Simulation Based Distracted Driver Detection System using Alcohol Sensor and Fusion of Bioelectric Signals to Disseminate them through V2V/V2I to Alleviate Risky Driving

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DECLARATION

We hereby declare that research work titled "Simulation based Distracted Driver Detection System using Alcohol Sensor and Fusion of Bioelectric Signals to Disseminate them through V2V/V2I to Alleviate Risky Driving" is our own work. The work has not been presented elsewhere for assessment. Wherever material has been used from other sources, it has been properly referred.

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ABSTRACT

The rampant road accidents due to drowsy or drunk driving and its dire consequences of losing countless life including making million others maimed each year in the whole world, which claims the attention of all concerned to address this issue seriously. The fatalities occur as consequences of frequent road crashes due to drowsy driving in Bangladesh are also increasing in an unbridled way. Undoubtedly, the ubiquity of road accidents has become a perennial problem from which we need a feasible way out. Current research on using Body Sensor Network inspired us in developing a system that can disseminate the physiological state of the driver while driving to other nearby vehicles or emergency unit who can respond immediately to halt the affected vehicle. Prior to communication, detection of drunk or drowsy state is a necessity. Bioelectric signals like ECG and EEG contain the feature for different physical and mental states which can be interpreted through some parameters with accuracy. Extraction of the desired feature from the driver's ECG and EEG would certainly be capable of detecting the physical and the mental state of the subject. Although alcohol intoxication changes the ECG pattern, there are more convenient ways like using alcohol sensors to detect drunken state. Accumulating all the features collected from the subject, it can be sent to other vehicles and the emergency unit using VANET system. The proposed developed system generated ECG and EEG in simulation and extracted the necessary features from the subject and successfully combined these signals for communication. In addition, drunken state of the driver is also detected in this model. The idea of fusing bioelectric signals for distracted driving detection may contribute to reduce the number of uncontrollable road accidents.

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ABBREVIATION

ADC- Analog to Digital Converter

AV-Atrio Ventricular

aVF-Augmented Vector Foot

aVL-Augmented Vector Foot

aVR-Augmented Vector Right

BAC- Blood Alcohol Concentration

bpm- Beats Per Minute

BrAC- Breathe Alcohol Concentration

BSN- Body Sensor Network

CAN - Controller Area Network

DSRC- Dedicated Short-Range Communication

DUI - Driving Under the Influence

DWI - Driving While Impaired

EAR - Eye Aspect Ratio

ECG-Electrocardiogram

edf -European Data Format

EEG - Electrocephalogram

EMG - Electromyogram

EOG - Electrooculogram

GDP – Gross Domestic Product

GHSA - Governors Highway Safety Association

GPIB- General Purpose Interface Bus

GPS- Global Positioning System

GSM- Global system for Mobile

HF - High Frequency

HRV - Heart Rate Variability

IDE – Integrated Development Environment

ITS - Intelligent Transport System

LA - Left Arm

LabVIEW - Laboratory Virtual Instrument Engineering Workbench

LED- Light Emitting Diode

LF - Low Frequency

LL - Left Leg

MANET - Mobile Ad Hoc Networks

NHTSA - National Highway Traffic Safety Administration

NREM -Non Rapid Eye Movement

OBU- On Board Unit

PCB – Printed Circuit Board

PIC - Peripheral Interface Controller

RA - Right Arm

RL - Right Leg

RSU - Road Side Unit

REM – Rapid Eye Movement

SA – Sino Atria

SDLP - Standard Deviation of Lane Position

USB- Universal Serial Bus

V2I- Vehicle to Infrastructure

V2V-Vehicle to Vehicle

VANET- Vehicular Ad Hoc Networks

VISA - Virtual Instrument Software Architecture

WBAN - Wireless Body Area Network

WHO – World Health Organization

Wi-Fi – Wireless Fidelity

WAVE - Wireless Access in Vehicular Environments

CHAPTER 1

INTRODUCTION

1.1. Recent Scenario

Road accidents have become ubiquitous in our hectic world that surrounds us. The common feature that the daily newspaper focuses is about the road crashes and its deadly consequences of fatal injuries, mental trauma, and death of myriad number of people in the whole world. The rate of the road accidents is not steady, but rapidly on the rise in an unbridled way. In Bangladesh, the scenario is obviously not different from other countries; rather the numbers of accidents occurring in our country constantly remind us that we are hardly safe in the road. This continuously recurring event has raised the question worldwide for resolving this issue by reducing the number through imposing some feasible steps. Since driver's role is highly significant for the safety driving, the importance on both physical and mental states during driving is the prior issues to bring under vigilance. Apart from poor traffic and unlicensed driver issue, road accidents in the whole world mostly occur due to lack of physical and mental fitness of the driver needed for cautious driving. Unbearable workload, over stress, fatigue, continuous loss of sleep etc. turn the driver distracted while driving. Moreover, there is a common trend among the drivers preferring to remain alcoholic during driving that again results in distraction. Drowsiness, falling asleep, drunkenness and other forms of distraction of the driver during driving are found to be associated with recent road accidents. Regarding the sleep loss, a study suggests that remaining sleepless for more than 20 hours brings in the same disruption in body and mind that might occur due to blood alcohol concentration's legal limit of 0.08[1]. A survey published in the Daily Star shows that an average of 64 people previously affected with injuries from road accidents die every day [2]. Another report of the same newspaper showed that within the span of first six-month of 2017, 5400 people got injured and 2297 people lost their lives due to road accidents in Bangladesh [3].

Figure 2.1.1: Drowsy Driver on Road [4]

The consequences of road accidents abroad also look gloomy. An estimation of NHTSA revealed on the basis of police report that 0.1 million road crashes occur each year due to drowsy driving results in more than 1500 deaths including 71000 injuries. According to the American Sleep Foundation, about half of U.S. adult drivers admit to have fallen into drowsy during driving. Another report claimed that about 20% admitted to fall into sleep on the wheel at some point in the past year while more than 40% confessed that this had happened at least once in their driving careers [5].

Figure 1.1.2: A Drunk and Drowsy Driver [6]

Figure 1.1.3: Road Accident in Bangladesh [7]

Apart from being drowsy on the wheel, the state of being drunk during driving is not less threatening. The number of drunken driver is also causing disastrous accidents. The same source NHTSA reported about 10497 fatal accidents while drivers were drunk and allegedly found having BAC level 0.8g/dL (800ppm) or higher. In Bangladesh, the drunken driving allegation is also common although no statistical survey has been taken so far.

Whether in Bangladesh or abroad, distraction while driving due to drowsiness, falling asleep, and alcohol intoxication bring unfillable void, nothing can compensate such huge damages. Conniving and then being oblivion of this fact will simply add the number with the present statistics.

1.2. Introduction to Distracted Driving

Recent scenario that we described earlier surfaces the issue that distracted driving is the central reason for ominous road accidents. This situation is found more exacerbated in the developing countries like Bangladesh where motorization rockets up with population and drivers are inefficient. Even the duration of driving hour is so high that it is not humanly manageable to drive ensuring safety. While continuous attention of the driver to respond to frequently changing events on the street is indispensable for safety, slight diversion undoubtedly ensues intractable situation.

Figure 1.2.1: Sleepy Driver [8]

Drowsiness expedites distraction of the driver that arises from sleep loss or continuous driving for exaggerated hours. However, drunken state is another factor that also derails driver's attention from safe driving. Distracted driving may include other reasons but in most cases it occurs for the factors we already mentioned.

The issue for distracted driving is by no way evadable if we want to see a world of less road accidents. Detecting drowsiness or drunken state of the driver during driving can alert concerned people to halt the vehicle. Distracted driver must be brought under vigilance while he is driving. The sensible way to eliminate distraction problem is to detect them first.

1.3. Impact of Distracted Driving in the Economy of Bangladesh

Road accident snatches away life and in turn, hinders national economy to grow as every working people contribute to GDP. People who are maimed or handicapped owing to accident immediately turn to liabilities of the country.

World Health Organization (WHO) revealed a fact that around 2% of GDP loss in Bangladesh is caused due to road accidents [9]. Moreover, a significant number of accident victims lose their job and even the opportunity to rejoin anywhere. A survey shows that around 0.7% disabled and 27.6 % of the partly disabled accident victims had the experience of losing their jobs. In addition to this report, around 67.9 % of the disabled and 24 % of the partly disabled also remained unemployed for a long time after losing their previous jobs [10].The consequences unbearably degrade the national economy.

1.4. Problems with the Traditional Driving System

In the existing driving system, there is no mechanism to detect and monitor the physical state of the driver while on driving. Detecting physical state during driving is really a challenge in our present system unless he is brought visible every moment to some agents. Our traditional driving system supports only to drive the vehicle. No additional technology is embedded to recognize other problems no matter how relevant it is associated with detecting adverse driving. What they can hardly do, they can install a CCTV in the vehicle which will record everything happened with the driver and later it will be checked. However, this is of no use if accident occur, CCTV cannot be a remedial to avoid accident.

The scenario might look better in the developed countries where drivers are not allowed to drive beyond the specified duration. In some cities, VANET communication system (Vehicular Ad Hoc Networks) including V2V and V2I system are incorporated for safety driving that improved the communication part of conveying message from vehicle to other desired zone, however, detecting the exact physical state of distracted driver still remains an obstacle despite automobile have embedded the advance communication system with their manufactured vehicle [11].

Human being can rarely avoid follies, hence, in developed countries, still drivers are found falling into sleep on the steering. Detecting the exact physical state feasible for the driver is still under research. In Bangladesh, development of communication system is far apart, people just started thinking on the detection of distracted driving.

1.5. Introduction to Software used

Our whole thesis work is implemented through simulation process. We researched on finding the parameters by analyzing bioelectric signals and the related sensors. We were choosy even to decide on selecting proper software so the simulation can interpret almost the same scenario of the real world. We distinctly mention the following two software.

- Proteus 8 Professional
- NI LabVIEW 2017

With the Proteus 8 Professional software, the state of drunkenness is detected which is one part of our thesis work. Proteus helps to configure our schematic circuit and interpret our simulation result correctly to justify our assumption. It is used for circuit simulation and PCB designing [12] which comprises of several modules for schematic capture, firmware IDE and PCB layout that appear as tabs inside a single, integrated application. To measure amount of alcohol we choose MQ-3 sensor to connect with Proteus via a microcontroller.

LabVIEW software is chosen for its ability to deal with bioelectric signals as we worked with two bioelectric signals to establish our thesis work. Laboratory Virtual Instrument Engineering Workbench is the elaboration of LabVIEW. LabVIEW provides a platform for system-designing and visual programming language from National Instruments which offers an approach of graphical programming. It also helps sin visualizing every aspect of its application which includes configuring hardware, data measurement and also debugging [13]. We simulated ECG and EEG signals in LabVIEW software to show the detection of drowsiness by extracting relevant features from them, an important part of our thesis.

1.6. Motivation

The fatalities, destruction, causalities of countless people due to road accident primarily moved us to look into the matter. The deprivation, frustration and misery with the life of the victim and his dependence moved us to look for whether we have anything to contribute in alleviation such sad tragedies. When we delved into the matter, we found that we may get rid of this continuously recurred problem if we can develop a system that will detect the physical and mental state of the driver during driving. As the students of electrical engineering, we are acquainted with the analysis of signal although they are all prototype. Our research gave us the idea of biomedical signals that carry useful information of the activity of corresponding organ where the signal is generated. With the continuation of our study, we discovered that drowsiness is related with the less activity of our brain and our heart. Analyzing the cardiac and the brain signal features for drowsiness is possible to extract.

Hence, two factors motivated us to do our thesis work with this topic, one is associated with distressful life of the accident victims and another is the engineering challenge to extract the drowsiness feature from two bioelectric signals ECG and EEG.

1.7. Literature Review

Undoubtedly, numerous researches on drowsiness detection system have been done, some explored new findings, added valuable ideas and many are still going on. Detection of drowsiness using a single bioelectric signal i.e. either ECG or EEG or EMG has been tried theoretically with complex mathematical analysis. Some practically implemented works are there using any of bioelectric signal separately. No practical works on the detection of drowsiness by the fusion of ECG and EEG have not yet seen. In [14] integration and fusion of several bio-sensors have been talked about in order to measure four physiological and behavioral measures associated with driver to ensure safety driving. These four measures include states like drowsiness, drunken, emotional disorder and distracted driving. However, this was only a theoretical approach and validity of possibility of fusing signal from the characteristic point of view was analyzed.

In [15], three different measures have been proposed in determining the driver drowsiness. They are Vehicular-based, Behavioral and Physiological measures. There has been a lot of research going on correlation among different physiological sensors like ECG, EEG, EMG and EOG in determining drowsiness of driver. This paper suffers from the same limitation of not focusing the fact whether these signals coincide at certain points.

From study of [16] it is found that EEG and EMG can be combined to detect the vigilance level of driver. Both signals were combined to increase the accuracy level of the result found. Although EEG can give drowsy state of the driver but there is discrepancy with the accuracy of the result.

Now, ECG is used mainly in determining the physiological states. Studies of the papers [17, 18], shows that there is a relation between ECG and drowsiness. The heart rate obtained from the ECG decreases when a driver is found in fatigue condition. Furthermore, it shows a relationship to degree of drowsiness of the subject. The bpm can be measured with the help of ECG, stated in paper [19]. This paper focuses on how R-R interval gives us heart rate or BPM from ECG. In [20] Driver's vigilance detection with combination of ECG and PPG sensor is shown and the result is shown using smart-watch. Combination of both of these gives more accurate results.

In [21] a method has been proposed for detecting the drunk and drowsy level of the driver using alcohol sensor and open CV using raspberry pi. In this paper, first they used the Arduino for detecting the drunken state of the subject with alcohol sensor. For second part, they have used a camera and open CV in order to detect whether the driver is drowsy or not based on determining if the eyes are closed or not. They have used raspberry-pi for their purpose.

The research work on the detection of drowsiness inspired us to fuse two bioelectric signals which inherently match at some point. We combined ECG and EEG to exhibit more precisely the exact state of the driver. We also used MQ-3 sensors to asses beforehand whether the driver is drunk.

1.8. Thesis Overview

The key concept of our thesis is to ensure safety driving by observing the current state of a driver and alarming him before any serious issue occurs. In our thesis work we have developed a system that can detect the drunk state as well the drowsy state of a driver. Our work highlighted on two issues related to the detection of the physiological state which are the drowsy state and the drunken state respectively. The parameters of drowsiness are extracted from EEG and ECG separately, and then we combined them for confirming driver's drowsy state. Alcohol detection part is separately done; it is not combined with the bioelectric signals for its impracticality.

For all sort of state detections, we developed some algorithms considering accepted or desired thresholds. The algorithms are made in a way that would automatically activate selected LEDs and buzz the buzzer to warn the driver and the passengers of the vehicle.

For the drunk detection, MQ3 sensor senses the amount alcohol and sends this message to the LCD display via Arduino Uno. Three LEDs of three different colors are there to indicate three possible states of alcohol intoxication. The schematic circuit in Proteus plays the role to collect signal from the microcontroller and send it to the display LCD.

As LabVIEW performs the best with the bioelectric signals, we preferred LabVIEW as mentioned earlier. The generation, extraction and combination of ECG and EEG all are done with the aid of this software. It is to be noted that for EEG we used biomedical toolkit.

1.9. Overview of the Following Chapters

The following chapters are organized as such:

Chapter 2: Sensors

In chapter-2, the sensors used for our thesis has been described in great detail. The inner mechanism, the chemical reactions, the circuit inbuilt, the type etc. has been mentioned with figure. The ins and outs of the sensors are described here. The limitations and overview of the sensors have been discussed as well.

Chapter 3: Bioelectric Signals

In chaper-3, the signals obtained from the sensors have been focused in great detail. The type of the signals and the importance of it in our thesis are mentioned here. The signals we get from ECG, EEG and Alcohol sensor are different. The signals are differentiated and described elaborately.

Chapter 4: The Working Procedure and Application

In chapter-4, the algorithm and working procedure of our thesis is mentioned. How the signal are processed from the sensors and calculated to obtain the desired outputs is also mentioned in great detail. The overall picture of our work is described here and the thresholds used are also indicated. The individual algorithms and flowchart of Alcohol, ECG, EEG and combined part is described here.

Chapter 5: Simulation and Data Collection

In chapter-5, the simulation process has been described in great detail. The Circuit-Diagram and its explanation are provided for individual software. The data collection process and the results after simulation are also described in this segment. The individual simulation process and the combined parts are described separately here.

Chapter 6: Conclusion

In chapter-6, an overall summary of our work is pictured in a nutshell. Moreover the future scope of our thesis work is also covered.

CHAPTER 2

SENSORS

2.1. Introduction

A sensor by its name senses some types of input from the surrounding physical environment. It is a device that detects and responds in a way according to its embedded characteristics. The input could be light, heat, motion, moisture, pressure etc. However, the output of the sensor is generally a signal that is converted to the decipherable display for future reading or further processing. For example, a photo sensor detects the presence of visible, infrared or ultraviolet light as an input and transmits electric signals as an output

Our context of discussing sensors will focus mainly on measuring bioelectric signals like ECG, EEG and another semiconductor sensor that detects the concentration of alcohol from human breath. Although our task is completely on simulation basis, study of relevant physical sensors enhance the comprehensibility of the signal for which we are interested.

2.2. ECG Sensors

2.2.1. Overview

We shall study in details about bioelectric signals in chapter three. To keep the coherence, we shall just take a glance on the nature of such signals. The continuous and coherent cell's electric activity generate bioelectric signal. These ionic cells flow through body fluid to the area of unexcited cells. Flow of these electric charges constitutes electric current and consequently, a potential difference.

ECG sensors then should have the ability to detect this potential difference and of course in a noninvasive way. Obviously, we need conducting plates what we call here electrodes which would measure the electric potential containing significant information of heart activity.

2.2.2. Silver, Silver-chloride Electrode

The electrodes are designed in a way that they should not polarize while extracting signals from the body. In other word, when current passes through electrode, electrode potential should not change with it.

Silver- silver chloride (Ag-AgCl) electrodes contain these characteristics. Electrodes generally made of stainless steel are not acceptable for its susceptible nature with the body skin. A potential difference of 10mV in contact with saline water between the electrodes is found, whereas this value is 2.5mV for silver-silver chloride electrodes [22]. These electrodes are preferred over other electrodes for its nontoxic characteristics [23].Since silver chloride is not that much soluble in water; it is used to manufacture ECG electrodes [24].

Silver-silver chloride electrodes meet the demands that match significantly with medical practice. They have highly reproducible parameters and superior properties of longer lifetime.

2.2.3. ECG Electrode Placement & ECG Leads

In 12 lead electrode systems, 10 surface electrodes are fixed in different location of the body to record electrical activity of heart. For appropriate impedance matching, a gel is used between electrodes and the body skin. Four for limb electrodes, six chest electrodes make a total of 10 surface electrodes. The following table describes the different locations of ECG electrodes.

Table 2.2.3.1: Location of Positioning Different Electrode on Body to Record ECG [25]

No.	Electrode Name	Placement of Electrode on Body part
1	Right Arm(RA)	Right Arm that hinders bony part
2	Left Arm (LA)	Left Arm that hinders bony part
3	Right Leg (RL)	Right Leg that hinders bony part
4	Left Leg (LL)	Left Leg that hinders bony part
5	Lead V1	Space adjacent to right of sternum
6	Lead V2	Space adjacent to left of sternum
7	Lead V3	Space between lead V2 and lead V4
8	Lead V4	Mid position – clavicular line
9	Lead V5	At equal altitude of V4 lead but at the anterior axillary line
10	Lead V6	At equal altitude of V4 & V5 lead but at the maxillary line

In reality, 12 electrodes are reduced to 10 electrodes. Three for limbs, six for pericardial and one for reference are used to record ECG. Leads that detect limbs are not unipolar, they are essentially bipolar.

Lead location is described below.

1. Lead I – indicates potential between negative Right Arm and positive Left Arm electrodes.

2. Lead II – indicates potential between negative Right leg and positive Left leg electrodes.

3. Lead III – indicates potential between negative Left Arm and positive Left Leg electrodes.

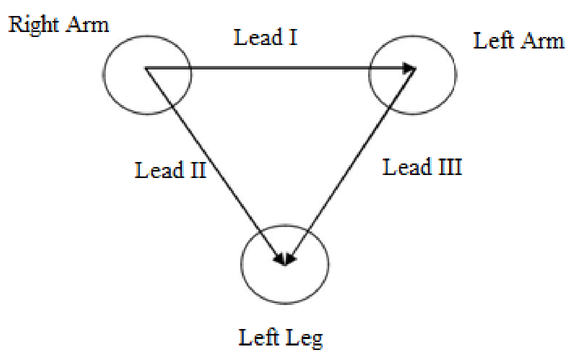

Figure 2.2.3.1: Einthoven's Triangle [26]

Einthoven triangle is a theoretical triangle drawn around the heart with heart at the center. These three limb leads form the points of the vertices that form this triangle.
According to Einthoven's law, the vector sum of the projections on all three lines equals to zero.

Lead I – Lead II + Lead III = 0.

4. Lead aVR or augmented Vector Right – indicates potential between positive Right Arm and negative electrodes formed by LA and LL.

5. Lead aVL or augmented Vector Left – indicates potential between positive LA and negative electrodes formed by RA and LL.

6. Lead aVF or augmented Vector foot– indicates potential between positive LL and negative electrodes formed by RA and LA.

7. Pericardial leads V1-V6– indicates potential between positive V1-V6 on the chest and negative electrodes formed in conjunction with three distinct limb leads.

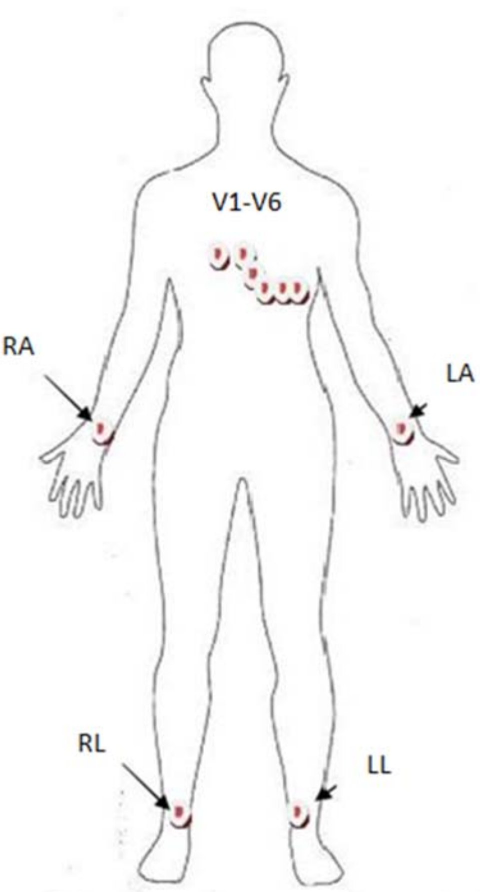

Figure 2.2.3.2: Montage Electrodes Assembly for 12 Lead ECG [27]

2.2.4. Limitations and Scopes of Improvement

Real Time Live needs (RTL) acquisition of ECG requires the availability of a subject and the associated tools. Although the presence of a subject is an essential necessity for recognition for this mode, in many cases, subjects and the hardware tools may not be achieved together. To detect drowsy driver, it is completely impractical to connect the huge number of ECG electrodes with the subject while he is driving. In such cases, an ECG simulator with differently embedded ECG arrangement might be used as a source for electrode potential to collect real time virtual (RTV) ECG. Since, ECG is one of the best recorded data that detects drowsiness, and LabVIEW suits best with bioelectric signal, we considered this software to process ECG signal.

2.3. EEG Sensors

2.3.1. Overview

Electroencephalogram (EEG) is a noninvasive method to record a potential difference between two electrodes, one is active load placed on the scalp, other is either at ear lobe or at any convenient position of the body used as a reference nose.

Sensors to measure EEG are designed in a way so that they can record electrical activity of the brain waves using placing electrodes at the scalp. The electrical activity recorded from the brain reveals the fact how interconnections among neuron are made.

