DAFM) to check the driver drowsiness stage. The unique heart rate calculation algorithm checks the status of driver vigilance. If the driver is found to be drowsy the system invokes the alarm. In the first level an alarm is given to awake the driver. If the heart rate variation is found to be consistent, even after the first level warning, it implies that the driver has fallen asleep or having cardiac related problems, or an accident has occurred and the driver has lost his consciousness, or the driver died due to an accident. Then the system will disseminate the second level warning constituting an emergency message that consists of vehicle identification number and GPS location to the rescue force, traffic control unit and police. The emergency notification will be send through GPRS or GSM module.

V. UHVD ALGORITHM TO MONITOR AND ALERT DRIVER DROWSINESS

The UHVD employs a universal approach to set the unique normal heart rate (HR) of the driver, each time the system initiates. Once the normal HR is set the algorithm calculates the unique threshold based on the heart rate. The algorithm then continuously scans each pulse if it goes below the threshold set value. The flow diagram of the system is given in Fig. 3.

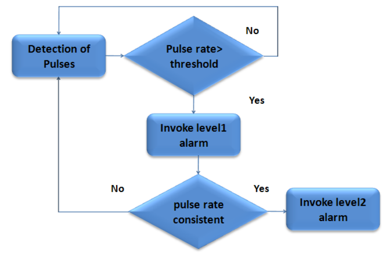

Fig. 3. Flow diagram of system

A. Unique HR and threshold calculation

The unique heart rate of the driver has to be calculated each time of initiating the driving process. For availing the best prediction accuracy, the HR is taken for analysis subsequent to a standard initial running time of the system. For each pulse detected, a corresponding pulse signal is received and the count of signals obtained for a standard time unit is determined. By using statistical means, the average HR is obtained and the same is set as the standard normal pulse rate of the driver. The standard normal heart rate of the driver is calculated as

$$Hbs = \sum_{i=1}^{Nb} \frac{Hbi}{Nb} * \frac{1}{60} \tag{1}$$

Nb is the monitoring period to determine the pulse rate, Hbs is the heart rate reading obtained during the monitoring period. Hbi is the heart rate during each sampling period. The number of pulses so obtained within a particular interval of time is averaged and set this value as the standard normal pulse rate of the driver. Hbs is considered as the standard reading of the driver. For each individual the above reading is different. The threshold value, Ht is calculated based on this standard pulse rate as in (2).

$$Ht = Hbs \frac{Pt}{100} \tag{2}$$

where Pt is the threshold percentage value. When the calculated value goes below the threshold set value, the system considers it as a drowsy state.

B. Algorithm for analysing the HR of the driver

The heart rate continuously traced through the sensors will be closely monitored in order to determine the variations in the pattern of pulse values. If any change in the HR against the dynamic normal heart rate value is noted and if HR deteriorates for a specific interval it will invoke the critical analysis algorithm for a thorough analysis.

C. Critical analysis algorithm for HR monitoring (CAA)

When the preliminary analysis of the pulse value indicates any variation against the set normal .To have a false proof system we go for a critical analysis where the CAA monitors the HR against the calculated threshold value. CAA analyzes the cohesion of such variation in order to write off the chances of false alarm. When the variation found is consistent, it will invoke the alarming system.

D. Algorithm for warning the driver and data transmission

A multi stage warning alarm system is used in wireless sensor system (WSS). The alarm initialized by the WSS is supposed to alert the drowsy driver to regain his HR into normal value. Even after giving a warning alarm to the driver, if the HR value remains consistent a second level warning system is issued to traffic authorities and rescue forces through the transmission unit. The data is transmitted through GSM/GPRS module incorporated with the system because GSM is most popularly used over the world. A GPS module is incorporated within the data transmission unit of the WSS or synchronised with the GPS unit in the vehicle.

