Drivers Drowsiness Detection via EEG followed by Emergency Parking of a Miniature Car

Submitted by

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Abstract

Brain-Computer Interface (BCI) is a way to establish communication between the brain and computers allowing the users to control a computer system without moving a muscle. It also allows the computer to record and analyze the user's neuro-psychological brain activities. The range of BCI applications has increased in the past decade due to the use of modern machine learning and signal processing methods. Among these numerous applications, lately, the use of EEG records for driver safety has been considered. Vehicle accidents are rapidly increasing in many countries. One of the most demanding technologies for the active prevention of fatal road accidents is drowsiness monitoring systems since drowsiness and fatigue are some of the leading causes of severe accidents on motorways and highways. According to surveys, almost every day, about 3,200 human lives are lost in road accidents across the world. The leading cause of these accidents is driver's fatigue and drowsiness. According to a survey by Zonked, fatigue-related accidents have been increased by almost 34.8 percent in Pakistan. This problem needs to be considered seriously and dealt with. This project aims to decrease the number of fatigue-related incidents. To achieve that purpose, driver's drowsiness is to be detected using the brain signals extracted by an EEG headset. A miniature car will be used for demonstration purposes which on drowsiness detection will shift to autonomous mode and then park along the emergency lane.

Chapter 1

Introduction

Brain-Computer Interface (BCI) is an interesting way to control a device. BCI or Brain Machine Interface (BMI) establishes a direct interface between the brain and some external device. It allows humans to communicate with a computer by thoughts. The basic idea is to capture the thoughts of a person by inspecting his/her brain waves. There are two methods to do so: invasive and non-invasive. Invasive methods rely on objects or substances introduced into the brain of the subject whereas non-invasive methods do not require object implantation or drug inoculation into the subject's brain. In this case, the subject interacts with the computer through wearable devices. In the beginning, the researchers of BCI worked mostly in the area of key applications such as immediate control, but later on, they expanded their research focusing on the applications for paralyzed patients. The use of modern machine learning and signal processing methods are the reason for the rapid increase of BCI applications in the past decade including, communication, prosthetic control, robotics, and security. An important area considered by most of the researchers is the safety of people where their main focus is on making daily activities more secure. Since the human-made mistakes are one of the major causes of daily accidents, the BCI researchers have considered human-safety as a fertile area for work. A traffic collision, also known as Motor Vehicle Collison (MVC) due to a human error may result in severe injury, property damage and even in death. A non-human factor can also contribute in the risk of accidents, such as vehicle design, road design, or some natural cause but human-caused factors such as lack of concentration, decision-making skills, and abilities, use of drugs and drowsiness play a significant role in fatal collisions.

A 1985 published study for British and American auto accidents reported that driver error, drunkenness, and other similar human factors contribute to almost 93 % of road crashes. Some common driver's impairments include alcohol, physical impairment, distraction, drug use, drowsiness and combination of these factors. Falling asleep suddenly as a result of some sleep disorder or fatigue can lead in losing the car control ending up in an accident. According to the National Highway Traffic Safety Administration (NHTSA), almost 100,000 vehicle crashes in each year are direct result of driver's drowsiness. These crashes resulted in approximately 1550 deaths, 71000 injuries. These statistics suggests that drowsiness of a driver is a major cause leading to road accidents. Many approaches have been selected to prevent the accidents caused by the drowsiness of a driver however, electroencephalogram (EEG) opened new research area in terms of analyzing brain. activity. EEG can be used to investigate almost all the behavioral and physical activities. Also, EEG can be used to analyze a person's central nervous system activity through a driving task and evaluate the consciousness and attention levels to prevent the possible risk. This technique is noninvasive in which the electrodes are placed on the surface of brain. Although invasive electrodes are used in limited applications electroencephalogram measures voltage variations resulting from electric current within the neurons of the brain.

For preventing car accidents caused by sleepiness, the system should detect drowsiness accurately and rapidly. For recognizing drowsiness stage, EEG data must be classified using a classifier. A decent way to prevent road accidents is to park the car in the emergency lane after the drowsiness of the driver is detected. Several methodologies are there for this purpose to be worked upon including lane-assistance via open computer vision (CV).

1.1 Problem Statement

Nowadays, driver's drowsiness has continued to play a major role in the contribution of road accidents especially among long distance truck drivers. Despite the fact that the government is putting great effort and taking several measures to overcome this problem, but this still continues.

Providing drowsiness detection system among the drivers has not been achieved making it difficult to enforce relevant legislations. Previous research on drowsiness detections systems that the complexity of the problem is mainly due to three challenges, namely: accuracy, speed and reliability. A few systems that are available in the market lack robustness and their accuracy is a major area to work on. There is hence great need to implement a drowsiness detection system that discriminate between drowsy and active state with higher accuracy. This project aims to address the many accidents associated with drowsiness.

1.2 Objectives of the Project

The purpose of the project is:

1. To develop a system that is able to detect drowsiness based on BCI
2. Emergency Parking of a miniature car

1.3 Scope of the Project

From the surveys cited above, road-related accidents are increasing day by day. To resolve this issue, drowsiness detection systems play an essential role, such as the described system which benefits society by reducing these accidents. By taking over the car control in the case of drowsiness, would decrease the accident risk. And would give the control back after the successful parking of the car.

1.4 Demonstration

This project is designed as “Proof of Concept” and its demonstration will proceed as follows, The user feeling fatigue wearing an EEG headset will be remotely controlling a RC Car on a track, just like a driver driving on a road, on the detection of drowsiness the car shifts to autonomous mode and overrides the RC control. The car follows a truck insuring safety and then parks along the emergency lane.

1.5 Organization of Report.

The remainder of this dissertation is organized as follows:

Chapter 1 describes the Introduction, objectives of the project, the problem statement,

the work scopes , demonstration and overview of the project.

Chapter 2 introduces fundamental concepts, flow chart and terminology related to drowsiness, which are needed to understand the complexity of a detection and measurement process.

The second part of the chapter discusses the methodology of the car

Chapter 3 presents data acquisition of brain signals and simulations of EEG signals in detail and describes the whole process.

This chapter also includes image processing, noise reduction and processing methods

for recorded signals, and the observed results.

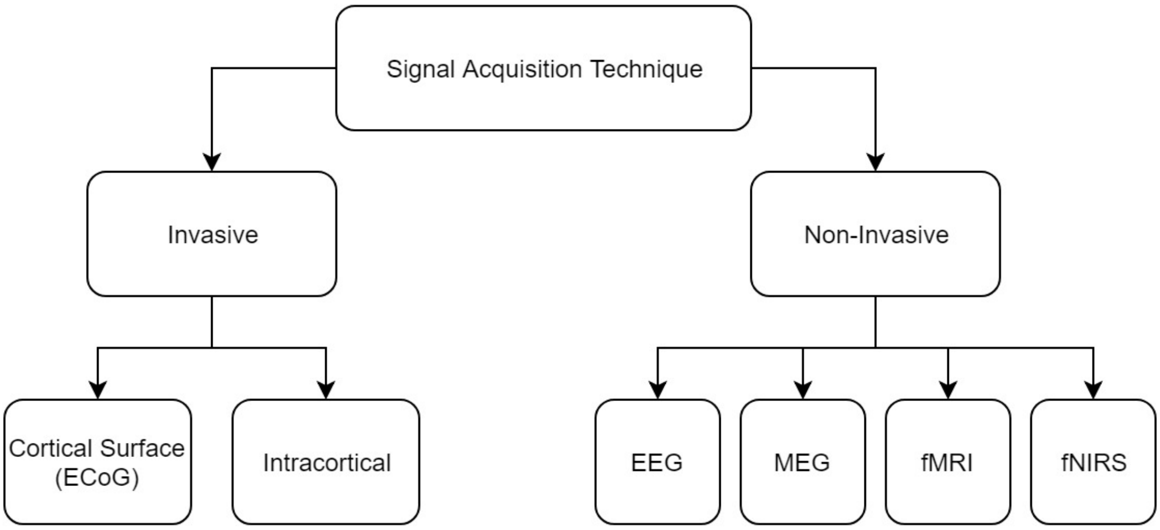
Chapter 4 deals with the component’s listings and their descriptions. The experimental setup of the whole system is discussed in this chapter.

Chapter 2

Description

2.1 Brain Signal Acquisition Techniques

There are different techniques used for brain signal acquisition. The elementary goal of these techniques is to acquire the electrical signals that pass between neurons in the brain and interpret them as a signal that is sensed by electronic devices. These signals are then used to control different mechanisms.



