

TRAIN COMFORT ANALYSIS USING ACCELERATION MEASUREMENT AND NEURAL NETWORK



A thesis submitted by

HARCHAND (GL)	(18ES33)
MAHESH KUMAR	(18ES37)
SADAM RAHIMOON	(18ES39)

Supervisor

Prof. Dr. Bhawani S. Chowdhry

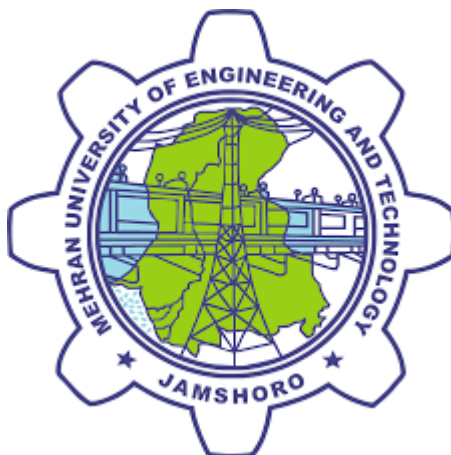
Co-Supervisor

Engr. Ali Akbar Shah

Submitted in the partial fulfillment of the requirements for the degree of Bachelor of
Engineering in Electronics

Faculty of Electrical, Electronics & Computer Engineering
MEHRAN UNIVERSITY OF ENGINEERING & TECHNOLOGY, JAMSHORO

October 2022



CERTIFICATE

This is to certify that “**Project/Thesis Report on, “TRAIN COMFORT ANALYSIS USING ACCELERATION MEASUREMENT AND NEURAL NETWORK”**” is submitted in partial fulfillment of the requirement for the degree of Bachelor of Electronic Engineering by the following students:

HARCHAND (GL)	(18ES33)
MAHESH KUMAR	(18ES37)
SADAM RAHIMOON	(18ES39)

Supervisor

PROF. DR. BHAWANI S. CHOWDHRY

Co-Supervisor

ENGR ALI AKBAR SHAH

(Chairman, Department of Electronic Engineering)

Date: _____

DEDICATION

We are dedicating our whole efforts to our respected

“PARENTS & TEACHERS”

Whom we are really inspired. their pure love, devotion

Natural attitude and sincerity matter of great

Pleasure and pride for us.

Their encourage and simulating morally, socially and

academically based teachings have always been

proved for us a

“PATH TOWARDS SUCCESS”

They have given us name which caused our

identification in society

ACKNOWLEDGEMENT

It is enormous thanks to Almighty ALLAH who is Omniscient and Merciful who bestowed & enabled us to complete the task.

Always some people get a bigger share than other people not because they are better but because they arrive at the right time and right place to offer their services. So thanks to all those who helped us in completing this project.

With great respect and thanks, we express our gratitude to our Supervisor **Prof. Dr. BHAWANI S. CHOWDHRY** and Co-Supervisor **Engr ALI AKBAR SHAH** for allowing us to work in this project.

They support us a lot for our Bachelor of Electronics Engineering study and thesis project for their patience, motivation, enthusiasm and immense knowledge Their guidance helped us in all the time of project and writing of our thesis. We could not have imagined having a better advisor and mentor for our Bachelor of Electronics Engineering project.

Last, but not least, our families for their understanding, patience, encouragement and support. Thank you for all the support, comments and guidance.

May ALLAH bless all these wonderful people.

ABSTRACT

The railway is the backbone of the country's economy as passengers rely heavily on it due to its affordability. However, in Pakistan, not only the safety of the railway is compromised but also its ride comfort. There is an absence of any standardization platform status that could rate the riding standards of the trains currently operational in Pakistan. To address this, we are aimed at providing a solution that will not only analyse the railway ride comfort based on acceleration measurement but also will acquire brain signals, which will exhibit the current comfort of passengers. This proposed instrumentation will comprise EEG sensors and a train-mounted accelerometer module (in order to understand the effect of train vibration on the human comfort level), which will be tested on volunteers from different age groups on almost all of the operational trains of Pakistan. The data collected will pass through a machine machine-based data analytic model which will provide the comfort rating of the various trains. This study will ultimately help passengers from different age groups in making the decision of which train they should choose for traveling. Moreover, as this project is in collaboration with the Pakistan Railways, they can use this study in determining their fair rates.

Table of Contents

ABSTRACT.....	v
Table of Contents	viii
List of Figures.....	ixx
List of Abbreviations	x
1. INTRODUCTION.....	1
1.1 History.....	4
1.2 Problem Statement.....	4
1.3 Aims And Objectives	5
1.3.1 Aims:.....	5
1.3.2 Objectives:	5
1.4 project scope.....	5
2. LITERATURE REVIEW	6
2.1 Introduction.	6
2.2 Literature Review	6
2.3 Methods.....	11
3. DESIGN AND METHODOLOGY.....	15
3.1 Introduction.....	15
3.2 Block diagram.....	15
3.3 Flow chart of comfort level analysis.....	17
3.4 Methodology.....	18
3.5 Pressure Points Validation.....	19
3.6 Hardware Connection.....	20
3.6.1 Circuit Diagram Of Adxl 345 Module.....	21
3.6.2 Circuit Diagram Of Eeg Module.....	21
3.7 Arduino IDE Code Overview.....	22
3.7.1 Wireless Router (Access Point).....	22
3.7.1.1 Complete Code Of Creating Access Point.....	22
3.7.2 Accelerometer Module.....	23
3.7.2.1 Complete Code For Creating Accelerometer Module.....	23

3.7.2.2 Serial Monitor Output Of Accelerometer Module.....	25
3.7.3 EEG MODULE.....	26
3.7.3.1 Complete Code of Eeg Module.....	26
3.8 Python Code Overview.....	30
3.8.1 Flask Blueprint.....	30
3.8.2 Python Code Of Wireless Network.....	30
3.8.3 Main Python Run Code.....	31
4. RESULTS AND DISCUSSION	33
4.1 Result and the Project	33
4.2 Time Interval.....	34
4.3 Model Creation.....	34
4.4 Code Flow	35
4.5 Real Time Project Vallidation.....	35
5. CONCLUSION AND FUTURE RECOMMENDATIONS	36
5.1 Conclusion.....	36
5.2 Advantage.....	36
REFERENCES.....	37

List of Figures

Figure 1-1 Components.....	3
Figure 2-1 Dummy Model	Error! Bookmark not defined.
Figure 2-2 Model of Subjective Ride Comfort	Error! Bookmark not defined.
Figure 2-3 Ride Comfort Index.....	Error! Bookmark not defined.
Figure 3-1 Block diagram of Project mechanism	Error! Bookmark not defined.
Figure 3-2 Pressure point validation during filed trials	Error! Bookmark not defined.
Figure 3-3 Pressure Points	Error! Bookmark not defined.
Figure 3-4 SPI connection between ADXL 345 and NodeMCU	Error! Bookmark not defined.
defined.	
Figure 3-5 EEG Connection	Error! Bookmark not defined.
Figure 4-3 Pakistan Railways	Error! Bookmark not defined.

List of Abbreviations

EEG	Electroencephalograph
TF Record	Tensor Flow
ACK	Acknowledge
HSR	High-speed railroad

CHAPTER 1

INTRODUCTION

High-speed railroads (HSRs) have been widely and rapidly developed in worldwide transportation because of advantages such as positive energy efficiency, safety, and dependability. The constant acceleration of high-speed trains raises the excitation frequency of track imperfections and amplifies the contact between the vehicle and the track, reducing train comfort. Under these conditions, people are growing increasingly unsatisfied with train trip comfort. Furthermore, the irregularity of the tracks, a sort of stationary random excitation, and the variable arrangement of seats in the automobile body are to blame for the passengers' uncertainty of ride comfort. As a result, it is critical to increase passenger trip comfort and use the stationary random vibration method to study the zonal distribution of train comfort and the key influencing elements in order to offer a theoretical foundation for comfort improvement. [1]

Train ride comfort is the main indexes of evaluating in the trains, has the significant influence on riding and safe during the travel. The most sensitivity of human sensation differs in the direction of vibration and sound. As the vibration environment becomes more complex as the increasing the speed of train. Train is the most used system in traveling and it is most uncomfortable when vibration or motion in vertical direction [2]

The riding experience and well-being of passengers during transit are significantly impacted by ride comfort, one of the key metrics used to assess train performance. [3] The vibration directions and frequency range to be considered in real application may typically be identified from this perspective since the sensitivities of human sense vary in vibration directions and vibration frequency.[4] The vertical direction is the direction that researchers focus on the most when it comes to ride comfort. [5,6,7]. Due to their non-negligible contribution, such as lateral, vertical, and roll vibration in [8], vibrations from other directions begin to catch the researchers' attention as the vibration environment becomes more and more complex as train speed increases. Since the human body is not sensitive to vibrations over 20 Hz, which is notably true in the lateral and roll directions [9], the frequency range that is often taken into account for ride comfort is 0.5–20 Hz [10]

Acceleration on the carbody floor and human-seat interactions must be used to measure ride comfort in cars [11,12]. Most studies have so far ignored the human-seat system out of simplicity and merely evaluated ride comfort using acceleration at the seat base [13]. However, because of the intricate dynamics of the train seat, the vibration that is conveyed from the floor to the seated passengers can be altered. It was demonstrated through experimentation that passengers could dampen the flexural vibration of the car's body and that their distribution, posture, and foot position may affect the car's dynamics [14, 15]. Therefore, investigating ride comfort methodically utilising a comprehensive track-train-seat-human system will allow for more precise vehicle dynamics description and ride comfort evaluation using the accelerations measured at the human-seat interfaces [16, 17, 18]

The authors of the given study have long been interested in the running features and behaviours of wheeled modes of transportation. Their study is primarily concerned with ride safety, passenger comfort, and strategies to improve these. For these goals, they developed several simulation models, ran numerous computer simulations, and conducted tests on test stands. Their study focuses on rail vehicles as well as their safety and comfort. Various occurrences have been seen during these actions. Among them, it has been discovered that it is feasible to indicate decreasing running safety or comfort by studying changes in vehicle characteristics such as: mass and inertia parameters, suspension system parameters, contact element design (wheel/rail contact), the influence of input factors, including the excitation of a vehicle's mechanical system, stochastic phenomena during track running, and other influences.

In this paper, we use EEG sensor which detect the activities in human brain which is appearing in the human brain during the travel, it actually detects the how much people is uncomfortable in the train and ACCELEROMETER which actually placed/fixed at the seat and detect the vibration occurred in the train. And then we acquire the results which is detected from the EEG and ACCELEROMETER and then both data transfer to the main embedded server via wireless connection and data showed on the web page and set threshold that how much vibration and noise safe for human, mean not effect-able for human.

Now a days, train speed is increasing rapidly (600 kmph and 1200 kmph) in developed countries so peoples demand to increase safety and comfort of the train , if only increase in speed in not effect-able without safe in train during the travel,.in Pakistan trains are in some how bad condition and more uncomfortable to travel at least 100km continuously, so there should need of analysis and meed the standard (The standards ISO 2631 EN 12299)

The railway is an important part of the national economy. Because of the benefits of environmental preservation, convenience, speed, and safety, an increasing number of passengers prefer to travel vast distances by train [19].According to recent study, in Pakistan 80,000 peoples used train to travel and also generating 240 million dollars per year In 2014, the Ministry of Railways launched and started Pakistan Railway’s Vision 2026, which looks to increase PR's share in transportation sector of Pakistan from 4% to 20%, using US\$3.9 billion China–Pakistan Economic Corridor rail upgrade. The vision includes building new locomotives, development and.improvement of current rail infrastructure and increase in average train speed, improved on-time performance and enhance of passenger services. The first phase of project was completed in 2017, and the second phase was completed in 2021. Among them is the ML-1 project which will be completed in three phases with the cost of US\$4.9 billion.



Fig 1.1 Components

1.1 HISTORY

Pakistan Railways is indeed the binding force that connects every part of the country. It is the mode which the majority of the population adopts to travel and gets connected. Undoubtedly, Pakistan Railways has the infrastructure that suits the need of the people in a very orderly manner. Whether it is cargo or transportation Pakistan railways is indeed the first option of the majority. Sir Henry Edward, who was then the commissioner of Sindh, started the study on railways in the year 1858. According to the proposed plan, a railway track from Karachi city to kotri, Chenab to Multan and then to Lahore would be developed. Finally, on the 13th of May 1861, the track connecting Karachi and kotri was activated. The track was a hundred and five miles long; the track holds its position today and is used by traffic. Moreover, in 1889 a line connecting kemari and Karachi city was developed, and subsequently, in 1897 the track from keemari to kotri was inaugurated. During the last quarter of the 19th century, a rail line connecting Peshawar, Lahore, and Multan was initiated. The project was later completed in the starting few years of the 20 centuries [2,3]. Then the single solitary organization had the following segments: Scinde Railways. Indian flotilla company, Delhi Railways, and the Punjab Railways.

1.2 PROBLEM STATEMENT

Safety and comfort are the key parameters of any transportation, so a compromise to them can lead to a catastrophic outcome. There are different factors that can create ride discomfort such as, vibrations, slouched posture on seats, and temperature. This Project focuses on the analysis and diagnosing the ride comfort level based on acceleration measurement units (mainly accelerometer), EEG sensors by using Neural Network algorithm.

1.3 AIMS AND OBJECTIVES

1.3.1 AIMS:

Aim of this project is to provide comfort ride in train and safe travel, also meet with safety standard.

1.3.2 OBJECTIVES:

- i. Developing Sensors connection (ADXL345 And EEG) with NodeMCU using Arduino IDE. And creating an access point.
- ii. Creating the main server, which runs under Python Language, Collects Data from both sensors, via a Wifi access point, Configured in the third NodeMcu. And performs data analysis and Monitoring.
- iii. Showing the real-time data on graphs and comfort level in the results on Graphical interface.

1.4 PROJECT SCOPE

In Pakistan the many areas where trains are popular to travel but safety and safe travel is important during travel, in local class there is noise and pollution but in business class noise is , but some how less as compare to local class so , this project is to reduce noise and make train comfortable by analyzing through EEG sensor and ACCELEROMRTER sensor which detect the vibration and factors affecting on human body , by though we make train comfortable and safe travel and also, people can rate the train service that which is better for passengers by using application.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature review allows us to understand the current state of research in a particular field. It also includes information about improvements, methods, and potential research topics. It distinguishes your research from the research of others in the field.

2.2 COMFORT ANALYSIS

The main goal of this research aims to provide a solution that will not only analyze the railway ride comfort based on acceleration measurement but also will acquire brain signals, which will exhibit the current comfort of passengers. The aim is to analyze the comfort of the train through acceleration measurement and EEG sensors by using a neural network algorithm.

