Neural Activity Collection and Analysis

Functional Specification

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1. Introduction

1.1 Overview

The goal of development is to create a windows application that allows users to use an Interaxon MUSE EEG headset to record their focus levels while watching a video. These readings would then be uploaded to a MySQL database, where they could be downloaded by another authorised individual to be viewed adjacent to the original video, and automatically identify key moments of interest in the video. The user could also download multiple readings from multiple individuals and view the summarised readings of the group, see a visualisation of them and view moments the system has identified as impactful on focus..

This system would also allow users to manually identify key points during a video that viewers collectively lost or gained focus, which would then allow them to improve their videos' focus retention. As video lectures are the primary method of teaching during the COVID-19 lockdown, this system is being developed to help improve the quality of learning being done during this time.

1.2 Business Context

The two main business contexts that this system is applicable to are education and marketing. It would be extremely useful for lecturers and teachers to know exactly where students begin to lose focus in order to improve the learning experience. In the context of marketing, it would be reasonable to assume that it would be very useful in a focus group situation, knowing where potential viewers of an advertisement would stop paying attention would help creating more engaging marketing campaigns.

1.3 Glossary

EEG:
Electro**E**ncephalo**G**raphy. the measurement of electrical activity in different parts of the brain and its recording as a visual trace.

MySQL:
An open source relational database management system (RDBMS) based on Structured Query Language(SQL).

2. General Description

2.1 Product / System Functions

Record Session

The most critical feature of our system is the ability to record EEG data from a device and store it so that users can view the data at a later time. Users will be able to start a recording of a session and see their readings displayed on a graph in real time. They will be able to temporarily pause the recording with a pause button, as well as end it whenever they want via a stop button.

View Session

Once a user has recorded a session, it is imperative that they are able to view any session they have previously saved. They will be able to select any number of saved sessions of a video and view them side by side, which would ideally allow them to identify any major times where attention tended to rise or fall.

Upload Session

In order to allow an individual to easily allow others to view data for a session that they have recorded, users will be able to upload their sessions to an online database that can be searched through and pulled from. Users will be able to upload multiple sessions at once, and sessions can be marked as private, which can only be viewed and downloaded by authorised users.

View Online Sessions

Users will be able to search through the database of uploaded sessions through the use of a search bar which will display all sessions that have names or uploader usernames that match the given search terms. Users will also be able to view their own uploaded sessions, and will have the ability to delete them.

Download Session

Users will be able to select any number of sessions from the online sessions they have viewed and download them to their PC.

Identify Key Moments In Session

The system will be able to analyse a session and determine moments, or “Key Points” that seem to be turning points where focus began to increase or decrease. The user will be able to view these when viewing a session.

Summarise Multiple Sessions

In order to allow users to determine specific points during a video that viewers’ attention tends to either increase or decrease, it is important that users will be able to generate one greatly informative visualisation of data from multiple sessions. In order to achieve this, users will be able to use a number of features, such as taking multiple sessions and combining them into one “combined session” by averaging readings, or viewing correlations between points of interest where focus changed.

Visualise Session Against Video

To improve a user's ability to identify why a viewer's attention might change at a given moment in a video, the user will be able to select an MP4 video file of the relevant video to be displayed frame by frame above the selected session graphs. This would help to manually determine if any visual changes played a role in changes in attention.

Storing User Data

As well as storing the user's sessions in an online MySQL database, the user data must also be stored. User data will also be stored in a MySQL database, with passwords only being stored as salted hashes to prevent user security being compromised in the case of a cyberattack. Passwords will be checked by applying the hashing function to a given password and checking if the resulting hash is the same as the stored hash. If it is, the user is authorised access to the account.

2.2 User Characteristics and Objectives

Due to the fact that users of the system will be both the individuals who create videos and those who are watching said videos, it cannot be expected that all users who use the system will be particularly proficient in computer systems and software usage. Therefore, the user interface must be intuitive, simple and easy to use without much explanation or learning required. As the specifications of any given user cannot be known, the software must be as lightweight and optimised as possible.

Ideally, the system will provide a service for users to easily visualise a video's focus retention among viewers, in a way that's clear, easy to understand and relatively simple to do. A user who is only using the software to record their focus session should have an extremely easy experience to do so, and should not be prompted with potentially confusing information or options unless an "advanced" option is selected. Any data that must be uploaded or downloaded should be relatively small to ensure that the user's PC's performance is not compromised.

