Using facial emotion detection to identify and improve an individual's mood

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Declaration of Originality

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Abstract

This project is aimed at aiding society and individuals to keep a good mindset and take care of their mental well-being. The impacts of suicide rates going up combined with problems like cyberbullying being an increasing problem and the correlation between physical activity and mental health have driven this project to become another helping piece in this complex problem of the world. With increasing awareness of mental health, more people pay attention and take care of their own mental health. This application can help any individual who struggles with mental health to be a steppingstone in helping the individual get a better state of mind. The application takes a deep dive into the world of artificial intelligence and unites it with an easy to access interface like a web application. This means that the application can be used by more people and could reach more people. There have been considerations made in every step of the application of how to make sure it is the best version that it can be and the most secure that it can be.

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I would like to extend my thanks to my supervisor, Dr. Zhenhua Feng, for his support and guidance through this project and our FEPS teaching staff for promptly responding to enquiries.

I would also like to thank my family, friends and everyone else who has been there for me during this time.

Contents

Abbreviations

Number	Abbreviation	Meaning
1	CNN	Convolutional Neural Network
2	DNN	Deep Convolutional Neural Network
3	FER	Facial Emotion Recognition
4	SSL	Secure Sockets Layer
5	HTTP	Hypertext Transfer Protocol
6	HTTPS	Hypertext Transfer Protocol Secure
7	APP	Application

List of Figures

List of Tables

1 Introduction

1.1 Problem Background

The problem background of this project is a complex problem which is composed of smaller pieces. In this section, each of those pieces will be described and how they collectively form the problem background.

1.1.1 Suicide rates

Suicide and mental health have been a major concern for humans for a long time. Every year, more than 700.000 people die from suicide. Suicide represents the fourth leading cause of death among 15–19-year-olds and about 77% of suicides occur in low- and middle-income countries.

In addition to this, individuals that experience abuse, loss and a sense of isolation are more susceptible to suicidal behavior [1]. This represents an ongoing problem in our modern-day society and suicide prevention efforts are actively being put into place to lower these numbers.

The number of people with mental health problem has been steadily increasing over the past years. Figure 1 is showing the steady increase in the number of people with depression since 1990.

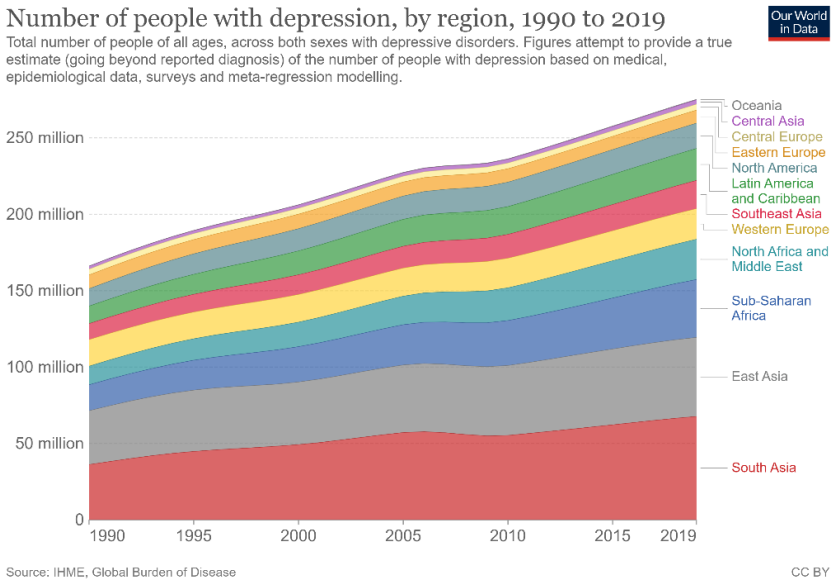


Figure 1: Number of people with depression, by region [3]

1.1.2 Teen suicide

According to [44] the attempted suicide rates in teens remained constant throughout the 1990s to 2000s, declined from 2005 to 2009 but then reversed in the coming years. The suicide attempts that required medical attention and the percentage of teens that seriously thought

about suicide followed similar trends. The primary demographic that this application targets are teens and teenagers because they can be the most influenced by others and susceptible to suicidal thoughts induced by other people on the internet.

1.1.3 Cyberbullying

In the study conducted by Hinduja et. al [45] they found that around 20% of participants have been seriously thinking about suicide and 19% have attempted it. For bullying, the numbers ranged from 6% to 27% for bullying with offending and from 11% to 29% for bullying with victimization. With regards to cyberbullying, the rates for bullying with offending the other person are between 9% and 23% and between 5% and 18% for victimization. The study concluded with results indicating that bullying and cyberbullying are associated with an increase in suicidal ideation. This is an important factor for the problem background because most teens spend most of their time online and thus are susceptible to becoming victims of bullying and cyberbullying.

In Figure 2 it can be observed how the time spent online on social media is slowly increasing over the past years. While this number already represents a big part of our day (145 minutes), the time spent online on other applications and means can only be higher. The numbers may have increased even more with the global situation.

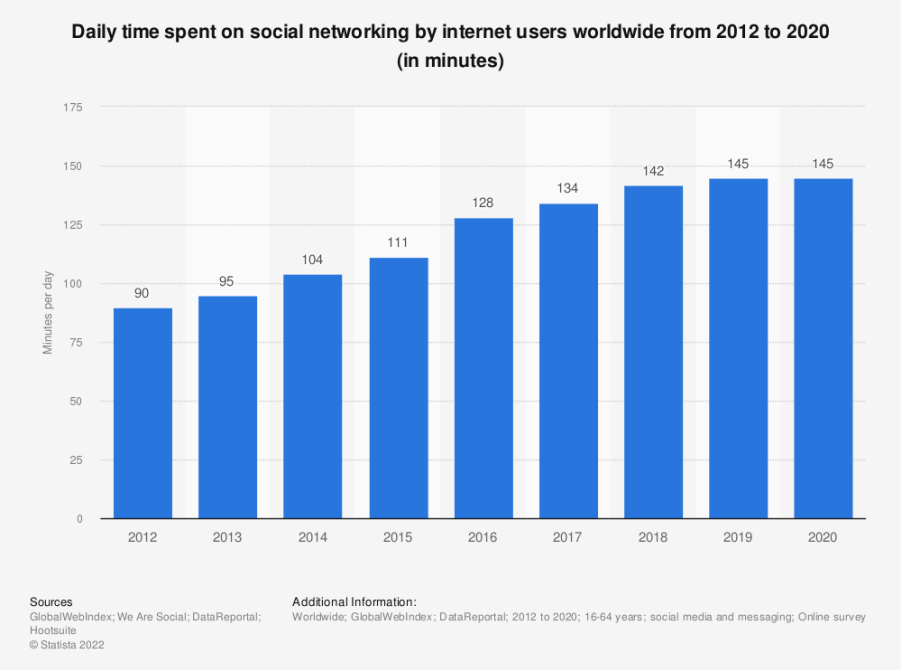


Figure 2: Daily time spent on social media [4]

1.1.4 The link between physical exercise and suicidal thoughts

According to Grasdalsmoen et al. [2] physical activity and mental health are both major concerns worldwide. In this study, it was shown that there could be a link between mental health and physical exercise. Women with low levels of physical activity had nearly three times

the odds of self-reported depression compared to women that exercise every day. Even stronger effects were measured on men.

Given this and the recent global situation, there can be a major concern that even more people have considered suicide or have bad mental health because of the isolation, lack of physical exercise and lack of human interaction which all are essential to human life, especially interacting with other humans.

1.2 Project Description

This project aims to successfully identify and suggest activities and other means to improve an individual's mood in case it's a negative one. This could help avoiding excessively sad states of mind and any negative effects that can come from them, including self-harm and suicide. The project tries to help the user feel better and, if needed, provides the phone numbers to important services that can help the individual when it's a more serious matter.

This paper will address the process of building a possible solution to help with the described problem. It will first explain the problem and the proposed solution, along with the necessary tools to facilitate the realization of the solution. The possible datasets that can be used to train the machine learning algorithm will be mentioned and the chosen one will be highlighted. The machine learning algorithm will then be incorporated into a web application through the required libraries and frameworks to be able have easy access to it. After the successful setup and deployment of the application, tests will be conducted to verify the functionality and identify any hidden bugs that may have been oversighted in the design or development phase. The application will represent a hybrid between machine learning and web application, as shown in Figure 3, with focus on making the user experience smooth and easy.

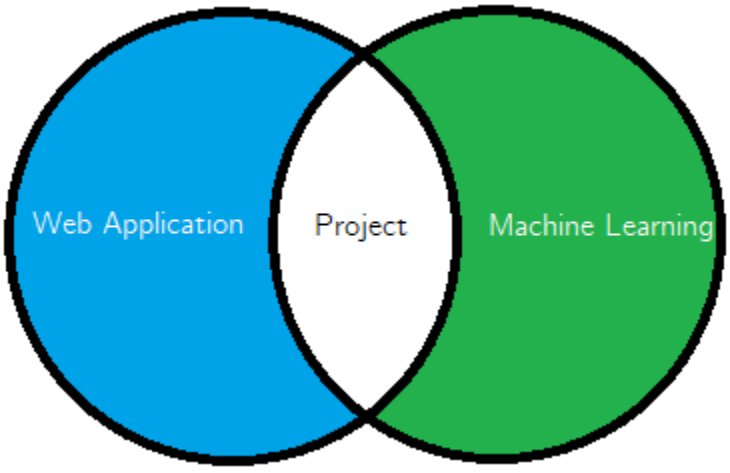


Figure 3: How the different areas of the project merge together

The application will allow the user to start the emotion detection process. This process will consist of the user agreeing on the web application accessing the webcam for the transmission of the short video, the sent frames being analyzed by the machine learning model and the

identified emotion will be displayed to the user, along with suggestions to improve the negative emotion or keep the positive emotion, depending on what was recognized by the algorithm.

1.3 Project Aims

This section contains the aims of this project as well as details about each step. These aims are reflected in the evaluation part of this paper.

Step 1: Choose the frameworks that will be used to accomplish this project

To be able to create and make this project available for people to use anywhere, certain criteria must be met for it to run and function as intended. Some of those criteria include a design that can be utilized on almost any device, maintainability of the project so it can easily be maintained and repaired in a minimum amount of time and extensibility so there can be new functionality added to it if needed.

Step 2: Choose the dataset to evaluate and train the model

Machine learning models are heavily dependent on data that they can learn from and improve, thus having a good and sizeable dataset is important in any task that involves machine learning. The choice of the dataset will impact how well the algorithm can classify emotions, how many it can identify and how accurate the prediction is.

Step 3: Build the model train it on the data

After the data was acquired, a model must be developed which can predict the emotion of the user with an accuracy of minimum 65%.

Step 4: Linking the trained model with the web application

To get the predictions quickly, the two parts of the project must be linked together with appropriate and compatible software to ensure a smooth user experience and minimal troubleshooting for incompatibilities and bugs.

Step 5: Deploy the web application and test the functionality

After the successful integration of the model into the web application, a testing phase must be conducted to make sure the intended functionality works, and any problems can be addressed in a timely manner.

1.4 Report Structure

Section 1 includes the introduction and the main problem that led to the development of this application.

Section 2 depicts the literature review that previously existed regarding the method used to solve the problem at hand.

Section 3 enlists the system requirements.

Section 4 states the choice and reasoning for the software development technique.

Section 5 focuses on the system design choices and the frameworks and libraries used.

Section 6 shows the design documentation for the website and the different iterations it went through.

Section 7 contains all the testing that has been conducted in the application.

Section 8 shows the different artificial intelligence models that have been used and tested against each other and the results.

Section 9 lists the legal social ethical and professional issues.

Section 10 has the conclusion and possible future work.

2 Literature review

This section of the paper will introduce some of the existing solutions for each step of the facial emotion recognition process.

2.1 History of Facial Emotion Recognition and current state-of-the-art

The term facial emotion recognition (FER) was first invented in the 1980s. Ever since then, various machine learning techniques were used to try and recognize the seven basic emotions: anger, fear, disgust, contempt, joy, sadness and surprise. These ML techniques have evolved over the years with technological advancements dictating big leaps in new discoveries since more theoretical algorithms could be put into practice with the improved tech. Some of these algorithms were: random forests, support vector machines, deep belief networks and recurrent neural networks.

There are some important factors that play an important role in FER and have led to better solutions being developed to account for these variable factors. These factors are: illumination, the light intensity that is falling on the object affects the classification of the model; expression intensity, the accuracy of the algorithm is better when the emotion is less subtle; occlusion, if this is present, it introduces noise into the outliers and extracted features and it makes it more difficult for the model to extract features from that occluded part.

In the beginning of FER, the algorithms had 3 essential parts that had to be taken care of with different components, namely: pre-processing, feature extraction and emotion classification. We will briefly touch on all these components and what they imply.

Pre-processing is the first step in which noise is removed and data compression is done. There are three main steps to this: facial detection, where an algorithm determines whether the face is present or not in the frame and encapsulates it in a box made out of coordinates; dimension reduction, where the previously mentioned box is used and the picture is cropped to fit only the face in it and have less noise overall in the frame; normalization, after the dimension reduction is completed, the image is then normalized to help the model and speed the training up.

Feature extraction follows right after pre-processing has been done. This is the step in which the features that are important for the model are extracted, for example: face edges, corners, diagonal, lips, eyes. These feature extractions help a model learn faster.

Emotion classification is the last step where the extracted features are used to classify the emotion present in the frame. Various classification techniques can be used for this step.

All these separate models became obsolete once the Convolutional Neural Network (CNN) has been invented. CNN's, together with Deep Convolutional Neural Networks (DNN), represent today's state-of-the-art for facial emotion recognition. These have been a big advancement in neural network because of how they work: the input signal is decomposed into a set of invariant features which provide a strong way to extract relevant features, such as texture and the key-points. After training, the model is ready to interpret an image in an effective way.

2.2 CNNs

This section will describe the main state-of-the-art method used nowadays in facial emotion recognition through a wide range of papers.

Zhang et al. [5] combined a DNN and CBAM to achieve state-of-the-art results in the FER2013 and CK+ datasets. This algorithm combines a DNN like the visual geometry group (VGG) with the convolutional blocks being the core part of the model. Their experimental results show that the created model shows a good feature expression ability

Ullah et al. [6] introduced a new FER model based on image super-resolution. They are passing the collected images through a facial super-resolution phase, which then go through a two-dimensional canonical correlation analysis. After that, the face is recognized, facial features get extracted and are passed to a hybrid classifier that includes a Long-Short Term Memory Network and CNN. The performance is then evaluated over different datasets and comparing it with different models to show the new techniques' supremacy.

Gloor et al. [7] have researched the capabilities of AI in facial emotion recognition and that the features produced can predict people's personality and moral values. To train their AI, they used a tool which utilizes a CNN architecture like ResNet-34. They added a seventh emotion, neutral, which greatly increased the accuracy when none of the six Ekman emotions were recognized.

Atanassov et al. [8] proposed a multimodal approach to improve the accuracy of facial emotion recognition with observing the person's body language as well. The paper combines the authors' own FER-based CNN model and other available pre-trained body emotion recognition CNN. A hybrid model is then created to enhance the students' learning based on their positive, negative or neutral body and facial emotions.

Shahabinejad et al. [9] introduces a novel face recognition-based attention FER which feeds subtle face recognition features through the FER network. A special attention map from the feature map of a CNN is created and then fed into the facial emotion recognition CNN. Testing carried out on two challenging datasets, AffectNet and AFEW underline the superiority of the novel model.

Khan et al. [10] introduces transfer learning and pre-trained network to try and solve the lack of emotion datasets available for deep learning. In the paper, they are proposing a MobileNetV2 based approach, a CNN where they transfer the weights from the model trained on ImageNet and retrain the fully connected layer. They achieve better accuracy than some of the state-of-the-art algorithms with their proposed idea.

Gill et al. [11] propose a new CNN model architecture that distinguishes six emotions, namely: happy, sad, angry, surprise, bore, and disgust. They use three facial datasets that encapsulate these emotions. The results of their proposed model show good potential, where the attained accuracy is better than existing research solutions.

Tegani et al. [12] have suggested implementing a deep CNN to solve the problem of facial recognition in the light of the pandemic. Their proposed solution is a deep CNN that is complemented by the JAFFE dataset in which they simulate the usage of masks through editing the dataset. They use feature extraction on the masked and unmasked dataset which then gets fed into the model. Their results show that the proposed model successfully surpasses the traditional methods in processing masked faces.

Udeh et al. [13] propose a new method that enhances the human-robot interaction and emotion recognition. The suggested method uses a Hybrid Genetic Algorithm with Stochastic Gradient Descent with a deep CNN to help find the better weights for the CNN. They also incorporate the head pose with the facial information to make the model more robust. The results show that the proposed method outperforms the state-of-the-art methods in facial expression in human-robot interactions.

Mishra et al. [14] experiment with a new method of pre-processing the images before feeding them into the CNN. Their proposed method smoothens the images before feeding them to the CNN model through different smoothing processes that take part in the image pre-processing stage. Their experiments showed that the proposed method can be powerful if the right filter can be found and may thus increase accuracy further.

Mouheb et al. [15] created an online web application that would recognize the students' emotions during online classes. They tested multiple state-of-the-art deep learning approaches for the face detection and emotion recognition. Their chosen methods are multi-task cascaded convolutional neural networks and the VGG-16 architecture. Their results show that real-time emotion assessment for video conferencing is fast, viable and presents good accuracy.

Agarwal et al. [16] researched the robustness and efficiency of multimodal techniques in emotion recognition. They have experimented with facial emotion recognition, speech emotion recognition and electroencephalogram. Their results showed that researchers have already implemented Facial-Speech, Speech-ECG and Facial-ECG because of their capabilities to provide more valid results. Out of these, Facial-EEG have provided the best and most robust predictions.

Coreau et al. [17] explored data augmentation techniques in conjunction with CNNs and RNNs. The experiments showed that there are optimal solutions which can be deployed on devices with less computational power. The paper exhibits three methods, a simple CNN with data augmentation, a second CNN based on EfficientNetB1 and a CNN combined with an RNN, each tuned for different datasets which show impressive performance and underline the claim of the paper.

Lei et al. [18] proposed a new method for solving the problems of camera shooting distance, indoor illumination and other factors in a classroom. They explored the use of GANs in conjunction with a CNN to address the aforementioned problems. They results have shown that the data enhancements and model refinement have positive effects on the facial recognition process.

Leng [19] proposed a new method of optimizing the execution time of CNNs used for facial emotion recognition. The study shows a method in which a BatchNormalization layer is inserted in between the convolutional layers to delete the unimportant convolutional layer channels. The BatchNormalization layer also supports simultaneous training of multiple images, which further accelerates the model response speed. The proposed architecture shows robustness and a potential basis for further research.

Sun et al. [20] introduce a novel method to recognizing facial emotions. They propose a new architecture which consists of a CNN that introduces the attention technique for extracting features in the regions of interest (ROI) of the face. This attention technique is added in the first layer of convolution to make it extract more robust features. Their comprehensive comparative experiments have shown that the proposed method is robust and very effective in improving the performance of FER.

Jain et at. [21] conducted a study on the effect of deep learning and FER through the tools and modules that are brought together in the paper. They combined a CNN with different tools available for everyone and managed to build a Deep Convolutional Neural Network that they trained on a broad database. Their results have shown that the mean squared error decreases proportionally to how much variety the CNN gets in training data.

Srinivas et al. [22] propose a new method to improve facial emotion recognition. Their new method combines a VGG model-based CNN, histogram of oriented gradients, landmark detector and SVM. They test the algorithms on their own and then combine the methods which lead to an increase in accuracy and the possibility of further research into combining automatic and hand-crafted methods together.

Boughanem et al. [23] introduced a new method for facial emotion recognition in the wild. They noticed that a lot of the methods that are used for FER in the wild are geared towards posed and environment-controlled emotions. Their proposed method uses CNN models that have been pre-trained and some of their shallow layers have been frozen, with the classification layer being removed and replaced with their own SVM. Their proposed architecture has achieved remarkable performance with the VGG19 and ResNet101 pre-trained models and outperformed some of the state-of-the-art methods for FER in the wild.

Tennakoon et al. [24] proposed a new solution that can be deployed in the e-learning space to boost interactivity of students. Their proposal encapsulates head pose estimation, drowsiness detection, FER and gaze estimation. They are employing CNNs for both FER and gaze estimation. Through these methods they are trying to generate questions and quizzes for students that show less interest to increase their attention. The proposed method could be used in both secondary and tertiary education where asynchronous e-learning mode is used.

Tomar et al. [25] introduced a hybrid framework for facial emotion recognition. Their proposed framework consists of a CNN that is used as a feature selector and extractor and a best-tuned SVM model followed by the same CNN model. The model has been tested in real-time live facial emotion samples and has achieved results that are better than some state-of-the-art methods.

They have also observed that the hybridization of different classifiers enhances the overall accuracy in conventional and live video conditions.

Poulose et al. [26] proposed a new method for FER in autonomous driving systems. They proposed the integration of a feature vector extraction technique along with a CNN that uses those extracted features. The CNN architecture of choice was a ResNet architecture. To validate their newly proposed method, they created their own dataset which were captured with a camera and compared the results of their method with the state-of-the-art algorithm results on the same dataset. Their experiments showed that the proposed model offers a significant improvement in the driver monitoring systems' performance.

Shen et al. [27] introduced a novel single network for FER which combines ResNet with the Sobel features that can emphasize edge information effectively and 10-crop testing to further improve the performance of the model. They chose to combine ResNet with Sobel feature vector extracted from the images because ResNet focuses mainly on global features and the accuracy can be improved by including local features. Their results have shown that the proposed single network architecture achieves better or comparable accuracy with other state-of-the-art methods.

Khattak et al. [28] propose a new architecture for facial emotion detection, age detection and gender detection from facial expressions. The proposed architecture is a mix of convolutions and pooling to ensure both low-level and high-level features are extracted from the images. The experiments conducted with the proposed model show that it outperforms the baseline works by achieving high accuracy scores.

Bodavarapu et al. [29] proposed a new method for low resolution and low-reliable images. Their method consists of a novel hybrid filtering method and a CNN. The novel hybrid filtering method is a combination of Gaussian, bilateral and non-local means of filtering techniques. With this, they managed to increase the accuracy of a lot of pre-trained models as well as their own model. The results show that their proposed method outperforms the traditional methods.

Shah et al. [30] proposed a low cost and effective CNN architecture to recognize human emotions based on their facial expressions. Their proposed architecture can detect seven emotions and uses Haar Cascade from the built-in library in OpenCV to reduce the insignificant pixels in a frame. The results show that the proposed CNN can detect real-time emotion and is low cost compared to state-of-the-art models.

Meghdadi et al. [31] introduces a new deep learning model aimed at being very lightweight and effective at the same time. Their model is named ResEZAP which comes from the components of the model; the base is a modified Resnet block that includes Global Max Pooling and Average Pooling as well as Zero padding after each block. The model consists of 3 such blocks and is extremely low-cost and lightweight. Their experiments have shown a very good accuracy for how small the model is and have shown that the model is deployable on devices that have limited computational power and can handle real-time FER easily.

Donuk et al. [32] have proposed a hybrid approach to facial emotion recognition. Their proposed model consists of a CNN which extracts features from the images, feature selection occurs with a binary particle swarm optimization (BPSO) and the classification is done through an SVM. The addition of the BPSO and SVM have shown improved accuracy of the CNN. The experimental results also show that the model is better or comparable with state-of-the-art models.

Mukhopadhyay et al. [33] introduced a new approach to detect basic facial emotions from textural images using CNNs. In this proposed approach, the images are grayscaled and the local binary pattern (LBP) technique is applied to them. After that, they get fed into the proposed CNN structure and the trained model is tested. The experimental results show that the CNN model with LBP outperforms some of the state-of-the-art models. This is due to the extra low-level information provided to the CNN by the LBP images.

Joshi et al. [34] proposed a new design for a CNN that can handle both facial and speech emotion recognition. This paper also discusses the application of human emotion recognition for telepsychology, for mental health professionals to be able to get real-time emotional data from their patients for better treatment. To accomplish this, the CNN was tested on two different datasets to assess the robustness on both FER and speech emotion recognition. The results have shown that the proposed system is a good baseline to expand research on. Both the facial and speech emotion recognition accuracies can be improved to deliver more accurate and precise results.

Kumari et al. [35] introduced a new method for a deep CNN to recognize facial emotions efficiently. This method aims to solve the problem of poor performance of models on images with poor visibility and noise. The proposed method initially applies a contrast-limited adaptive histogram equalization (CLAHE) to improve the visibility of the input images, after which a modified joint trilateral filter is applied to the image to remove the impact of noise and, finally, are fed into an efficient deep CNN. Their analysis shows that the proposed model performs considerably better than some state-of-the-art models.

Tripathi [36] proposes deep learning techniques to improve accuracy in one of the older datasets, FER2013. Initially, three deep learning models are tested and the best of those three is further optimized and analyzed. VGG-19 was the model that was used and improved on with various optimizers, along with a k-fold validation to evaluate the model. The results show a big improvement over the state-of-the-art methods.

Adhikary et al. [37] proposed a new end-to-end pipeline that combines pose estimation and facial emotion recognition to analyze human behavior. Their pipeline consists of pose estimation, activity recognition, which is made through a CNN, and face extraction which then gets passed into the CNN. They trained each part of the pipeline individually with their corresponding datasets and have achieved results that show improvements over the state-of-the-art methods.

Mahajan et al. [38] proposed a 2 channel CNN for facial emotion recognition. The first channel in the model has the standard CNN structure and the second layer consists of local features of

the image. The information from both channels is then fed into the fully connected layer which is used for classification. The second channel consists of a histogram of oriented gradients with face landmarks on a sliding window. The results show that the proposed method outperforms other solutions in terms of accuracy and precision.

3 System requirements

It is crucial to analyze your system and to conclude the system requirements that must be met in order to achieve the wanted outcome. These requirements are split into two different categories: functional and non-functional. Functional requirements define the behavior and functionality that the system must implement. Non-functional requirements define performance attributes of systems. These two types of requirements help ensure good user experience.

3.1 Functional requirements

Number	Name	Description	Reason
1	Pick methods	Display a screen where the user can pick a method of face recognition	Offer the user a broader choice in terms of data that they can provide.
2	Upload file to server	Let the user choose an image file and send it to the backend for emotion recognition	User may not want to provide data through other methods
3	Upload taken picture to server	Let the user take a picture with their webcam and send it to the face recognition	User may not want to provide data through other methods
4	Upload taken video to server	Let the user take a short video with their webcam and send it to the face recognition	User may not want to provide data through other methods
5	Offer feedback	Let the user offer feedback on the suggested activities to improve the application.	User may not like the activities they were provided by the application and can thus offer various feedback to improve the application for future users

Table 1: Functional Requirements

3.2 Non-functional requirements

Number	Category	Description
1	Accuracy	The web application should offer multiple layers of validation and security to ensure the data from the user is safe.
2	Availability	The system should be running and available 24/7 and without limitations as to how many requests a user can make in 24 hours
3	Compliance	The system should comply with the Data Protection Act 1998 regarding the transmission, processing and storage of personally identifiable information. The system will provide users with a privacy policy and users must be able to see their data before sending it to the server.
4	Interface	The interface should be easy to use, clear and with data displayed in the appropriate format for the device that it is being viewed on.
5	Security	All user data must be transferred and processed securely, and the application should be secure against common application vulnerabilities.

Table 2: Non-functional requirements

4 Software development method

Picking the right software development method for the task at hand is crucial. There are typically 6 stages through which a project goes: planning, analysis, design, implementation, testing, maintenance. Each software development method goes through all these stages but their approach to how to progress through stages is very different from one another which is the reason why picking the right model for the task is important.

4.1 Waterfall model

The waterfall model represents a sequential method of software development that divides into the before mentioned 6 stages. It's one of the oldest and well-known methods in software development. Each phase must be completed before the next phase can begin. Phases do not overlap, and each phase performs one specific activity during the software development lifecycle.

