© 2019 IJSRST | Volume 6 | Issue 6 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
International Journal of Scientific Research in Science and Technology

Non Invasive Sensors Based Driver Drowsiness and Alertness Detection System

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ABSTRACT

Several methods were proposed by different researchers to observe the behavior of the driver. Various factors such as driver behavior, driver state or physiological behavior, vehicle condition, and other external factors are responsible for road accidents. The state of the driver can be categorized as attentive or drowsy. The drowsiness in drivers is due to fatigue, sleepiness, or alcohol intoxication (i.e., being drunk). This paper proposes a system comprising a pulse sensor, accelerometer, and alcohol sensor, etc. that regularly monitors the driver alertness and generates alerts if drowsiness is detected. The algorithm uses driver's data, sensors data and employs HRV analysis for the determination of driver's fatigue. Section 3 and 4 of the paper discuss the proposed method and algorithm and section 5 presents the hardware implementation.

Introduction

Based on observation and different research works drowsiness can be measured by

- Vehicle-based approaches
- Behavior-based approaches
- Physiological-signal based approaches

In a vehicle-based approach, multiple sensors are integrated into the different parts of the vehicles. Sensors monitor the variations in speed, acceleration, braking, lane position, handwheel angle and predict the onset of drowsiness in the driver [1,2]. This method is easy to implement and also non-invasive. However, these approaches can be too slow to detect driver drowsiness [3]. Also, sometimes false alarm is activated due to uneven roads or other reasons.

The behavioral-based approach relies on vision analysis to watch the driver's behavior, including eye-closure, eye-blinking, yawning, head pose, hand gesture, etc., through a camera directed to the driver's face [4,5]. Different tracking sensors, cameras, and image analyses are used to detect the drowsiness in the driver. Some of the fatigue symptoms include no blinking, closed eyelids, open mouth during yawning, head tilt, etc. This approach is popular in the automobile industry as it is reliable and non-intrusive in nature.

Physiological-signal based approach is the most accurate method which monitors brain activity, eye movement, heart rate, etc. for determining the state of the driver [6, 7, 8]. ECG (electrocardiogram) sensor is used to observe a driver's pulse, which supplies an indication of the driver's level of fatigue indirectly giving the state of drowsiness. EEG (electroencephalogram) is used for monitoring brain waves, EMG (electromyogram) is used for detecting muscle fatigue and EOG (electrooculogram) is used for monitoring eye movements. All these sensors produce accurate results but they are invasive and thus uncomfortable for the driver to wear during driving. Thus, there is a need for a system that reliably detects the drowsy state of the driver and generates alerts in time to prevent accidents.

The Proposed System

This paper aims to detect drowsiness in drivers to prevent accidents and to improve safety on the road. The proposed method comprises sensors embedded in the vehicle, onboard or cloud storage, an Analysis server, and multiple alert mechanisms.

One of the non-invasive sensors is a pulse sensor which is integrated over the steering wheel of the vehicle. Alcohol sensors can also be embedded near the center of the steering wheel that will prevent the driver from starting the vehicle if he is drunk. The pulse sensor can be implemented as bendable conductive electrodes that are wrapped around the steering wheel and enable detection of ECG signals when the driver places a hand over the wheel while driving. Pulse sensors regularly measure ECG signals and store them in onboard data storage. This storage can also be implemented in the cloud and in that case, there is a wireless system integrated into the vehicle that can be used by pulse sensors to directly upload the acquired ECG signal to the cloud storage. Analysis server can also be implemented in on-board processing unit or in the cloud. The analysis server comprises Heart Rate Variability (HRV) analyzer. Typical ECG signal comprises QRS complex wave. The time interval between two QRS waves is known as the RR interval and can be used for heart rate calculation. The acquired ECG signal is preprocessed to remove noise and then feature extraction is utilized for detecting R peaks and thus calculating pulse rate. The calculated heart rate is compared against the set threshold and basis the comparison result the state of the driver is determined. The state of the driver can be categorized as alert (normal heart rate), drowsy (low heart rate), and abnormal (high heart rate). Once the state is determined, it is used for deciding further action. If drowsiness is detected, the alert mechanism is activated. The alert mechanism is a multi-level alarm system comprising a buzzer, vibration sensor. These sensors are integrated into the vehicle i.e., a buzzer can be embedded in the dashboard and a vibration sensor can be embedded in the seat. An accelerometer can also be integrated into the vehicle for detecting if the vehicle is in an accident and turned or slid more than the normal range. If abnormal movement is detected by the accelerometer, then the SOS signal is sent through GPS and GSM module to the nearest rescue or reporting center for sending medical or relief measures.

Algorithm

The previous section explains the proposed system comprising sensors, sensor data storage, analysis server, and multi-level alarm system. The algorithm initializes once the driver puts in the key for starting the engine.

Step 1. Once the key is inserted alcohol sensor is activated and it monitors the breath of the driver at regular intervals. If the alcohol content in the breath is above the set threshold level, the engine is turned off and thus it prevents a drunk driver from driving. If the measured alcohol content is within the range, then the algorithm proceeds to the next step.