Different acceleration inputs, interconnected system architectures, preparation algorithms and objective functions were orderly examined, and optimum parameters were derivative. There has been obtained a new understanding of how anthropometric data affects riding comfort. According to the findings, the suggested technique is more accurate than existing standards in estimating subjective ride comfort. On public roads and in a controlled setting, data from a variety of field experiments involving 10 individuals were used to train neural networks. The study is supplemented by a clustering and sensitivity analysis, which finds the most crucial variables affecting the subjective assessment of ride comfort.[20]

To predict the journey comfort of bus passengers in real-time, a three-layer artificial neural network (ANN) model is developed. The trip comfort of bus passengers is a significant aspect that is known to attract increased ridership towards a sustainable public transport system. The ride comfort index in ISO 2631-1997 (vibration dose value and maximum transient vibration value), passenger-related features (posture, location, facing, gender, age, weight, and height), and vehicle-related parameters (speed, acceleration, and jerk) are the inputs. The output is passenger rating (collected from a specialized mobile

application). The ANN model performed satisfactorily and showed good input-output correlation, with an average MSE of 0.03 and an R-value of 0.83, respectively. To determine the relative importance of each variable in the ANN model, sensitivity analysis was also carried out. The results showed that all influencing factors contributed similarly, between 4 and 6 per cent. According to the connection weight technique, elements connected to passengers often contribute somewhat more to trip comfort assessment than do ones related to vehicles. Given that automated bus guidance systems use a significant degree of machine learning and artificial intelligence, it is crucial to design ANN models that can accurately predict how comfortable a bus journey would be (AB). The current research findings can assist AB designers and engineers in enhancing AB technologies to increase passenger comfort aboard. [21]

To demonstrate a systematic method for objectifying human comfort it includes the subjective comfort evaluation's prediction into the idea stage of the product development process. The subjectively perceived comfort of each passenger is calculated using a human feeling model based on artificial neural networks (ANN). In this study, two instances of the implementation of the proposed approaches are discussed. The first illustration shows an examination of comfort-related design elements for the drive train, such as the mass of inertia and the damping of the dual mass flywheel, as well as the friction coefficient gradient of the clutch friction pair. It is anticipated that the subsequent vibrational characteristics and subjective evaluations will occur during startup. In the second illustration, a 5-speed manual transmission's gear rattle tendency is determined. The ANN-based models representing the NVH specialists are developed to forecast the occurrence of gear rattles and to assess the resulting annoyance level. As a result, there is a solid link between subjective assessments and anticipated evaluations. As a result, the suggested approach may be used to assess various gearbox systems for new product concepts. As a result, the development period and expenses could be drastically cut. [22]

To identify the possible pathways for comfort degrading in high-speed rail systems and established an evaluation approach using machine learning to measure passenger comfort, this study uses the subjective approach to measure overall ride comfort, collecting

real-time data from twenty passengers. It was identified that the passengers who were in a state of comfort the brain areas (BA6/13/20/24/31/40/47) of passengers who experienced discomfort had strong beta band activation. An evaluation model based on the LightGBM algorithm was trained using six different types of characteristics collected from EEG data to assess the general comfort of train passengers. [23]

A model predictive control (MPC) approach integrated with machine learning to manage energy consumption and occupants' comfort (thermal and visual comfort) in a smart building is developed. To learn and estimate the building's requirements, climatic conditions, and electricity usage, neural networks (NNs) are established. The performance of the proposed learning-based MPC approach is compared to a model-based building control framework on a building that has been installed using EnergyPlus software. Resulting of the simulation, In terms of maintaining residents' comfort and lowering energy usage, the control method exceeds the traditional MPC by a wide margin. [24]

BP neural network and MATLAB software is used to obtain the correlations between the ride comfort indices to examine the relationships between different ride comfort rating metrics. Ride comfort is essential to both vehicle design and evaluation, different evaluation methods are discussed and recommended in research for assessing ride comfort in rail. The findings of this study can instantly change one index to another. They can easily obtain the evaluation result in terms of the required ride comfort index even when the raw data are unavailable or incomplete and the ride comfort is evaluated using one technique.[25]

A new approach for evaluating passenger car vibration comfort based on the precise contents of vibration signals is developed utilizing deep learning. To create a sample dataset, four-passenger automobiles are tested at various speeds and on various kinds of roads. A new data augmentation approach for deep learning that incorporates data segmentation and resampling is presented and tested to get around the dataset size limitations. Two fundamental models are created using two neural networks, the feed-forward neural network and gated recurrent units, where the gated recurrent units take into account the time sequence characteristic of vibration data. In addition, the frequency content is considered by generating two additional structures by adding a Fast Fourier

transform layer to the fundamental models. The findings in this study show that the suggested data augmentation strategy quickly increases the dataset and makes it possible to use deep learning to evaluate ride satisfaction. [26]

To analyze and find patterns between the subjective comfort values reported by study participants on a comfort scale of 1- 7, mechanical vibrations were noticed, measured in m/s^2 . To ensure the quality of the data, statistical techniques were applied to data that had been gathered as part of an earlier independent study. The machine learning models analyzed in this research have shown substantial possibilities for identifying complex patterns connecting emotions and thoughts to mechanical variables. During the estimation of the 6 or 7 levels of comfort, the precision level of models was up to 50%. [27]

To estimate lateral car-body accelerations a neural network-based optimal model is trained. It is possible to define the lateral dynamic behavior normally by comparing these predictions to the values obtained from the train measurements. Any variation from this general character will indicate a decline in comfort or a possible degeneration of the suspension and damping components. This model was developed using data from a particular train unit that included characteristics like lateral and vertical car-body accelerations, among others, that were recorded every second in 2017. The prediction of lateral car-body accelerations yields a minimum average inaccuracy of 0.034 m/s^2 . The average error is approximately 2.27% as reflected in the coaches of passengers in EN14363. Hence, an effective model is produced. [28]

To explore the comfort of the journey in rail cars, a rigid-flexible coupled train-seat-human model was created. For evaluating ride comfort, the weighted acceleration r.m.s. value at the seat pan was used. A power spectral density perspective was used to describe the contribution of various carbody modes to ride comfort. When the seat and bogie positions are far from the first bending mode's nodes, the first bending mode's function is more essential than that of other bending modes. In this case, the first bending mode's bogie spacing filter effect can be used to estimate the peaks and drops of the equivalent acceleration at the floor or human-seat interface as a function of speed or first bending frequency. To appropriately assess ride comfort, the human seat system had to be

included. With higher bending rigidity or slower speed, the ride comfort showed a general trend of improvement. Also, effectively increasing the damping ratio of the bending modes increased ride comfort. The riding comfort was decreased by stiffening or dampening the human-seat vertical contact with the seat pan. No matter the speed, the carbody centre and two ends of the ride were the least comfortable riding experiences. [29]

The ride comfort at vertical vibrations of the railway vehicle is analysed and evaluated using Sperling's and the mean comfort methods. The two methodologies share the fact that the comfort indices—namely, the ride comfort index NMVZ and the ride comfort index W_z —are used to estimate the comfort sensation. The values of these indexes were calculated by numerical simulations. The advantage of using numerical simulation results over experimental results—on which the majority of earlier research was based—lies in the ability to examine ride comfort indices while accounting for the influence of velocity and specific parameters that affect the behaviour of vertical vibrations of the carbody, such as carbody flexibility and suspension damping. The numerical simulation applications were created using a "flexible carbody" type model and an original model of the secondary suspension. These models were based on a theoretical model of the vehicle that takes into account significant aspects impacting the behaviour of vertical vibrations of the carbody. The results primarily demonstrate that, under equal vehicle operating conditions, the two assessment techniques result in dramatically different ride comfort outcomes.[30]

Anthropometric dummies and mathematical models were used to analyze the comfort and safety of passenger rail vehicles. In train emergency impact modelling with impediments, oscillograms of parameters for the dynamic interaction of dummies with interior car elements and a control cabinet of an electric train were obtained. The resulting analysis has made it possible to identify the internal components of the rolling stock that are most likely to cause injuries and draw conclusions regarding their safety. The outcomes of the analysis of the passenger rolling stock's comfort and safety can be applied to the creation of technical solutions for locomotives and trains. [31]

Pressure changes primarily take place as trains move through tunnels. Passengers on trains experience aural discomfort because of these aerodynamic effects. This study

investigated passenger pressure comfort by conducting a field investigation on the Cologne-Frankfurt/Main high-speed rail line and a simulation study in the pressure chamber TITAN (DLR-Institute of Aerospace Medicine) with 31 individuals. The discomfort of passengers was identified with the help of a generalized estimation equation model based on the parameters contributing to creating discomfort.[32]

As a resource for social consumption during the transportation process, the comfortable surroundings in railways passenger coaches could be considered. In order to develop a quantitative technique for calculating the RPCB while taking ticket prices into account, the authors of this study have chosen a number of objective and subjective criteria. Making the initial data dimensionless, figuring out how much each index weighs, and then figuring out the RPCBs are the three steps of this method. The data gathered from two different types of trains were used to validate the suggested strategy. The findings indicate that the RPCB and ticket price have a linear relationship with a correlation coefficient of 0.9616.[33]

To qualitatively assess and validate the comfort of transit trains by using longitudinal acceleration data gathered in Beijing subway systems and passenger feedback data. First, they create four regular fuzzy set-based comfort measurement models, whose parameters are established by field data and the experiences of subject-matter experts. The four regular fuzzy set models are then averaged to provide a combinational model, which elaborates a detailed measurement for the comfort of the ride. They conducted a questionnaire survey in the Beijing subway to verify the developed models. It is found that the averaging model performs better than any ordinary fuzzy set model when compared to the comfort levels and values derived by other models. Additionally, the improved model has higher accuracy and resilience for measuring riding comfort than the average model.[34]

2.3 METHODS:

There are numerous techniques that are used for ride comfort analysis as mentioned above. All of these come with different pros and cons in terms of accuracy, cost, availability, etc. A detailed discussion of this technique is given below in context to this. They are referenced from this set of research papers [35-41].

2.3.1 OBJECTIVE RIDE COMFORT MEASURES

An innovative dummy is an effective tool for an objective vehicle ride comfort evaluation. [35] The advantages of using an objective ride for comfort measures are the characterization of driving impression, impression scales of driving for comparisons, repeatability, and problem identification that occurred during driving. [36]

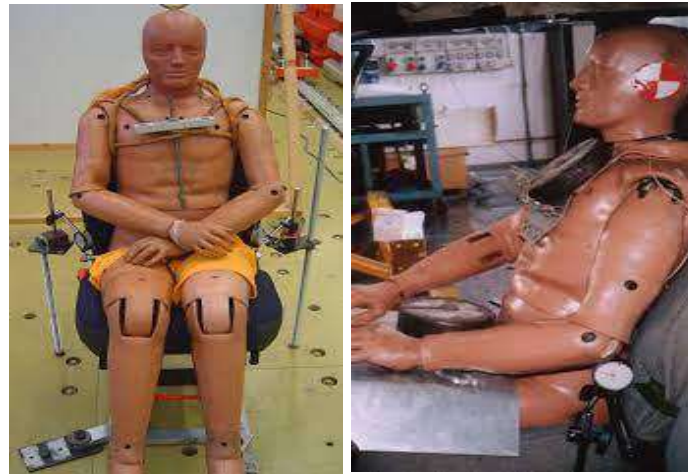


Fig 2.1 Dummy Model

2.3.2 SUBJECTIVE RIDE COMFORT MEASURES:

This type of ride comfort analysis relies on how the user is feeling. The questionnaires ask users to attribute their pain to a particular area of the seat. The automakers created thorough subjective evaluation methods using highly organized questionnaires. Body mapping is another approach that is employed in subjective measurement. The respondent will be asked to rate the parts of their bodies that are uncomfortable and to assign a scale to that discomfort. [37]

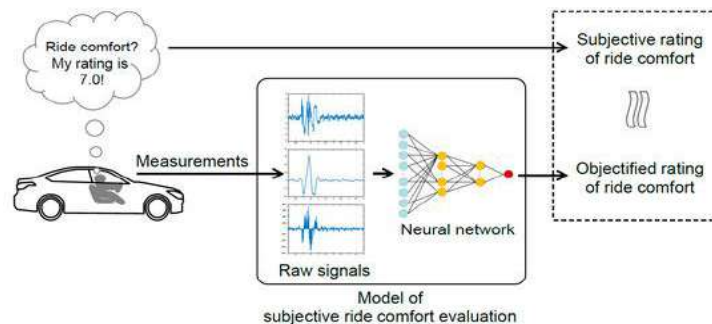


Fig 2.2 Model of Subjective ride comfort

2.3.3 RIDE COMFORT ANALYSIS USING ARTIFICIAL NEURAL NETWORKS (ANNS):

Several real-world applications have long used artificial neural networks (ANN), one of the artificial intelligence algorithms. It has the capacity to detect any set of input and output accurately without the need for a physical model, and yet the outputs of ANN do take into consideration all the dynamics connecting the input to the output. [38]

2.3.4 VIBRATION COMFORT EVALUATION FEED-FORWARD NEURAL NETWORK.

An artificial neural network of this kind that does not have looping connections between nodes is known as a feedforward neural network. Due to the fact that all input only travels forward, feedforward neural networks are so termed. Here is how it works; a classifier employs the equation $y = f^*(x)$. The network feedforward will map $y = f(x; \theta)$. After that, it stores in memory the value of that most closely resembles the function.[39]

2.3.5 Sperling's Method

The most popular techniques for evaluating passenger comfort on trains include Sperling's method. The dynamic reaction of a passenger to the vehicle body during an average train trip must be monitored by sensors to determine the degrees of ride comfort. With the frequency weighting curves corresponding to the various assessment techniques, the recorded time-domain accelerations would be processed. The frequency-weighted accelerations were used to produce the different ride comfort indices, including Sperling's index (WZ), Mean Comfort index (Nmv), and Continuous Comfort index (CC). After that, the frequency-referenced accelerations were weighted using the proper frequency factor to account for different ride comfort indices. [40]

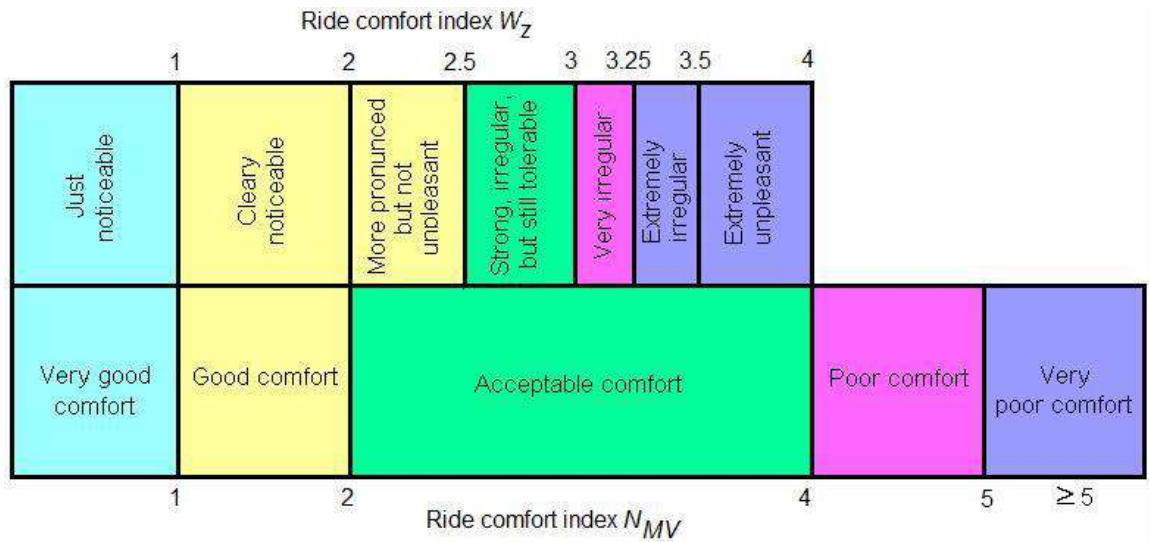


Fig 2.3 Ride Comfort index

2.3.6 COMFORT ANALYSIS USING ANTHROPOMETRIC DUMMIES.

A good motor vehicle seat should provide potential seat users with a sufficient level of vibration comfort. The anthropodynamic dummies that will be used to assess the vibration comfort have a structure similar to a seated human body, taking into mind the body areas where the experimental testing will be conducted. Where the head, thorax, and abdomen are distinct, a dummy with at least four degrees of freedom should be employed.[41]

CHAPTER 3

COMFORT LEVEL ANALYSIS

3.1 INTRODUCTION

In Pakistan, rail transportation plays a significant function in providing the necessary framework to fulfil the demands of a rapidly expanding economy. A comfortable environment in railway passenger carriages can be regarded as a resource for social consumption during the transport process. However, the Safety and comfort of passenger traffic one of the key problems of railway transport. The project is complemented by a clustering and sensitivity analysis, which finds the most critical factors influencing subjective ride comfort assessment. In this chapter objective of comfort level analysis is achieved.