2.3 Operational Scenarios

Set Up and Account Management

On initial startup of the program, the user will be prompted to sign in or make an account. To make an account, users must provide a username, an email and a password. Once an account is successfully created and they have signed in, they will then be able to connect their EEG headset to the program. The user will then be prompted to provide a directory path for session recordings to be placed in, known as the "session directory". They will then be shown the "home" menu.

Once a user has signed in, they can choose to perform a number of actions on their account by accessing the "Account" button on the home menu. A user can change their password, change their linked email address, or change their session directory.

Session Creation
The user selects “New Session” on the program’s home menu. The user is prompted to give a name to the session. They are shown a new menu with an empty graph and a “record” button. The user presses the record button, and the readings from the EEG device begin to be displayed on the graph. Two more buttons appear, a “pause” button and a “stop recording” button. The pause button temporarily halts the recording of data, and the stop button ends the recording and the data is saved to a CSV file in the session directory under the given name. The user can view the generated graph before returning to the home menu.

Session Management
The user selects “Manage Session” from the home menu. They are shown a screen with a list of all of the sessions they have in their session directory, and can select one or more via a tick box beside each file. Once the desired sessions have been selected, the user has three options. They can choose to view the selected session graphs side by side, create a new session by averaging all selected sessions into one, or upload the selected sessions to the session database. If the user chooses to upload a session or sessions, they can choose to set the sessions as private, and provide a list of usernames that can access the session.

If a user selects “View Session(s), they have the option to select an MP4 file of the video that was used to create the sessions, and visualise the session(s) next to a reel of frames of the video to allow the user to identify any visual changes that might affect focus retention. The user can zoom in to view the graph in more detail, or look at specific frames of video. If a user zooms out, the shown frames are spread out accordingly to give a more general view of the video.

Uploaded Session Management
The user selects “Uploaded Sessions” from the home menu. They are shown a screen with an empty table and a search bar, and a button that reads “My Uploads”. The user can then enter a term into the search bar and select “search” to view all public sessions with either the name of the given search term, or public sessions uploaded by a user with a username matching the search term. Any matching private sessions that have the user’s username listed as able to view the session will also be listed. The user can then select any number of listed sessions, and download them to their session directory.

The user can also select the My Uploads button, which displays all sessions that have been uploaded by the user. The user can choose to download these files again, or delete them from the database.

2.4 Constraints

Hardware Costs
One of our greatest constraints is that of affordable hardware. EEG devices are expensive and we do not have the luxury of testing out multiple different devices to determine the one most ideal for our goals.

Time
We have limited time to implement the features of this project. Therefore, it may be necessary to exclude features of low criticality to the system's usability and allow for a small number of bugs in order to deliver a functional project within the allotted time frame. These problems likely will not be an issue in the context of demonstrating our project, however they would need to be fixed if the project was to be used in an actual academic or commercial setting.

Learning Constraints
This project will be the first time we will be working with Java UI, EEG devices and MySQL online databases, so a large amount of time will be dedicated to education and research alone.

Social Distancing
Due to social distancing regulations, it may be difficult to test the EEG device on multiple individuals and multiple PCs.

3. Functional Requirements

3.1 Register Account

Description

This function allows users to create a new account. When a user opens the program for the first time or after they sign out, they must either sign in or register a new account to access the rest of the program features. The user must provide their desired username, password and email address. The given password will be stored as a salted hash in the database, and the user will be sent an email to confirm account creation.

Criticality

This feature is essential for the system's online functionality, which we consider to be a very high priority aspect of this project and is therefore of high criticality.

Technical Issues

The primary technical issue we can foresee that we will have to address is making calls to a RESTful API that will store the given data in a MySQL database. Using a secure hashing algorithm may also prove to be problematic.

Dependencies

None.

3.2 Sign In

Description

This function allows users to sign into their account once they have been registered. A user must provide their email and password. If an incorrect password is entered 5 times in a row, the user will be unable to login for 10 minutes.

Criticality

This function is essential for our system as the online functionality would be impossible without it.

Technical Issues

Similar to registration, the main issues are making API calls, and correctly hashing the password attempts.

Dependencies

Register Account.

3.3 Sign Out

Description

Allows a user to sign out of their account , and brings them to the sign in screen.

Criticality

High criticality, necessary for any system using accounts.

Technical Issues

None.

Dependencies

Sign In.