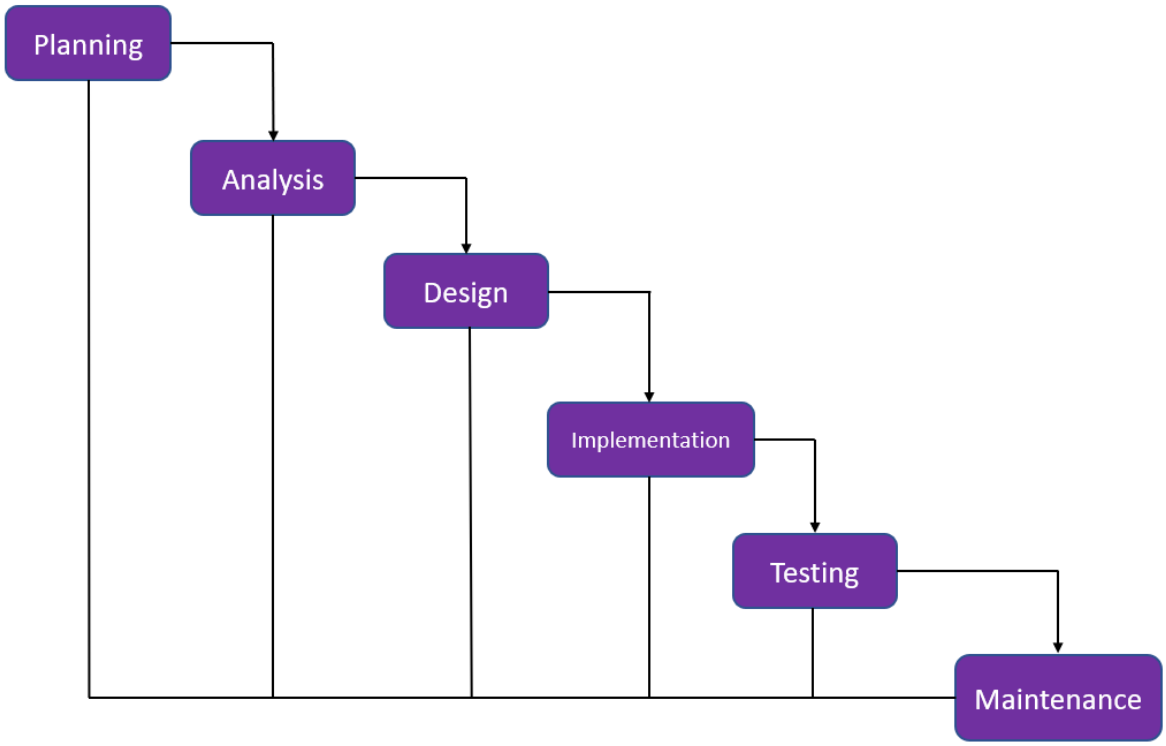


Figure 4: Waterfall Model

This method is not the most suitable for any system, despite being one of the oldest. It has strict limitations as to how each phase should be handled and you cannot mix phases to suit your development needs.

4.2 Extreme programming

Extreme programming represents a type of agile software development. This method is designed to improve the quality of software and the quality of life of the development team. Extreme programming also focuses on feedback and possible requirement changes.

Other parts of extreme programming include programming in pairs, doing extensive code reviews, unit testing on all code and only coding features when they become necessary.

In this method every element of traditional software engineering practice is taken to the extreme, for example code reviews can happen continuously (especially when programming in pairs is enforced).

4.3 Iterative model

The iterative model starts with a set of requirements which are then used to iteratively enhance the version of the system until the full system is implemented. In each iteration, design choices are improved, and new functionalities are added. The idea of this method is to develop a system with the help of repeated cycles and in small portions at a time.

This method suits projects that have a determined requirement set that can slightly change over the course of the development cycle. A key advantage is that the software is available to test much earlier in the development cycle.

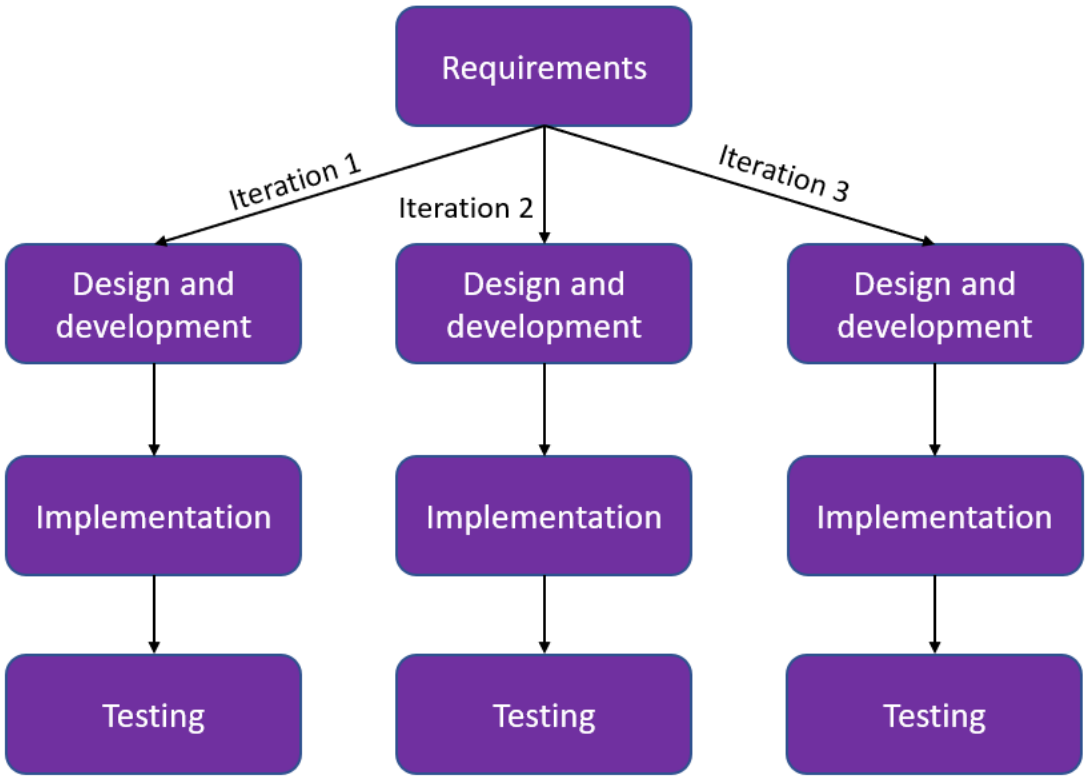


Figure 5: Iterative model

4.4 Chosen model

The chosen software development method for this project is the iterative model. Since all the requirements have been defined in the beginning and may only slightly change in the process, this method was the most suitable. With this model, the software is available to test early on and bugs can be identified and solved very quickly.

The waterfall method was not suitable for this project because of how restrictive it is in the phases of software development. Due to the nature of the project, changes may need to be made in earlier iterations or stages of the development cycle which, in the waterfall model, is not possible.

Extreme programming was a more flexible development method but the project had one set task, not multiple ones that would result in multiple releases of the project.

The iterative model presents the suitable method for this project and workload.

5 Design Choices

In this section, the software design choices will be elaborated and explained. The web application part is going to be separate from the neural network and the findings and results of the neural network testing will be shown in detail in the evaluation section, along with the corresponding graphs and tables.

5.1 Website design choices

5.1.1 Frontend

Since the web application is designed to rely on a REST api for handling the requests, the frontend framework choice has not been tied to compatibility with the backend. These two pieces communicate through JSON/Form data requests and those do not represent limiting factors.

The framework of choice for the frontend is ReactJS. ReactJS has been chosen because of personal experience with the framework prior to the application and the popularity of the framework. Being such a widespread and popular framework, a lot of libraries and utilities are available, whether they are built-in or come separate as packages that can be downloaded using the nodejs package manager.

Different packages were installed to make the application experience better and help with development. The built-in react router and react-router-dom were downgraded to version 5 because of previous familiarity with the version and to speed up development process and not spend time learning differences between versions. This minor downgrade does not affect performance or security in any way. The package “react-cookie” was also installed to help with setting and modifying cookies quicker and easier. Material UI for React has also been installed to help display loading SVGs when the response from the server takes longer than expected. The packages “react-collapsed”, “react-webcam” and “react-flexview” aid with the display of collapsible objects, handle the webcam along with recording and taking pictures with the webcam and make flexboxes easier and quicker to work with. For the feature that enables the user to download their recommended activities based on their emotion, the packages “html2canvas” and “jsPDF” were installed and used. The webpage gets rendered into a canvas with html2canvas and that picture of the webpage gets put into a .pdf document with the help of jsPDF which is then given to the user to download.

5.1.2 Backend

The backend server is made using the Flask. This framework was chosen because it makes it easy to implement and integrate a neural network in the design and flow of the application and because of experience with coding in Python before. This programming language and framework make it easier to integrate crucial features from this application with the help of libraries and other tools that the framework offers. Some of the crucial features were analyzing video footage and the rating system and security around the entire system.

The analysis of video footage was done with the help of the libraries “opencv-python” and “imageio”. For ethical reasons, the application was designed to never save any file that the user has sent towards the server. Therefore, the only library that I have found to support an incoming video and process it frame by frame was “imageio”. The other package that was implicated in this process has been the package that handled the face detection and face crop in every method. Each frame is put through face detection, and if there is no face detected a counter goes up. If the face detection passes, then the image moves onto cropping and then into the neural network. The results of the neural network get saved in separate arrays to be accessed when all the frames have been processed. After all the frames have been processed, the counter that is responsible for the number of frames that did not have a face in it gets checked against the total number of frames. If the number of frames that had a face in it are less than 30% of the total frames, an error is sent to the frontend. If this check passes, the arrays that were keeping track of the neural network results are checked. The most found emotion is picked and the overall confidence level is calculated. If this confidence level is under 70%, the second most predicted label is included in the response as well along with the suggested activities from the corresponding json files.

The ratings are handled via the feedback that is given in the frontend and are based on the tokens that are generated in the security of the application. A request must have a valid token that has not expired yet for the feedback to be processed. Once the user gives feedback on the suggested activities from the frontend, those values get passed to the backend where they are processed. If the given value is 0 that means the user did not offer any feedback and the rating will not change. If the value is between 0 and 1 then the review is classified as bad and thus 10% of the current rating is taken off. If the value is between 1 and 2.5 then the review is classified as negative and 5% of the current rating if taken off. If the value is 2.5 then the review is neutral, and the rating does not change. If the rating is above 2.5 and below 4, the rating is classified as good, and the current rating is increased by 5%. Finally, if the rating is above 4 then the rating is classified as excellent, and the current rating is increased by 10%. At the end the “json” library is used to write the new ratings to the corresponding files.

The security of the application involves the libraries “python-magic” and “secrets”. On every route that is receiving files or base64 encoded binary files, each file’s mime type is checked with the help of “python-magic” to ensure that the passed file is not a malicious one. Before this check, when the route receives a request, a function is called that is checking an array of tokens that have been issued to the users. If the function finds that the 1-hour time from when the token was creates has passed, with the help of the library “datetime”, then that token gets removed from the array. At the end of a successful emotion recognition, when the data is prepared to be sent back to the frontend, a token is generated using the “secrets” library inside of a function and is given a 1-hour time limit. This token, along with the time limit, are stored in the aforementioned array before getting sent off to the frontend with the other data in a JSON body.

Along the libraries that were mentioned, different other libraries have been installed to help with the different functionalities. These libraries are “flask-cors”, which handles the cross-origin

requests, “numpy” which is used with “tensorflow” for the neural network section and “base64” to handle the base64 encoded binaries that are received.

5.1.3 Privacy policy

The user cannot proceed to send their data to the server before reading and accepting the privacy policy and terms of use. This document details how the data is secured, what data is used and how it is used. It is very important for the user to read this document and agree to it before providing any data for the facial emotion recognition process. During every data submission stage, the user is able to download and view their data before submitting it to the server, as well as downloading their final ratings in PDF form before hitting the submit button.

5.2 Neural network design choices

The statistics and all figures related to performance can be found in Section 8: Evaluation.

5.2.1 Own CNN model

This CNN model takes inspiration from the VGG blocks that can be seen in the VGG19 architecture but modifies and adapts the architecture to fit the problem. There were 5 blocks used in total. The first block was made up of two convolutions with 32 neurons each and kernel size of 3, each convolution was followed up by a batch normalization and at the end of the block there is a max pooling 2D with (2,2) pool size and a dropout layer. The second block is made up of three convolutions with 64 neurons each, first two convolutions have kernel size 3 while the last one has kernel size 5. Each convolution is followed by a batch normalization and, at the end, a max pooling 2D with (2,2) pool size and dropout. The last three blocks have the same architecture: four convolutions, the first three have kernel size 3 and the last one has kernel size 5. Each of these convolutions is followed by a batch normalization and at the end there is a max pooling 2D layer with (2,2) pool size and dropout. Block number 3 has 128 neurons in each convolution, block number 4 has 128 neurons again and block number 5 has 256 neurons. All convolution layers in the network have the padding set to “same” so the image size doesn’t get changed and are activated using the “relu” function. At the end there is a flatten function after the fifth block and a dense layer with 7 neurons that is activated with the “softmax” function.

The model has dropout after every block to help with overfitting and keep training new neurons with new information. This was the best model that I’ve found in this iteration of the neural network.

5.2.2 Modified Resnet architecture

The baseline for these neural networks was ResNet50 trained from scratch. The previous model that was created using modified VGG blocks was not performing the best and I have tried to improve the baseline model. The convolutional and identity blocks have not been changed at all, only the overall number of neurons and the architecture in the first block. The zero padding has been removed from the first block, the first convolution has been changed from 64 neurons with a (7,7) kernel size to 4 neurons with a (3,3) kernel size and the max pooling at the end of

the first block was also removed. The following blocks have not been changed regarding their structure, but every block's neuron count has been cut in half. These changes have been made because the baseline results have been worse than the architecture discussed in the previous section and because the features that we are trying to identify in the picture are very small. On top of that, the pictures are very small size as well and do not need a very wide network to perform well.

5.2.3 Different models for other datasets

Because the datasets were so vastly different, the networks have performed very differently on them. Two of the datasets were very small compared to the third one which has led to models varying in performance and thus having to make attempt to make new models for the specific datasets. There are also issues with a dataset being in a specific format that is not supported by the used deep learning library which could have caused the bad performance.

For example, the model designed for CK+ dataset has only 4 convolutions and two max pooling separated into two blocks. The first block has 2 convolutions followed by a max pooling and the second block has the same architecture but with more neurons.

The JAFFE model, although very simple has had difficulties with the data because of the incompatibility that is mentioned in Section 8: Evaluation.

5.3 System diagrams

5.3.1 Use case diagram

A use case diagram is a depiction of how the user can interact with a system. The use case diagram can show different types of users of the system and various use cases throughout this system. The next figure is going to show the interaction of a user with the proposed web application.

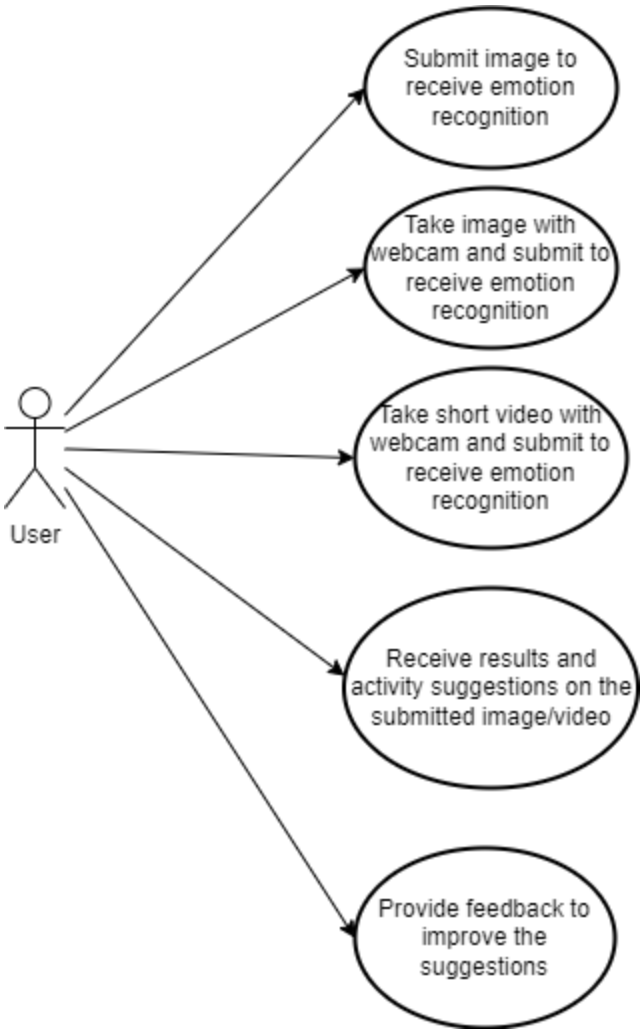


Figure 6: Use case diagram of the application

5.3.2 Flow chart

The use case diagram in the prior section offers a high-level view of the system and how a user interacts with it. This high-level view can be broken down into multiple other events, giving a better view of the system. To achieve this, the following flow chart has been created.

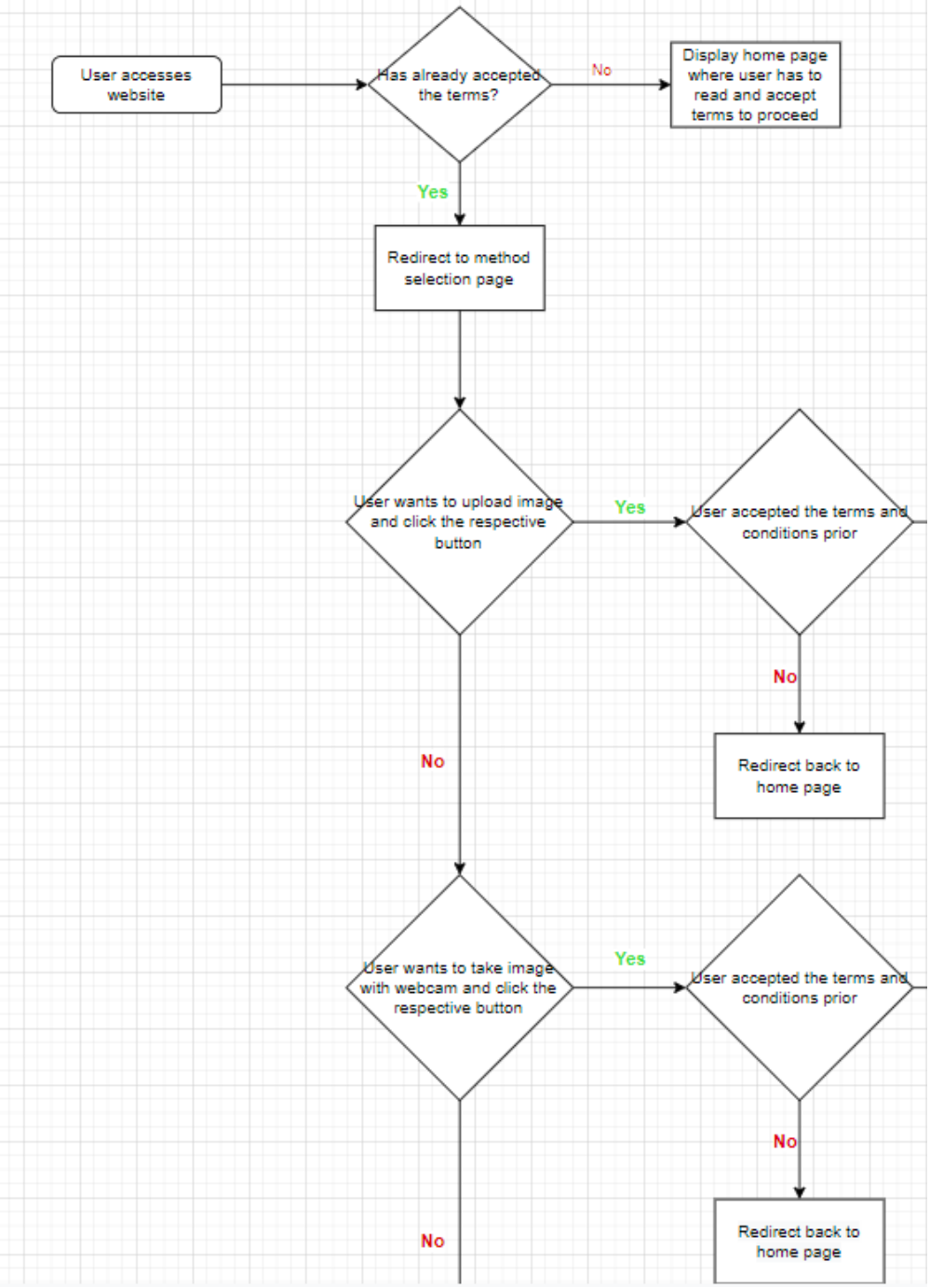


Figure 7: The first part of the flow chart. The full flow chart is viewable in Appendix A: Flow chart of the application

6 Design documentation

6.1 Website design documentation

Having a mobile-first approach to the design was an important factor for this app. The application should provide good support for a vast range of devices including mobile devices, tablets and desktop personal computers. The first set of design choices have looked like the following pictures:

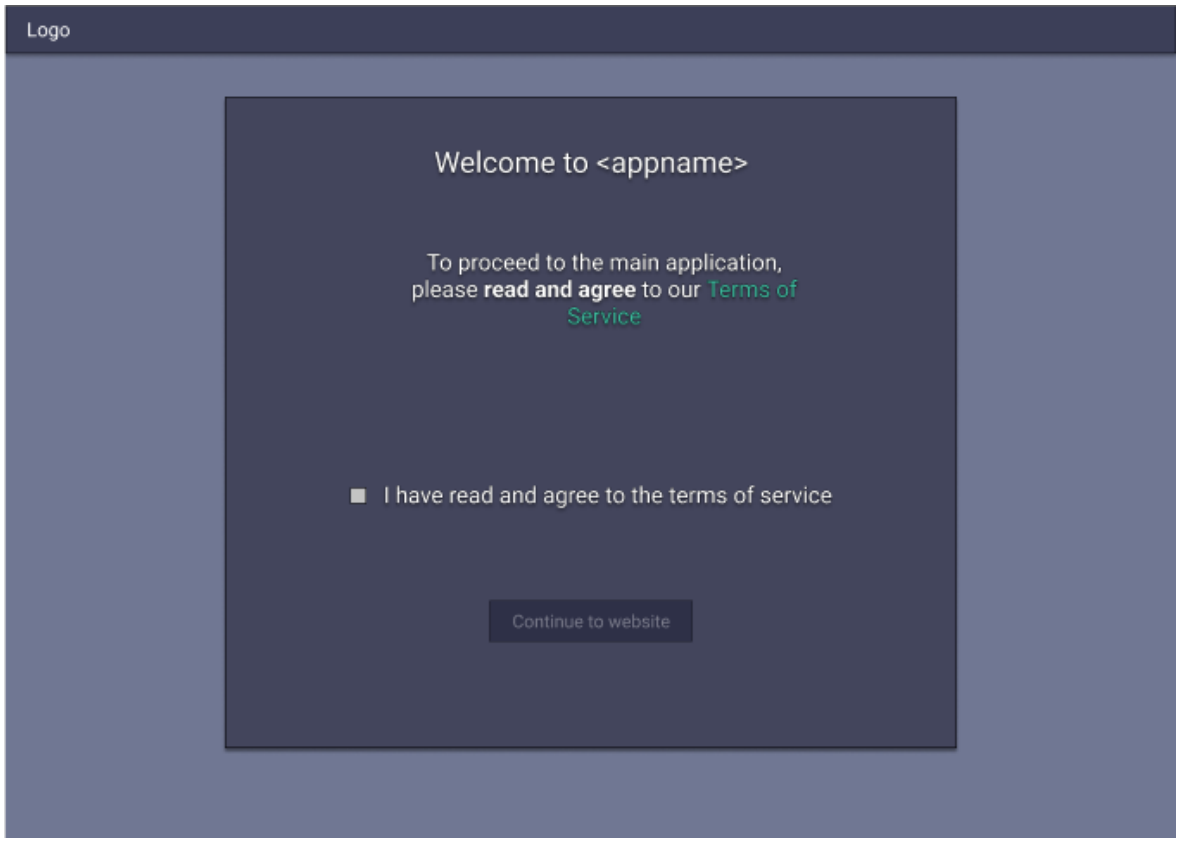


Figure 8: Initial home page

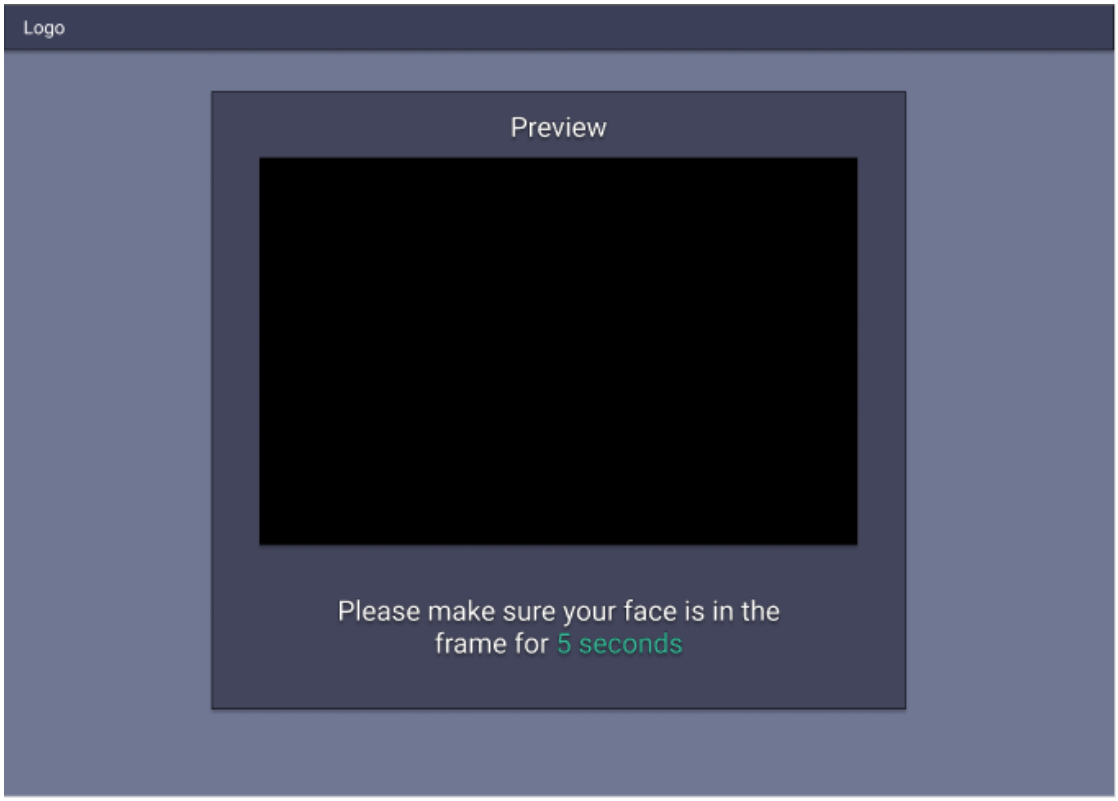


Figure 9: Initial capture screen

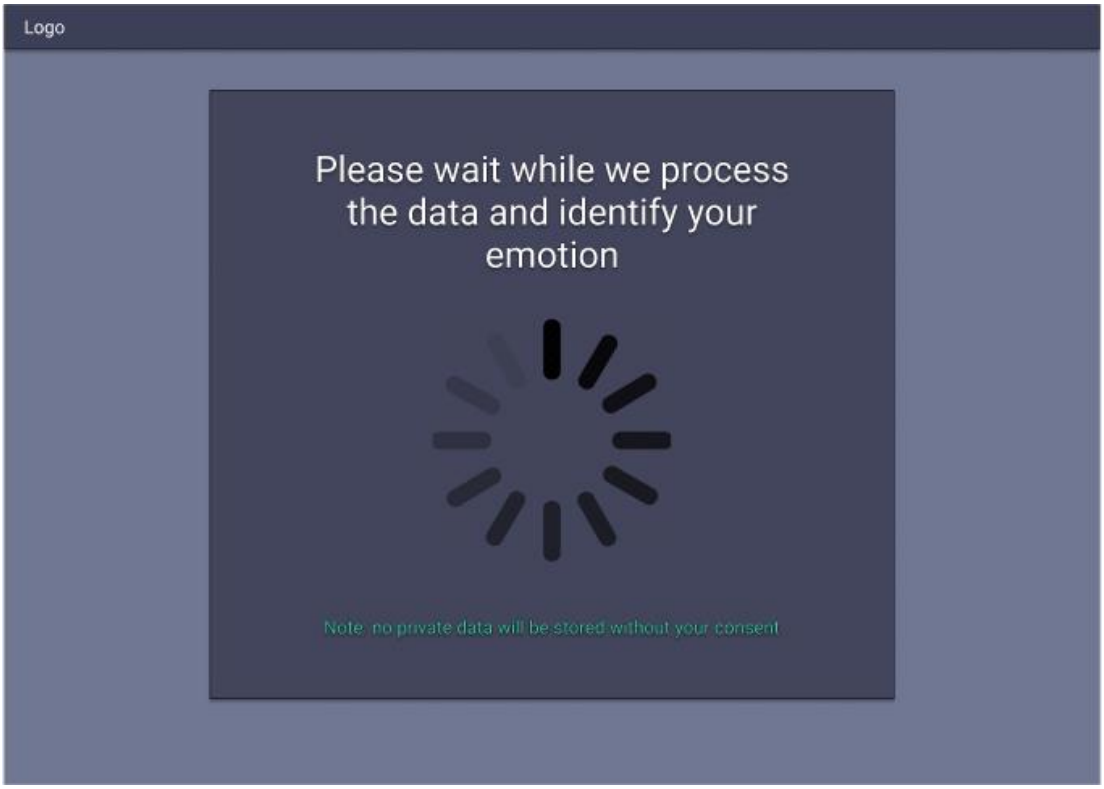


Figure 10: Initial wait screen

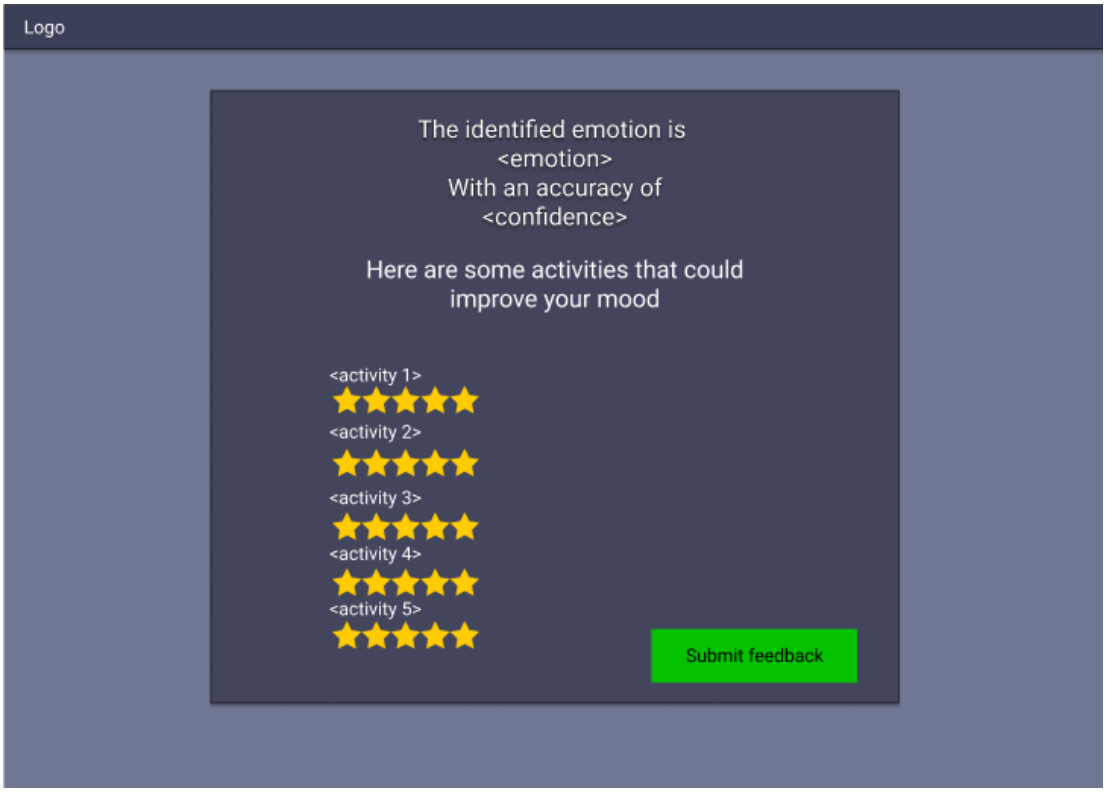


Figure 11: Initial rating screen

With these first designs, further research has been conducted into the impact of colors on an individual's mood.

