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Driver Fatigue Monitoring Using EEG Signal and Gas Seepage Detection

R Sharmila [1] ,Gnanavel G[2], Sharmila R[3*]

[1,2,3*] *Embedded System Technologies,Anna university, Tamilnadu, India*

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Abstract--Statistically about 50percent of road accident is due to the driver drowsiness. In this paper, we describe a real time online protocol that controls the vehicle depends on the driver fatigue level. A direct technique is to analyse the EEG (Electroencephalography) signal. An electrode is placed in driver scalp and acquired the EEG signal of driver at every moment, for feature extraction the FFT (Fast Fourier Transform) is used. Then, the feature extracted EEG signal is given to the microcontroller. It can detect the various threshold level of the driver fatigue, then compare and depends upon the driver fatigue level it can control the speed of the vehicle at certain limit. The gas sensor is used to detect the ac gas leakage ,depend on the sensing signal the microcontroller open a car window automatically, in order to reduce the Freon ac gas it mixed with the co2 gas**.**

Keywords- EEG, EOG, EMG, ECG, FFT, System Architecture

I.INTRODUCTION

Fatigue is a complex state which manifests itself in the form of lack of alertness and reduced mental or physical performance, often accompanied by drowsiness. In transportation systems, it is a major cause of fatal road accidents. Earlier research has established that fatigue is responsible for 20–30% of total road fatalities. In India, at least 13 people die every hour in road accidents. In 2007, 1.4lakh people in India lost their lives as compared to 41282 in UK. It can be observed that the accident severity is increasing every year. Research has also linked the effects of sleep deprivation to alcohol intoxication. Sleepiness has been shown to exacerbate the sedating effects of alcohol so that even low levels of alcohol make the sleepy driver much more impaired and much more likely to fall asleep at the wheel. The symptoms of fatigue are in the form of drowsiness, tiredness or weakness. There are many approaches to detect fatigue from several measurements. One approach is to measure the ocular parameters such as eye movement and Percentage Closure of Eyes (PERCLOS) and another method is to measure the physiological variables like Electroencephalogram (EEG), Electrooculogram (EOG) ,Electromyogram (EMG), Electrocardiogram (ECG).

In previous method the Eye movement and percentage closure of eyes (PERCLOS) are two important parameters for detecting drowsiness. It has been observed that eye movement decreases while blink rate increases as a person enters into the state of fatigue. Different techniques have been developed for measurement of eye movement and blink rate using facial image of the subject. Many researchers have used PERCLOS for non-intrusive fatigue detection .A number of studies on ECG has shown a reduction in heart rate and change in the heart rate variability during fatigue. Research on EMG reveals that when a muscle becomes fatigued, its stiffness changes, the amplitude of the EMG signal increases, and the spectrum shifts towards lower frequencies. A number of techniques can be used for fatigue detection, EEG is considered to be the most significant and reliable. EEG is a record of electric potential from the human scalp, which is a result of excitatory and inhibitory post-synaptic potentials generated by cell bodies and dendrites of pyramidal neurons. It is closely associated with mental and physical activities. For different activities the EEG recording may be different either in terms of magnitude or in terms of frequency or both.

These quantifications involve calculation of features like energy in different bands of signals and their interactions. Classical methods to quantify EEG signal (such as Fourier Transform) is generally based on power spectral analysis. Such type of analysis assumes that the signal is stationary within the analysis window. But, EEG signal is highly non-stationary in nature and is very difficult to find its complete statistical characteristics either in time domain or frequency domain rendering most of the classical methods inadequate for analysis. In recent times, Wavelet Transform has been used in EEG signal analysis for detecting epilepsy, brain injury, or micro-arousal in sleep, etc. It provides a multi-resolution time-scale representation of the signal and is considered as a potential tool for study of non-stationary signals. It offers good time resolution at high frequencies and good frequency resolution at low frequencies.

A gas detector is a device which detects the presence of various gases within an area, usually as part of a safety system. This type of equipment is used to detect a gas leak and interface with a control system so a process can be automatically shut down. A gas detector can also sound an alarm to operators in the area where the leak is occurring, giving them the opportunity to leave the area. This type of device is important because there are many gases that can be harmful to organic life, such as humans or animals.Gas detectors are usually battery operated. They transmit warnings via a series of audible and visible signals such as alarms and flashing lights, when dangerous levels of gas

Corresponding Author: *Sharmila R*
Department of EEE, Anna University, India

vapors are detected. As detectors measure a gas concentration, the sensor responds to a calibration gas, which serves as the reference point or scale. As a sensor's detection exceeds a preset alarm level, the alarm or signal will be activated.