VI. EXPERIMENTATION

The prototype of driver drowsiness detection system using IR reflective sensors was developed and tested using NI Labview software and NI ELVIS II+. The simulation result of pulse rate variation is given in the Fig. 4. The pulse

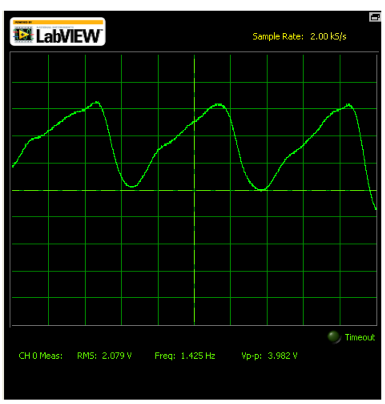

Fig. 4. Pulse rate variation from ISWN

signal obtained from the hand by placing the palm on the IR reflective sensors is captured as in figure. Here the feature point is repeated at intervals. Each signal peak in the feature point gives the heart beat variation rate. Consecutive signal peaks were analysed and checked the variation with actual set threshold value since the peak and interval between pulses determines the drowsiness state. The software developed takes the pulse value and calculates the amplitude in each feature point that is repeated at intervals.

VII. CONCLUSION AND FUTURE WORK

A non-obstructive, real-time, continuous monitoring method for determining the alertness of the driver is described in this paper. The proposed system designed and developed an intelligent steering wheel sensor network consisting of multiple embedded IR sensors to monitor the pulse rate of the driver and analyses the alertness of the driver. A two level warning system has been developed to disseminate the information in real-time. The system is characterised by maintaining simplicity, low cost and non-obstructive real time monitoring of drowsiness. The system presents is a universal system for measuring the unique pulse rate of individuals. The efficiency of the system could be further improved by employing the sensors on seat belt for achieving better accuracy.

ACKNOWLEDGMENT

The authors would like to express gratitude for the immeasurable motivation and guidance provided by Sri. Mata Amritanandamayi Devi (AMMA), Chancellor of Amrita University. Mr. Anuroop A. Nair inspired us to start such an ambitious project. The authors would also like to acknowledge the help from Ms. Rekha P. Manoj on the different programming aspects.

REFERENCES

[1] Federal Motor Carrier Safety Administration Office of Analysis, Research and Technology, *An Evaluation of Emerging Driver Fatigue Detection Measures and Technologies*, Cambridge, Publication No FMCSA-RRR-09-006, June2009.

[2] L. Barr, H. Howarth, S. Popkin, R.J Carroll, and A. John. "A review and evaluation of driver fatigue detection measures and technologies", Volpe National Transportation Systems Center Cambridge, Massachusetts.

[3] P.S Rau, "Drowsy driver detection and warning:Field operation test design, data analyse and progress", National Highway Traffic Safety Administration, US.

[4] M. Leechawengwongs, E. Leechawengwongs, C. Sukying, and U. Udomsubpayakul. "Role of drowsy driving in traffic accidents: A questionnaire survey of Thai commercial bus/truck drivers", J Med Assoc Thai. 89, 11, Nov 2006.

[5] T. C Chieh, M. M Mustafa, A. Hussain, E. Zahedi, and Burhanuddin. "Driver fatigue detection using steering grip force", presented at Student Conference on Research and Development (SCOReD) 2003 Proceedings, Malaysia.

[6] R. Wu, C. Lin, S. Liang, T. Huang, Y. Chen, and T. Jung . "Estimating Driving Performance Based on EEG Spectrum and Fuzzy Neural Network", IEEE, 2004.

[7] Q. Cai, J. Sun, L. Xia, and X. Zhao. "Implementation of a Wireless Pulse Oximeter Based on Wrist Band Sensor". Presented at 3rd International Conference on Biomedical Engineering and Informatics (BMEI), 2010.

[8] A. Anund, G. Kecklund, B. Peters, and T. Akerstedt, (2008). "Driver sleepiness and individual differences in preferences for Countermeasures", *Journal of Sleep Research* [Online]. 17,1,16-22. Available: http://www.ncbi.nlm.nih.gov/pubmed/18275551

[9] http://www.shiftworkdisorder.com/new-study-shows-drowsiness-a-major-cause-of-vehicle-crashes-virginia/

[10] Officer Phil Constantien(September 11th, 2009), Statistics Related to Drowsy Driver Crashes, Shift work disorder news, US. Available: http://www.shiftworkdisorder.com/statistics-related-to-drowsy-driver-crashes-10375.html

[11] M. J Flores, J. M Armingol, A. and Escalera. "Real-Time Drowsiness Detection System for an Intelligent Vehicle", Intelligent Vehicles Symposium, The Netherlands, IEEE, June 2008.