3.2 BLOCK DIAGRAM

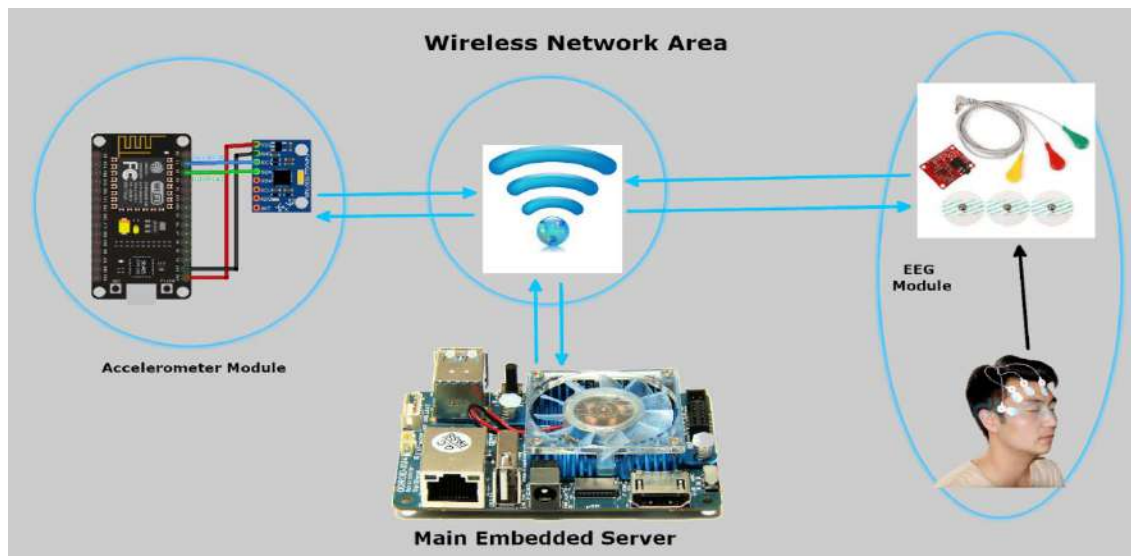
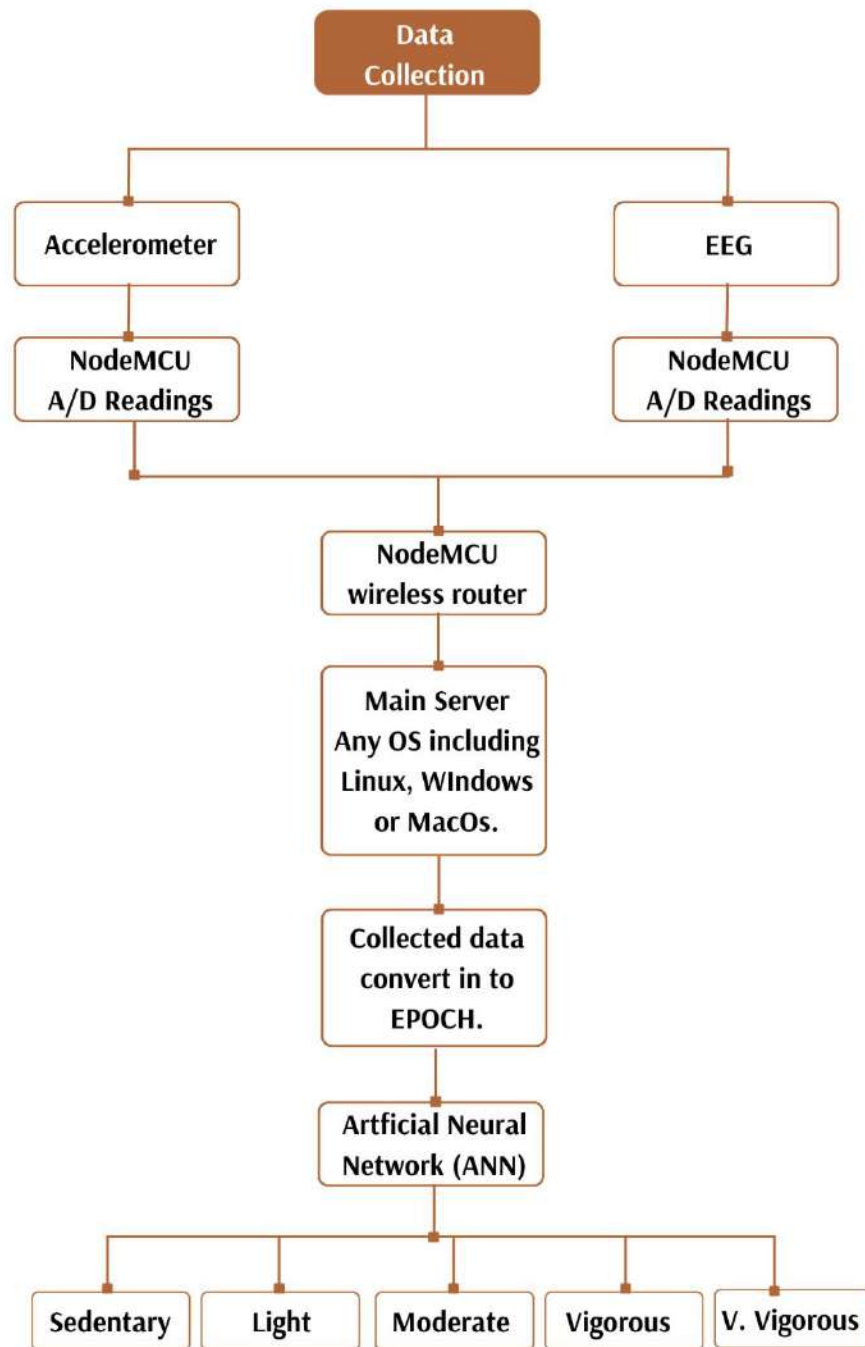


Fig 3.1 Block diagram of project mechanism

This block diagram shows the working mechanism of the project. Both the EEG and Accelerometer sensors are connected to the NodeMCU(Microcontroller) hardware. There is a third NodeMCU hardware which is acting as a wireless router which is connecting the sensors with the main embedded Server.

3.3 FLOW CHART OF COMFORT LEVEL ANALYSIS



3.4 METHODOLOGY

This chapter comprises both hardware and software parts. For the hardware part, the EEG sensor and Accelerometer are being used to collect the data. Each sensor is attached to NodeMCU(ESP8266) which collects analog reading and converts it into a digital reading. EEG Sensor sends data to the main server every millisecond. Whereas the Accelerometer sensor also sends the data to the main server every second with x, y and z positions. The NodeMCU is a component rich MCU with coordinated Wi-Fi and Bluetooth network that has a wide scope of uses such as in IoT projects. So, to establish a wireless router another NodeMCU is used which acts as an access point. All client and server communication is being done via a Wi-Fi interface. This access point connects all the sensors with the main server. The main server, which is running under Python Language, Collects Data from both sensors, via a Wi-Fi access point, Configured in the third NodeMCU. and performs data analysis and Monitoring.

The main server converts all the gathered data into EPOCH. The data coming from EEG is divided into 5 Epochs. Where Epoch means, that server collects 600 samples and divides them into 600/10 segments. Then, performs AI techniques to calculate the current outcome of the real-time EEG readings. Along with the EEG, Accelerometer data is also collected into 100 samples and divided into the correct Epoch Timelines, so that states of Jumps, comfort or jerks, can be calculated during each Epoch time.

3.5 PRESSURE POINTS VALIDATION

We have identified and validated the pressure points that are optimal for the collection of the EEG data during the field trial through “The Mehran Express Railway” from Karachi to Hyderabad. The points in the human body which go under the effect of discomfort during the journey on the train are identified. We also validate the point on the human head where the EEG sensor is going to attach.

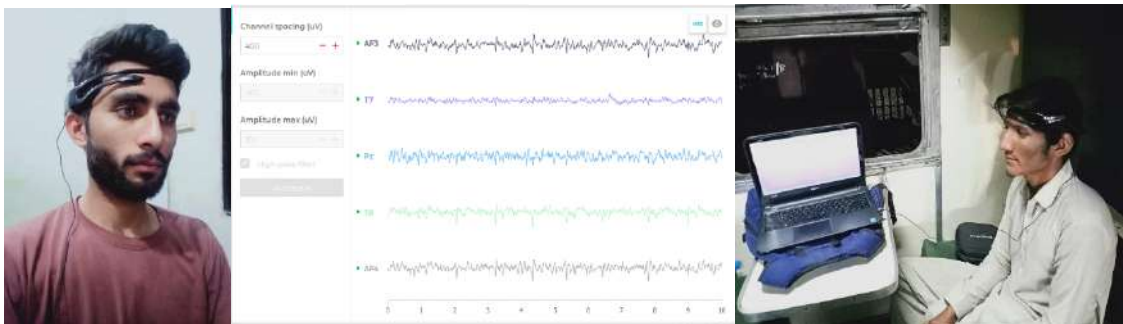


Fig 3.2 Pressure point validation during field trials

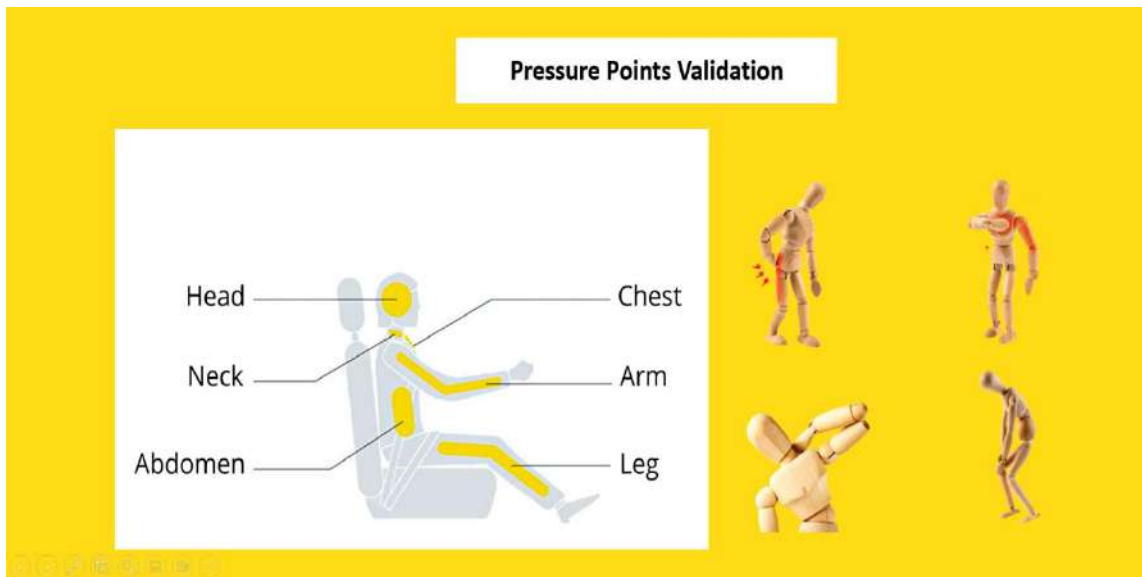


Fig 3.3 Pressure points

3.6 HARDWARE CONNECTION

All the sensors are connected to NodeMCU Hardware which fetches analogue readings of the EEG sensors and accelerometer (ADXL345), which sends the data to the database (main server) created in Python. Simplex communication of the sensory network and the main server is performed using a wireless network.

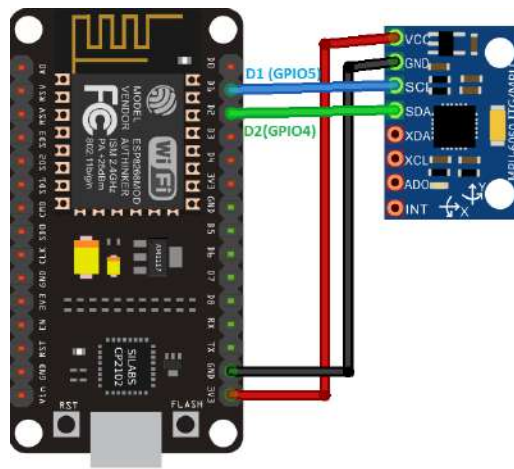
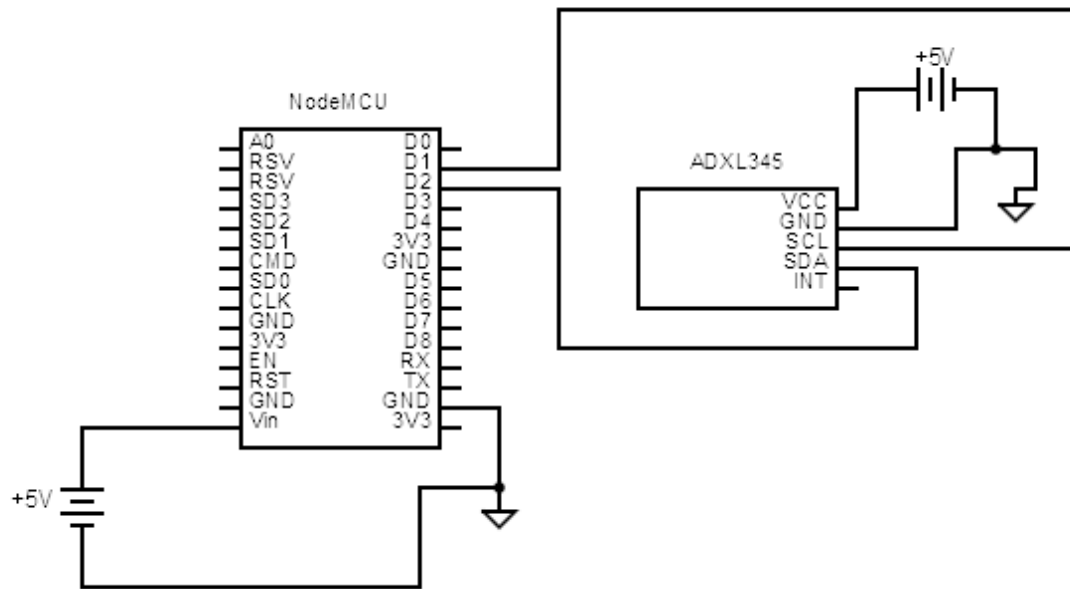


Fig 3.4 SPI Connection between ADXL 345 and NodeMCU

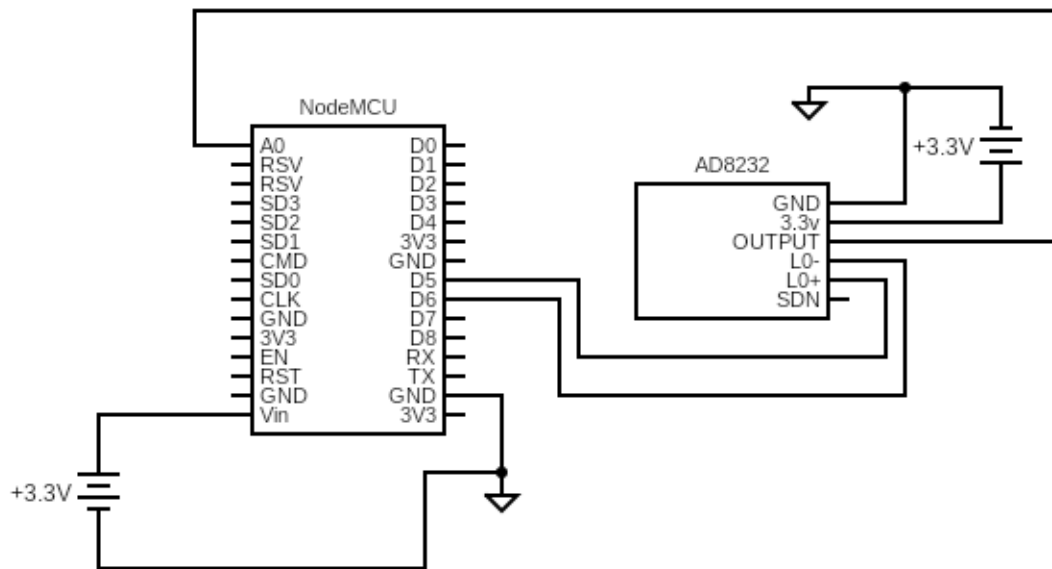


Fig 3.5 EEG Connection

3.6.1 CIRCUIT DIAGRAM OF ADXL 345 MODULE



3.6.2 CIRCUIT DIAGRAM OF EEG MODULE



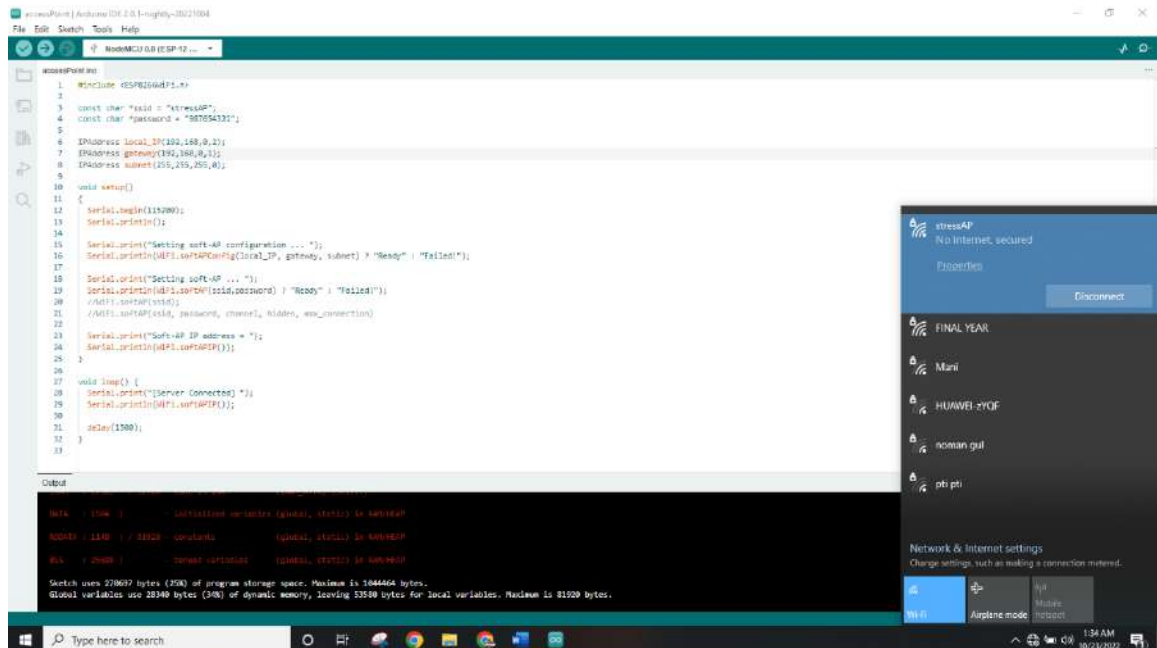
3.7 ARDUINO IDE CODE OVERVIEW

There are two parts of the code here. One is the Hardware side Code, which is written in C++, and the other is written in Python.

3.7.1 WIRELESS ROUTER (ACCESS POINT)

A Wi-Fi chip called the Lolin NodeMCU ESP8266 V3 can be utilised in a number of IoT applications. This module features a built-in Micro-USB that is simple to configure and contains switches for the flash and reset. To configure the NodeMCU Arduino IDE is being used. After putting the header file in the code, we named the wireless network “StressAP” along with the password “987654321”. A static IP address is assigned to make sure that its IP address does not change. To start the serial data a baud rate of 115200 is also fixed.