The electrical activity in the brain is generated by the groups of cerebral cortical neurons, near the scalp where the EEG electrodes are placed on. Each scalp electrode collects approximately an estimated 6 cm^2 synchronous cortical activity.

The recorded electrical activity from the scalp is actually a gross resultant of the inhibitory or excitatory postsynaptic potentials (not action potentials, we shall see in chapter 3) .This summated activity behaves like an electric dipole with positive and negative poles slightly separated from each other.

The neurons form the dipole and the dipole vector determines the orientation of the position of electrodes. For parallel orientation of electrodes with the dipole, it measures the activity of generating potential and for perpendicular orientation, it mostly senses negative electrode [28]. In this case, the positive end of the neuron dipole is sub-cortical and can be recorded only with depth electrodes.

The cortical neurons in the brain are intertwined. If EEG shows sinusoidal pattern, it indicates the oscillatory vibration at cortex of the scalp. To measure the electrical activity of the neuron, Electrode placement on the scalp should have the resemblance with the neuronal dipole alignment.

2.3.2. EEG electrode Placement

Electrodes can be attached to the scalp in several ways. However, to locate the point at the scalp for positioning electrodes, 10/20 system is an internationally accepted method in commensuration with the identified position on cerebral cortex.

The number 10 and 20 bear special significance that describes the distance between electrodes in percent.

To locate and trace inside the hemisphere (Skull) each site is designated with different letter and number.

Electrode	Lobe
F	Frontal
T	Temporal
C	Central *
P	Parietal
O	Occipital

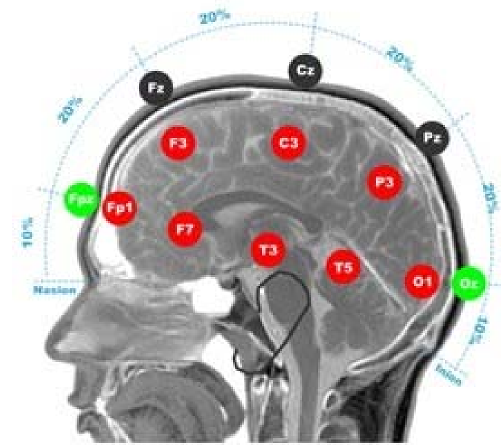

Figure 2.3.2.1: EEG Electrode Placement [29]

In figure 2.3.2.1, there is no central lobe; the 'C' letter is used for identification purposes. The 'z' (zero) position is for the electrode placement at the midline. Sets of even (2, 4, 6, 8) and odd (1, 3, 5, 7) number corresponds to electrode positions on the right hemisphere and on the left hemisphere respectively [30].

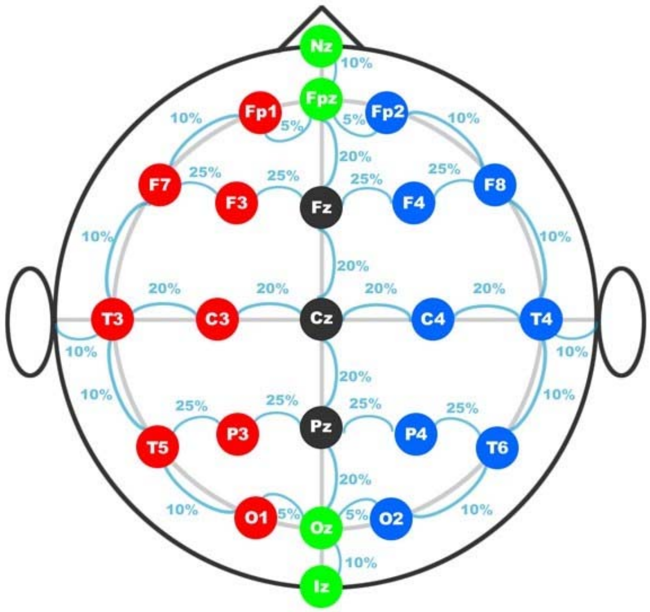

Figure 2.3.2.2: 10/20 Systems Electrodes distances [31]

The standard EEG leads placement systems we discussed where a minimum of 21 are needed to be fixed on the head. Nasion to the Inion distance is taken first where the first electrodes covers 10% distance; the remainingcovers20%.

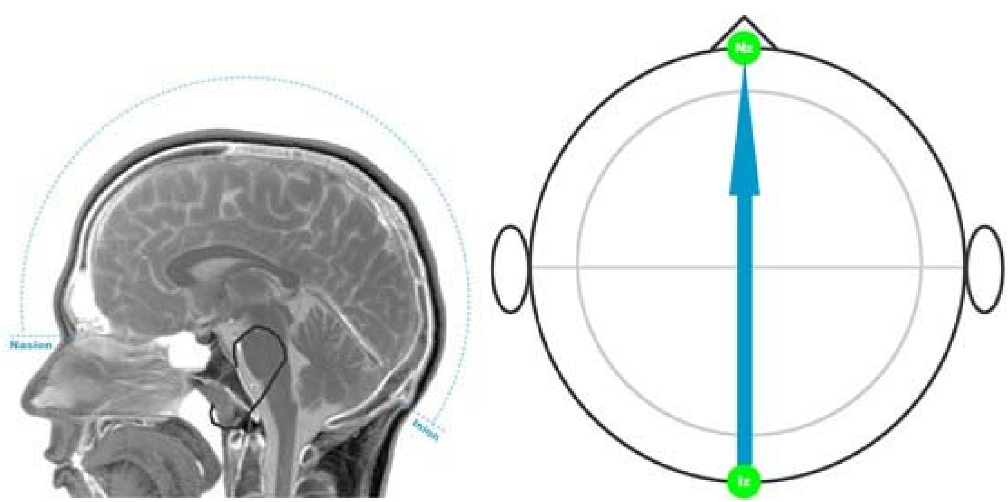

Figure2.3.2.3: 10/20 Systems Nasion to Inion distance [32]

There are other measurements as well. Similar measurements are made from both pre-auricular areas to determine the placements of the remaining electrodes.

We have already mentioned that conventionally, the event and odd number indicates left and right side electrodes. The international system accepted to record brain signal refers to frontal polar, frontal, temporal, central, parietal, and occipital regions [33].

It is to be noted that the orientation of the electrodes should be made parallel to record neuronal activity so that it can pick the highest amplitude that signifies the which band of EEG signal to be dominant.

2.3.3. EEG Electrode Characteristics

As we mentioned earlier, to record bioelectric signal Silver chloride electrodes can be the best choices for its ability to remain stable in contact with water.

Nowadays metal disks are used to form EEG electrodes for medical practice. Cup shaped is preferred in designing electrodes for the convenience of holding paste since the collection of data from the patient to the electroencephalographic (EEG) machine starts at the EEG electrode, it is highly important to use efficient electrodes because bad electrodes distort brain electrical activity and create their own signals although it is unintended. Accuracy of the signal that is extracted with the electrodes at the scalp is the utmost priority.

Starting with the electrodes at the scalp with a scrub of the electrode site with a pumice-laced detergent that lightly eliminates the oily nature of the skin, passing of current is well ensured. A conductive gel that has salts as an ingredient is usually applied over the skin to enhance current flow from the skin to electrodes. Another reason to choose Silver-chloride electrodes is because the silver is purposely oxidized with a chloride solution; facilitate conversion of ionic current flow to electron current flow.

Silver and chloride ions on the electrode surface are free to pass into the gel solution. However, separation of oil layer and skin containing opposite charges form a capacitor. Therefore, impedance is developed in the passage of current to flow to the electrodes. The capacitor also acts as a low-frequency filter, further distorting signal.

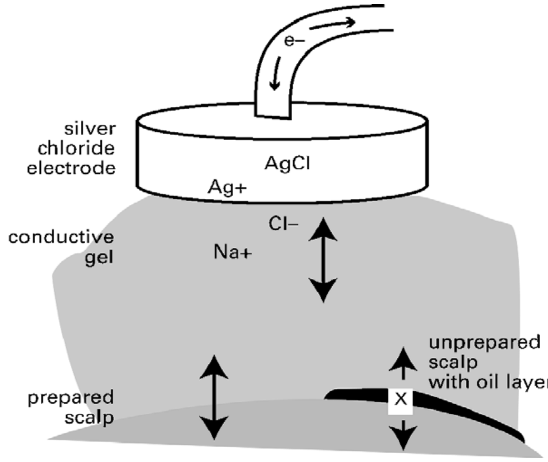

Figure 2.3.3.1: Scalp Electrodes [34]

2.3.4. Limitations and Scopes of Improvement

Although noninvasive, putting 21 efficient electrodes over scalp positioning each with a great accuracy is not a simple task and any discrepancy with the electrode placement fails to interpret actual electrical activity of the brain signal because of spatial dislocations. Current EEG technique is limited with taking signals only from the cortex and cannot extract anything by delving into the region of deep brain activity. Another limitation is that extracted data are full of muscle vibration and external noise, some of which are left with the recorded signal even after filtering. Neurons that form large electric dipole, EEG can only respond to them, shorter dipoles are ignored. Even a lot of chemical activities which did not turn into electric activity cannot be captured with current EEG machine. The recent advancement with the incorporation of MRI (Magnetic Resonance Imaging) provides an image of brain map and information of brain activity can be retrieved from that map. The simulation based software LabVIEW that we used to analyze EEG signal for feature extraction can provide data without distortion, our task to extract information from EEG is not interrupted.

2.4. Alcohol Sensor

2.4.1. Overview

The consumption of alcohol by the driver is rife and as a consequence, fatal accidents occur causing physical impairment and even an unfotunate death very ferquently. The way to get a rid of this problem is bringing the drivers down to go for the test whether he is drunk beyond to a tolerable limit. MQ-3 sensor serves this purspose measuring amount of alcohol consumption by analyzing breath of the subject.

MQ-3 is mainly a semiconductor gas sensor with a sensitive and lowers conductive material SnO_2. It is strongly sensitive to alcohol and when this sensor detects alcohol in breath, the conductivity goes high. Hence, a relationship can be established with the concentration of alcohol it detects and change of conductivity-the change of voltage as its consequence.

2.4.2. Physical look, Pin diagram and Internal Circuitry

Figure 2.4.2.1: Physical outlook of MQ3 Alcohol Sensor [35]

MQ3 gas sensor is embedded in micro AL2O3 ceramic tube containing Tin Dioxide (SnO2) sensitive layer, measuring electrode. Tin Dioxide layer senses the alcohol concentration in a way that as it detects more alcohol in breath; the lower conductivity of the sensors accelerates. It can measure Alcohol level within the range of 0.05mg/L—10mg/L [36].

Figure 2.4.2.2: MQ3 Sensor with extended pin [37]

MQ-3 Sensor Module Pin Configuration:

- VCC ↔ 5.0V
- GND ↔ power supply ground
- AOUT ↔ Analog output
- DOUT ↔ Digital output

Out of 6 pins embedded I Alcohol sensor only 4 are used, two for supplying heat and other two for the ground and the power respectively. Tin oxide is used in the sensor with a coil for generating heat in it. Since, the sensor can generate, it is sometimes identified as Thermal sensor. There is a heating system inside the sensor, which is made up of aluminum oxide, tin dioxide. It has heat coils to produce heat, and thus it is also used as a heat sensor. The pin diagram with the configuration of the alcohol sensor is given below.

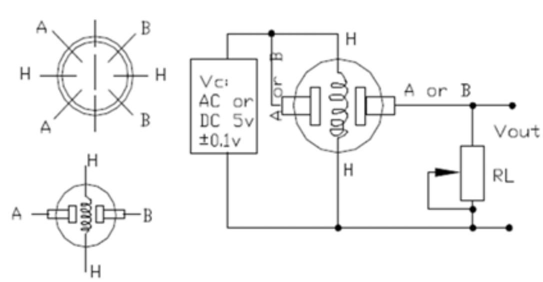

Figure 2.4.2.3: Pin Diagram and Configuration of MQ3 Sensor [38]

MQ-3 sensor is powered by the Arduino 5V DC excitation and output voltage across the resistor is interfaced to the analog input channel (A0) of the Arduino which has built-in ADC. Increase in breath alcohol concentration increases ADC count of the analog channel A0 and that is read on the LCD.

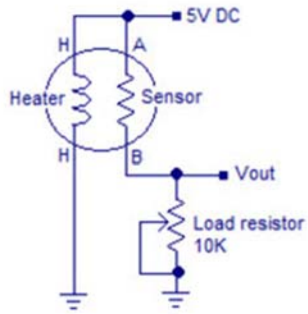

Figure 2.4.2.4: Internal Connection of MQ3 Sensor [39]

The above figure shows a basic test circuit of the sensor. The circuit shows a heater coil that needs a voltage to maintain the temperature. A resistance of 10k is in series with the sensor and voltage is measured across it when the sensor senses alcohol.

2.4.3. Blood Alcohol Concentration (BAC) vs. Breath Alcohol Concentration (BrAC)

Blood Alcohol Concentration (BAC) is used to determine the alcohol level present in human's body. It is a laboratory test and so on-road detection of BAC of drunk driver is not feasible. An alternative way is to measure the Breath Alcohol Concentration (BrAC) using a breath analyzer and the BrAC value obtained are mathematically related with BAC value. So, MQ3 sensor is used as a breath analyzer to measure alcohol level.

A numerical factor of 2100:1 converts Blood Alcohol Contents (BAC) and the Breath Alcohol contents (BrAC). That is, for every 1 mg of alcohol in the breath, there are 2100mg of alcohol in the blood. For better understanding suppose, a person with 0.5% of BAC level is considered to have an amount of 5000 mg/L alcohol in their blood and 5000/2100 = 2.38 mg alcohol level in their breath [40].

BAC =2100 x BrAC (Breath Alcohol Content)

Once the MQ-3 sensor provides BrAC value, we will convert it to BAC level using the relationship between BrAC and BAC. The BrAC threshold limits equivalents to BAC threshold value depending on the equation given below, where BAC threshold value is 0.8 g/dL or 0.08% BAC.

So, if we want to take BrAC threshold then,

$BrAC_{threshold} = BAC_{threshold} / 2100$

$= (0.8 \text{ g/L}) / 2100$

$= 0.4 \text{ mg/L}$

Now, Blood Alcohol Concentration refers to ethyl alcohol or ethanol percentage present in a human's blood. At present, the legal limit is set at .08% blood alcohol concentration (BAC) for driving under the influence or in impaired condition. So we can measure the Blood Alcohol Concentration of a driver by converting the BAC level to mg/L and then to ppm. That's how we can convert the percentage value of BAC to normal integer value of mg/L or ppm for the sensor to calculate. Conversion process can be described as follows.

Table 2.4.3.1: Conversion of BrAC to BAC [41]

No.	Equations	Description
1	0.08% BAC = 800mg/L	0.1%BAC=1000mg/L, BAC= Blood Alcohol Concentration
2	0.08 g/dL=800mg/L	1g/dL=10000mg/L
3	800mg/L =800ppm	1mg/L=1 ppm, here ppm=parts per million

We have represented the BAC or Blood alcohol concentration in ppm in our Thesis using the MQ3 sensor.

The MQ3 sensor can be fixed at a definite distance from the subject, located on the steering wheel which measures the alcohol concentration in the breath of the subject.

2.4.4. Limitation and Scope of Improvisation

To detect whether the driver is alcoholic, MQ-3 sensor should position in a way so that it can pull in enough breathe when the driver exhales. If the driver deliberately covers his mouth, or use a mask for reason, the breathing amount will be scanty and will not be sufficient for the sensor to trigger its action. Sometimes it might happen that the driver intentionally hides his breathe putting something over the sensor to avert the situation, the sensor will not function. Not all the vehicles are kept enclosed, particularly; non AC vehicle, where windows beside the driver remain wide open and air circulates, then the sensor will give wrong result of alcohol concentration. Noise and dust that blocks the vent of the sensors also make the sensor less efficient.

A camera installed in the vehicle can monitor the activity of the driver which will prevent driver's intentional motives to evade the situation. Sensors might be positioned at different position near the mouth of the driver.

2.4.5. Conclusions

MQ-3 gas sensor is a good and feasible choice for the alcohol detection. If the manufacturers embed the sensors with every vehicle, situation might be improved. We used MQ3 sensors in our thesis for alcohol detection along with other two signals ECG and EEG for drowsiness detection. Incorporation of these sensors altogether to detect the distraction of a driver from driving which is our current task can contribute the best result to achieve the desired goal.

CHAPTER 3

BIOELECTRIC SIGNALS

3.1 Introduction

With the inception of the idea that the physiological process generate electric signal demonstrated by Galvani in the 18^{th} century, one important fact is surfaced that the electric signals generated in the tissues may also contain the information of how the different part of the body is functioning. The living tissues of human body, mainly nerves and muscles act as the power station to generate these signals what we call bioelectric signals today. The bioelectric potential differences are developed due to muscular contraction that occurs for the migration of ions and in some cases, due to electrochemical changes [42].

The ionic fluids surround the cells in the human body and consist of sodium ion, potassium ion and chlorine ion. Although the membrane around the excitable cells instantly allow potassium and chlorine ion to flow, it impedes the sodium ion despite of its high concentration gradient across the cell membrane. Sodium ion remains at its resting state and is positively charged while inner surface of the membrane is negative that makes outer surface positive. The potential developed in the cell is called resting potential and the cell in this situation is termed as polarized. When this resting potential falls, cell is said to be depolarized.

It is obvious how the distribution of oppositely charged between the inside and outside of the cell incorporate a potential difference that seems like the behavior of a tiny biological battery. Experiment shows that the resting potential within the cell with respect to outside cell is nearly -70mV and when the cell gets excited, the outer side of the cell becomes positive with respect to interior. This is called depolarization and in this situation the potential goes to +30mV [43]. Depolarization state cannot last long and soon Re-polarization to reestablish the resting potential is found to occur.

The reasons for alternating depolarization and repolarization to occur continuously are related with changing the distribution of charges. Resting potential is achieved due to positive and negative charge distribution over exterior and interior of the surface of the cell membrane when the corresponding cell remains at rest. However, human body cell cannot remain at rest for long and faces excitation. Positive and negative polarity interchanges. The exterior surface now becomes positive. Resting potential collapse and to regain the resting potential, re-polarization occur. The whole process is due to internal functioning of the cell and the behavior of the ionic cells of the fluid inside the body.

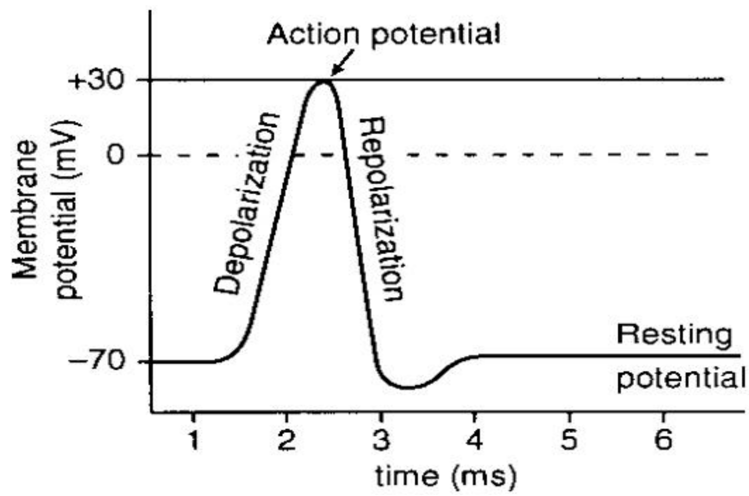

Figure 3.1.1: A typical cell potential waveform [44]

Figure 3.1.1 shows that during depolarization cell potential escalates quickly as high a +30mV what we call as action potential that we will see later as the most important factor to measure the signal from outside with sensors. Cell excitation plays the role to generate action potential, but when the excitation dwindles, cell potential declines to resting potential through re-polarization.

The generated wave of excitation propagates through the muscle and causes contraction. The phenomenon is mostly seen in the cardiac activity and with the smooth muscles. Electric potential is developed with each muscular contraction where muscle in motion remains negative with respect to outside. The voltage developed due to contraction is what we already termed as action potential. To generate an action potential, the cell must be stimulated above a certain minimum value. After a few milliseconds, it recoils to the resting potential known as refractory period.

Table 3.1.1: The typical Amplitude of some Bioelectric Signal

No.	Type of Bioelectric Signal	Typical Amplitude of Signal
1	Electrocardiogram (ECG)	1 mV
2	Electroencephalogram (EEG)	100μV
3	Electromyogram (EMG)	300μV
4	Electro-Oculogram (EOG)	500μV

Our consideration is two major bioelectric signals, ECG and EEG for their characteristics that provides the best feature we are currently seeking for.

3.2. Electrocardiogram (ECG)

3.2.1. Electrocardiogram (ECG) Interpretation

ECG is a recording of the electrical activities associated with the heart that generates bioelectric events. Periodicity in ECG signal is found only in case of heart that gives normal beat although there might be mixed some unpredictable anomalies. Cardiac functions and some irregularities associated with the cardio system are interpreted from the graph. Interestingly, some important features related with the heart activity e.g. distraction, palpitations and the irregular rhythm what we call arrhythmia can be extracted from the recorded ECG. Our main purpose with ECG is to collect the state of the heartbeat when the subject is falling into drowsiness and into arrhythmia.

As ECG data gives almost an accurate data of the physical state of the subject, we choose it to detect the drowsiness of the driver. However, before rushing into what we have got from ECG for our thesis work, we like to go in brief with the cardio function and the inherent relation of ECG waves with heart activities.

3.2.2. Cardiac function and the Origin of ECG Signal

The heart with its four chambers, function together for pumping blood throughout the whole body. Two atria known as right atrium and left atrium are two chambers while other two chambers are known as ventricle, one is at right and other is at left.

The right atrium is the receptor of the blood in dearth of oxygen that gathers from different parts of the body. On way to arrive in right atrium, it passages through superior vena cava and inferior vena cava. Getting pumped at right atrium, blood flows to right ventricles, from there pumping pushes blood to lungs for being oxygenated. After arrival at left atrium, it pumps the blood to left ventricles. Through the cycle of pumping, left ventricles pumps blood and blood rushes to the circulatory system through right aorta which is the largest artery in the human body.

However, we are interested to see how electrical signals are generated in the heart. The electrical conductivity of the Cardiac system apparently looks mysterious due to its ability to generate electric potential from the intrinsic self-excitatory cells inside the heart.

The heart's electrical activity originates from the electrical impulses generated from two important nodes. The inherent conduction system is formed basing on these two nodes, SA node and AV node. Not only these two nodes act as pacemakers, they actively help continuing the heart beat even without any signal from the nervous system.

SA node of heart discharges electricity due to auto excitation of the specialized cells in the right atrium. As told earlier, it locates at the right atrium continuously generating charge for discharging at 60-100 per minute [45].

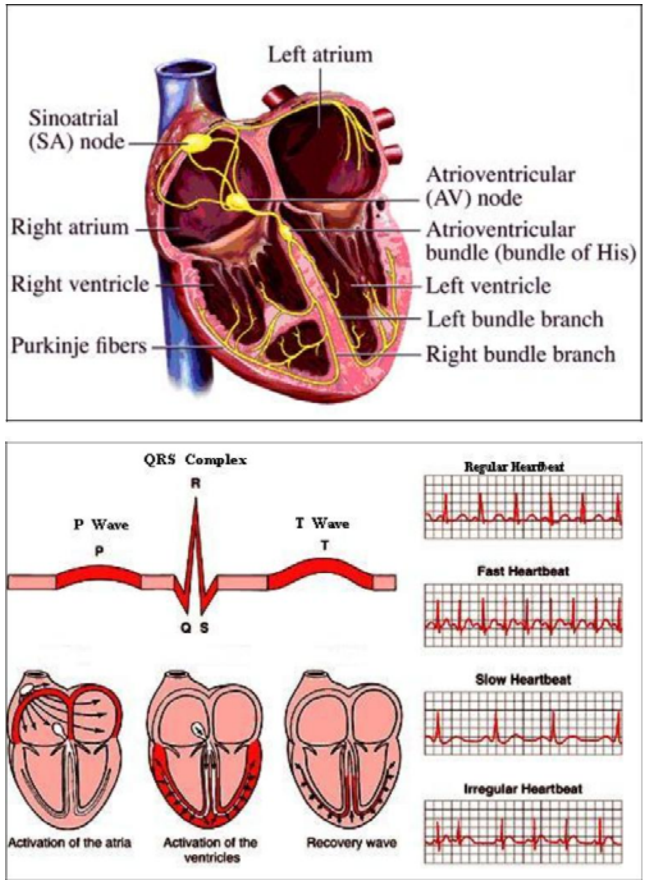

Figure 3.2.2.1: A typical cross section of heart showing different nodes and associated signals [46]

Both atria contract due to discharge of cells from SA node and impulse is transmitted to AV node, which is located in between two ventricles. Electric wave then travels to the lower part of the ventricles through bundle branches. This makes ventricles to contract and energize blood to flow through the whole body [47].