Kurt et al. [39] has observed the effects of colors on college students. Their results show that colors affect the psychological state of student as well as how they feel about a certain place.

There are four psychological primary colors that have been described in the paper before as well as other scientists: red, blue, green and yellow.

Wright [41] says that red, being the longest in wavelength, is the most powerful and strong color. It has the property of appearing nearer than other colors and therefore it grabs people's attention.

Eiseman [40] states that yellow is an open, outgoing and friendly color. It is often associated with comedy, playfulness and a happy mood.

Eiseman [40] also claims that green is considered an emotionally calming color, giving the sense of refreshment, harmony and equilibrium.

Wright [41] also claims that blue encourages intellectual activity, reason and logical thought. It is the color of intellect, a soothing, calming color.

With these considerations in mind, a redesign of the color palette of the website has been conducted. The results are depicted below.

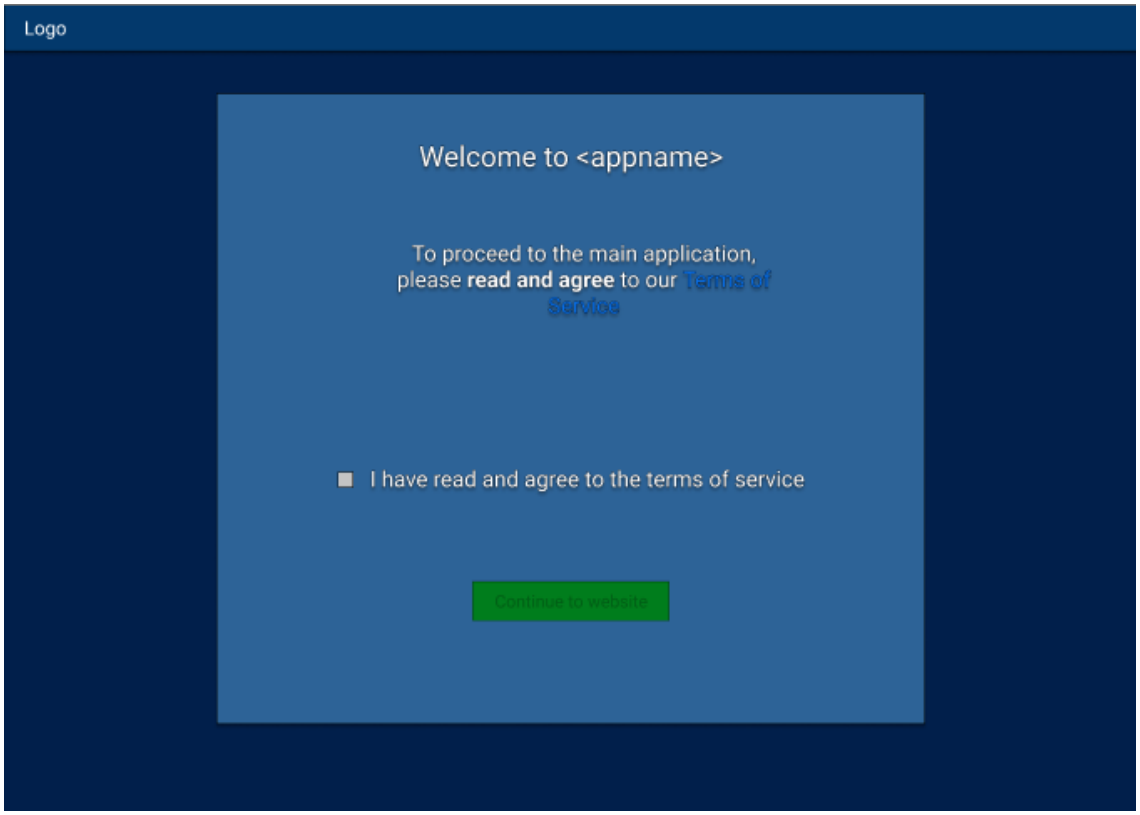


Figure 12: Revised home screen

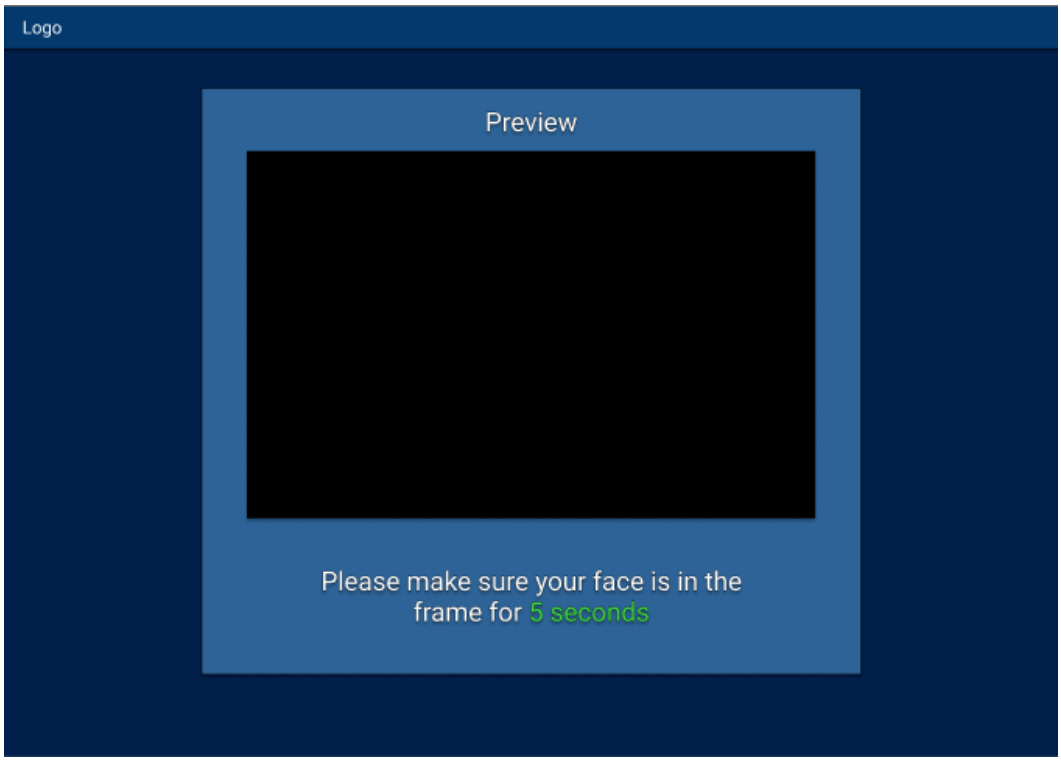


Figure 13: Revised capture screen

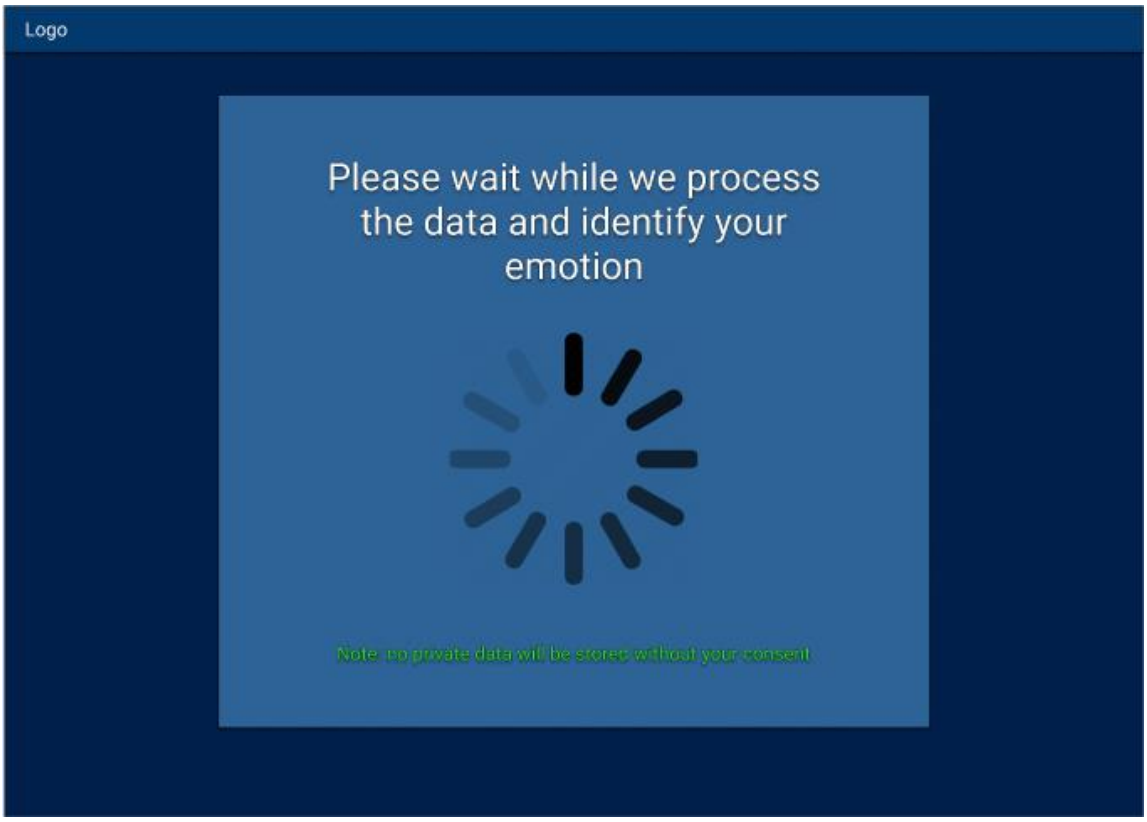


Figure 14: Revised loading screen

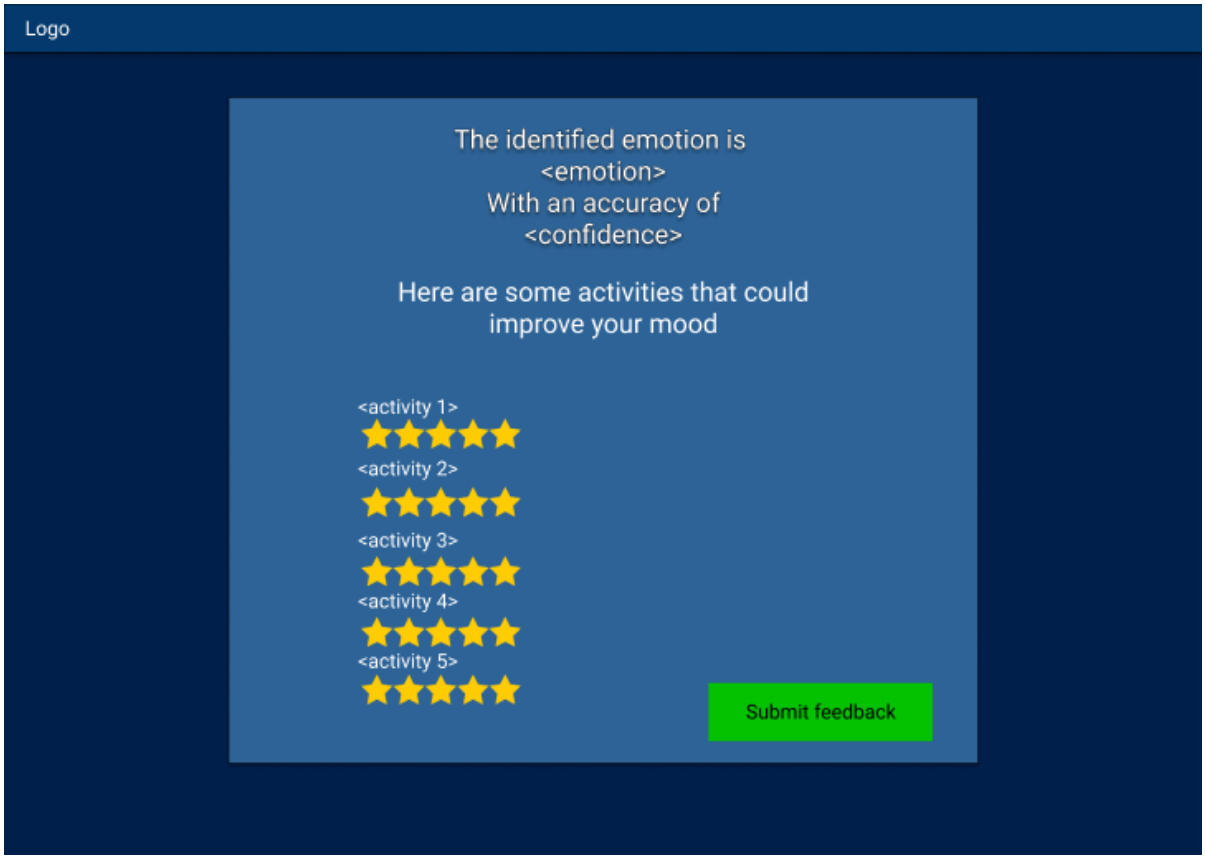


Figure 15: Revised ratings screen

These designs have been coupled with Flask as backend API and ReactJS as front-end to make the pages responsive for a good user experience. They have also been changed and edited to improve the experience and to add more ways for the user to give data which is used to attempt to identify the emotion. The final implemented design is shown below.