3.7.1.1 COMPLETE CODE OF CREATING ACCESS POINT



```
1 #include <ESP8266WiFi.h>
2
3 const char *ssid = "stressAP";
4 const char *password = "987654321";
5
6 IPAddress local_IP(192,168,0,2);
7 IPAddress gateway(192,168,0,1);
8 IPAddress subnet(255,255,0,0);
9
10 void setup()
11 {
12   Serial.begin(115200);
13   Serial.println();
14
15   Serial.println("Setting soft-AP configuration ...");
16   Serial.println(WiFi.softAPConfig(local_IP, gateway, subnet) ? "Ready" : "Failed");
17
18   Serial.println("Setting soft-AP ...");
19   Serial.println(WiFi.softAP(ssid, password) ? "Ready" : "Failed");
20   //WiFi.softAP(ssid);
21   //WiFi.softAP(ssid, password, channel, hidden, wpa_connection);
22
23   Serial.println("Soft-AP IP address = ");
24   Serial.println(WiFi.softAPIP());
25 }
26
27 void loop() {
28   Serial.println("Server Connected");
29   Serial.println(WiFi.softAPIP());
30
31   delay(1000);
32 }
33 }
```

Output

```
WiFi : 192.168.0.2  SoftAP IP address (local_IP) is 192.168.0.2
WiFi : 192.168.0.2  SoftAP IP address (local_IP) is 192.168.0.2
WiFi : 192.168.0.2  SoftAP IP address (local_IP) is 192.168.0.2
Sketch uses 270697 bytes (43%) of program storage space. Maximum is 644664 bytes.
Global variables use 28340 bytes (34%) of dynamic memory, leaving 53590 bytes for local variables. Maximum is 61500 bytes.
```

Fig 3.6 Code for creating wireless network “StresAP”


```

ADXL_Code | Arduino IDE 2.0.1-nightly-20211004
File Edit Sketch Tools Help
ESP8266 0.0 (ESP-12 Module)
ADXL_Code.ino
27
28 void setup_wifi()
29 {
30 // Configure static IP address
31 if (!WiFi.config(local_IP, gateway, subnet)) {
32   Serial.println("STA Failed to configure");
33 }
34 WiFi.begin(ssid, password);
35 int counter = 0;
36 while (WiFi.status() != WL_CONNECTED)
37 {
38   delay(1000);
39   Serial.println("Connecting...");
40   Serial.println(counter);
41   Serial.println();
42   counter++;
43 }
44 Serial.println("WiFi connected.");
45 Serial.println("IP address: ");
46 Serial.println(WiFi.localIP());
47 }
48
49 void setup()
50 {
51   Serial.begin(115200);
52   sprintf(hostString, "ESP_XXXX", ESP.getChipId());
53   Serial.println(hostString);
54   Serial.println(hostString);
55   WiFi.hostname(hostString);
56   if (!WiFi.begin(hostString))
57     Serial.println("Oops, no AP detected ... Check your wiring!");
58   while(1);
59 }
60
61 SerialMonitor X
62 Not connected. Select a board and a port to connect automatically.
63
64 Connected with wifewebap, channel 1
65 IP: 192.168.0.1, mac: 2800-100-100-0, gw: 192.168.0.1
66 AP: 192.168.0.1, mac: 2800-100-100-0, gw: 192.168.0.1
67 Connecting...
68
69
70 WiFi connected.
71 IP address: 192.168.0.8
72 HOST responder started

```

Fig 3.8 Code for creating Accelerometer Module

```

ADXL_Code | Arduino IDE 2.0.1-nightly-20211004
File Edit Sketch Tools Help
ESP8266 0.0 (ESP-12 Module)
ADXL_Code.ino
60 }
61 void setup_wifi()
62 {
63   Serial.begin(ADXL545_BAUD_0);
64   if (!WiFi.begin("esp")) {
65     Serial.println("Error setting up WiFi responder!");
66   }
67   Serial.println("WiFi responder started");
68   Serial.println("Sending MDNS query");
69   int n = MDNS.queryService("responder", "tcp");
70   if (n == 0) {
71     Serial.println("No service found");
72   }
73   else {
74     Serial.println("Service found");
75     Serial.println("Host: " + String(MDNS.hostname(0)));
76     Serial.println("IP: " + String(MDNS.IP(0)));
77     Serial.println("Port: " + String(MDNS.port(0)));
78   }
79 }
80
81 void loop()
82 {
83   sensor's_event_t event;
84   accel.getEvent(&event);
85   x = (event.acceleration.x)/9.8;
86   y = (event.acceleration.y)/9.8;
87   z = (event.acceleration.z)/9.8;
88   // Serial.print(x); Serial.print(",");
89   // Serial.print(y); Serial.print(",");
90   // Serial.println(z);
91   String fullStr = String(x) + "," + String(y) + "," + String(z);
92   Serial.println(fullStr);
93 }
94
95 SerialMonitor X
96 Not connected. Select a board and a port to connect automatically.
97
98 Connected with wifewebap, channel 1
99 IP: 192.168.0.1, mac: 2800-100-100-0, gw: 192.168.0.1
100 AP: 192.168.0.1, mac: 2800-100-100-0, gw: 192.168.0.1
101 Connecting...
102
103
104 WiFi connected.
105 IP address: 192.168.0.8
106 HOST responder started

```

Fig 3.9 Code for creating Accelerometer Module

```
ADXL_Code.ino
70 Serial.println("Port: " + String(DIG.port(0)));
71 }
72 }
73 }
74 }
75 }
76 }
77 }
78 }
79 }
80 }
81 }
82 void loop()
83 {
84   sensor_event_t event;
85   accel_getEvent(&event);
86   x = (event.acceleration.x)/9.8;
87   y = (event.acceleration.y)/9.8;
88   z = (event.acceleration.z)/9.8;
89   // Serial.print(x); Serial.print(", ");
90   // Serial.print(y); Serial.print(", ");
91   // Serial.print(z);
92   String fullStr = String(x) + "," + String(y) + "," + String(z);
93   Serial.println(fullStr);
94   //.....
95   if (WiFi.status() != WL_CONNECTED) {
96     setup_wifi();
97   } else {
98     WiFiClient client;
99     HTTPClient http;
100
101     // http.begin(client, "http://192.168.1.3:8080/updateADXL");
102     http.begin(client, "http://192.168.0.100:8080/updateADXL");
103     http.addHeader("Content-Type", "text/plain");
104
105     int httpCode = http.POST(fullStr);
106     http.end();
107   }
108   //.....
109   delay(1000);
110 }
111 }
```

Output SerialMonitor X:

```
Not connected. Select a board and a port to connect automatically.
connected with esp8266AP, address 0
ip:192.168.0.3,mask:255.255.255.0,gw:192.168.0.1
ip:192.168.0.3,mask:255.255.255.0,gw:192.168.0.1
Connecting...
41
WiFi connected.
IP address: 192.168.0.8
HTTP response received
Sending ADXL query
Rx packets found
0.44,-0.11,-0.18
0.31,-0.01,-0.10
pm:spm:type:0.0
0.34,-0.55,-0.16
0.34,-0.54,-0.16
0.34,-0.55,-0.17
0.34,-0.54,-0.16
0.34,-0.54,-0.16
0.34,-0.54,-0.16
0.34,-0.54,-0.17
0.34,-0.54,-0.16
-0.21,-1.02,-0.42
0.46,-0.76,-0.18
-0.32,-0.64,-0.28
0.31,0.25,0.33
-0.34,0.53,0.43
0.34,-0.31,0.18
0.34,-0.31,0.18
131.05,-0.00,132.14
8.02,-0.01,0.01
132.09,-0.00,133.15
[Server Connected] 192.168.0.1
[Server Connected] 192.168.0.1
```

Fig 3.10 Code for creating Accelerometer Module

3.7.2.2 SERIAL MONITOR OUTPUT OF ACCELEROMETER MODULE

```
ADXL_Code.ino
93 Serial.println(fullStr);
94 //.....
95 if (WiFi.status() != WL_CONNECTED) {
96   setup_wifi();
97 } else {
98   WiFiClient client;
99   HTTPClient http;
100
101   // http.begin(client, "http://192.168.1.3:8080/updateADXL");
102   http.begin(client, "http://192.168.0.100:8080/updateADXL");
103
104   int httpCode = http.POST(fullStr);
105   http.end();
106 }
107 //.....
108 delay(1000);
109 }
```

Output SerialMonitor X:

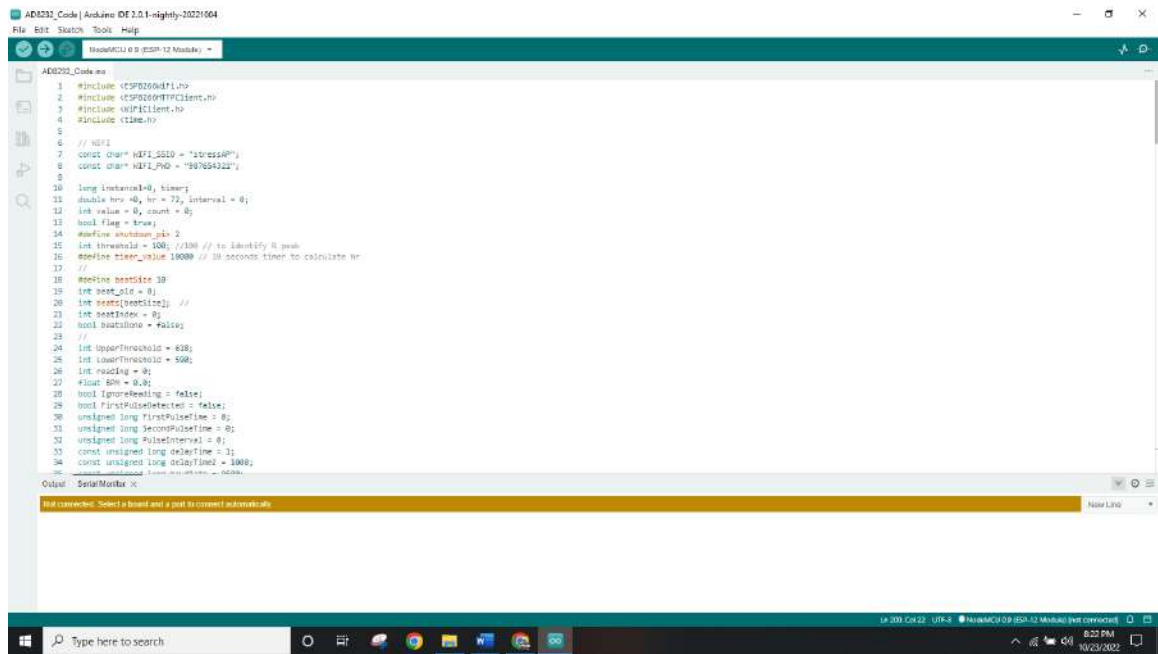
```
Not connected. Select a board and a port to connect automatically.
connected with esp8266AP, address 0
ip:192.168.0.3,mask:255.255.255.0,gw:192.168.0.1
ip:192.168.0.3,mask:255.255.255.0,gw:192.168.0.1
Connecting...
41
WiFi connected.
IP address: 192.168.0.8
HTTP response received
Sending ADXL query
Rx packets found
0.44,-0.11,-0.18
0.31,-0.01,-0.10
pm:spm:type:0.0
0.34,-0.55,-0.16
0.34,-0.54,-0.16
0.34,-0.55,-0.17
0.34,-0.54,-0.16
0.34,-0.54,-0.16
0.34,-0.54,-0.16
0.34,-0.54,-0.17
0.34,-0.54,-0.16
-0.21,-1.02,-0.42
0.46,-0.76,-0.18
-0.32,-0.64,-0.28
0.31,0.25,0.33
-0.34,0.53,0.43
0.34,-0.31,0.18
0.34,-0.31,0.18
131.05,-0.00,132.14
8.02,-0.01,0.01
132.09,-0.00,133.15
[Server Connected] 192.168.0.1
[Server Connected] 192.168.0.1
```

Fig 3.11 Serial monitor result of Accelerometer Module

3.7.3 EEG MODULE

An AD8232 ECG Sensor is being used to monitor the stress level which is connected to the NodeMCU hardware. To set up the connection we used Arduino IDE and included the libraries such as ESP8266 which gives the specific Wi-Fi functions that we are calling to establish a network connection. The heart rate in ECG lies between 60 to 100 beats per minute, in our module, we initialize it by 72. Along with that, we have initialized the upper threshold at 618 and the lower threshold at 590. Whereas, the minimum value coming from the sensor is 0 and the maximum value is 1023. It also has a static IP which tries to connect with the access point named “StressAP”. Once, the connection is built, it will send the data to the access point.