Electrical activity that develops due to contraction of the muscles of the heart reveals the facts of the state of the heart. ECG records this heart activity

3.2.3. Location and Function of Different Nodes

The electrical activity of heart is primarily done through two nodes, namely SA node and AV node. As told earlier, SA node which is located in the right atria has the ability to be self-excited with its excitatory cells; they can spontaneously depolarize and generate the action potentials without being stimulated by other signals. The self-generated wave from SA node migrates. Depolarization occurs. Right atria get influenced by SA node transmits signal to AV node.

To sum up the conductivity of the cardiac system, SA node contributes major part by generating action potentials although other node like AV node has a significant role.SA node sets the rate at which heart beats, normally, 60–100 beats per minute (bpm) varying person to person[48].

SA node, despite being capable of generating its own action potential, responds to autonomic nervous system. It cannot alone set the heart rate without the aid of autonomic nervous system [49]. It simply serves usual function of heart.

Another junction point is the AV node. The action potential this node gains from SA node transfers it again to the bundle of HIS (Wilhelm His, German physician), that results in depolarization of ventricular muscle cells. The contraction of ventricles occurs.

The AV node slightly slows the neural impulse from the SA node, which causes a delay between depolarization of the atria and the ventricles. Another consequence of slowing down of neural impulse is the lower rate of ventricular contraction which is 40-60bpm without autonomic nervous stimulation. The autonomic nervous stimulation like Sympathetic nervous stimulation increases heart rate, while parasympathetic nervous stimulation decreases heart rate by acting on the AV node.

Impulses delivered form SA node impedes by the influence of AV node. The muscles of the ventricle contract again. Heart rate increases due to Sympathetic nervous stimulation while it decrease when stimulation due to parasympathetic nervous occur. [50].

Hence, electric impulse is originated from two vital nodes, SA node and AV node, of the heart through depolarization of charge and muscular contraction. SA node generates signals and AV nodes collect it and thereafter blood circulation occurs.

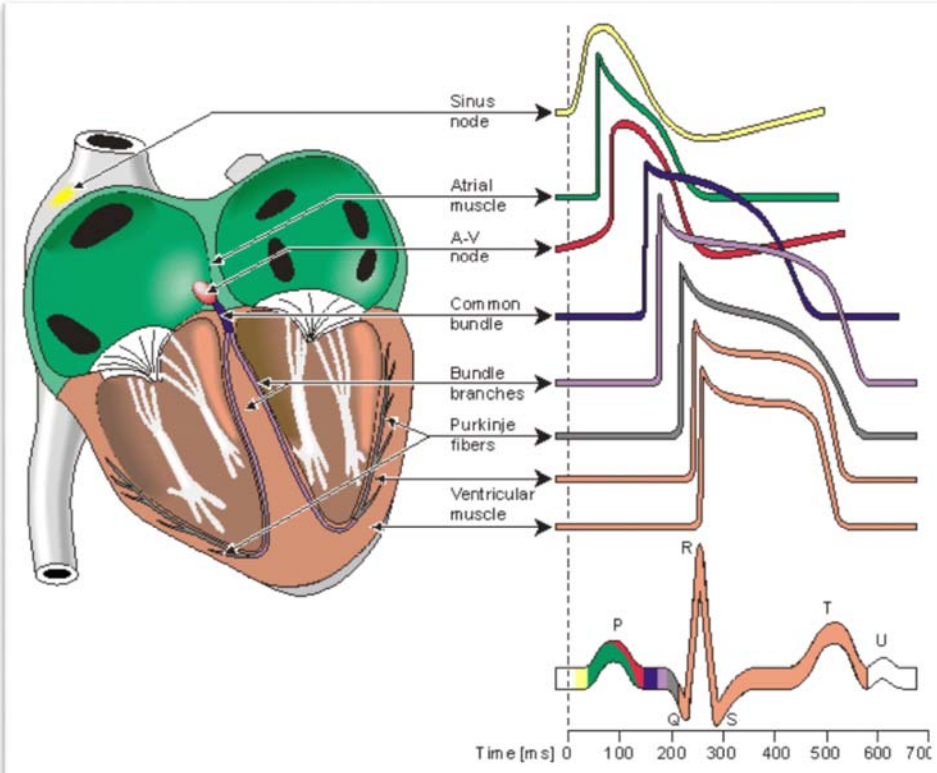

Figure 3.2.3.1: Different Waveform and their Location of Generation in Heart [51]

3.2.4. Nature of Different Waves in ECG

We have already learnt that heart generates electric signal with its self-developed action potential without the aid of any external agent. Obviously, this signal carries the numerous information related to the state of the heart, hence, conceiving this signal and portraying it properly would certainly benefit to detect any sort of abnormality occurred. An electrocardiogram (ECG) does this purpose by recording heart's electrical activity. A graph is traced over a time. The rate and regularity of heartbeats as well as the size and position of the heart can be assessed from ECG.

As this signal is of very low amplitude and low frequency as well, the measuring device should have the capability to amplify and filter this signal to decipher the information coded in it. The output for the ECG reveals fact through some waves, each bearing a distinct electrical and mechanical event occurs in cardiac system. Any variation with the time period or amplitude of these waves carry different feature and detection of the malfunction of heart becomes possible. The best features of a driver's ability to drive, which is our current task to explore can also be extracted from ECG as told earlier.

Typically, a P wave, QRS complex and a T wave constitute an ECG wave pattern in a complete cycle. Atrial depolarization causes a P wave, depolarization of ventricles generate QRS and repolarization produce T wave. We shall see how action potentials generated in SA node contributes to form a pattern for ECG.

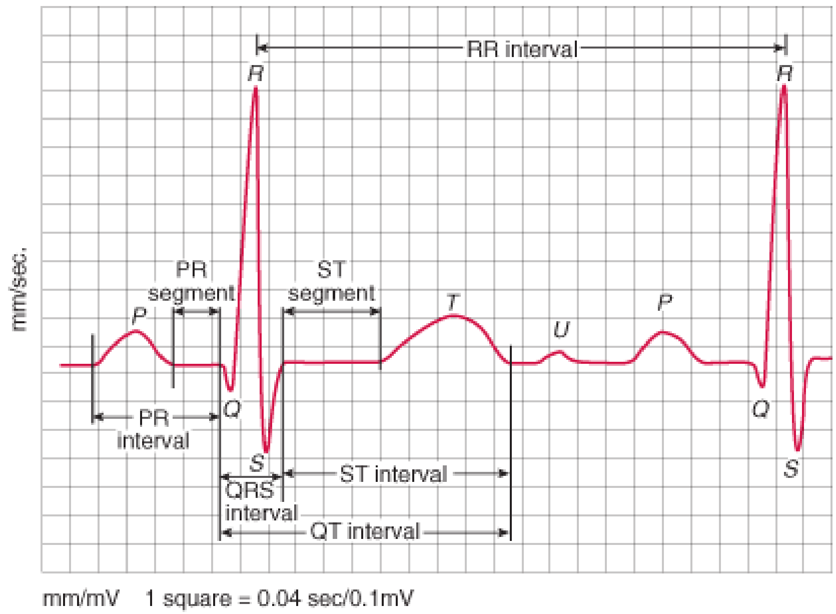

Figure 3.2.4.1: A Typical ECG Signal [52]

The vertical axis measure voltage (mV) signifying the electrical strength and the horizontal axis measures time or time interval between two signals or the time period of the cardiac cycle. The above graph is a typical ECG showing different peak and time interval of some desired parameters.

A synopsis of ECG wave significance and parameters are described below:

We earlier told about atria depolarization. This atria depolarization generates P wave, the initiator wave section of ECG. If P wave sustains more than its prescribed time, it specifies atria enlargement.
In fact, P wave also indicate Atria contract as SA node directly generates it. The action potential that this node generates, spreads, as a consequence atria contraction occur.

The changes of the amplitude P wave indicate the problems with special chemical ingredients in the body. It detects the concentration potassium ion in the body that has the ability to change different activity shown by the nerve.

An ECG that do not have P wave refer one kind of fibrillation. The fibrillation of atria refers to anomaly, disorganization and fast vibration of heart known as arrhythmia [53].

Next to P wave in the ECG, come R wave, T wave and other significant intervals. The interval between P wave and R wave measure the rate of depolarization. We measure P-R interval from ECG time axis. Any deviation of regular PR interval of 0.20s indicts sever heart problem what we colloquially say as heart block [54].

The QRS complex refers to the summation of three waves juxtaposed one after another. This complex with three waves in it refers to depolarization and contraction of ventricles.

The generation of P-Q segment is due to the arrival of the signal to AV node from SA node that stays for a while to allow the ventricles to be filled with blood. Two inversions as we see in ECG are two downtrend waves Q and S. However, the uptrend of QRS, the R wave is of our interest because of containing important information we need for our task. The Q and S waves are downward waves while the R wave, an upward wave, contains the most significant feature of an ECG.

Like all ECG wave QRS complex also has time interval and any interval exceeding the regular value 0.12s indicate another problem in the heart, maybe a block in bundle branch [55].

The ST segment of ECG contains the information of the position of the heart. It detects elevation that we call myocardial infarction and at the same time it also traces depression that is medically termed as ischemia [56].

The later part of ST segment, the T wave traces how muscles of the heart repolarize. The ventricle of the heart changes its charge and is measured by T wave of ECG. After depolarization, repolarization is an obvious consequence of coming back to stable position. So, T wave gives stability of the cardiac system.

U part of ECG not always visible on an ECG because of its small size it compared to the other waves [57].

Amplitude, duration and clinical significance may be categorized as follows:

- The amplitude of P-wave determining factor of potassium ion concentration — 0.25 mV

- The amplitude of R-wave containing information about heart beat — 1.60 mV (highest peak in the ECG)
- The amplitude of Q-wave a downtrend or an inverted segment — 25% R wave
- The amplitude of T -wave determining factor of the change from depolarization to repolarization — 0.1 to 0.5 mV

Table 3.2.4.1: Clinical Significance of ECG

No.	Name of the Wave	Duration(ms)	Features
1	P wave	80-100	Enlargement of the atria, Fibrillation
2	PR segment	120-200	Cardiac blocks, tachycardia
3	QRS complex	80-120	Myocardia elevation
4	QT	200-400	Coronary Heart disease
5	ST segment	80-120	Myocardial Infraction
6	T	120-160	ventricular hypertrophy
7	U	20-40	Hypercalcemia

3.2.5. Heart Rate

Our target from ECG is to take heart rate because it describes the drowsiness state of the subject. As the heart relaxes and contracts, it pumps the blood through the body. Heart rate is a measurement of how many times the heart completes the cardiac cycle that refers to frequency. The R-R interval in the ECG corresponds to the heart rate.

Usually, heart rate is calculated as the number of either relaxation in one minute or contraction in one minute. This indicate the heart beat measured in bpm "beats per minute"

Human heart beats at about 70 bpm (males) and 75 bpm (females) on average, but this varies with individuals [58]. The following formula [59] is used to calculate heart rate.

$$Heart\ rate\ = \frac{1}{interval\ between\ R - R\ peak(sec)} \times 60$$

The range of heart beat is normally between 50 bpm and 120bpm. Heart beat less than this figure gives Bradycardia and higher value than 120bpm gives tachycardia. Athletes and Obese may have different rate.

The generation of self-generated action potential in SA node and the conduction system of AV node actually generate this heartbeat.

They are stimulated by also Sympathetic nervous system that causes to increase the heart rate. Influence of Parasympathetic nervous system act in the reverse way, both nodes decreases the heart rate.

SA node alters its polarization state and AV nodes it conducting states.

Average Heart Rate (60-100 bpm) indicates normal rate when the heart beats at normal pace. The electric signal generated at the heart faces no hindrances to pass [60].

American Heart Association [61] says that Bradycardia is not a disease but a disordered rhythm of heart showing less heart rate than normal. Having a slow heart rate can reduce the amount of oxygen throughout the body, causing dizziness for the heart not to pump adequate oxygen to the body which will impair continuation of work. Fatigue and drowsiness are two symptoms of Bradycardia. The heart rate goes below 50bpm.We will consider in our thesis work less than 50 bpm heart rate as the standard for drowsiness state of the subject.

Figure 3.2.5.1: ECG showing sinus Bradycardia [62]

Tachycardia is another disorder of the rhythm of the heart when heart beats too fast. Heart rate goes as high as and beyond 120 bpm. We call it arrhythmia, when abnormality in heart produces rapid electric signals, which accelerates the heart rate. The following graph shows the state of arrhythmia, the sinus node sends out electrical signals faster than usual, speeding up the rate of more than 120 beats per minute.

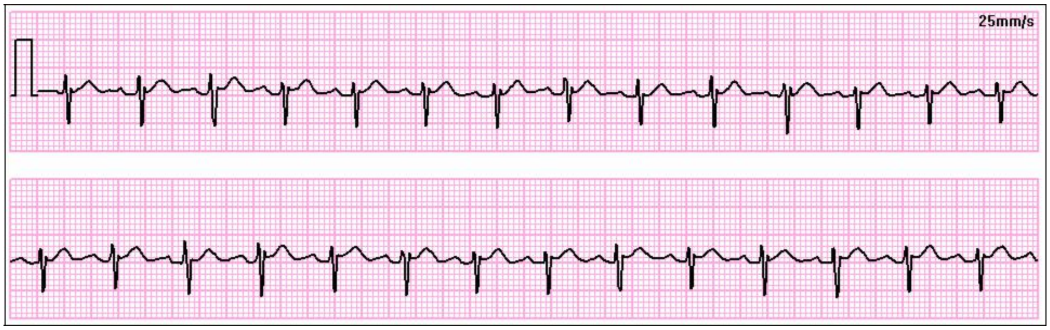

Figure 3.2.5.2: ECG showing Sinus Tachycardia [63]

The following figure 3.2.5.3 shows the R-R interval that we sought for to measure the heart rate.

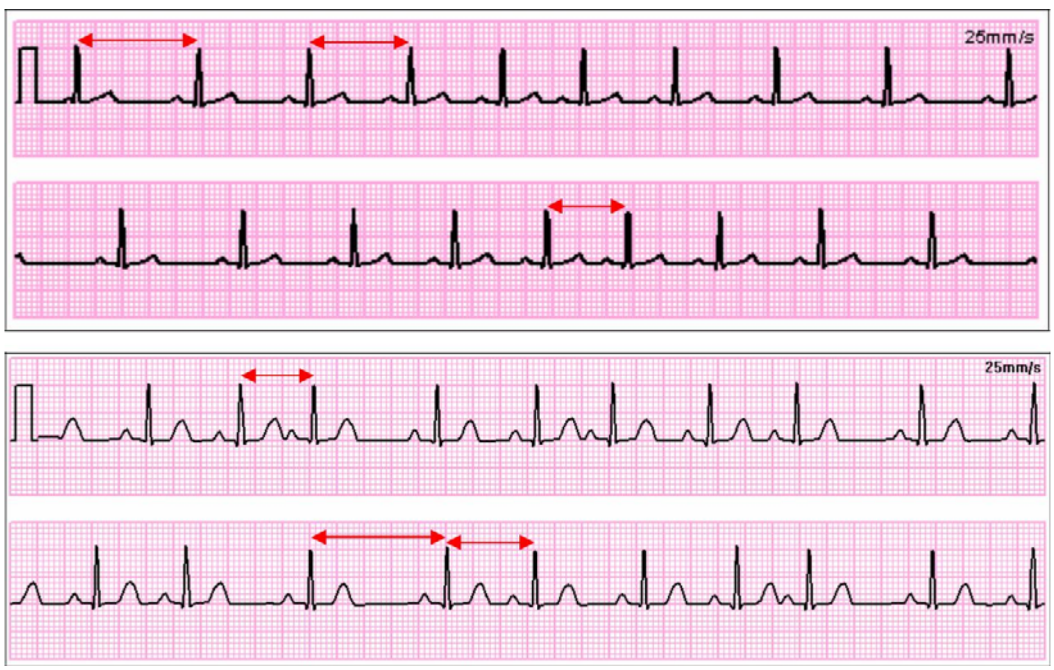

Figure 3.2.5.3: R-R interval that determines heartbeat [64]

In our thesis work, we used biomedical toolkit to generate ECG signal and LabVIEW for processing this signal to extract desired features. As ECG signal is of low frequency and low amplitude and it contains also noises, filtration and amplification are required to observe this signal. Considering an arbitrary signal, we incorporated several characteristics to generate

ECG and measured R-R interval from it for our interest of existing thesis work. With the variation of this interval, heart beat also changes. We carefully observed whether the data, we extracted match with regular data found by recognized experimentalists. Although the threshold limit of the subject going down to drowsiness from awareness varies significantly with the individuals, the threshold limit of 50 bpm is widely accepted.

3.3 Electroencephalogram (EEG)

3.3.1. EEG as a Bioelectric Signal

After the discovery of the electrical activity in the brain more than a century ago by Catton [65], slowly it became accepted as a tool of analysis of brain function although there remained much controversy with electroencephalogram or EEG at the beginning. On one hand, there was complexity with neuronal generators of electric signal and the other is the way how it is achieved externally.

Interestingly, neurons are self-excitable cells having inherent electric properties [66] and electric and magnetic field due this electrical activity are generated in the brain. We use electrodes at a short distance from this signal source. The EEG is the sum of all electrical activities of neuron, thereby focuses different states of brain indicating relaxation, activeness, drowsiness, deep sleep and other brain related activities. In EEG, brain related electric potentials are recorded at the scalp with the electrodes and the measured signal being very weak (30-100μV) needs to be amplified for analysis.

3.3.2. Origin of Brain Signal

Electric activity of Neurons contributes to time-varying current when activated. These are ionic currents. Two forms of neural activation are found [67], one is fast depolarization of and the other is the steady variation in membrane potential due to synaptic activation.

The action potential due to rapid change in membrane potential abruptly shifts between negative and positive jumps from negative to positive and generate resting potential This generates the impulse containing a remarkable property. The amplitude of the achieved signal is not attenuate.

The slower postsynaptic potentials, the excitatory and the inhibitory potentials all depend on a specific transmitter of signal known as neuro transmitter [68].

Therefore, the synaptic activity can have the resemblance of a sink–source configuration centering on the neurons and the neurons for its geometry of locations can be considered as electric dipoles.

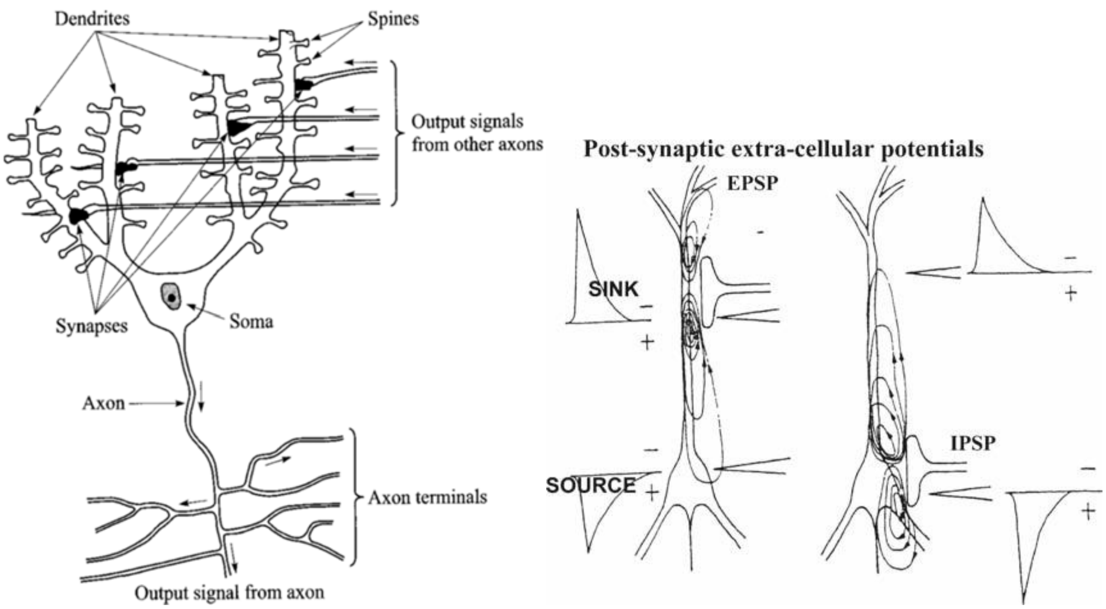

Figure 3.3.2.1: Biological Neuron [69]

3.3.3. Rhythms of Brain

Our interest is not about all types of activities that neurons show, only some significant and relevant with our work with four bands activities in the alpha frequency range, beta and delta rhythms are our objectives to focus.

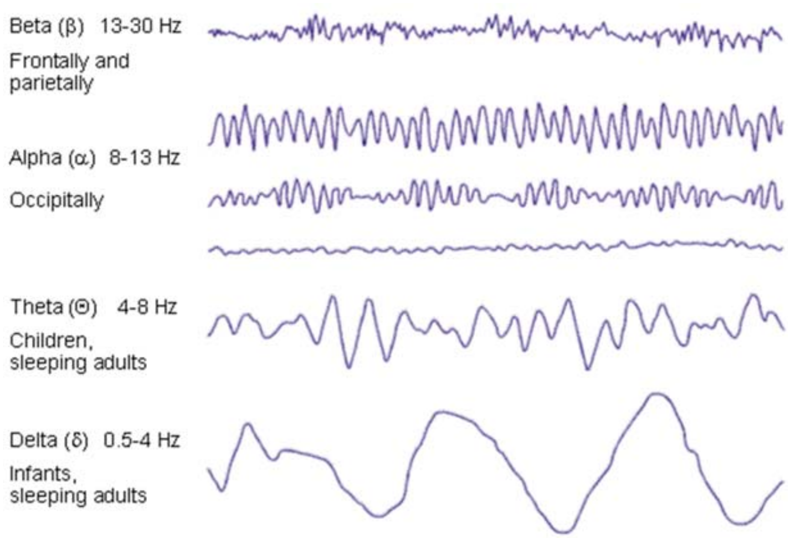

Figure 3.3.3.1: Different rhythms of Brain (frequency range may slightly differ) [70]

3.3.4. Sleep EEG Phenomena

The neurophysiology of sleep describes two distinct EEG phenomena, the waves between 8 and 13Hz which is produced at the time generation and the delta waves (0.5–4 Hz), which are dominant in the deeper sleep.

Neuroscience suggests that the sleep spindles are generated in the thalamic cortical circuits. The neuronal populations have special characteristics to generate spindles.