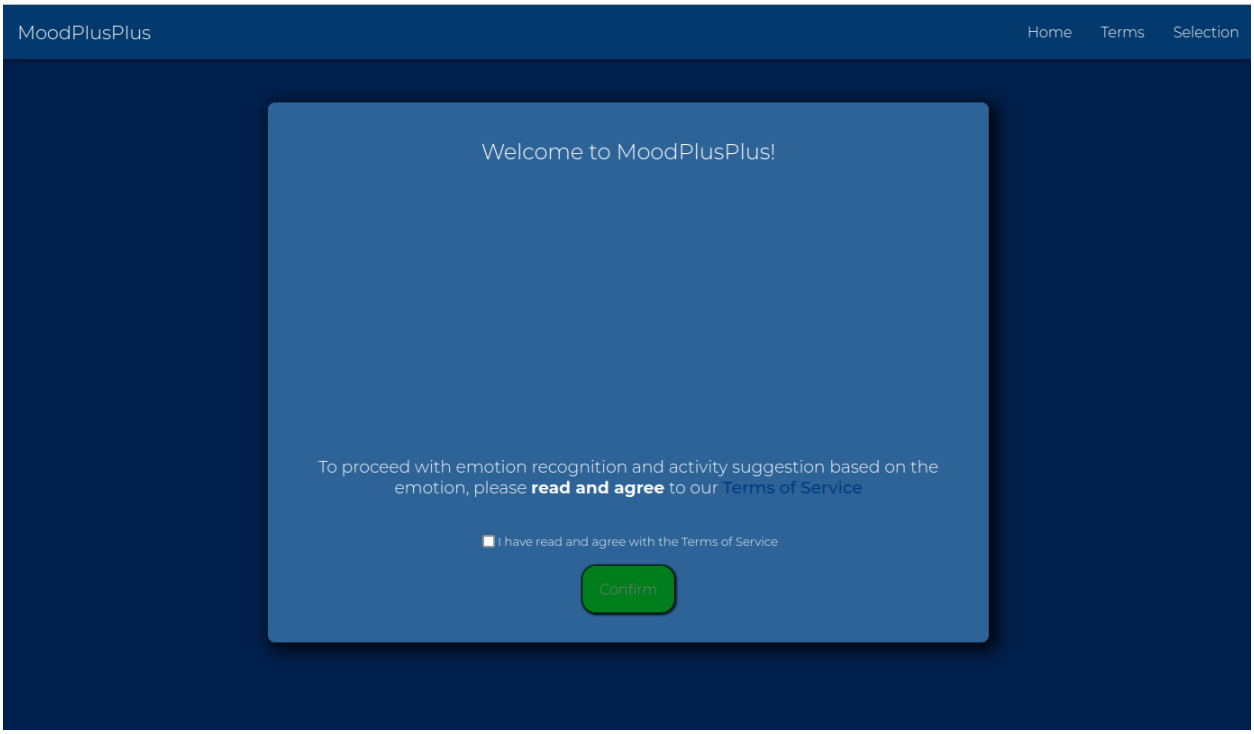


Figure 16: Finished home screen

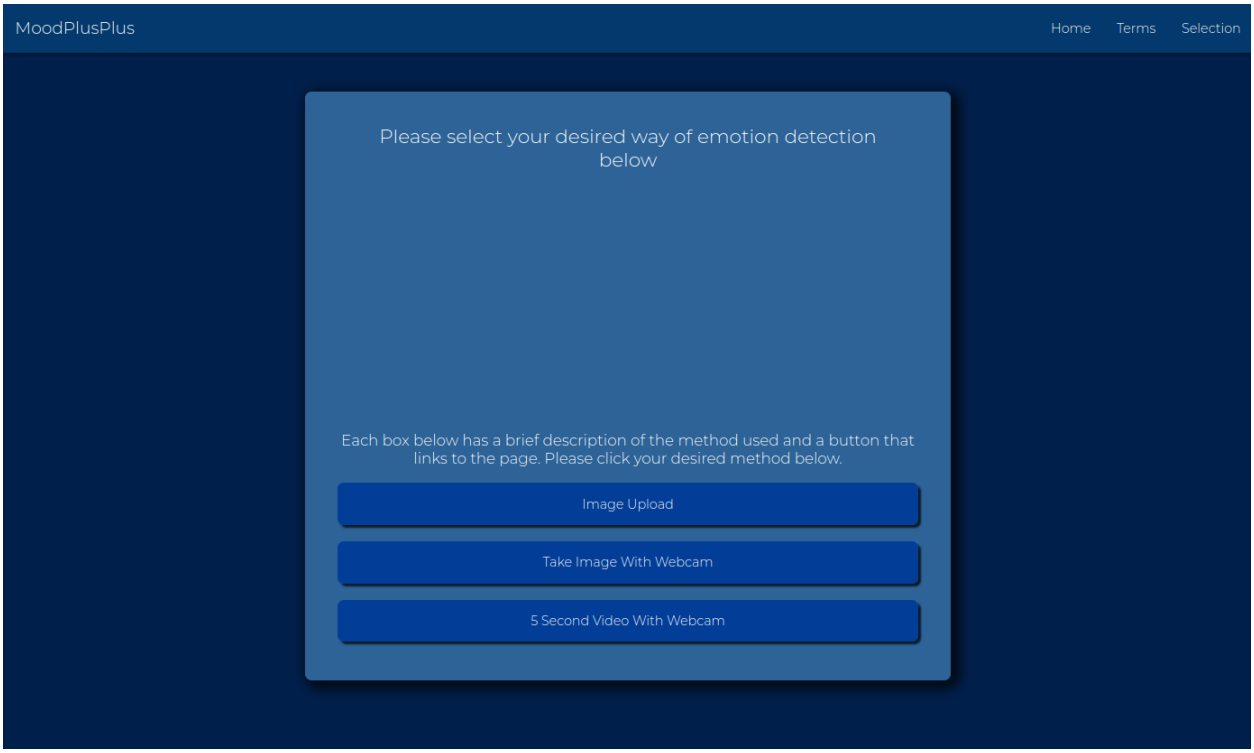


Figure 17: Finished method selection screen

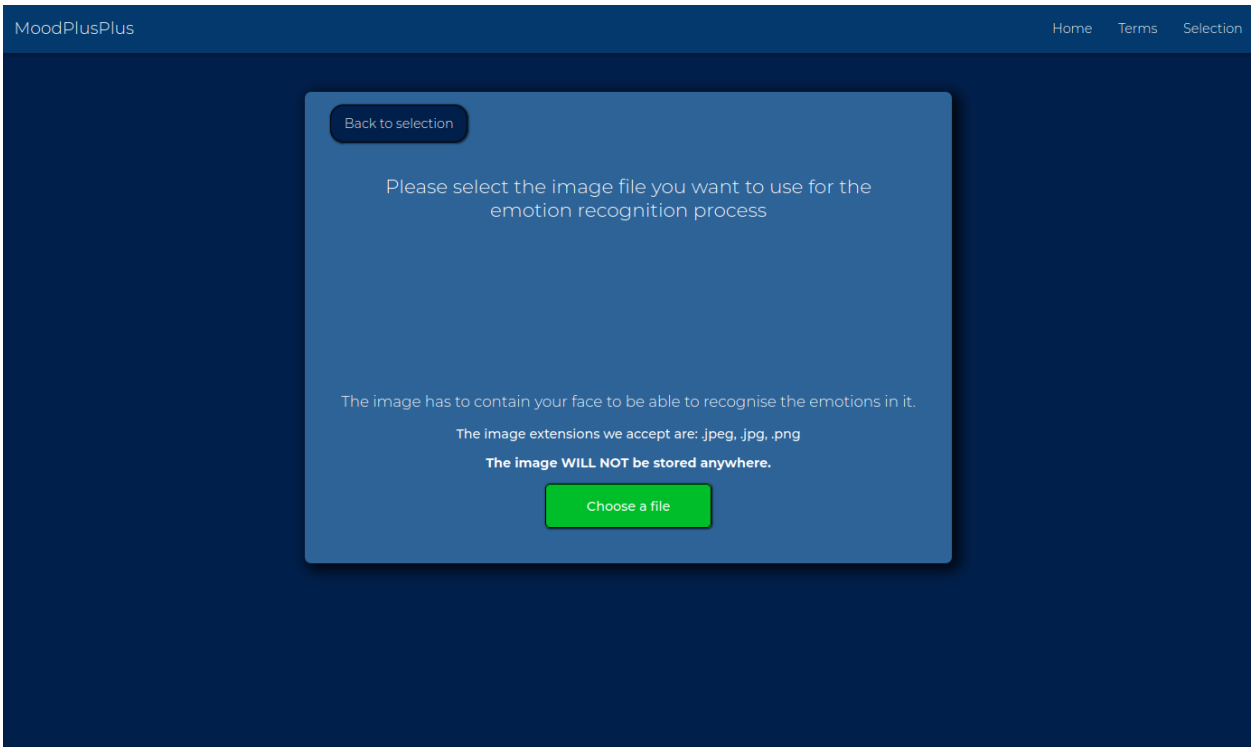


Figure 18: Finished Upload Image screen

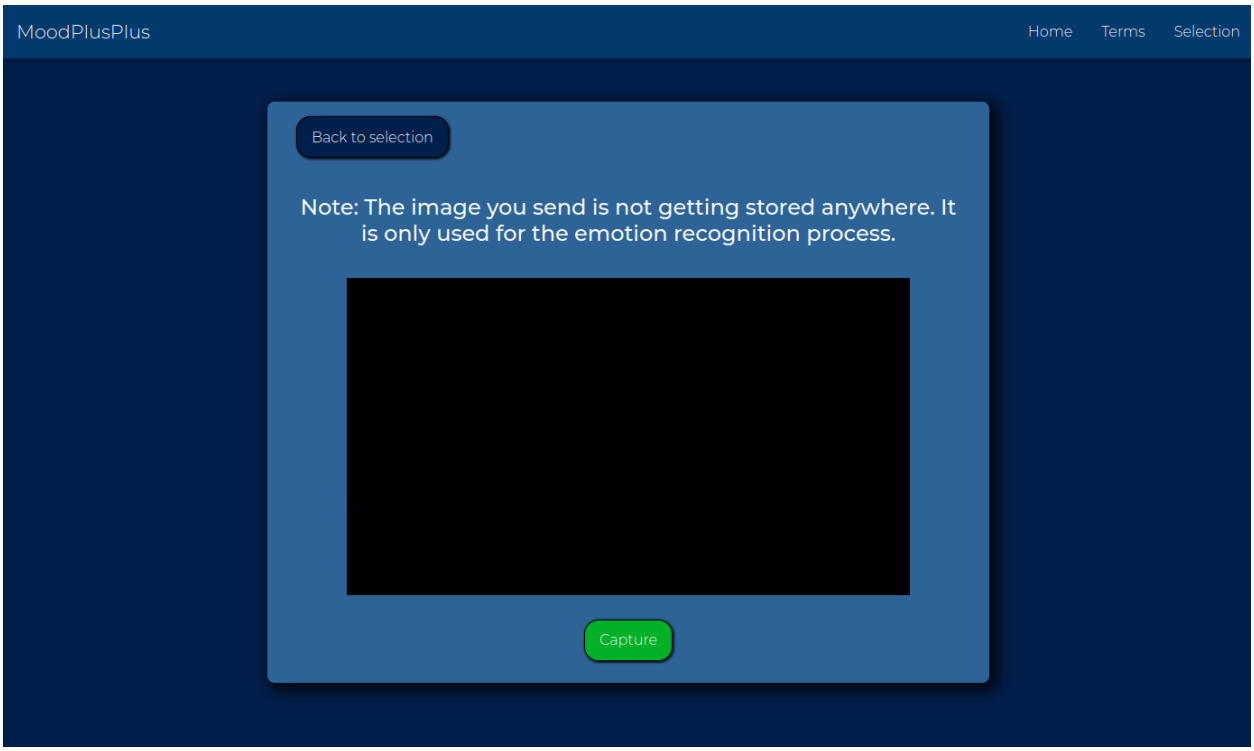


Figure 19: Finished Take image screen

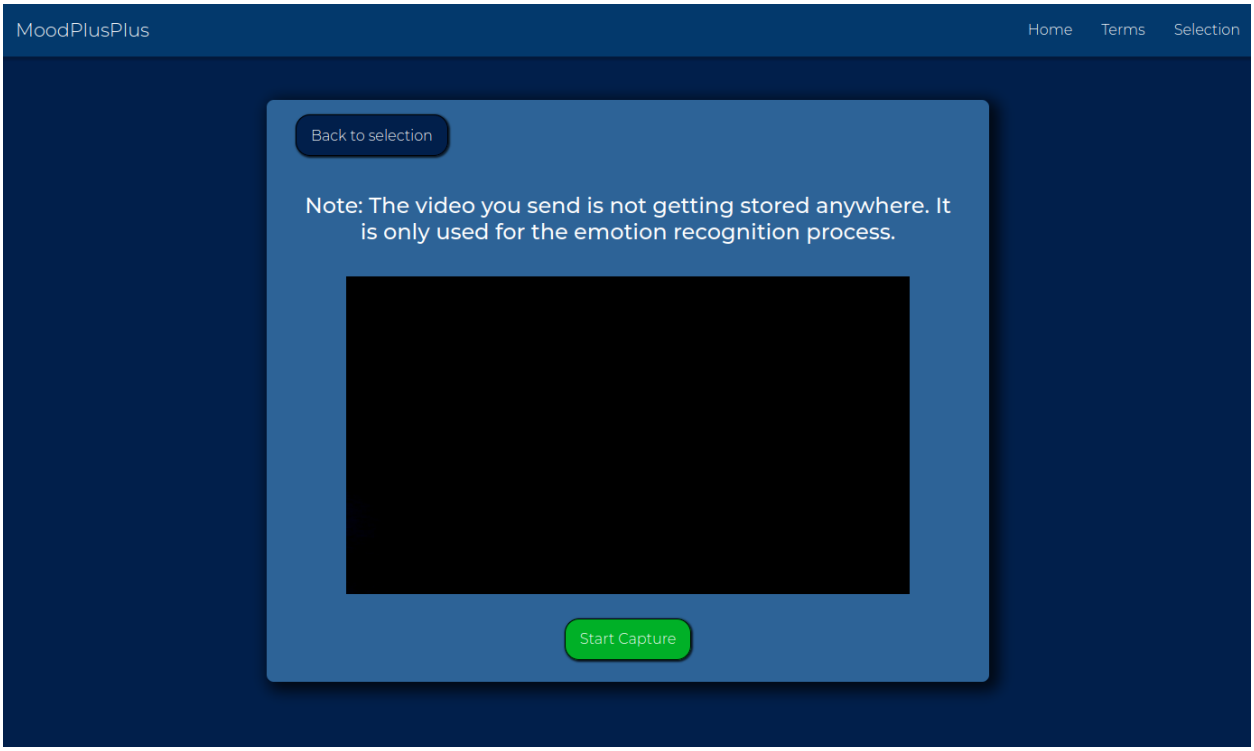


Figure 20: Finished video screen

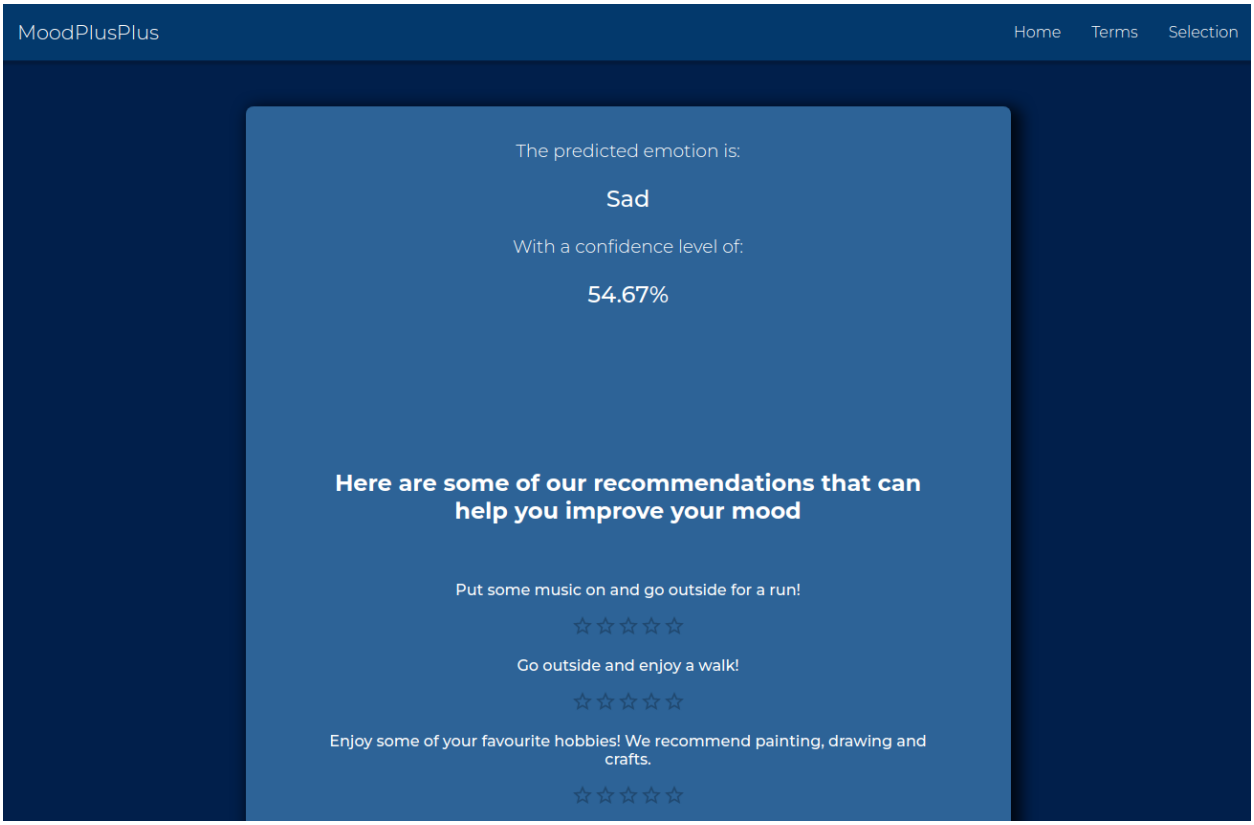


Figure 21: Finished rating screen part 1

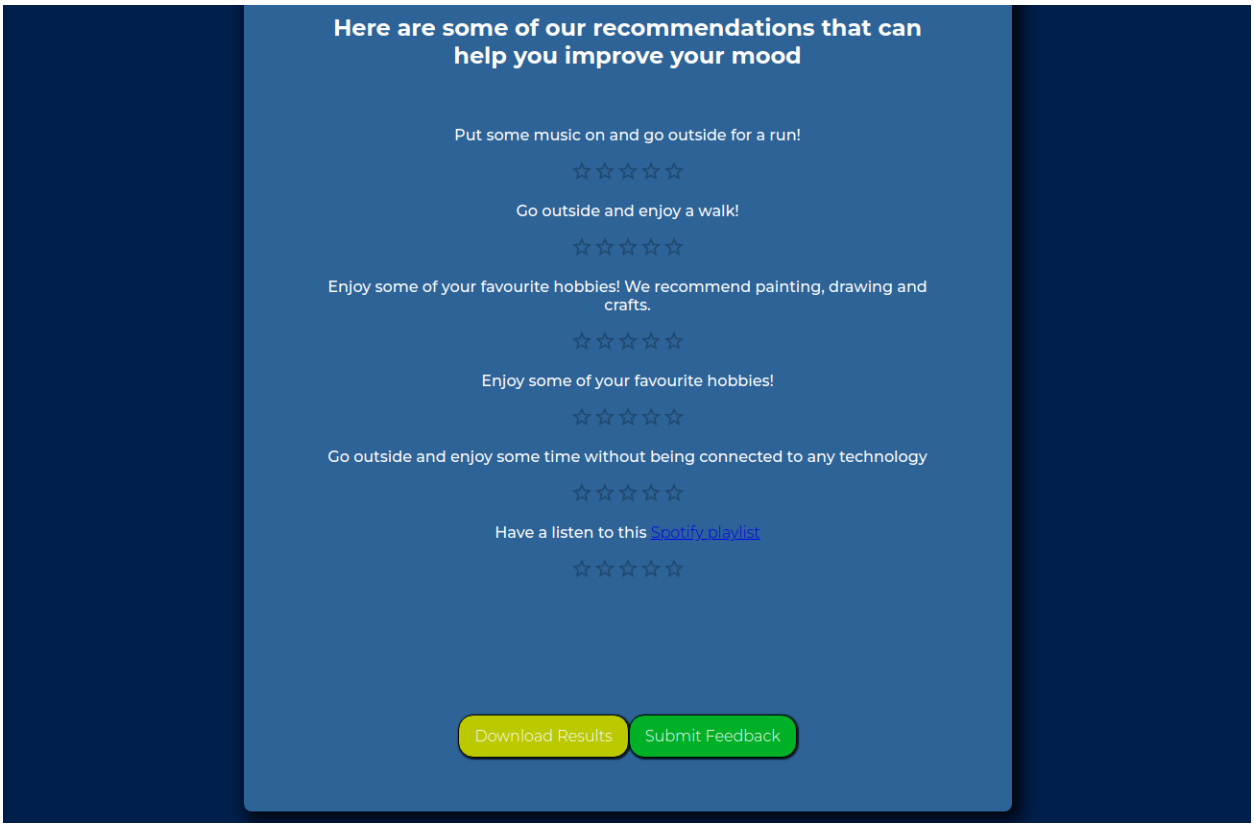


Figure 22: Finished rating screen part 2

7 Testing

7.1 Functionality testing

A functionality test has been conducted at every build stage of the application. At each new stage, the app has been thoroughly tested to ensure that every button and clickable event triggers and does what it is supposed to do. Along with the previous tests, cookie tests were also made every build as well as link validation and invalid input validations. Link validations were done to make sure users couldn't skip forward in the application process without setting the valid cookies, internal and external links were pointing to where they should and, in case links were modified, broken links can be detected and repaired. Invalid input validations would ensure that the user would see an error displayed when something crucial for the application's functionality was missing, for example an image or a video on which the emotion recognition process should be done.

7.2 Interface testing

Interface testing, just like functionality testing, has been done at every new stage of the application. This incorporated verifying that the communication between the frontend and the backend is done properly, compatibility is not broken by newly added libraries or packages and if errors between the frontend and backend are handled properly. Every error that can be observed in the Security Testing section is handled in the frontend and displayed in a custom page depending on the origin of the error. The messages are custom made for each of the three different methods of sending images or videos for the emotion recognition.

7.3 Compatibility testing

The application has been tested on different browsers and different screen sizes to ensure that all users have the best experience while operating the website. Tests have been done on different operating systems: Windows, Linux and Android as well as on different browsers, for example Google Chrome, Opera and Firefox. Along with that, different screen sizes have been tested. The screenshots from the section prior to this contain screenshots from a 1920x1080 monitor. The screenshots below are provided from smartphone and ultra-wide monitor screen sizes. The mobile screenshots are taken on IPhone 11 Pro/X resolution, 375x812 pixels, and the ultra-wide monitor resolution is 2560x1080.

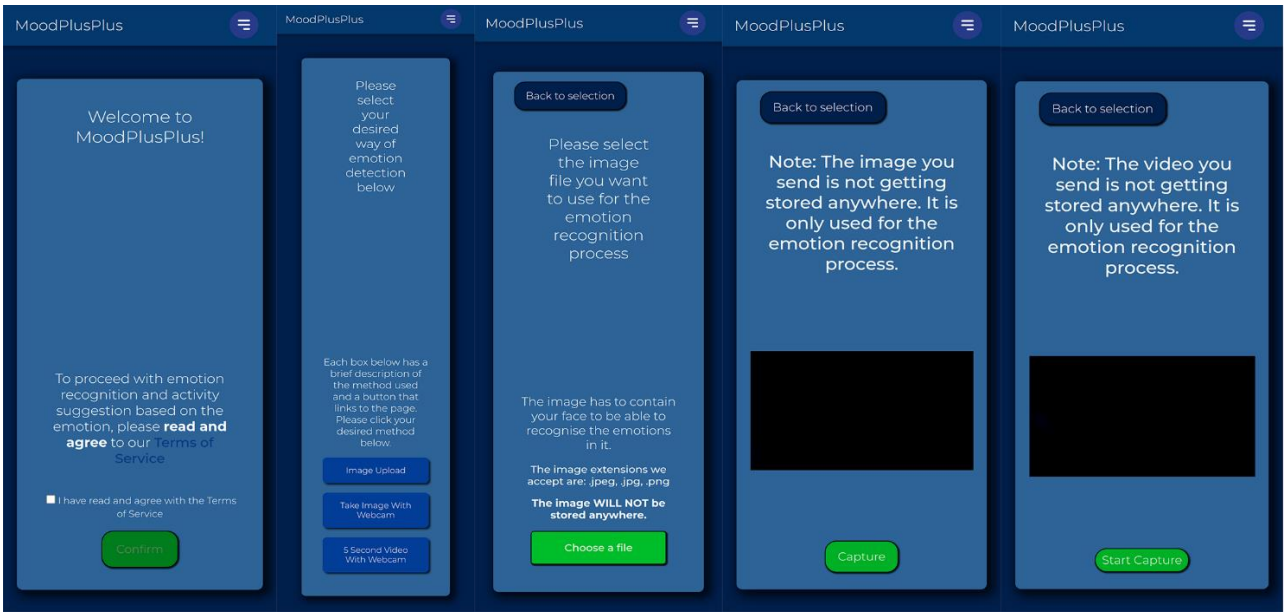


Figure 23: Website on mobile devices

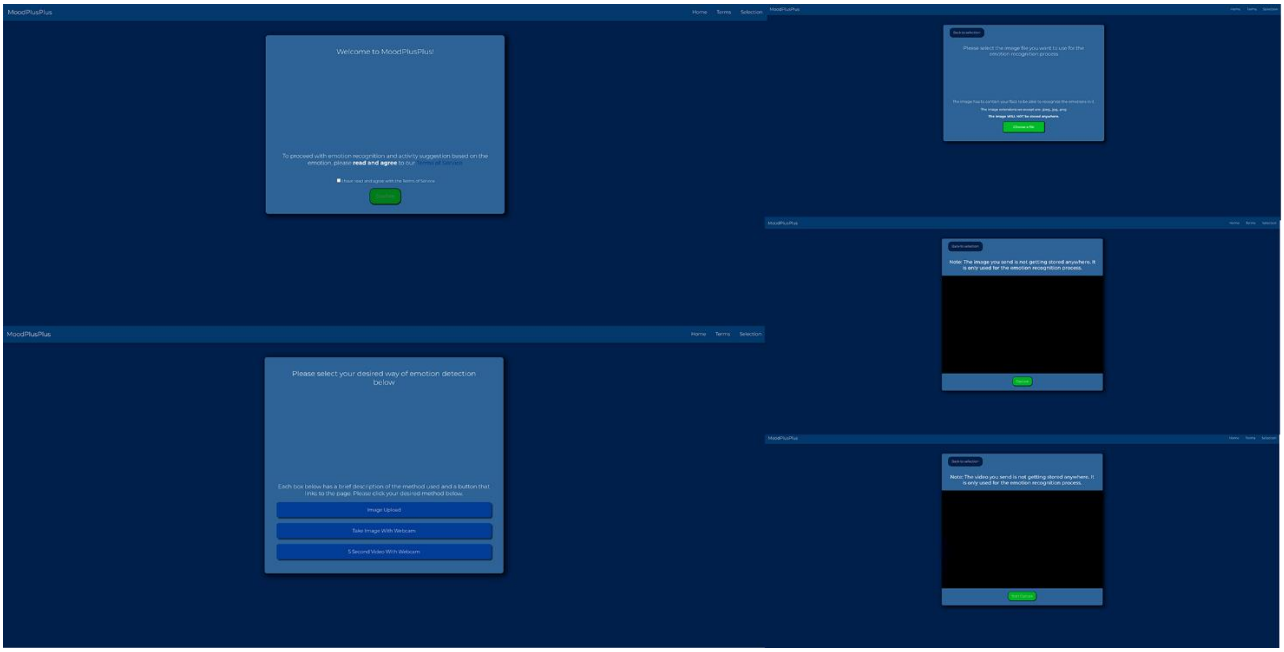


Figure 24: Website on ultra-wide monitors

7.4 Performance testing

Performance testing was conducted on all endpoints and web pages. The average response time of the application is under a second and, on parts where there is a longer wait time involved, loading effects are displayed on the screen to ensure the user knows the web application is working and did not stop. One such route is /uploadVideo because of the nature of the process behind working with videos. The recorded 5 second video is sent to the backend where it is split

into frames and each individual frame gets analyzed independently before sending the result of the whole video back to the frontend to display.

On top of this, the Flask server runs in threaded mode by default which means it can handle concurrent events by default. If the number of concurrent requests exceed the capabilities imposed by the operating system or the computer's CPU, then the events are placed in a queue, meaning that having exceeded the concurrency limits would result just in a linear increase in memory usage. There aren't any global variables (declared with a "g" in front of the variable name) present inside the server which could cause concurrency issues.

7.5 Security testing

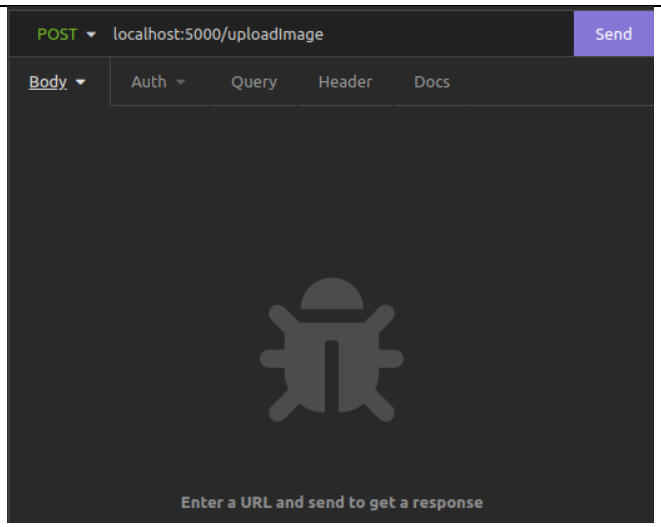
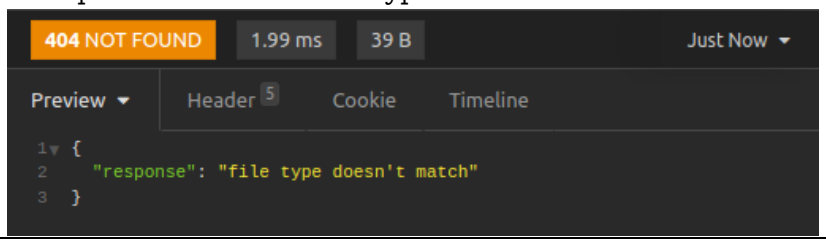
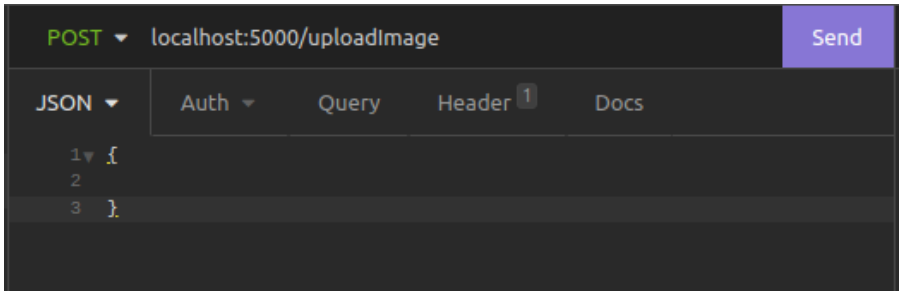
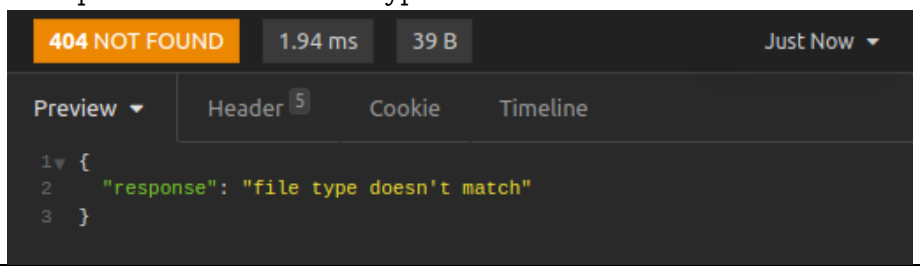
In this section we will test the security of the proposed application with the use of the Insomnia.Rest application. For each route in the server side there have been validations and check put into place to ensure no malicious users can gain access and cause harm to the application. The server makes use of the library python-magic to check the mime types of the files that it receives and, if a file with a different mime type than the accepted ones gets parsed, it will return an error. There's also been a token system coded to make sure that the ratings which can be given at the end of the emotion recognition process cannot be given by a person that has not gone through the entire application's process. These tokens are valid for 1 hour after they are generated in the emotion recognition process.

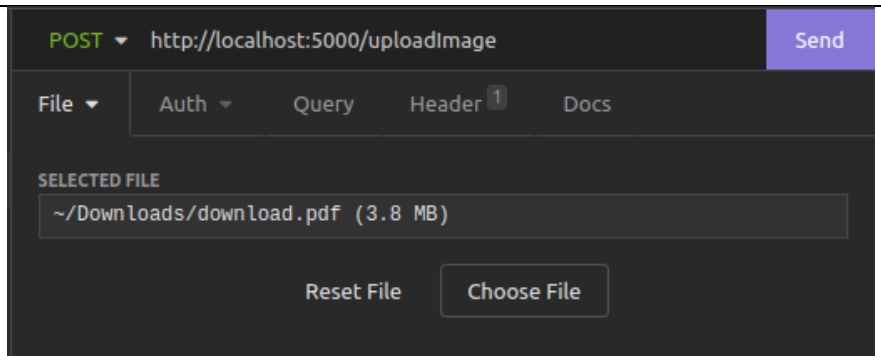
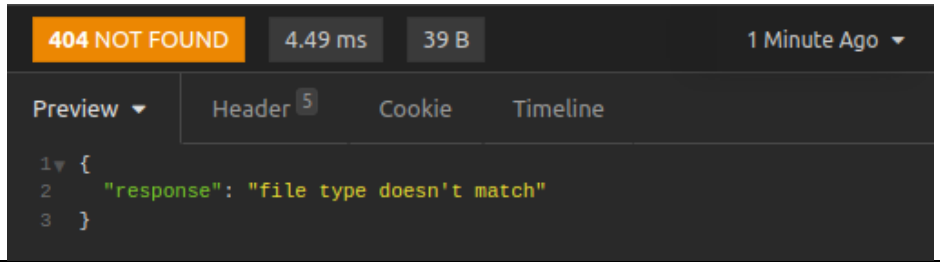
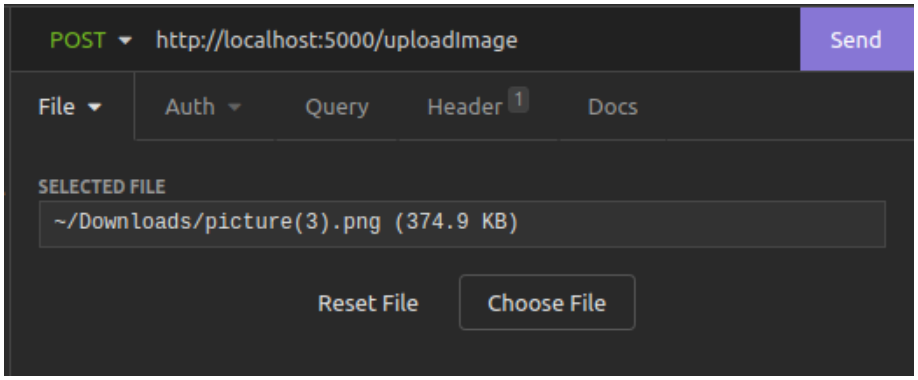
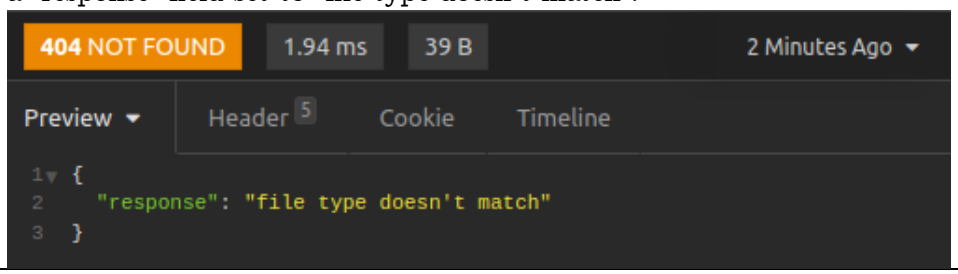
The server is designed to only accept certain file types on different routes. The /uploadImage route only accepts jpg, png and jpeg binary files, the /uploadCapture route only accepts jpg, png and jpeg base64 encoded files and the /uploadVideo route only accept mkv and webm video types. All routes expect the files or data to be present in a multipart form data.

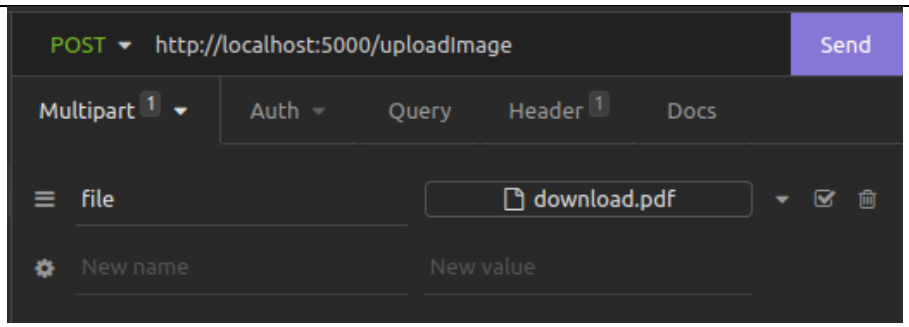
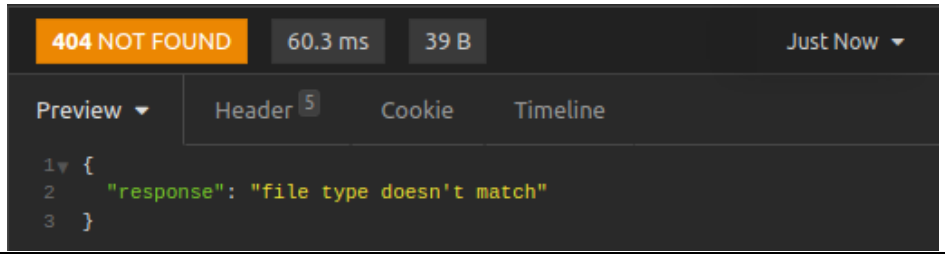
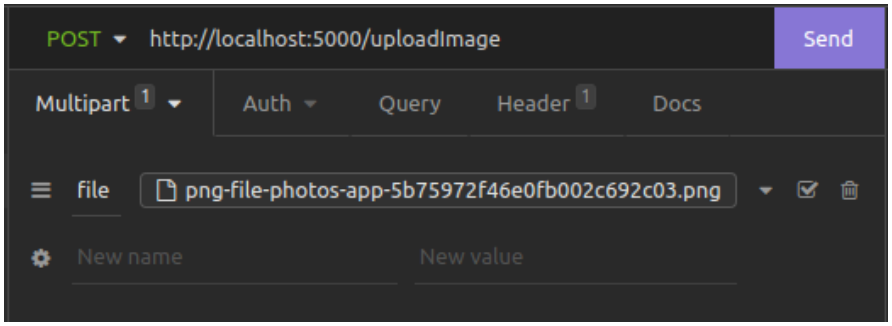
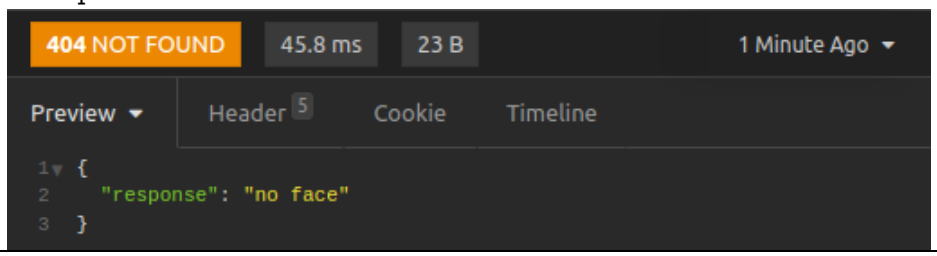
Since this application is a proof of concept and is not deployed into the internet, the communication channel between the frontend and the backend is handled as a HTTPS on http://localhost. Browsers treat http://localhost differently, although it isn't HTTPS it behaves like HTTPS in most cases. On http://localhost most features that require certain security guarantees are supported and behave like they would be on an HTTPS site. This is the case for the web application described in this paper, all features behave like they would be on HTTPS. On the internet, HTTPS and SSL would have to be set up to ensure maximum security along with encryption.