3.7.3.1 COMPLETE CODE OF EEG MODULE



```
AD8232_Code | Arduino IDE 2.0.1-nightly-2021044
File Edit Sketch Tools Help
NodeMCU 0.9 (ESP-12 Module)
AD8232_Code.ino
1 #include <ESP8266.h>
2 #include <ESP8266HTTPClient.h>
3 #include <WiFiClient.h>
4 #include <time.h>
5
6 // SSID
7 const char* SSID_SSID = "StressAP";
8 const char* SSID_PWD = "987654321";
9
10 long Interval=0, kuser;
11 double hrv=0, hr = 72, Interval = 0;
12 int value = 0, count = 0;
13 bool flag = true;
14 #define ANTI_ALIAS_P1 2
15 int Interval = 100; //100 // to identify R peak
16 #define timer_value 10000 // 10 seconds timer to calculate hr
17
18 //define maxsize IP
19 int beat_siz = 0;
20 int next(beat_siz); //
21 int nextIndex = 0;
22 bool nextIndex = false;
23
24 int UpperThreshold = 618;
25 int LowerThreshold = 590;
26 int reading = 0;
27 float RM = 0.0;
28 bool ignorebeating = false;
29 bool firstPulseDetected = false;
30 unsigned long firstPulseTime = 0;
31 unsigned long secondPulseTime = 0;
32 unsigned long PulseInterval = 0;
33 const unsigned long delayTime = 1;
34 const unsigned long delayTime2 = 1000;
35
36 //-----
37
38 //-----
39
40 //-----
41
42 //-----
43
44 //-----
45
46 //-----
47
48 //-----
49
50 //-----
51
52 //-----
53
54 //-----
55
56 //-----
57
58 //-----
59
60 //-----
61
62 //-----
63
64 //-----
65
66 //-----
67
68 //-----
69
70 //-----
71
72 //-----
73
74 //-----
75
76 //-----
77
78 //-----
79
80 //-----
81
82 //-----
83
84 //-----
85
86 //-----
87
88 //-----
89
90 //-----
91
92 //-----
93
94 //-----
95
96 //-----
97
98 //-----
99
100 //-----
101
102 //-----
103
104 //-----
105
106 //-----
107
108 //-----
109
110 //-----
111
112 //-----
113
114 //-----
115
116 //-----
117
118 //-----
119
120 //-----
121
122 //-----
123
124 //-----
125
126 //-----
127
128 //-----
129
130 //-----
131
132 //-----
133
134 //-----
135
136 //-----
137
138 //-----
139
140 //-----
141
142 //-----
143
144 //-----
145
146 //-----
147
148 //-----
149
150 //-----
151
152 //-----
153
154 //-----
155
156 //-----
157
158 //-----
159
160 //-----
161
162 //-----
163
164 //-----
165
166 //-----
167
168 //-----
169
170 //-----
171
172 //-----
173
174 //-----
175
176 //-----
177
178 //-----
179
180 //-----
181
182 //-----
183
184 //-----
185
186 //-----
187
188 //-----
189
190 //-----
191
192 //-----
193
194 //-----
195
196 //-----
197
198 //-----
199
200 //-----
201
202 //-----
203
204 //-----
205
206 //-----
207
208 //-----
209
210 //-----
211
212 //-----
213
214 //-----
215
216 //-----
217
218 //-----
219
220 //-----
221
222 //-----
223
224 //-----
225
226 //-----
227
228 //-----
229
230 //-----
231
232 //-----
233
234 //-----
235
236 //-----
237
238 //-----
239
240 //-----
241
242 //-----
243
244 //-----
245
246 //-----
247
248 //-----
249
250 //-----
251
252 //-----
253
254 //-----
255
256 //-----
257
258 //-----
259
260 //-----
261
262 //-----
263
264 //-----
265
266 //-----
267
268 //-----
269
270 //-----
271
272 //-----
273
274 //-----
275
276 //-----
277
278 //-----
279
280 //-----
281
282 //-----
283
284 //-----
285
286 //-----
287
288 //-----
289
290 //-----
291
292 //-----
293
294 //-----
295
296 //-----
297
298 //-----
299
300 //-----
301
302 //-----
303
304 //-----
305
306 //-----
307
308 //-----
309
310 //-----
311
312 //-----
313
314 //-----
315
316 //-----
317
318 //-----
319
320 //-----
321
322 //-----
323
324 //-----
325
326 //-----
327
328 //-----
329
330 //-----
331
332 //-----
333
334 //-----
335
336 //-----
337
338 //-----
339
340 //-----
341
342 //-----
343
344 //-----
345
346 //-----
347
348 //-----
349
350 //-----
351
352 //-----
353
354 //-----
355
356 //-----
357
358 //-----
359
360 //-----
361
362 //-----
363
364 //-----
365
366 //-----
367
368 //-----
369
370 //-----
371
372 //-----
373
374 //-----
375
376 //-----
377
378 //-----
379
380 //-----
381
382 //-----
383
384 //-----
385
386 //-----
387
388 //-----
389
390 //-----
391
392 //-----
393
394 //-----
395
396 //-----
397
398 //-----
399
400 //-----
401
402 //-----
403
404 //-----
405
406 //-----
407
408 //-----
409
410 //-----
411
412 //-----
413
414 //-----
415
416 //-----
417
418 //-----
419
420 //-----
421
422 //-----
423
424 //-----
425
426 //-----
427
428 //-----
429
430 //-----
431
432 //-----
433
434 //-----
435
436 //-----
437
438 //-----
439
440 //-----
441
442 //-----
443
444 //-----
445
446 //-----
447
448 //-----
449
450 //-----
451
452 //-----
453
454 //-----
455
456 //-----
457
458 //-----
459
460 //-----
461
462 //-----
463
464 //-----
465
466 //-----
467
468 //-----
469
470 //-----
471
472 //-----
473
474 //-----
475
476 //-----
477
478 //-----
479
480 //-----
481
482 //-----
483
484 //-----
485
486 //-----
487
488 //-----
489
490 //-----
491
492 //-----
493
494 //-----
495
496 //-----
497
498 //-----
499
500 //-----
501
502 //-----
503
504 //-----
505
506 //-----
507
508 //-----
509
510 //-----
511
512 //-----
513
514 //-----
515
516 //-----
517
518 //-----
519
520 //-----
521
522 //-----
523
524 //-----
525
526 //-----
527
528 //-----
529
530 //-----
531
532 //-----
533
534 //-----
535
536 //-----
537
538 //-----
539
540 //-----
541
542 //-----
543
544 //-----
545
546 //-----
547
548 //-----
549
550 //-----
551
552 //-----
553
554 //-----
555
556 //-----
557
558 //-----
559
560 //-----
561
562 //-----
563
564 //-----
565
566 //-----
567
568 //-----
569
570 //-----
571
572 //-----
573
574 //-----
575
576 //-----
577
578 //-----
579
580 //-----
581
582 //-----
583
584 //-----
585
586 //-----
587
588 //-----
589
590 //-----
591
592 //-----
593
594 //-----
595
596 //-----
597
598 //-----
599
600 //-----
601
602 //-----
603
604 //-----
605
606 //-----
607
608 //-----
609
610 //-----
611
612 //-----
613
614 //-----
615
616 //-----
617
618 //-----
619
620 //-----
621
622 //-----
623
624 //-----
625
626 //-----
627
628 //-----
629
630 //-----
631
632 //-----
633
634 //-----
635
636 //-----
637
638 //-----
639
640 //-----
641
642 //-----
643
644 //-----
645
646 //-----
647
648 //-----
649
650 //-----
651
652 //-----
653
654 //-----
655
656 //-----
657
658 //-----
659
660 //-----
661
662 //-----
663
664 //-----
665
666 //-----
667
668 //-----
669
670 //-----
671
672 //-----
673
674 //-----
675
676 //-----
677
678 //-----
679
680 //-----
681
682 //-----
683
684 //-----
685
686 //-----
687
688 //-----
689
690 //-----
691
692 //-----
693
694 //-----
695
696 //-----
697
698 //-----
699
700 //-----
701
702 //-----
703
704 //-----
705
706 //-----
707
708 //-----
709
710 //-----
711
712 //-----
713
714 //-----
715
716 //-----
717
718 //-----
719
720 //-----
721
722 //-----
723
724 //-----
725
726 //-----
727
728 //-----
729
730 //-----
731
732 //-----
733
734 //-----
735
736 //-----
737
738 //-----
739
740 //-----
741
742 //-----
743
744 //-----
745
746 //-----
747
748 //-----
749
750 //-----
751
752 //-----
753
754 //-----
755
756 //-----
757
758 //-----
759
760 //-----
761
762 //-----
763
764 //-----
765
766 //-----
767
768 //-----
769
770 //-----
771
772 //-----
773
774 //-----
775
776 //-----
777
778 //-----
779
780 //-----
781
782 //-----
783
784 //-----
785
786 //-----
787
788 //-----
789
790 //-----
791
792 //-----
793
794 //-----
795
796 //-----
797
798 //-----
799
800 //-----
801
802 //-----
803
804 //-----
805
806 //-----
807
808 //-----
809
810 //-----
811
812 //-----
813
814 //-----
815
816 //-----
817
818 //-----
819
820 //-----
821
822 //-----
823
824 //-----
825
826 //-----
827
828 //-----
829
830 //-----
831
832 //-----
833
834 //-----
835
836 //-----
837
838 //-----
839
840 //-----
841
842 //-----
843
844 //-----
845
846 //-----
847
848 //-----
849
850 //-----
851
852 //-----
853
854 //-----
855
856 //-----
857
858 //-----
859
860 //-----
861
862 //-----
863
864 //-----
865
866 //-----
867
868 //-----
869
870 //-----
871
872 //-----
873
874 //-----
875
876 //-----
877
878 //-----
879
880 //-----
881
882 //-----
883
884 //-----
885
886 //-----
887
888 //-----
889
890 //-----
891
892 //-----
893
894 //-----
895
896 //-----
897
898 //-----
899
900 //-----
901
902 //-----
903
904 //-----
905
906 //-----
907
908 //-----
909
910 //-----
911
912 //-----
913
914 //-----
915
916 //-----
917
918 //-----
919
920 //-----
921
922 //-----
923
924 //-----
925
926 //-----
927
928 //-----
929
930 //-----
931
932 //-----
933
934 //-----
935
936 //-----
937
938 //-----
939
940 //-----
941
942 //-----
943
944 //-----
945
946 //-----
947
948 //-----
949
950 //-----
951
952 //-----
953
954 //-----
955
956 //-----
957
958 //-----
959
960 //-----
961
962 //-----
963
964 //-----
965
966 //-----
967
968 //-----
969
970 //-----
971
972 //-----
973
974 //-----
975
976 //-----
977
978 //-----
979
980 //-----
981
982 //-----
983
984 //-----
985
986 //-----
987
988 //-----
989
990 //-----
991
992 //-----
993
994 //-----
995
996 //-----
997
998 //-----
999
1000 //-----
1001
1002 //-----
1003
1004 //-----
1005
1006 //-----
1007
1008 //-----
1009
1010 //-----
1011
1012 //-----
1013
1014 //-----
1015
1016 //-----
1017
1018 //-----
1019
1020 //-----
1021
1022 //-----
1023
1024 //-----
1025
1026 //-----
1027
1028 //-----
1029
1030 //-----
1031
1032 //-----
1033
1034 //-----
1035
1036 //-----
1037
1038 //-----
1039
1040 //-----
1041
1042 //-----
1043
1044 //-----
1045
1046 //-----
1047
1048 //-----
1049
1050 //-----
1051
1052 //-----
1053
1054 //-----
1055
1056 //-----
1057
1058 //-----
1059
1060 //-----
1061
1062 //-----
1063
1064 //-----
1065
1066 //-----
1067
1068 //-----
1069
1070 //-----
1071
1072 //-----
1073
1074 //-----
1075
1076 //-----
1077
1078 //-----
1079
1080 //-----
1081
1082 //-----
1083
1084 //-----
1085
1086 //-----
1087
1088 //-----
1089
1090 //-----
1091
1092 //-----
1093
1094 //-----
1095
1096 //-----
1097
1098 //-----
1099
1100 //-----
1101
1102 //-----
1103
1104 //-----
1105
1106 //-----
1107
1108 //-----
1109
1110 //-----
1111
1112 //-----
1113
1114 //-----
1115
1116 //-----
1117
1118 //-----
1119
1120 //-----
1121
1122 //-----
1123
1124 //-----
1125
1126 //-----
1127
1128 //-----
1129
1130 //-----
1131
1132 //-----
1133
1134 //-----
1135
1136 //-----
1137
1138 //-----
1139
1140 //-----
1141
1142 //-----
1143
1144 //-----
1145
1146 //-----
1147
1148 //-----
1149
1150 //-----
1151
1152 //-----
1153
1154 //-----
1155
1156 //-----
1157
1158 //-----
1159
1160 //-----
1161
1162 //-----
1163
1164 //-----
1165
1166 //-----
1167
1168 //-----
1169
1170 //-----
1171
1172 //-----
1173
1174 //-----
1175
1176 //-----
1177
1178 //-----
1179
1180 //-----
1181
1182 //-----
1183
1184 //-----
1185
1186 //-----
1187
1188 //-----
1189
1190 //-----
1191
1192 //-----
1193
1194 //-----
1195
1196 //-----
1197
1198 //-----
1199
1200 //-----
1201
1202 //-----
1203
1204 //-----
1205
1206 //-----
1207
1208 //-----
1209
1210 //-----
1211
1212 //-----
1213
1214 //-----
1215
1216 //-----
1217
1218 //-----
1219
1220 //-----
1221
1222 //-----
1223
1224 //-----
1225
1226 //-----
1227
1228 //-----
1229
1230 //-----
1231
1232 //-----
1233
1234 //-----
1235
1236 //-----
1237
1238 //-----
1239
1240 //-----
1241
1242 //-----
1243
1244 //-----
1245
1246 //-----
1247
1248 //-----
1249
1250 //-----
1251
1252 //-----
1253
1254 //-----
1255
1256 //-----
1257
1258 //-----
1259
1260 //-----
1261
1262 //-----
1263
1264 //-----
1265
1266 //-----
1267
1268 //-----
1269
1270 //-----
1271
1272 //-----
1273
1274 //-----
1275
1276 //-----
1277
1278 //-----
1279
1280 //-----
1281
1282 //-----
1283
1284 //-----
1285
1286 //-----
1287
1288 //-----
1289
1290 //-----
1291
1292 //-----
1293
1294 //-----
1295
1296 //-----
1297
1298 //-----
1299
1300 //-----
1301
1302 //-----
1303
1304 //-----
1305
1306 //-----
1307
1308 //-----
1309
1310 //-----
1311
1312 //-----
1313
1314 //-----
1315
1316 //-----
1317
1318 //-----
1319
1320 //-----
1321
1322 //-----
1323
1324 //-----
1325
1326 //-----
1327
1328 //-----
1329
1330 //-----
1331
1332 //-----
1333
1334 //-----
1335
1336 //-----
1337
1338 //-----
1339
1340 //-----
1341
1342 //-----
1343
1344 //-----
1345
1346 //-----
1347
1348 //-----
1349
1350 //-----
1351
1352 //-----
1353
1354 //-----
1355
1356 //-----
1357
1358 //-----
1359
1360 //-----
1361
1362 //-----
1363
1364 //-----
1365
1366 //-----
1367
1368 //-----
1369
1370 //-----
1371
1372 //-----
1373
1374 //-----
1375
1376 //-----
1377
1378 //-----
1379
1380 //-----
1381
1382 //-----
1383
1384 //-----
1385
1386 //-----
1387
1388 //-----
1389
1390 //-----
1391
1392 //-----
1393
1394 //-----
1395
1396 //-----
1397
1398 //-----
1399
1400 //-----
1401
1402 //-----
1403
1404 //-----
1405
1406 //-----
1407
1408 //-----
1409
1410 //-----
1411
1412 //-----
1413
1414 //-----
1415
1416 //-----
1417
1418 //-----
1419
1420 //-----
1421
1422 //-----
1423
1424 //-----
1425
1426 //-----
1427
1428 //-----
1429
1430 //-----
1431
1432 //-----
1433
1434 //-----
1435
1436 //-----
1437
1438 //-----
1439
1440 //-----
1441
1442 //-----
1443
1444 //-----
1445
1446 //-----
1447
1448 //-----
1449
1450 //-----
1451
1452 //-----
1453
1454 //-----
1455
1456 //-----
1457
1458 //-----
1459
1460 //-----
1461
1462 //-----
1463
1464 //-----
1465
1466 //-----
1467
1468 //-----
1469
1470 //-----
1471
1472 //-----
1473
1474 //-----
1475
1476 //-----
1477
1478 //-----
1479
1480 //-----
1481
1482 //-----
1483
1484 //-----
1485
1486 //-----
1487
1488 //-----
1489
1490 //-----
1491
1492 //-----
1493
1494 //-----
1495
1496 //-----
1497
1498 //-----
1499
1500 //-----
1501
1502 //-----
1503
1504 //-----
1505
1506 //-----
1507
1508 //-----
1509
1510 //-----
1511
1512 //-----
1513
1514 //-----
1515
1516 //-----
1517
1518 //-----
1519
1520 //-----
1521
1522 //-----
1523
1524 //-----
1525
1526 //-----
1527
1528 //-----
1529
1530 //-----
1531
1532 //-----
1533
1534 //-----
1535
1536 //-----
1537
1538 //-----
1539
1540 //-----
1541
1542 //-----
1543
1544 //-----
1545
1546 //-----
1547
1548 //-----
1549
1550 //-----
1551
1552 //-----
1553
1554 //-----
1555
1556 //-----
1557
1558 //-----
1559
1560 //-----
1561
1562 //-----
1563
1564 //-----
1565
1566 //-----
1567
1568 //-----
1569
1570 //-----
1571
1572 //-----
1573
1574 //-----
1575
1576 //-----
1577
1578 //-----
1579
1580 //-----
1581
1582 //-----
1583
1584 //-----
1585
1586 //-----
1587
1588 //-----
1589
1590 //-----
1591
1592 //-----
1593
1594 //-----
1595
1596 //-----
1597
1598 //-----
1599
1600 //-----
1601
1602 //-----
1603
1604 //-----
1605
1606 //-----
1607
1608 //-----
1609
1610 //-----
1611
1612 //-----
1613
1614 //-----
1615
1616 //-----
1617
1618 //-----
1619
1620 //-----
1621
1622 //-----
1623
1624 //-----
1625
1626 //-----
1627
1628 //-----
1629
1630 //-----
1631
1632 //-----
1633
1634 //-----
1635
1636 //-----
1637
1638 //-----
1639
1640 //-----
1641
1642 //-----
1643
1644 //-----
1645
1646 //-----
1647
1648 //-----
1649
1650 //-----
1651
1652 //-----
1653
1654 //-----
1655
1656 //-----
1657
1658 //-----
1659
1660 //-----
1661
1662 //-----
1663
1664 //-----
1665
1666 //-----
1667
1668 //-----
1669
1670 //-----
1671
1672 //-----
1673
1674 //-----
1675
1676 //-----
1677
1678 //-----
1679
1680 //-----
1681
1682 //-----
1683
1684 //-----
1685
1686 //-----
1687
1688 //-----
1689
1690 //-----
1691
1692 //-----
1693
1694 //-----
1695
1696 //-----
1697
1698 //-----
1699
1700 //-----
1701
1702 //-----
1703
1704 //-----
1705
1706 //-----
1707
1708 //-----
1709
1710 //-----
1711
1712 //-----
1713
1714 //-----
1715
1716 //-----
1717
1718 //-----
1719
1720 //-----
1721
1722 //-----
1723
1724 //-----
1725
1726 //-----
1727
1728 //-----
1729
1730 //-----
1731
1732 //-----
1733
1734 //-----
1735
1736 //-----
1737
1738 //-----
1739
1740 //-----
1741
1742 //-----
1743
1744 //-----
1745
1746 //-----
1747
1748 //-----
1749
1750 //-----
1751
1752 //-----
1753
1754 //-----
1755
1756 //-----
1757
1758 //-----
1759
1760 //-----
1761
1762 //-----
1763
1764 //-----
1765
1766 //-----
1767
1768 //-----
1769
1770 //-----
1771
1772 //-----
1773
1774 //-----
1775
1776 //-----
1777
1778 //-----
1779
1780 //-----
1781
1782 //-----
1783
1784 //-----
1785
1786 //-----
1787
1788 //-----
1789
1790 //-----
1791
1792 //-----
1793
1794 //-----
1795
1796 //-----
1797
1798 //-----
1799
1800 //-----
1801
1802 //-----
1803
1804 //-----
1805
1806 //-----
1807
1808 //-----
1809
1810 //-----
1811
1812 //-----
1813
1814 //-----
1815
1816 //-----
1817
1818 //-----
1819
1820 //-----
1821
1822 //-----
1823
1824 //-----
1825
1826 //-----
1827
1828 //-----
1829
1830 //-----
1831
1832 //-----
1833
1834 //-----
1835
1836 //-----
1837
1838 //-----
1839
1840 //-----
1841
1842 //-----
1843
1844 //-----
1845
1846 //-----
1847
1848 //-----
1849
1850 //-----
1851
1852 //-----
1853
1854 //-----
1855
1856 //-----
1857
1858 //-----
1859
1860 //-----
1861
1862 //-----
1863
1864 //-----
1865
1866 //-----
1867
1868 //-----
1869
1870 //-----
1871
1872 //-----
1873
1874 //-----
1875
1876 //-----
1877
1878 //-----
1879
1880 //-----
1881
1882 //-----
1883
1884 //-----
1885
1886 //-----
1887
1888 //-----
1889
1890 //-----
1891
1892 //-----
1893
1894 //-----
1895
1896 //-----
1897
1898 //-----
1899
1900 //-----
1901
1902 //-----
1903
1904 //-----
1905
1906 //-----
1907
1908 //-----
1909
1910 //-----
1911
1912 //-----
1913
1914 //-----
1915
1916 //-----
1917
1918 //-----
1919
1920 //-----
1921
1922 //-----
1923
1924 //-----
1925
1926 //-----
1927
1928 //-----
1929
1930 //-----
1931
1932 //-----
1933
1934 //-----
1935
1936 //-----
1937
1938 //-----
1939
1940 //-----
1941
1942 //-----
1943
1944 //-----
1945
1946 //-----
1947
1948 //-----
1949
1950 //-----
1951
1952 //-----
1953
1954 //-----
1955
1956 //-----
1957
1958 //-----
1959
1960 //-----
1961
1962 //-----
1963
1964 //-----
1965
1966 //-----
1967
1968 //-----
1969
1970 //-----
1971
1972 //-----
1973
1974 //-----
1975
1976 //-----
1977
1978 //-----
1979
1980 //-----
1981
1982 //-----
1983
1984 //-----
1985
1986 //-----
1987
1988 //-----
1989
1990 //-----
1991
1992 //-----
1993
1994 //-----
1995
1996 //-----
1997
1998 //-----
1999
2000 //-----
2001
2002 //-----
2003
2004 //-----
2005
2006 //-----
2007
2008 //-----
2009
2010 //-----
2011
2012 //-----
2013
2014 //-----
2015
2016 //-----
2017
2018 //-----
2019
2020 //-----
2021
2022 //-----
2023
2024 //-----
2025
2026 //-----
2027
2028 //-----
2029
2030 //-----
2031
2032 //-----
2033
2034 //-----
2035
2036 //-----
2037
2038 //-----
2039
2040 //-----
2041
2042 //-----
2043
2044 //-----
2045
2046 //-----
2047
2048 //-----
2049
2050 //-----
2051
2052 //-----
2053
2054 //-----
2055
2056 //-----
2057
2058 //-----
2059
2060 //-----
2061
2062 //-----
2063
2064 //-----
2065
2066 //-----
2067
2068 //-----
2069
2070 //-----
2071
2072 //-----
2073
2074 //-----
2075
2076 //-----
2077
2078 //-----
2079
2080 //-----
2081
2082 //-----
2083
2084 //-----
2085
2086 //-----
2087
2088 //-----
2089
2090 //-----
2091
2092 //-----
2093
2094 //-----
2095
2096 //-----
2097
2098 //-----
2099
2100 //-----
2101
2102 //-----
2103
2104 //-----
2105
2106 //-----
2107
2108 //-----
2109
2110 //-----
2111
2112 //-----
2113
2114 //-----
2115
2116 //-----
2117
2118 //-----
2119
2120 //-----
2121