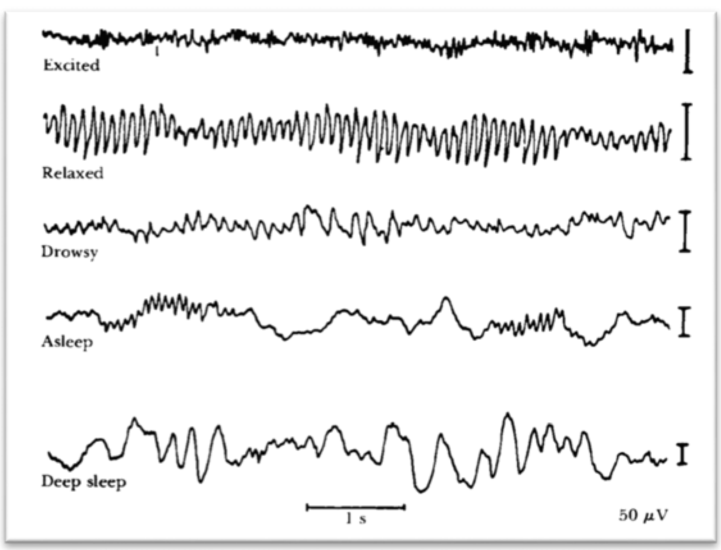

Figure 3.3.4.1: EEG from awakening state to sleep state [71]

There are experimental evidences during sleep stage; in thalamus spindle oscillations are generated. They can be recorded in the brain [72].

One question may arise how are these oscillations controlled by the systems? The fact that brain stem control spindles can also block thalamic oscillation. However, it is often misunderstood that slow-wave sleep, characterized by typical EEG delta activity does not correspond to a state where cortical neurons are inactive, neurons remain active even in delta stage .Electric activity of neuron verify this phenomena [73].

Regarding neuronal excitation, the distinction between delta sleep and wakefulness is that in the former case, the neurons tend to show activity with relatively prolonged soundlessness. Whereas the latter pattern is full of vibrations. This issue is still unraveled.

3.3.5. Alpha Rhythms of Neocortex and Thalamus

The behavioral states at which different band oscillations occur are quite different although it is difficult to explain the reasons behind it. The experimental result revealed that alpha rhythm occurs in the visual cortex. Intra cortical connectivity propels the flow of alpha signal through the channels. The movement of alpha wave is slow due to impedances around the cortex. The velocity is tentatively measured as around $0.3cms^{-1}$ [74]. Hence, Visual cortex is responsible for generating alpha rhythm.

In the awakening state recording of alpha wave corresponds to occipital areas [75]. The reduced alpha rhythm amplitude tends to have a chance with suspected relationship between heart rate and alpha is not yet finalized [76].

3.3.6. Beta Rhythm of Neocortex

The tracing of high-frequency rhythms in the neocortex covers two major areas, the visual cortex and the somatic motor cortex. In quest of how beta signal is generated it is found that beta certainly roots down in the cortex [77]. Thus vibration of beta can be collected from different points of the cortex. The slow rate of neuronal vibration suffers from one fourth wavelength phase shift. That is an indication of phase shift oscillation [78].

3.3.7. Justification of measuring EEG

Distribution of electric potentials at the scalp due to neuronal fact is a problem to analyze because locating points at the scalp from which potential is measured is not uniquely solved [79]. It is based upon the assumptions on the hypothesis of the activities of neuron. The consideration of neuron being a dipole cannot show sufficient explanation for its own evidence. If the neurons are electric dipole, we get electric field and consequently electric potential at different point on the scalp. Bipolar current distribution can explain everything of neuronal electric field and magnetic field.

It is obvious that gaining information about the generated electric field as well as magnetic field gives a logical expectation of collecting more information about different bands of frequencies produced in brain. However, the dipole analysis neuron and its consequences is not straight forward.

Even knowledge of the properties of the individual neurons is not sufficient. It is necessary to understand how populations of neurons interact and undergo self-organization processes to form dynamical assemblies. The latter constitute the functional substrate of complex brain functions.

However, both trivialities and non-trivialities to extract information from brain need the conceptual accuracy about the action and electrical behavior of brain cell in full length. We neither have any unique model why such electric activities are developed and how they can be measured accurately, nor do they assumed parameters exhibit the uniform characteristics. Moreover, extraction from the different nodes of the scalp gives only surface neuronal activities, not the activities played by the deeper brain. Hence, it is an urgency to construct a perfect model that matches with the electrical activity exhibited by neuron.

3.3.8. EEG Waves and its Consequences

All human brain can generate four or five patterns of electric waves of different frequencies that we can see in the EEG. Across the cortex these waves are produced and they carry significant information about different mental and physical states. It is important to note that brain always produce all waves at a time that is reflected in EEG. Physical state is defined by locating a wave which is dominant.

The name of the waves already discussed is arranged from high to low according to their frequencies. Beta, alpha, theta and delta are mostly discussed in day to day activities.

Beta waves bearing high frequency and of low amplitude indicate awakening state, when in EEG signal beta becomes dominant, the situation refers that the subject is suffered from stimulating factors-excited or rational state can be described with beta wave of EEG. However, exact amount of beta indicate thinking state though, exaggerated beta pushes the subject to anxiety state. Having the right amount of beta waves allows us to focus and complete work-based tasks easily.

Frequency range of Beta wave: 13 Hz to 30 Hz (High)

Symptom: Anxiety, Over Stress, Chaotic

Alpha wave extends its frequency in the range that bridge between two states- awakening and sleepy. Sometimes it indicates for relaxation.

Frequency range of Alpha wave: 8 Hz to 13 Hz (Moderate)

Symptom: too relaxed

Theta wave involves drowsiness. When theta waves become dominant, people will found to turn from awareness to drowsiness.

Frequency range of Theta wave: 4Hz to 8Hz (Slow)

Symptoms: inattentiveness, drowsiness, depression etc.

Finally, Delta waves are almost standstill. However, delta has highest amplitude and it is the important characteristics of this slow wave. When delta waves become dominant, the subject is found sleepy. The slowest recorded brain waves of highest amplitude in human beings indicating deep sleep. When delta wave is dominant, it indicates deepest level of sleep.

Frequency Range of Delta wave: 1Hz to 4 Hz (Slowest).

Symptom: Quick turning to deep sleep

The following table shows EEG bands and corresponding physical states altogether to get a quick review.

Table 3.3.8.1: EEG from awakening state to sleep state [80]

No.	Band	Frequency(Hz)	Physical or Mental State
1	Beta	13-30	Anxiety, Over Stress
2	Alpha	8-13	Relax
3	Theta	4-8	Drowsiness
4	Delta	0.5-4	Sleep

Hence, delta wave of EEG indicates highest level of distraction. When EEG of a subject is taken, if either theta or delta becomes dominant, the subject is losing or has lost the ability of being attentive to the action he is involved with.

Theta and Delta waves of EEG clearly indicate the change of the physical and the mental state of awareness to sleep via drowsiness with accuracy. For the drowsy driving detection, EEG signal of the driver may be considered as a good choice although taking EEG of a driver while driving is not that easy. A good number of non-evasive electrodes make it too difficult to take EEG. Whatever the situation is, our task is to extract delta or theta signal from the EEG signal of the subject if he falls into sleep. The possibility of desired signal extraction has become easier with the innovation of software based biomedical signal generator.

3.3.9. Indispensability of EEG signal

Out of all biomedical signals like ECG, EEG, EMG or EOG, EEG provides the most effective indication of different physical and mental changes that each living being has to go through because it is for the neuronal excitation that generates electricity. The main objective of considering EEG signal is to extract the theta and delta signal that best describe the distraction of the subject due to drowsiness. Since, EEG of a certain subject exhibits all the electric waves at a time and the accuracy of the state of the subject is defined by the wave which is dominant at that instant, we need to wait for theta and delta signal to declare the subject as drowsy.

Although other bioelectric signals like EMG or EOG can also be used to detect drowsy driver more conveniently, EEG gives more accuracy and next to it, is ECG to describe the states of the driver. As we already mentioned that when heart rate starts going below 50bpm, the subject eventually begins falling into drowsiness. However, an additional search became an emergency whether two distinct signals coming from two different systems have any cause-effect relationship.

3.4. Correlation between two Signals

It has scientific evidences that automatic nervous system changes during different physical and mental state change as the subject turns from awareness to drowsiness. Analysis of Cardiac electric signal suggests that physical state of the subject varies with the heart rate or heart rate variability. As we found in different recognized sources (sources are previously mentioned) that in drowsy state, the heart beat goes down less than 50bpm. Frequency analysis of vibration between two QRS, that is, in R-R intervals of ECG has provide this result and R-R interval results in heart beat and in heart rate variability.

As we found in some research paper, both sympathetic and parasympathetic activities are dictated by low frequency (LF; 0.04–0.15 Hz) while only parasympathetic nervous system dictate high frequency (HF; > 0.15Hz). In addition, the ratio between low and high frequency is also a marker to measure nervous activity [81]. An increase in HF component and a decrease in LF component indicate NREM or tendency to fall into drowsiness. Hence, it is an established fact that cardiovascular states are associated with typical changes in HRV or in other word, change in heart rate which is measured in bpm calculated from R-R interval. In our research, we considered the heart rate in bpm as a determining factor of the drowsiness state of the subject [82].

Extraction of the desired parameter for drowsiness from EEG needs Fast Fourier Transformation or Wavelet transformation. Spectral analysis with FFT gives theta (4-8Hz) and delta (0.5Hz-4Hz) as the drowsiness and sleep state. What is obvious from the factual evidence is that during the state of drowsiness ECG record gives heart rate below 50 bpm and EEG record shows a theta state to indicate the same physical state.

It is an intriguing question then to look for if there is any causation, coherence, correlation or coincidence between two signals ECG and EEG. Is EEG causation for EEG as we all know that brain controls all body activities?

Since, cardio system generates its own electric potential from the excitation of SA node and AV node of the cardio system help the signal to pass to the atria or ventricles interpreting as if the whole cardiac system runs by itself. It makes us confused even to think that heart itself has a brain. The research until 2017 has not found whether EEG is a causation of ECG [83].

Neuro scientists and Cardio scientists have to depend on the statistical result a way to explore the relationship between two signals. Correlation and regression analysis serves some purposes depending upon the relevant varieties of the data [84].

A simplistic version of interpreting correlated result is that zero correlation coefficient means the that the two states are not correlated, positive correlation coefficient means the that the two states are correlated in such a way that one increases or decreases with the increase or decrease of the other and finally, the negative correlation coefficient means one increases or decreases with the decrease or decrease of the other. The bigger number exhibits stronger correlation. The typical statistical formula for the Pearson's coefficient of correlation is

$$r = \frac{S_{xy}}{\sqrt{S_{xx}S_{yy}}}$$

Where, $S_{xx} = \sum x^2 - \frac{(\sum x)^2}{n} S_{yy} = \sum y^2 - \frac{(\sum y)^2}{n} S_{xy} = \sum xy - \frac{\sum x \sum y}{n}$

Though new, some researchers have found a good and convincible result in favor of the correlation between ECG for drowsiness and EEG for theta and delta states. The other states are still in progress. A recent study and the analysis of their data for ECG and EEG in the drowsy state produced the following graph.

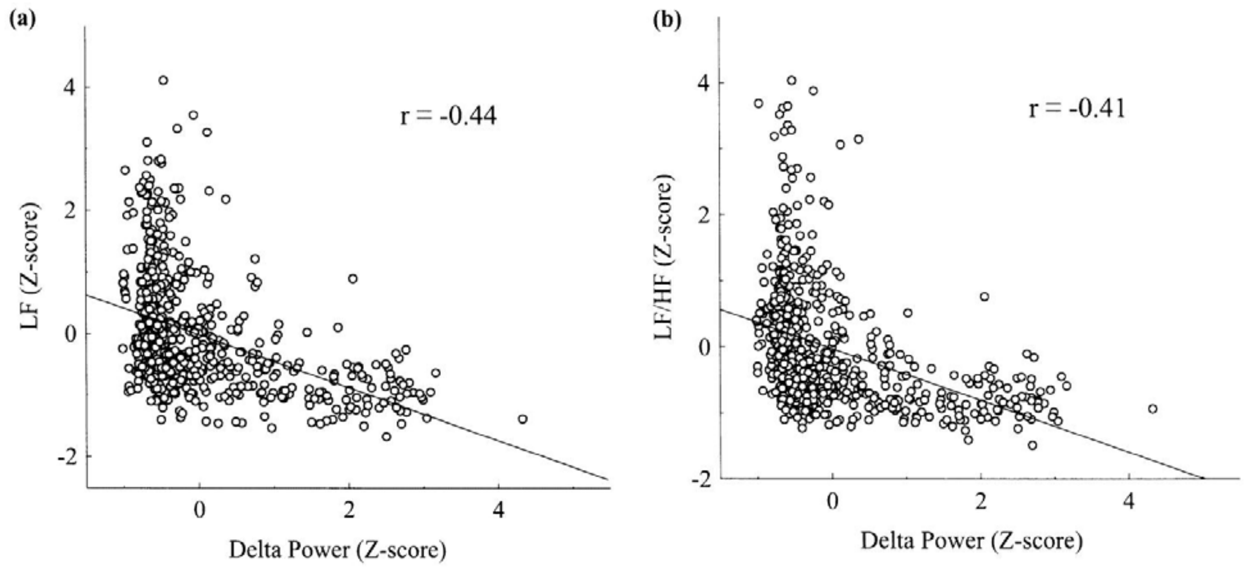

Figure 3.4.1: Correlation between LF/RF in Heart Rate and Theta-Delta power for EEG [85]

The correlation coefficient $r = -0.41$ indicates a moderate negative correlation between heart beat for ECG and theta-delta state for EEG. If heart beat goes low, delta power goes high. Lower bpm with heart has a significant correlation with theta-delta state of EEG which gives us a clue that we can go for fusion of two bioelectric signals. If both ECG and EEG confirm the drowsy state of the driver, we can decisively conclude that the subject is certainly drowsy.

3.5 Alcohol Detecting Signal

3.5.1. Detecting Alcohol

The two bioelectric signals ECG and EEG discussed above are generated in the internal nervous system that gives us natural change of physical state during different activities. We have found two signals giving the same state of drowsiness are correlated. We have included an external factor taking alcohol that substantially hinders smooth driving although it apparently seems to have nothing to do with bioelectric signals. However, with high rise of binge drinking by the driver and its fatal consequences, alcohol taking beyond a certain level while driving has become punishable offence since late 1970s.The inclusion of detection of alcohol with our thesis is not only for its association with the risk of accident but also its correlation with heart beat. ECG wave pattern gives different rhythm of heart beat if the subject is alcoholic.

3.5.2. Impact of Alcohol on Heart Beat

LMU University Hospital Munich Department of Cardiology investigated on several samples to find the effect of alcohol on heart beat [86].

The alcohol concentration in breath was 0.85 g/kg. Researchers found that with the intoxication of alcohol heart beats goes high. This indicates arrhythmia.

In ECG chapter we saw different pattern waves and its parameters. The conduction state represented by PR and QRS, re-polarization represented by QT and the excitation by RR interval constituted the ECG wave. The investigators found that the heart rate goes high with the amount of alcohol consumption [87]. High heart rate triggers arrhythmia.

3.5.3. Conclusions

Despite the consumption of alcohol influences the heart racing high, we considered it a separate issue as a cause of impaired driving. We did not include it with our ECG-EEG combination at the present moment. The reason is the ECG and EEG has intrinsic natural characteristics, some in common that occurred naturally. Alcohol is an external factor that can change mental state and behavioral attitude. Moreover, out of many features in ECG, consumption of alcohol deals only with heart rate so far the research suggests. Sometimes, in some cases consumption of alcohol makes the subject drowsy specially, who are new indicating low heartbeat. However, whether consumption of alcohol makes heart beat go high or low, it causes fatal accidents. The purpose to include detection of alcohol is to address the issue.

CHAPTER 4

THE WORKING PROCEDURE AND APPLICATION

4.1. Introduction

The main motive of our work is to give the world a better place by improving the healthy driving condition and communication system network. We have already mentioned the consequences faced by the victims of road accidents. Therefore, to avoid such fatal and non-fatal accidents, we are using BSNs to determine the mental state of the driver. Furthermore, we are using a MQ3 Alcohol sensor for detecting if the driver is drunk. A synopsis of whole working system is given here to maintain the flow of continuity of our work. We have seen in the earlier chapters how each sensor provides desired signal to detect the different states of the subject. Out of several BSNs for detecting the state of the driver during driving, priority is given to choose a system that best describes the state and is also cost efficient. Through the process of huge research on bioelectric signals and other external sensors, ECG and EEG are found to be the best in terms of accuracy for the detection of distracted driving. We have described that the desired features of ECG and EEG extracted separately are allowed to match with the different threshold values and are combined to confirm drowsiness state more efficiently. For the bioelectric signal part, we told earlier that we used LabVIEW software as it best fits for its usability. For alcohol detection part, we also told that sensor provides information to microcontroller to detect the exact state of alcohol intoxication. LEDs, buzzer and LCD display are used in the circuits to make our outputs more comprehensible. This chapter will deal with our working steps, operational circuits and their behavior at different stages. We shall go through each of them in details.

Although our work is on simulation basis, we have the ideas of how they can be implemented in real world. Provision of keeping LEDs connected with the microcontroller can be installed on both sides of the driving seat to aware driver from distraction and also at the back of the vehicle to notice other vehicles on the road about the distracted state of the driver. The whole setup can be installed inside the vehicle and closer to the driver’s seat to get the desired results

4.2. Overall block diagram and Explanation

The overall picture of our proposed system is explained in steps through the following block diagram.The following diagram shows the microcontroller to take alcohol sensor input out of three inputs that would be discussed eventually. Two outputs from the microcontroller serve two different purposes. One activates buzzer to buzz, and LED to glow, and the other for communicating information to emergency unit through V2V/V2I network (details in chapter 6.2).

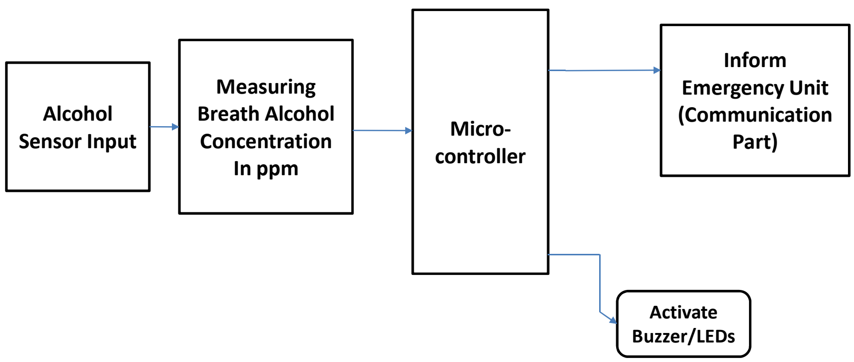

Figure 4.2.1: Overall Block Diagram (Alcohol part)

The second input is from the ECG signal when the heartbeat of the driver is above 120 bpm. This heartbeat is abnormal (Arrhythmia) and it indicates that there is a chance of heart attack. We will inform the emergency unit for this case. The third input is from the EEG and ECG signals combined together. To detect the driver's drowsy state more accurately, we are considering the ECG signal when the heartbeat goes below 50 bpm and EEG signal when the Delta or Theta band becomes dominant. The corresponding output for the combined part controls a buzzer to alert the driver. The reference value for the thresholds selected is mentioned in chapter 4.7. Our work focuses on the signal accumulation, processing, combining and feeding it to the microcontroller to obtain the desired outputs (Glowing respective LEDs and activating buzzer).

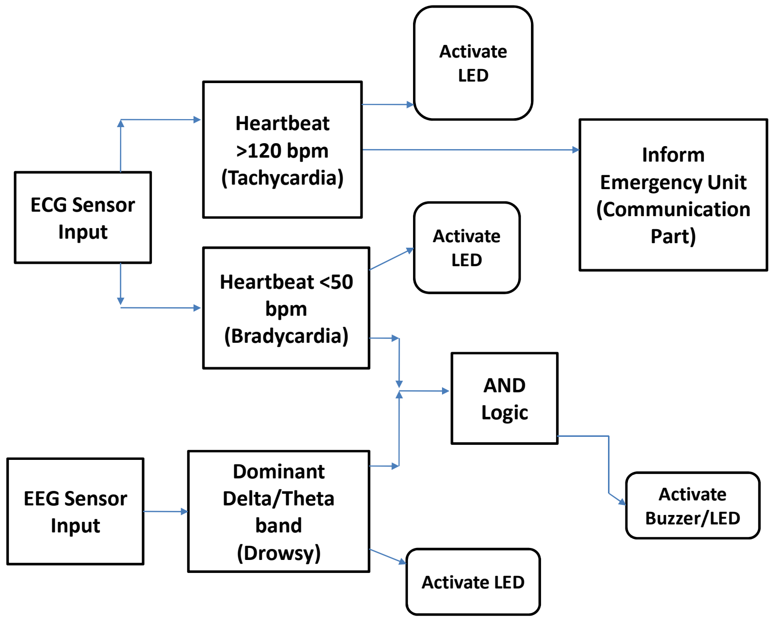

Figure 4.2.2: Overall Block Diagram (Combined part)

The sensors takes different signals from the subject's body and after processing it feeds the data to the microcontroller or other controlling unit for matching the thresholds to detect drunk, drowsy or distracted state. Once we get the output from the microcontroller, the rest is the communication part, which could be done by android device or any monitoring device. The monitoring station decides if it has to send the decision to other nearby vehicle or the emergency unit through VANET communication system.

4.3. MQ3 Alcohol Sensor Flowchart

Accidents occurred due to distraction of the drunk drivers are not uncommon in today's world. To detect the drunk driver, we told that we chose MQ3 semiconductor alcohol sensor. Our simulation system collects data from Alcohol sensor library available in Proteus. In real life, the MQ3 sensor measures alcohol concentration level analyzing breathe of the diver when he exhales. However, in our simulation work, data in ppm (parts per million) are collected from the MQ3 library available in Proteus by varying its resistance with the help of a potentiometer. The following flowchart describes the working flow of the simulation circuit for drunk detection.

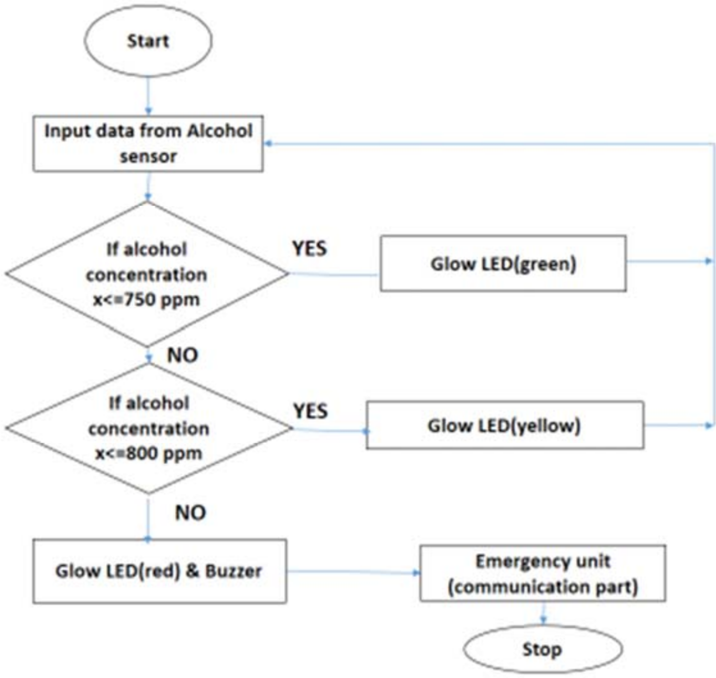

Figure 4.3.1: Flowchart of MQ3 Alcohol sensor

Once the sensor senses alcohol, the rest is matching with the thresholds and glowing corresponding LEDs by the microcontroller. We have considered ppm below 750 as the first case. The second case is for a ppm in between 750 – 800. The last and the third case are for ppm above 800 [88].

In USA, the legal standard for driving in drunk condition was 1000 ppm for years. However this legal standard has been reduced to 800 ppm in several states. According to the American Medical Association a person can be impaired if the alcohol intoxication is found 500 ppm [89] Worldwide accepted value of 800 ppm is used now as a standard reference for drunk driving. A detailed description of the total scenario is represented in the table below.