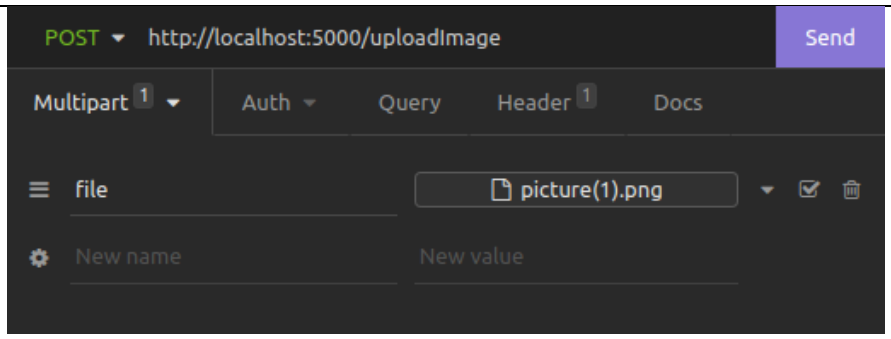
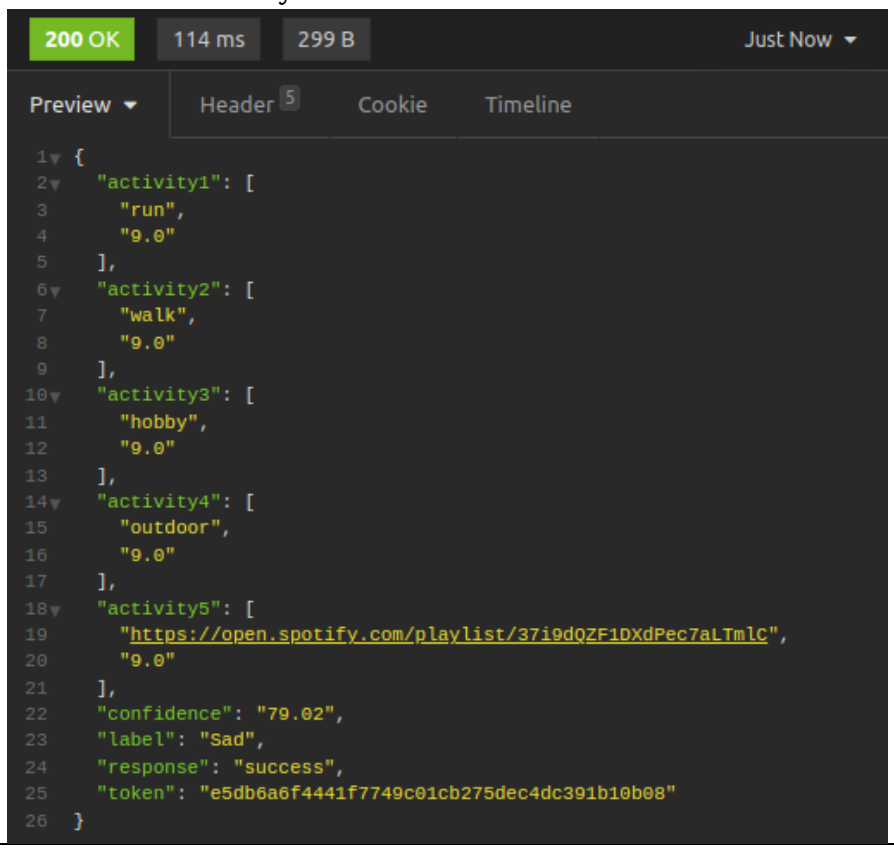
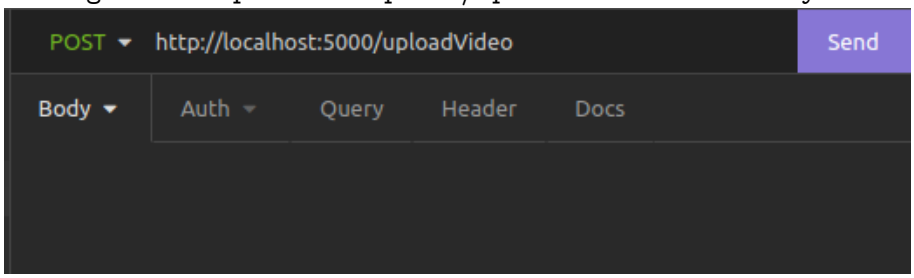
The table below contains all the tests that have been conducted as well as the expected result and if the application passed the test.

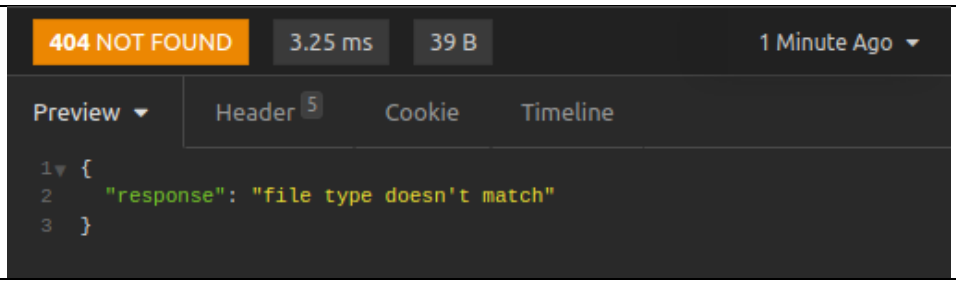
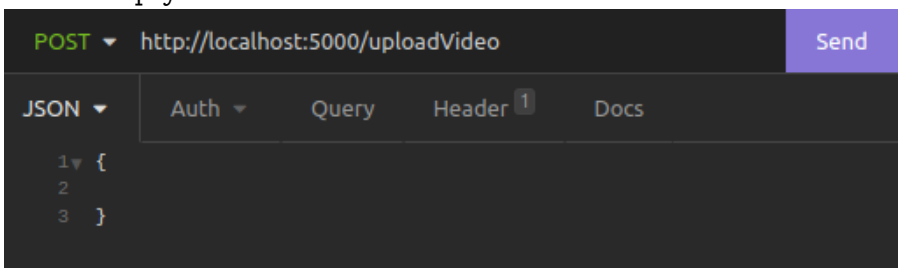
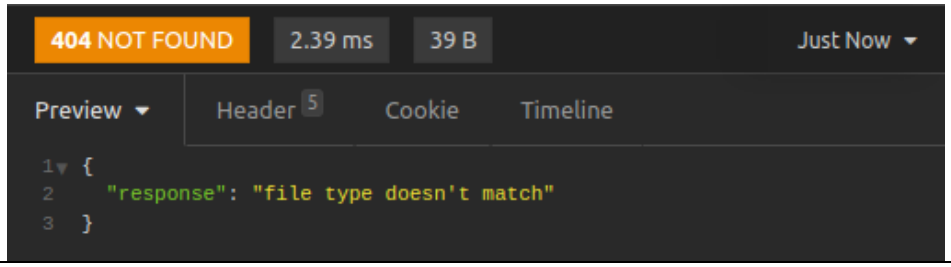
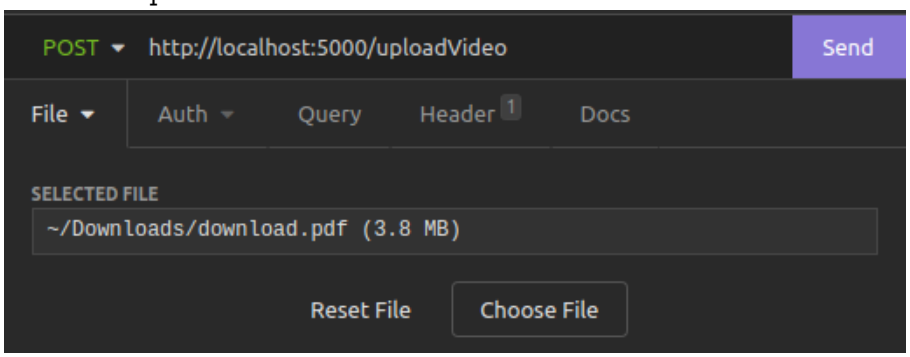
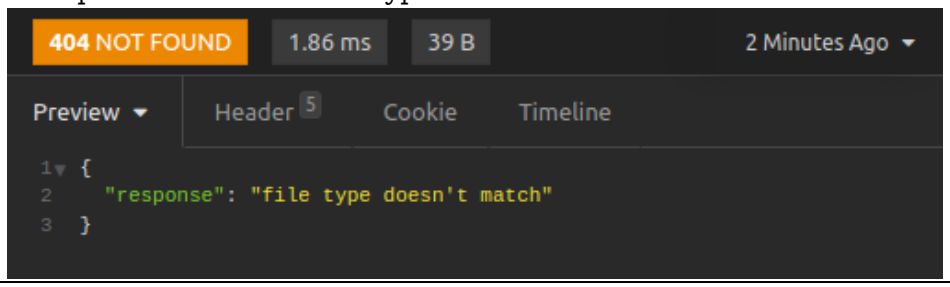
Number	Test description and expected behavior	Outcome
1	Testing POST request to endpoint /uploadImage with no body in the request.	Test passed.

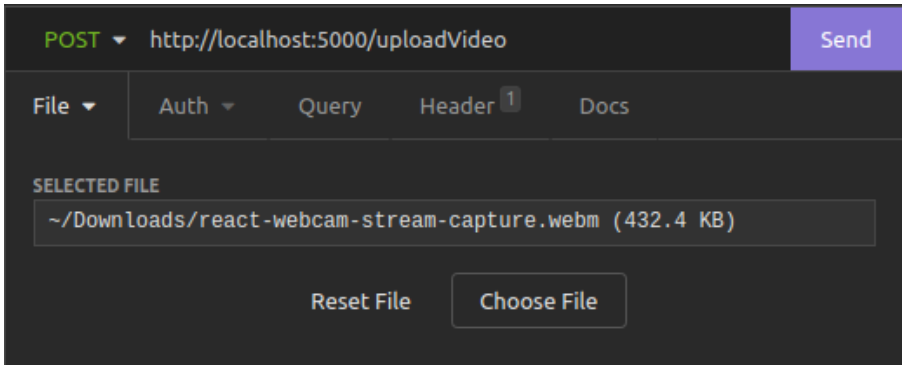
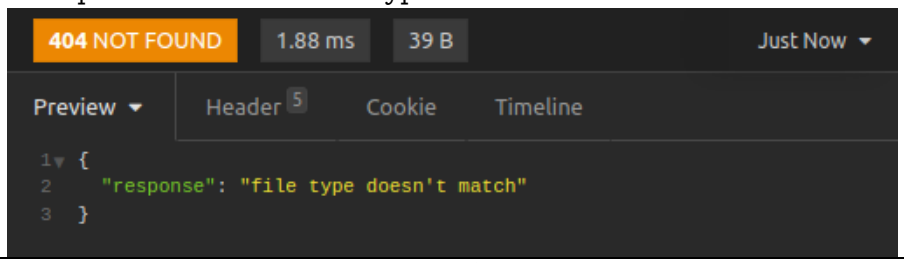
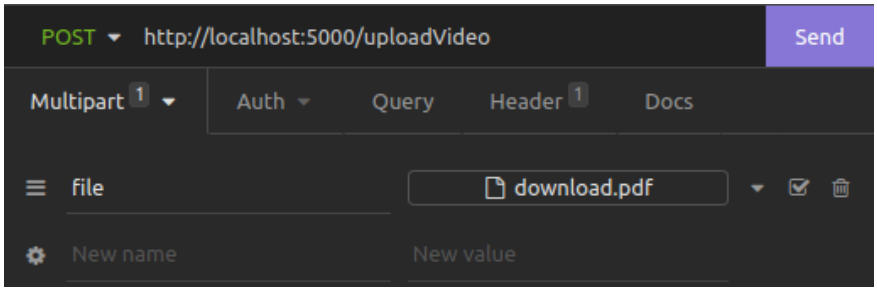
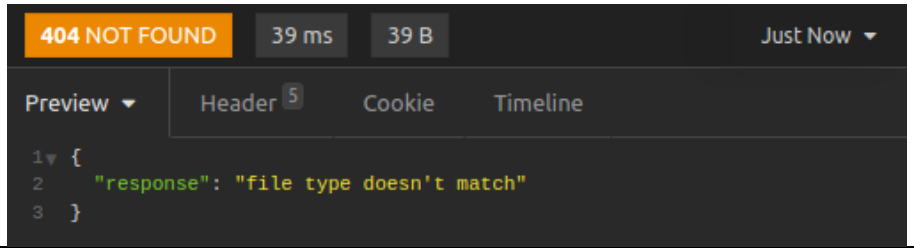
	 Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match". 	
2	Testing POST request to endpoint /uploadImage with an empty JSON body.  Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match". 	Test passed.
3	Testing POST request to endpoint /uploadImage with a binary file type that is not permitted.	Test passed.

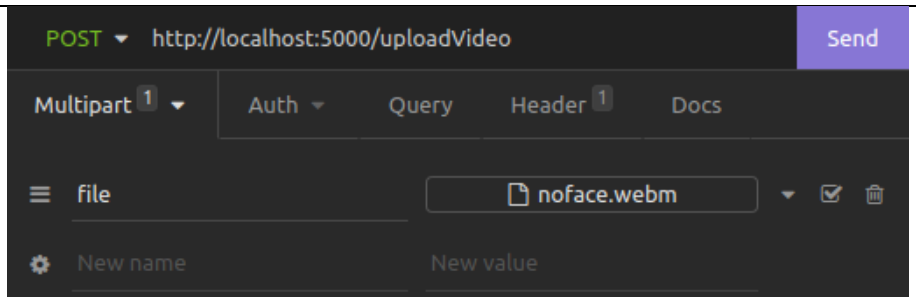
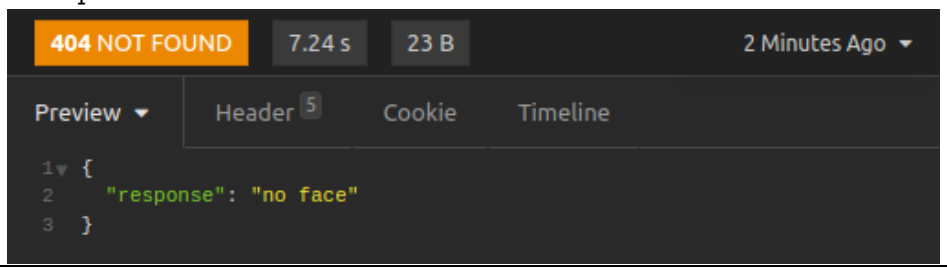
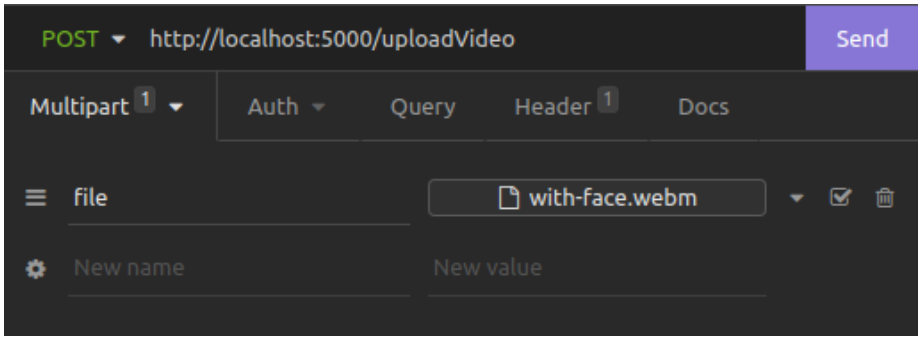
	 Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match". 	
4	Testing POST request to endpoint /uploadImage with binary file type that is permitted.  Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match". 	Test Passed.
5	Testing POST request to endpoint /uploadImage with multipart form body and a binary file type that isn't permitted in the "file" field of the form.	Test passed.

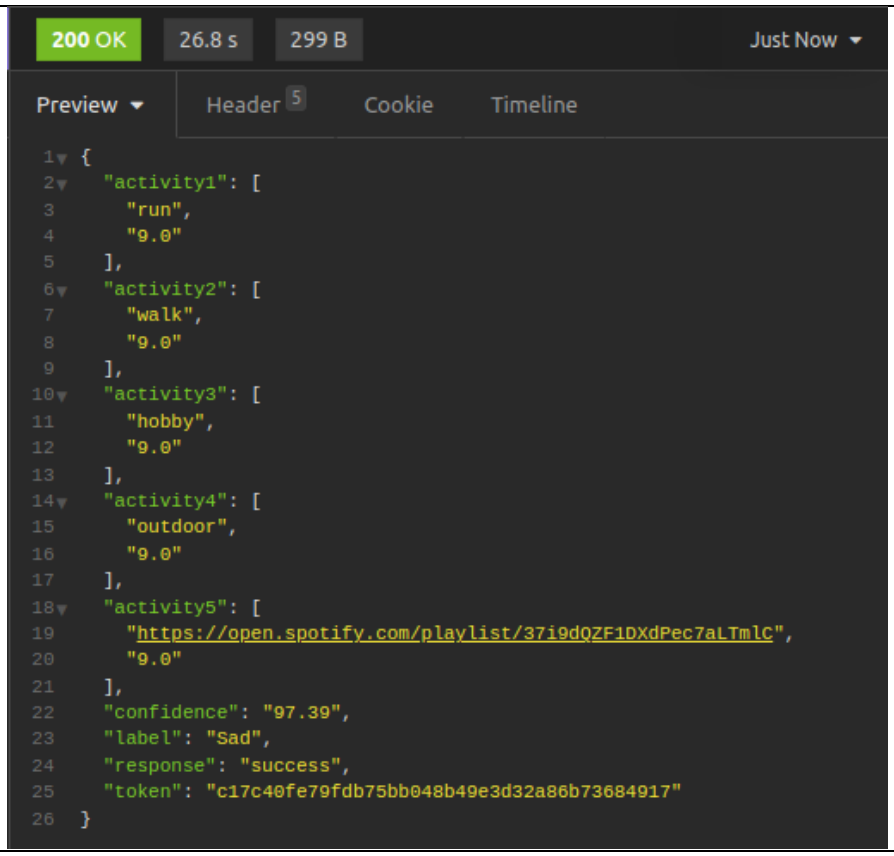
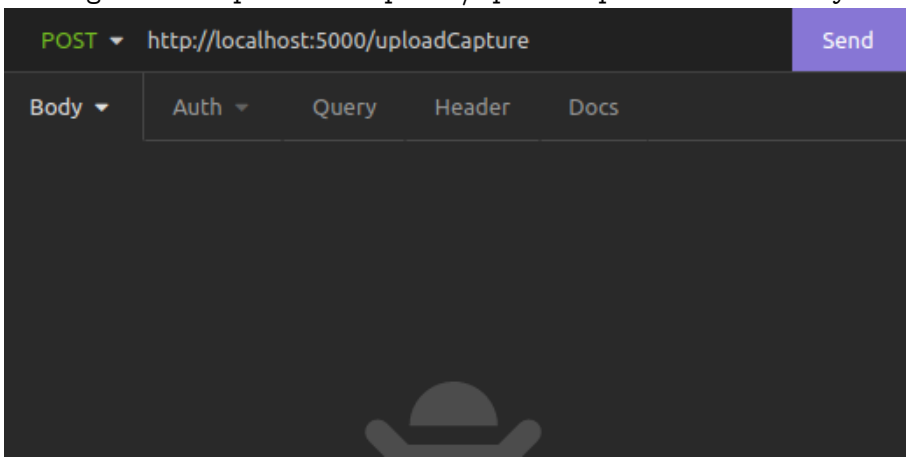
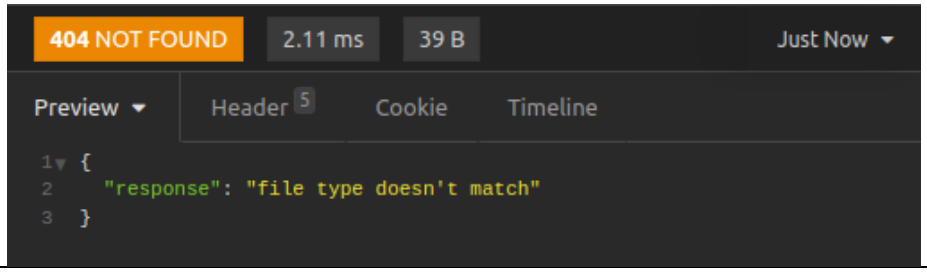
	 Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match". 	
6	Testing POST request to endpoint /uploadImage with multipart form body that has a permitted binary file type with no face in it.  Expected response: 404 status code message with a JSON body that has a "response" field set to "no face". 	Test passed.
7	Testing POST request to endpoint /uploadImage with multipart form body that has a permitted binary file type with a face in it.	Test passed.

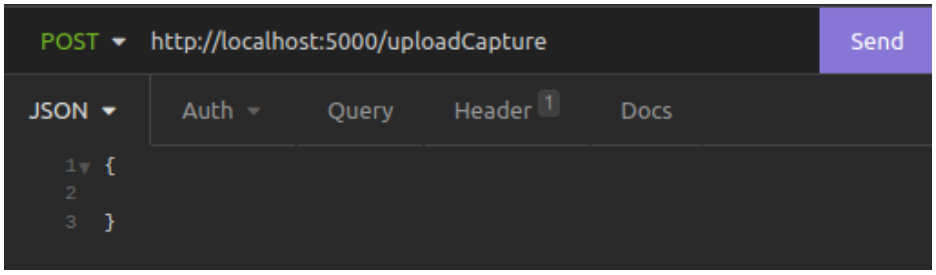
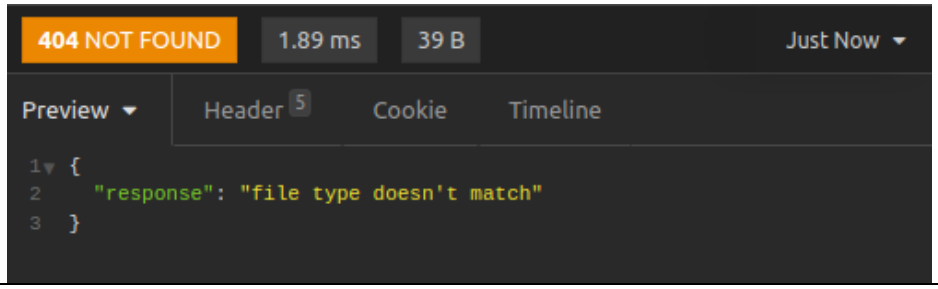
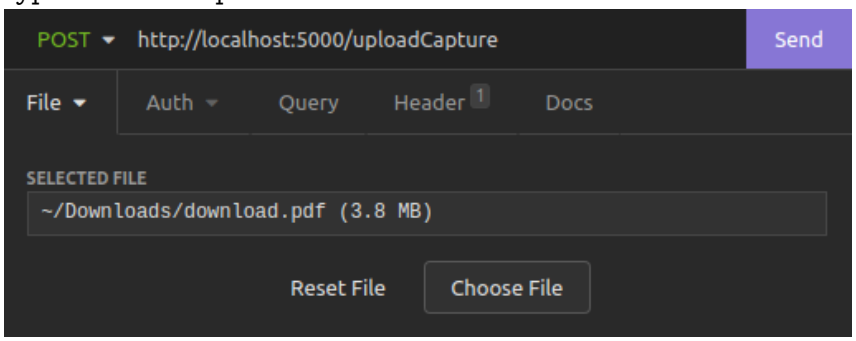
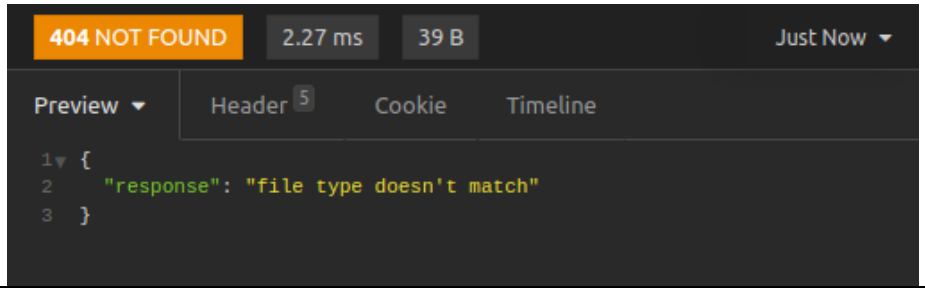
	 Expected response: 200 status code message with a JSON body that contains the necessary fields for the frontend. 	
8	Testing POST request to endpoint /uploadVideo with no body.  Expected response: 404 status code message with a JSON body that has a “response” field set to “file type doesn't match”.	Test passed.

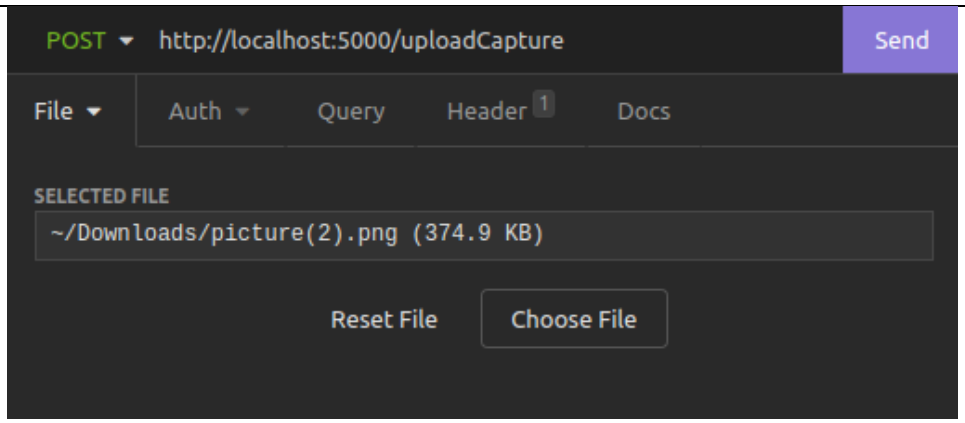
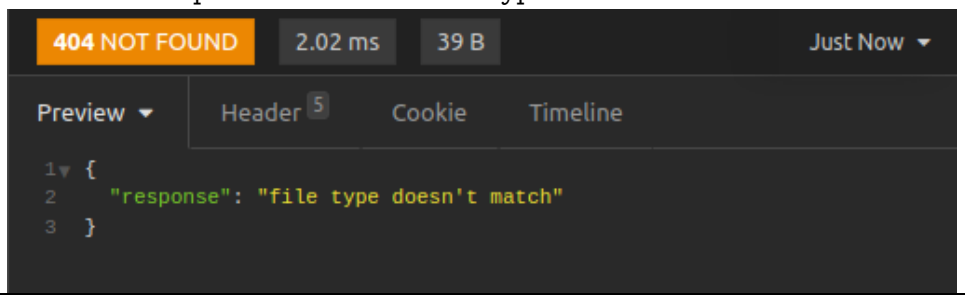
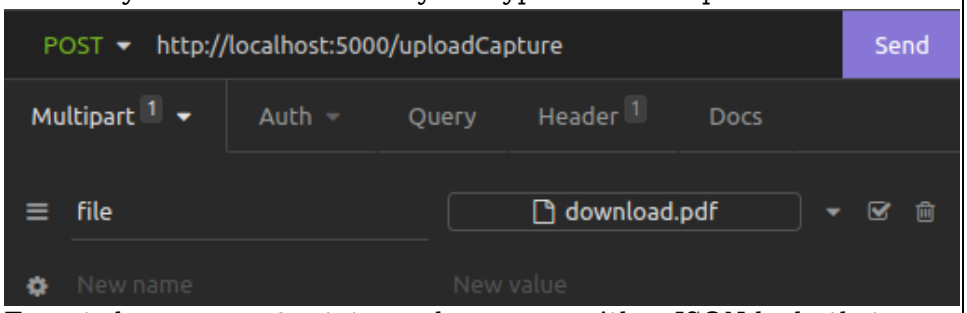
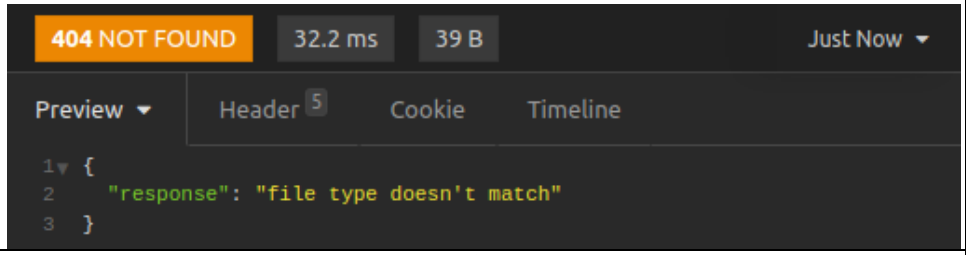
		
9	Testing POST request to endpoint /uploadVideo with a JSON body that is empty.  Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match". 	Test passed.
10	Testing POST request to endpoint /uploadVideo with a binary file type that is not permitted.  Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match" 	Test passed.