```

```

AD8231_Code | Arduino IDE 2.0.1-nightly-20221004
File Edit Sketch Tools Help
Arduino IDE 0.9 (ESP-12 Module)
AD8231_Code.ino
34 const unsigned long delayTime = 1000;
35 const unsigned long timeout = 3000;
36 unsigned long previousMillis = 0;
37 unsigned long previousMillis2 = 0;
38
39 long counter = 0;
40 //Your Domain name with URL path or IP address with path
41 String serverName = "http://192.168.0.106:8850/getConnection";
42 unsigned long lastTime = 0;
43 unsigned long timerDelay = 2000//2000;
44 // Set your static IP address
45 IPAddress local_IP(192, 168, 0, 43);
46 // Set your Gateway IP address
47 IPAddress gateway(192, 168, 0, 1);
48
49 IPAddress subnet(255, 255, 255, 0);
50 int sensorValue = 0;
51 int sensorMin = 1000; // minimum sensor value
52 int sensorMax = 0; // maximum sensor value
53
54
55 void setup_wifi()
56 {
57 // Configures static IP address
58 if (!WiFi.config(local_IP, gateway, subnet)) {
59 Serial.println("STA failed to configure");
60 }
61 // WiFi.begin(WIFI_SSID, WIFI_PASS);
62 WiFi.begin(WIFI_SSID, WIFI_PASS);
63 int counter = 0;
64 while (WiFi.status() != WL_CONNECTED)
65 {
66 delay(1000);
67 Serial.println("Connecting...");
68 }
69 }
70
71 void loop()
72 {
73 // Your code here
74 }
75
76 void setup()
77 {
78 // Initialize the serial communication
79 Serial.begin(9600);
80 Serial.println("Serial setup...");
81 pinMode(5, INPUT); // Setup for leads off detection IO = gpio 5
82 pinMode(4, INPUT); // Setup for leads off detection IO = gpio 4
83 // pinMode(output_pin, OUTPUT);
84 // pinMode(LED_BUILTIN, OUTPUT);
85 // calls to during the first five seconds
86 // while (millis() < 5000) {
87 // sensorValue = analogRead(A0);
88 // }
89 // record the maximum sensor value
90 // if (sensorValue > sensorMax) {
91 // sensorMax = sensorValue;
92 // }
93 // }
94 // record the minimum sensor value
95 // if (sensorValue < sensorMin) {
96 // sensorMin = sensorValue;
97 // }
98 // }
99 // threshold = (sensorMax + sensorMin) / 2;
100 }
101 }
102 }
103 }
104 }
105 }
106 }
107 }
108 }
109 }
110 }
111 }
112 }
113 }
114 }
115 }
116 }
117 }
118 }
119 }
120 }
121 }
122 }
123 }
124 }
125 }
126 }
127 }
128 }
129 }
130 }
131 }
132 }
133 }
134 }
135 }
136 }
137 }
138 }
139 }
140 }
141 }
142 }
143 }
144 }
145 }
146 }
147 }
148 }
149 }
150 }
151 }
152 }
153 }
154 }
155 }
156 }
157 }
158 }
159 }
160 }
161 }
162 }
163 }
164 }
165 }
166 }
167 }
168 }
169 }
170 }
171 }
172 }
173 }
174 }
175 }
176 }
177 }
178 }
179 }
180 }
181 }
182 }
183 }
184 }
185 }
186 }
187 }
188 }
189 }
190 }
191 }
192 }
193 }
194 }
195 }
196 }
197 }
198 }
199 }
200 }
201 }
202 }
203 }
204 }
205 }
206 }
207 }
208 }
209 }
210 }
211 }
212 }
213 }
214 }
215 }
216 }
217 }
218 }
219 }
220 }
221 }
222 }
223 }
224 }
225 }
226 }
227 }
228 }
229 }
230 }
231 }
232 }
233 }
234 }
235 }
236 }
237 }
238 }
239 }
240 }
241 }
242 }
243 }
244 }
245 }
246 }
247 }
248 }
249 }
250 }
251 }
252 }
253 }
254 }
255 }
256 }
257 }
258 }
259 }
260 }
261 }
262 }
263 }
264 }
265 }
266 }
267 }
268 }
269 }
270 }
271 }
272 }
273 }
274 }
275 }
276 }
277 }
278 }
279 }
280 }
281 }
282 }
283 }
284 }
285 }
286 }
287 }
288 }
289 }
290 }
291 }
292 }
293 }
294 }
295 }
296 }
297 }
298 }
299 }
300 }
301 }
302 }
303 }
304 }
305 }
306 }
307 }
308 }
309 }
310 }
311 }
312 }
313 }
314 }
315 }
316 }
317 }
318 }
319 }
320 }
321 }
322 }
323 }
324 }
325 }
326 }
327 }
328 }
329 }
330 }
331 }
332 }
333 }
334 }
335 }
336 }
337 }
338 }
339 }
340 }
341 }
342 }
343 }
344 }
345 }
346 }
347 }
348 }
349 }
350 }
351 }
352 }
353 }
354 }
355 }
356 }
357 }
358 }
359 }
360 }
361 }
362 }
363 }
364 }
365 }
366 }
367 }
368 }
369 }
370 }
371 }
372 }
373 }
374 }
375 }
376 }
377 }
378 }
379 }
380 }
381 }
382 }
383 }
384 }
385 }
386 }
387 }
388 }
389 }
390 }
391 }
392 }
393 }
394 }
395 }
396 }
397 }
398 }
399 }
400 }
401 }
402 }
403 }
404 }
405 }
406 }
407 }
408 }
409 }
410 }
411 }
412 }
413 }
414 }
415 }
416 }
417 }
418 }
419 }
420 }
421 }
422 }
423 }
424 }
425 }
426 }
427 }
428 }
429 }
430 }
431 }
432 }
433 }
434 }
435 }
436 }
437 }
438 }
439 }
440 }
441 }
442 }
443 }
444 }
445 }
446 }
447 }
448 }
449 }
450 }
451 }
452 }
453 }
454 }
455 }
456 }
457 }
458 }
459 }
460 }
461 }
462 }
463 }
464 }
465 }
466 }
467 }
468 }
469 }
470 }
471 }
472 }
473 }
474 }
475 }
476 }
477 }
478 }
479 }
480 }
481 }
482 }
483 }
484 }
485 }
486 }
487 }
488 }
489 }
490 }
491 }
492 }
493 }
494 }
495 }
496 }
497 }
498 }
499 }
500 }
501 }
502 }
503 }
504 }
505 }
506 }
507 }
508 }
509 }
510 }
511 }
512 }
513 }
514 }
515 }
516 }
517 }
518 }
519 }
520 }
521 }
522 }
523 }
524 }
525 }
526 }
527 }
528 }
529 }
530 }
531 }
532 }
533 }
534 }
535 }
536 }
537 }
538 }
539 }
540 }
541 }
542 }
543 }
544 }
545 }
546 }
547 }
548 }
549 }
550 }
551 }
552 }
553 }
554 }
555 }
556 }
557 }
558 }
559 }
560 }
561 }
562 }
563 }
564 }
565 }
566 }
567 }
568 }
569 }
570 }
571 }
572 }
573 }
574 }
575 }
576 }
577 }
578 }
579 }
580 }
581 }
582 }
583 }
584 }
585 }
586 }
587 }
588 }
589 }
590 }
591 }
592 }
593 }
594 }
595 }
596 }
597 }
598 }
599 }
600 }
601 }
602 }
603 }
604 }
605 }
606 }
607 }
608 }
609 }
610 }
611 }
612 }
613 }
614 }
615 }
616 }
617 }
618 }
619 }
620 }
621 }
622 }
623 }
624 }
625 }
626 }
627 }
628 }
629 }
630 }
631 }
632 }
633 }
634 }
635 }
636 }
637 }
638 }
639 }
640 }
641 }
642 }
643 }
644 }
645 }
646 }
647 }
648 }
649 }
650 }
651 }
652 }
653 }
654 }
655 }
656 }
657 }
658 }
659 }
660 }
661 }
662 }
663 }
664 }
665 }
666 }
667 }
668 }
669 }
670 }
671 }
672 }
673 }
674 }
675 }
676 }
677 }
678 }
679 }
680 }
681 }
682 }
683 }
684 }
685 }
686 }
687 }
688 }
689 }
690 }
691 }
692 }
693 }
694 }
695 }
696 }
697 }
698 }
699 }
700 }
701 }
702 }
703 }
704 }
705 }
706 }
707 }
708 }
709 }
710 }
711 }
712 }
713 }
714 }
715 }
716 }
717 }
718 }
719 }
720 }
721 }
722 }
723 }
724 }
725 }
726 }
727 }
728 }
729 }
730 }
731 }
732 }
733 }
734 }
735 }
736 }
737 }
738 }
739 }
740 }
741 }
742 }
743 }
744 }
745 }
746 }
747 }
748 }
749 }
750 }
751 }
752 }
753 }
754 }
755 }
756 }
757 }
758 }
759 }
760 }
761 }
762 }
763 }
764 }
765 }
766 }
767 }
768 }
769 }
770 }
771 }
772 }
773 }
774 }
775 }
776 }
777 }
778 }
779 }
780 }
781 }
782 }
783 }
784 }
785 }
786 }
787 }
788 }
789 }
790 }
791 }
792 }
793 }
794 }
795 }
796 }
797 }
798 }
799 }
800 }
801 }
802 }
803 }
804 }
805 }
806 }
807 }
808 }
809 }
810 }
811 }
812 }
813 }
814 }
815 }
816 }
817 }
818 }
819 }
820 }
821 }
822 }
823 }
824 }
825 }
826 }
827 }
828 }
829 }
830 }
831 }
832 }
833 }
834 }
835 }
836 }
837 }
838 }
839 }
840 }
841 }
842 }
843 }
844 }
845 }
846 }
847 }
848 }
849 }
850 }
851 }
852 }
853 }
854 }
855 }
856 }
857 }
858 }
859 }
860 }
861 }
862 }
863 }
864 }
865 }
866 }
867 }
868 }
869 }
870 }
871 }
872 }
873 }
874 }
875 }
876 }
877 }
878 }
879 }
880 }
881 }
882 }
883 }
884 }
885 }
886 }
887 }
888 }
889 }
890 }
891 }
892 }
893 }
894 }
895 }
896 }
897 }
898 }
899 }
900 }
901 }
902 }
903 }
904 }
905 }
906 }
907 }
908 }
909 }
910 }
911 }
912 }
913 }
914 }
915 }
916 }
917 }
918 }
919 }
920 }
921 }
922 }
923 }
924 }
925 }
926 }
927 }
928 }
929 }
930 }
931 }
932 }
933 }
934 }
935 }
936 }
937 }
938 }
939 }
940 }
941 }
942 }
943 }
944 }
945 }
946 }
947 }
948 }
949 }
950 }
951 }
952 }
953 }
954 }
955 }
956 }
957 }
958 }
959 }
960 }
961 }
962 }
963 }
964 }
965 }
966 }
967 }
968 }
969 }
970 }
971 }
972 }
973 }
974 }
975 }
976 }
977 }
978 }
979 }
980 }
981 }
982 }
983 }
984 }
985 }
986 }
987 }
988 }
989 }
990 }
991 }
992 }
993 }
994 }
995 }
996 }
997 }
998 }
999 }
1000 }
1001 }
1002 }
1003 }
1004 }
1005 }
1006 }
1007 }
1008 }
1009 }
1010 }
1011 }
1012 }
1013 }
1014 }
1015 }
1016 }
1017 }
1018 }
1019 }
1020 }
1021 }
1022 }
1023 }
1024 }
1025 }
1026 }
1027 }
1028 }
1029 }
1030 }
1031 }
1032 }
1033 }
1034 }
1035 }
1036 }
1037 }
1038 }
1039 }
1040 }
1041 }
1042 }
1043 }
1044 }
1045 }
1046 }
1047 }
1048 }
1049 }
1050 }
1051 }
1052 }
1053 }
1054 }
1055 }
1056 }
1057 }
1058 }
1059 }
1060 }
1061 }
1062 }
1063 }
1064 }
1065 }
1066 }
1067 }
1068 }
1069 }
1070 }
1071 }
1072 }
1073 }
1074 }
1075 }
1076 }
1077 }
1078 }
1079 }
1080 }
1081 }
1082 }
1083 }
1084 }
1085 }
1086 }
1087 }
1088 }
1089 }
1090 }
1091 }
1092 }
1093 }
1094 }
1095 }
1096 }
1097 }
1098 }
1099 }
1100 }
1101 }
1102 }
1103 }
1104 }
1105 }
1106 }
1107 }
1108 }
1109 }
1110 }
1111 }
1112 }
1113 }
1114 }
1115 }
1116 }
1117 }
1118 }
1119 }
1120 }
1121 }
1122 }
1123 }
1124 }
1125 }
1126 }
1127 }
1128 }
1129 }
1130 }
1131 }
1132 }
1133 }
1134 }
1135 }
1136 }
1137 }
1138 }
1139 }
1140 }
1141 }
1142 }
1143 }
1144 }
1145 }
1146 }
1147 }
1148 }
1149 }
1150 }
1151 }
1152 }
1153 }
1154 }
1155 }
1156 }
1157 }
1158 }
1159 }
1160 }
1161 }
1162 }
1163 }
1164 }
1165 }
1166 }
1167 }
1168 }
1169 }
1170 }
1171 }
1172 }
1173 }
1174 }
1175 }
1176 }
1177 }
1178 }
1179 }
1180 }
1181 }
1182 }
1183 }
1184 }
1185 }
1186 }
1187 }
1188 }
1189 }
1190 }
1191 }
1192 }
1193 }
1194 }
1195 }
1196 }
1197 }
1198 }
1199 }
1200 }
1201 }
1202 }
1203 }
1204 }
1205 }
1206 }
1207 }
1208 }
1209 }
1210 }
1211 }
1212 }
1213 }
1214 }
1215 }
1216 }
1217 }
1218 }
1219 }
1220 }
1221 }
1222 }
1223 }
1224 }
1225 }
1226 }
1227 }
1228 }
1229 }
1230 }
1231 }
1232 }
1233 }
1234 }
1235 }
1236 }
1237 }
1238 }
1239 }
1240 }
1241 }
1242 }
1243 }
1244 }
1245 }
1246 }
1247 }
1248 }
1249 }
1250 }
1251 }
1252 }
1253 }
1254 }
1255 }
1256 }
1257 }
1258 }
1259 }
1260 }
1261 }
1262 }
1263 }
1264 }
1265 }
1266 }
1267 }
1268 }
1269 }
1270 }
1271 }
1272 }
1273 }
1274 }
1275 }
1276 }
1277 }
1278 }
1279 }
1280 }
1281 }
1282 }
1283 }
1284 }
1285 }
1286 }
1287 }
1288 }
1289 }
1290 }
1291 }
1292 }
1293 }
1294 }
1295 }
1296 }
1297 }
1298 }
1299 }
1300 }
1301 }
1302 }
1303 }
1304 }
1305 }
1306 }
1307 }
1308 }
1309 }
1310 }
1311 }
1312 }
1313 }
1314 }
1315 }
1316 }
1317 }
1318 }
1319 }
1320 }
1321 }
1322 }
1323 }
1324 }
1325 }
1326 }
1327 }
1328 }
1329 }
1330 }
1331 }
1332 }
1333 }
1334 }
1335 }
1336 }
1337 }
1338 }
1339 }
1340 }
1341 }
1342 }
1343 }
1344 }
1345 }
1346 }
1347 }
1348 }
1349 }
1350 }
1351 }
1352 }
1353 }
1354 }
1355 }
1356 }
1357 }
1358 }
1359 }
1360 }
1361 }
1362 }
1363 }
1364 }
1365 }
1366 }
1367 }
1368 }
1369 }
1370 }
1371 }
1372 }
1373 }
1374 }
1375 }
1376 }
1377 }
1378 }
1379 }
1380 }
1381 }
1382 }
1383 }
1384 }
1385 }
1386 }
1387 }
1388 }
1389 }
1390 }
1391 }
1392 }
1393 }
1394 }
1395 }
1396 }
1397 }
1398 }
1399 }
1400 }
1401 }
1402 }
1403 }
1404 }
1405 }
1406 }
1407 }
1408 }
1409 }
1410 }
1411 }
1412 }
1413 }
1414 }
1415 }
1416 }
1417 }
1418 }
1419 }
1420 }
1421 }
1422 }
1423 }
1424 }
1425 }
1426 }
1427 }
1428 }
1429 }
1430 }
1431 }
1432 }
1433 }
1434 }
1435 }
1436 }
1437 }
1438 }
1439 }
1440 }
1441 }
1442 }
1443 }
1444 }
1445 }
1446 }
1447 }
1448 }
1449 }
1450 }
1451 }
1452 }
1453 }
1454 }
1455 }
1456 }
1457 }
1458 }
1459 }
1460 }
1461 }
1462 }
1463 }
1464 }
1465 }
1466 }
1467 }
1468 }
1469 }
1470 }
1471 }
1472 }
1473 }
1474 }
1475 }
1476 }
1477 }
1478 }
1479 }
1480 }
1481 }
1482 }
1483 }
1484 }
1485 }
1486 }
1487 }
1488 }
1489 }
1490 }
1491 }
1492 }
1493 }
1494 }
1495 }
1496 }
1497 }
1498 }
1499 }
1500 }
1501 }
1502 }
1503 }
1504 }
1505 }
1506 }
1507 }
1508 }
1509 }
1510 }
1511 }
1512 }
1513 }
1514 }
1515 }
1516 }
1517 }
1518 }
1519 }
1520 }
1521 }
1522 }
1523 }
1524 }
1525 }
1526 }
1527 }
1528 }
1529 }
1530 }
1531 }
1532 }
1533 }
1534 }
1535 }
1536 }
1537 }
1538 }
1539 }
1540 }
1541 }
1542 }
1543 }
1544 }
1545 }
1546 }
1547 }
1548 }
1549 }
1550 }
1551 }
1552 }
1553 }
1554 }
1555 }
1556 }
1557 }
1558 }
1559 }
1560 }
1561 }
1562 }
1563 }
1564 }
1565 }
1566 }
1567 }
1568 }
1569 }
1570 }
1571 }
1572 }
1573 }
1574 }
1575 }
1576 }
1577 }
1578 }
1579 }
1580 }
1581 }
1582 }
1583 }
1584 }
1585 }
1586 }
1587 }
1588 }
1589 }
1590 }
1591 }
1592 }
1593 }
1594 }
1595 }
1596 }
1597 }
1598 }
1599 }
1600 }
1601 }
1602 }
1603 }
1604 }
1605 }
1606 }
1607 }
1608 }
1609 }
1610 }
1611 }
1612 }
1613 }
1614 }
1615 }
1616 }
1617 }
1618 }
1619 }
1620 }
1621 }
1622 }
1623 }
1624 }
1625 }
1626 }
1627 }
1628 }
1629 }
1630 }
1631 }
1632 }
1633 }
1634 }
1635 }
1636 }
1637 }
1638 }
1639 }
1640 }
1641 }
1642 }
1643 }
1644 }
1645 }
1646 }
1647 }
1648 }
1649 }
1650 }
1651 }
1652 }
1653 }
1654 }
1655 }
1656 }
1657 }
1658 }
1659 }
1660 }
1661 }
1662 }
1663 }
1664 }
1665 }
1666 }
1667 }
1668 }
1669 }
1670 }
1671 }
1672 }
1673 }
1674 }
1675 }
1676 }
1677 }
1678 }
1679 }
1680 }
1681 }
1682 }
1683 }
1684 }
1685 }
1686 }
1687 }
1688 }
1689 }
1690 }
1691 }
1692 }
1693 }
1694 }
1695 }
1696 }
1697 }
1698 }
1699 }
1700 }
1701 }
1702 }
1703 }
1704 }
1705 }
1706 }
1707 }
1708 }
1709 }
1710 }
1711 }
1712 }
1713 }
1714 }
1715 }
1716 }
1717 }
1718 }
1719 }
1720 }
1721 }
1722 }
1723 }
1724 }
1725 }
1726 }
1727 }
1728 }
1729 }
1730 }
1731 }
1732 }
1733 }
1734 }
1735 }
1736 }
1737 }
1738 }
1739 }
1740 }
1741 }
1742 }
1743 }
1744 }
1745 }
1746 }
1747 }
1748 }
1749 }
1750 }
1751 }
1752 }
1753 }
1754 }
1755 }
1756 }
1757 }
1758 }
1759 }
1760 }
1761 }
1762 }
1763 }
1764 }
1765 }
1766 }
1767 }
1768 }
1769 }
1770 }
1771 }
1772 }
1773 }
1774 }
1775 }
1776 }
1777 }
1778 }
1779 }
1780 }
1781 }
1782 }
1783 }
1784 }
1785 }
1786 }
1787 }
1788 }
1789 }
1790 }
1791 }
1792 }
1793 }
1794 }
1795 }
1796 }
1797 }
1798 }
1799 }
1800 }
1801 }
1802 }
1803 }
1804 }
1805 }
1806 }
1807 }
1808 }
1809 }
1810 }
1811 }
1812 }
1813 }
1814 }
1815 }
1816 }
1817 }
1818 }
1819 }
1820 }
1821 }
1822 }
1823 }
1824 }
1825 }
1826 }
1827 }
1828 }
1829 }
1830 }
1831 }
1832 }
1833 }
1834 }
1835 }
1836 }
1837 }
1838 }
1839 }
1840 }
1841 }
1842 }
1843 }
1844 }
1845 }
1846 }
1847 }
1848 }
1849 }
1850 }
1851 }
1852 }
1853 }
1854 }
1855 }
1856 }
1857 }
1858 }
1859 }
1860 }
1861 }
1862 }
1863 }
1864 }
1865 }
1866 }
1867 }
1868 }
1869 }
1870 }
1871 }
1872 }
1873 }
1874 }
1875 }
1876 }
1877 }
1878 }
1879 }
1880 }
1881 }
1882 }
1883 }
1884 }
1885 }
1886 }
1887 }
1888 }
1889 }
1890 }
1891 }
1892 }
1893 }
1894 }
1895 }
1896 }
1897 }
1898 }
1899 }
1900 }
1901 }
1902 }
1903 }
1904 }
1905 }
1906 }
1907 }
1908 }
1909 }
1910 }
1911 }
1912 }
1913 }
1914 }
1915 }
1916 }
1917 }
1918 }
1919 }
1920 }
1921 }
1922 }
1923 }
1924 }
1925 }
1926 }
1927 }
1928 }
1929 }
1930 }
1931 }
1932 }
1933 }
1934 }
1935 }
1936 }
1937 }
1938 }
1939 }
1940 }
1941 }
1942 }
1943 }
1944 }
1945 }
1946 }
1947 }
1948 }
1949 }
1950 }
1951 }
1952 }
1953 }
1954 }
1955 }
1956 }
1957 }
1958 }
1959 }
1960 }
1961 }
1962 }
1963 }
1964 }
1965 }
1966 }
1967 }
1968 }
1969 }
1970 }
1971 }
1972 }
1973 }
1974 }
1975 }
1976 }
1977 }
1978 }
1979 }
1980 }
1981 }
1982 }
1983 }
1984 }
1985 }
1986 }
1987 }
1988 }
1989 }
1990 }
1991 }
1992 }
1993 }
1994 }
1995 }
1996 }
1997 }
1998 }
1999 }
2000 }
2001 }
2002 }
2003 }
2004 }
2005 }
2006 }
2007 }
2008 }
2009 }
2010 }
2011 }
2012 }
2013 }
2014 }
2015 }
2016 }
2017 }
2018 }
2019 }
2020 }
2021 }
2022 }
2023 }
2024 }
2025 }
2026 }
2027 }
2028 }
2029 }
2030 }
2031 }
2032 }
2033 }
2034 }
2035 }
2036 }
2037 }
2038 }
2039 }
2040 }
2041 }
2042 }
2043 }
2044 }
2045 }
2046 }
2047 }
2048 }
2049 }
2050 }
2051 }
2052 }
2053 }
2054 }
2055 }
2056 }
2057 }
2058 }
2059 }
2060 }
2061 }
2062 }
2063 }
2064 }
2065 }
2066 }
2067 }
2068 }
2069 }
2070 }
2071 }
2072 }
2073 }
2074 }
2075 }
2076 }
2077 }
2078 }
2079 }
2080 }
2081 }
2082 }
2083 }
2084 }
2085 }
2086 }
2087 }
2088 }
2089 }
2090 }
2091 }
2092 }
2093 }
2094 }
2095 }
2096 }
2097 }
2098 }
2099 }
2100 }
2101 }
2102 }
2103 }
2104 }
2105 }
2106 }
2107 }
2108 }
2109 }
2110 }
2111 }
2112 }
2113 }
2114 }
2115 }
2116 }
2117 }
2118 }
2119 }
2120 }
2121 }
2122 }
2123 }
2124 }
2125 }
2126 }
2127 }
2128 }
2129 }
2130 }
2131 }
2132 }
2133 }
2134 }
2135 }
2136 }
2137 }
2138 }
2139 }
2140 }
2141 }
2142 }
2143 }
2144 }
2145 }
2146 }
2147 }
2148 }
2149 }
2150 }
2151 }
2152 }
2153 }
2154 }
2155 }
2156 }
2157 }
2158 }
2159 }
2160 }
2161 }
2162 }
2163 }
2164 }
2165 }
2166 }
2167 }
2168 }
2169 }
2170 }
2171 }
2172 }
2173 }
2174 }
2175 }
2176 }
21
```



```

ADK231_Code | Arduino IDE 2.0.1-nightly-2021004
File Edit Sketch Tools Help
Arduino IDE 0.9 (ESP-12 Module)

ADK231_Code.ino
164 // Serial.print(0);
165 // Serial.print(" "); millis() - time;
166 // Serial.print(millis() - time);
167 // Serial.print(millis() - time);
168 // Serial.print(7);
169 Serial.println(value);
170 send();
171 delay(1);
172 }
173 }
174
175 void setup()
176 {
177 // send an HTTP GET request depending on timerDelay
178 if (millis() > timerDelay) {
179 //check WiFi connection status
180 if(WiFi.status() != WL_CONNECTED){
181 WiFiClient client;
182 HTTPClient http;
183 String urlStr = String(value);
184
185 // Your Domain name with URL path or IP address with path
186 http.begin(client, urlStr);
187 http.addHeader("Content-Type", "text/plain");
188 int httpCode = http.GET(urlStr);
189 // Free resources
190 http.end();
191 }
192 else {
193 Serial.println("WiFi Disconnected");
194 setup_wifi();
195 }
196 lastTime = millis();
197 }
}

Output SerialMonitor X
Not connected. Select a board and a port to connect automatically.