Table 4.3.1: MQ3 Alcohol Sensor Threshold Selection and Description

No.	**Details**		
	Alcohol concentration, X (ppm)	**Corresponding decision**	**Description**
1	X<750	Glow Green LED	The Driver is sober and fit to drive.

2	750<X<=800	Glow Yellow LED	The Driver is slightly drunk. It's better not to drive for him.
3	X>800	Glow Red LED and active Buzzer. Emergency unit will be activated if the vehicle is not stopped.	The Driver is drunk and not fit to drive.

4.4. ECG flowchart

We described in several places that a driver's state can be accurately measured by bioelectric signals using different BSNs (Body Sensor networks). We are generating an ECG signal in LabVIEW and taking data by varying the frequency of the signal for our simulation. Here we are considering only the heart rate of the driver to detect the distraction. Different heart rate indicates different states of the driver [90]. The following table which is also given in chapter 3 is drawn here to maintain the coherence.

Table 4.4.1: Different Heartbeats Describing Different States

No.	Heartbeat (bpm)	Description
1	Less than 60 bpm	Abnormal or Drowsy (**Bradycardia**)
2	Around 60 to 100 bpm	Normal
3	More than 100 bpm	Abnormal (**Tachycardia**)

A saw tooth signal in frequency domain looks like the ECG pattern. We, therefore, choose an arbitrary saw tooth signal to generate ECG waveform. It is then allowed to go through a low pass filter and then a high pass filter. We got the ECG waveform. The next job is sampling, converting and amplifying to detect the QRS peaks from the signal. From the QRS peaks we are calculating the heartbeat (x) by measuring R-R interval. Finally, we are matching the bpm (beats per minute) with the selected threshold to know the driver's state.

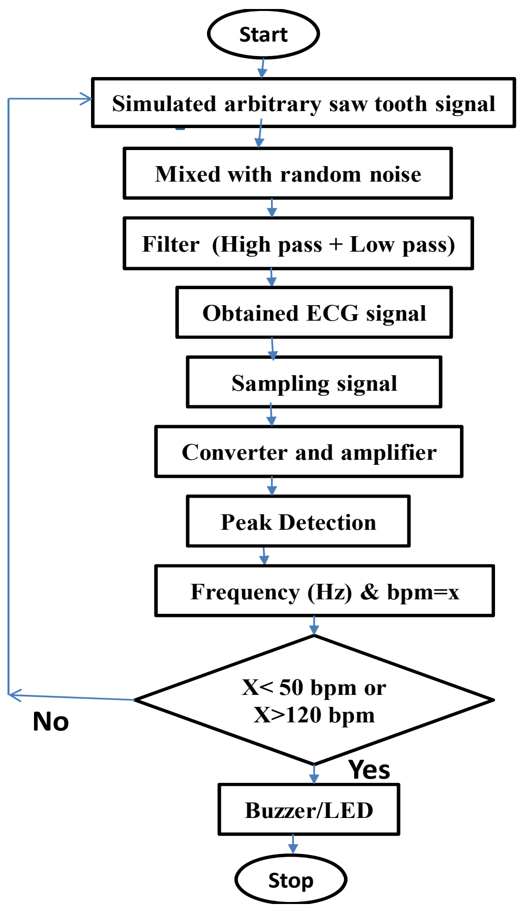

Figure 4.4.1: Flowchart of ECG Sensor

If the threshold matches with the existing bpm of the driver than it resembles that the driver is distracted and unfit for driving. Thus the algorithm will automatically activate a buzzer to alert the driver and also the passengers of the vehicle. But if the threshold doesn't match then it goes back to collect the signal again and repeats the process.

4.5. EEG flowchart

EEG indicates drowsiness with an increase in the frequency spectrum of electrical activity of brainwave bands. EEG is used as a reference indicator for its efficiency in determining drowsy state that defines the mental state of the subject. This is for the fact that the brain gives the exact state of a person. However, EEG result can fluctuate due to other issues faced by the person.

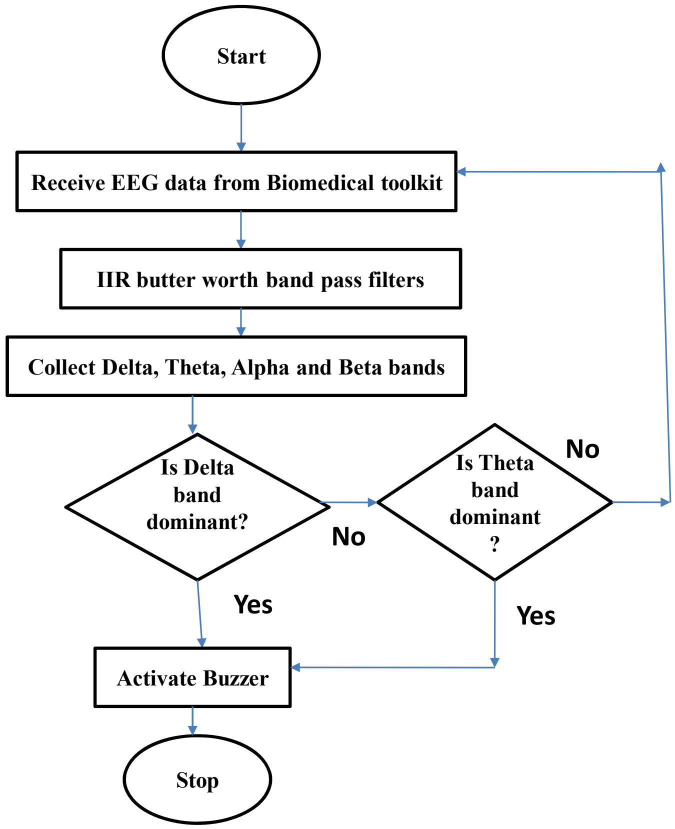

Figure 4.5.1: Flowchart of EEG Sensor

In our simulation work, we have generated the EEG signal from the biomedical toolkit in LabVIEW. Afterwards, we pass the data obtained from the signal through IIR Butter worth band pass signal with different frequency ranges. This gives us the Delta, Theta, Alpha and Beta bands. Once we get the bands, we check which bands are most dominant. Delta and Theta band domination represents that the driver is distracted and unfit for driving. So, in that case, the algorithm automatically activates a buzzer to buzz and corresponding LED to glow. The table below gives a detail description of the bands.

Table 4.5.1: EEG Brainwave description [91]

No.	Brainwave Type	Frequency Range	Mental State and conditions
1	Delta, δ	.5 - 3Hz	Deep dreamless sleep
2	Theta, Θ	4 - 7Hz	Fantasy, imaginary dream
3	Alpha, α	8 - 12Hz	Relaxed but not drowsy
4	Low Beta, β	13 - 15Hz	Formerly SMR
5	Midrange Beta, β	16 - 20Hz	Thinking, aware of self & surroundings
6	High Beta, β	21 - 30Hz	Alertness, agitation
7	Gamma	30 - 100Hz	Motor Functions, higher mental activity

4.6. Combined Flowchart

Our whole work is separated into three parts. The first part is the alcohol part which has been simulated in Proteus with the available MQ3 sensor library. Whereas the second and the third part for the ECG (Distracted), ECG (drowsy) and EEG (drowsy) signals combined is done in LabVIEW. These combined inputs will help the microcontroller give us a more accurate result to detect the driver's state. The working procedure of the alcohol part is the same as Figure 4.3.1 and the second part which determines if there is any heart problem, which happens for heartbeat greater than 120 bpm. Here, we are glowing a Blue LED to indicate a distracted state. The third part of our work which determines the drowsy state of the driver is described in the flowchart below.

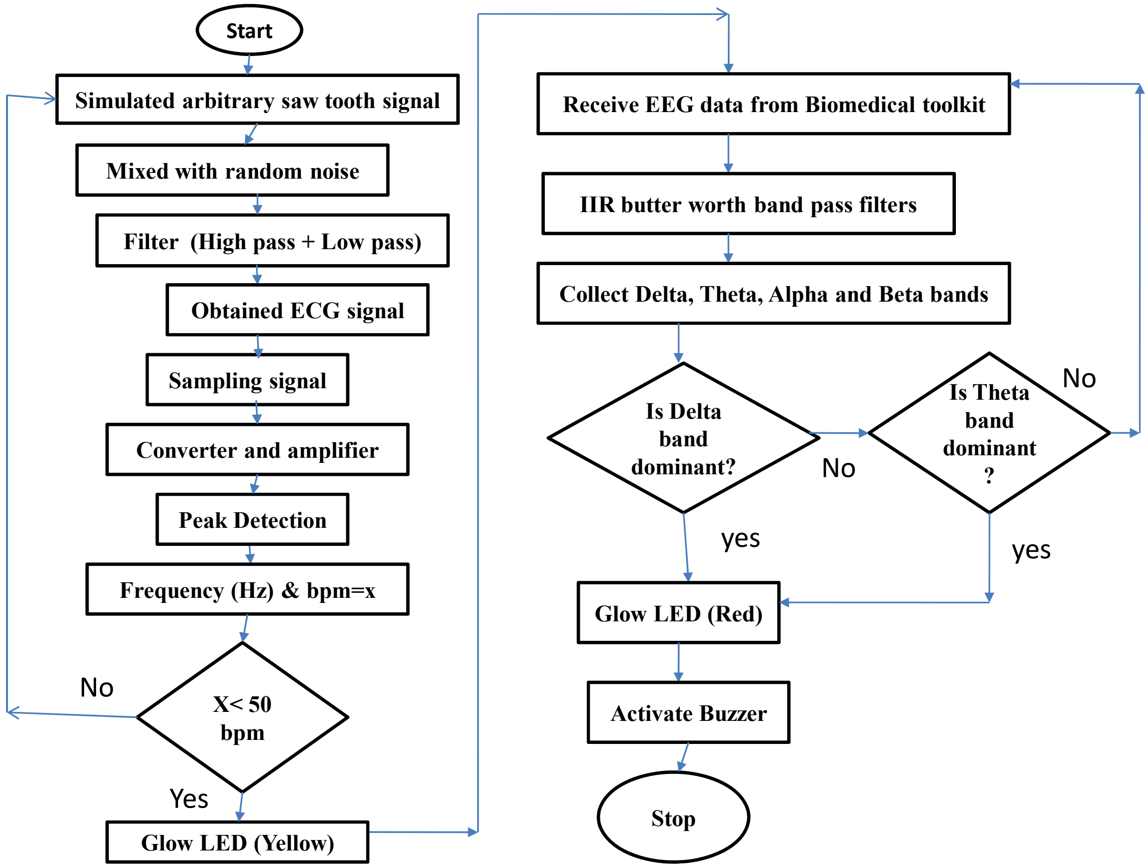

Figure 4.6.1: Flowchart of ECG and EEG signals Combined

The acquisition of ECG signal from a sawtooth signal and processing of it in LabVIEW to obtain the QRS peaks is already described. Then, by calculation from the R-R peaks we get the frequency and bpm(x). We verify whether the heart rate is below 50 bpm, and if so, then the algorithm glows a Yellow LED automatically to indicate that the driver is drowsy from of ECG signal. The next part is acquisition of the EEG signal and processing of it. We read an .edf (European Data Format) file taken from physio net and filter it through an IIR band pass filter and collect the different bands. Here we verify whether Delta or Theta band is dominant as both represent a drowsy/sleepy state. So if, the obtained values from the EEG signal indicate a drowsy/sleepy state then a Red LED glows. Lastly, we activate a buzzer to alert the driver when it is confirmed that the driver is drowsy from the combined inputs. The whole simulation of this proposed method is done using the LabVIEW.

4.7. Thresholds

Human's mental and physical state can be determined using different body sensors or parameters. In our case, we are using an Alcohol sensor to detect if the driver is drunk or not. Furthermore we used ECG sensor to detect only the subject's heart rate for determining if he is drowsy or distracted [92]. ECG has other features too but for simplicity we are only considering the heart rate in our case. Finally, we are using an EEG sensor to determine the driver's state by measuring the brainwave bands. Table 4.7.1 gives a clear idea about the possible states obtained from the sensor used.

Table 4.7.1: Driver's Possible States

No.	**Details**			
	Sensor Name	**Parameters**		**Mental State and conditions**
1	MQ3 Alcohol Sensor	Less than 800 ppm		Normal
		Equal or more than 800 ppm		Drunk
2	ECG Sensor	Less than 50 bpm		Abnormal (**Bradycardia**)
		Around 60 to 100 bpm		Normal
		More than 120 bpm		Abnormal (**Tachycardia**)
3	EEG Sensor	Brainwave Type	Frequency Range	
		Delta, δ	.5 - 3Hz	Deep sleep
		Theta, ϴ	4 - 8Hz	Drowsy or sleepy
		Alpha, α	8 - 13Hz	Relaxed
		Low Beta, β	13 - 15Hz	Formerly SMR
		Midrange Beta,	16 - 20Hz	Thinking, aware of self

		β		& surroundings
		High Beta, β	21 - 30Hz	Alertness, agitation
		Gamma	30 - 100Hz	Motor Functions, higher mental activity

The most important part of our thesis was to select the appropriate thresholds so that our algorithm gives us the required data perfectly. From our research work, we came to decide the following thresholds for the individual sensors. We chose 800 ppm for alcohol concentration as there is legal limit up to 800 ppm. Again a normal person's heart rate can vary around 60 to 100bpm. So we took 50 bpm as the lower threshold and 120 bpm as the upper threshold for detecting the subject's state. A detailed description of the selected thresholds and the corresponding driver's state is mentioned on the Table 4.7.2 ([93], [94] and [95]).

Table 4.7.2: Selected Thresholds

No.	**Details**		
	Sensor Name	**Threshold**	**Description**
1	MQ3 Alcohol Sensor	Greater or equal to 800 ppm	The Driver is drunk and not fit to drive.
2	ECG Sensor	Less than 50 bpm or more than 120 bpm	Abnormal heart rate. Therefore the Driver is distracted and not fit to drive.
3	EEG Sensor	Dominant Delta or Theta band	The Driver is either in sleepy or dreamy stage. Therefore, the Driver is careless and not fit to drive.

4.8. Output Decision

We have used different sensors to determine different sates of a driver to ensure safety avoiding fatal and non-fatal accidents. In order to maintain safety, we need to decide what to do with the obtained sensor values. Once a driver is detected to be drunk, drowsy or distracted we have to decide the next step to ensure safety of the driver and the passengers. Thus the importance of the action taken is beyond comparison. We have to glow a LED where it requires a visual alertness and we have to activate a buzzer whenever it needs to alert the driver by sound. For example, when a driver is drowsy he needs to be alerted by using a buzzer and not a LED. Again, for emergency cases the emergency unit must be informed through VANET communication. The Table 4.8.1 describes the corresponding decisions for different states of the driver.

Table 4.8.1: Output Decisions

No.	**Details**		
	Sensor Name	**Drivers State**	**Output Decisions**
1	MQ3 Alcohol Sensor	Sober (ppm < 750)	Glow Green LED LCD message: "Driver is sober "
		Drunk but in legal limit (750 < ppm <= 800)	Glow Yellow LED LCD message: "Alcohol detected!"
		Fully Drunk (ppm > 800)	Glow Red LED and active Buzzer. If the vehicle is not stopped the Emergency unit is informed automatically. LCD message: "Driver is Drunk!"

2	ECG Sensor	Drowsy (bpm< 50)	Glow Red LED
		Arrhythmia (bpm> 120)	Glow Orange LED
3	EEG Sensor	Sleepy (Dominant Delta)	Glow Red LED and actives Buzzer in the combined part.
		Dreamy (Dominant Theta)	Glow Red LED
4	ECG + EEG combined	Drowsy (bpm< 50) + Sleepy/ Dreamy (Dominant Delta/Theta)	Glow Red LED and active a buzzer

4.9. Conclusion

This chapter describes the working procedure and the algorithms used for our work. Our work is divided in two parts, Alcohol detection part and the ECG-EEG combined part respectively. From these two parts we are taking three inputs. First input is from the Alcohol sensor in ppm. Second one is from the ECG part if heart rate is above 120 bpm. Finally, the third input is the combined input from ECG, when heart rate is below 50 bpm and EEG, when Delta/Theta band is dominant. These inputs have selective outputs to alert a distracted driver. The outputs for definite inputs are described in the chapter 4.8.

CHAPTER 5

SIMULATION AND DATA COLLECTION

5.1 Introduction

In our thesis work, we simulated using MQ-3 gas sensor for alcohol detection which is connected to a microcontroller (Arduino Uno) inbuilt in Proteus and for the generation and feature extraction of both the bioelectric signals we preferred LabVIEW software. Along with displaying data, state of the driver in the LCD display in case of alcohol detection and different states for both ECG and EEG signals in the window of LabVIEW software, we collected data and arranged them sequentially to interpret the exact state of the driver. For alcohol detection part, a threshold limit of 800ppm is incorporated into our code and for drowsiness detection from ECG, the Heart rate less than 50 bpm and theta/delta band for EEG have been considered as the standards.

5.2. Alcohol Sensor Simulation

5.2.1. Introduction

The whole simulation work is done in Proteus 8 software. A variable resistance (Potentiometer) is connected in series with the MQ3 gas sensor and voltage across the resistance changes with the change of this resistance. When the driver exhales, the highly sensitive MQ-3 sensors to alcohol, the conductivity of which goes up with the rise of alcohol content, analyzes his breathe and the system provides the information about the amount of alcohol intoxication and the state of the driver in the LCD connected in the simulation circuit if the driver is drunk.

5.2.2. The Circuit-Diagram and Explanation

The following circuit diagram (Figure 5.2.2.1) shows the simulated circuit for measuring the amount of alcohol intoxication of the subject. The analog voltage across the resistance with MQ-3 sensor is fed to the Arduino Uno for ADC. In the output side of the microcontroller, three LEDs of different colors, Green, Yellow and Red are connected to indicate sober state, drunken but not beyond the allowed limit and fully drunken states respectively. An LCD display at the output displays continuously the alcohol content and state of the subject. A buzzer buzzes at the transition to the drunken state to alarm the driver and the passengers so that action can be taken to stop the vehicle.

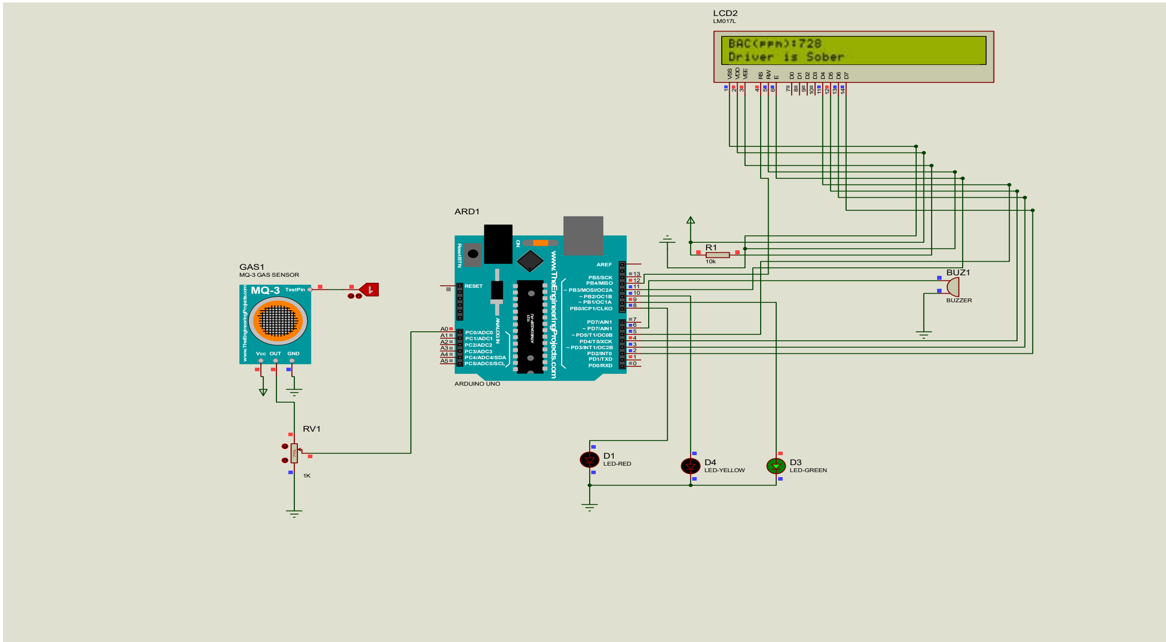

Figure 5.2.2.1: Simulation Circuit for Alcohol Detection

The display in the above circuit shows one of our results. Alcohol content found analyzing breathes is 720 ppm which is less than the legal permitted value, hence exhibiting the state of the driver that the Driver is Sober. Green LED glows to indicate this sober state.

If the sensor senses more alcohol content, which is achieved by changing resistance of the potentiometer in the simulation circuit, the displayed result will differ if the alcohol content is found nearly the transitional value. The LCD display in the same simulation circuit below (Figure 5.2.2.2) exhibit a different result showing that the driver is on the brink. The reason is obvious. The sensor found more alcohol content in when the driver exhales. The figure is 779 ppm which is also one of our collected data from our experiment.

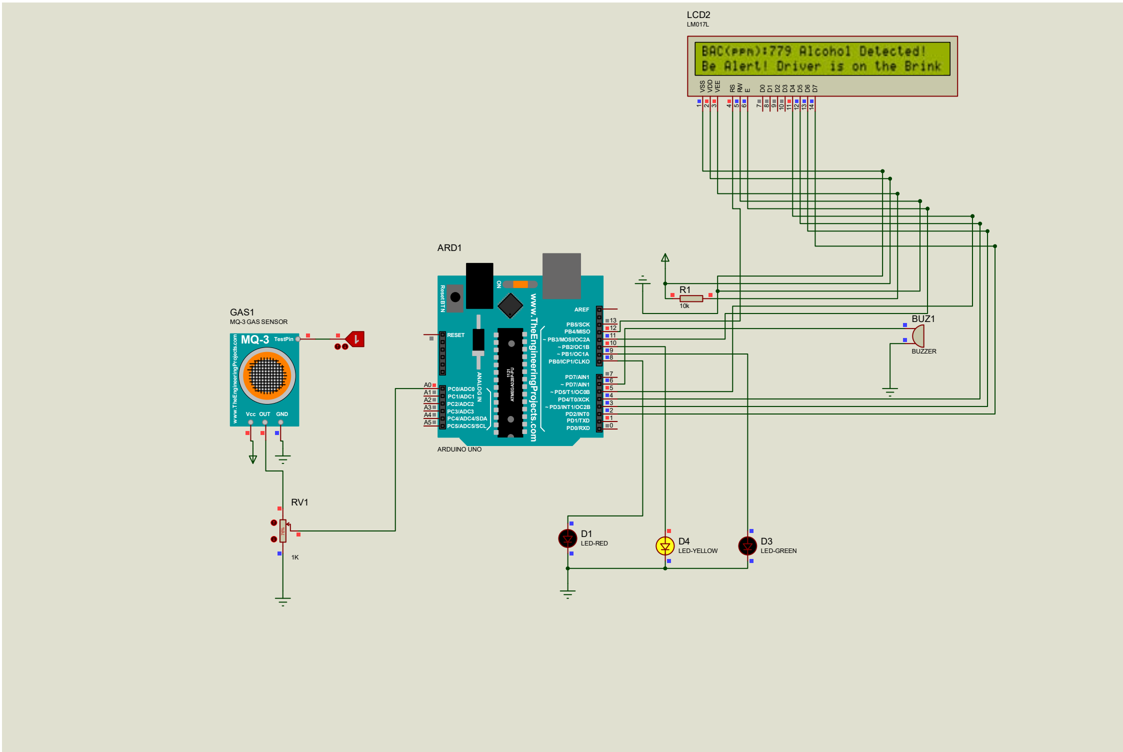

Figure 5.2.2.2: Sensor sensed more Alcohol Content

This time alcohol content is nearly 800ppm indicating about to drunken state according permissible limit. The Yellow LED lights up showing the state of the driver along with displayed result in the LCD display.

The programming code that we developed makes the process continuous. Let us look at the following display.