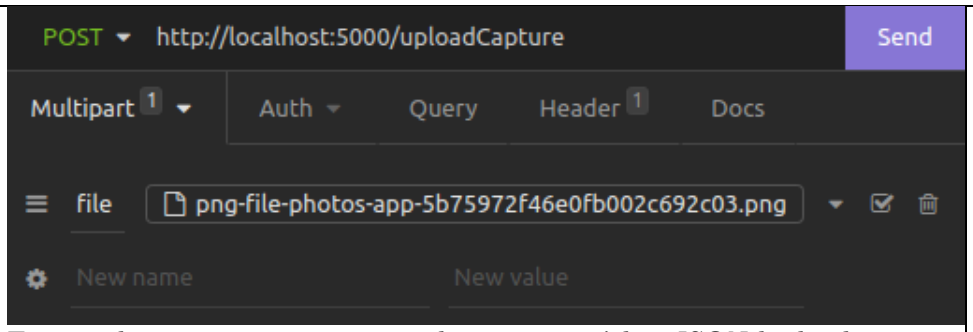
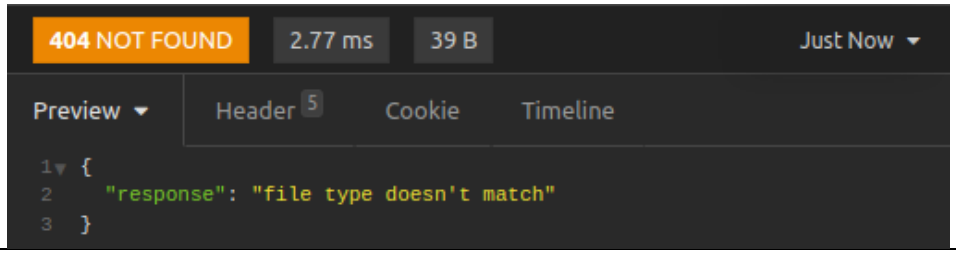
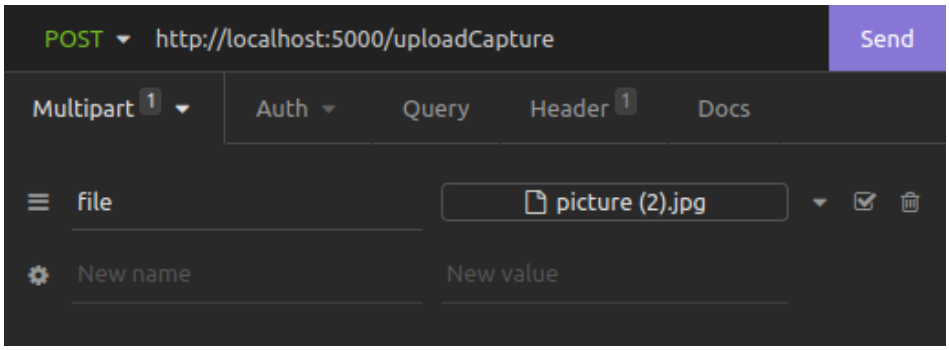
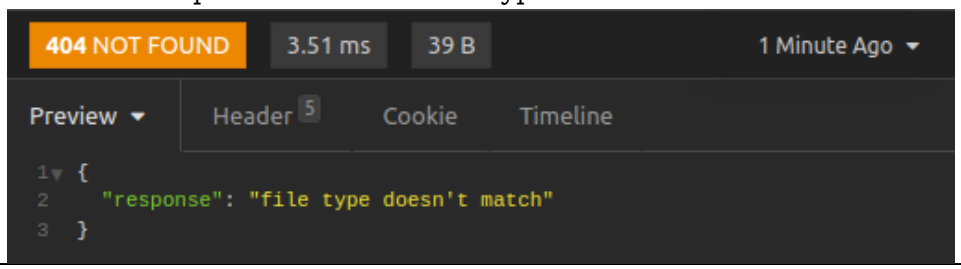
11	Testing POST request to endpoint /uploadVideo with a binary file type that is permitted.  Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match".  	Test passed.
12	Testing POST request to endpoint /uploadVideo with multipart form body that contains a binary file type that is not permitted.  Expected response: 404 status code message with a JSON body that has a "response" field set to "file type doesn't match".  	Test passed.
13	Testing POST request to endpoint /uploadVideo with multipart form body that contains a binary file type that is permitted but has no face in it.	Test passed.

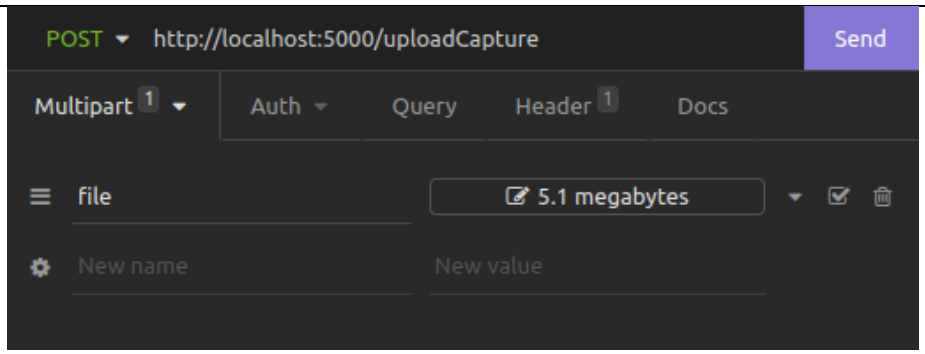
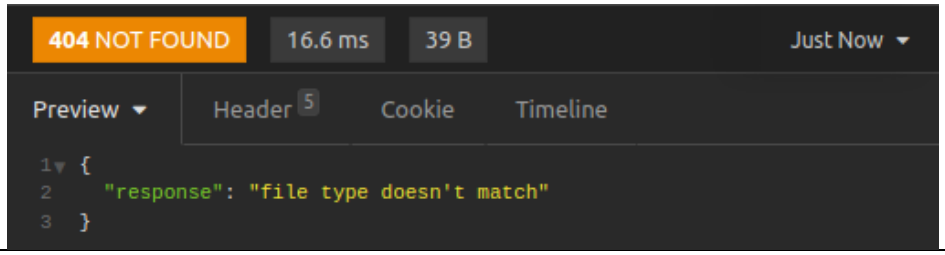
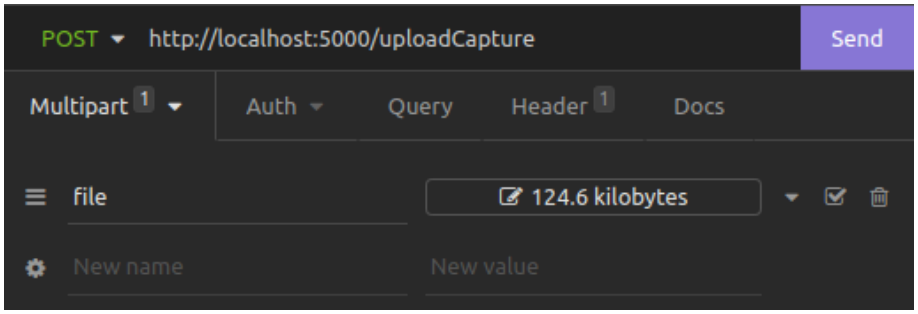
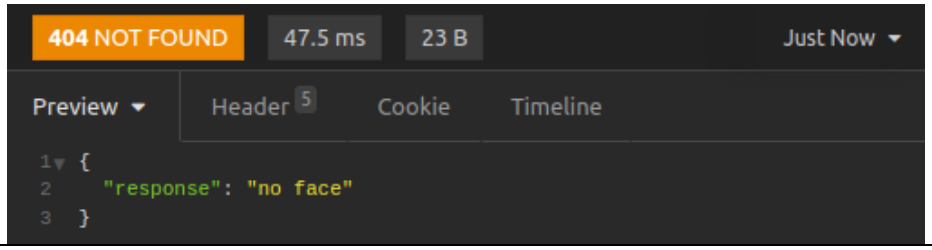
	 Expected response: 404 status code message with a JSON body that has a "response" field set to "no face". 	
14	Testing POST to endpoint /uploadVideo with multipart form body that contains a binary file type that is permitted and has a face in it.  Expected response: 200 status code message with a JSON body that contains the necessary fields for the frontend.	Test passed.

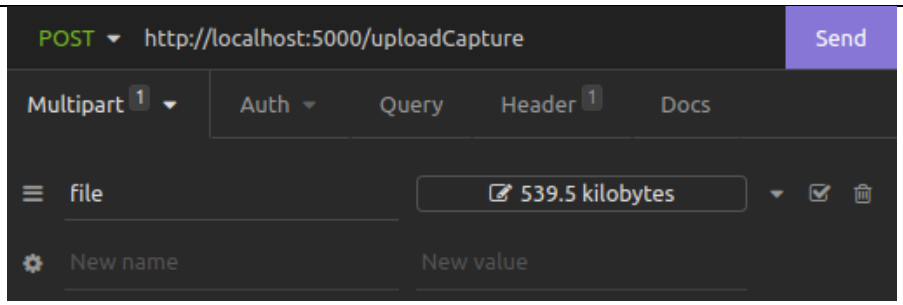
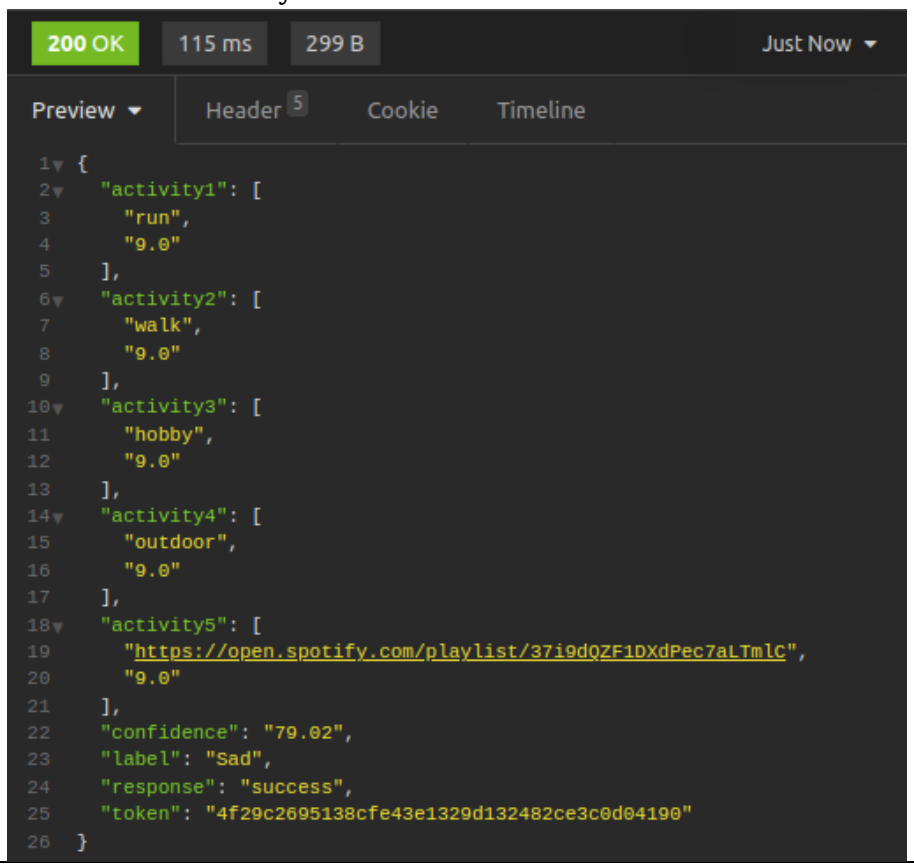
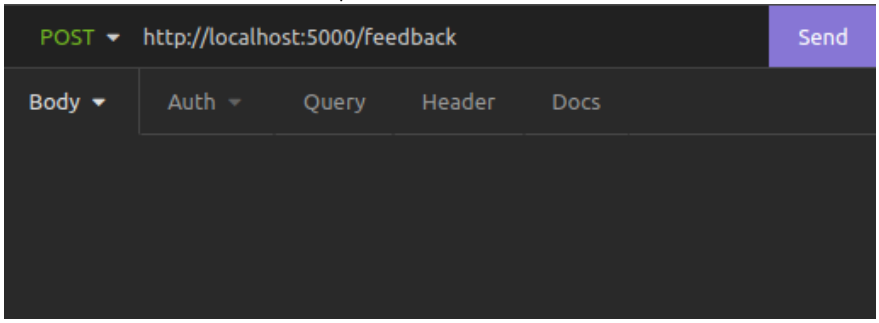
		
15	Testing POST request to endpoint /uploadCapture with no body.  Expected response: 404 status code with a JSON body that contains a "response" field set to "file type doesn't match" 	Test passed.

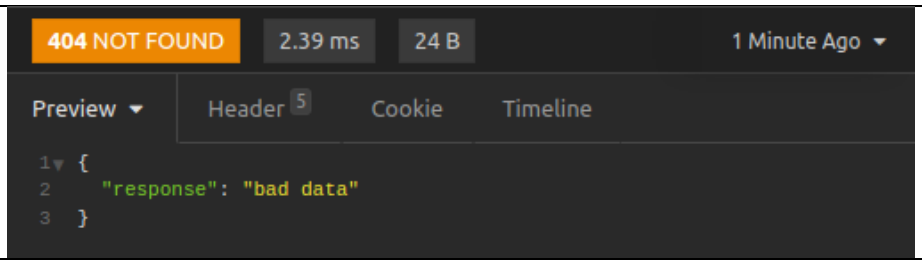
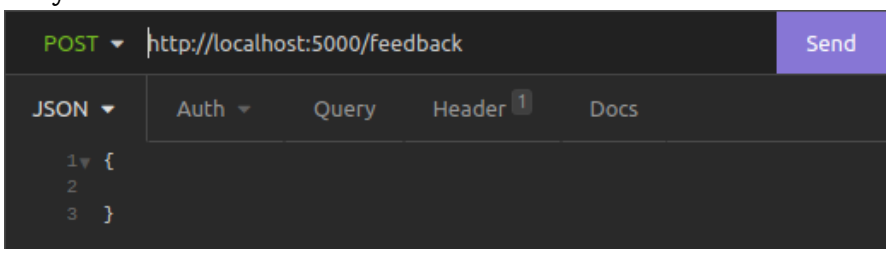
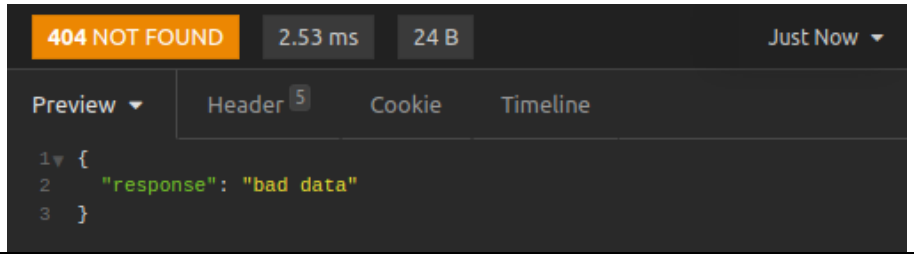
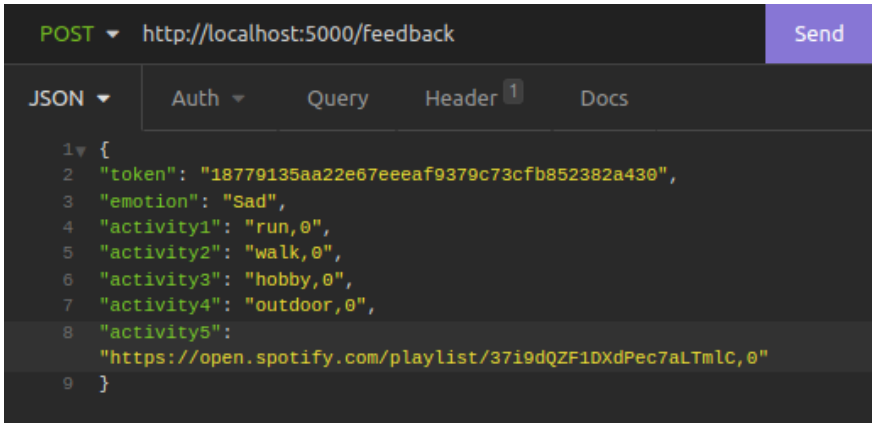
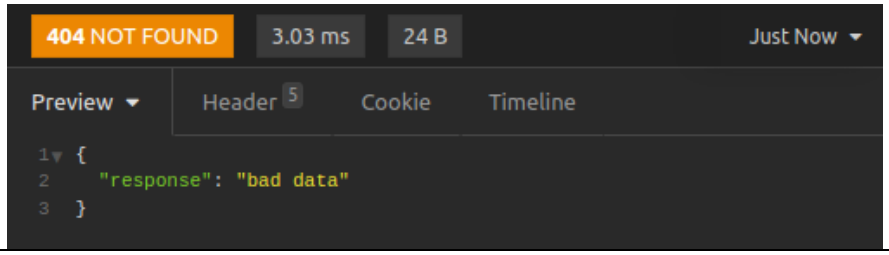
16	Testing POST request to endpoint /uploadCapture with an empty JSON body.  Expected response: 404 status code with a JSON body that has a "response" field set to "file type doesn't match". 	Test passed.
17	Testing POST request to endpoint /uploadCapture with a binary file type that is not permitted.  Expected response: 404 status code with a JSON body that contains a "response" field set to "file type doesn't match" 	Test passed.
18	Testing POST request to endpoint /uploadCapture with a binary file type that is permitted.	Test passed.

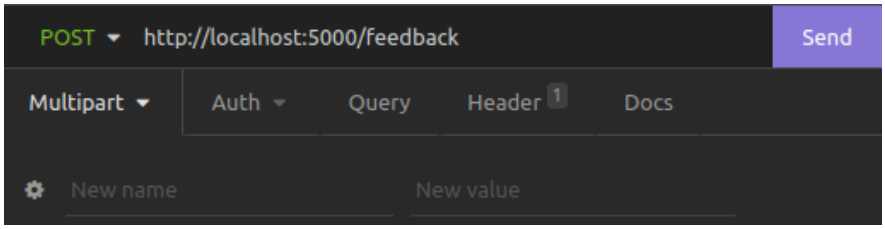
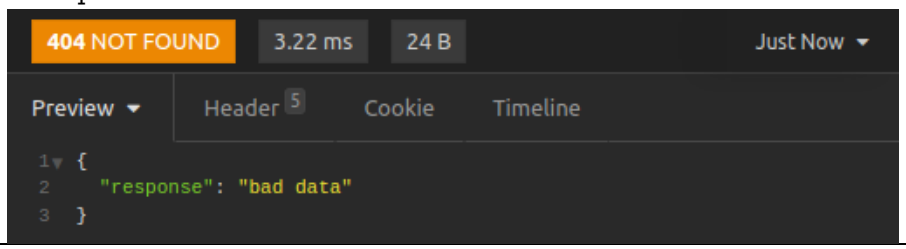
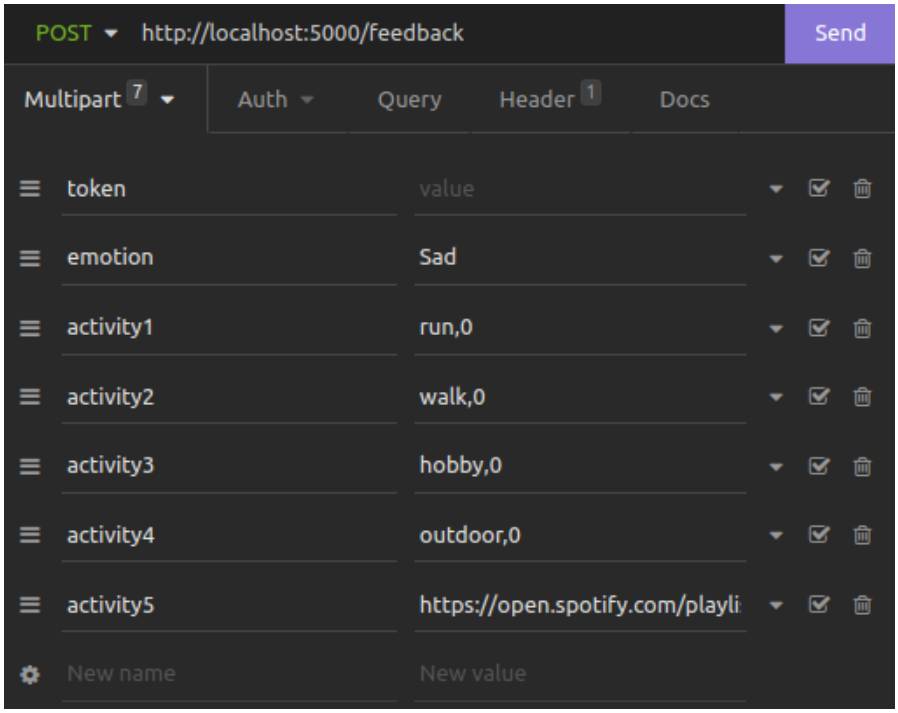
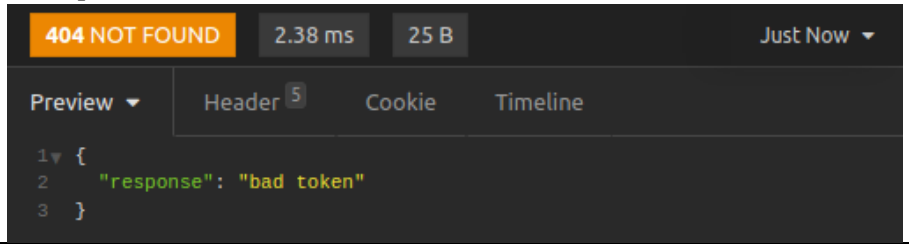
	 Expected response: 404 status code message with a JSON body that contains a "response" field set to "file type doesn't match". 	
19	Testing POST request to endpoint /uploadCapture with a multipart form body that contains a binary file type that is not permitted.  Expected response: 404 status code message with a JSON body that contains a "response" field set to "file type doesn't match". 	Test passed.
20	Testing POST request to endpoint /uploadCapture with a multipart form body that contains a binary file type that is permitted but has no face in it.	Test passed.

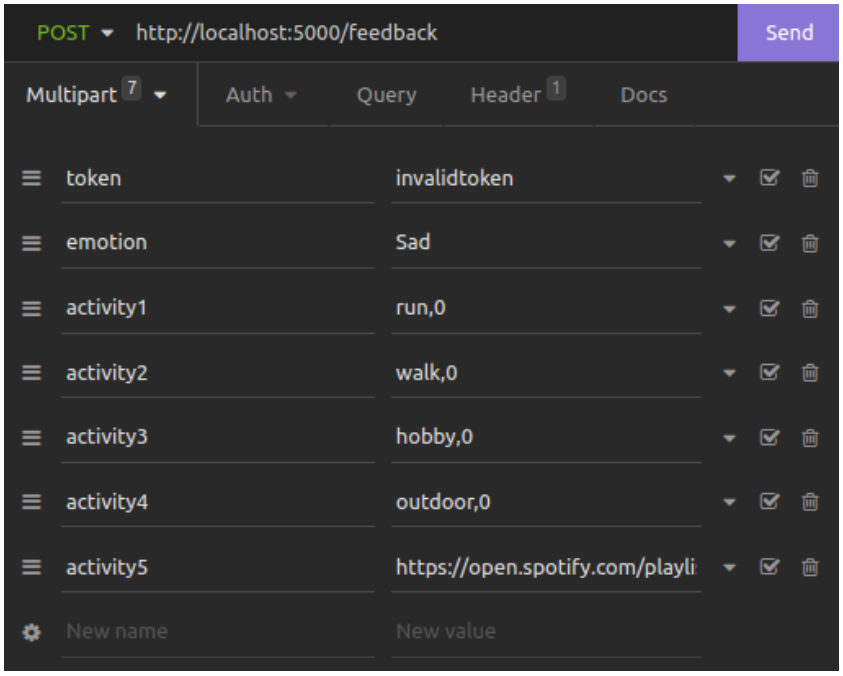
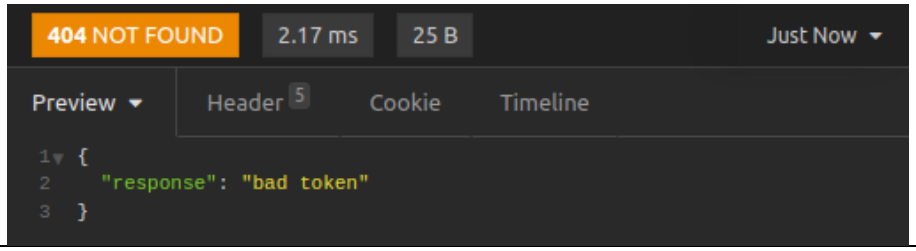
	 Expected response: 404 status code message with a JSON body that contains a "response" field set to "file type doesn't match". 	
21	Testing POST request to endpoint /uploadCapture with a multipart form body that contains a binary file type that is permitted and has a face in it.  Expected response: 404 status code message with a JSON body that contains a "response" field set to "file type doesn't match". 	Test passed.
22	Testing POST request to endpoint /uploadCapture with a multipart form body that contains a base64 encoded binary file type that is not permitted.	Test passed.

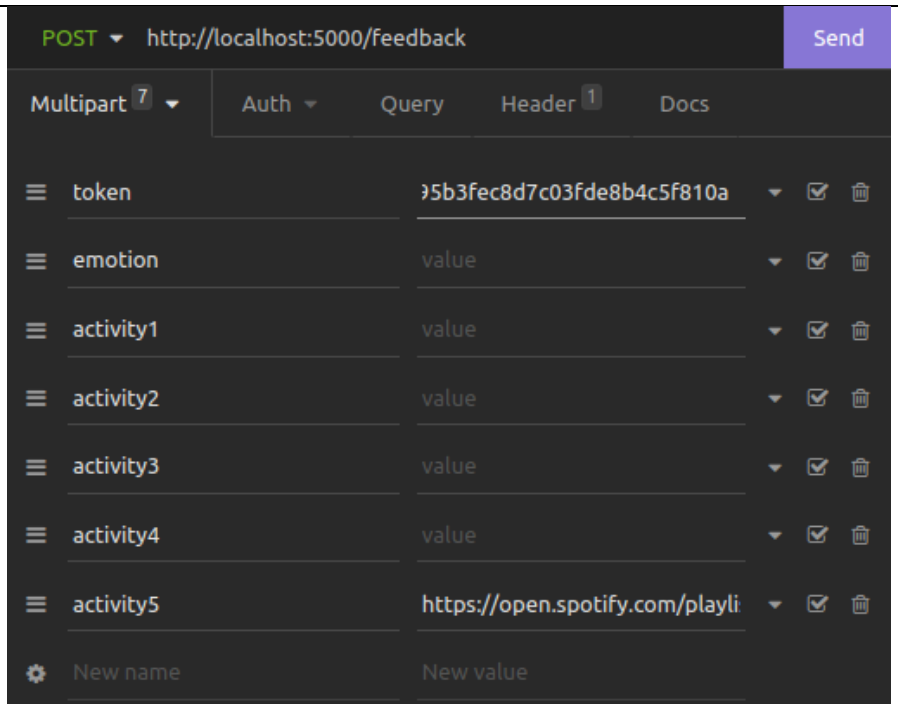
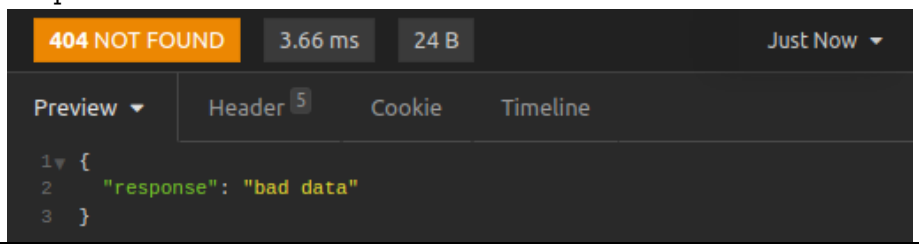
	 Expected response: 404 status code message with a JSON body that contains the "response" field set to "file type doesn't match". 	
23	Testing POST request to endpoint /uploadCapture with a multipart form body that contains a base64 encoded binary file type that is permitted but has no face in it.  Expected response: 404 status code message that contains a "response" field set to "no face". 	Test passed.
24	Testing POST request to endpoint /uploadCapture with a multipart form body that contains a base64 encoded binary file type that is permitted and has a face in it.	Test passed.