Step 2. As the driver starts driving, by placing a hand around the steering wheel, pulse sensors are activated and they measure and send the ECG signal to the sensor data storage. When the driver starts, the Analysis server picks up measured ECG signals, extracts heart rate, and thus calculates the threshold range for a normal heart that is specific to that particular driver. Once the threshold range is set this is called "Alert state". The threshold range is the range between the low and high threshold.

Step 3. Now the real-time monitoring starts. ECG signals are measured by pulse sensors and then stored in the sensor data storage.

Step 4. The analysis server removes noise from the received ECG signal by filtering and rectification. After these features are extracted from the noise-free ECG signal including peak and QRS complex detection.

Step 5. HRV Analyzer further processes the signal to determine RR interval and thus heart rate. The heart rate is continuously compared to the threshold range.

Step 6. If the heart rate is lower than the low threshold then the state of the driver is set to the "Drowsy state" and a multi-level alert system is activated. The first alert is provided by turning on the buzzer and a timer is started. If the driver wakes up and turns OFF the alarm within a predetermined time then, the state is changed to "Alert State" and process form step 3 is repeated. If the driver does not respond before the expiration of the timer, the second level alert is activated which is seat vibration is turned ON with a louder buzzer sound. If the driver still doesn't respond within the second predetermined time period, then GPS and GSM modules are activated to send the vehicle location to a nearby reporting center. Also, automatic control of the vehicle can be used for applying brakes and turning on the lights so that other vehicles can see that this vehicle is not moving. Once the alarm is reset by the driver then the algorithm repeats from step 3.

Step 7. If the heart rate is higher than the high threshold then the state of the driver is set to the "Abnormal state" and again the multi-level alert system is activated. In this first alert is provided by the buzzer and simultaneously GPS and GSM module is used to send the coordinates to the nearest medical or reporting center so that help can be sent to the driver. If the driver does not respond within a set time period the brakes are applied through automatic control and parking lights are turned on for alerting other vehicles on the road. If the alarm is reset by the driver, then the state of the driver is updated as "Alert state" and the algorithm repeats from step 3.

Hardware Implementation

The suggested hardware prototype consists of an embedded system design consisting of MEMS-Micro electro-mechanical system, GSM-global subscriber module, GPS-global position system, and alcohol detector. All sensors' data is collected by the multiplexer and given to the microcontroller for further processing.

LCD (Liquid crystal display) is used to display the state of driver alertness. The alarm system consists of a buzzer and also a seat vibrator. GPS and GSM module is used to monitor and transmit coordinates of the vehicle to the reporting center. A relay system is used to control the speed of the vehicle and turn off the engine in case of no response from the driver.

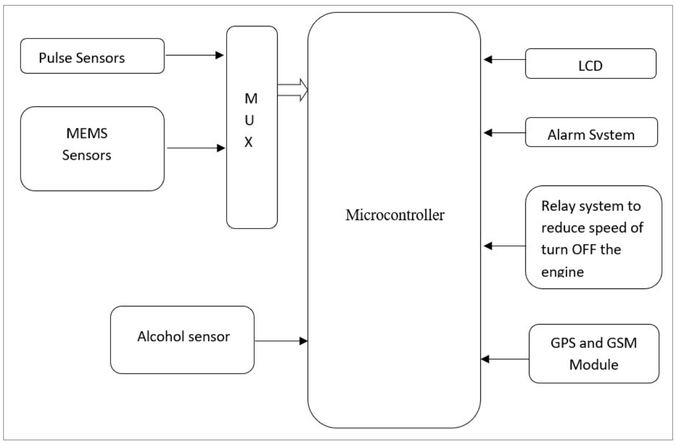

Fig 1. Block diagram of the Proposed System

The Prototype of the proposed system (Fig, 2) is developed using the below components. A motor with a fan is representing the engine of the vehicle. Arduino UNO board comprising ATmega328P microcontroller is used in this implementation.

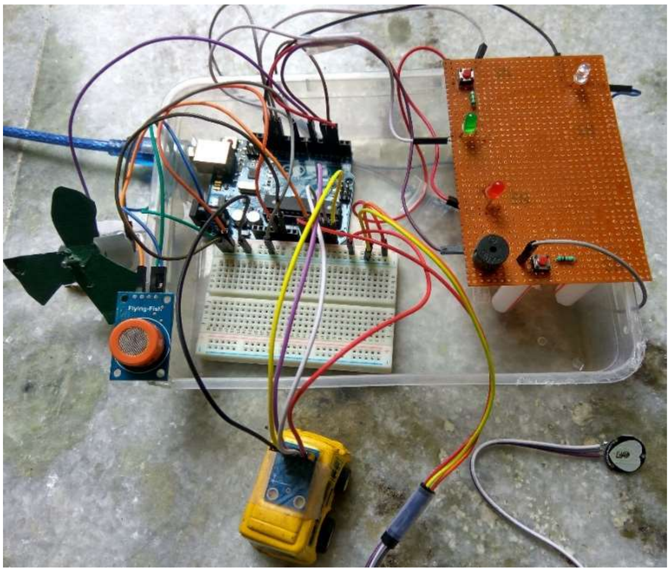

Fig 2. Prototype of the Proposed System

Components:

MEMS-Based accelerometers - The MEMS (Micro Electro Mechanical Systems) accelerometers can be categorized into two microsystem architectures: piezo-resistive and capacitive. The similarity in the above two is that they both possess internal proof masses that are excited by acceleration, however, they have different transduction mechanism which is used to the movement correlation of the internal proof mass to accelerate. The Capacitive accelerometers comprise a differential capacitor whose balance is disrupted by the proof mass movement. Piezoresistive accelerometers employ induction for attaching proof mass to the sensor that detects the movement of the mass. MPU 6050 6-axis accelerometer is used in this prototype that can be calibrated for detecting the turning of the vehicle during accidents.

Alcohol sensor -A semiconductor sensor MQ303A is used for detecting alcohol presence in alcohol. It is highly sensitive thus responds quickly to alcohol. It can act as a portable alcohol detector, has a very long life, and is also not expensive. Blood alcohol level (BAC) is usually measured in grams per deciliter (g/dL). The sensor output data can be processed by the microcontroller to present the output in BAC. If the output is above the threshold alert is activated according to the proposed algorithm.

Pulse sensor - The Pulse Sensor Amped is used for capturing heart rate. It enables real-time monitoring of heart rate. The Pulse Sensor Amped is a plug-and-play heart-rate sensor based on the principle of photoplethysmography. The sensor comprises a photo LED. When the sensor is placed in contact with a particular part of the body (such as fingers in this case), the heart rate is calculated based on the variation of the light signal produced by phot LED. It further comprises an amplification and noise cancellation circuitry that helps in producing reliable, consistent pulse rates. As it requires a 5V DC supply and consumes only 4mA, it is very convenient to use in Arduino projects.

LCD Display - A liquid crystal display (LCD) is a flat, thin display device that is made up of multiple monochrome or color pixels array placed in front of a reflector or a light source. The LCD in this prototype represents the dashboard of the vehicle (such as the infotainment screen). It is used for displaying sensor outputs and driver alert messages along with his current status.

Relay System - A relay can be defined as an electrically activated device. The relay circuit can be divided into two sections: - Input circuit and the output circuit. The input circuit is called a control system and the output circuit is a controlled system. A relay is widely exploited in automatic circuit control. So, it is said that as an automatic switch actuated by a low-current signal to control a high-power circuit. A relay has many advantages like moving with lower inertia, stability, highly reliable, compact. It is widely applied in devices that need power protection, automation field, remote controlling, electro-mechanics, and power electronics. The middle part between the input and output part is for coupling and isolating input current besides output actuation.

GPS and GSM module - The Global Positioning System (GPS) is a satellite-based navigation system. GPS module calculates coordinates of the vehicle and these coordinates can be transmitted via radio signals to the reporting center. GSM is cellular technology, which is used for transmitting both data services and mobile voice. GSM operating frequency range is 900MHz and 1.8GHz bands. GSM supports data transfer speeds of up to 9.6 kbps. It can also send SMS if needed.

A Bluetooth HC-05 module is used in the prototype, that can be programmed to transmit sensor data, output, and alerts to the external device via Bluetooth. In this case, a smartphone was paired and all the results were displayed on the smartphone screen.

Alarm Unit - A buzzer is used as an alerting mechanism for indicating the drowsy state of the driver. In this prototype, a 5V piezo-buzzer is used. These are based on the piezoelectric effect. When mechanical pressure is applied to certain materials it produces electricity and vice-versa. When exposed to an alternating electric field they stretch or compress, in accordance with the frequency of the signal by this means producing sound.

Conclusion

This paper discusses the various ways in which drowsiness can be detected in order to prevent accidents and save lives and resources. Different drowsiness detecting measures i.e., subjective, vehicle-based, physiological, and behavioral measures are explained. This paper proposes a noninvasive sensors-based system for detecting drowsiness in the early stages and generating multi-level alerts. The steering wheel sensor network consists of sensors to monitor the pulse rate of the driver and hence aids in analyzing the alertness of the driver. A two-level warning system has been developed. The system is characterized by maintaining simplicity, low cost, and non-obstructive real-time monitoring of drowsiness. Pulse sensors used in this embedded network are helpful in determining drowsiness in the driver in an effective manner.

Future Aspects

This system has a wide scope since the purpose of improving safety in vehicles is a highly focused issue.

The proposed system uses pulse sensors along with alcohol sensors and MEMS sensors to detect alertness in the driver. To make this system more efficient advantages of other measures like behavioral measures, other physiological measures can be utilized. The efficiency of the system could be further improved by employing the sensors on the seat belt for achieving better accuracy.

Hybrid systems can be developed by combining vision-based analysis and various physiological sensors to develop a robust system. Some other sensors like temperature sensors, gas or smoke sensors can also be used. The addition of eye blink sensors also improves the performance of the proposed system. This could further improve the accuracy of the system that will help in detecting drowsiness in the early stages and appropriate actions can be taken.

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