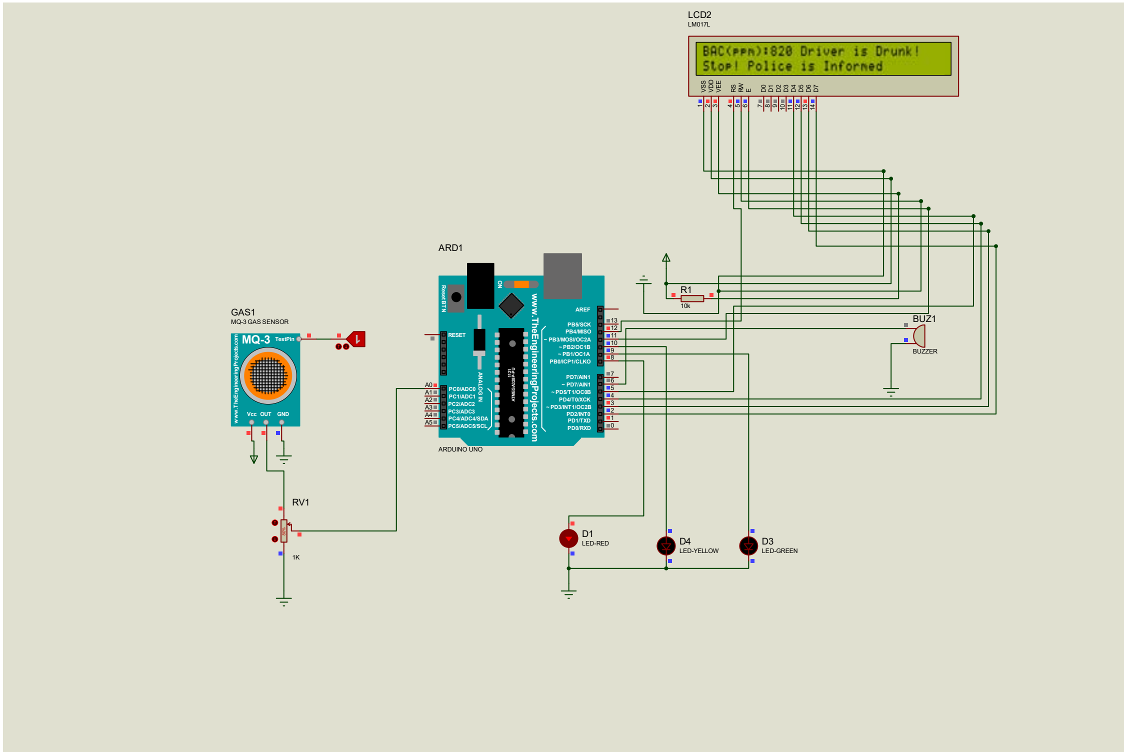

Figure 5.2.2.3: Display shows Drunken State of the Driver

The alcohol content sensed by the sensor is more than the transitional value. Drunken state is detected and a warning message to halt the vehicle as police is informed is displayed. The Red LED will glow and the buzzer starts buzzing.

5.2.3. Simulation data

Each of simulated data in the following table is the outcome of how the sensor in the circuit senses the alcohol content.

Table 5.2.3.1: Data for Alcohol Detection from our Simulation Circuit

No.	Pot. Resistance (%)	Amount of Alcohol (ppm)	State of the Driver
1	61	625	Sober
2	64	656	Sober
3	69	707	Sober
4	73	748	Sober

5	74	758	Alcohol Detected
6	76	779	Alcohol Detected
7	78	799	Alcohol Detected
8	79	810	Fully Drunk
9	80	820	Fully Drunk
10	84	861	Fully Drunk
11	95	974	Fully Drunk

Potentiometer resistance in the simulation circuit controls the amount of alcohol content. Here we took a 1k potentiometer for our simulation and changed the resistance value to get different ppm values. In real time data, MQ-3 gas sensor directly senses amount of alcohol content from the air when the driver exhales. Content of alcohol varies there according to how much alcohol the driver has actually taken. In our simulation circuit, potentiometer resistance serves this purpose. Raising this resistance indicates more amount of alcohol intoxication. We got our data for alcohol content accordingly. In our code we used the conversion factor from BrAC to BAC for converting our result of alcohol content in ppm unit.

5.2.4. Simulation Results Analysis

The states of soberness, drunkenness and in between these two states are in accordance with the threshold value for alcohol amount in the driver's breathing. When the driver is fully drunk, the alcohol content surpasses 800ppm which matches with the standard limit. The figures in chapter 5.2.2 show the results along with the circuit diagram.

5.2.5. Comments

Our result is consistent with the one with real time arrangement. In real time alcohol detection with MQ-3 sensor, the more the alcohol contents the sensor senses, the BrAC record will increase accordingly. In our simulated result, the more voltage the sensor sense, the more BAC will be recorded. There is no significant difference between real time and simulation result.

5.3 ECG Simulation

5.3.1. Introduction

Feature extraction from ECG for either drowsiness or arrhythmia is indeed a challenging task for the complexity of its generation, the detection of QRS complex and the determination of the value of R-R interval. Both the drowsiness state and the arrhythmia state are controlled by the R-R interval of the ECG. Even with the widely used software LabVIEW that we used generate ECG and extract desired feature from it is also a tedious task.

The saw-tooth wave has a strong resemblance in frequency domain with the QRS complex of any pattern of ECG. That gave us a clue to consider an arbitrary saw-tooth wave feeding to LabVIEW mixing additional frequencies with it. After proper filtration, first with high pass then with low pass we arrive at with complete ECG pattern.

5.3.2. The Circuit-Diagram and Explanation

We designed the following circuit in LabVIEW to generate ECG.

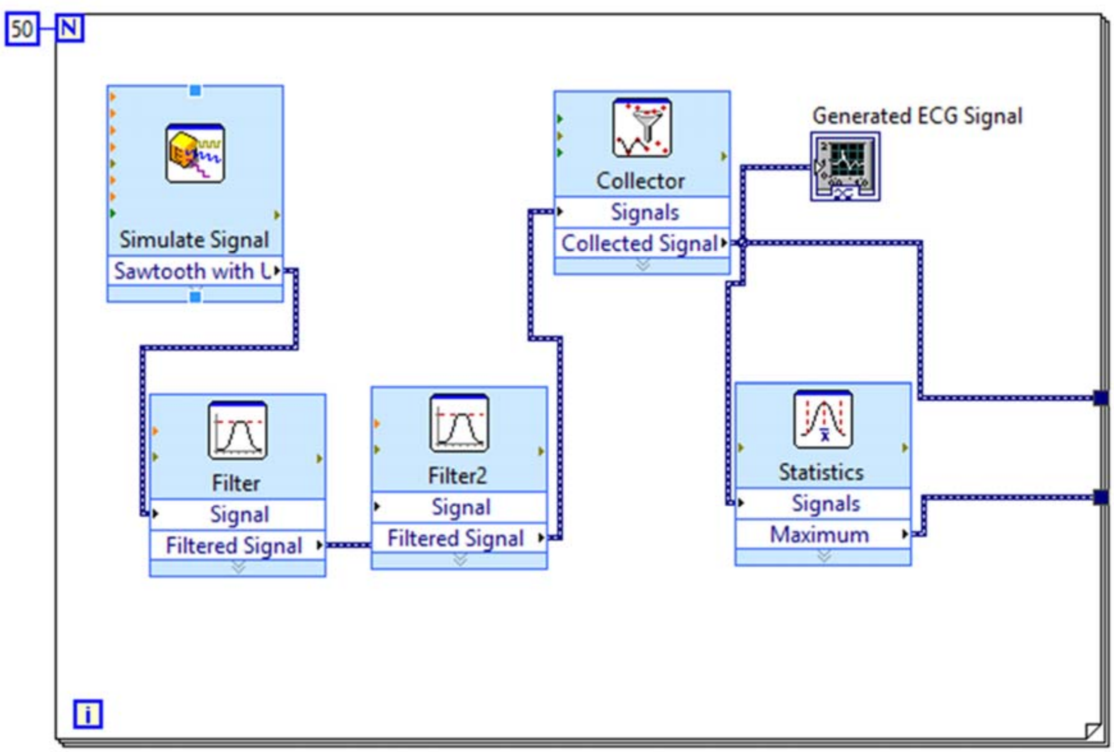

Figure 5.3.2.1: ECG Generation circuit

The idea to configure the above circuit for ECG generation is comprehensible if we understand why the saw-tooth wave is chosen as an arbitrary input and what the purpose of statistics after the signal being processed through first high pass and then low pass filters. In the previous section, we described why the saw-tooth wave is fed at the input.

Low frequency components in ECG have high amplitude and high frequency component of it has low amplitude. Therefore, ECG having the lowest frequency components plays the major role in the observed amplitudes.

In analyzing the circuit, frequency range of different component of ECG will be a helpful. Lowest possible frequency is associated with P wave and that is 0.67Hz. The highest frequency is associated with QRS complex which is 50Hz.

As the arbitrary signal contains frequencies beyond the range of 0.67-50Hz we need to use both low and high pass filters. The cutoff frequency of most widely used high pass filter is 1Hz and that of low pass filter is 40 Hz. Hence, to obtain the signal of ECG we must add one low pass filter and one high pass filter where cut off frequency of low pass filter is higher than that of high pass filter.

The filtered signal is collected and ECG is generated but still it needs to go through some statistical distribution, we can call it Gaussian distribution. It is done to achieve the curve that best fits.

5.3.3. Operational Circuit for Feature Extraction

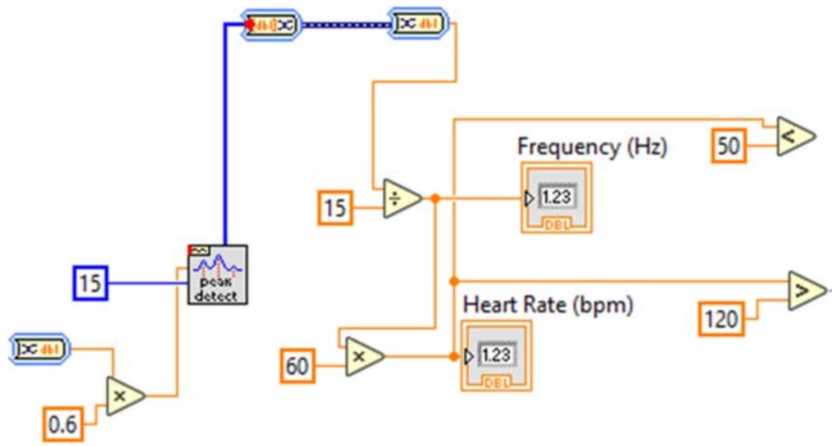

Figure 5.3.3.1: Heart beat calculation circuit from ECG Signal

To detect QRS peak we need to amplify the signal as ECG output amplitude is too low. LabVIEW provides a multiplier to serve this purpose. As soon as the peak is detected, R-R interval is simply the time difference between two peaks. However, to achieve heart rate, we need to go through a further mathematical manipulation. It is simply counting the number of peaks in one minute or 60s. The window is showing the heart rate in bpm. In ECG circuit, we considered two threshold value, one is 50 bpm indicating drowsiness another is 120 bpm referring arrhythmia. Beat per minute or bpm less than 50 refers to Bradycardia and above 120 corresponds to Tachycardia.

5.3.4. Simulation Data

The following table executes the data and the corresponding physical state of the driver that we collected from our simulation circuit operation. Each heart rate corresponds to a frequency and as frequency rises, heart rate increases.

Table 5.3.4.1: ECG Simulation Data

No.	Frequency (Hz)	Heart rate (bpm)	Physical state of the driver
1	0.19	11	Drowsy
2	0.27	16	Drowsy
3	0.34	20	Drowsy
4	0.42	24	Drowsy
5	0.63	36	Drowsy
6	0.74	44	Drowsy
7	0.79	47	Drowsy
8	0.86	52	Normal
9	1.03	60	Normal
10	1.26	75	Normal
11	1.38	82	Normal
12	1.65	99	Normal
13	1.74	104	Normal
14	1.86	112	Normal
15	1.92	115	Normal
16	1.98	118	Normal
17	2.05	123	Arrhythmia
18	2.11	126	Arrhythmia
19	2.23	133	Arrhythmia
20	2.43	145	Arrhythmia
21	2.54	152	Arrhythmia

Heart rate in between 52 bpm and 118 bpm indicates the normal state of the driver because it is within the standard limit. However, as the heart rate goes down, the subject falls into drowsiness and when it exceeds 120 bpm that is heart beats too fast, arrhythmia is detected.

5.3.5. Simulation Results Analysis

The drowsiness, arrhythmia and in between these two states what is known as the normal state of the heart are successfully achieved in our result. Arrhythmia also makes distraction; hence detection of arrhythmia adds an additional advantage for the detection of drowsiness. The figures below give a better idea of our results.

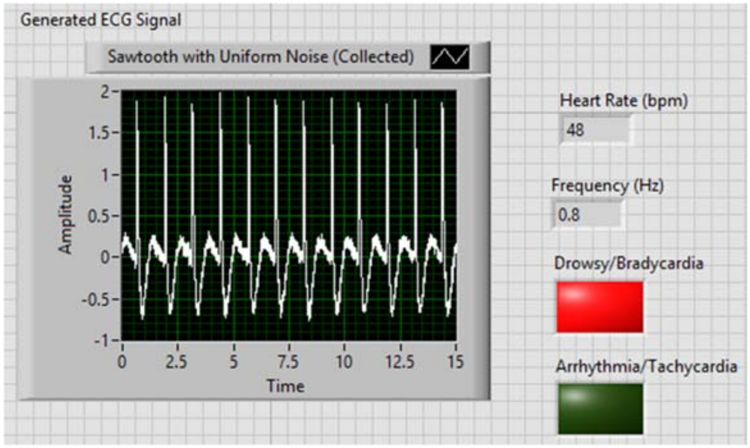

Figure 5.3.5.1: ECG Data indicating Drowsy state

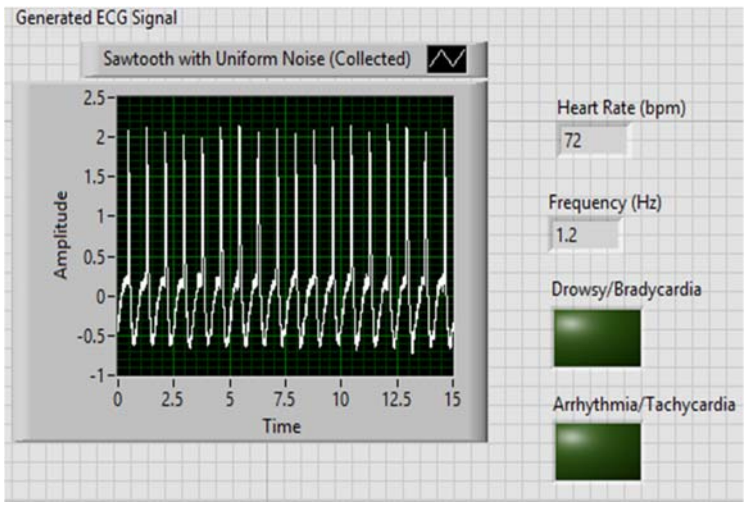

Figure 5.3.5.2: ECG Data indicating Normal state

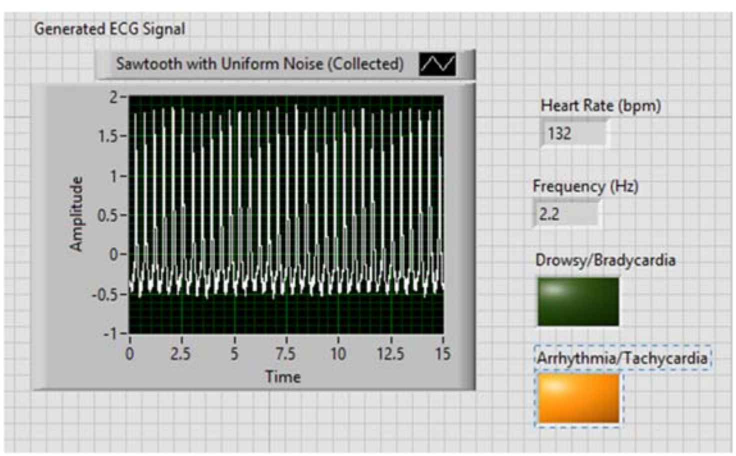

Figure 5.3.5.2: ECG Data indicating Arrhythmia State

5.3.6. Comments

We generated and extracted of our desired feature from ECG using LabVIEW software. Each step of generation matches with the characteristics of each segment of ECG wave. As we told earlier there is a frequency range of ECG wave, we need to reject some frequencies mixed with the input wave. Even in hardware generation of ECG we do the same process to reject noises due to muscle vibration which has a frequency slightly above 40 Hz. Hence low pass filter is essential to reject all frequencies above 40Hz. Again for vibration of electrodes which has a frequency less than 1Hz, a high pass filter should be used. Car should be taken of choosing the cut off frequencies of the filter. Since, saw-tooth wave in frequency domain has the same pattern of spikes as the ECG contains, it is a rational choice to choose it as a base wave for constructing ECG in LabVIEW [96].

5.4 EEG Simulation

5.4.1 Introduction

EEG records the neuronal electrical activity by noninvasive electrodes at different position on the scalp. We have simulated EEG signal in Lab View using biomedical toolkit. The LabVIEW biomedical toolkit provides the application of bio-signal including tools which can be used for accomplishing, preprocessing and analyzing bioelectric signals. The biomedical toolkit needs to be installed externally with LabVIEW to provide signals.

5.4.2 Circuit Diagram and Explanation

A set of raw EEG data is taken from the site physionet.org as .edf file to feed at the input of the biomedical toolkit in LabVIEW software for analyzing and identifying the different features of EEG signals. Simulated EEG signal contains various frequency bands such as Delta, Theta, Alpha and Beta frequency band. Each of these frequency wavebands determines different electrical activities of neurons indicating different physical state.

5.4.3. Operational Circuits for Feature Extraction

An .edf file containing EEG raw data is fed at the input of the Biomedical Toolkit where raw EEG data is incorporated in the file from the physionet.org. The raw EEG signal contains data from 32 neuronal nodes that needs to be filtered. Through this filtering process the four principal bands of EEG signal are achieved that significantly indicate four different physiological state of the subject. As we told earlier, a single EEG signal contains all form frequency bands, but identified with the most dominant band. The band with highest amplitude is considered as dominant.

EEG signal is filtered in IIR butter worth band pass filter as it contains infinite number of impulses. This filter has a strong capability to show nonlinear phase response. In addition it serves as a good bandpass for its better responsively to frequency. The filter is set with different cut off frequencies (low and high) according to the output requirement. To get delta signal, lower cut off frequency of.5 Hz and upper cut off frequency of 4 Hz was set in the bandpass filter. Similarly for Theta brainwave a lower cut off frequency of 4 Hz and an upper cut off frequency 8 Hz are set. Again, for Alpha brainwave band lower cut off frequency of 8 Hz and upper cut off frequency of 13 Hz and lastly, for beta brainwave band a lower cut off frequency of 13 Hz and upper frequency band of 30 Hz is set.

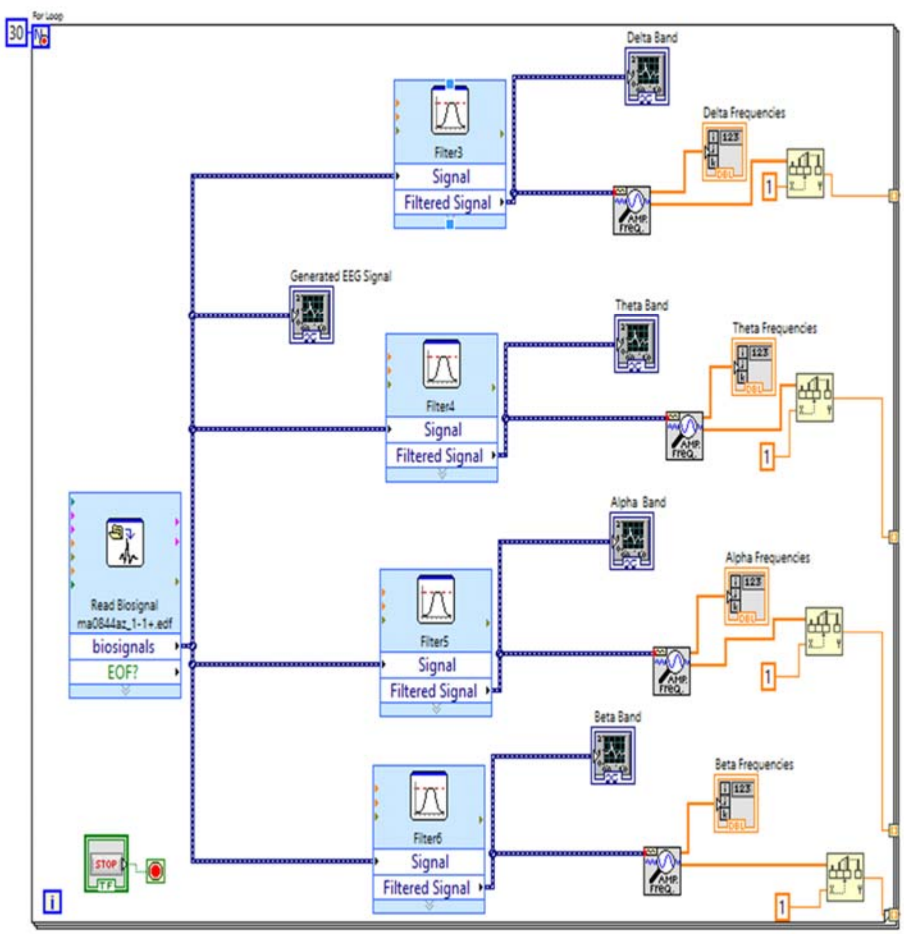

Figure 5.4.3.1: EEG Signal Generation and Filtering Process

The filtered signals allowed to pass another block here its exact frequency and corresponding amplitude are measured. The front panel shows the bands with corresponding frequencies [Figure: 5.4.3.2]. The frequency of each wave band is measured using single tone measurement module. The complete block diagram is built up inside a For loop to execute the program for a definite number of times.

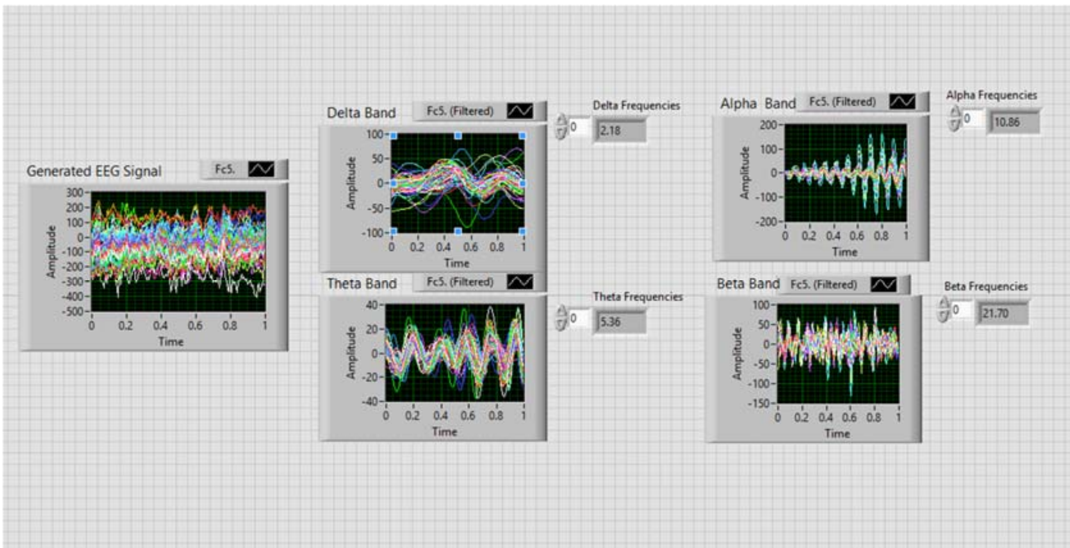

Figure 5.4.3.2: Front Panel Showing Graphical EEG Signal and the Wave Bands

The next step is the task to find the dominant band. In this step the average amplitude of Delta, Theta, Alpha and Beta bands are taken using mean vi module. The mean vi module takes the standard deviation mean of the amplitudes of each wave band, then passes through a built array module which links together multiple elements. The array gathers all the mean amplitudes of the waves and it compares among them. The mean amplitude values are then compared with each other to find the maximum mean among them [97]. This maximum mean to a string displays the calculated result. For example, if the calculated dominant value corresponds to Delta waveband then it displays the sleepy state. Similarly, if the dominant value corresponds to Theta waveband, it displays the drowsy state. If it is Alpha waveband, it displays relaxation state and the Beta wave notifies anxious or active state.