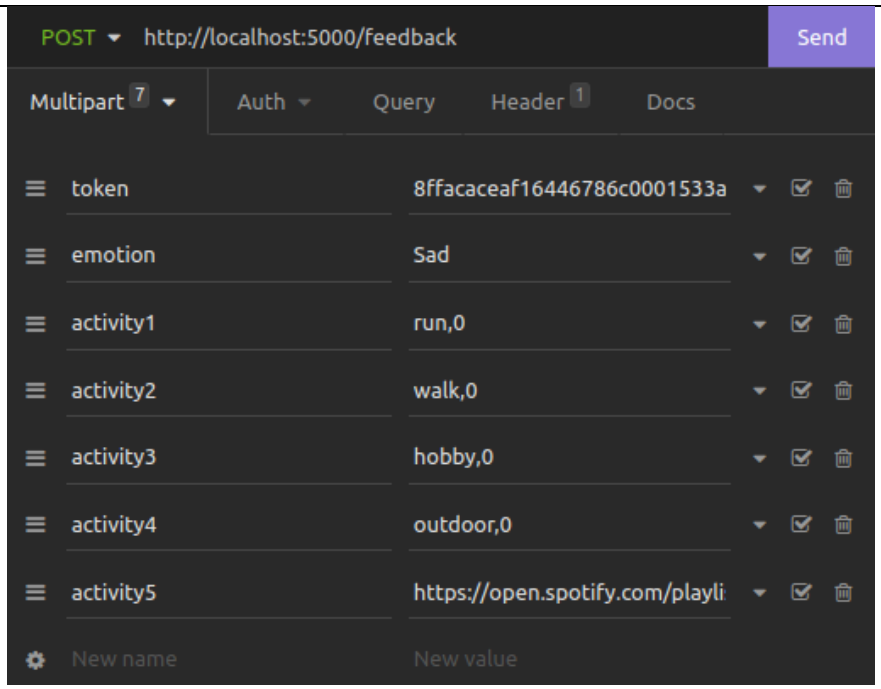
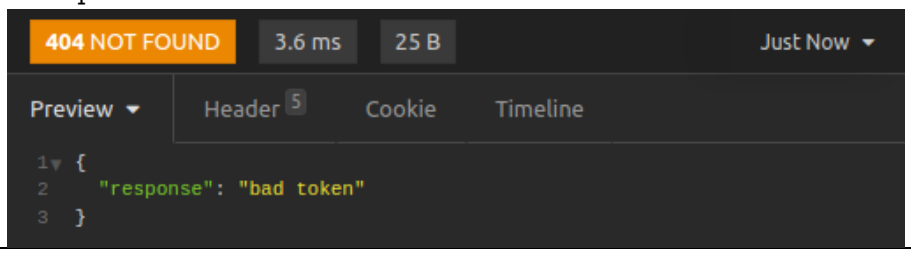
	 Expected response: 200 status code message with a JSON body that contains the necessary fields for the frontend. 	
25	Testing POST request to /feedback with no body.  Expected response: 404 status code message with a JSON body that has the “response” field set to “bad data”	Test passed.

		
26	Testing POST request on endpoint /feedback with an empty JSON body.  Expected response: 404 status code message with a JSON body that has a "response" field set to "bad data". 	Test passed.
27	Testing POST request on endpoint /feedback with a JSON body with correct data.  Expected response: 404 status code message with a JSON body that has a "response" field set to "bad data". 	Test passed.

28	Testing POST request on endpoint /feedback with an empty multipart form body.  Expected response: 404 status code message with a JSON body that has a "response" field set to "bad data" 	Test passed.
29	Testing POST request on endpoint /feedback with a multipart form body that is missing a token value.  Expected response: 404 status code message with a JSON body that has a "response" field set to "bad token". 	Test passed.

30	Testing POST request on endpoint /feedback with a multipart form body that has an incorrect token value.  Expected response: 404 status code message with a JSON body that has a "response" field set to "bad token".  	Test passed.
31	Testing POST request on endpoint /feedback with a multipart form body that has a correct token value but no other values.	Test passed.

	 Expected result: 404 status code message with a JSON body that has a "response" field set to "bad data". 	
32	Testing POST request on endpoint /feedback with a multipart form body that has an expired token.	

	 Expected response: 404 status code message with a JSON body that has a "response" field set to "bad token". 	
33	Testing POST request on endpoint /feedback with a multipart form body that has all correct data.	Test passed.

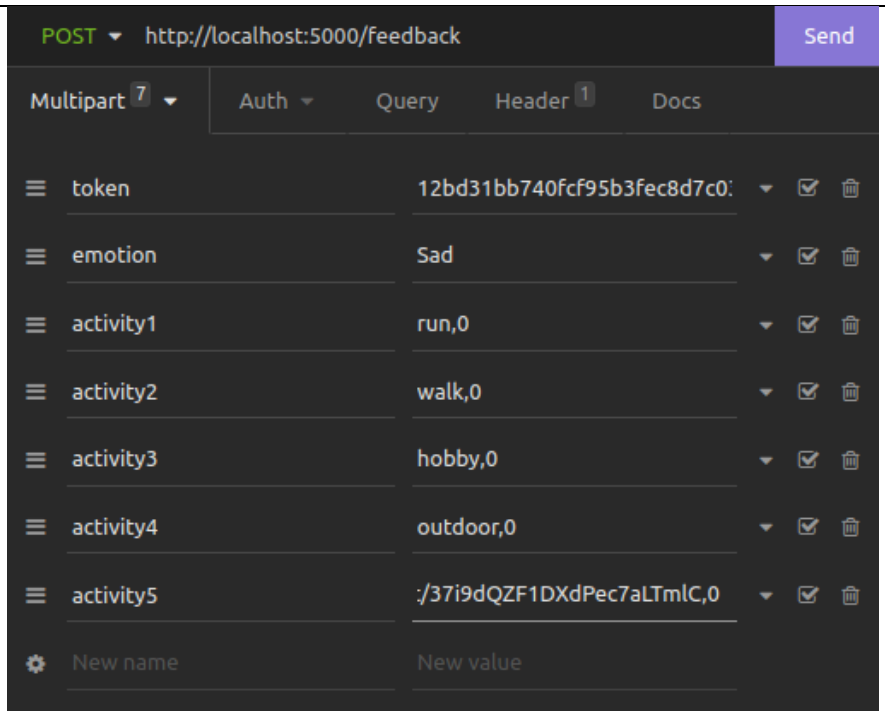
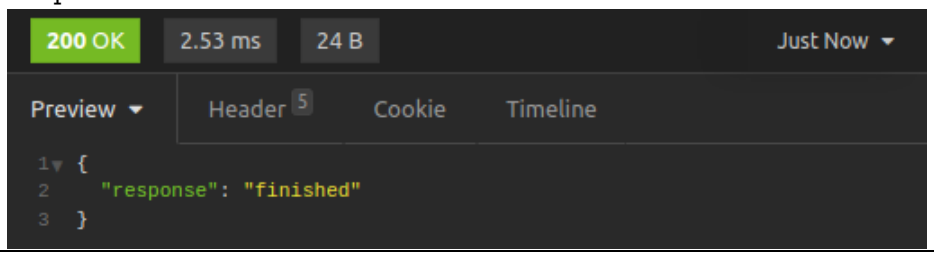
	 Expected result: 200 status code message with a JSON body that has a "response" field set to "finished". 	

Table 3: Security testing with Insomnia.Rest application

8 Evaluation

8.1 Neural network evaluation

8.1.1 Preface

The datasets used in this section are JAFFE [46], CK+ [47] and FER2013 [48]. Because these datasets are not very big, image data augmentation techniques were used. There were also benefits observed in rescaling the pixel value into (-1,1) instead of (0,1).

8.1.2 Resnet50 baseline

Resnet50 comes pretrained in the tensorflow library only with weights from ImageNet which also require you to have the input shape in RGB. Because all the images in facial emotion recognition are grayscale, we must retrain the network from scratch. This was done with the help of a github repository [42] that had the architecture of Resnet50 coded for tensorflow.

Here are the results of Resnet50 on the datasets.

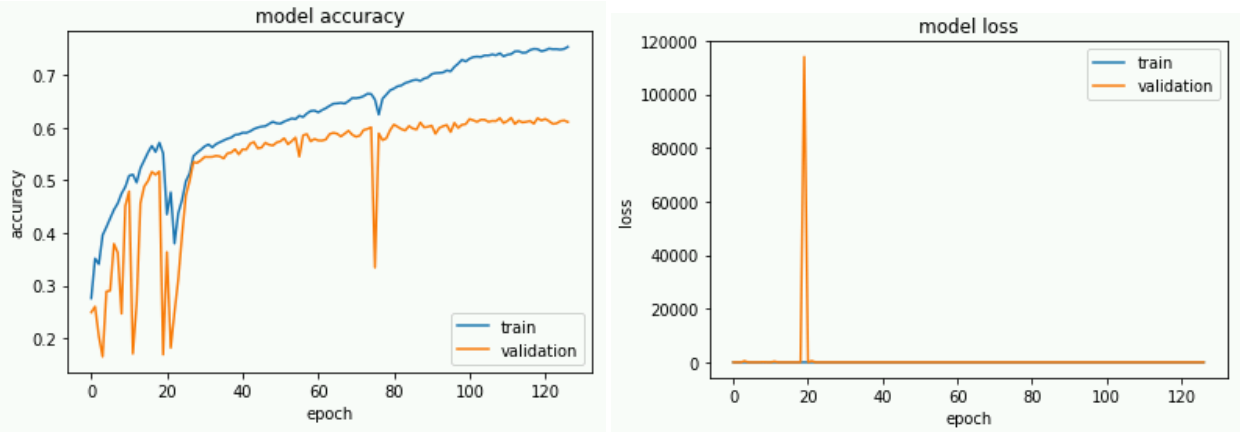


Figure 25: Resnet50 trained on FER2013 dataset

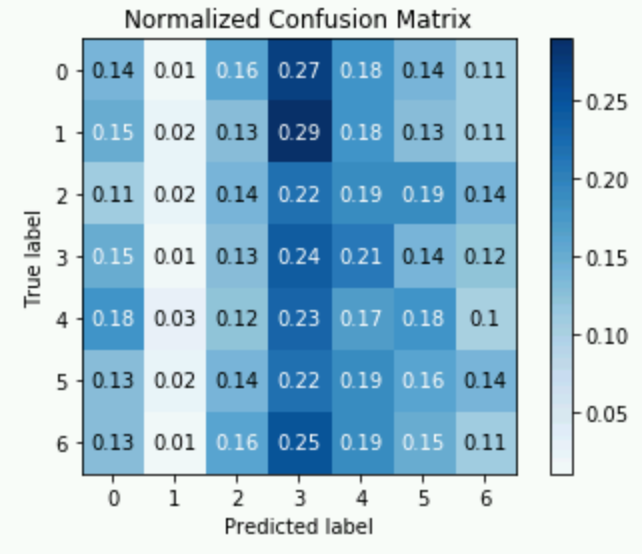
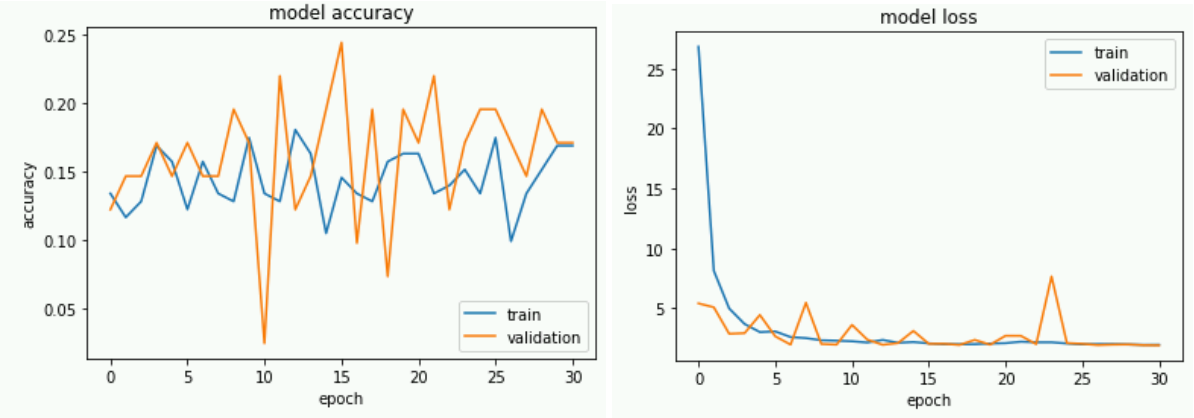


Figure 26: Confusion matrix for Resnet50 trained on FER2013 dataset



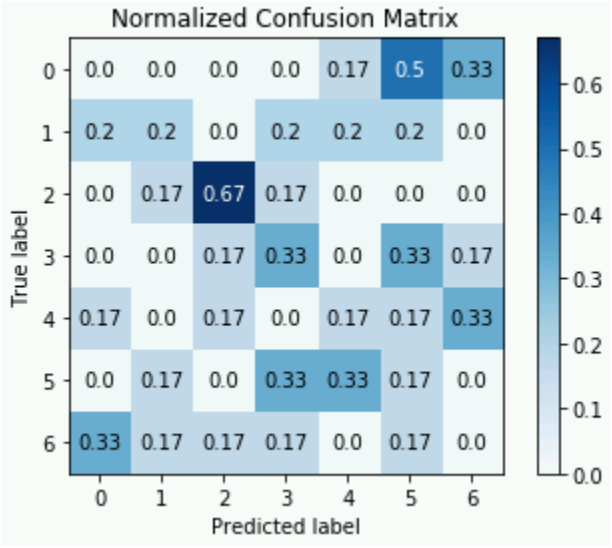


Figure 27: Resnet50 trained on JAFFE dataset

Figure 28: Confusion matrix for Resnet50 trained on JAFFE dataset

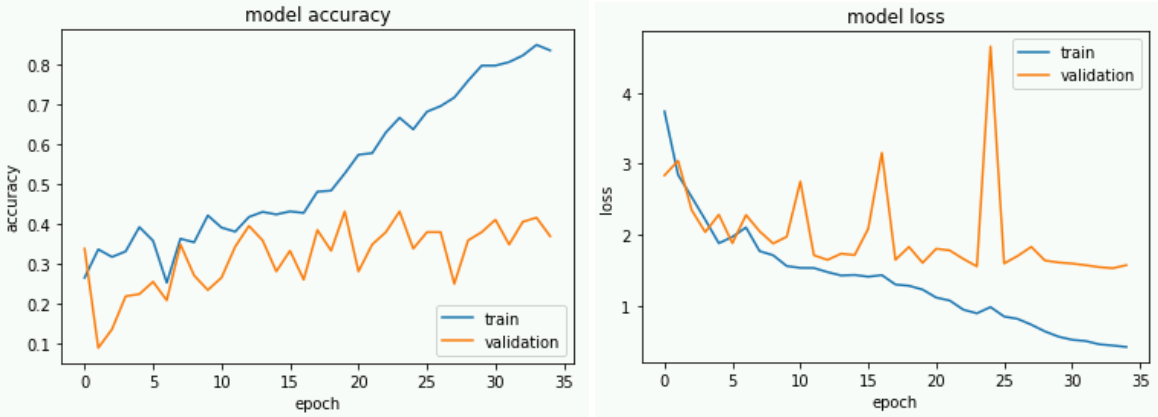


Figure 29: Resnet50 trained on CK+ dataset

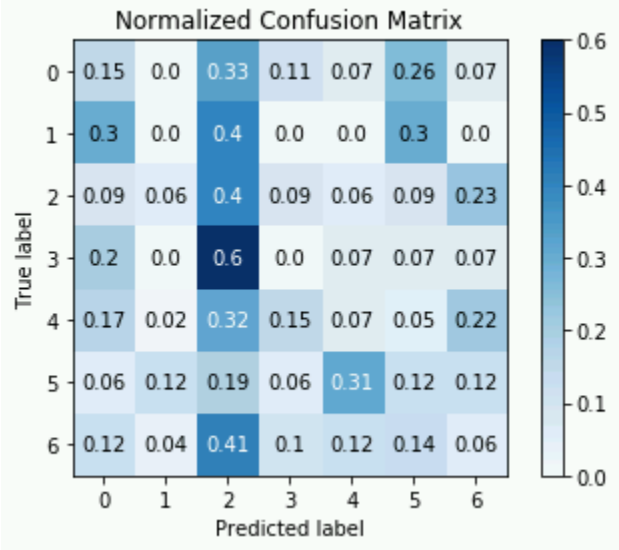


Figure 30: Confusion Matrix for Resnet50 trained on CK+ dataset

8.1.3 Own model

Here are the plots and graphs for my personal model across the datasets

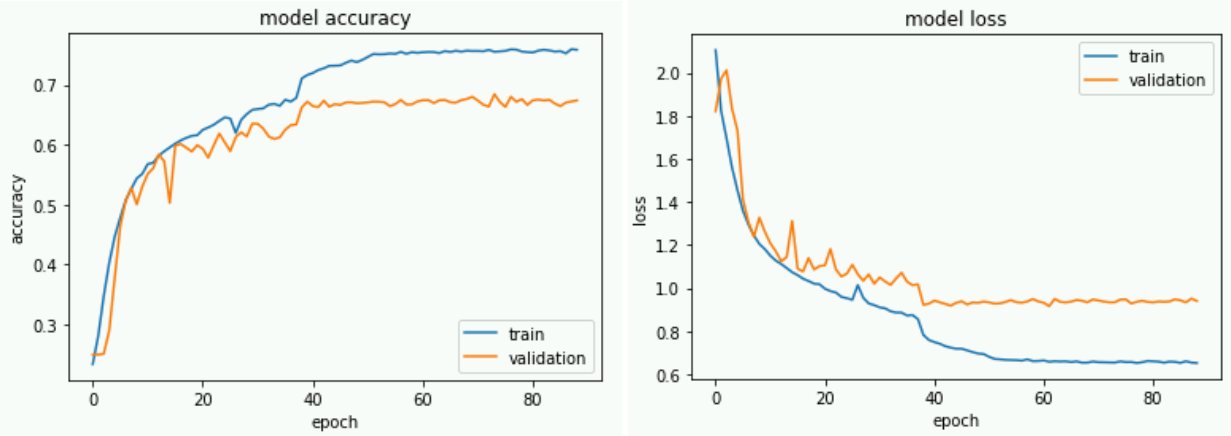


Figure 31: Own model trained on FER2013

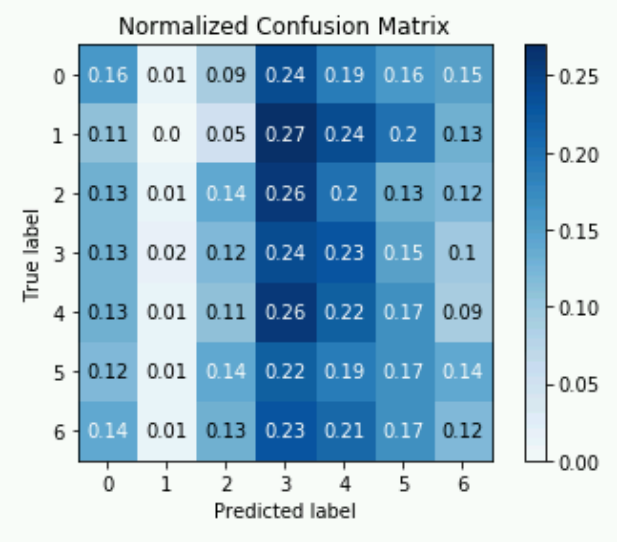


Figure 32: Confusion matrix of own model trained on FER2013

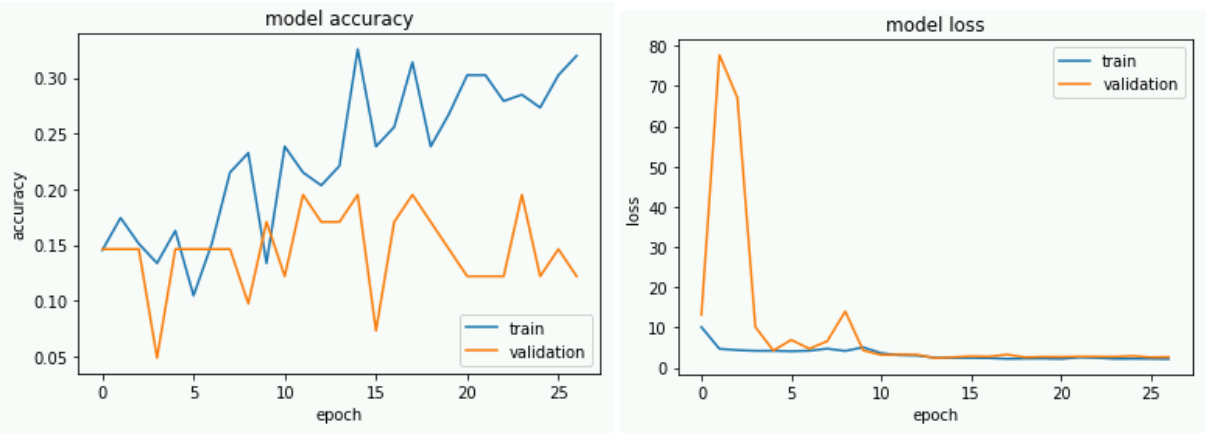


Figure 33: Own model trained on JAFFE

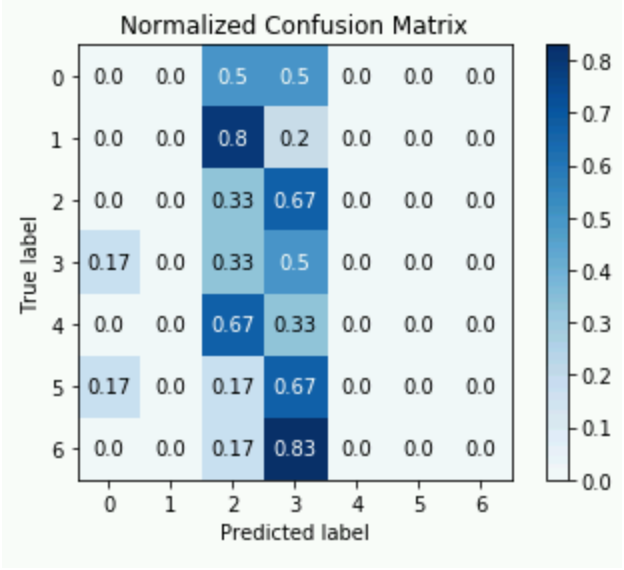


Figure 34: Confusion matrix of own model trained on JAFFE

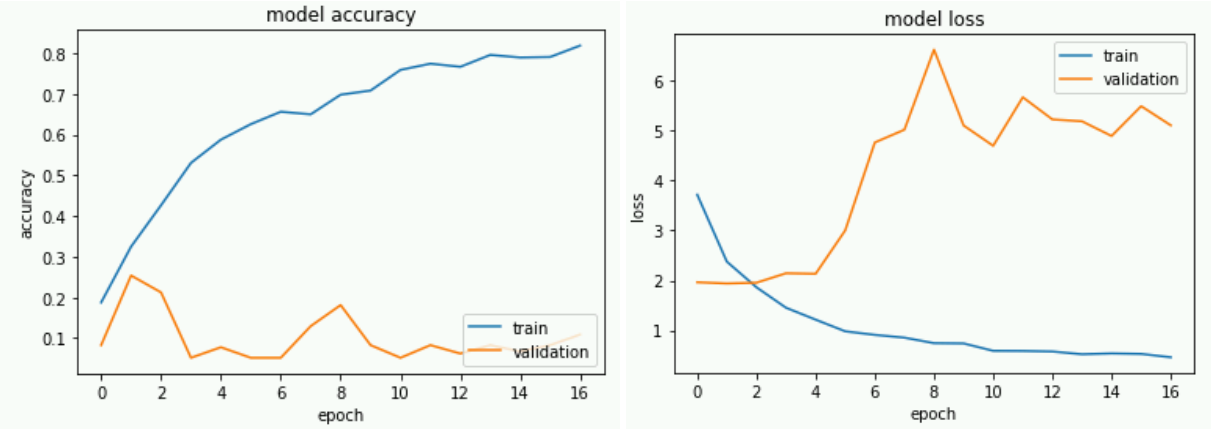


Figure 35: Own model trained on CK+

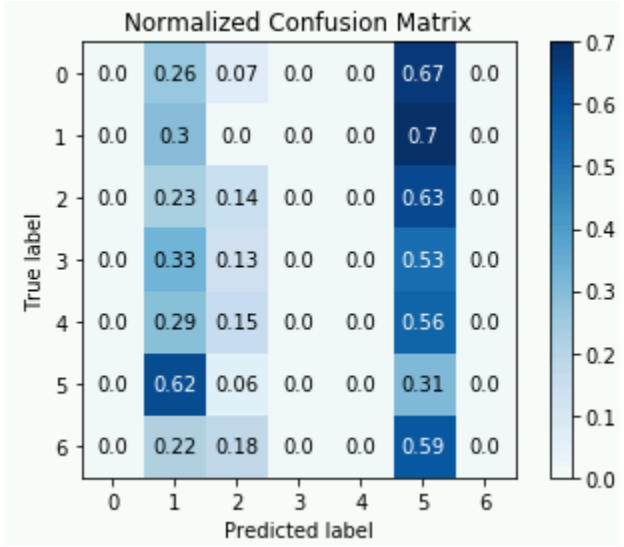


Figure 36: Confusion matrix of own model trained on CK+

8.1.3 Modified Resnet50

Here are the plots and graphs for the modified resnet50 architecture.