2.1: Signal Acquisition Techniques

2.1.1 Invasive BCI

Invasive BCI involves the insertion of electrodes into the brain cortex and is regarded as a technique for acquiring highest quality signals but is prone to scar-tissue build-up, causing the signals to become weaker as the body reacts to external object in the brain

2.1.2 Partially invasive of Semi Invasive

Partially invasive BCI involves the insertion of electrodes into the skull but in the grey matter. Signals acquired by this technique are comparatively weaker and there is less risk of scar tissue formation when compared with Invasive BCI technique

2.1.3 Non-Invasive BCI

Non-Invasive BCI technique makes sure that the electrodes are placed on the scalp. Acquirement of signals by such technique results in weak signals. There are two significant methods of Non-Invasive Technique:

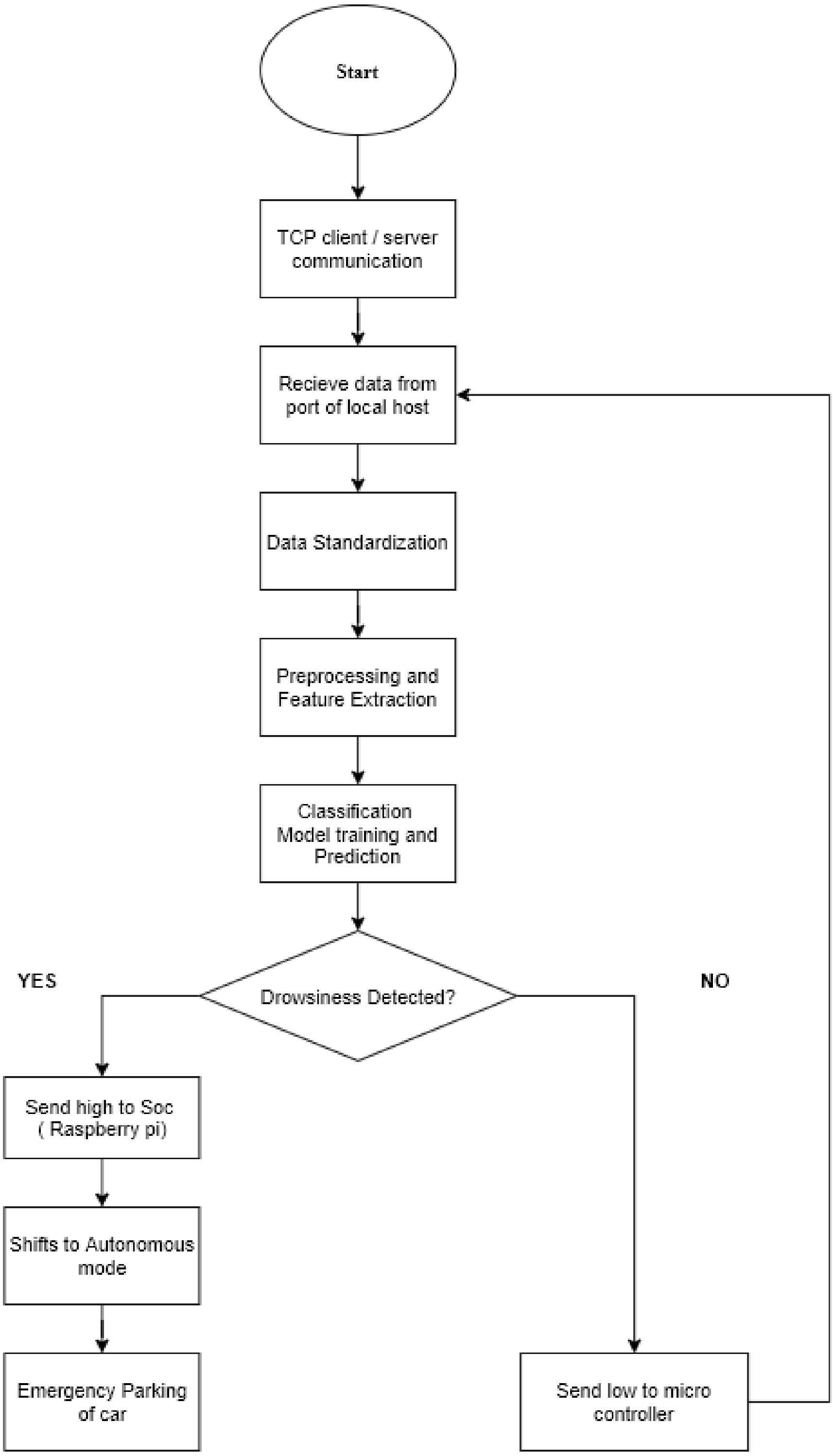
1. The **“Blood flow methods”** incorporates Functional Magnetic Resonance Imaging(fMRI) and functional Near-Infrared Imaging Spectroscopy (fNIRS). fMRI aims to determine brain activity correlate of behavior by recognizing the brain regions that become “active” during the performance of a task. fNIRs recognizes optical properties of tissues enabling the continuous, non-invasive, and safe monitoring of changes in blood oxygenation and blood volume related to human brain function
2. **“Electromagnetic based methods**” include Magnetoencephalography (MEG), Electroencephalography (EEG). MEG is used to measure the magnetic fields produced Description by electrical activity in the brain. The recording of signals is procured by placing electrodes on the scalp with a conductive gel or paste. The numbers of electrodes are from few to 128.

2.2 Methodology

2.2.1 Proposed Methodology for Drowsiness Detection

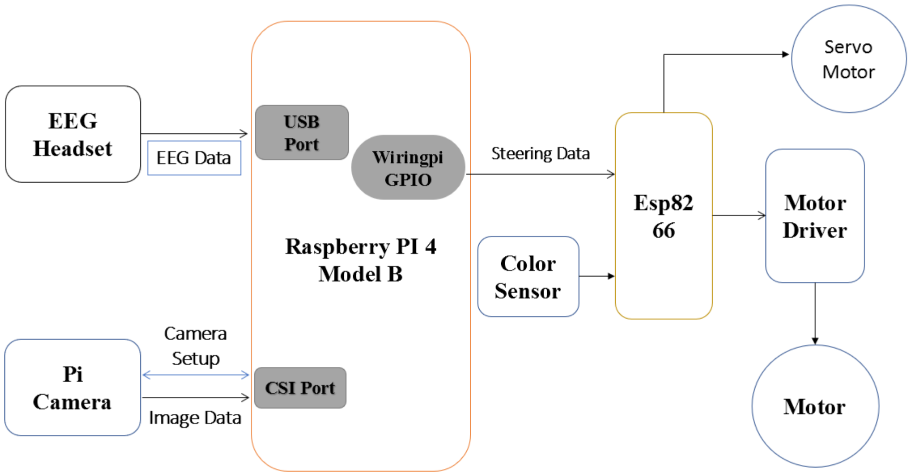
The headset” EMOTIV Epoch+”, used in this project, will detect the EEG signals of different required commands from the brain which will be preprocessed using digital signal processing techniques and then required features will be extracted from the given signal. Then classification of the required features will be done based on different algorithms designed by experts of the fields. The controller will detect the required signals and process it depending on the programming and generates the demanded output.

i. Flow Chart

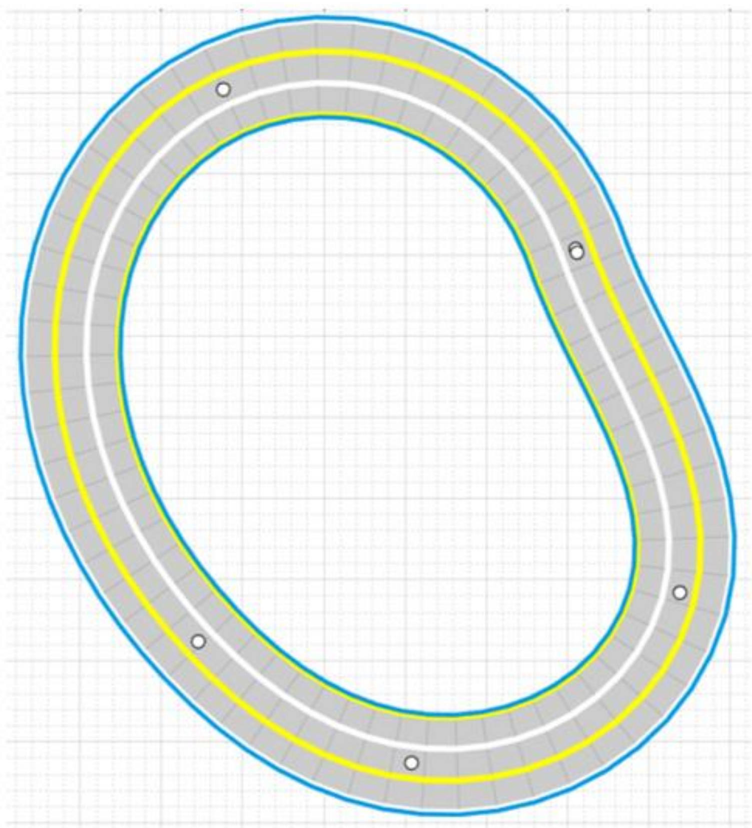


2.2: Flow Diagram

ii. Block Diagram



iii. Track



2.iii : track

2.2.2 Data Acquisition

There should be a device proficient in grabbing data from brain signals. We use the EMOTIV Epoc+EEG headset to collect the date from the brain. EMOTIV Epoch+ headset has 14 channels. The main edge of using EMOTIV headset is that it has 14 channels and its accuracy is a little bit better than other headsets.