II.SYSTEM ARCHITECTURE

The hardware of this system consists mainly of two major parts: a physiological signal acquisition module and an EEG signal processing and control module. First, EEG signal was obtained by EEG electrode, and then was amplified and filtered by EEG amplifier and acquisition unit in the physiological acquisition module. Next, EEG signal was pre-processed by microprocessor unit and transmitted to the EEG signal processing and control module. After receiving EEG signal, it would be monitored and analyzed by our drowsiness detection algorithm implemented in embedded signal processing unit. If the drowsiness condition was detected, warning tone would be triggered to alarm the driver and control the speed of the vehicle.

A. physiological signal acquisition module

EEG is recording of electrical activity along the scalp produced by firing of neurons within the brain. In clinical context, EEG refers to recording of brain's spontaneous electrical activity over a short period of time, as recorded from multiple electrodes placed on the scalp. Scalp EEG activity show oscillations at a variety of frequencies. Several of these oscillations have characteristic frequency ranges, spatial distributions and are associated with different states of brain functioning. The different rhythmic frequency bands are alpha, beta, theta, delta.EEG electrodes transform ionic currents from cerebral tissue into electrical currents used by the various stages in Figure 1. *Two* Silver-silver chloride (*Ag-AgCl*) biomedical *scalp* electrodes are used to acquire signals. Driving is a complex task involving simultaneous activities of different parts of the brain. Different lobes of the brain are related to various functionalities. The frontal lobe is associated with planning, reasoning, movement, emotion and problem solving. The parietal lobe is associated with movement, recognition, perception of stimuli whereas temporal lobe is associated with recognition and perception of auditory stimuli, memory, and speech. This makes the spatial placement of electrodes in EEG recordings a critical parameter. Using the International 10–20 electrodes placement system, the number of

EEG channels used can be as high as 19 or as low as 4 . In this work, thirteen scalp electrodes were used in addition to reference and ground to collect the signals from locations Fp1, Fp2, F3, F4, T3, T4, C3, C4, P3, P4, O1, O2, and CZ following the international 10–20 system. The sampling frequency was kept at 256 Hz with 16 bit A/D conversion. The physiological signal acquisition module mainly consists of EEG amplifier and acquisition unit, microprocessor unit. Here, EEG amplifier and acquisition unit, which includes a preamplifier, a band-pass filter and a 12-bits analog-to-digital converter (ADC) with sampling rate of 512 Hz, was designed to amplify and filter EEG signal. The gain of EEG amplifier and acquisition unit was set to about 5040 times with the frequency band of 0.1 - 100 Hz. Microprocessor unit was used to control the ADC to obtain, pre-process and send EEG data to control unit.

Instrumentation amplifier is chosen for the initial amplification stage. The amplifier chosen is specifically designed to remove noise using high common-mode-rejection (100dB at Gain≥10). A sixth order Bessel Filter is designed for the purpose of filtering. Bessel filter is an all-pole filter with a characteristic feature of maximally flat group delay and an almost linear phase response. Absence of overshoot and ringing in time-domain response to step and pulse input is another distinguishing characteristic of Bessel filter. The cut-off is fixed at 30Hz. A sleep slope is obtained when the order is high. But for this work, sixth order is found to be sufficient. Samples are taken with a 10-bit successive approximation Analog to digital converter (ADC). The ADC uses a data transfer controller to store samples into the FFT input array without help from CPU. It has a 64 data points wide FFT input array. After the input array is filled, FFT is computed and input is cleared. Output array is searched for the highest value. Frequency at that value is considered the dominant input frequency. The different rhythmic frequency bands are shown in Figure1.

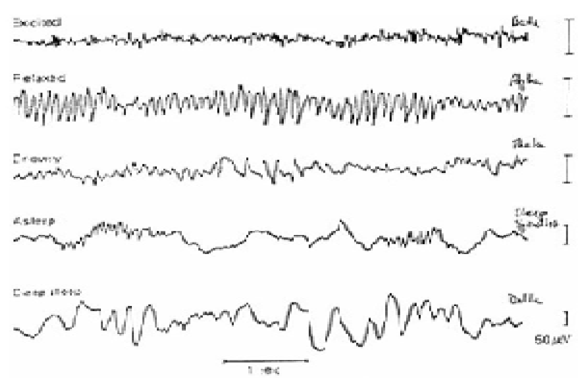

Figure: 1 brainwave frequency bands

Brainwave signals	Frequency range
High beta	Above 18hz
Mid beta	15-18hz
Low beta	12-15hz
Alpha	8-12hz
Theta	4-8hz
delta	0-4hz

Table 1: **B**rainwave signal frequency range

This transition of EEG signal is detected by frequency analysis of the brainwaves using Fast Fourier Transform (FFT). EEG is a strong tool for exploring brain activity. EEG measures the brain activity directly, while other methods record changes in blood flow or metabolic activity. Even though EEG signals are weak, efficient amplifiers can be implemented to amplify the signals to a sufficient level. Thus analyzing and monitoring drowsiness using EEG data is straight-forward in comparison with the other two methods. Hence in this work we have made an effort to detect drowsiness by analyzing EEG.