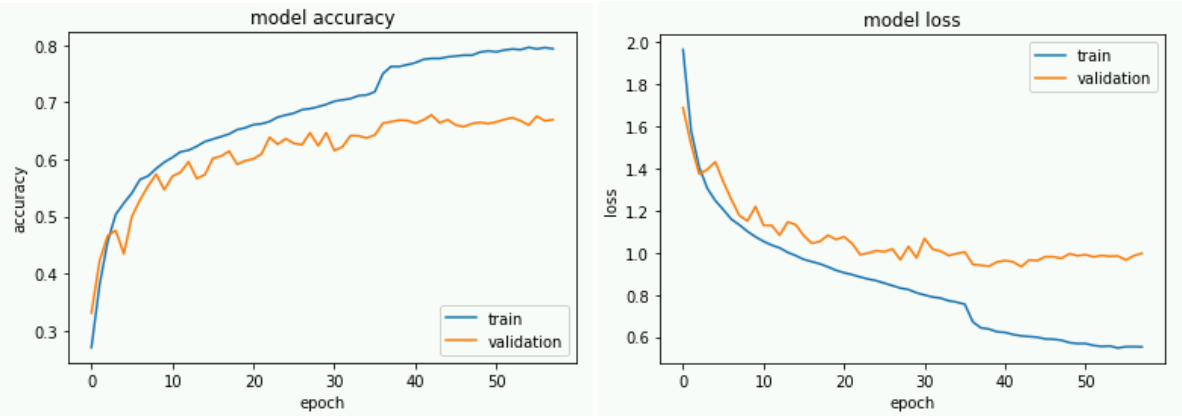


Figure 37: Modified Resnet50 on FER2013 dataset

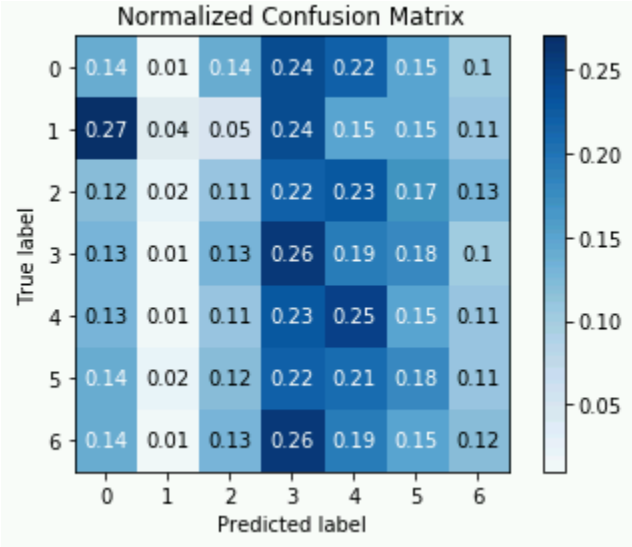


Figure 38: Confusion matrix of modified Resnet50 on FER2013 dataset

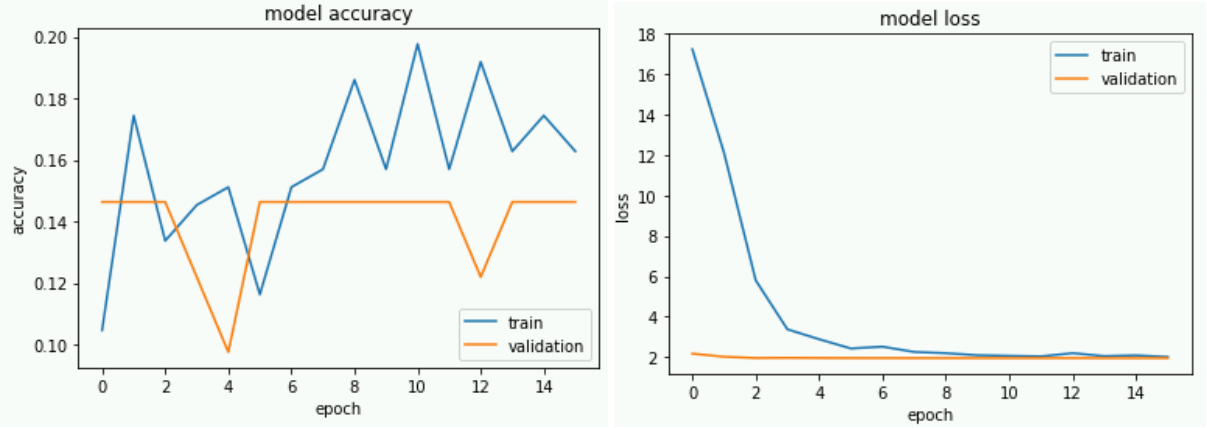


Figure 39: Modified Resnet50 trained on JAFFE dataset

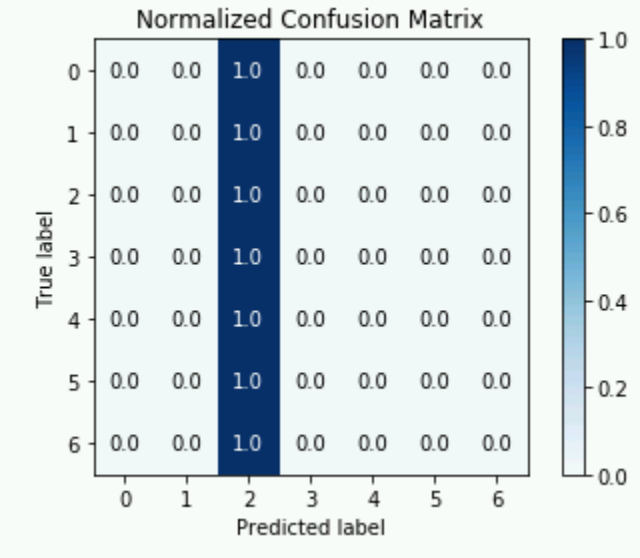


Figure 40: Confusion matrix of modified Resnet50 on JAFFE dataset

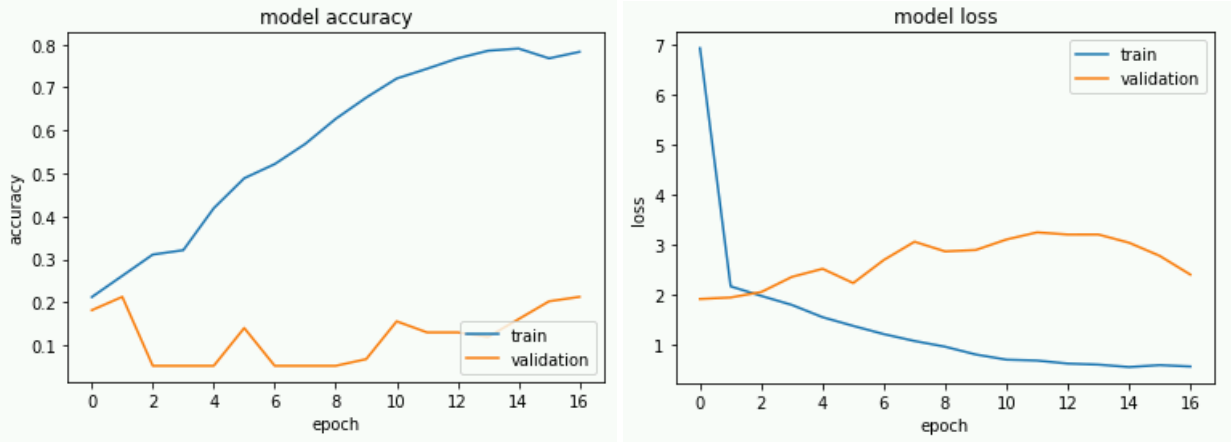


Figure 41: Modified Resnet50 trained on CK+ dataset

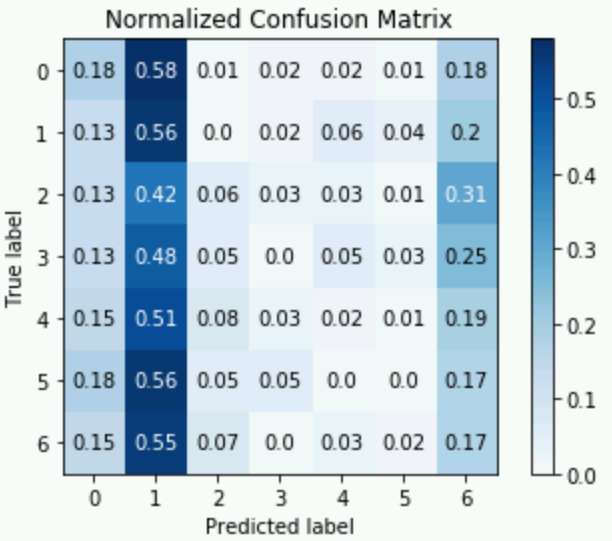


Figure 42: Confusion matrix for modified Resnet50 on CK+ dataset

8.1.4 New model for JAFFE

Because of the results of the previous models on this dataset, a new CNN has been designed to try and achieve better results. Here are the plots of this new CNN.

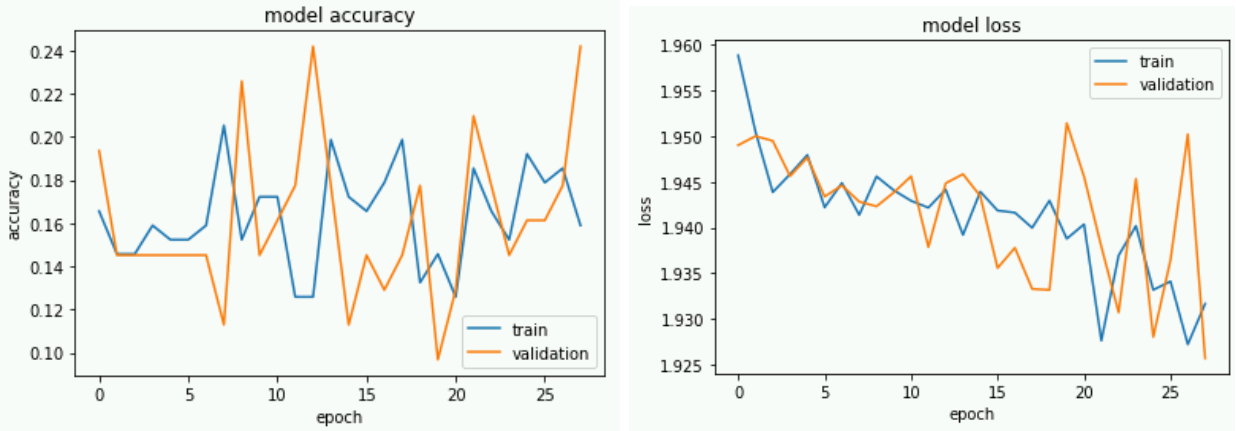


Figure 43: New CNN model trained on JAFFE dataset

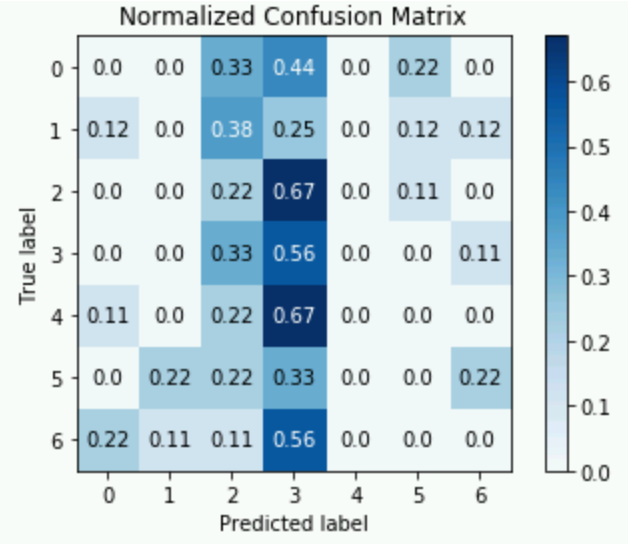


Figure 44: Confusion matrix of new CNN model trained on JAFFE

8.1.5 New model for CK+

This dataset, just like JAFFE, has shown to be unique and difficult for previous models to do well on, thus a different architecture had to be made for this dataset. Here are the plots and graphs for the model.

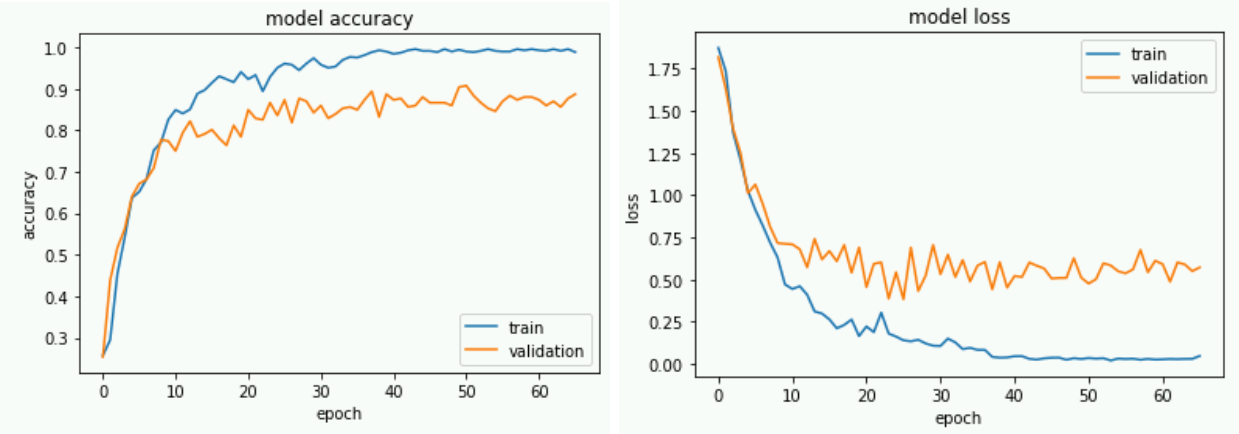


Figure 45: New model trained on CK+ dataset

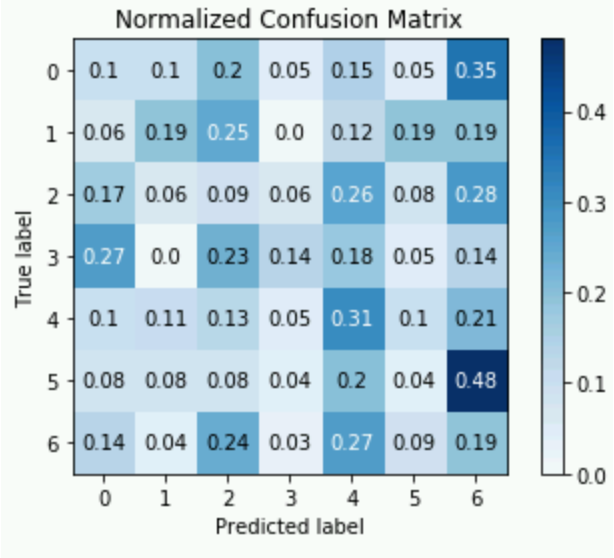


Figure 46: Confusion matrix for new model trained on CK+ dataset

8.1.6 Discussion

All results will be compiled in a table below and discussed.

Model	JAFFE	FER2013	CK+
Baseline Resnet	24.39%	61.88%	43.00%
Own model	19.51%	68.43%	25.38%
Modified Resnet	14.64%	67.79%	21.24%
New model for JAFFE	24.19%	-	-
New model for CK+	-	-	90.73%

Table 4: Performance of models across datasets

From this we can conclude that regular resnet performs the best out of all for JAFFE dataset with .tiff images, my version of CNN with a structure similar to VGG blocks performs the best on FER2013, closely behind it being the modified resnet which has beat the baseline by a significant amount. Finally, the CK set saw the best result with the new model created specifically for this dataset.

The performance on JAFFE may be errored because the tensorflow version that we use on the lab machines (2.3) throws a warning when it is loading .tiff images. These .tiff messages are getting converted into RGBA which causes issues with the image pixels because of the pixel depth being converted as well. The limitations on the lab machines also caused me not to be able to properly implement spatial attention with the modified resnet and convolutional block attention modules with the modified resnet to compare modern techniques and their performance with the older ones.

However, on CK+ a small and shallow network has shown to work the best out of all the networks.

Despite how well the custom model for CK+ performed, the model that is used in the prediction process in the web application is my own model pretrained on the FER2013 dataset because of how big the dataset is and how it encapsulates better the capabilities of the network.

8.2 Activity suggestion evaluation

The activities that are issues at the end of the application are inspired by the article written by J. Leckey [43] in which the effectiveness of creative activities on mental well-being within the mental health context was researched. From the literature reviewed, it can be deducted that arts and culture have a positive effect on the well-being of individuals. It has also shown that the evidence suggested positive outcomes but there was no clear evidence of a connection.

Because of this, some of the activities have been chosen from the arts and culture background, mixed with playlists that are intended to make an individual feel better and activities that engage the individual in physical activity.

9 LSEP issues

There are no Legal, Social or Professional issues within this project. There has been a privacy policy created which the user has to accept before he can provide any data. This check, along with the different other measures that have been implemented are safeguarding the user's privacy and the data confidentiality. At no point in the application's process does the user's data get stored anywhere on the application. At any point in the application's process the user is able to view their data that they are about to send to the server.

10 Conclusion and future work

The project shows that there is a possible problem arising soon within the context of cyber bullying, people not practicing physical activities as much as before and mental health which correlates closely with these problems.

It is also shown that artificial intelligence can be used as a tool to try and recognize when an individual is in a negative mood and recommend activities such that the individual is improving his mood. The rating system that is put into place is ensuring that only the activities that have received the most positive feedback, and thus are the best, will be shown. All these pieces tie in together to make a well-rounded system that can be beneficial for a lot of people and help society.

Future work can be related to making a more robust network that could perform well on all three chosen datasets as well as improve the web application to include more features, like a pop-up that, if clicked, shows the local suicide prevention line. On top of that, a chat could also be added where people could talk or leave messages when they are in a certain mood to help others or feel that they are not alone.

This idea can also be extended into a mobile application which could help reaching more users.

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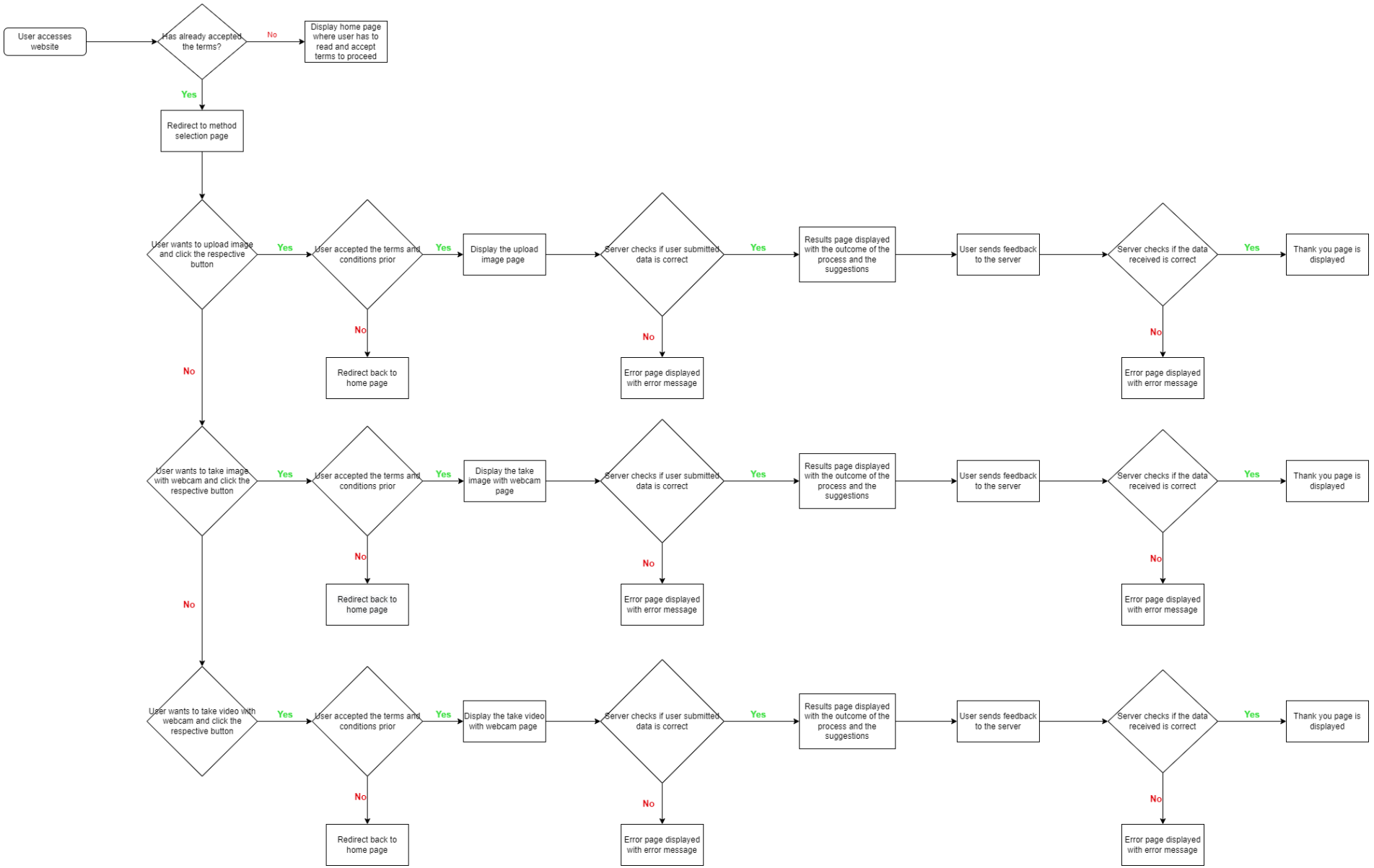
Appendices

Appendix A: Flow chart of the application

The flow chart of the web application is viewable on the next page


User accesses website
Has already accepted the terms?
No
Display home page where user has to read and accept terms to proceed
Yes
Redirect to method selection page
User wants to upload image and click the respective button
Yes
User accepted the terms and conditions prior
Yes
Display the upload image page
Server checks if user submitted data is correct
Yes
Results page displayed with the outcome of the process and the suggestions
User sends feedback to the server
Server checks if the data received is correct
Yes
Thank you page is displayed
No
Redirect back to home page
No
Error page displayed with error message
No
Error page displayed with error message
No
User wants to take image with webcam and click the respective button
Yes
User accepted the terms and conditions prior
Yes
Display the take image with webcam page
Server checks if user submitted data is correct
Yes
Results page displayed with the outcome of the process and the suggestions
User sends feedback to the server
Server checks if the data received is correct
Yes
Thank you page is displayed
No
Redirect back to home page
No
Error page displayed with error message
No
Error page displayed with error message
No
User wants to take video with webcam and click the respective button
Yes
User accepted the terms and conditions prior
Yes
Display the take video with webcam page
Server checks if user submitted data is correct
Yes
Results page displayed with the outcome of the process and the suggestions
User sends feedback to the server
Server checks if the data received is correct
Yes
Thank you page is displayed
No
Redirect back to home page
No
Error page displayed with error message
No
Error page displayed with error message

Appendix B: SAGE HDR Form

The SAGE HDR Form is attached from the next page.

SAGE-HDR (v3.4 19/05/22)

Response ID	Completion date
899668-899650-95387898	24 May 2022, 02:18 (BST)

1	**Applicant Name**	Andrei-Albert Kiss
1.a	**University of Surrey email address**	ak01815@surrey.ac.uk
1.b	**Level of research**	Undergraduate
1.b.i	**Please enter your University of Surrey supervisor's name. If you have more than one supervisor, enter the details of the individual who will check this submission.**	Zhenhua Feng
1.b.ii	**Please enter your supervisor's University of Surrey email address. If you have more than one supervisor, enter the details of the supervisor who will check this submission.**	z.feng@surrey.ac.uk
1.c	**School or Department**	Computer Science
1.d	**Faculty**	FEPS - Faculty of Engineering and Physical Sciences

2	**Project title**	Using facial emotion detection to identify and improve an individual’s mood

3	**Please enter a brief summary of your project and its methodology in 250 words. Please include information such as your research method/s, sample, where your research will be conducted and an overview of the aims and objectives of your research.**	The project uses a web application and a neural network to predict a person's mood and suggests activities to improve the mood. The user can choose to send an image, take a photo with the webcam or take a short video with the webcam. These sent items are never saved or locally stored at any point in time on the server side and are discarded after the request has finished. The AI is trained with publicly available datasets like FER2013 and CK+ and with JAFFE from which permission was requested and received by the owner of the dataset.

4	**Are you planning to join on to an existing Standard Study Protocol (SSP)? SSPs are overarching pre-approved protocols that can be used by multiple researchers investigating a similar topic area using identical methodologies. Please note, SSPs are only being used by one school currently and cannot be used by other schools. Using an SSP requires permission and sign-off from the SSP owner**	NO

5	**Are you making an amendment to a project with a current University of Surrey favourable ethical opinion or approval in place?**	NO

6	**Does your research involve any animals, animal data or animal derived tissue, including cell lines?**	NO

8	**Does your project involve human participants (including human data and/or any human tissue*)?**	NO

9	**Will you be accessing any organisations, facilities or areas that may require prior permission? This includes organisations such as schools (Headteacher authorisation), care homes (manager permission), military facilities, closed online forums, private social media pages etc. If you are unsure, please contact ethics@surrey.ac.uk.**	NO

10	**Does your project involve any type of human tissue research? This includes Human Tissue Authority (HTA) relevant, or non-relevant tissue (e.g. non-cellular such as plasma or serum), any genetic material, samples that have been previously collected, samples being collected directly from the donor or obtained from another researcher, organisation or commercial source.**	NO

11	**Does your research involve exposure of participants to any hazardous materials e.g. chemicals, pathogens, biological agents or does it involve any activities or locations that may pose a risk of harm to the researcher or participant?**	NO

12	**Will you be importing or exporting any samples (including human, animal, plant or microbial/pathogen samples) to or from the UK?**	NO

13	**Will any participant visits be taking place in the Clinical Research Building (CRB)? (involving clinical procedures; if only visiting the CRB to collect/drop-off equipment or to meet with the research team (i.e. for informed consent/discussion) select 'NO').**	NO

14	**Will you be working with any collaborators or third parties to deliver any aspect of the research project?**	NO

15	**Are you conducting a service evaluation or an audit? Or using data from a service evaluation or audit?**	NO

16	**Does your funder, collaborator or other stakeholder require a mandatory ethics review to take place at the University of Surrey?**	NO

17	**Does your research involve accessing students' results or performance data? For example, accessing SITS data.**	NO

18	**Will ANY research activity take place outside of the UK?**	NO

19	**Are you undertaking security-sensitive research, as defined in the text below?**	NO

20	**Does your project require the processing of special category1 data?**	YES
20.a	**Please ensure that you adhere to the data protection guidance**	I am an UG or PGT student and I understand that I have to abide by the 'Data protection and security for undergraduate and postgraduate taught student projects' policy found at https://research.surrey.ac.uk/ethics

21	**Have you selected YES to one or more of the above governance risk questions on this page (Q10-Q20)?**	YES
21.a	**You have selected one or more governance risks. Your project requires at least a governance review to assess the risks associated with your research. Please continue with the SAGE-HDR form to assess whether you also require an ethical review of your project.**	• I understand that I have to submit my project for at least a governance review as I have selected one or more governance risks. • I understand that I have to complete the remainder of this SAGE-HDR form to assess whether I also require an ethical review of my project.

22	**Does your project process personal data2? Processing covers any activity performed with personal data, whether digitally or using other formats, and includes contacting, collecting, recording, organising, viewing, structuring, storing, adapting, transferring, altering, retrieving, consulting, marketing, using, disclosing, transmitting, communicating, disseminating, making available, aligning, analysing, combining, restricting, erasing, archiving, destroying.**	YES
22.a	**Please ensure that your protocol provides the details on what you will collect, the purpose and how you will manage the data in your study. Alternatively, provide a separate data management plan.**	I understand that in my protocol or data management plan I will detail how personal data will be processed.
22.b	**Who is the Data Controller for your study? For Undergraduate and Postgraduate Taught students, the University of Surrey is usually the data controller.**	University of Surrey

22.c	**Will you be sharing identifiable or pseudonymised data with persons external to the University of Surrey?**	NO
22.d	**Will you be obtaining potential participant contact details from publicly available information, databases and/or other sources?**	NO
22.e	**On completion of your project, do you intend to retain personal information for future research purposes?**	NO
22.f	**Please ensure that you adhere to the data protection guidance**	I am an UG or PGT student and I understand that I have to abide by the 'Data protection and security for undergraduate and postgraduate taught student projects' policy found at https://research.surrey.ac.uk/ethics

23	**Are you using a platform, system or server external to the University approved platforms (Outside of Microsoft Office programs, Sharepoint or OneDrive)?**	NO

24	**Does your research involve any of the above statements? If yes, your study may require external ethical review or regulatory approval**	NO

25	**Does your research involve any of the above? If yes, your study may require external ethical review or regulatory approval**	NO

26	**Does your project require ethics review from another institution? (For example: collaborative research with the NHS REC, the Ministry of Defence, the Ministry of Justice and/or other universities in the UK or abroad)**	NO

27	**Does your research involve any of the following individuals or higher-risk methodologies? Select all that apply or select 'not applicable' if no options apply to your research. Please note: the UEC reviewers may deem the nature of the research of certain high risk projects unsuitable to be undertaken by undergraduate students**	NOT APPLICABLE - none of the above high-risk options apply to my research.

28	**Does your research involve any of the following individuals or medium-risk methodologies? Select all that apply or select 'not applicable' if no options apply to your research.**	NOT APPLICABLE - none of the above medium-risk options apply to my research.

29	**Does your research involve any of the following individuals or lower-risk methodologies? Select all that apply or select 'not applicable' if no options apply to your research.**	NOT APPLICABLE - none of the above lower-risk options apply to my research.

30	**Declarations**	• I confirm that I have read the University's Code on Good Research Practice and ethics policy and all relevant professional and regulatory guidelines applicable to my research and that I will conduct my research in accordance with these. • I confirm that I have provided accurate and complete information regarding my research project • I understand that a false declaration or providing misleading information will be considered potential research misconduct resulting in a formal investigation and subsequent disciplinary proceedings liable for reporting to external bodies • I understand that if my answers to this form have indicated that I must submit an ethics and governance application, that I will NOT commence my research until a Favourable Ethical Opinion is issued and governance checks are cleared. If I do so, this will be considered research misconduct and result in a formal investigation and subsequent disciplinary proceedings liable for reporting to external bodies. • I understand that if I have selected 'YES' on any governance risk questions and/or have selected any options on the higher, medium or lower risk criteria then I MUST submit an ethics and governance application (EGA) for review before conducting any research. If I have NOT selected any governance risks or selected any of the higher, medium or lower ethical risk criteria, I understand I can proceed with my research without review and

		acknowledge that my SAGE answers and research project will be subject to audit and inspection by the RIGO team at a later date to check compliance.

31	**If I am conducting research as a student:**	• I confirm that I have discussed my responses to the questions on this form with my supervisor to ensure they are correct. • I confirm that if I am handling any information that can identify people, such as names, email addresses or audio/video recordings and images, I will adhere to the security requirements set out in the relevant Data Protection Policy