Each band corresponds to a LED which glows automatically if that band is found dominant.

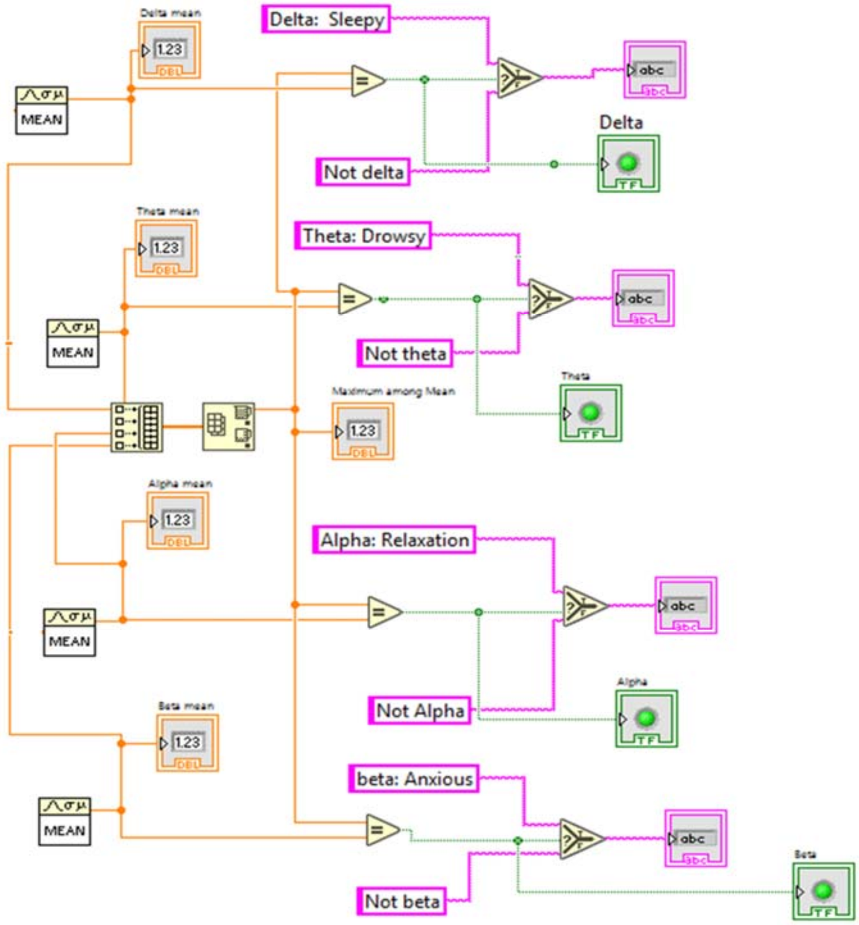

Figure 5.4.3.3: EEG Signal Calculation for Obtaining the Dominant Band

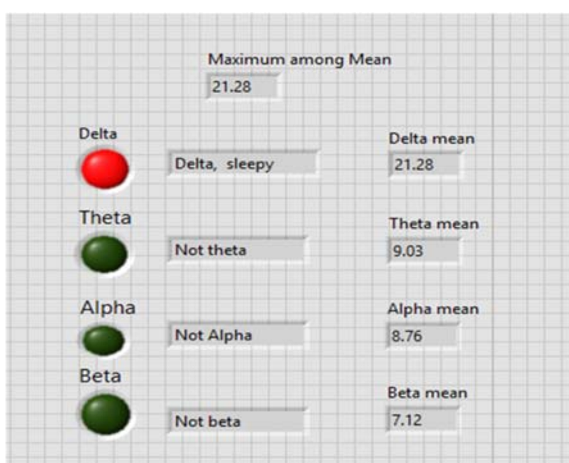

Figure 5.4.3.4: Front Panel showing EEG Signal Outputs

5.4.4. Simulation Data Table

The following table shows our simulated data and the physical state of the subject.

Table 5.4.4.1: EEG Simulation Data

Sample Data	Details				
	Wave band	**Frequency (Hz)**	**Mean Amplitude (mV)**	**Maximum Amplitude mean (mV)**	**Comments**
Sample 1	Delta	2.27	33.20	33.20	Delta dominant
	Theta	5.30	15.61		
	Alpha	11.24	18.10		
	Beta	16.24	16.45		
Sample 2	Delta	2.65	20.05	20.05	Delta dominant
	Theta	5.89	12.22		
	Alpha	10.56	13.46		
	Beta	15.50	11.02		
Sample 3	Delta	2.54	4.92	7.43	Alpha dominant
	Theta	3.90	3.73		
	Alpha	10.33	7.43		
	Beta	25.67	6.02		
Sample 4	Delta	1.85	12.44	12.44	Delta dominant
	Theta	3.96	4.79		
	Alpha	10.66	3.87		
	Beta	25.39	2.02		
Sample 5	Delta	2.03	5.73	7.30	Beta dominant
	Theta	5.83	4.24		
	Alpha	11.36	5.30		
	Beta	21.36	7.30		
	Delta	1.41	27.59		

Sample 6	Theta	4.48	30.48	30.48	Theta dominant
	Alpha	8.52	14.93		
	Beta	20.57	11.28		
Sample 7	Delta	1.71	12.28	12.32	Alpha dominant
	Theta	5.13	7.34		
	Alpha	8.86	12.32		
	Beta	28.58	7.56		
Sample 8	Delta	2.73	4.94	7.57	Beta dominant
	Theta	5.58	4.13		
	Alpha	11.49	4.98		
	Beta	22.36	7.57		
Sample 9	Delta	2.42	21.28	21.28	Delta dominant
	Theta	6.56	9.03		
	Alpha	8.43	8.76		
	Beta	13.68	7.12		
Sample 10	Delta	2.22	4.66	7.55	Beta dominant
	Theta	5.43	4.62		
	Alpha	10.80	6.05		
	Beta	24.23	7.55		

5.4.5. Simulation Data Analysis

In section 5.4.3 we have taken 10 samples. Each sample contains EEG raw data. In every sample, the four principal wave bands Delta, Theta, Alpha and Beta are measured from EEG raw signal and corresponding frequency and amplitude mean value are calculated. Among four of these mean values the maximum mean is obtained which shows the corresponding dominating wave band. For example in Sample 1 Delta, Theta, Alpha and Beta bands have frequencies of 2.27, 5.30, 11.24 and 16.24 Hz and mean values of 33.20, 15.61, 18.10 and 16.45 units respectively. Among four of these means maximum mean denotes to Delta wave band. Thus we conclude to the point the subject is in sleepy state as the Delta band in dominant.

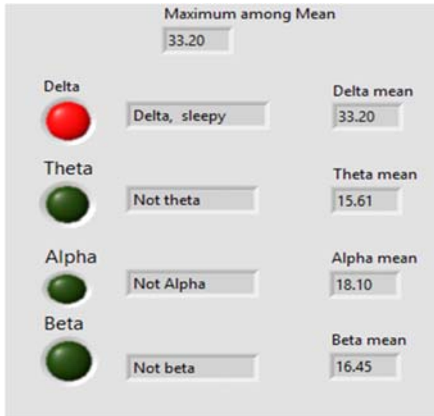

Figure 5.4.5.1: Front Panel shows Sample 1 Output (Delta Band Dominates)

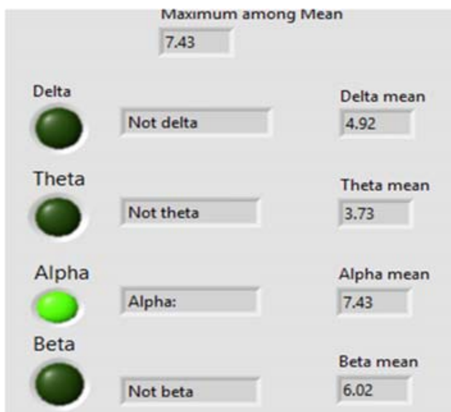

Figure 5.4.5.2: Front Panel shows Sample 3 Output (Alpha Band Dominates)

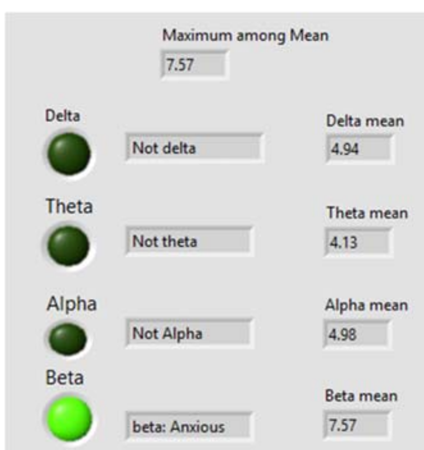

Figure 5.4.5.3: Front Panel shows Sample 8 Output (Beta Band Dominates)

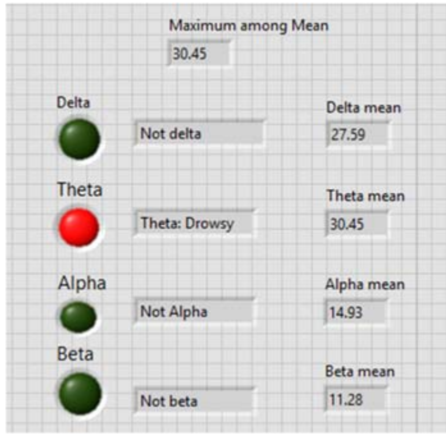

Figure 5.4.5.4: Front Panel shows Sample 6 Output (Theta Band Dominates)

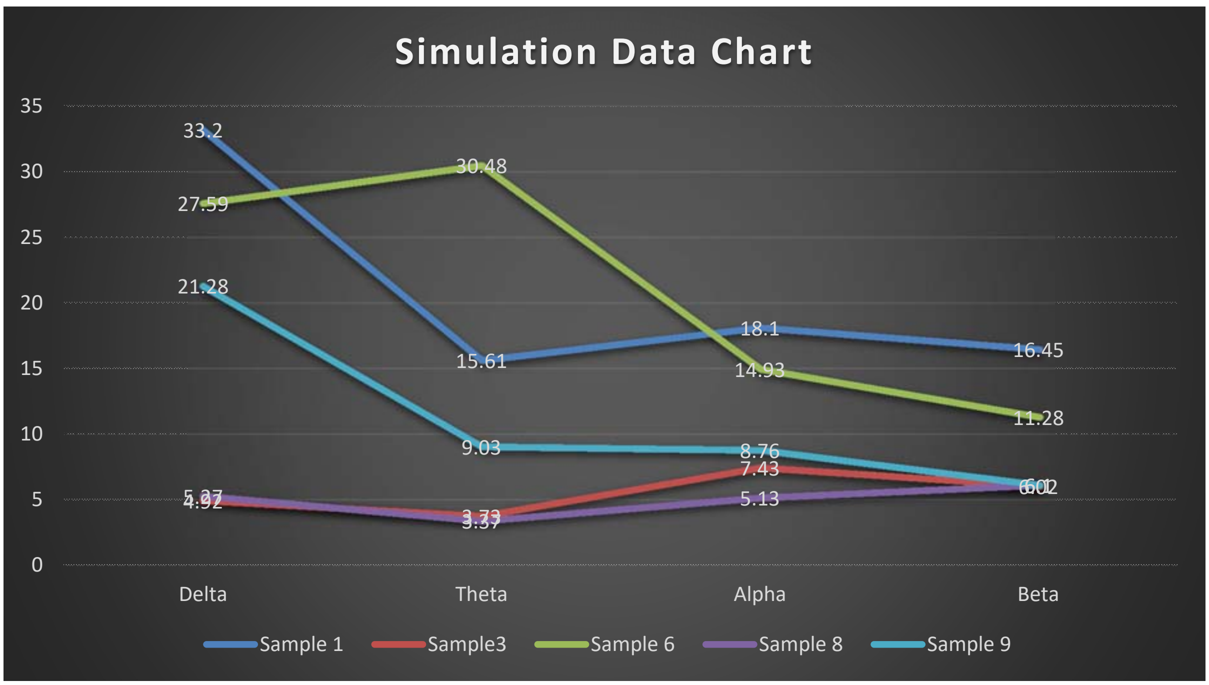

Figure 5.4.5.5: Simulation Data Graphical chart for Different Samples

Figure 5.4.4.5 shows the graphical representation of four wave bands and corresponding mean values for five different samples. Each graphical line represents a sample which contains Delta, Theta, Alpha and Beta wave band and their corresponding mean values.

5.4.6. Comments

The .edf file collected from the physionet gives us the raw EEG signal of a subject [98]. The dominant brainwave is calculated from the signal which represents the physiological state of the subject. EEG results are considered as the most accurate and authentic for determining physiological states.

5.5 ECG and EEG Combined simulation

5.5.1 Introduction

Heart is the first organ formed in the womb in the embryonic stage. Brain formed later and heart fist fed the brain by pumping blood to it. This natural occurrence introduces a situation where we need to ponder whether ECG and EEG signals can be sampled together. We can conclusively state that the brain signal cannot be the causation for the heart to generate ECG. Even we have seen in chapter 3 that heart generates its own bioelectric signal as its different nodes are self- excitatory.

The coherence between EEG and ECG that we only need is about the drowsiness state that both signals provide separately. We have seen in the analysis of cardiac signal that physical state varies with the obtained heart rate and when the heart rate goes below 50bpm, the subject turns to drowsy. For the drowsiness state and the sleepy state, we considered theta (4-8Hz) and delta (0.5-4Hz) waves.

Since both EEG and ECG give the state for drowsiness, we can go for correlation analysis between the data samples of both signals.

In chapter 3 we mentioned that a group of researchers recently worked on this issue and have found a convincible result to combine both signals together in the drowsiness and sleepy state. We got a significant negative correlation coefficient $r = -0.41$between ECG and EEG in the drowsiness states. This result made us more confirm that our idea to fuse them has a valid context.

The correlation result suggests that if heart beat goes low, delta power goes high. Lower bpm with heart has a significant correlation with theta-delta state of EEG which match with the result we got from our combined result of ECG and EEG. If both ECG and EEG confirm the drowsy state of the driver, we can decisively conclude that the subject is certainly drowsy.

5.5.2. Circuit Diagram and Explanation

In section 5.3 the average heart rate is calculated from the QRS peak. Whether the driver is sleepy or distracted can be determined by the subject's heart rate (bpm). If the heart rate is found to be less than 50 bpm then the driver is in sleepy or drowsy state and if the heart rate is more than 120 bpm then the driver is distracted or we can say he is facing Arrhythmia. The normal heart rate of an adult human being is in between 60 to 100 bpm. In section 5.4 four types of wave bands Delta, Theta, Alpha and Beta is measured from EEG signal. Among these wave bands Delta and Theta band is related to drowsy or sleepy state. So the purpose of this section is to combine both EEG and ECG in order to get a confirmed output result. As Delta and Theta bands both are responsible for drowsy or sleepy state so we can say the driver is distracted in either of the cases. Thus a Boolean OR gate is used where Delta and Theta are given as input so that if any of the two is dominant we can get an output from the OR gate.

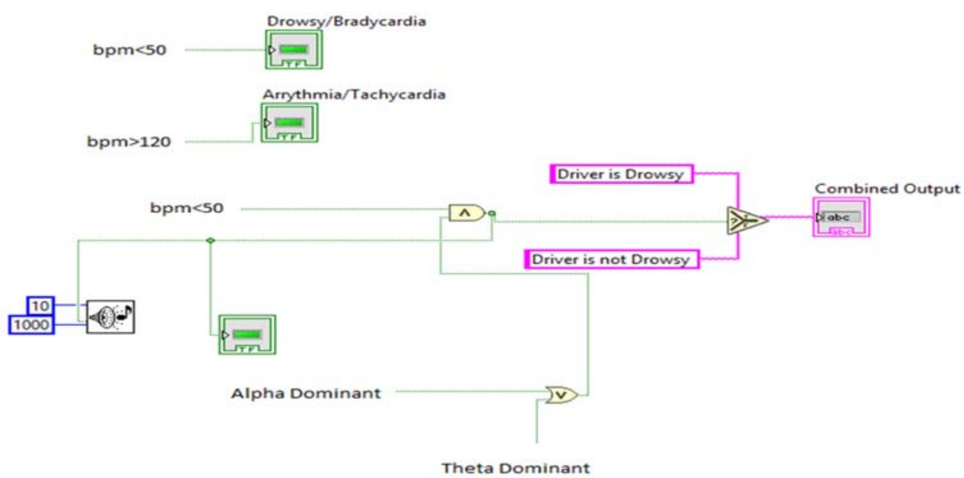

Figure 5.5.2.1: Combination Circuit of EEG and ECG signals

On the other hand from ECG signal we get the heart rate in bpm. The heart rate less than 50 bpm indicates drowsiness. So we want a final confirmed output when EEG and ECG both indicate a same condition. A Boolean AND gate is used where one input comes from the output of OR gate and another input is from calculated heart rate for less than 50 bpm. When both EEG and ECG detect the same condition then the final output shows that the driver is drowsy and a Red LED glows alongside a buzzer.

Figure 5.5.2.2: Front Panel Showing Confirmed Final Combined Output

The figure 5.5.2.2 shows for a lower heart rate (40 bpm) from ECG and dominant Delta wave band we get a combined output result. It confirms us that the driver is drowsy or distracted and is not fit to drive.

5.5.3. Simulation Data Table

Similar to the data collection for ECG and EEG signals, we have collected data for the combination of the two. We get the state of the subject from ECG and EEG separately and the combine the results through a AND gate to get a confirmed result. If the two results don't indicate a same condition than our final output will not come but there will be individual outputs.

Table 5.5.3.1: Combined Simulation Data

Cases	Details			
	Bioelectric signals	**Physical states**	**Separate outputs**	**Combined output**
Case 1	ECG	Drowsy	Drowsy	Drowsy
		Arrhythmia		
	EEG	Sleepy	Drowsy	
		Drowsy		

		Relaxed		
		Anxious		
Case 2	ECG	Drowsy	Drowsy	Drowsy
		Arrhythmia		
	EEG	Sleepy	Sleepy	
		Drowsy		
		Relaxed		
		Anxious		
Case 3	ECG	Drowsy	Arrhythmia	Not Drowsy but Distracted
		Arrhythmia		
	EEG	Sleepy	Drowsy	
		Drowsy		
		Relaxed		
		Anxious		
Case 4	ECG	Drowsy	Arrhythmia	Not Drowsy but Distracted
		Arrhythmia		
	EEG	Sleepy	Sleepy	
		Drowsy		
		Relaxed		
		Anxious		
Case 5	ECG	Drowsy	Drowsy	Not Drowsy but Distracted
		Arrhythmia		
	EEG	Sleepy	Relaxed	
		Drowsy		
		Relaxed		
		Anxious		
Case 6	ECG	Drowsy	Arrhythmia	Not Drowsy but Distracted
		Arrhythmia		
	EEG	Sleepy	Anxious	
		Drowsy		
		Relaxed		

		Anxious		

5.5.4. Simulation Data Analysis

In section 5.5.3 six cases are developed where two bio-signals EEG and ECG determines various physiological states. EEG and ECG both signal gives separate outputs. If both separate outputs show same condition then the final result is determined. For case 1 and case 2 EEG and ECG both signal indicates drowsy or sleepy states. Therefore the combined result confirms that the driver is drowsy. But for other cases two bioelectric signals are giving different physiological states in separate outputs so combined result is driver is not drowsy but if the driver is distracted than it will be shown from the individual outputs.

Figure 5.5.4.1: Front Panel giving a Confirmed Output by Combination of Signals

Figure 5.5.4.1shows ECG and EEG both determine drowsiness so the combined output confirming that the driver is drowsy. It activates a buzzer and a Red LED to alert the driver and passengers.

Figure 5.5.4.2: Front Panel showing the Driver is distracted

Figure 5.5.4.2 shows that ECG determines Arrhythmia and EEG determines drowsiness. The two signals indicate two different physiological states therefore the combined output result is driver is not drowsy but distracted. Thus no buzzer is activated in this case.

5.5.5. Comments

As we get individual outputs from ECG and EEG determining the physiological states of the subject, we combine the results passing through a logical AND gate. We know that a logical AND works only either the cases are 1 or the cases are 0. So a 1-1 in the input gives a 1 at the output, indicating the driver is drowsy and for an opposite case it indicates with a message that the driver is not drowsy.

CHAPTER 6

CONCLUSION

6.1 Introduction

This chapter is the final touch of our thesis but not the end of this rigorous task. It will begin with a synopsis of our whole work with a hope for the future progress exploring and adding something technologically advanced with our design for the continuation of this work. Hence, the temporal end of our tedious task will then start for a new beginning.

6.2 Summary

The main motive of our thesis is to make the world a better and safer place for the human beings by designing an effective and improved system for the detection of distracted driver as the road accidents due to distracted driving snatch away millions of life and makes million others maimed for the whole life. The ubiquity of road accidents makes them a perennial problem from which we need a feasible way out. This has moved us choosing this topic as our undergrad thesis task.

To detect the drunk driver while driving we considered MQ-3 Alcohol sensor in our simulation world. The sensor analyzes the breathe of the driver when he exhales, measures the alcohol contents and as soon as it detects optimum level of allowed alcohol, the system automatically activate a buzzer to buzz and a LED to glow for the comprehension of the alarming situation. Drunk state will be automatically detected. In our simulation world, we used Proteus 8 Professional software. However, this is a tiny part of our task.

Another reason for the distraction is that the driver becomes drowsy or falls asleep while driving. Since drowsiness is a physical state related with the change of cardiac and brain activity, we sought for extracting the feature for drowsiness, arrhythmia from cardiac signal ECG and brain signal EEG. Extraction of desired features is done with LabVIEW software separately for ECG and EEG. However, at this stage, to combine them we needed to know whether signals generate at the heart and signals generated at the brain are at all correlated. When our research gave an affirmatory answer regarding the correlation between ECG and EEG signal, we combined them with the same software.

By combining two bioelectric signals, drowsiness is detected with more confirmation. ECG and EEG separately detect drowsiness of the subject. Our circuit simulation worked that way.

In our combined circuit for ECG and EEG the common feature strengthened the confirmation that the individual signals contributed.

6.3. Future Scopes

Myriad scopes are open to extend our work in connection with communication which is obviously a dire necessity. Communicating the current states of the driver to desired places will add an excellent development of our thesis work. Other than communication part, there remains some development work left with the system for future improvement.

6.3.1. Interfacing LabVIEW and Proteus Simulation and Hardware Implementation

In our developed system we have worked on the simulation process where we have combined ECG and EEG for drowsiness detection in LabVIEW and alcohol sensor for detection of drunk state in Proteus. It can be implemented in hardware where all three sensors will be embedded in the vehicle and detect the driver's physical state.

For hardware implementation we can use a single microcontroller for all the three sensors using Arduino toolkit of LabVIEW. With the help of LabVIEW Interface for Arduino, we can quickly and easily create graphical user interfaces for virtual component that is compatible with the Arduino microcontroller and send signal or messages directly to Arduino [99].

When signal from all three sensors are fed into a single Arduino device, detection of distraction would be more confirmatory and if any of the state drowsy or drunk is detected we can set the buzzer/LED on.