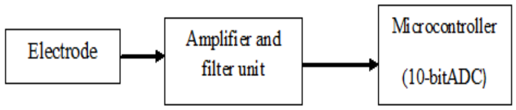

Figure: 2 Physiological Signal Acquisition Module.

1)Action performed while driving:

High beta : Allowing the driving action.
Mid beta : Permitting the speed to be below a first lower limit
Low beta : Permitting the speed to be below the second lower limit
Alpha : Activating an alarm signal.
Theta : Activating an alarm signal for longer duration.
Delta : Turning on a relay that doesn't allow vehicle to start ignition and activate the indicator

B. EEG Signal Processing and Control Module

The signal processing module which owns powerful computations and supports various peripheral interfaces was designed as a platform which perform real-time EEG-based drowsiness detection algorithm. The embedded module mainly consists of EEG signal processing unit, and warning tone device unit. After receiving EEG data from the transmission unit, the embedded signal processing unit would real-time process, analyze and display EEG data. If the drowsiness condition was detected, the warning tone device unit would be triggered to alarm the driver. The method of data analysis involves pre-processing, artifact removal, and computation of features based on Fast Fourier Transform for estimation of fatigue. The pre-processing stage includes filtering and normalization followed by artifact removal using wavelet based thresholding.

1)Pre-processing

The raw EEG data is contaminated with numerous high frequency and low frequency noise known as artifacts. The high frequency noise is due to atmospheric thermal noise and power frequency noise. The low frequency noise is mainly due to eye movements, respiration and heart beats. They are characterized by amplitude in the millivolt range (whereas the actual EEG is in microvolt range) in the frequency band of 0–16 Hz . The raw EEG containing this noise at both ends of the spectrum was first processed using a band pass filter with cut-off frequencies of 0.5 Hz and 30 Hz followed by normalization. Normalization ensures removal of any unwanted biases that may have crept into experimental recordings.

2) Artifact removal using FFT

Wavelet Transform is a useful tool for time frequency analysis of neurophysiologic signals. Wavelets are small wave like oscillating functions that are localized in time and frequency. The original signal S(t) is first passed through a pair of high pass and low pass filters. The low frequency component approximates the signal while the high frequency components represent residuals between original and approximate signal. At successive levels the approximate component is further decomposed. After each stage of filtering, the output time series is down-sampled by two and then fed to next level of input. the signal has been decomposed into four levels in which the detail component at level-1 approximately represents beta (b) band (15–30 Hz), detail component at level-2 represents alpha (a) band (8–15 Hz), detail component at level-3 represents theta (h) band (4–8 Hz) whereas the detail component at level-4 (d2:2–4 Hz) along with approximate (d1:0.5–2 Hz) component represent the delta (d) band (0.5–4 Hz) of the EEG signal.