2.2.3 Preprocessing

To prepare the EEG signal for classification it has to go through different procedures of them is preprocessing. The EEG signals received had to go through data filtration such as bandpass filters and median filters for noise removal.

2.2.4 Feature Extraction

The process of extracting representative characteristics i.e. mean, variance, and power spectral density (PSD) of a signal are known as feature extraction. The features which are extracted are then stored as "feature vectors" and they are passed to the classifiers. This process of feature extraction helps us to get the required data and helps to facilitate the classification of this data into classes of interest

2.2.5 Classification

The process of identifying patterns from the data based on statistical models built using the training data is known as the classification of the signal. In this processing are classified into different classes by identifying their patterns from the statistical models built using training data.

2.2.6 Output

The state of the subject i.e. drowsy or active is classified in data classification. If the driver is in a drowsy state, the signal will be received by raspberry pi which causes the car that was in manual mode to autonomous mode which after following a curve would park along the emergency lane.

2.2.7 Methodology of autonomous mode

Following steps are involved

1. Procurement of Image
2. Grayscale conversion
3. Application of mask for Area of interest
4. Noise suppression by averaging out the pixel values in a neighborhood
5. Edge detection
6. Histogram Processing
7. Error calculation

Chapter 2

Modelling and Simulation

3.1 Drowsiness detection

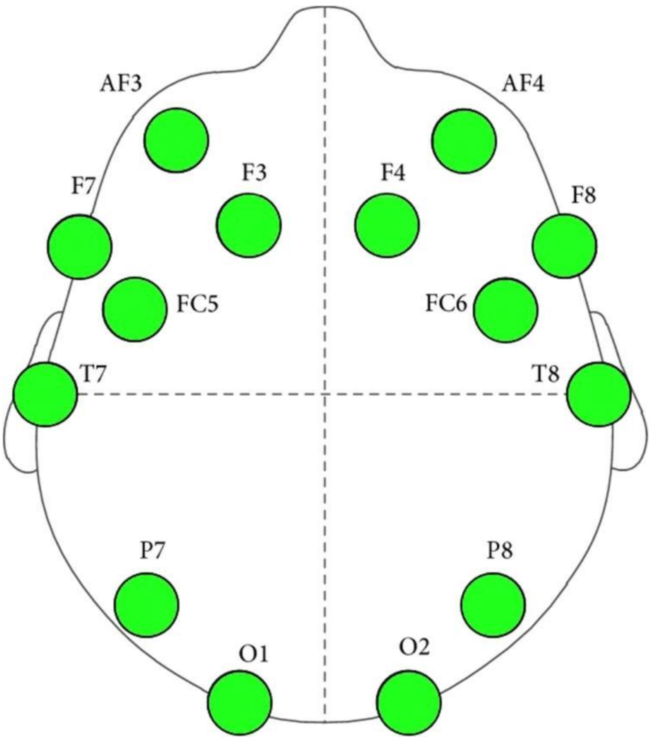
Advanced driver assistance is one of the most promising systems that may help drivers to control vehicles while reducing accidents and improving traffic safety. This system uses a brain-computer interface to monitor the neural activity of the brain for the detection of drowsiness. To implement drowsiness detection that will be followed by autonomous parking of the car, the brain signals must be processed and classified for decision making.

3.2 Electrode Placement

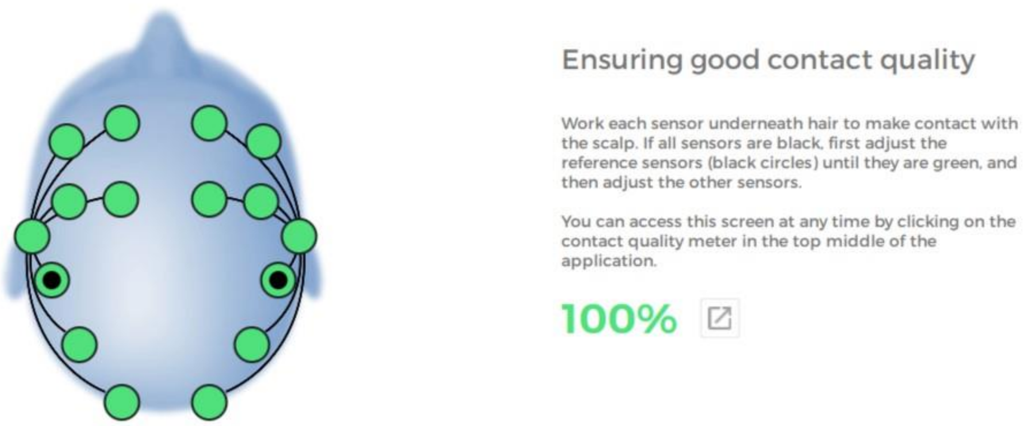
The electrode placement is done via the 10-20 system. It is regarded as an internationally accepted and recognized system that involves the placement of electrodes on the scalp. The ”10” and ”20” depicts that the actual distances between adjacent electrodes are either 10 percent or 20 percent of the total front back or right left distance of the skull. 10 particularly refer to 10 percent of the circumference while 20 particularly refer to 20 percent of the inner electrode distance. The location of the lobe is represented by a letter and hemisphere by a number. Basically, the central lobe does not exist; it is just for identification purposes. The right hemisphere is denoted by a set of even numbers 2,4,6,8 and the left hemisphere is 15 denoted by a set of odd numbers 1, 3, 5, 7.

3.3 Signal Processing

To study the effects of drowsiness, the EEG signals are recorded and out of 14 only 1 channel is selected



3.3: Electrodes location of 14 -channel Emotive EEG headset



3.3. *Emotive connectivity check*

3.3.1 Method of Data Extraction

For the purpose of data extraction 10 healthy subjects were selected. It was made sure that the subjects didn't smoke or took any sort of drugs. Each of the subject was given a consent form in which they agreed to participate in the experiment. Firstly, they were asked to participate in an overnight study program and the next day they were asked to wear the EEG headset and play an android car driving game which required shear concentration. Each of the member felt fatigue and readings were extracted during this process that lasted 10-20 minutes.

3.3.1: Readings from 1st subject

3.3.2 Selection of Channel

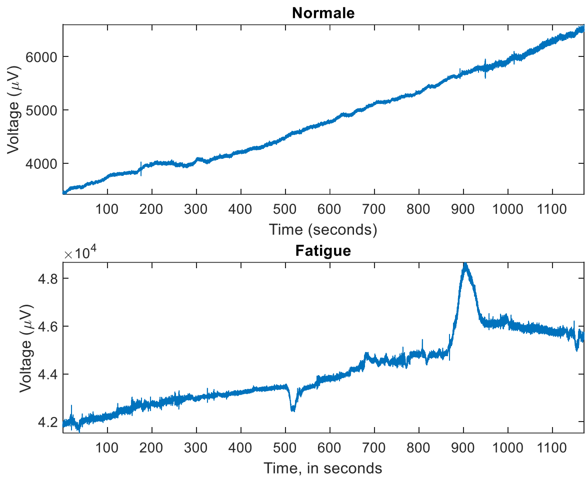
When people become fatigued and tired, they lose focus and try again and again to regain the lost concentration such is the behavior of a drowsy driver. Common studies have revealed that when a person is facing loss of concentration there is an abrupt increase in alpha and theta activity and a certain affect was also observed on the delta waves concentration. The waves mentioned above predominately originated from the occipital region during the normal and the wakeful state. Thus, the region O1 was selected for the purpose of drowsiness detection.

3.3.3 Preprocessing

The signals extracted were exported to MATLAB and were subjected to preprocessing. The preprocessing had the following steps.