3.4 Change User Password

Description

Allows a user to change the password used to access their account. Will require the user to input their old password. The new password will be encrypted with a salted hash and will replace the old password in the database.

Criticality

Medium criticality, a very useful feature to provide but not mandatory for full usage of the system.

Technical Issues

API calls and hashing.

Dependencies

Register, Sign In.

3.5 Change Session Directory

Description

Allows a user to choose a directory for recorded and generated sessions to be placed in.

Criticality

Low criticality, a generated folder in the program files could be used instead.

Technical Issues

Reading paths.

Dependencies

None.

3.6 Read EEG Signal

Description

Allows the system to take input from the EEG API and parse it as numerical data.

Criticality

High criticality, absolutely necessary to develop the system’s primary features.

Technical Issues

Interaxon MUSE API may not work as planned without major workarounds.

Dependencies

Interaxon MUSE EEG Headset.

3.7 Record Session

Description

Allows a user to record signals from their EEG headset and graph them in real time. The user can temporarily pause recording, or stop it to complete the session recording and store it as a CSV file in the Session Directory.

Criticality

High criticality, the primary feature of the system.

Technical Issues

EEG headset may be problematic to use, graphing values may be more difficult than anticipated.

Dependencies

Change Session Directory, Read EEG Signal.

3.8 Upload Session To Database

Description

Allows users to upload a saved session to the online session database, as either a public or private session. To upload a private session, the user must provide usernames of accounts that can access the session.

Criticality

Medium. Highly useful to allow users to share sessions securely without needing to send files over a third party application, which simplifies the process immensely.

Technical Issues

Uploading CSV files to a database may be difficult to implement.

Dependencies

Record Session, sign in.

3.9 Search Online Sessions

Description

A user that enters the Session Database screen will be able to enter a search term in the search bar, to list all sessions with a name or uploader username matching the search term are displayed, assuming the session is public or the user is marked as able to view the private session.

Criticality

Medium. Useful feature but the database isn't absolutely mandatory for the system to function.

Technical Issues

API calls to database, using MySQL to search database.

Dependencies

Sign in.

3.10 List Online Sessions

Description

When a user searches the online database for a session, this function formats the matching sessions into a list.

Criticality

Medium. The database isn't absolutely necessary for system functionality.

Technical Issues

Formatting matching sessions.

Dependencies

Search Online Sessions.

3.11 Download Session

Description

Allows a user to select a session they have listed from the Session Database and download it to their Session Directory.

Criticality

Medium. The database isn't absolutely necessary for system functionality.

Technical Issues

API calls to get a file from the database may be difficult.

Dependencies

List Online Sessions.

3.12 Delete Sessions From Database

Description

Allows the user to delete a session they had previously uploaded to the database.

Criticality

Medium. The database in general isn't absolutely necessary for system functionality.

Technical Issues

None.

Dependencies

Upload Session to Database.

3.13 View Sessions

Description

Allows a user to view a session they have saved in their Session Directory. They can view the generated graph, and upload a video, ideally the video used to create the session, to display a reel of its frames against the graph. The user can also view multiple sessions at once, overlayed or side by side.

Criticality

High. It is imperative that users will be able to use and view the data they have recorded without the need of third party software.

Technical Issues

Video processing and graphing values may be difficult to implement.

Dependencies

Record Session.

3.14 Analyse Session for Key Points

Description

This function reads in the values of the session and attempts to output the times during the session where focus tended to increase or decrease substantially.

Criticality

Medium. A very desirable feature to have as it automates the main purpose of the system.

Technical Issues

Data analysis on trends and changes may be potentially complex.

Dependencies

View Session.

3.15 Zoom In and Out of Session

Description

Allows the user to zoom in on a specific part of a session's graph in order to view a section more clearly. When zoomed in, if the user has added a video file to be viewed next to the graph, the video will scale with the zoom to display more frames of footage.

Criticality

Low. Not hugely impactful on system functionality, however it would be useful and expected of such a system.

Technical Issues

Scaling UI while zooming could be difficult to implement.

Dependencies

View Sessions.

3.16 Delete Sessions From PC

Description

Allows the user to delete sessions in their Session Directory without having to do so manually in a directory browser.

Criticality

Low. There is a reasonably simple alternative that would mean this function could exist without loss of utility.

Technical Issues

None.

Dependencies

None.

3.17 Average Sessions

Description

This function would take all given sessions and compute the average value for each time interval in the given data, and would then use this averaged data to generate a new averaged session.