```

Fig 3.17 Code for building EEG Module and sending data to access point

```

ADK231_Code | Arduino IDE 2.0.1-nightly-2021004
File Edit Sketch Tools Help
Arduino IDE 0.9 (ESP-12 Module)

ADK231_Code.ino
179 //check WiFi connection status
180 if(WiFi.status() != WL_CONNECTED){
181 WiFiClient client;
182 HTTPClient http;
183 String urlStr = String(value);
184
185 // Your Domain name with URL path or IP address with path
186 http.begin(client, urlStr);
187 http.addHeader("Content-Type", "text/plain");
188 int httpCode = http.GET(urlStr);
189 // Free resources
190 http.end();
191 }
192 else {
193 Serial.println("WiFi Disconnected");
194 setup_wifi();
195 }
196 lastTime = millis();
197 }
198 }
199
200 void calculateBMI ()
201 {
202 if(bmiIndex < bmiSize)
203 {
204 bmi[bmiIndex] = (value);
205 bmiIndex = bmiIndex + 1;
206 }
207 else if(bmiIndex == bmiSize)
208 {
209 bmiDone = true;
210 }
211 }
212 }

Output SerialMonitor X
Not connected. Select a board and a port to connect automatically.

```

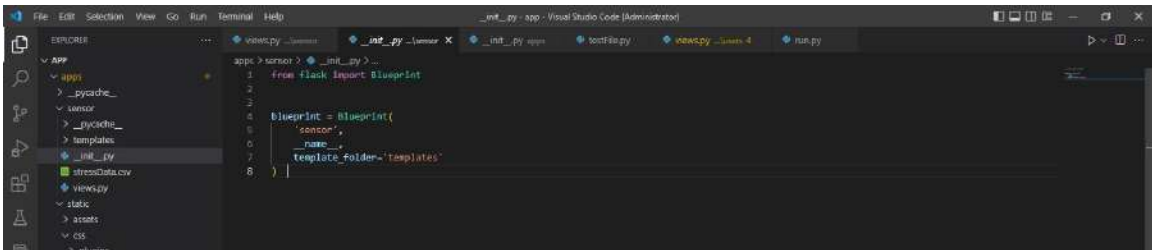
Fig 3.18 Code for building EEG Module and sending data to access point

3.8 PYTHON CODE OVERVIEW

In this section, the code flow in python is discussed. There are various files in this section which are being discussed one by one.