1. Removal of 50Hz AC noise from the channels

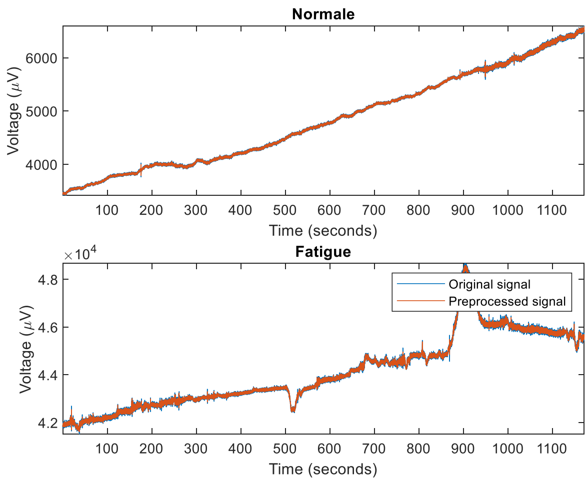
For the removal of this noise notch filter was used. It is said by the Emotiv Epoch that is has an inbuilt notch filter but it was applied as precautionary measures



1:. Plot of Normal and Fatigue State

2. Smoothing of channels

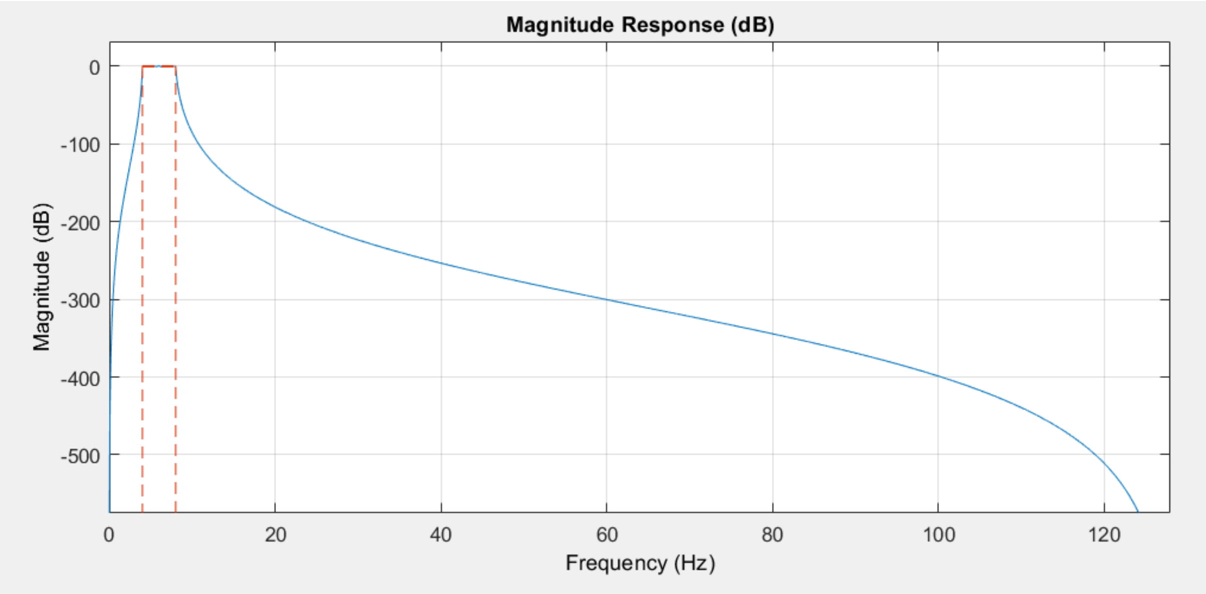
For smoothing of channels moving average filter was used which creates a series of average of subsets of the whole dataset of the channel. A median average was used which was observed to have advantage over the mean filter since the outlier values didn’t much affected the median value



2. Result after Smoothing of Signals

3. Creating and applying Filters for the extraction of the primary waves

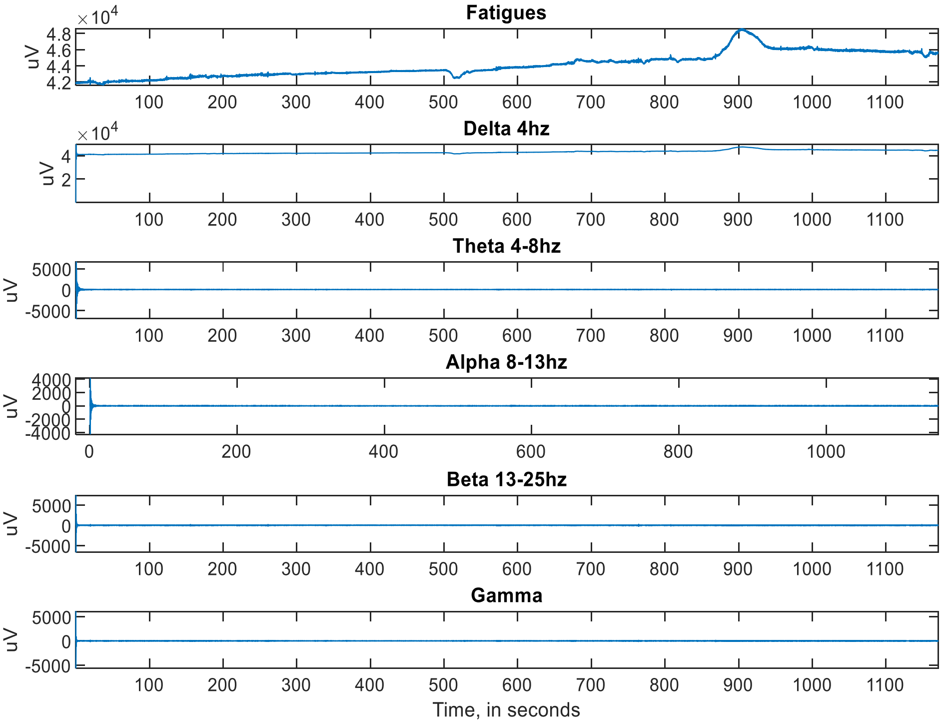
Filter creation was necessary for obtaining the alpha, beta, theta, gamma and delta waves. MATLAB's function designfilt () was used to generate the magnitude response of filter.