Criticality

High. Very useful feature which allows users to visualise their data easily, which is a primary goal of the system.

Technical Issues

None.

Dependencies

None.

3.18 Find Correlations Between Multiple Sessions

Description

This function allows the user to select multiple sessions that have had Key Points identified and finds correlations between where these points are found, and these findings are written to a .txt file in the Session Directory.

Criticality

Medium-high. While not extremely necessary, this feature would be highly useful and would give users more tools to find important information.

Technical Issues

None.

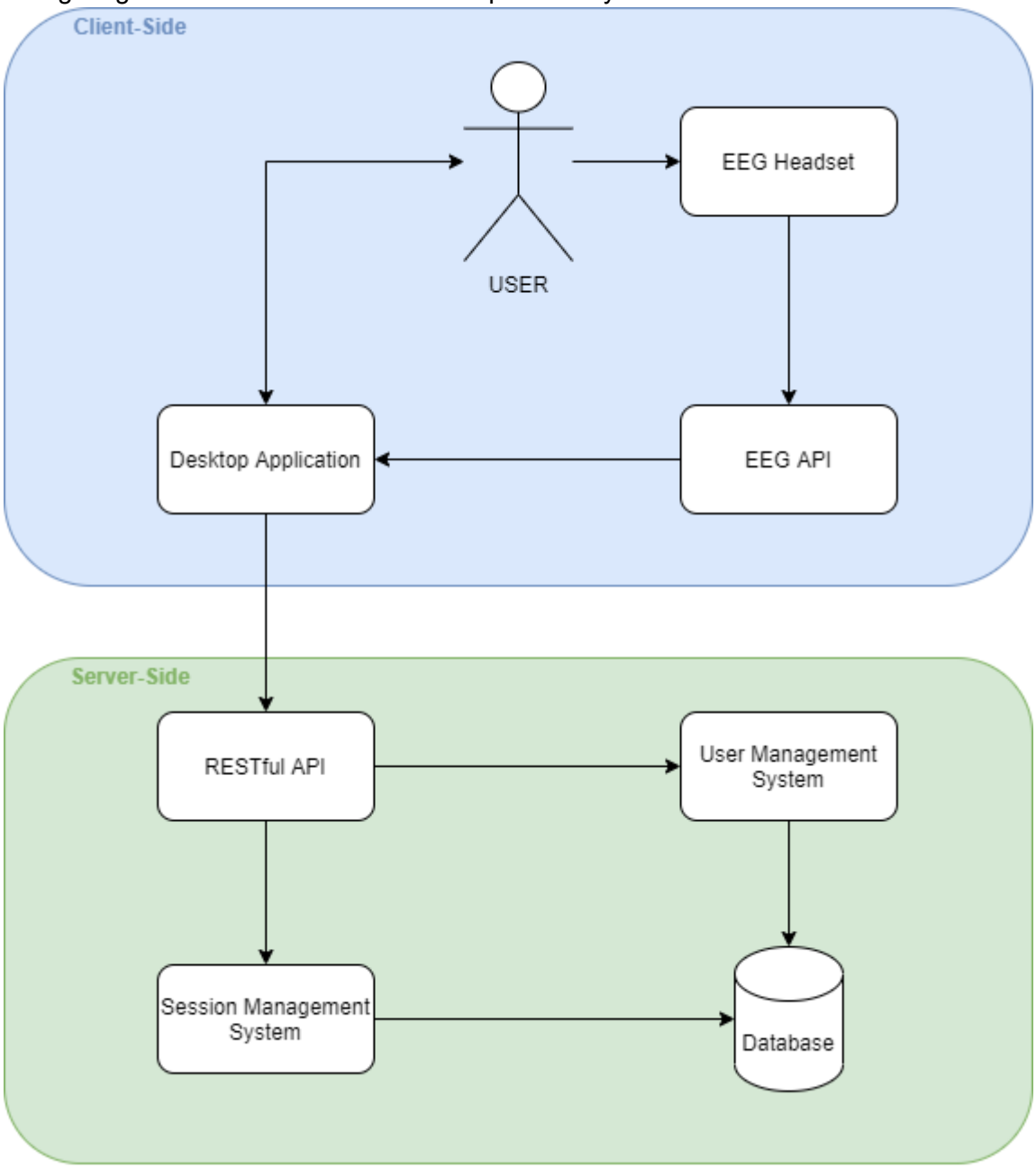
Dependencies

Analyse Session for Key Points.