Serial communication between LabVIEW and Proteus to interface all the sensors together may be an efficient choice to make system usable. Interfacing of LabVIEW and Proteus is possible with the help of NI-VISA function in LABVIEW. With the help of NI-VISA we can easily communicate using instrumentation buses like USB, Ethernet, GPIB, Serial communication etc. Communicating with a variety of instruments is possible and quite easy using NI-VISA because it requires easy commands [100]. That's how we can create a bridge among three sensors in our simulation.

Besides implementing our system in hardware and creating a connection among the three sensors that we have worked on, in future we can also work on incorporating more bio-sensors to detect different types of physiological measures from the driver and inform the physical and mental state of the driver.

6.3.2. Incorporating Alcohol Sensor with ECG

Based on the assessment taken by the LMU University Hospital Munich Department of Cardiology, we have found that there is connection between BAC and bpm. An increasing breath alcohol concentration (BAC) is significantly associated with sinus tachycardia that refers to bpm more than 100, what we term as arrhythmia [101]. They have also stated that the heart rate goes high with the amount of alcohol consumption and high heart rate triggers arrhythmia. So, we can create a relation among the ECG sensor and alcohol sensor as we did for the case of ECG and EEG signals. Incorporation of drunken state with the drowsiness state for ECG may be a good area for future improvement.

6.3.3. Fusion of more Sensors

6.3.3.1. EOG (Electrooculography)

Like EEG and ECG, we can add another bioelectric signal which is EOG (Electrooculography). EOG signal is generated while making eye movement. A research project has been developed in [102] on blink wave form where electrooculogram (EOG) data is used to develop the method of detecting driver's drowsiness.

This eye blink signal is very important in order to detect driver's drowsiness. A normal person's eye blinks spontaneously and the EOG signal has an amplitude of 100 to 400 μV and time duration for about 200 to 400 ms. For long blinks which has time duration more than 500 ms the EOG signal changes. Long blinks are usually found at night driving. When a person becomes sleepy or drowsy, the generated EOG signal reduces and the peak amplitude goes below 100μV [103].

6.3.3.2. EMG (Electromyogram)

Electromyogram is another bioelectric signal that is used in detecting the muscular activity during monotonous driving and muscle fatigue [104]. It is proved by the researchers that, EMG has different variables such as left biceps [LB], right biceps [RB], left forearm flexor (LW), right forearm flexor (RW) and frontal (L) muscle which are used in indicating fatigue of muscle caused while driving [105,106].

6.4. Communication Part

Detection of driver's distraction and drunken state necessitates in adding communication part with our system and that system will be closer to a complete system for our purpose.

Globally accredited vehicular ad-hoc networks (VANET) can be used to bring the distracted driver under vigilance and consequently, it can be a good remedial for reducing number of accidents to a minimum. Implementation of V2V and V2I network can add extra monitoring over the affected vehicle. Moreover, integration of VANET with WBAN and BSN will come in handy to establish a safer road environment in proving safety to the driver and passengers. This communication parts are focused in steps below.

6.4.1. V2V, V2I, RSU and VANET

V2V communication mainly refers to the dynamic wireless communication used by vehicles to pass different sorts of information under the protocols of dedicated short range communication (DSRC). The dedicated short-range communications usually operate around the 5.9 GHz frequency band [107, 108]. Under V2V communication system information as safety messages related to the driver or vehicle, stating the vehicle's current position and its speed, movement, braking status etc. are passed through to other vehicles in order to warn the other vehicle and let other vehicles' aware of the status of other cars moving along on the road. The information is passed to and received from other vehicles moving in the same surroundings. V2V enables to sense the position and status of other vehicle and as a result helps the driver to avoid any kind of possibilities of road accident or hazardous [109].

Similarly, like the V2V communication system, V2I communication also means the wireless communication between vehicle and roadside Infrastructure using the same protocols of DSRC [110]. With the help of V2I communication system, driver can be alerted so that any kind of possible crash or accidents can be avoided. With the help of V2I communication system it is possible to ensure that vehicle in staying in the right lane and alert the driver if the vehicle approaches towards any sort of infrastructure possibility leading towards crash.

RSU refers to communication system under DSRC protocol that is used in communicating between the road side unit (RSU) and the vehicle [111].Road side units are deployed in roads and highways at different interval [112]. With the help of this communication system like V2V and V2I possible road accidents can be avoided. RSU helps in traffic monitoring system and prevents collisions caused by traffic congestion.

In [113], a brief description of VANET is highlighted along with safety measures. VANET (Vehicular Ad hoc Networks) can be referred as computer network on mobile where connections are made between V2V and V2I considering them as mobile nodes in MANET. Under VANET each vehicle communicates with other vehicle using dedicated short-range communications (DSRC) around the 5.9 GHz frequency band [114]. All the vehicles which are within 100 to 300 meters are considered as a node or a router by the VANET and thus connect with them to create a wider range of network communication. As more vehicles join in it creates sort of a mobile internet that connects each of the vehicle and considers them as single node. It also comprised RSU that are deployed in roads and highways at different interval. VANET mainly focuses on three types of communication and they are vehicle to vehicle, vehicle to infrastructure and vehicle to roadside unit. VANET is supported by numerous applications and products like smart phones, laptop etc. and is on increasing state of development.

6.4.2. Integration of BSN and VANET

Nowadays, a lot of research has been going on BSN's (Body Sensor Network). BSN are used to monitor the driver state at certain occurrence. In future, we can incorporate the BSN with VANET (Vehicular Ad hoc Networks) in ensuring traffic safety. VANET has come across as an emerging technology in road safety for future. The use of V2V and V2I communication under VANET enables us to communicate with another vehicle wirelessly in the same zone and warn other vehicles sending the locations, state, speed etc. of the vehicle. With the help of VANET based system drivers can be warned ahead of time and as such any sort of accidents can be avoided as the driver has a better chance to react within the given time. In study [115], exactly this issue has been addressed.

Integration of both BSN and VANET provides an efficient proposed system that can help in reducing the number of road accidents. With the help of BSN, we can determine the physiological state of the driver whether he is drowsy, drunk, under stress or anger, any emotional distress etc. And combining it with VANET provides an opportunity to create a wireless network that allows alerts surrounding vehicles to avoid any sort crash or hazardous.

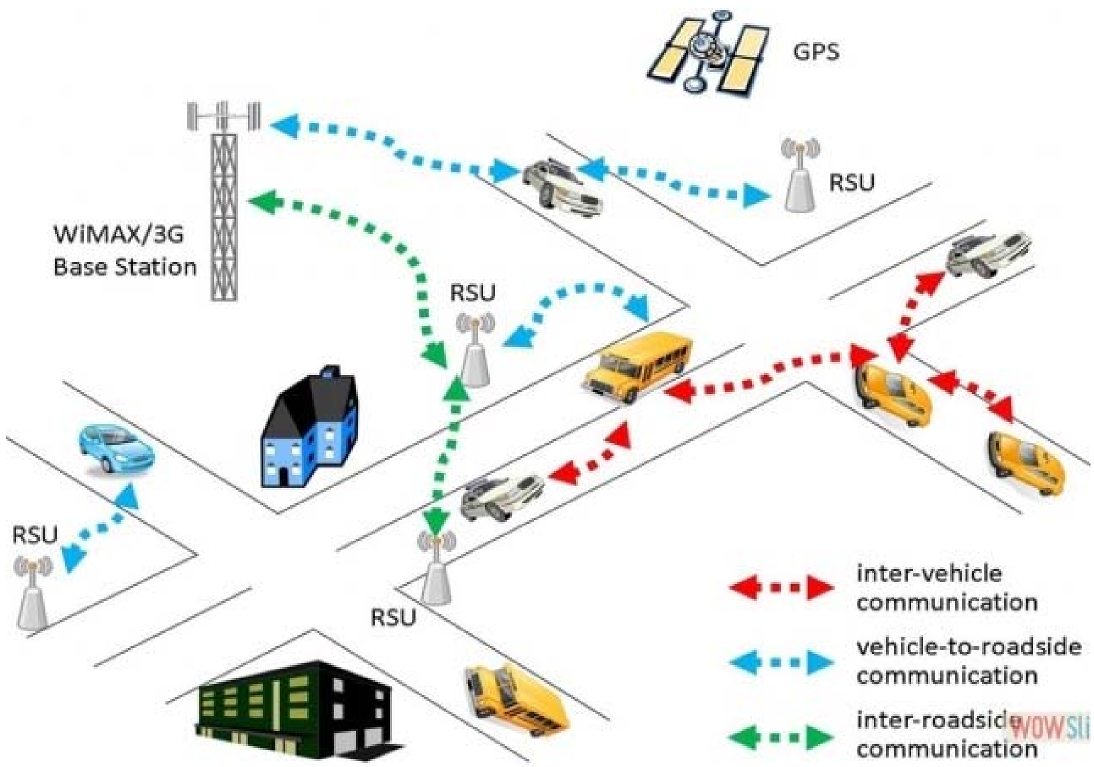

Figure 6.4.2.1: VANET Communication System [116]

Paper [117] also proposed an architecture ensuring safety by combining the BSN and VANET. Using the BSN, we can measure different physical measures related with the driver. We can incorporate bio-sensors like ECG, EEG, EMG, EOG, etc. under the BSN to detect different physical measures of the driver. In our developed system we have worked on three sensor ECG, EEG and Alcohol sensors, in future we can incorporate more sensor as discussed in the upper section and combine all of them to create a BSN network. These sensors will provide us four physiological behavior related to the driver as discussed in [118]. Fusion of different sensors is needed to detect different measures. For detecting the drowsy state fusion of ECG, EEG, EOG, EMG can be done and we have worked on two of them in our project. For detecting drunk driving alcohol sensor is proposed in this paper that we have worked on. For measuring the emotional state like anger or stress of the driver EMG, ECG, EDA, EEG, respiration sensors etc. can be accommodated and mechanisms like SVM (Support vector machines) along with (ANFIS) Adaptive Neuro-Fuzzy Inference system can be used to classify different emotional states.
Monitoring the whole system can be done wirelessly with help of Smartphone, cell phone, tablet, laptop, notebook etc. and after monitoring and evaluating the current state of the driver, resultant state is sent to the OBU (On Board Unit). OBU is built in inside the vehicle

and with the help of it we can communicate with other vehicles or infrastructure using V2V or V2I communication system under VANET. Monitoring station determine the state of the driver after processing and extracting different features and finally evaluating with different thresholds for different physiological state of the driver.

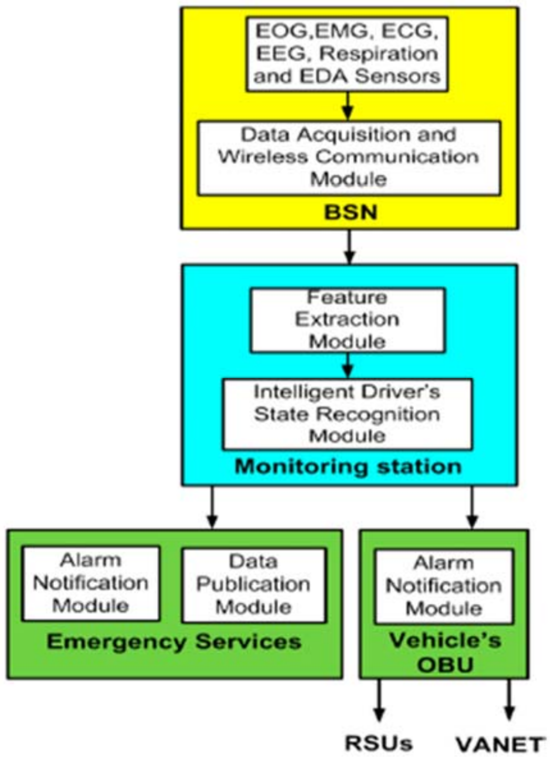

Figure 6.4.2.2: Overall Proposed Scenario[119]

If the monitoring device confirms any of the described four states related with the driver then alarm is buzzed and an emergency message is sent to the OBU (On Board Unit) of the vehicle. What OBU does is, it connects with VANET or RSUs wirelessly and alerts the surrounding vehicles, pedestrians to avoid any kind of hazardous situation or collision that might take place due to the impaired state of the driver. The communication between VANET and OBU is done wirelessly using Bluetooth, GSM module, 4G connection, Wi-Max etc. With the help of VANET the messages are sent to the nearby vehicles and pedestrians using this wireless communication and Emergency unit such as police, traffic control room are notified by the proposed system immediately so that necessary actions can be taken in time in avoiding any sort of collision or road accidents.

The paper in [120], has also proposed about some enforcement points that can be implemented on detection of impaired driving. These can be implemented in future with our proposed model. For different states of the driver different methods have been proposed here. In case of detection of any of the following four states described in [121], alert message can be sent from the OBU to VANET to warn other vehicles running on the road and pedestrians as discussed earlier. If driver refuses to stop on detection of drowsiness or drunken condition then the location of the vehicle can be sent to the nearest police station or traffic police to charge in stopping the vehicle to avoid any hazard or collision.

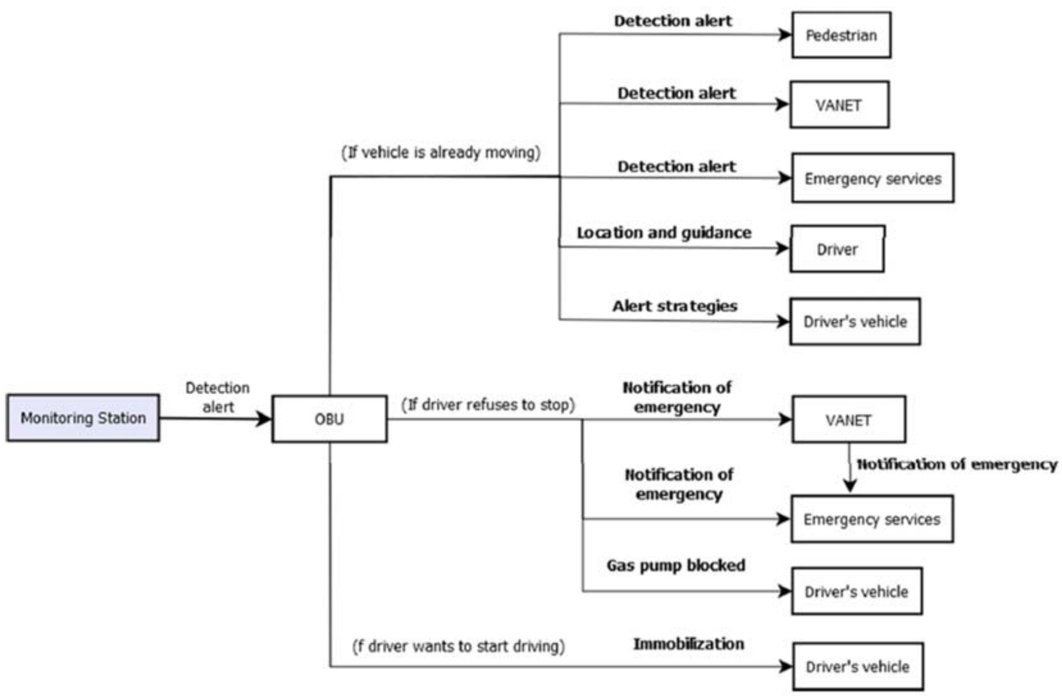

Figure 6.4.2.3: Enforcement points in case of Emergency [122]

Moreover, Immobilization of the vehicle can also be implemented so that the vehicle stops by itself if the driver denies stopping the vehicle once alarm has been given by the OBU.

Nowadays, a significant amount of research has been going on in facilitating and developing a new vision Intelligent Transport system (ITS). One of the Papers [123], an algorithm is proposed on avoiding vehicle collision especially in intersection point. The proposed method is pursued using V2V communication and GPS communication system. Different approaches such setting up video monitoring system and Communication with infrastructure using V2I system can be used in preventing collision between vehicles. In this case decision in made based on the potential collision system made by analyzing the information received from the global positioning system (GPS).

6.4.3. Integration of WBAN with VANET

WBAN (Wireless Body Area Network) refers to a network communication system that is designed to operate autonomously in connecting different body sensors inside and outside of a human body [124]. Under WBAN all the body sensors that are connected on the body or inside of the skin of a person are considered as independent nodes and this WBAN network expands over the whole body in connecting all the sensor nodes through wireless communication. With the help of the sensors incorporated in the body of a person, the subject's state can be analyzed. With the help of WBAN these sensor's data can be transmitted in order to warn the driver in avoiding any hazardous situation relating to road accidents.

In the proposed model pedestrians are needed to wear wireless body sensors [125]. This developed system can alert any vehicle or motor under any circumstances regarding the position of the pedestrians. The developed system will work efficiently in cautioning the driver for cases like any pedestrian suddenly running through the middle of the road, kids running accidentally in to the middle of the road from backyard while playing, handicapped people with limited vision subconsciously crossing the road etc.

Figure 6.4.3.1: WBAN and VANET Communication System [126]

The system works in such a way that wireless body sensors are attached with the body of the pedestrians and from that sensor the exact location of the pedestrians is transmitted wirelessly via VANET to the nearest approaching vehicles or road side infrastructure .As such the driver is already aware if any passenger is approaching towards the vehicle and he can avoid any worse situation being aware of the exact location of the pedestrian .In that case the driver might opt to brake suddenly or change lane or slow down speed in order to avoid possible hazardous or collision .It can be explained like that while a vehicle is passing through a road if any pedestrian comes in the middle of that road while crossing ;the vehicle approaching towards that passenger will be well aware of that situation and as a result although the passenger is in the middle of the road the driver is already aware of the position of the pedestrian and he can stop the car within the due time to avoid any sort of Collision with the passenger to avoid accident. In WBAN communication between body sensor of the pedestrian and vehicle or RSU is made using Wi-Fi. Other combination medium such as Bluetooth, GSM can also be used in that purpose.

With the ever-increasing use of smart phone, smart watch, GPS system the above proposed system is highly recommendable in avoiding the death rates of pedestrians occurring due the road accidents.

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APPENDIX

A. Code for Alcohol Content Detection using Arduino IDE Software in Proteus:

```
****************************************************************************
****************************************************************************
******
//Initialization of LCD and BUZZER
int red = 8;
int green = 9;
int yellow = 10;
int BUZZER=6;

#define BUZZER 6 //buzzer pin
#include <LiquidCrystal.h>
constintrs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystallcd(rs, en, d4, d5, d7);

//Defining Input and Output Pins
void setup()
{
lcd.clear();
Serial.begin(9600);
lcd.begin(32, 2);

pinMode(A0, INPUT);
pinMode(red,   OUTPUT);
pinMode(green, OUTPUT);
pinMode(yellow,  OUTPUT);
pinMode(BUZZER, OUTPUT);
digitalWrite(red,    LOW);
digitalWrite(green,  LOW);
digitalWrite(yellow,   LOW);
```

```
digitalWrite(BUZZER,   LOW);
}
```

// ADC and "BrAC to BAC" Conversion

```
void loop()
{
lcd.setCursor(0, 0);

intsensorValue = analogRead(A0);
float v= (sensorValue/10) * (5.0/1024.0);
int BAC= (v) * (2100);

lcd.setCursor(0, 0);
lcd.print("BAC(ppm):");
lcd.print(BAC);
```

//Setting the Thresholds

```
if (BAC <= 750)
 {
digitalWrite(red,    LOW);
digitalWrite(green, HIGH);
digitalWrite(yellow,   LOW);
digitalWrite(BUZZER,  LOW);

lcd.setCursor(0, 1);
lcd.print("Driver is Sober");

delay(500);
   }
if (BAC > 750 && BAC<= 800) {
digitalWrite(red,    LOW);
digitalWrite(green,  LOW);
digitalWrite(yellow,  HIGH);
digitalWrite(BUZZER,  LOW);
```

```
lcd.setCursor(13, 0);
lcd.print("Alcohol Detected!");
delay(500);
lcd.setCursor(0, 1);
lcd.print("Be Alert! Driver is on the Brink");
delay(500);
    }
if (BAC > 800) {
digitalWrite(red,   HIGH);
digitalWrite(green,  LOW);
digitalWrite(yellow,   LOW);
digitalWrite(BUZZER,  HIGH);

lcd.setCursor(13, 0);
lcd.print("Driver is Drunk!");
delay(500);
lcd.setCursor(0, 1);
lcd.print("Stop! Police is Informed");
delay(500);
    }
delay(1000);
}
```

B. EEG Waveform collected from physionet.orgin .edf format:

****
****
******

EEG Waveform Graph:

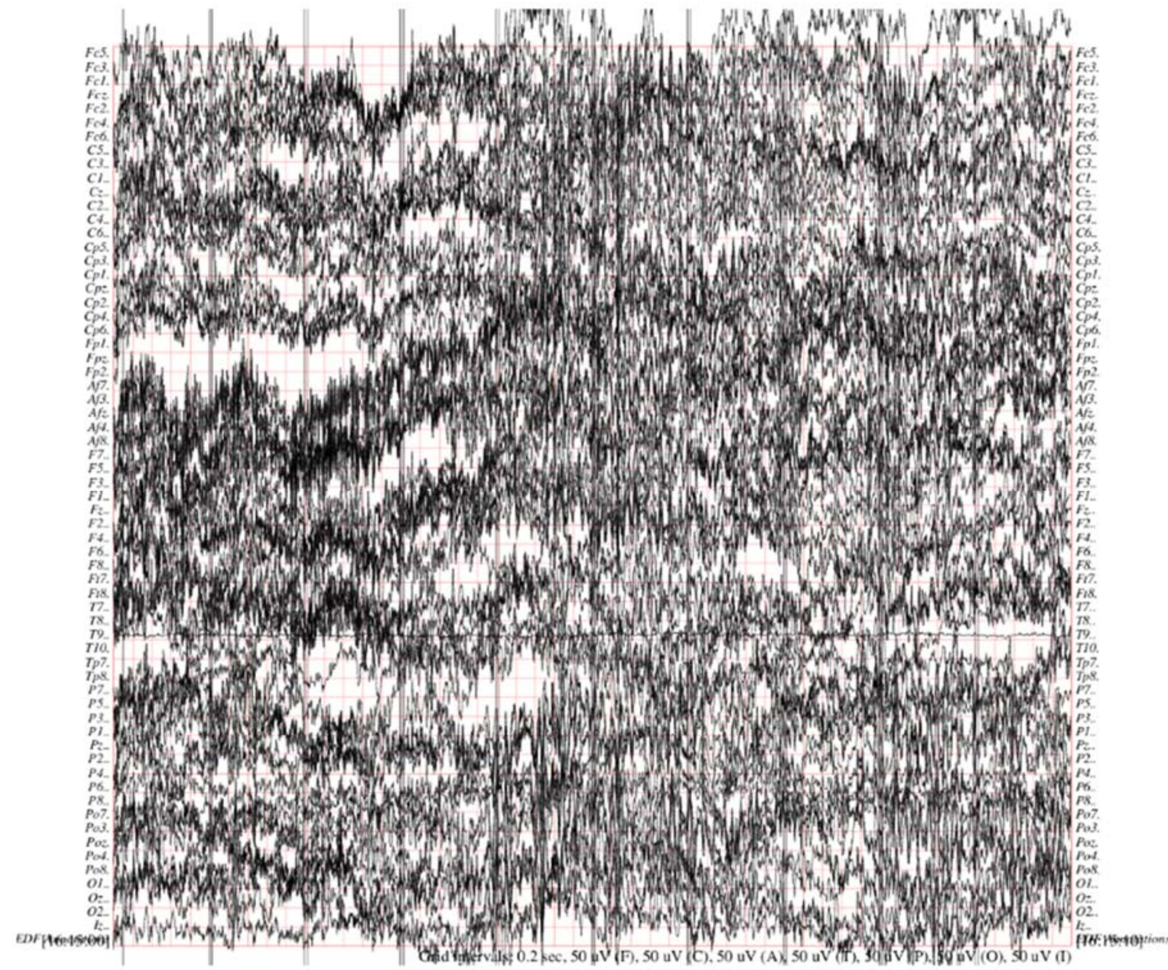

Figure: EEG Waveform Sample [127]