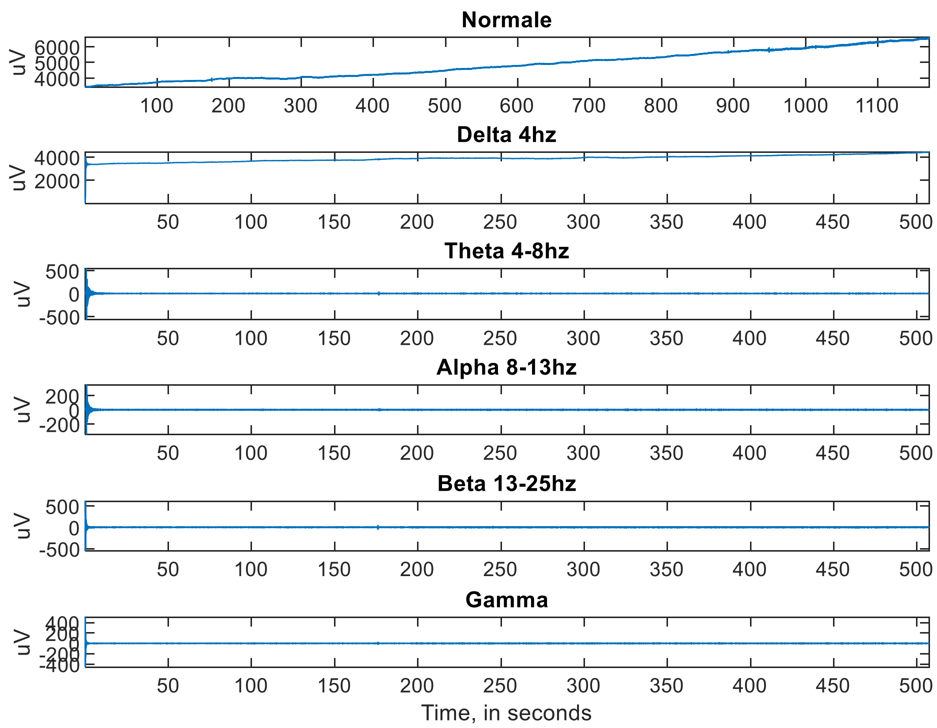
3. Bandpass filter for theta wave

4. Application of Filters

MATLAB's filt () command was used for the application of filter



4. O1 channel of fatigue Resolved



4. O1 channel of Normal Resolved

5. Power energy spectrum

Power of signal can be expressed as

$$P = \frac{V^2}{R}$$

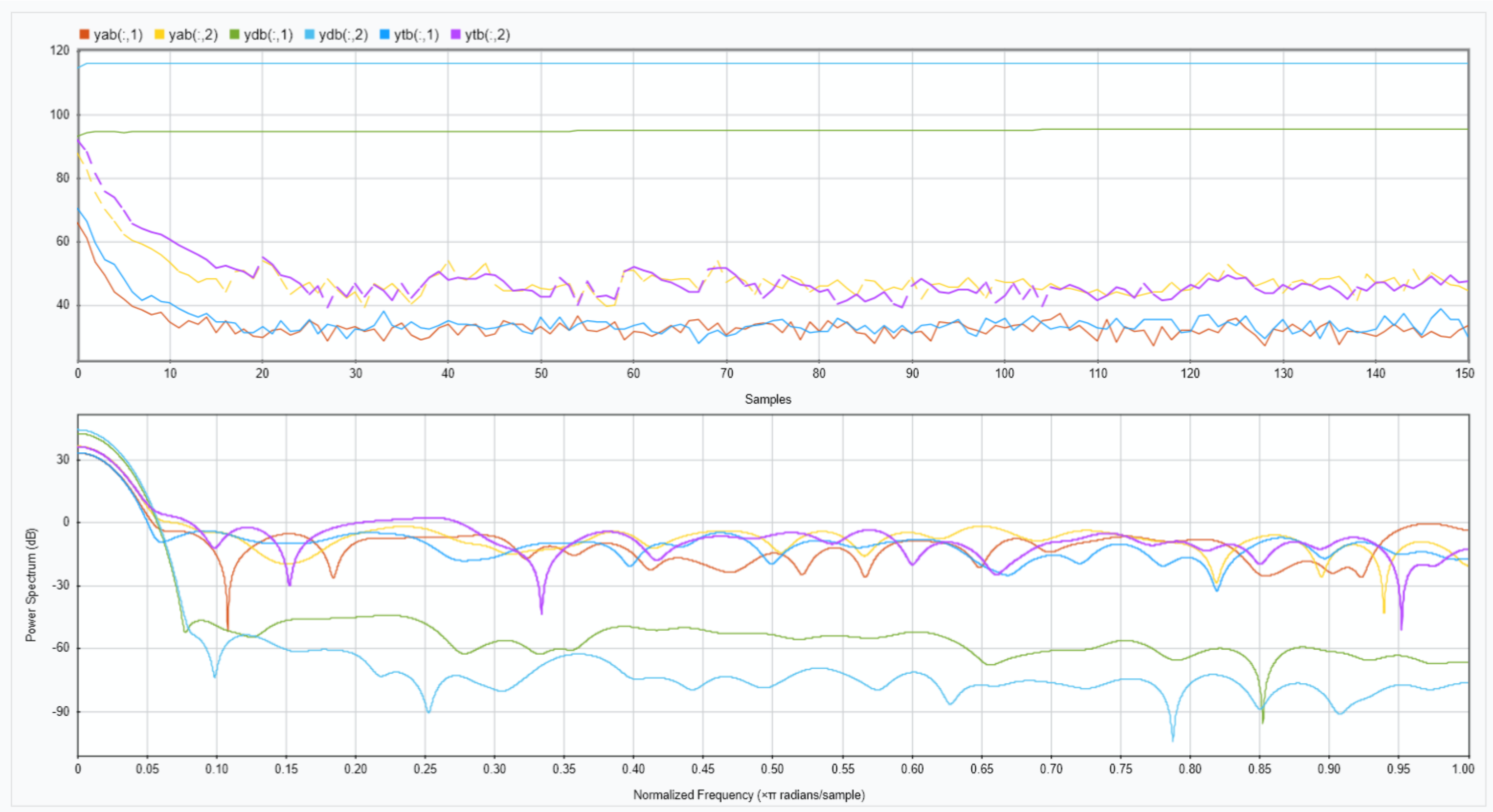
$$Here, V = voltage\ in\ \mu\text{Vs}$$

$$R = 1\ ohm$$

thus, $V^2$is the sum of the absolute squares of the samples of channeltime domain which is further divided by the signal length

$$n = \frac{N}{Fs}$$

6. Power expressed in decibels (dB)



6. Signal Analyzed

Yab Represents alpha waves
Ydb Represents delta waves
Ytb Represents theta waves

For converting to decibels MATLAB's function pow2db () was used. In the above graphs the dotted lines are the fatigue waves and rest are of awake state.

3.4. Feature Scaling

Data that was received through the above procedure was divided into features each of them had different scales in order make them go through they needed to be on one scale.

For this purpose, standardization was used

1. Standardization

Computation of transformed values by computing the difference of each feature of value from the mean of the values of the feature

$$x_{transformed} = \frac{x - mean(x)}{standard\ deviation\ (x)}$$

2. Removing Outliers

An outlier is an observation that is distant from other observations it may occur due to some experimental error. It requires removal since the machine learning algorithms are sensitive to range and distribution of any attribute values and thus result in misleading of the training process and thus it would further result in less accurate models and ultimately poor results. The MATLAB command isoutlier () checks for such data and marks them as 0 which are further negated from the data stream.

3.5. Classification

The classification algorithm used is K nearest mean neighbor's also known as KNN

1. KNN

KNN has the following steps for implementation, they are as follows

i. Choose the number of K Neighbors
ii. Compute the K neighbors of the new data point according to some distance measured such as Euclidean
iii. Count the number of data points from each category among the neighbors that were computed in step (ii)
iv. The new datapoint is assigned to the category with the most neighbors

Euclidean Distance

It is computed by the following formula

$$\sqrt{(X_{2-}X_1)^2 - (Y_{2-}Y_1)^2}$$

2. Pros of KNN

i. Easy implementation
ii. Flexible features
iii. Easily handles multiple class cases

3. Data Scatter

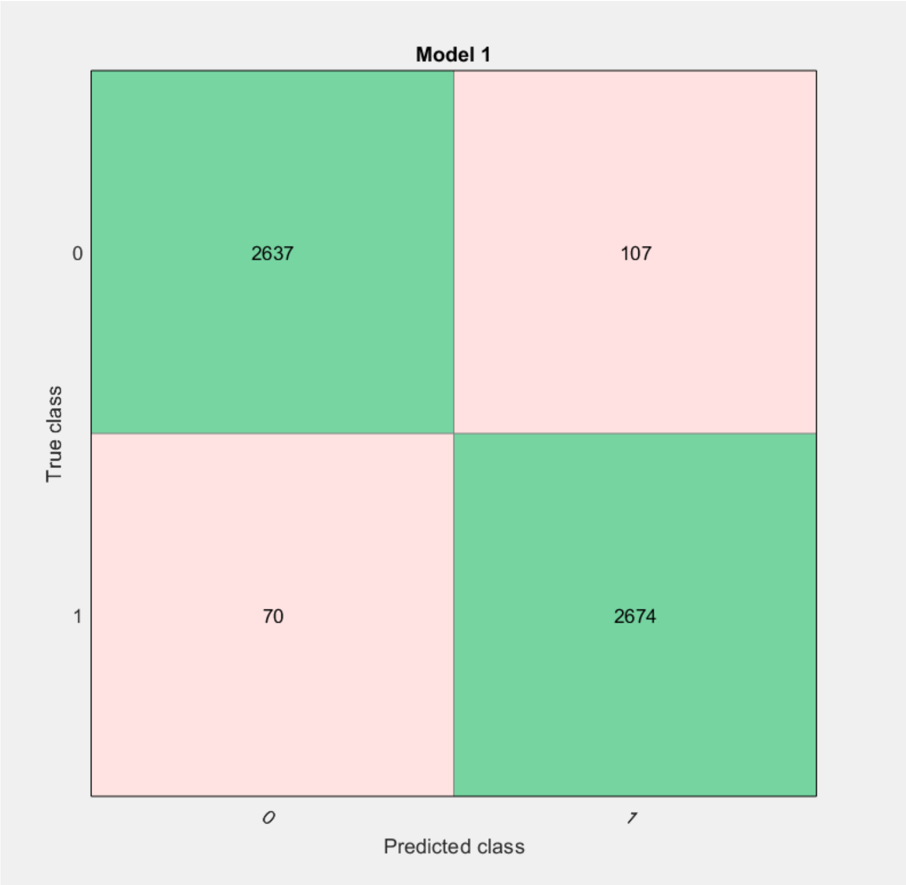
3. Data plot

4. Results of KNN

In order to decrease the dimensionality Principal Component Analysis was used with

n = 2 components. Model is based on 80 % training and 20 % test set. The number of neighbors were set to 1 for distance Euclidean was chosen. The accuracy turned out to be 96.8% was highest by any algorithm. The accuracy was algorithm can be improved by training the model more.

i. **Confusion Matrix**



i.. Confusion Matrix In the confusion matrix the green diagonal shows the number of correct observations whereas the pink one shows the false identifiers.

3.6 Conclusion

From the results above drowsiness detection was a success the whole process of drowsiness detection has a run time 1.12 s but it can be made better depends on the hardware used. The algorithm implemented has an accuracy of 96.8%. The model was exported and gave exceptional prediction results when live data was used for prediction.