4. System Architecture

4.1 System Architecture Diagram

The following diagram shows an overview of our planned system's architecture.



4.2 System Architecture Diagram Description

Desktop Application

The main interface users will use to access the system and its features. Written in Java, and will be available on Windows. Will ideally work on Windows 7, 8 and 10.

EEG Headset

The only hardware element of the project. Will detect electrical signals and pass them to the EEG API to be parsed. We plan to use the Interaxon Muse.

EEG API
The third party API provided by the developers of the Interaxon Muse in the Muse Software Development Kit.

RESTful API
API developed in Python using Flask. Will accept calls from the Desktop Application to add to or find data from the Database.

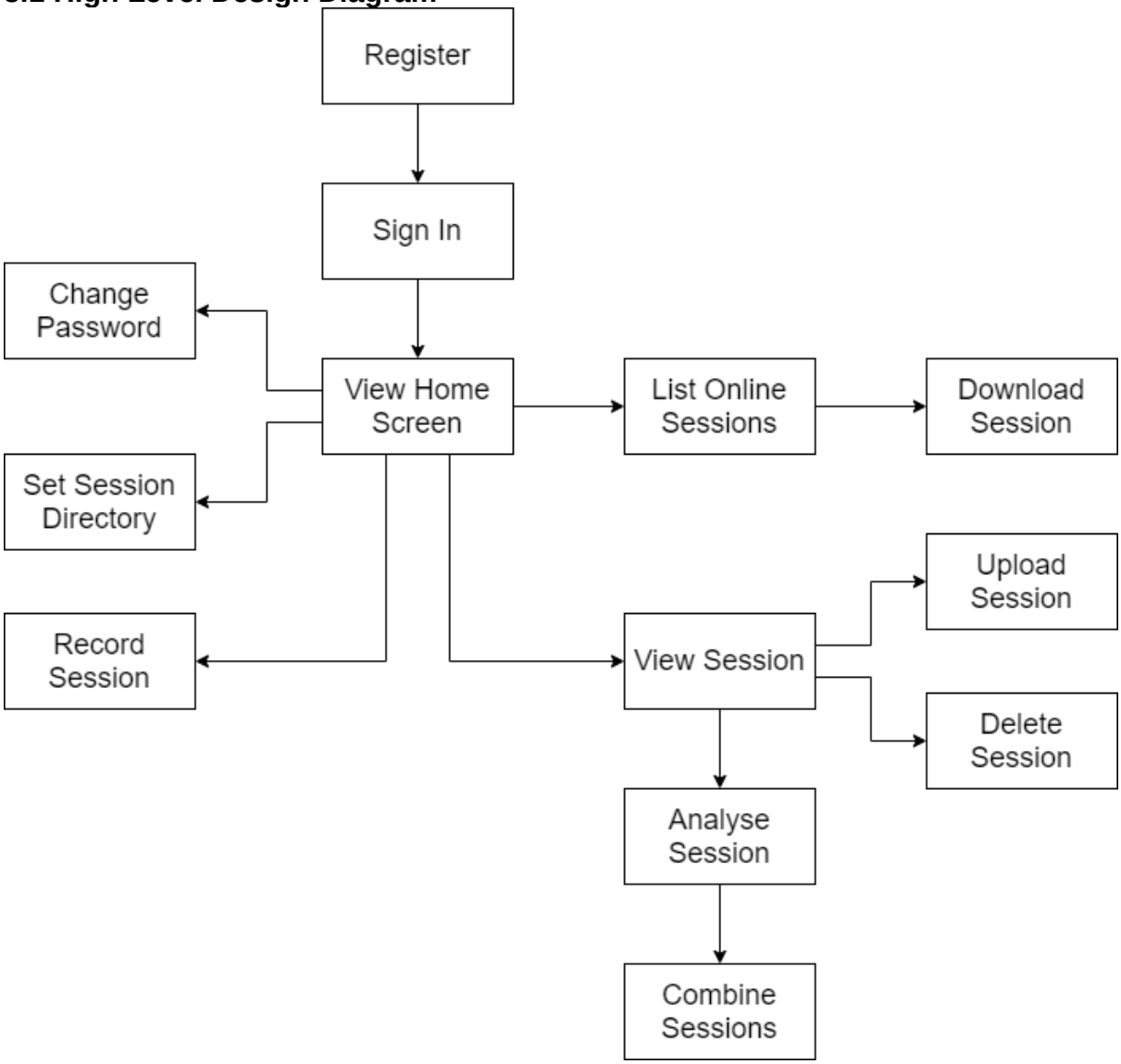
User Management System
A number of python scripts called by the Flask API to manage the creation, deletion and access of user accounts.