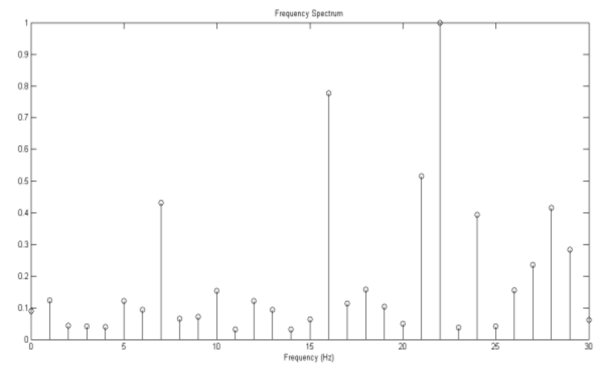

Figure:3 FFT of Active Brainwave signal

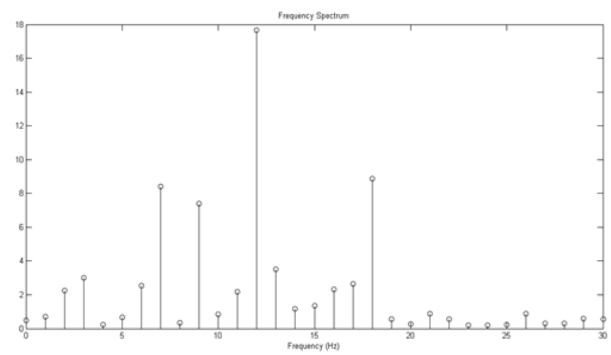

Figure:4 FFT of Drowsy Brainwave signal

Fourier Transform is the most commonly used method to study the frequency domain characteristics of signals. FFT can provide a basic understanding of the frequency content of EEG signals. This is due to the fact that FFT uses sinusoidal functions as its basis functions. For a given signal ***x(t)***, projections are computed onto the exponential basis function of frequency w *radians/s*. This also means that any discrete time signal may be represented by a sum of sines and cosines which are shifted and multiplied by co-efficient which results in a change in the amplitude and the co-efficient is large when a signal contains frequency component around the frequency *f*.

3)Control Module

Scalp EEG activity show oscillations at a variety of frequencies. Several of these oscillations have characteristic frequency ranges, spatial distributions and are associated with different states of brain functioning. The captured signals and the results obtained are stored in the PC's hard disk for their later study. To evaluate the driver's state in each moment, our algorithm combines the information about the physiologic parameters to offer the most appropriate decision considering the existent relationship among the different indicators.

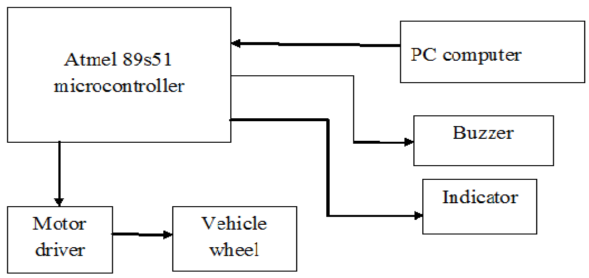

Figure: 5 EEG processing and control block

The Microcontroller can communicate to PC by using the serial port (RS232) or using a Bluetooth or Zigbee wireless module in order to send the results of the processing to a central system. The microcontroller check the frequency value at different conditions, depends upon the frequency level it controls the speed of the vehicle and also alert the driver using buzzer. The indicator is in on while the vehicle get stop condition that is the driver is in unconscious level or drinking alcohol.

III.GAS SEEPAGE MODULE

The KSS 532 and GSS 532 Ex semiconductor gas detectors are used for the detection of fluorinated and chlorinated refrigerants (Freon). The gas/vapour/air mixture diffuses through the flame protection barrier to the active metal oxide surface. A temporary shortage of oxygen electrons arises on the indirectly heated surface during the presence of a gas concentration. This shortage of electrons produces a change in the conductivity, and thereby changes the voltage, which is evaluated as a signal. If the gas concentration reduces, the missing oxygen electrons will be replaced from the ambient air once again. These gas detectors are designed to be implemented in Air condition applications; i.e. car in which no other gases are normally expected, because the oxidizing/reduction reaction with oxygen will lead to the detection of other Freons as well, and gases that are oxidized/reduced on the surface of the sensor could trigger false alarms.

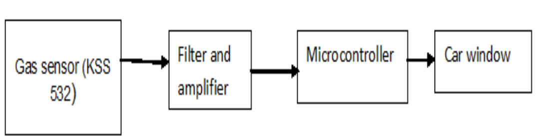

Figure:6 Gas leakage monitoring

In this paper the microcontroller is programmed to avoid fire accident through poisons gas leakage in an air conditioned car. The Freon gas sensor senses the gas concentration level, if the sensed concentration is greater than the normal sensors range in ppm level, then the car window will automatically open and buzzer is used to alert the driver indicating the toxic gas leakage.

IV.CONCLUSION

A straight-forward technique of acquisition and analysis of EEG data, once the signal is filtered, the feature extraction has been performed applying the method Fast Fourier Transform to convert the signal from the time domain to the frequency domain, in order to be able to obtain after that, the four classical frequency bands in EEG signal analysis: alpha, beta, theta and delta waves. When the classical frequency bands are calculated, these are grouped to form input vectors to microcontroller. The main goal of this paper is to control the speed of the vehicle under different sleeping conditions and to avoid the fire accident by using gas seepage monitoring.

Some of the improvements likely to be taken up in future include: (1) Using Autocorrelation function to detect sleep and drowsiness features (2) Even though Bessel filter usage has been effective, theoretically it does not have a maximally flat pass-band response, hence other filter types may be tested (3) Efficiency of the acquired data for clinical study is yet to be ascertained, hence expansion of the application in this direction is possible.

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