3.7. Lane Assistance

The second phase of this project involves lane detection and autonomous parking. This can be done by the applications of Image Processing.

3.8. Image Processing

The image processing is a form of signal processing where the input is an image, the output
of an image processing may be either an image or a video frame or may be related to an image. The image processing algorithm has three stages perception, processing and output. The first stage captures the image the next stage makes something of the pixels and the output gives that processed image

4. General block diagram of image processing

3.9. Images

Images are the most important data for analyzation of image processing applications. Various types of images are used for data analysis The digital image I(r,c) is represented as a two dimensional array of data, where the data of each co-ordinate at point (r,c) corresponds to the brightness of the image at that point. In digital image, a pixel is a smallest unit of image that can be controlled and addressable by coordinates and the intensity of each pixel is variable. They are represented in a 2-D matrix. The Different types of images used are RGB and Gray scale image.

3.10 Lane Detection Algorithm

The image processing step is required in order to process the output of the image sensor and extracts useful information that can be used by the controller for decision making.

3.11. Edge Detection

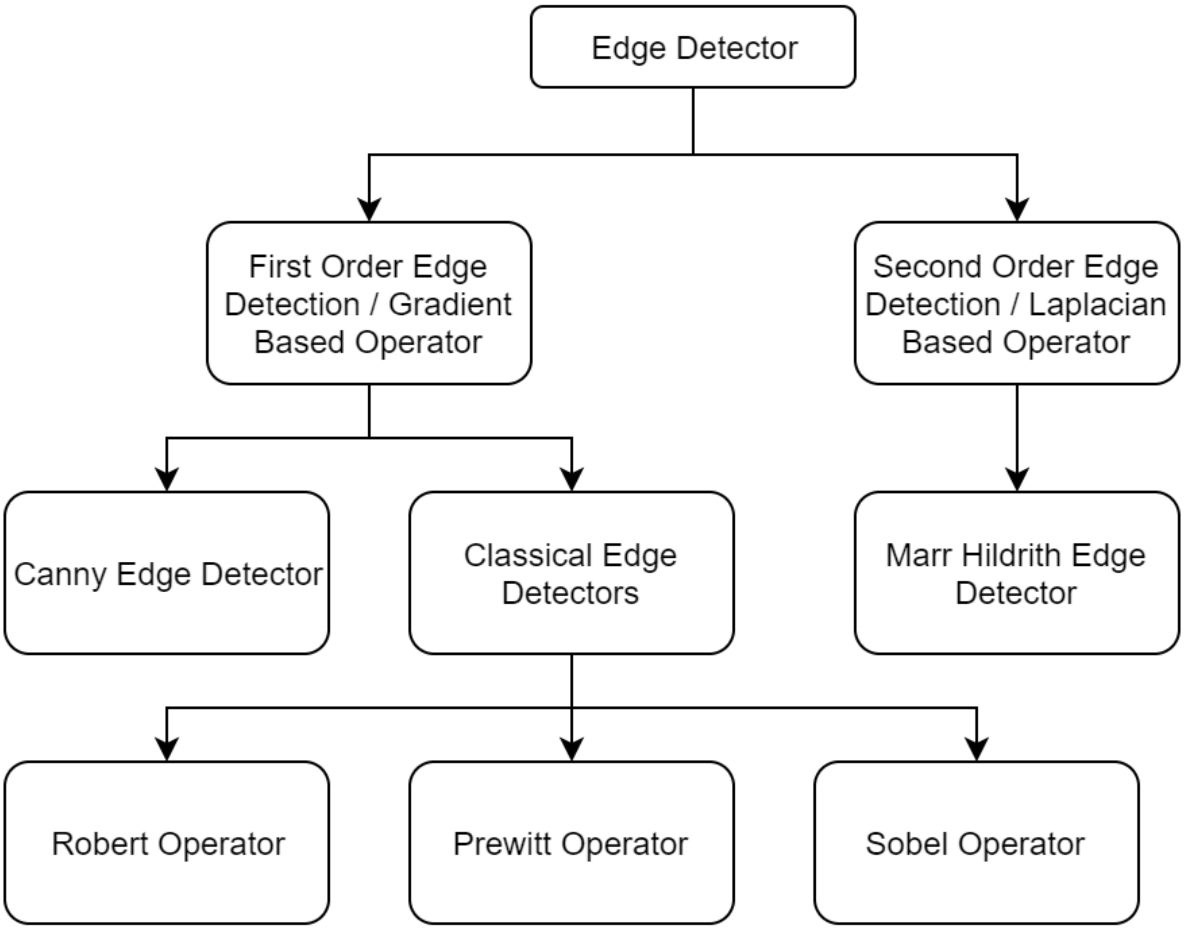
Edge detection is one of the applications of the image processing which is used for feature detections and extraction where the certain points are identified whose brightness changes sharply, thus decreasing the total data in an image and making sure that the structural properties are intact. Having a noisy image makes difficult to detect edges which results in blurred and noisy results Although point and line detection certainly are important in any discussion on image segmentation, edge detection is the most used tool for detecting meaningful discontinuities in intensity values. Such discontinuities are detected by using first- and second-order derivatives. The first-order derivative of choice in image processing is the gradient. We repeat the pertinent equations here for convenience.

-The gradient of a 2-D function, f(x,y),is defined as the vector

$$\nabla f = \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial h}{\partial y} \end{bmatrix}$$

3.12 Edge Detection Methodologies

Edge detection makes use of differential operators to detect changes in the gradients of the gray levels.



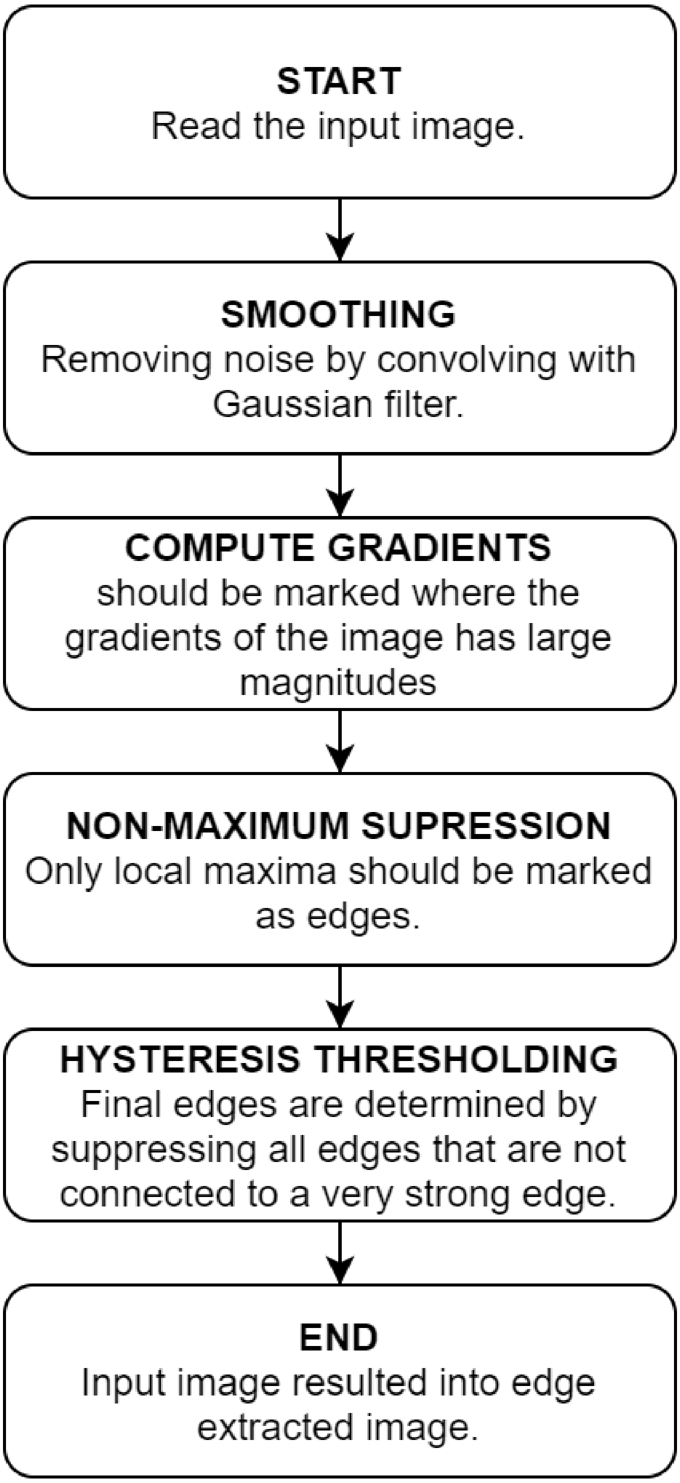
3.12. Types of Edge detectors

3.12.1 Canny Edge Detection

Canny edge detection technique provides good detection with clear response followed by good localization which makes it useful in current image processing techniques with further developments.