Session Management System
A number of python scripts called by the Flask API to manage the uploads, downloads and deletion of sessions.

Database
A MySQL database that stores user data and session data that has been uploaded.

5. High-Level Design

5.1 High Level Design Diagram



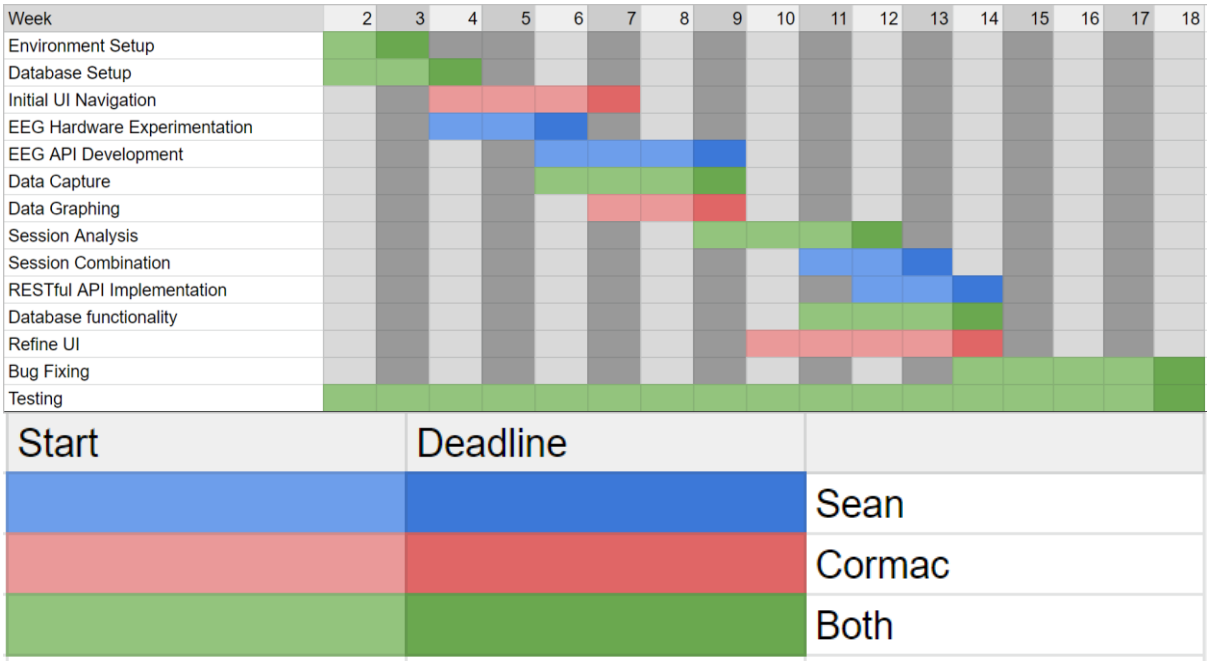
5.2 High Level Design Diagram Description

- **Register**
  Register an account with a username, email address and password to access the application.

- **Sign In**
  Log in to the user account using the registered email address and password.
- **View Home Screen**
  View the main screen that allows access to all other system features.
- **Change Password**
  Change the password used to access the currently logged in user account.
- **Set Session Directory**
  Set the directory where sessions are saved to.

- **Record Session**
  Record a session with the EEG headset.
- **List Online Sessions**
  List sessions stored in the database that match the given search term.
- **Download Session**
  Download a selected session from the database.
- **View Session**
  View a session stored in the Session Directory.
- **Upload Session**
  Uploads a session from the Session Directory to the database.
- **Delete Session**
  Delete a session from the Session Database.
- **Analyse Session**
  Perform analysis on a given session to find important information regarding when the data indicates an increase or decrease in focus.
- **Combine Sessions**
  Create a new session from averaging data from selected sessions and finding correlations in identified key moments.

6. Preliminary Schedule



7. Appendices

Electroencephalography: https://www.sciencedirect.com/topics/medicine-and-dentistry/electroencephalography
Flask: https://flask.palletsprojects.com/en/1.1.x/
Interaxon Muse: https://choosemuse.com/explore-muse-2/