3.8.1 FLASK BLUEPRINT

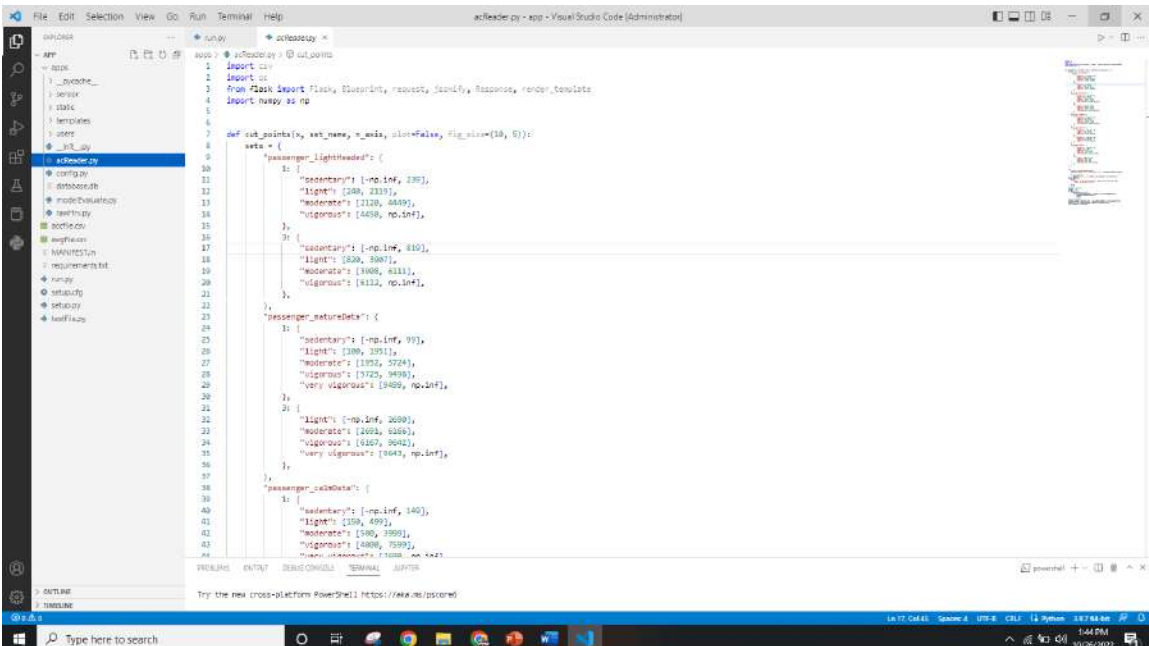
The fundamental idea behind blueprints is that they list the actions that should be taken when an application is registered. When sending requests between endpoints and creating URLs, Flask correlates the view functions with blueprints. The flask blueprint in this case is correlating with the template file.



```
1 from flask import Blueprint
2
3
4 blueprint = Blueprint(
5     'sensor',
6     name =
7     template_folder='templates'
8 )
```

Fig 3.19 The code for creating Flask Blueprint

3.8.2 PYTHON CODE OF WIRELESS NETWORK



```
1 import os
2 from flask import Flask, Blueprint, request, jsonify, Response, render_template
3 import numpy as np
4
5
6
7 def out_points(x, sat_name, r_ecc, plot=False, fig_size=(10, 5)):
8
9     sets = {
10         "passenger_lightdata": {
11             1: [
12                 "identifiers": [-np.inf, 235],
13                 "light": [200, 213],
14                 "moderate": [1120, 4400],
15                 "vigorous": [1450, np.inf],
16             ],
17             2: [
18                 "identifiers": [-np.inf, 810],
19                 "light": [200, 3007],
20                 "moderate": [1600, 811],
21                 "vigorous": [1810, np.inf],
22             ],
23         },
24         "passenger_maturedata": {
25             1: [
26                 "identifiers": [-np.inf, 99],
27                 "light": [100, 101],
28                 "moderate": [1100, 2000],
29                 "vigorous": [1720, 3490],
30                 "very vigorous": [3400, np.inf],
31             ],
32             2: [
33                 "light": [-np.inf, 2090],
34                 "moderate": [2000, 3000],
35                 "vigorous": [1600, 3000],
36                 "very vigorous": [3000, np.inf],
37             ],
38         },
39         "passenger_olddata": {
40             1: [
41                 "identifiers": [-np.inf, 140],
42                 "light": [100, 400],
43                 "moderate": [1400, 3500],
44                 "vigorous": [1400, 3500],
45                 "very vigorous": [1000, np.inf],
46             ],
47         },
48     }
```


CHAPTER 4

RESULT AND DISCUSSION

4.1 RESULT OF THE PROJECT

We have created a graphical interface to show the real-time data and results. The Update Results () method shows the results of the current stress state on the right-hand side of the graphical display, with EEG data at the top and Accelerometer data at the bottom, And combined results at the end of both the individual results.

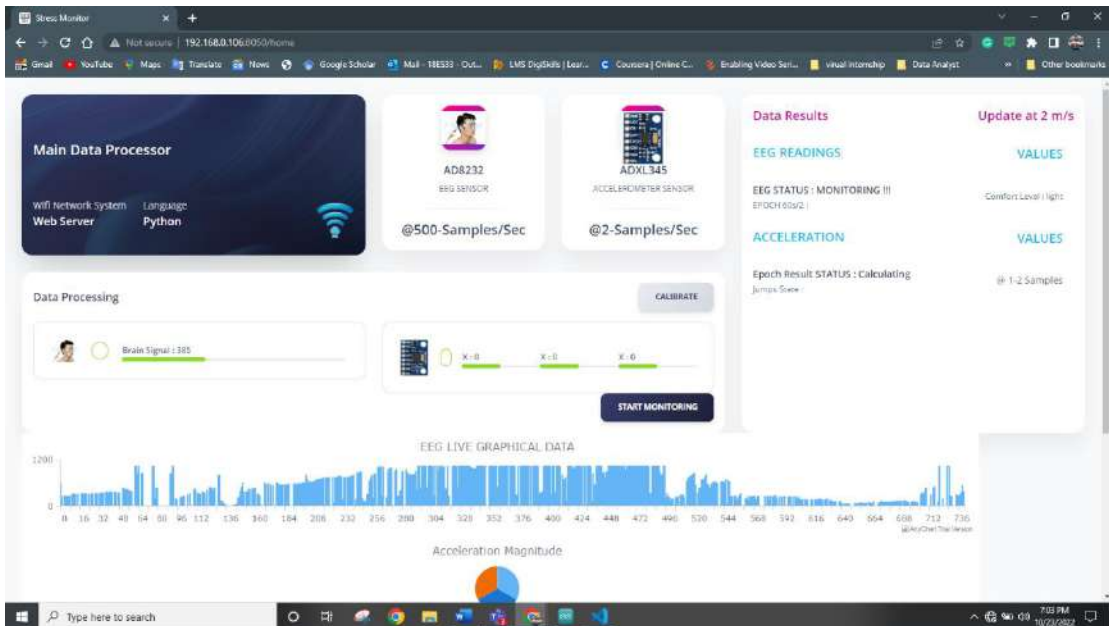


Fig 4.1 Graphical User Interface

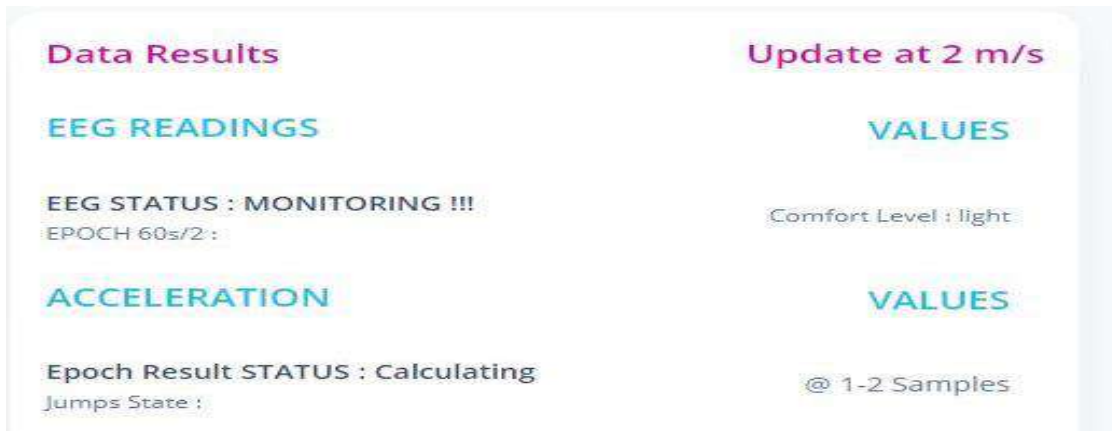


Fig 4.2. Data Results

4.2 TIME INTERVAL

Initially, we have to make sure that both sensors are sending data to the server. This is also shown in the form of a Graphical Interface, where real-time sensor data is shown in the graph.

If data is coming correctly, then we can start the monitoring, by pressing the start monitor button, on the UI. That will then start the monitoring. And after every 2 minutes, a person's state can be displayed on the screen.

We can obviously increase the monitoring interval. Like if we want to get the data reading after every 10 minutes, or after an hour. That way data will be analyzed after that time.

4.3 MODEL CREATION

We created the model after testing various Ai techniques, by creating the live CSV files, and giving those files to different models. In The end, we selected the best model which gives us accurate results.

4.4 CODE FLOW

1. Run Wi-fi access Point first. To have a “StressAP” Wi-fi network, so that sensors can connect.
- 2- Turn on EEG and Accelerometer.
- 3- Run the main Python Server. Which will automatically connect to the wireless Network.

4.5 REAL-TIME PROJECT VALIDATION

We validated our results on different trains in Pakistan. The results help to categorize the comfortable level of different trains in Pakistan. This will not only help passengers to check, which train is more comfortable but it will also help the Pakistan Railway to validate the price tag on the individual train.



Fig 4.3 Pakistan Railway

CHAPTER 5

CONCLUSION AND FUTURE RECOMMENDATIONS

5.1 CONCLUSION

The goal of this research is to analyze the comfort level of trains in Pakistan. We are providing a solution that will not only analyse the railway ride comfort based on acceleration measurement but also acquire the brain signals, which exhibit the current comfort of passengers. This proposed instrumentation is comprised of EEG sensors and a train-mounted accelerometer module. The results are shown on the graphical user interface which is created by the team using HTML and VISUAL Studio Code. This Project will help Pakistan Railways to add the comfort ratings of trains in their current application.

5.2 ADVANTAGES

- Train comfort level analysis checks the comfort level of trains operating in Pakistan and based on their comfort level price tag on the ticket could be justified.
- This analysis helps Pakistan Railways to rate their trains based on the comfort states and identify and work on those trains which are not following the comfort standard.
- This project can also be integrated with the “Pakistan Railways Mobile Application” to show passengers the trains with a high comfort level to low with the mentioned price tag.

REFERENCES

- [1] Z. Wu, N. Zhang, J. Yao, and V. Poliakov, “Analysis of Train Car-Body Comfort Zonal Distribution by Random Vibration Method,” *Applied Sciences*, vol. 12, no. 15, p. 7442, Jul. 2022, doi: 10.3390/app12157442.
- [2] Suzuki H. Research trends on riding comfort evaluation in japan. *Proc Inst Mech eng f j rail rapid transit* 1998;212(1):61-72.
- [3] Iwnicki S. *Handbook of railway vehicle dynamics*. Boca Raton: CRC Press; 2006
- [4] Griffin M. *Handbook of human vibration*. London: Academic Press; 1990.
- [5] Sun W, Zhou J, Thompson D, et al. Vertical random vibration analysis of vehicle-track coupled system using Green's function method. *Veh Syst Dyn*. 2014;52:362–389
- [6] Zhou J, Goodall R, Ren L, et al. Influences of car body vertical flexibility on ride quality of passenger railway vehicles. *Proc Inst Mech Eng F, J Rail Rapid Transit*. 2009;223:461–471
- [7] Kargarnovin MH, Younesian D, Thompson D, et al. Ride comfort of high-speed trains travelling over railway bridges. *Veh Syst Dyn*. 2005;43:173–197
- [8] Zhang Y-W, Zhao Y, Zhang Y-H, et al. Riding comfort optimization of railway trains based on pseudo-excitation method and symplectic method. *J Sound Vib*. 2013;332:5255–5270
- [9] ISO, ISO 2631-1: Mechanical vibration and shock—Evaluation of human exposure to wholebody vibration—Part1: General requirements, in, ISO, Switzerland, 1997.
- [10] Popp K, Kruse H, Kaiser I. Vehicle-track dynamics in the mid-frequency range. *Veh Syst Dyn*. 1999;31:423–464
- [11] ISO, ISO 2631-1: Mechanical vibration and shock—Evaluation of human exposure to wholebody vibration—Part1: General requirements, in, ISO, Switzerland, 1997.
- [12] I.U.o. Railways, UIC 513: guidelines for evaluating passenger comfort in relation to vibration in railway vehicles, in, UIC, Paris, 1994
- [13] Zhou J, Goodall R, Ren L, et al. Influences of car body vertical flexibility on ride quality of passenger railway vehicles. *Proc Inst Mech Eng F, J Rail Rapid Transit*. 2009;223:461–471.

- [14] Nagai M, Yoshida H, Tohtake T, et al. Coupled vibration of passenger and lightweight car-body in consideration of human-body biomechanics. *Veh Syst Dyn*. 2006;44:601–611.
- [15] Tomioka T, Takigami T. Experimental and numerical study on the effect due to passengers on flexural vibrations in railway vehicle car-bodies. *J Sound Vib*. 2015;343:1–19
- [16] Wu J, Qiu Y. Analysis of ride comfort of high-speed train based on a train-seat-human model in the vertical direction. *Veh Syst Dyn*. 2020.
- [17] Carlbom P, Berg M. Passengers, seats and carbody in rail vehicle dynamics. *Veh Syst Dyn*. 2002;37:290–300.
- [18] Kumar V, Rastogi V, Pathak PM. Simulation for whole-body vibration to assess ride comfort of a low–medium speed railway vehicle. *Simulation*. 2017;93:225–236.
- [19] Dhillon BS. *Human Reliability and Error in Transportation Systems*. Berlin: Springer Science & Business Media, 2007.
- [20] Cieslak, M., Kanarachos, S., Blundell, M., Diels, C., Burnett, M., & Baxendale, A. (2020). Accurate ride comfort estimation combining accelerometer measurements, anthropometric data and neural networks. *Neural Computing and Applications*, 32(12), 8747-8762.
- [21] Nguyen, T., Nguyen-Phuoc, D.Q. & Wong, Y.D. Developing artificial neural networks to estimate real-time onboard bus ride comfort. *Neural Comput & Applic* **33**, 5287–5299 (2021). <https://doi.org/10.1007/s00521-020-05318-3>
- [22] Lerspalungsanti, S., Albers, A., Ott, S. *et al*. Human ride comfort prediction of drive train using modeling method based on artificial neural networks. *Int.J Automot. Technol.* **16**, 153–166 (2015). <https://doi.org/10.1007/s12239-015-0017-2>
- [23] Liu, W., Lian, Z., & Zhao, B. (2007). A neural network evaluation model for individual thermal comfort. *Energy and Buildings*, 39(10), 1115-1122.
- [24] Eini, R., & Abdelwahed, S. (2020, September). A neural network-based model predictive control approach for buildings comfort management. In *2020 IEEE International Smart Cities Conference (ISC2)* (pp. 1-7). IEEE.
- [25] Qin, Y., Xue, Y., Xing, Z. Y., & Wang, Y. H. (2011). Study on Ride Comfort Indices Correlation Analysis Based on BP Neural Network. In *ICTIS 2011: Multimodal Approach*

to Sustained Transportation System Development: Information, Technology, Implementation (pp. 2283-2289).

[26] Du, X., Sun, C., Zheng, Y., Feng, X., & Li, N. (2021). Evaluation of vehicle vibration comfort using deep learning. *Measurement*, 173, 108634.

[27] Asarar, K. (2021). Predicting comfort in autonomous driving from vibration measurements using machine learning models.

[28] Martínez-Llop, P. G., Sanz Bobi, J. D. D., Solano Jiménez, Á., & Gutiérrez Sánchez, J. (2021). Condition-Based Maintenance for Normal Behaviour Characterisation of Railway Car-Body Acceleration Applying Neural Networks. *Sustainability*, 13(21), 12265.

[29] Wu, J., & Qiu, Y. (2021). Analysis of ride comfort of high-speed train based on a train-seat-human model in the vertical direction. *Vehicle System Dynamics*, 59(12), 1867-1893.

[30] Dumitriu, M., & Stănică, D. I. (2021). Study on the evaluation methods of the vertical ride comfort of railway vehicle—mean comfort method and sperling's method. *Applied Sciences*, 11(9), 3953.

[31] Kobishchanov, V., Antipin, D., Shorokhov, S., & Mitrakov, A. (2016, April). Use of anthropometric dummies of mathematical models in the safety and comfortableness analysis of a passenger rolling stock. In *IOP Conference Series: Materials Science and Engineering* (Vol. 124, No. 1, p. 012065). IOP Publishing.

[32] Schwanitz, S., Wittkowski, M., Rolny, V., Samel, C., & Basner, M. (2013). Continuous assessments of pressure comfort on a train—A field-laboratory comparison. *Applied ergonomics*, 44(1), 11-17.

[33] Huang, W., & Shuai, B. (2018). A methodology for calculating the passenger comfort benefits of railway travel. *Journal of Modern Transportation*, 26(2), 107-118.

[34] Ma, H., Chen, D., & Yin, J. (2020). Riding comfort evaluation based on longitudinal acceleration for urban rail transit—Mathematical models and experiments in Beijing subway. *Sustainability*, 12(11), 4541.

- [35] Mastinu, G., Gobbi, M., & Pennati, M. (2007, January). Objective Ride Comfort Measurement. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 48043, pp. 1125-1139).
- [36] Strandemar, K. (2005). *On objective measures for ride comfort evaluation* (Doctoral dissertation, KTH).
- [37] Tan, C., Delbressine, F., Chen, W., & Rauterberg, M. (2008). Subjective and objective measurements for comfortable truck drivers' seat. In *Proceedings of the Ninth International Symposium on Advanced Vehicle Control (AVEC 2008)* (pp. 851-856).
- [38] Yang, K. T. (2008). Artificial neural networks (ANNs): a new paradigm for thermal science and engineering. *Journal of heat transfer*, 130(9).
- [39] Sharma, P. (2022, August 31). Feedforward Neural Network: Its Layers, Functions, and Importance. *Analytics Vidhya*. Retrieved September 23, 2022, from <https://www.analyticsvidhya.com/blog/2022/01/feedforward-neural-network-its-layers-functions-and-importance/>
- [40] Jiang, Y., Chen, B. K., & Thompson, C. (2019, May 12). A comparison study of ride comfort indices between Sperling's method and EN 12299. *International Journal of Rail Transportation*, 7(4), 279–296. <https://doi.org/10.1080/23248378.2019.1616329>
- [41] Stańczyk, T. L., Zuska, A. (2014). Review of anthropodynamic dummies used to evaluate the effect of vibrations on sitting human (vehicle driver). *The Archives of Automotive Engineering – Archiwum Motoryzacji*, 65(3), 65-74.