The Canny edge marker is an edge affirmation director that utilizes a multi-compose tally to recognize a wide degree of edges in pictures.

Flowchart of Canny Edge Detection Algorithm



3.12.1. Canny edge Steps

3.13 Histogram Processing

A histogram tells you about the exposure of lightning on the image further what adjustments
will make the result better. An image is made up of pixels, each of which has three basic colors red, green, and blue. Their brightness varying from 0 to 255 for a digital image with a depth of 8-bits. A RGB histogram is generated when the computer looks through each of these RGB brightness values and projects how many are at each level from 0 through 255.

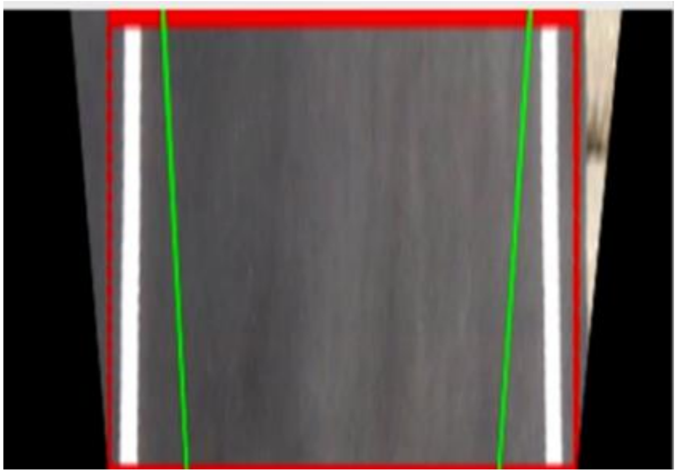
3.14 Error Calculation

Figure 3.6b illustrates the inverse perspective mapping where the sensor image is transformed by inverse perspective mapping (IPM) into a bird's eye view image. After IPM, the lane features such as intensity and geometry of the lane markings are preserved. as shown in Figure 3.6c, and they can be applied to locate the lane position by edge-based lane feature detection. The intensity difference between the lane markings and the ground pavement is often so strong that the IPM image can be converted to binary grayscale image and then filtered by an intensity threshold q:

$$q = kM(I)$$

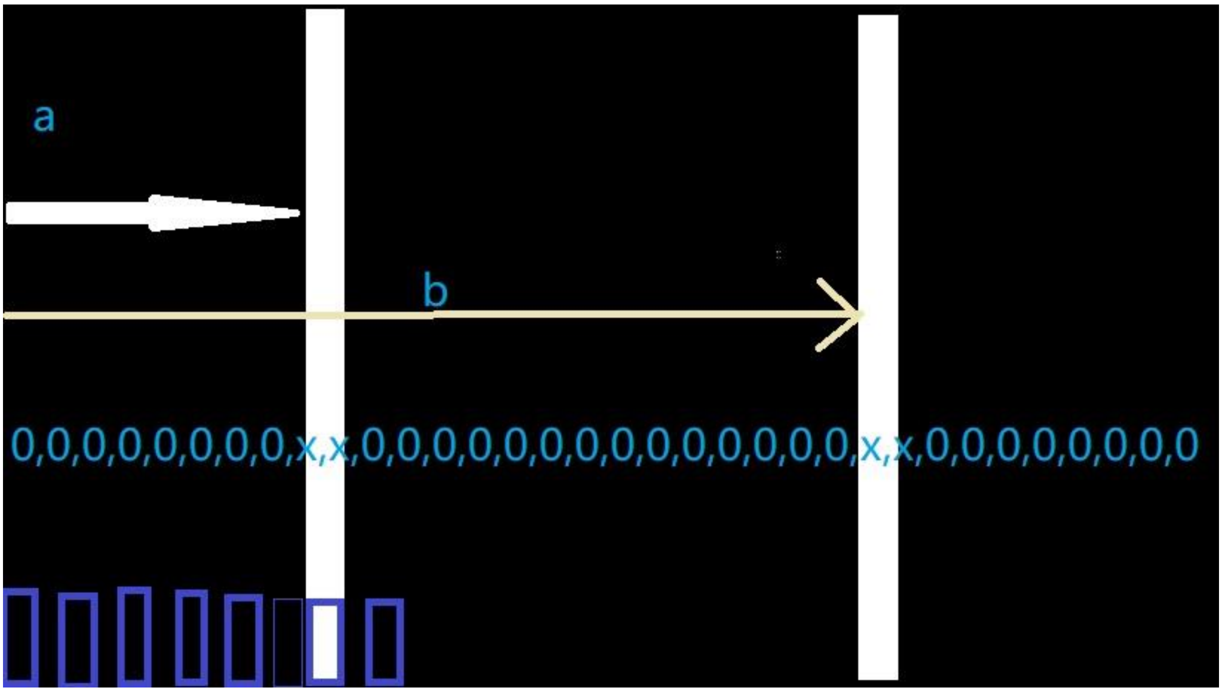
where k is a constant to preserve lane markings, M(I) is the peak with the highest intensity value in the histogram of the grayscale image, and I is the grayscale image. The position of the left and right lanes can be acquired. Noting that the lane markings close to the vehicle are approximately vertical after the transformation, hence the horizontal position of the left and right lane marking can be determined by the column intensity sum of the threshold image, and two lines LL and LR passing through xL and xR, respectively, are the initial guess of the position of the left and right lane marking.

5.a Sensor Image



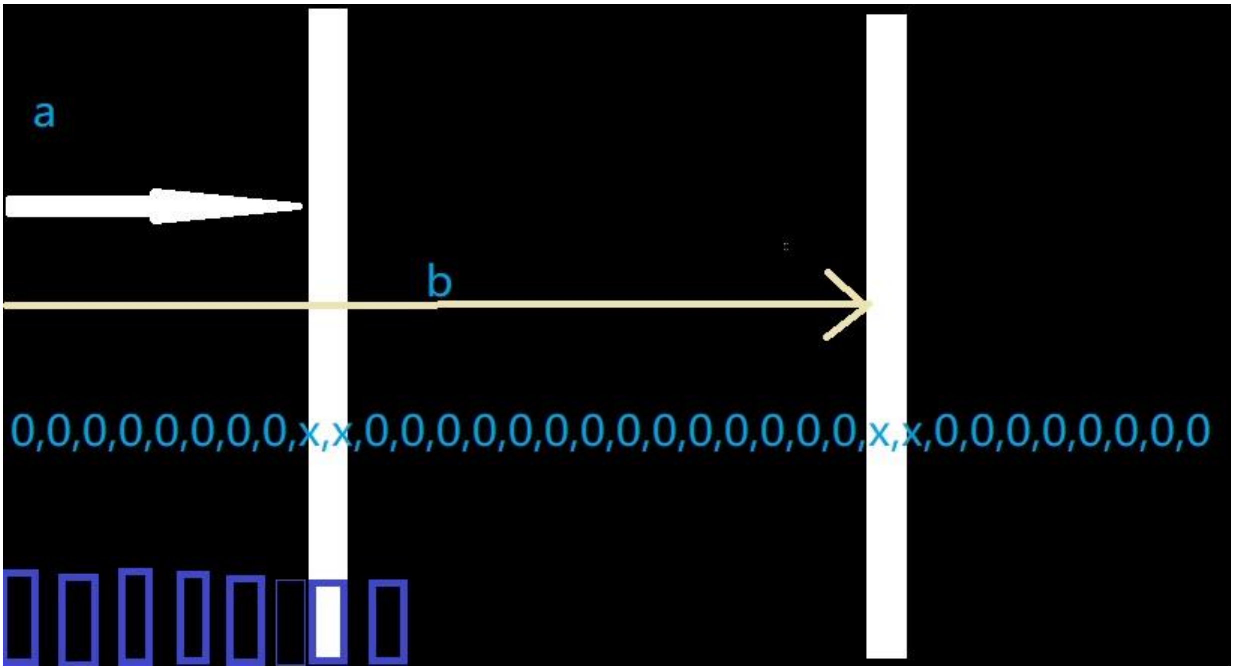
3.6. b Bird eye view

3.6.c Lane detection



3.6d. Error Calculation

3.14.1 Lane Centering



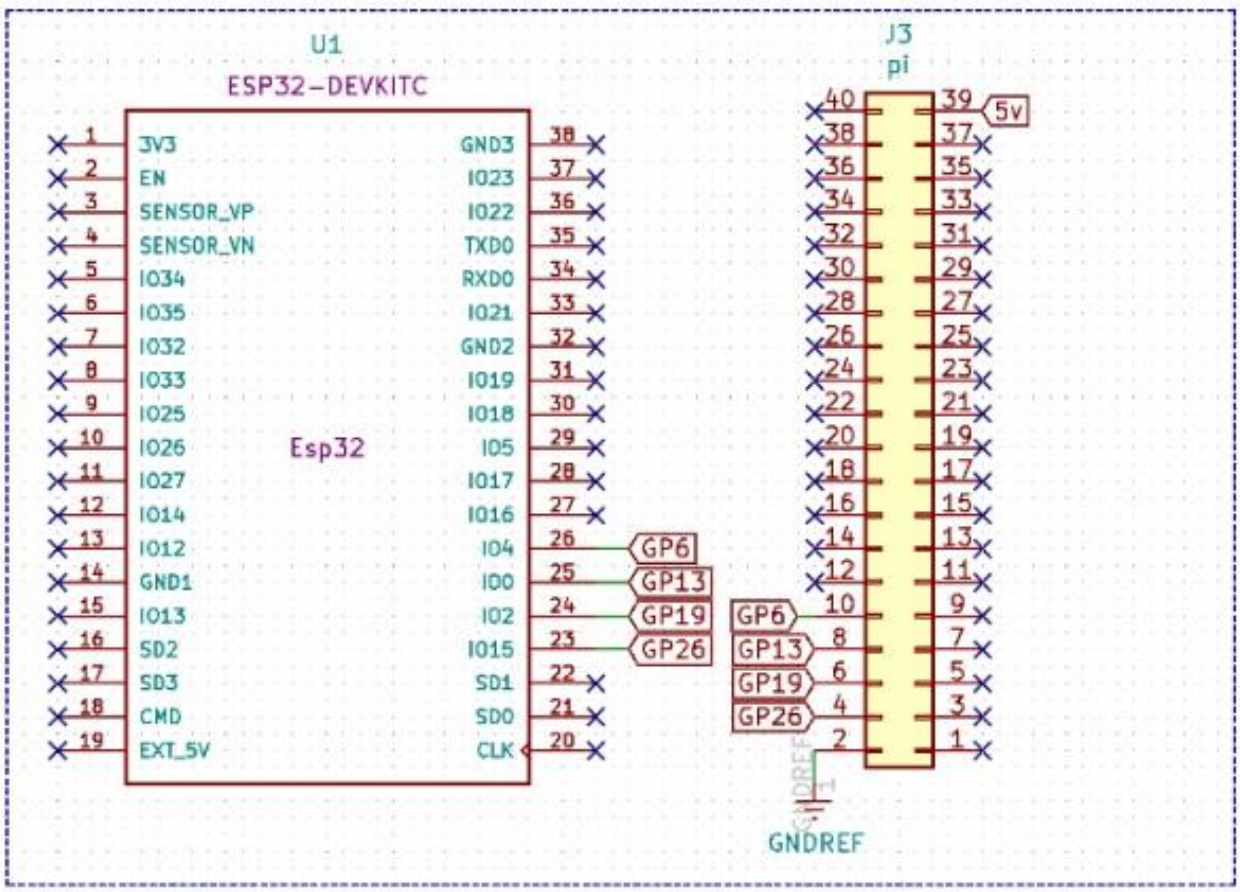
$$Lane\ Center = \frac{b-a}{2} + a$$

$$Error = Lane\ Center - Frame\ Center$$

3.15. Electronics Design

3.15.1 Control Unit

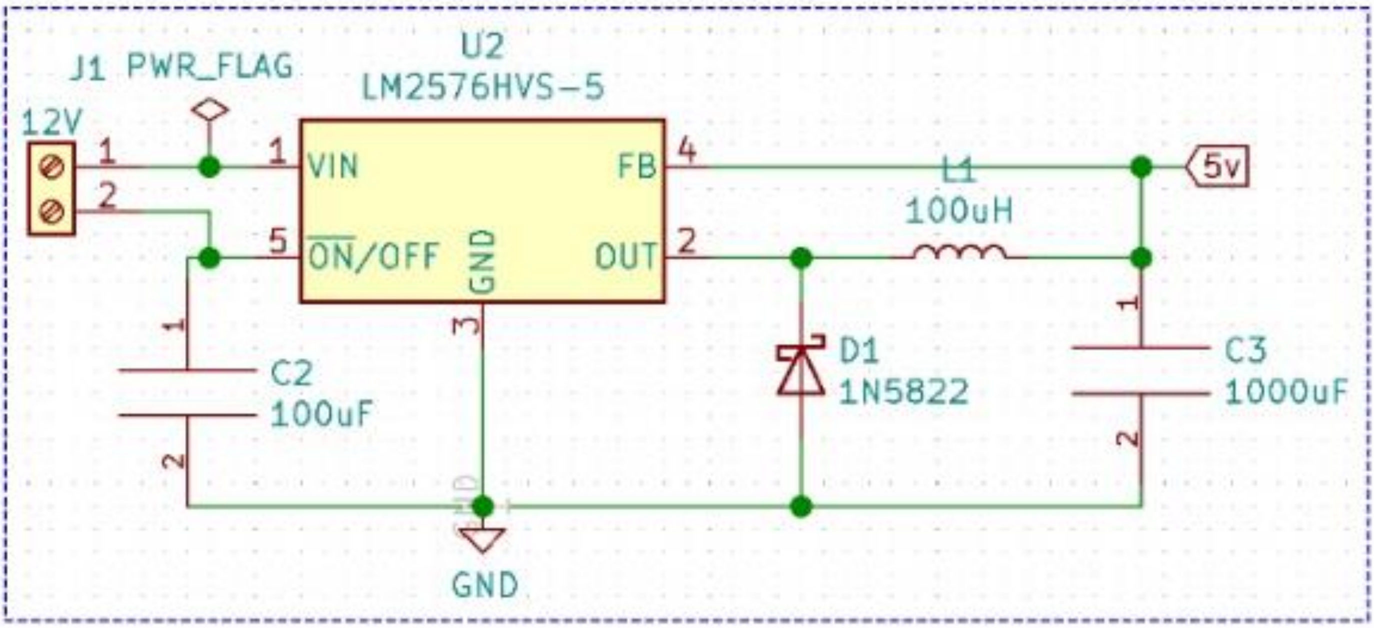
For the communication between ESP32 and the raspberry pi 4 the wiring pi pins of the pi are connected with the GPIOs of the ESP32



3.15.1: Control Unit of Car

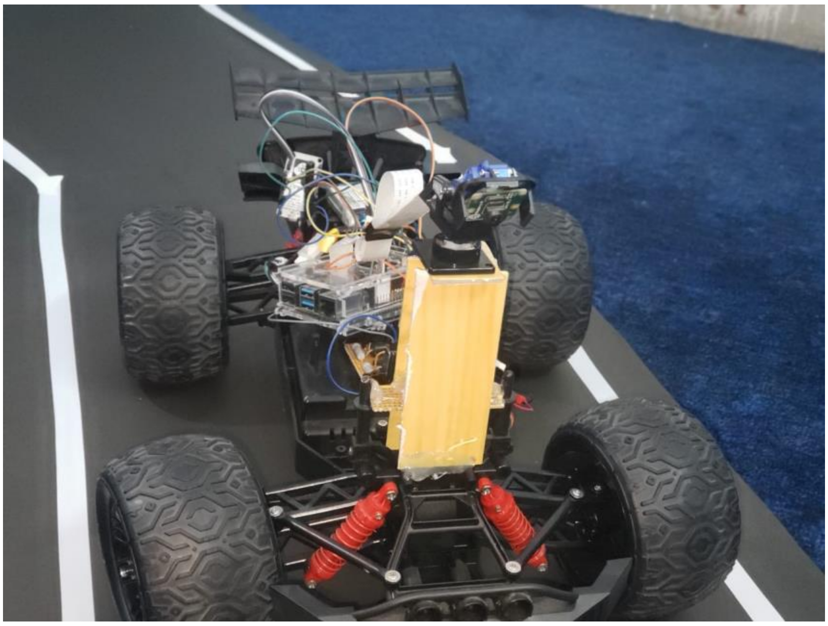
3.15.2 Power Source

For making the raspberry pi standalone, a voltage converter that steps down 12v to 5v 3A is used, named LM2576.The LM2576 is a buck switching regulator which drives 3A load with excellent efficiency. Furthermore, it includes fault protection and fixed frequency oscillator.



3.15.2. Power source

3.16 Projects Progress



3.16: Progress

The project had four phases

1. Design of Drowsiness Detection System
2. Remote Control of Car
3. Autonomous Control of Car
4. System Integration

Out of the 4 phases 3 have been completed and all that remains in phase 4.